THE COMPLETE
TECHNICAL PAPER PROCEEDINGS

FROM:

"WHAT YOU SEE IS WHAT YOU GET"
OR
HOW TO MAKE A PROPER F-CONNECTOR

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ABSTRACT

The most widely used part of a CATV system undoubtedly is the F-connector; yet consistent, accurate information on the correct preparation of its center conductor length is usually lacking.

Here, we take a careful look at the connector--jack assembly and note the changes over the years. We propose a standard for the center conductor length which will eliminate a significant number of field failures.

THE F-CONNECTOR PROBLEM

One of the things we all absorb from the first day we get involved with CATV is that we are dealing with a SYSTEM. In practical terms this means that EVERY PART must work, without exception, no matter how small for the whole system to work. Every tech can tell us horror stories about the loose screw or the cracked washer which caused an entire system outage. Let us, then, examine one aspect of the reliability of what is probably the single most commonly used component in the CATV system -- namely, the F-connector. After all, tens of millions are used each year. A generic fault would have major consequences in CATV. Our suspicions are aroused when we look through the log books of the systems' repair crews. If we count the percentage of trouble calls due to F-connectors, we find anywhere from 25 to 90 percent of all repairs are to tighten "loose" connectors or to re-make an intermittent or open one or wrench-tighten a termination.

When we found the same problem on our laboratory bench, we took the opportunity to look into it carefully. After all, it is the lowly F-connector which brings the RF signal from our carefully constructed system from the tap, through the ground block to the subscriber's TV set. Every single one of these connections must make secure and reliable electrical contact, regardless of temperature, wind or rain, or, as far as the subscriber is concerned, the system is down.

Adding to the problem is the fact that widely varying instructions as to what length to cut the center conductor exist among technicians. These range all the way from slightly below flush to 1/16" above flush and no idea of what the tolerance should be.

Let's start by examining precisely how the F-connector center contact is supposed to work by looking at Fig. 1, which shows a cross-sectional view of the female or port connector. In the center is shown the two contacting springs which, at their closure point, are supposed to make the connection with the center conductor of the male F-connector. As the male connector, shown in Fig. 2, is threaded onto the port, the center conductor is carried to meet the spring contacts' closure point.

Obviously, only if the center conductor is long enough will it penetrate the spring contacts' closure and establish a reliable pressure contact.

To see exactly how well and how reliably this works, we set up a simple test, as shown in TABLE 1. We counted how many half-turns (approximately 180 degrees hand/wrist rotation) it took to have a termination make contact. We cut the center conductors of the terminators to four lengths, 0 or flush, 1 mm. or 0.04", 2.5 mm. or 0.10", and 4 mm. or 0.16". We used 5 well-known tap brands and found that all of them took between 6 1/2 to 7 turns to "bottom" the male connector. This is graphically shown in Fig. 1 by the bracket labeled "6 1/2 turns."

The first column of the test, 0 or flush, shows that the distance which the male connector travels axially is about equal to the distance from the contact closure to the outside of the port. This is shown by the fact that three of the 9 sample did not make contact at all, (N/C); three just barely did (7 turns which is bottomed); while four did make contact in 5 turns. Out tests confirm that if the center conductor in the male F-connector is cut off flush with the outer shell face, it will have only just about reached the contact closure!

ONLY THE LENGTH OF CENTER CONDUCTOR PROTRUDING ABOVE THE SHELL FACE MAKES CONTACT WITH THE CLOSURE POINT. In other words, "what you see is what you get."

Depending upon tolerances, the center conductor, if cut flush with the shell face, may not contact the closure point at all, or might just touch without penetrating the closure point fully, thereby causing a lack of spring pressure on the contact. This is a condition which would cause an open or intermittent contact especially in cold weather when the cable would pull back.

Even if the center conductor were cut 1/16" above the shell face, as advised by most people, we found that the average penetration of the contact closure was only about 0.06". That much "grip" does not provide for a reliable connection given the mechanical and temperature stresses which the connection is subject to. F-connectors are notorious for loosening up which causes pull-back on the center conductor. Even corrosion might turn such a marginal connection into an intermittent one on a freezing night. No wonder that the repair logs show so many connectors being tightened or re-made!

A good rule to follow in setting the proper length of center conductor to cut is contained in "what you see is what you get." Once this is explained to the technicians as the length protruding beyond the shell, their judgement will pick a reasonable length.

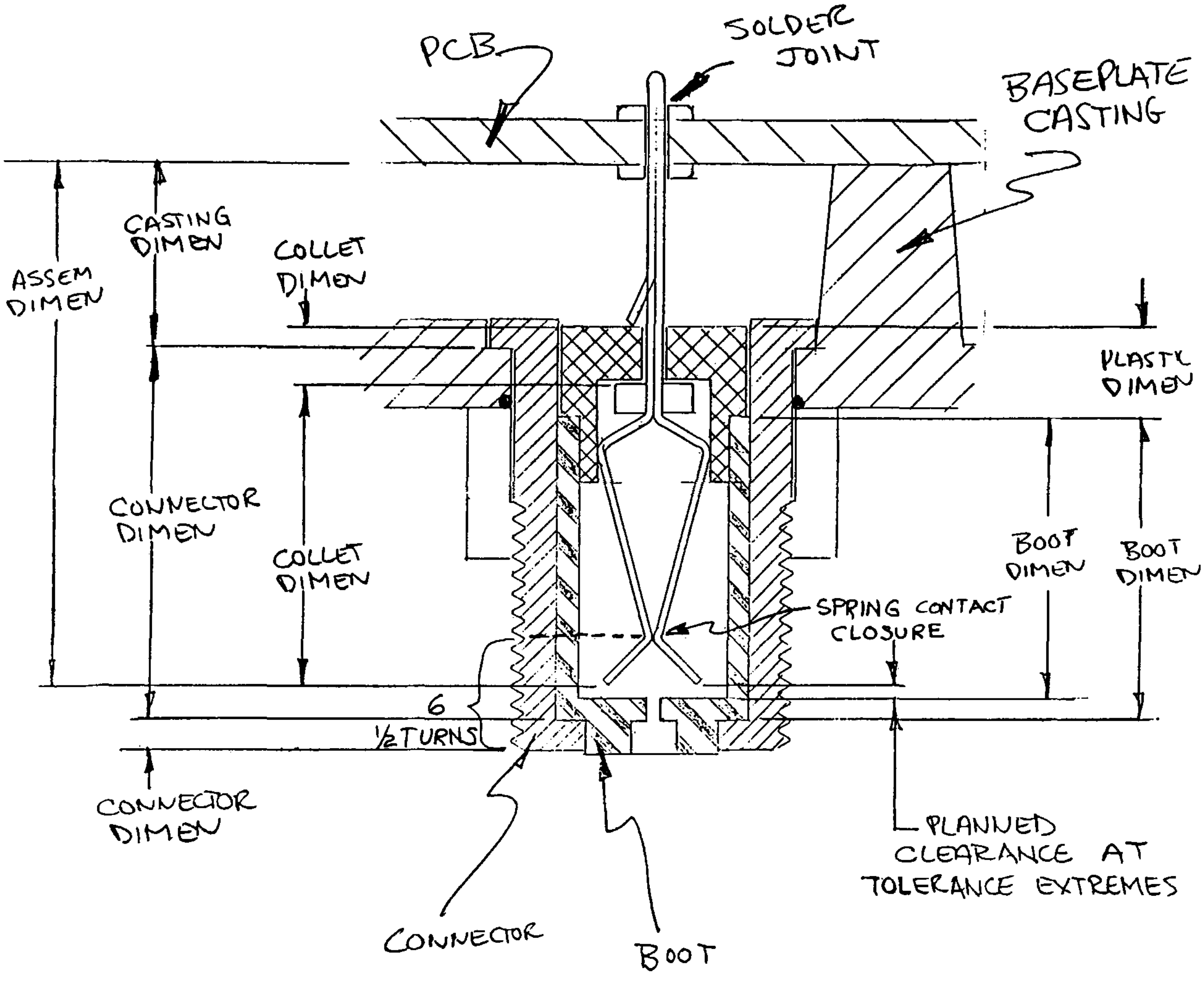
Our recommendation is that the center conductor should be cut between 1/8" to 1/4" beyond the shell. There is no danger from a conductor cut to these lengths; to the contrary, the extra length guarantees additional contact with the springs, as can be seen from Fig. 1. Every technician should understand that what is to be avoided are the barely-made connections which cause the system so much unnecessary cost and the techniciansso much unnecessary trouble.

HISTORICAL NOTE

For more than curiosity's sake, we traced the probable history of the connector and its drift to its present unsatisfactory state.

About 1980, a leading CATV manufacturer introduced the internal sealing boot which sealed the jack against moisture penetration on their taps. They carefully positioned the spring and collet assembly back from the internal boot so that they did not interfere. Otherwise the spring would have been prevented from closing freely on the center conductor; note Fig. 1 - "planned clearance of tolerance extremes." But, through the years, other companies adopted the same type of internal boot with slightly different designs, clearances and tolerances. This explains the wide variety of contact-turns listed in Table 1.

The standard we have proposed will provide a satisfactory contact with all the different types of F-type jacks.



EACH DIMEN. NOTED CARRIES WITH IT A ±.005" TOLERANCE

FIG. 1
TAP PORT CONNECTOR;
Cross Section

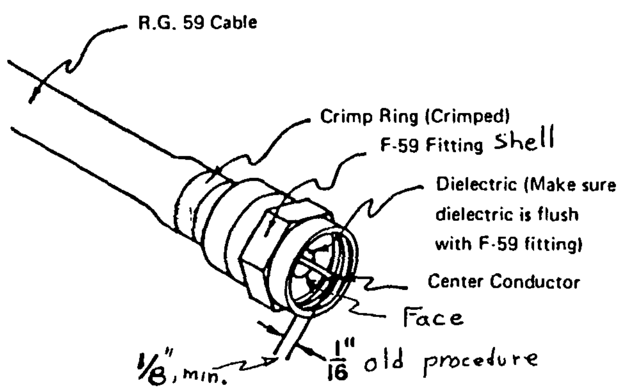


Figure 2 : Typical "F" Fitting Assembled.

		TURNS TO CONTACT			
TAP BRAND	PROJECTION ABOVE FLUSH	0	1 mm.	2.5 mm.	4 mm.
A		N/C	6	3	1
A		7	4	3	1
A		N/C	6	4	1
B		5	3	2	1
C		5	4	3	1
C		5	4	3	1
D		7	4	6	4
D		5	3	2	1
E		N/C	4	3	1

TABLE 1

TURNS vs. CENTER CONDUCTOR PROJECTION

ACKNOWLEDGEMENT

I wish to acknowledge the cooperation and assistance of Robert Wanderer of the United Artists Technology Center and Michael Hoffman of the United Artists Quality Assurance Department in this project.

A POINT-TO-MULTIPOINT FIBER OPTIC CATV TRANSPORT SYSTEM FOR THE CITY OF CLEVELAND, OHIO

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ABSTRACT

The use of fiber optic analog FM transmission in point-to-point CATV trunking applications is now well established and widespread. Owing to advances in single-mode fiber and device technologies, and the maturing of single-mode optical coupler manufacturing, it is now technically sound and economically attractive to implement point-to-multipoint CATV trunking on fiber in multiheadend/hub systems.

In this paper, we describe the Cleveland, Ohio, multiheadend/hub topology, the pros and cons of analog FM versus digital systems, fiber plant and headend/hub design considerations, and end-to-end performance of the installed system.

This system was manufactured and installed by Catel Telecommunications, Inc., of Fremont, California, for Ohio Bell Telephone (OBT), an AMERITECH company.

INTRODUCTION

The Ohio Bell Telephone Company is constructing a CATV system for the North Coast Cable Company, Ltd., the City of Cleveland CATV franchise operator.

The multichannel fiber optic trunking system and the headend/hubs will be owned, operated, and maintained by OBT. When complete, the CATV system will serve approximately 220,000 dwelling units. The ultimate objective for any CATV system design is to deliver and maintain high quality signals to all subscribers. Today's wide deviation FM-FDM fiber optic transport systems offer virtually transparent transmission of video, audio, and data for distances of more than 20 miles without repeaters.

Point-to-multipoint fiber systems can be configured in "star" or "tree" topologies such that high quality signals are carried deep into population centers, thus avoiding the need for long amplifier cascades in the distribution trunks. This design approach minimizes signal degradation, and enhances network reliability and availability.

The Cleveland system, believed to be the largest multiheadend fiber optic CATV point-to-multipoint system of its kind, was designed with those objectives in mind. It consists of one main headend and six regional headend/hubs (See Figure 1).

The initial design capacity (including future expansion) is for eighty-eight NTSC video channels and BTSC stereo TV or monaural program audio channels, together with thirty-five off-air broadcast FM radio signals, nine RS232C data channels, and an emergency alert control signal to be multiplexed and transmitted downstream on six optical fibers from the main headend to the six regional headend/hubs. In addition, there is sufficient bandwidth left for future new services.

In the upstream direction, up to twelve NTSC video channels and BTSC stereo TV or monaural program audio channels, together with nine RS-232-C data channels, are multiplexed and transmitted on one fiber from the regional headend/hubs to the main headend. In addition, two spare fibers (one for each direction) are available for maintenance purposes. Utilizing wide deviation FM-FDM techniques, similar to satellite video transmission, the Cleveland system offers integrated multiple services with capacity, flexibility, performance, and costs that are beyond the reach of today's digital systems.

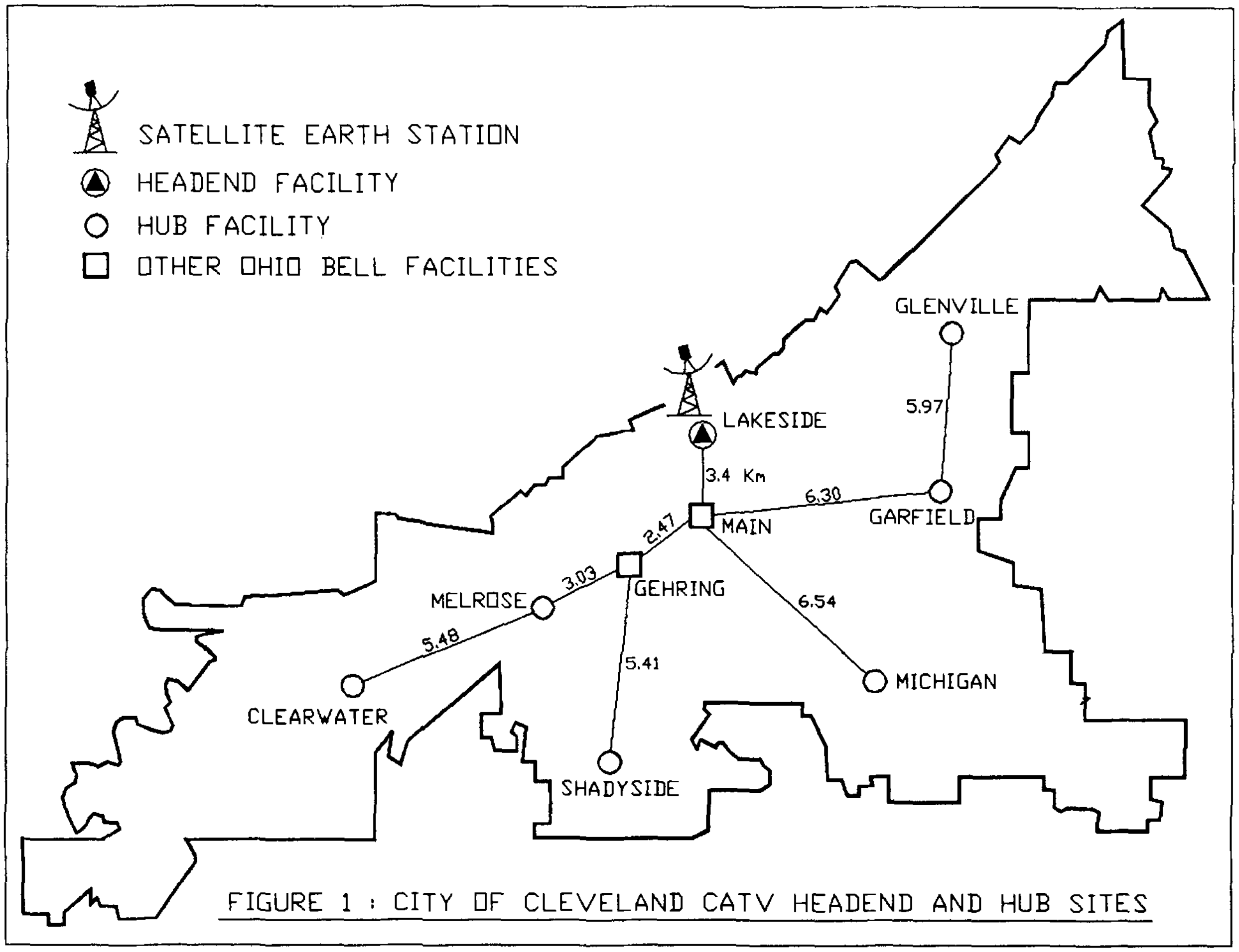

FIGURE 1 : CITY OF CLEVELAND CATV HEADEND AND HUB SITES

ANALOG VERSUS DIGITAL--THE SELECTION PROCESS

Modern CATV trunking systems have evolved into fully developed, integrated, multiple-service networks of high capacity, and great versatility and flexibility. We find that as technology advances and new services are introduced, it becomes necessary to accommodate a wide variety of signals, ranging from complex analog to simple data, on the same network. This must be done economically and without impacting the existing ongoing services. The viability of a given system, be it analog or digital, must therefore be examined with those considerations in mind.

In July 1986, OBT issued a Request for Proposal (RFP) detailing the requirements for the fiber optic system that will be discussed in this paper. Suppliers were requested to submit their proposals on an "engineer, furnish, and install" basis, utilizing their system features to the fullest advantage. All proposed systems, analog and digital alike, were evaluated from both technical and economic standpoints.

The basis for OBT's evaluation, which took place in the latter part of 1986, was the ten-point requirements summarized in Table 1.

Economically, the systems were judged using the "lifecost" analysis, which considers such economic factors as (a) system cost, (b) spare parts, (c) engineering charges, (d) installation charges, (e) software charges, (f) power requirements, (g) test equipment requirements, (h) failure rates, (i) shipping costs, (j) repair costs in and out of warranty, and (k) training costs.

Technical ranking was done on (a) specifications and features per items 1 through 9 of Table 1; and (b) hands-on verification tests that simulate operating conditions similar to the "real-life" system. The results of OBT's evaluation (see Table 1) indicate that on eight counts out of ten, analog

FM is the preferred choice over digital.

Undoubtedly, the future of telecommunications is with digital, and it will eventually prevail. However, digital CATV transport systems will only become viable when a total system design approach is undertaken, agreed standards are adopted, and cost becomes competitive.

Table 1 -- OHIO BELL EVALUATION, DIGITAL VERSUS ANALOG

Item	Requirements	Choice	Comments
1.	Maximum channel capacity	Analog	16 video ch/fiber analog; 8 video ch/fiber digital with 565 MB/S bit rate
2.	RS-250-B medium-haul or better	Analog	Video SNR better than 65 dB analog and 60 dB digital with 8-bit encoding and DPCM
3.	Accommodate BTSC format stereo or monaural audio	Analog	Digital could not handle signal format
4.	Accommodate broadcast FM radio channels	Analog	Digital could not handle signal format
5.	Accommodate bidirectional RS-232-C	Analog	Digital requires either individual fibers from each hub to headend for upstream data or "drop and insert" repeaters
6.	Controls, monitors, and alarms for maintenance	Digital	Digital is inherently easier to troubleshoot and maintain, compared to analog
7.	Upgrading flexibility	Analog	Digital is rigid and inflexible to upgrades; analog FDM is inherently flexible to upgrades
8.	Distances per Fig. 1	Either	Analog can span ≈25 miles without repeaters; the advantage of digital is in long-hauls of over 50 miles, where signals can be regenerated without loss of quality
9.	Accommodate upstream transmission	Analog	Same as 5
10.	Minimum "lifecost" for complete system	Analog	Digital systems are currently more costly

MULTIHEAD/HUB TOPOLOGY

As a provider of local telephone service to the City of Cleveland, Ohio Bell has had a unique advantage in selecting the optimum locations for the CATV headend and hubs. Naturally, they were placed in the telephone central offices, which are strategically located in the population centers throughout the city. Figure 1 depicts the city map, and the location of the satellite earth station and main headend facility (at Lakeside), as well as the six hubs in the telephone central offices (at Clearwater, Melrose, Shadyside, Michigan, Garfield, and Glenville).

The satellite earth station and the equipment associated with the signal feeds are owned, operated, and maintained by North Coast Cable Company. The signals that feed the entire CATV system (except upstream transmission) come from the North Coast Lakeside facility in the same building as the main headend.

At the time of activation in December 1987, there were thirty-seven C-band satellite TV receive signals, ten off-air TV channels, thirteen locally generated TV signals, thirty-five processed broadcast FM radio channels, and an emergency alert control signal. Nine additional bidirectional data channels were provided for monitoring and control of modulators, encoders, and trunk amplifiers. There were also four video and audio channels for transmission from each hub to the main headend.

In any system of this size and complexity, there are numerous feasible configurations of both fiber routing and channel loading. The following criteria were considered to determine those parameters:

- Maximize reliability and system availability.
- Provide an all-passive fiber plant.
- Minimize the number of fibers per cable, the number of cables, and the total system fiber kilometers.
- Minimize the number of fiber splices.
- Provide equal optical signal power at all hubs.
- Maximize expansion capabilities for both channel capacity and additional new services.
- Provide a virtually transparent point-to-multipoint transport system.
- Maximize system loss margin.
- Minimize "lifecost."

Figure 2 shows the chosen link topology, which is identical for both downstream and upstream transmission. The network consists of two FM trunks, east and west of Lakeside. The west trunk services the Clearwater, Melrose, and Shadyside hubs; the east trunk services the Glenville, Garfield, and Michigan hubs. Optical couplers are installed at the main facility to

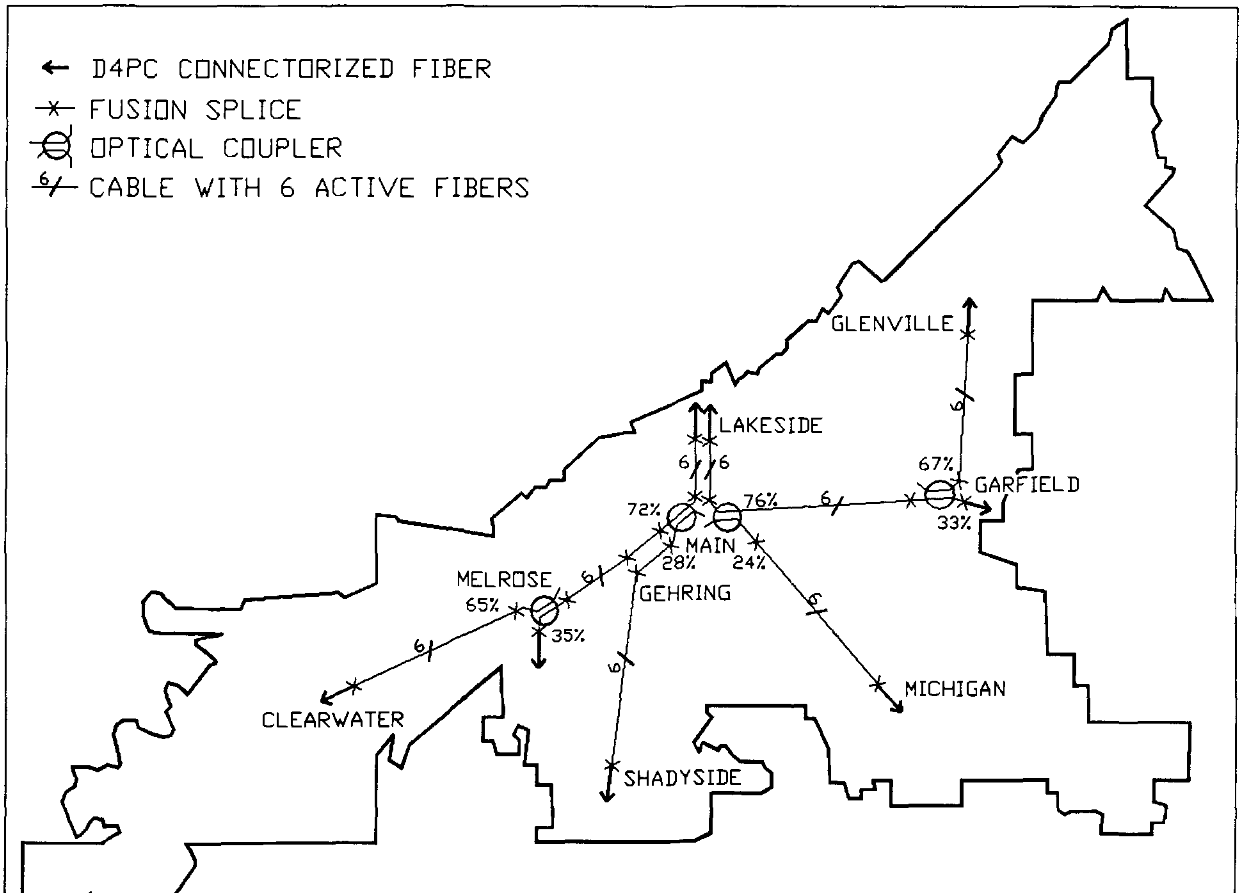

FIGURE 2 : CITY OF CLEVELAND CATV FIBER OPTIC PLANT

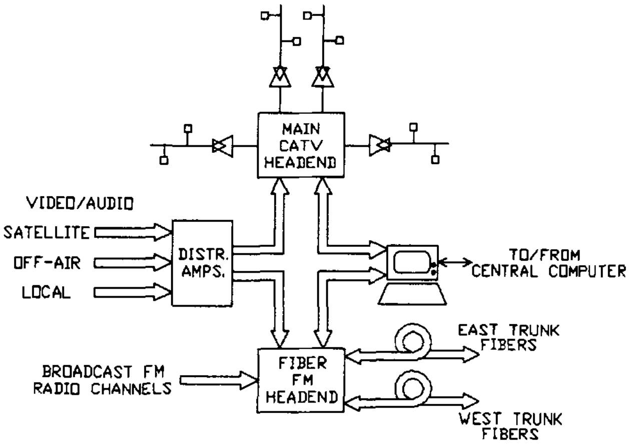

FIGURE 3 : MAIN HEADEND SYSTEM CONFIGURATION

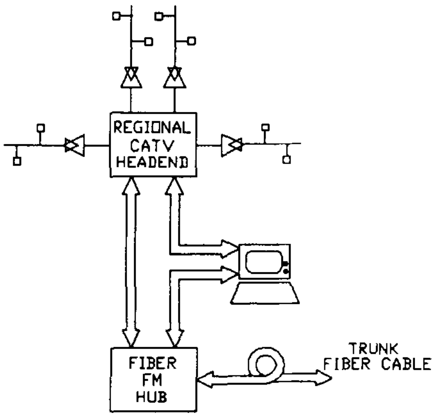

FIGURE 4 : REGIONAL HEADEND/HUB SYSTEM CONFIGURATION

split/combine the signals for transmission to and from the east and west hubs. Additional optical couplers are used at Garfield and Melrose to provide further signal splitting/combining to and from the remaining hubs.

Initially, there are six active fibers for each of the east and west trunks. Five are for downstream transmission, and one is for upstream transmission. Each fiber can carry a minimum of fourteen video and audio channels, as well as other services such as broadband (Ethernet) LAN, T1, T2, orderwire, telemetry, and so forth.

Figures 3 and 4 depict the main headend and regional headend/hub system configurations, respectively.

FIBER PLANT DESIGN

In general, the fiber plant design must meet both bandwidth and loss requirements of the system. The electrical bandwidth BW of the laser/fiber combination for a single-mode fiber is given by (1).

$$BW = \frac{0.187}{D \times \Delta\lambda \times L} \qquad (1)$$

where

D	is the total (chromatic plus waveguide) fiber dispersion in ps/nm and km
$\Delta\lambda$	is the RMS (root mean square) value of the laser diode spectrum in nm and
L	is the length of the fiber in km.

An InGaAsP Fabry-Perot laser has a typical $\Delta\lambda$ of 3 nm, and the fiber dispersion in a ±10 nm window around 1300 nm is from 0 to 3 ps/nm x km. A worst-case design must account for spread in laser center wavelength from unit to unit, as well as long-term wavelength drift due to aging. Conservatively, we will assume a wavelength shift of 10 nm, resulting in a maximum dispersion of 3 ps/nm x km and a calculated bandwidth distance product of 21 GHz x km. The longest link in our system is approximately 15 km; the minimum available bandwidth is therefore 1.5 GHz. Since the required system bandwidth is 550 MHz, the fiber link bandwidth is clearly not a limiting factor.

Next, we will address fiber plant loss and the system loss budget. Total fiber plant loss A_T in dB is given by (2).

$$A_T = A_F + A_S + A_{CR} + A_{EL} + A_C \qquad (2)$$

where

A_F	is total fiber loss
A_S	is loss due to splices
A_{CR}	is loss of optical couplers due to coupling ratios
A_{EL}	is excess loss of the optical coupler and
A_C	is loss due to optical connectors.

The fiber plant parameters and loss data in Table 2 are based on the following assumptions:

(1) Maximum fiber attenuation at 1300 nm is 0.5 dB/km.

(2) Maximum splice (fusion) loss is 0.2 dB.

Table 2 -- FIBER PLANT DATA

Parameter	LAKESIDE TO					
	MCHGN	GRFLD	GLNVL	SHDSD	MLRS	CLWTR
Distance (km)	9.94	9.70	15.67	11.28	8.90	14.38
Fiber Loss A_F (dB)	4.97	4.85	7.85	5.64	4.45	7.19
Main Couplers CR (%)	24.00	76.00	76.00	28.00	72.00	72.00
Main Couplers A_{CR} (dB)	6.20	1.20	1.20	5.53	1.43	1.43
Melrose Coupler CR (%)	--	--	--	--	35.00	65.00
Melrose Coupler A_{CR} (dB)	--	--	--	--	4.56	1.87
Garfield Coupler CR (%)	--	33.00	67.00	--	--	--
Garfield Coupler A_{CR} (dB)	--	4.81	1.74	--	--	--
Couplers EL (dB)	0.10	0.20	0.20	0.10	0.20	0.20
Splice Losses A_S (dB)	0.80	1.20	1.20	0.80	1.20	1.20
Connector Losses A_C (dB)	1.00	1.00	1.00	1.00	1.00	1.00
Total Loss A_T (dB)	13.07	13.26	13.19	13.27	13.04	13.09
Measured Average Loss A_{TM} (dB)	10.60	10.60	10.40	10.90	10.40	10.50
Measured Maximum Loss A_{MAX} (dB)	11.00	10.90	10.80	11.10	10.80	10.90
Measured Minimum Loss A_{MIN} (dB)	10.20	10.00	10.00	10.40	9.90	10.10

(3) Couplers are fusion spliced directly to the fiber cable.

(4) Excess loss of couplers is 0.1 dB.

(5) Connector loss allowance is 0.5 dB.

To equalize the path losses, the coupling ration CR is calculated from Equation (3).

$$CR = \frac{10^{\frac{\Delta A}{10}}}{1 + 10^{\frac{\Delta A}{10}}} \qquad (3)$$

where ΔA is the dB difference in the path losses.

From Table 2 we observe that, indeed, total loss A_T from headend to each hub is equalized with less than 0.5 dB. Also, measured average loss A_{TM} of the link is consistently lower than calculated loss by approximately 2.5 dB, which is typical for worst-case designs. These lower losses are attributed mainly to lower fiber loss and lower splice and connector losses achieved by careful selection of components and high quality installation. To avoid losses due to dissimilar fibers, the pigtails, patchcords, and couplers were made of the same type of fiber as the cable. The cable was pulled in long sections without intermediate splices, except for one at the Gehring facility. The optical connectors used are a physical contact (PC) type, which were chosen to minimize back reflections. For the same reason, fusion splicing was used rather than mechanical splices.

SYSTEM LOSS BUDGET

The system loss budget can now be determined from Figure 5, which depicts the weighted video signal-to-noise ratio (SNRw) as a function of received optical power/transmission distance for sixteen channels per fiber loading and 4-MHz deviation, with sync tip to peak white (STPW) preemphasized video. The data in Figure 5 was obtained experimentally, by measuring several transmitter-receiver pairs. Typically, there is a 2- to 3-dB difference in SNRw between the best and the worst channel. For the purpose of the loss budget calculation (see Table 3), we have used the worst-channel data and the 60-dB SNRw as a minimum requirement. The resulting system gain is 20 dB with 2 dB of allocated margin, and a remaining unallocated system margin of 6.7 dB minimum for a total of 8.7 dB calculated system margin. The actual installed system margin is 10.7 dB minimum, and the operating region is on the flat part of the SNRw curve.

The flat SNRw section of Figure 5 is characterized by the relative intensity noise (RIN) of the link, which includes the laser, the fiber plant, and the detector. In this region, the performance of the system is maximized, and typically meets RS-250-B short-haul requirements. To realize this very

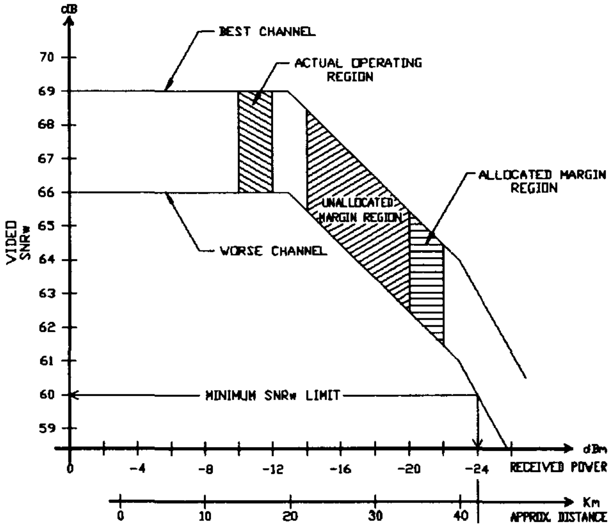

FIGURE 5 · VIDEO SNRw VERSUS RECEIVED POWER

Table 3 -- SYSTEM LOSS BUDGET

A.	Transmitter output power (min)	-2.0 dBm
B.	Receiver input power (min)	-24.0 dBm
C.	System gain (A-B)	22.0 dBm
D.	Allocated Margin for Equipment (temperature, aging, etc.)	1.0 dB
E.	Allocated margin for fiber plant (splices, connectors, etc.)	1.0 dB
F.	Total allocated margin (D+E)	2.0 dB
G.	System gain with allocated margin (C-F)	20.0 dB
H.	Total Loss A_T from Table 2	13.3 dB
I.	Unallocated system margin (G-H)	6.7 dB
J.	Measured maximum loss A_{MAX} from Table 2	11.1 dB
K.	Unallocated actual system margin (G-I)	8.9 dB
L.	Total calculated system margin (F+I)	8.7 dB
M.	Total actual system margin (F+K)	10.7 dB

high system performance, one must choose a laser that is relatively insensitive to back reflections, and has low RIN and mode partitioning noise characteristics. Furthermore, the back reflection from splices, connectors, and the fiber-to-detector interface should be minmized.

HEADEND/HUB DESIGN

The fiber/FM headend and hub diagrams are shown in Figures 6 and 7, respectively. The system was initially equipped with five groups of twelve video/audio channels per fiber, for a total of sixty channels. The thirty-five broadcast FM radio channels are processed (frequency translated and RF level equalized) and transmitted on fiber number one, together with their video/audio channels. The frequency plan for downstream transmission is shown in Figure 8A. Spacing between the video/audio channels is 34 MHz, and 400 kHz between the FM channels. All video input and output signals are NTSC baseband nonscrambled. The audio interfaces are at 4.5 MHz with either BTSC stereo TV or monaural formats. In order to preserve the high quality (SNR, separation, etc.) of both the video and the audio, the 4.5 MHz audio is frequency doubled before it is combined with the video baseband signal. This results in twice the deviation and a 6-dB SNR improvement, negligable crosstalk between video and audio (and vice versa), and the means to easily separate the video and audio at the receive sites.

The composite video/9-MHz audio signal feeds a low phase-noise linear FM modulator. The deviation (adjustable) was set to 4 MHz STPW, which is the best compromise between channel spacing and SNR. Frequency agile converters (adjustable in 1-MHz increments) and passive RF combiners provide frequency division multiplexing (FDM) to the RF carriers. The combined FM-FDM signal is split into two identical signals, which feed the east and west trunk optical transmitters.

Frequency shift keying (FSK) data modems are used to transmit the nine RS-232-C data channels and the emergency alert control signal on fiber number two, together with the second group of twelve video/audio channels. Currently, fibers three, four, and five carry twelve video/audio channels each. In the upstream direction, the signals from three transmitters are optically combined on one fiber for each east and west trunk. The frequency plan for the

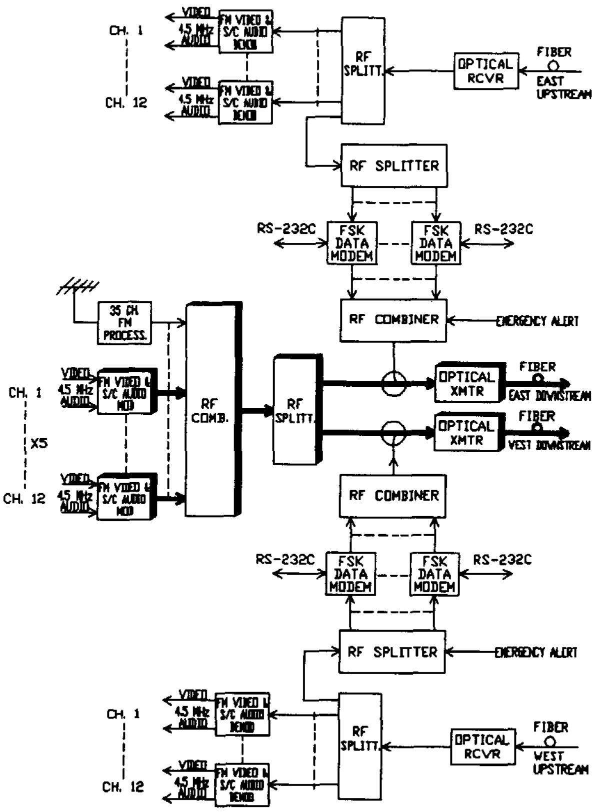

FIGURE 6 : FIBER/FM HEADEND

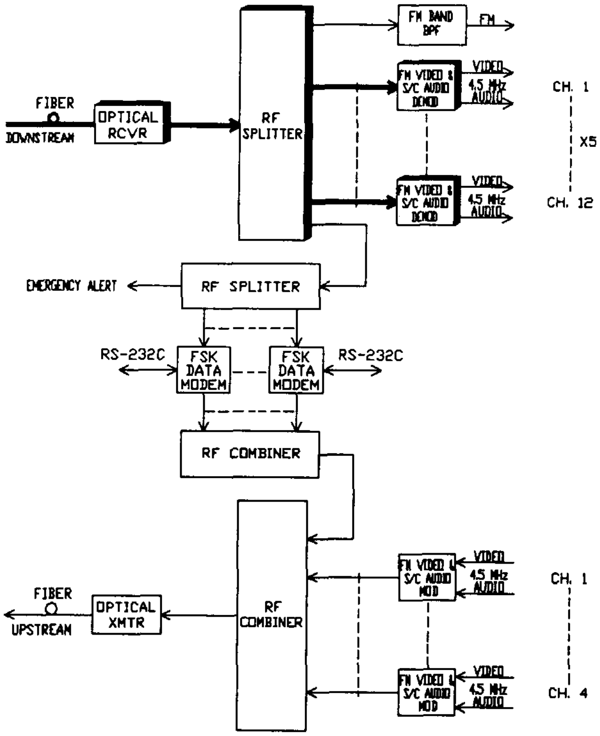

FIGURE 7 : FIBER/FM HUB

upstream transmission is depicted in Figure 8B. All six hub sites are identical in design; each receives all the channels from the headend and transmits four video/audio channels and three RS-232-C data channels

The 5 to 40 MHz band is reserved for future new services such as orderwire, T1 or T2, broadband LAN, and alarm remoting. The optical transmitters/receivers and the FM modulators/demodulators provide the alarm outputs that can be transmitted to the main headend via the upstream fiber link.

NOTES:

1. FM IS TRANSMITTED ON FIBER No. 1 ONLY.
2. DATA IS TRANSMITTED ON FIBER No. 2 (DOWNSTREAM) AND No. 6 (UPSTREAM).
3. AUDIO IS TRANSMITTED ON 9 MHz SUBCARRIER ABOVE VIDEO.

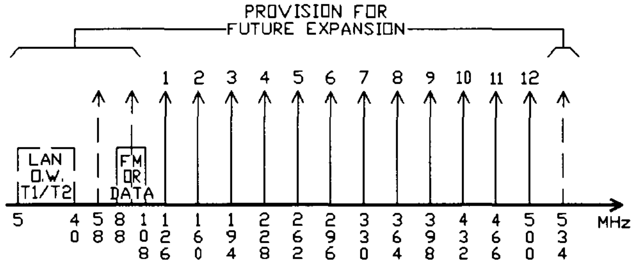

FIGURE 8A : FREQUENCY PLAN DOWNSTREAM

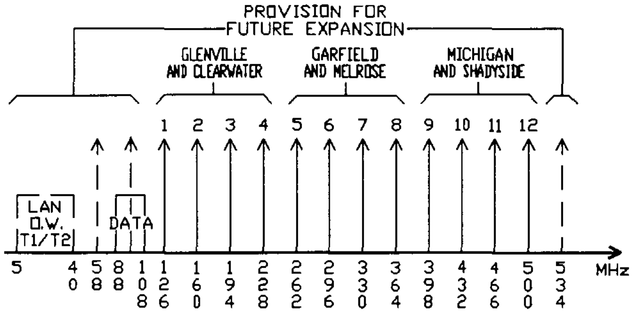

FIGURE 8B : FREQUENCY PLAN UPSTREAM

SYSTEM PERFORMANCE

The Cleveland system was designed to provide near short-haul EIA RS-250-B performance, and a guaranteed medium-haul performance. Back-to-back (without the fiber optics), the video SNRw is in excess of 73 dB. The video/audio parameters (except SNR) are not affected by the broadband fiber link which is virtually transparent to frequency modulated signals. The only degradation mechanisms are additive broadband and intermodulation noise. The advantage of wide deviation FM is in its immunity to broadband and intermodulation noise. The video SNRw is given by (4).

$$SNR_W = K + CNR + 10\log\frac{B_{IF}}{B_F} + 20\log\frac{1.6\,\Delta F}{B_F} \qquad (4)$$

where

K	is constant (≈23.7 dB) made of weighting network, deemphasis, and rms to p-p conversion factors
CNR	is carrier-to-noise radio in the IF bandwidth
B_{IF}	is IF bandwidth
B_F	is baseband filter bandwidth and
ΔF	is sync tip to peak white (STPW) deviation.

With $\Delta F = 4$ MHz, $B_{IF} = 30$ MHz and $B_F = 5$ MHz, the SNR_W is improved by approximately 34 dB above CNR.

The end-to-end performance of a typical video/audio channel is shown in Table 4. The short-haul specifications are included for comparison purposes. The histograms of the video SNR_W are included in Figure 9.

Table 4 -- CLEVELAND F/O TRANSPORT SYSTEM TYPICAL END-TO-END PERFORMANCE

	Parameter	Requirement	Measured Value	Short-Haul
NTSC Video	Multiburst 0.5	≤±0.25 dB	0.0 dB	≤±0.10 dB
	Multiburst 1.0	≤±0.35 dB	-0.2 dB	≤±0.15 dB
	Multiburst 2.0	≤±0.50 dB	-0.3 dB	<±0.15 dB
	Multiburst 3.0	≤±0.60 dB	-0.1 dB	<±0.20 dB
	Multiburst 3.58	≤±0.35 dB	0.1 dB	<±0.10 dB
	Multiburst 4.2	≤±0.60 dB	0.4 dB	<±0.20 dB
	C/L Gain	≤± 4.0 IRE	1.0 IRE	≤± 1.0 IRE
	C/L Delay	≤±33.0 nsec	10.0 nsec	≤±20.0 nsec
	DIFF Gain	≤ 5.0%	0.57%	≤2.0%
	DIFF Phase	≤±1.3°	0.46°	≤0.5°
	Field Time	≤3.0 IRE	1.0 IRE	≤3.0 IRE
	Line Time	≤1.0 IRE	0.4 IRE	≤0.5 IRE
	Short Time	≤4.0 IRE	2.8 IRE	≤4.0 IRE
	Long Time	≤8.0 IRE	1.0 IRE	≤8.0 IRE
	C/L Intermod	≤2.0%	-0.4%	≤1.0°
	C Nonlinear Gain	≤2.0%	0.0%	≤1.0%
	C Nonlinear Phase	<2.0°	0.0°	≤1.0°
	S/N Weighted	≥60.0 dB	67.7 dB	>67.0 dB
Audio	THD	≤ 1.0%	0.2%	≤1.0%
	S/N	>65.0 dB	67.0 dB	>66.0 dB

In conclusion, the Cleveland system fully meets, and in most cases exceeds, the design requirements and performance expectations.

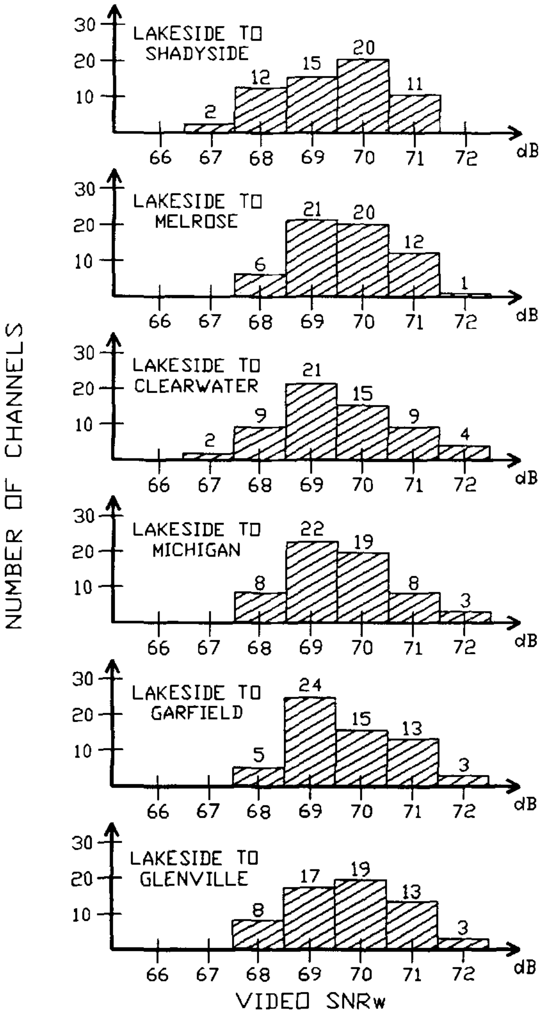

FIGURE 9 : VIDEO SNRw HISTOGRAMS

A PRACTICAL APPROACH TO AIRBORNE SIGNAL LEAKAGE TESTING (CLI)

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Cablesystems Engineering

ABSTRACT

Over the past three years, a development program has been undertaken to design, construct and calibrate an equipment package suitable for airborne signal leakage measurement. The Final Report of the Federal Communications Commission, Advisory Committee on Cable Leakage, issued November 1, 1979, outlined the basic parameters in testing cable television systems for cumulative leakage. The conclusions and recommendations of this report were based on airborne test results primarily from small cable systems. This paper will focus on a practical approach to airborne testing.

At the time of writing, systems ranging in size from 2,000 subscribers in 6 square miles of plant, to 250,000 subscribers in 400 square miles have been tested. In the final development stage, more than 100 hours of flight time was logged in verifying equipment performance, calibration and methodology of airborne testing. A specific calibration method and testing procedure has been documented, to ensure standardization of airborne measurements.

These airborne signal leakage measurement packages are now being used on a regular basis to test cable plant. Test results from selected flyovers will be presented with this paper.

INTRODUCTION

Cumulative signal leakage is a field of radio frequency energy, exhibiting no distinct plane of polarization, existing in the airspace above an active cable television system. The airborne signal leakage specification, as defined by the FCC, requires a maximum leakage criteria of 10 uV/m at 1,500 ft. altitude (450 m) above a cable system. To better understand this test method, visualize thousands of very small leaks from the system, without any specific relationship to each other, and all interacting on the input of an airborne receiver. The requirements for receiving and measuring this type of signal are significantly different than for conventional communications receiving apparatus. While most receiving applications are intended to preselect one specific communication, this system must recognize and collectively measure a multiplicity of signals. The equipment to measure such a group of signal sources must have very precise specifications. While the allowable level of signal leakage at 1,500 ft. above the cable systems is 10 uV/m, one should not assume that this is the threshold level for measurement. The equipment must have a dynamic range substantially above and below this level. Furthermore, any measurement taken within these parameters must be linear. The receiver must also be capable of withstanding severe overload, as may occur should a pilot accidentally transmit on the monitored frequency. The desired signal may, at times, be almost buried in the noise floor of the receiver, so stability and selectively are extremely important design considerations. The ultimate capability of the collection package must accommodate precise calibration repeatability to guarantee the accuracy of testing.

AIRCRAFT CHOICE

After experimenting with different aircraft, it was found necessary to set down selection criteria for the type of aircraft, receiving equipment and antennas. To avoid any compromise on the selection of the aircraft type, the following criteria were established.

1. The aircraft should be a high wing aircraft with good downward visibility.

2. The aircraft must be reliable, readily available and capable of instrument flight as well as visual flight.

3. It should be relatively simple to fly, have a reputation as a well behaved aircraft at low altitude and have excellent gliding characteristics.

4. Operating cost is a consideration.

5. Executive type aircraft should not be used. A "work horse" such as the type of aircraft normally found in flying schools is preferable.

The aircraft which was found to be the most suitable in meeting these criteria is the Cessna 172, a four passenger, high wing, single engine configuration, which is readily available throughout North America. In fact, there are 9,000 such aircraft currently in use. It is easy to fly, performs well in the 90 to 100 knot air speed range, and has six hours of flying time with normal fuel reserves. Similar type aircraft meeting the above criteria could also be used.

AIRCRAFT ANTENNA

The initial approach to airborne leakage measurements was to attempt to use existing navigational or communications mounted antennas which are part of the aircraft electronics package. Early in the development program the existing VOR antenna installation on our test aircraft was used for receiving signal leakage. However, extensive testing using a calibrated discrete leak showed that test results were unreliable and inconsistent. The conventional communications and navigational antennas on aircraft are primarily designed to receive signals from communication points on the horizon. These antennas do not have directivity in the downward direction, partially due to their placement and orientation. Because these antennas also have very poor directional capabilities, they typically are not satisfactory for differentiating signal sources. One of the main problems experienced with the conventional aircraft communication or navigation antenna is the hull effect (or reflective surface effect) of the aircraft, in this special application. This is normally not a problem in airborne communications, but severely curtails the probability of repeatability and calibration accuracy for airborne leakage measurements. Referring to my earlier comments on the literally thousands of leaks which will be within the horizon of the antenna, all being received from different directions, different field strengths, phase relationships, etc., it is inevitable that incorrect readings will be generated as a result of the reflective surfaces of the aircraft bouncing signal into the antenna. In calibration testing, using a discrete leak in accordance with the FCC prescribed test methods, it was found that the hull effect would create nulls and peaks in the signal as the aircraft passed over the signal source. For accurate testing, the received signal should not be influenced by the aircraft itself. Antenna placement and orientation should be such that the aircraft is in a null point of the antenna.

One of the original concepts of the airborne signal leakage tests was to have "a universal mounting" which would allow the test package to be installed on any Cessna 172 aircraft in a matter of minutes, without any structural changes to the aircraft itself. The intent was to be able to easily source an aircraft, mount the antenna and equipment in minutes, with no requirements for recertification or modification of the aircraft. However, since antenna performance is so critical to both sensitivity and geographic definition, it was necessary to develop a special antenna with the proper characteristics. This antenna pattern also must not be disturbed in any way by the aircraft itself. A balanced antenna is also necessary for increased noise rejection. In our search for the best antenna, a spar-mounted, co-axial dipole situated behind the aircraft's tail assembly was chosen. In this configuration the aircraft is on the antenna's insensitive axis and distortion of the antenna's dipole pattern is negligable. At an altitude of 450 m, an area spanning 900 m laterally by 500 m fore and aft is within the -3 dB contour of this antenna.

COLLECTION PACKAGE

The collection package is specifically designed for ease of shipping from point to point in a specialized shipping container, and for ease of mounting in the aircraft. In fact, once the antenna brackets have been permanently installed on the aircraft, the antenna and equipment package can be installed and removed in a matter of minutes. The testing process is designed for operation by the aircraft pilot, without the need for any other personnel in the aircraft, with a few exceptions.

The package consists of two parts: a ground based RF carrier source installed in the headend, and the airborne equipment package. Within the airborne equipment package there are several separate component blocks. It contains a sophisticated LORAN-C navigational unit, a computer and CRT display, a specially designed receiver, disk drive, power supply, etc. To facilitate ease of operation, the right front seat of the aircraft is removed and this "black box" mounts directly in its place. Equipment layout allows the pilot easy access to all equipment controls and CRT screen. A special keypad for function control is mounted on a saddle which is strapped to the pilot's right leg. The LORAN-C receiver is capable of storing a complete grid pattern in its memory, which is sequentially accessed during the audit process. Where LORAN-C navigation can be used, signal leakage testing can be accommodated using only the pilot of the aircraft. In certain areas west of the Mississippi and east of the Rockies, LORAN-C coverage is unreliable or unavailable. In these areas, an observer supplements the LORAN-C information and the aircraft is flown on a ground recognition grid as opposed to an electronic grid.

During airborne testing the aircraft equipped with our test package is flown in a sequence of parallel paths over the cable system being tested. The flight legs are spaced a distance of 900 m apart so that the receive antenna's -3 dB contour just overlaps on each pass. Flight passes are flown in a north-south direction then repeated in an east-west direction. Cable system coverage is complete with this grid pattern.

A cross track error indication from the Loran receiver allows for a very accurate flight path to be flown. At the end of each pass over the cable system, the collected data, along with flight path start-stop co-ordinates, are transferred to floppy disk while the aircraft is being turned around to begin the next sampling run (see Figure 1).

CALIBRATION

As previously mentioned, calibration is a critical factor in airborne signal leakage tests. Part 76.611 of the FCC rules suggests that calibration should be made in the community being tested or within a reasonable time frame to performing the measurements. While this may be quite satisfactory for ground CLI testing, airborne calibration should not be undertaken in close proximity to a cable system, a major airport or aircraft communication facility. Our primary calibration standard uses the recommended methods outlined in associated FCC documentation. Calibration is performed at a significant distance from any major communication facility, cable system or an interfering source. To maintain calibration accuracy we employ a secondary standard of test procedures and equipment, which is carried with the aircraft, and which verifies performance accuracy and calibration before and after the testing process.

COMPUTER AIDED DRAFTING AND PROCESSING

While a preliminary analysis of cable system leakage is available from the collection equipment even before the aircraft has landed, collected data is transferred to a more powerful computer to undergo further processing. Word processing capability is also integrated into the system, to prepare an accompanying written report.

Data files from the collection unit's floppy disk are down loaded to the computer aided drafting system. A map outline of the active plant area is digitized and stored in the computer memory as a map drawing file. A map creation program calculates paths flown by the aircraft from latitude and longitude co-ordinates stored during the airborne data collection process. Signal level information is then processed as follows:

first - accurate positions of measurements along the data collection flight path are established;

second - signal levels are sorted into windows for signal level vs. color identification as well as signal level vs. width of line presentation; and,

third - signal level data collected from outside of the active plant boundary is discarded and signal level files contain only information collected from the cable system's active plant.

The 90th percentile is accurately calculated from these files. A map displaying the cable system plant boundary with received cumulative signal levels, plotted along the calculated aircraft flight path, is generated for a visual presentation of the extent of cable system signal leakage (see Figure 2).

FIGURE 1

AIRBORNE COLLECTION PACKAGE

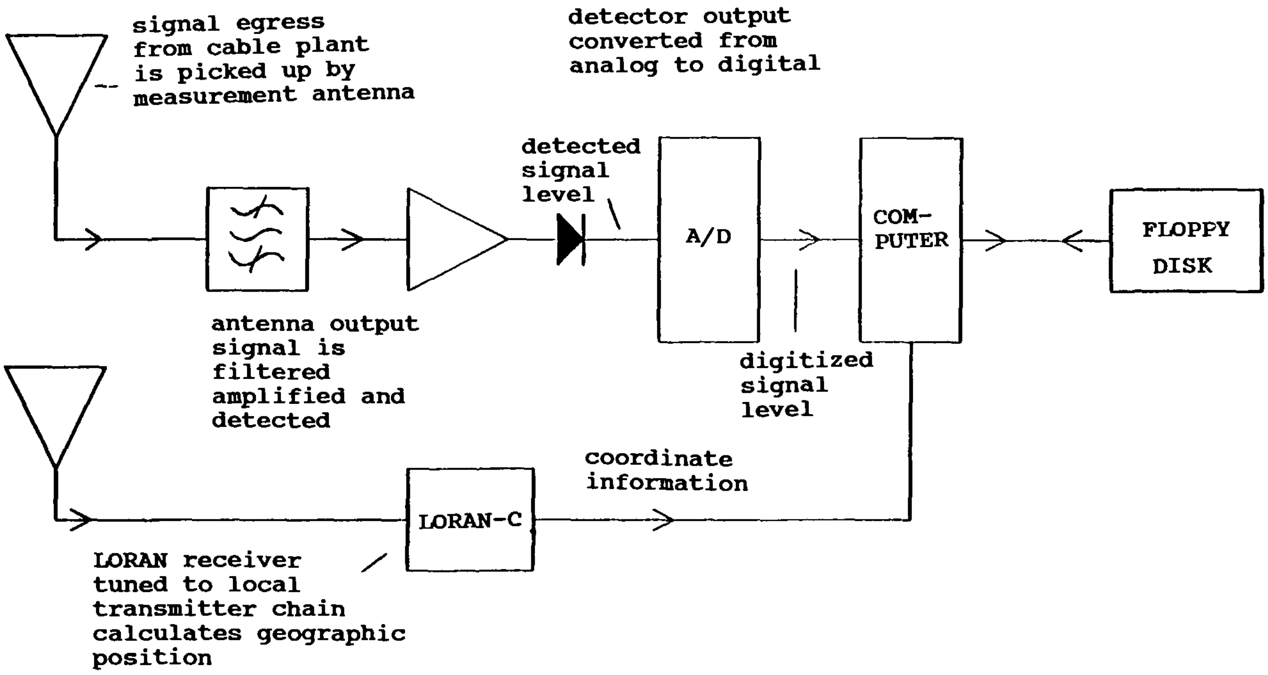
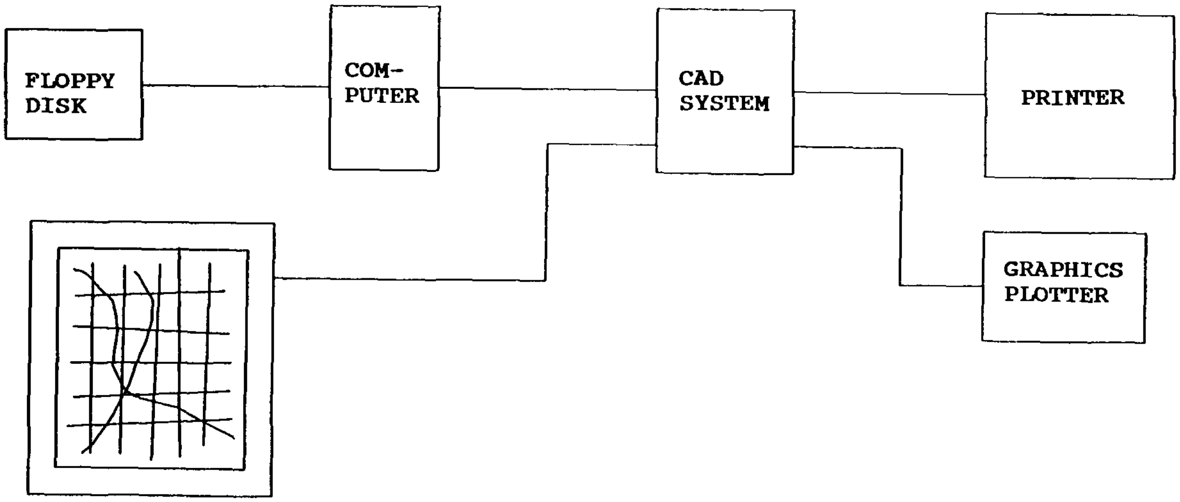


FIGURE 2

CAD PROCESSING/MAPPING PACKAGE



MAP DIGITIZER

TEST RESULTS

If a cable system has been reasonably well maintained, and regular signal leakage control procedures have been followed, the mapping will give good geographic identification of problem areas. If little or no signal leakage efforts have been undertaken by the system management, then the overall map presentation will show levels of signal leakage totally blanketing the cable area. Level differences can also reflect the integrity of the components used during the various phases of the original construction, and the specific demographics (e.g. multi-units, older building wiring, areas of improperly installed plant etcetera).

In summary, airborne testing provides a cable system operator with a global prospective of cable leakage. In a well maintained plant, specific "hot spots" can be identified readily for increased maintenance attention. In a poorly maintained plant, the magnitude of the problem facing the cable operator in correcting signal leakage will be very apparent. As an example, a three hour long flyover of a 50,000 - 75,000 subscriber system will provide a full understanding and recognition of the depth of the signal leakage problem in the system. A similar analysis of thousands of ground based readings will not provide the conceptional level of understanding that can be achieved during a review of an airborne signal leakage map. The airborne signal leakage map is most valuable in defining signal leakage problems to senior management and corporate executives. It provides an instant recognition of the dimension of the signal leakage, and the relationship to maintenance requirements can be identified though this interpretation. A multiple system operator has the ability, at the Corporate level, to better understand the condition of each cable plant, and the implications for each system of the Cumulative Leakage Index requirements commencing in July, 1990. This allows informed decisions in allocation of resources to meet these requirements.

A GLOBAL PROSPECTIVE

Let us now examine the implications that we face in the next two years in order to meet the 1990 requirements. Many cable system operators are actively performing ground checks to verify whether the ground based measurements of I infinity and I 3,000 can be met with the existing cable plant. In large cable systems, particularly those in metropolitan areas with high rise apartments, multi-units, and very large geographic areas, it is extremely difficult to meet the I infinity method of calculating CLI. The I infinity formula is a theoretical formula, correlated from airborne tests done by the FCC. These tests were performed on relatively small cable systems where the I infinity method may be quite appropriate. However, since the accumulation of leakage measurements in the I infinity formula does not recognize free space attenuation, all signals are deemed to be at the same geographic location, when collected within the formula. From a practical interference point of view, failure to recognize the free space attenuation factors and the slant range implications makes it extremely difficult to meet this CLI test in large geographic areas. In cities more than 10 miles (16 km) in diameter, the inadequacy of the formula becomes quite obvious. Nevertheless, systems have a choice of three methods of meeting CLI. The I infinity method for large systems is, in our point-of-view, inappropriate. The I 3,000 formula, which is better in that it recognizes the implications of free space attenuation, is more applicable, but does not consider all factors and involves many calculations. The airborne method of signal leakage described here records an accurate interference factor in a matter of hours.

We have discussed earlier the implications of airborne signal leakage in terms of ability to measure signal leakage involving large amounts of cable plant in short periods of time. To give this a bit more perspective, based on testing to date and average flying times for systems, a few rules of thumb can be developed. For each hour of actual system flying time (ignoring ferrying time for the aircraft to and from the system) approximately 200 miles of cable plant, 10,000 - 20,000 subscribers, or 25 square miles of geographic area can be tested. Obviously the length of the test is a function of the size of the geographic area, since this determines the number of passes over the system. One Ontario system with 28,000 subscribers and 240 miles of plant was flown in approximately 1 hour and 20 minutes. Another 65,000 subscriber system was flown in 2 hours and 30 minutes.

Let us now look at what might be required to perform airborne signal leakage testing throughout the United States. As mentioned earlier, our approach was to concentrate on the type of aircraft which would be most suitable for the actual measurements, and to give less priority to flight speed during aircraft ferrying time between franchises. A reasonable zone for an aircraft to perform airborne signal leakage testing from one operations base would be approximately a 500 mile radius. This represents a 785,000 square mile area. Given that the United States is approximately 3.6 million square miles, the practical number of aircraft required to do airborne signal leakage tests throughout the U.S. should not be more than 15-20 aircraft. Since the aircraft need only be used on an as-required basis once modified, airborne signal leakage equipment need not be dedicated to an individual aircraft. By examining a total number of cabled households in the United States, the total plant miles, and some extrapolation from the sample of signal leakage tests already conducted by our company, we can draw the rough assumption that there are 8-10 route miles of cable plant per square mile of cabled community. This will vary significantly from community to community; however, on balance it is a safe assumption. Similarly since there is approximately 700,000 miles of cable plant in the U.S., and we can fly 200 cable miles per hour, approximately 3,500 hours of flying would be required to perform airborne signal leakage in all cable systems in the continental United States. If we assume that ferrying time is approximately equal to airborne testing time, then 7000 hours per year of flying time would be required. However, since smaller systems can be grouped and flown sequentially, and some small systems in remote locations may prefer ground-based testing, the estimated total flying time could be approximately 5,000 hours per year. With strategically placed aircraft, this equates to 300-500 hours per aircraft per year.

The equipment is essentially automated, with minimal operational training required. A professional pilot could perform airborne signal leakage testing, and could simply download the data at the end of each day of flying, to a central processing point via telephone line into the CAD system to produce the necessary mapping. Using overnight courier the information could be returned to the system within two to three days. A support person would be required to assist in interfacing with system personnel and headend equipment set up, if it is anticipated that a large number of flyovers would be occurring in an immediate geographic area. Pilots for this type of aircraft are readily available, and can be easily trained to perform airborne leakage testing, due to the highly automated nature of the collection package.

CONCLUSION

The use of airborne signal leakage testing methods is a practical and efficient approach to system certification for signal leakage purposes. While ground patrol, coupled with system maintenance, will always be required to meet system leakage requirements, airborne tests will provide efficient and conclusive annual audit testing for compliance with FCC CLI regulations. It will also assist in identifying signal leakage missed by the ground patrols. The advantages of being able to quickly obtain a signal leakage profile of an operating system and identify geographically "hot spots" is a significant management tool in the operation of cable plant. Irrespective of the regulatory requirements, the signal leakage audit also provides a profile of maintenance effectiveness and system component integrity, which is also valuable to the cable operator.

REFERENCES

Final Report of the Advisory Committee on Cable Leakage to the Chief, Television Bureau, Federal Communications Commission November 1, 1979.

A TECHNICAL ANALYSIS OF A HYBRID FIBER/COAXIAL CABLE TELEVISION SYSTEM

Perry Rogan, Raleigh B. Stelle III, Louis Williamson

American Television and Communications

Abstract **- Improvements in the quality of the delivered NTSC signal in CATV systems may be obtained by the application of fiber backbone technology.**

These signal improvements will be the result of decreased cascades of traditional cable television amplifiers following the fiber node. These improvements are measurable in terms of carrier-to-noise ratio, and intermodulation products.

The resulting improvement in system overhead may be exchanged for additional bandwidth, for increased system reach, or for improved quality of the delivered signal.

This paper presents the evaluation we performed for one of our existing systems. We show the improvements in performance which are obtained with fiber backbone. We also show how the same system can be upgraded from 270 MHz to 550 MHz, without changing trunk cable, trunk locations, or using microwave hubs. The 270-550 MHz upgrade example focuses on the exchange of performance for additional bandwidth.

SCOPE

American Television and Communications (ATC) management directed the engineering staff to undertake the analyses described herein because of its belief that our future depends on six primary operational considerations.

1. Delivery of signal quality directly comparable to present and perceived future sources, while providing economics comparable to, or better than, alternatives now available to our systems.
2. The ability to transport to the home, any enhancement which may be forthcoming in the art of television systems.
3. The ability of our systems to offer ancillary services which may become desirable to our subscribers.
4. The ability of our systems to meet competitive situations in a cost effective manner.
5. The ability of our systems to operate in a more reliable fashion.
6. The ability of our systems to take advantage of a more flexible evolutionary architecture.

This paper will deal only with the technical performance aspects of the application of the fiber backbone concept. Financial modeling which is an inherent part of any decision making process will be presented by other members of the ATC Engineering staff in a separate paper.

FIBER BACKBONE

The fiber backbone concept requires that conventional amplifier cascades be reduced to a small number, such as 2, 3, 4, or 5. In order to create such short cascades, a number of "fiber nodes" must be created. Each node is connected to the headend by single mode optical fiber which transmits the optical signal from the headend to the node.

In the headend, the radio frequency (RF) signals are converted to optical frequencies, and coupled onto the fiber.

The multi-fiber cable follows traditional trunk routings and is likely to be overlashed to existing cable. As the fiber proceeds toward the furthest node point, it is split, and spliced many times. Examples of these routes are included in the appendix.

At the fiber node location, we believe the equipment required will be housed in an enclosure similar to existing trunk amplifiers. The purpose of the node is to terminate the optical fiber cable, and convert the optical signal on that fiber to RF for transmission to the home via traditional cable television trunk and line extender amplifiers.

How good must the node RF performance be?

We believe the signals recovered from the fiber must have at least 55 dB carrier-to-noise, -65 dB composite triple beat and -65 dB composite second order performance.

OPTICAL LINK PERFORMANCE

ATC staff engineers began active experimentation in fiber optic transmission systems in the spring of 1987. While our focus is directed primarily at broadband amplitude modulated, vestigial sideband (AM-VSB) transmission, we also closely monitor the progress being made in the area of FM transmission on fiber. Either modulation technique (AM, or FM) may be applied to the fiber backbone approach.

Several vendors of lasers, fiber, and detectors were contacted with requests for product information and sample items. The initial results were disappointing, yielding carrier-to-noise ratios of 47 dB, and composite triple beat ratios of 50 dB. With these devices, the second order performance was unacceptable. The composite second order beat products were eliminated from the band of interest by choosing an octave of bandwidth from 200-400 MHz for the initial experiments. In practical application, it may be necessary to convert the 55-550 spectrum to 605-1155 MHz prior to modulating the laser. Two advantages are expected from this process. One advantage is that all second order products will fall outside the band of interest, and may be removed by filtering. The second advantage is that this frequency range allows the laser to function in a more favorable region of its operating characteristics.

This performance was initially perceived as disappointing because it was so far from the performance required to make the fiber backbone concept a reality. The disappointments did not last very long, however.

The following graph, Fig. 1, indicates the performance improvements we have been able to observe from the various components of fiber systems to date.

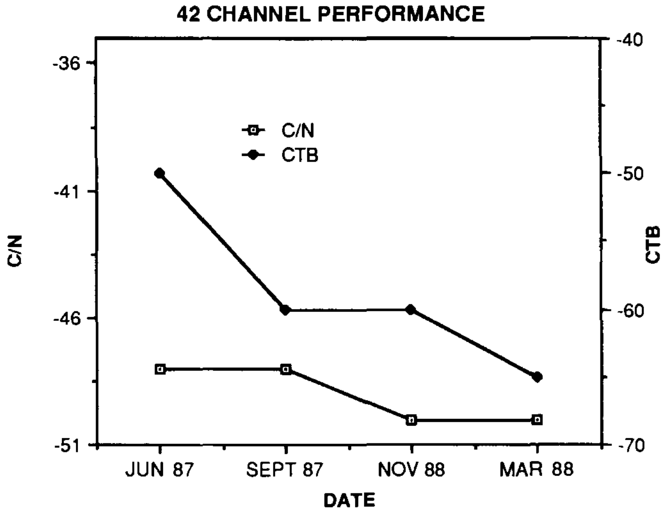


Figure 1. Link Performance over 15 KM

The best performance observed so far produces 48 dB carrier-to-noise ratios and -65 dB composite triple beat dB with 42 channel loading, through 15 Km of fiber.

A future element of the fiber experiment is to block convert the 42 channel spectrum (55-330 MHz) to 605-935 MHz. At these frequencies the signals occupy less than an octave of bandwidth and we will be better able to determine the second order performance. Experiments are presently in progress on this phase of the project, and will be reported as they produce meaningful data.

The progress made in laser technology over the past year makes us very optimistic that the required node performance goals of 55 dB carrier-to-noise, -65 dB composite triple beat, and -65 dB composite second order over 15 Km of single mode fiber are goals which will be achieved in the near future, at acceptable prices.

An especially significant item of note is that in our discussions with various manufacturers of lasers and detectors, we have learned that there are no known physical limits preventing the laser and detector manufacturers from creating devices with the parameters required to deliver the performance we expect.

Assuming that the required node performance is obtainable, we analyzed the performance improvements which can be expected in the sample 270 MHz system. We then performed an analysis on this same system to determine the performance achievable if the system were to be upgraded to 550 MHz.

In the 550 MHz upgrade, we decided to attempt to use the same trunk cable and amplifier locations, and to "drop-in" appropriate 550 MHz amplifiers, if possible.

COMPUTER ANALYSIS

All of the analyses presented are performed with various computer programs which permit the entry of all necessary variables, and calculate performance accordingly. Several of the exhibits are the printouts from these programs. The programs require the entry of the equipment operating parameters in the area designated "Manufacturer's Specifications". The operating parameters, as the equipment is applied in the system, are entered in the "System's Specifications" area. Included in this area is the data for the number of each type of amplifier in cascade. In the area labeled "Calculated Equipment Specifications", the program calculates the performance which is expected from the contribution of each of the elements cascaded (i.e., trunk, bridger, line extender, and converter), derating appropriately for the operational parameters chosen. The "Calculated System Specifications" area indicates the expected performance of the elements in cascade, indicating "end of the line" performance. Using a program simplifies the repetitive process necessary to arrive at optimum solutions to diverse system applications.

The following material represents our progress to date in the process of arriving at an optimum solution to the problem of implementing the fiber backbone concepts.

SIGNAL QUALITY IMPROVEMENTS

As stated in the abstract, one of the goals of our project was to improve the performance of an existing 270 MHz system. The following section describes the processes we used, and the results obtained from applying the fiber backbone to this system.

The system chosen for analysis is one of ATC's older 270 MHz systems which has been in operation for more than 15 years, and which requires improved operational performance to meet competitive pressures, and market demands. The system segment analyzed consists of 375 miles of plant, serving approximately 10,000 subscribers. The longest cascade consists of 28 trunk amplifiers, one bridger, and two line extenders. The trunk spacing is 21 dB, and the cable is .750" P-3. The distribution levels are 48/41 dBmV for the bridger, and 43/37 for the line extenders. The end of the line performance of this system is: 46.7 dB carrier-to-noise, -56.2 dB composite triple beat, and -60.3 dB composite second order.

The system performance is shown in the cascade analysis, Exhibit 1 of the appendix.

Implementation of a fiber backbone in this system will yield an improvement in carrier-to-noise of 4.8 to 5.7 dB, depending on the number of amplifiers cascaded after the fiber node. In this example, the intermodulation products were slightly worse after implementing the fiber backbone. These intermodulation products are the result of the high tap levels required in the distribution portion of the system, to meet end of the line tap levels. See Fig. 2, below, and Exhibits 1, 2, 3, and 4 of the appendix.

SYSTEM END PERFORMANCE DATA

	C/N	CTB	CSO	NODES
BEFORE FIBER BACKBONE	46.7	-56.1	-60.3	0
AFTER FIBER BACKBONE 2 TRUNK IN CASCADE	52.4	-55.2	-61.3	61
AFTER FIBER BACKBONE 3 TRUNK IN CASCADE	51.9	-55.1	-61.2	41
AFTER FIBER BACKBONE 4 TRUNK IN CASCADE	51.5	-55	-61	29

Figure 2. end of the line performance calculations based on trunk cascade and "quad power" line extenders.

Fig. 2 shows the end of line comparisons for different cascades after the fiber node. Exhibit 1 shows the present system performance. Exhibit 2 shows the performance with the fiber backbone with four trunk amplifiers cascaded after the node. Exhibit 3 shows the performance with two trunk amplifiers cascaded after the node.

This range of improvements is made possible by the flexibility of system architecture produced by implementing the fiber backbone concept.

In this example, our goals were:

1. Reuse as much of the existing plant as possible to minimize the complexity of any future upgrade which might be undertaken. Existing equipment was reused, and only direction reversals on approximately half the trunk locations were required.
2. Provide performance improvements which will allow this system to meet present market pressures, and permit future bandwidth expansion as necessary. The goal of improved carrier-to-noise was met. (4.8-5.7 dB).

As the system design for the quality improvement example evolved, it was necessary to consider the number of fiber node locations to be used. Several alternatives were evaluated with emphasis on the system performance with various cascades after the fiber node. An analysis of the number of nodes required is contained in Figure 3 below. It can be seen that in each of the 209 existing trunk amplifiers is a node location; the number on nodes required is 209. Similarly, if the number of amplifiers cascaded rises to 28 (the original cascade), the number of nodes is one. Between these values, we selected the numbers 2, 3, and 4 for cascade and fiber route evaluation.

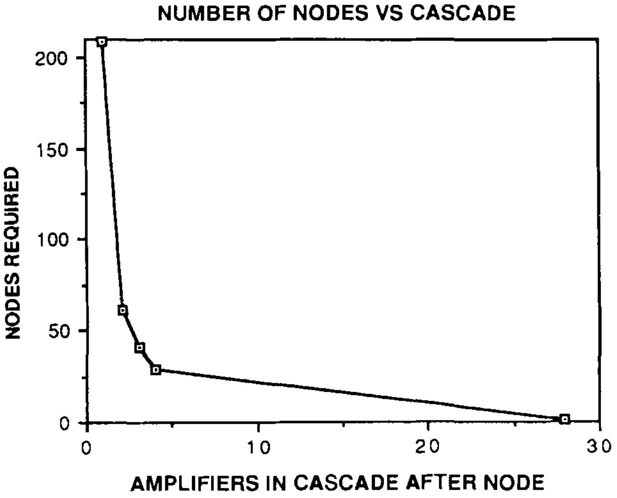


Figure 3. The relationship between cascade selected, and fiber nodes required.

Due to this system's architecture, and the curve from Figure 3, it appears there is no apparent advantage to continuing beyond the four in cascade point. To do so would defeat our purpose because of the buildup of noise and distortion in longer cascades.

As a preamble to the next section, two terms to be used require definition. They are: route miles, and fiber miles. A "route mile" is total linear distance which will require lashing of the fiber bearing cable to the existing plant. The "total fiber mileage" is the sum of the distances from each node to the headend, with one fiber run per node.

For each of the analyses presented we have calculated the route mileage to provide an indication of the magnitude of the overlashing required, and the fiber mileage to indicate the possible fiber costs.

The node location data, and fiber mileages for the system analyzed, are shown below.

For four in cascade after the node: (miles)
1. Route mileage = 43.7
2. Fiber mileage = 128.6
3. Nearest node = 1.13
4. Furthest node = 8.99

For three in cascade after the node:
1. Route mileage = 45.3
2. Fiber mileage = 174.6
3. Nearest node = .9
4. Furthest node = 8.61

For two in cascade after the node:
1. Route mileage = 50.9
2. Fiber mileage = 248
3. Nearest node = .9
4. Furthest node = 8.99

The fiber routings for the three cascade examples tested (2, 3, and 4 after the node) are shown in Exhibits 6, 7, and 8 respectively. These exhibits are located in the appendix.

FIBER ANALYSIS VS CASCADE

	ROUTE MILES	FIBER MILES	NODES (FIBERS)	NEAREST NODE, MI.	FARTHEST NODE, MI.
2 CASCADE	50.9	248	61	.9	8.99
3 CASCADE	45.3	174.6	41	.9	8.61
4 CASCADE	43.7	128.6	29	1.13	8.99

Figure 4. Fiber requirements versus cascade chosen.

Figure 4 is a tabulation of the number of nodes, fiber miles, and route miles for each cascade evaluated.

Design samples were performed to determine the architecture of the system after application of the fiber backbone. The typical trunk routings for each cascade evaluated are shown in Exhibits 8, 9, and 10 of the appendix. While it was not necessary to physically relocate any of the trunk stations, 50% of them will require reversal.

The distribution portions of the original system remain unchanged.

Another point of interest is that the same node locations will be used regardless of whether the plan is to simply upgrade the system performance, or to increase the bandwidth. This condition occurs because the same trunk locations and cascades will be used in either situation.

The preceding information shows the performance improvements which can be achieved with existing plants. As can be seen, the performance improvements in themselves are significant. Even more significant is with this performance in place, the stage is set at any time in the future to upgrade this system to 550 MHz. Not only can this system be upgraded, it can be upgraded for a relatively low cost compared to the alternative of a total rebuild.

270-550 Upgrade

The performance improvements generated by the fiber backbone approach and very short amplifier cascades permits an exchange of end of the line performance for expanded bandwidth. Adding improved technologies permits the upgrading of this 270 MHz system to 550 MHz, while maintaining adequate end of the line performance, with no change in trunk cable, distribution cable, or trunk locations.

The test design for the upgrade of the system was a sample of 15.8 miles of plant, with areas selected to represent an average sample of the densities in existence. Three areas of five miles each were designed, with densities ranging from less than 75 homes per mile, to densities exceeding 130 homes per mile.

DISTRIBUTION ANALYSIS

The analysis process of this upgrade began with the end of the line performance criteria established for our systems. It was determined that these parameters would be met or exceeded in the 550 MHz upgrade.

The major performance specifications to be met are:

1. 46 dB carrier-to-noise
2. -53 dB composite triple beat
3. -53 composite second order
4. +15/10 dBmV at the tap
   (drops are 150 ft. RG-6)

These specifications forced the levels required, and the distribution distortion values.

Various line extender and bridger technologies were evaluated to determine which would offer the most economical upgrade while meeting the performance required. It was possible to meet end of the line performance with either two "quad power" line extenders in cascade, or three power doubling line extenders. Three conventional line extenders in cascade failed to meet the required performance criteria. The use of three line extenders in cascade requires the addition of up to 147% more line extenders than the "quad power" choice, and in that case, 46% of the distribution system required the use of three line extenders in cascade.

END OF LINE PERFORMANCE	QUAD LE (2)	P.D. LE (3)	CONV LE (3)
C/N	48.4	-47.9	-48.3
CTB	-52.5	-52.3	-49.0
CSO	--59.8	-59.8	-49.0

Figure 5. End of line performance versus line extender technology..

Fig. 5 shows the distribution end of the line performance of the line extenders evaluated. Complete 550 MHz cascade analysis is shown for each of the line extender technologies evaluated. These analyses appear as Exhibits 5, 12, and 13 of the appendix.

TRUNK ANALYSIS

The next phase of the analysis was to examine the trunk from the fiber node to the bridger input. The P-3 cable in use on the example system has a 270 MHz loss of .85 dB/100. At 550 Mhz, this same cable has 1.21 dB loss/100 ft., or 29.97 dB per span at 550 MHz. Fig. 6 shows the attenuation versus frequency for this cable.

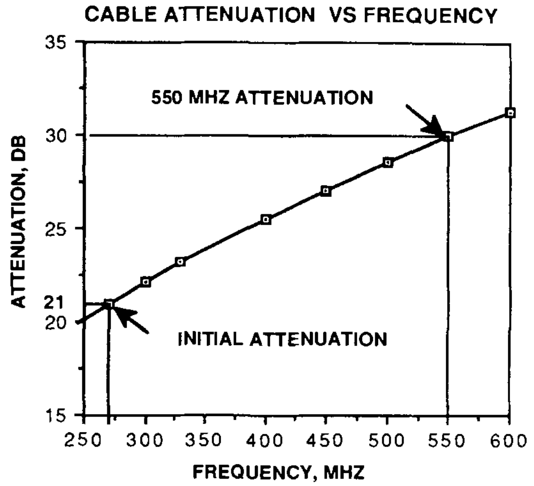


Figure 6. Operational gain required when upgrading from 270 - 550 MHz.

Since 30 dB gain trunk stations are available in several technologies, it appeared possible to "drop-in" the new amplifiers in the existing locations.

Utilizing feed forward technology, trunk cascades of 2, 3, and 4 were analyzed for headroom. The headroom graphs display the carrier-to-noise and composite triple beat limits which are achieved with the output levels chosen. The graphs of these performances are shown in Fig's. 7, 8, and 9. Exhibits 5, 12, and 13 of the appendix provide full cascade analysis.

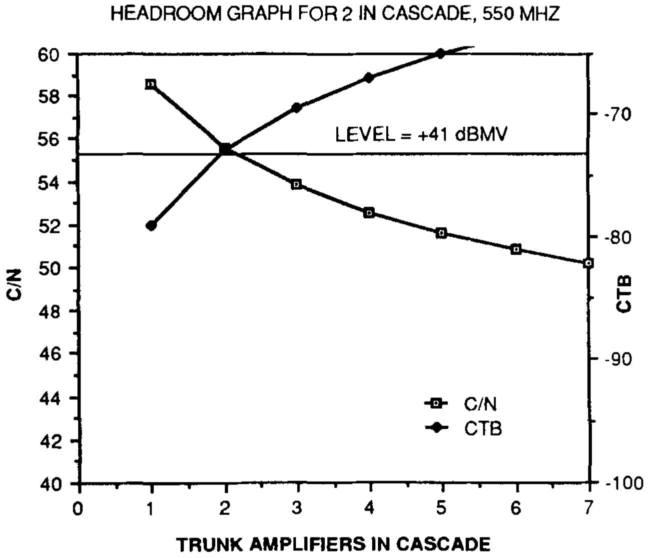


Figure 7

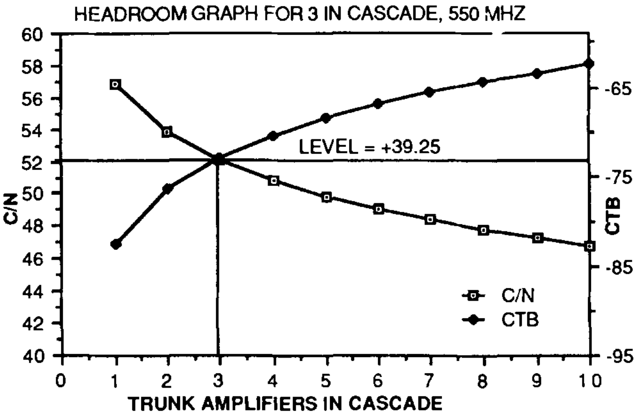


Figure 8

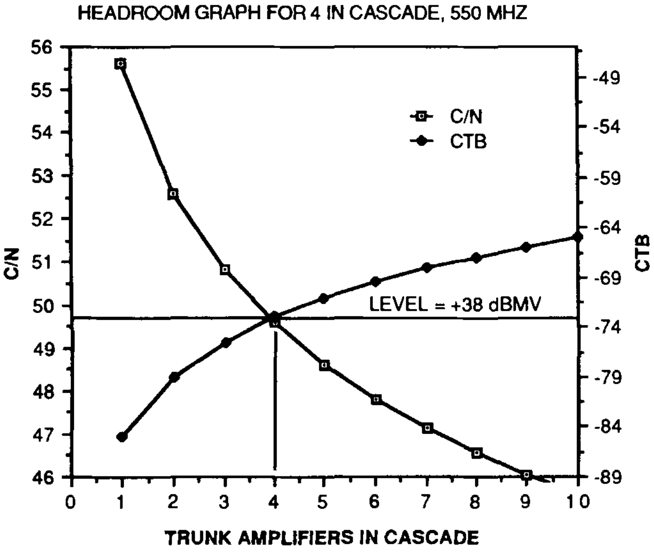


Figure 9

From the preceding graphs and exhibits, one can see that the improvement to be expected from shortening the cascade after the node is in the area of carrier-to-noise. The example system required high distribution levels and in this example, at least, it was not possible to make the usual exchange of carrier-to-noise for distortion. The distribution of this system is the limiting distortion factor, and the trunk contribution is relatively minor. Even so, it is possible to deliver a signal with 51.9 dB carrier-to-noise, to the subscriber's TV set. This performance may well be what is required to make enhanced television systems a reality.

ALTERNATE SOLUTIONS

Analysis was performed to establish whether the proposed upgrade could be accomplished without the use of AML, or other hub techniques.

Further headroom analysis graphs were prepared to determine what performance could be expected with "normal" 22 dB spacing after replacement of the trunk cable. The results appear in Fig's. 10 and 11.

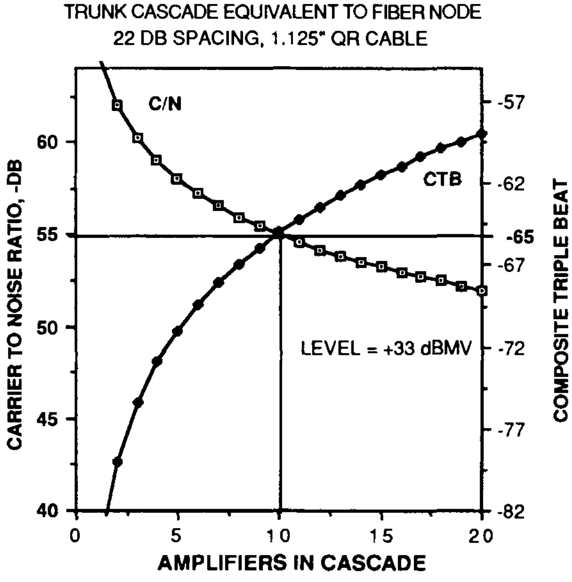


Figure 10

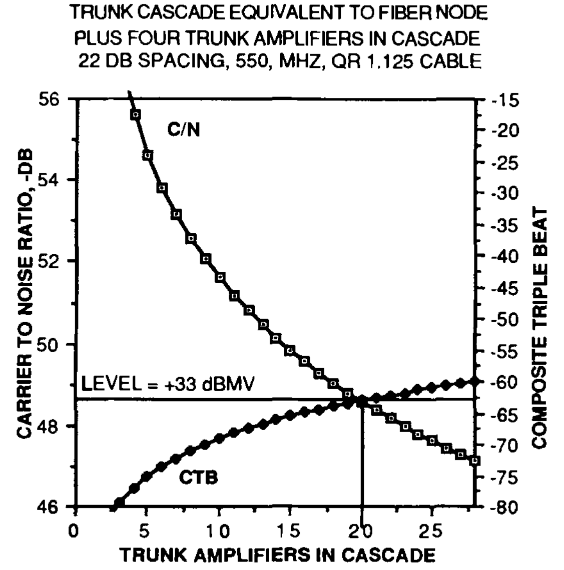


Figure 11

Fig. 10 shows that performance equal to that of the fiber node was reached after a cascade of 10 feed forward trunk amplifiers.

Fig. 11 shows that performance equal to the fiber node plus four trunk amplifiers in cascade was reached after a cascade of 20.

Since replacing the trunk cable permitted the direct replacement of the amplifier locations, one can see that the "reach" is inadequate to replace the original 28 in cascade, and some sort of hub network will be required to complete the upgrade from 270 to 550 MHz.

This section of the paper shows that an upgrade from 270 MHz to 550 MHz can be accomplished using the fiber backbone concept. It has further demonstrated that this upgrade cannot be accomplished otherwise without resort to hub techniques.

SUMMARY

In this paper, we demonstrated the following:

1. The improvement in signal quality which may be obtained by application of the fiber backbone concept to an existing 270 MHz system.
2. The potential to upgrade our example system to a greater bandwidth, by trading improved performance for that bandwidth.
3. The upgrade of a 270 Mhz system to 550 MHz while preserving trunk cable and trunk locations, and without resorting to AML or other hub techniques.
4. The application of the fiber backbone concept will provide new opportunities for the cable television community to take advantage of performance technologies as they occur.
5. As will be seen in the financial models to be presented later, the expense of the fiber backbone is less than a total rebuild, and it appears possible that this technology will permit upgrades which are not possible with any amplifier technology available today, or in the foreseeable future.

It is the authors' opinion that the ideas and concepts set forth in the abstract have been proven. We have shown that quality improvements can be attained; and that these improvements are not only measurable, but substantial; and we have shown a working upgrade example from 270 to 550 MHz which in the worst case not only betters original system performance, but a 550 MHz system which has the performance to transport enhanced television systems or other services.

Our peers, in a parallel effort, have shown that the fiber backbone concept is economically viable as we have proven its technical feasibility.

We must stress that while there is, today, no equipment commercially available which supplies all the desired performance at the price necessary to transform the fiber backbone concept into reality, the authors' are confident that the performance predicted herein will be attainable in the foreseeable future.

ACKNOWLEDGEMENT

We would like to thank George Salvador, and the ATC Design Department for their assistance with the design analysis for this paper, and we would also like to thank the other members of the Engineering and Technology staff at ATC for their valuable assistance.

APPENDIX

CATV SYSTEM DISTORTIONS

SYSTEM NAME.		FWD. BW	4.0	FWD. NOISE	-59.2
DATE	1-Mar 1988	REV. BW	4.000	REV. NOISE	-59.2

MANUFACTURER SPECIFICATIONS	TRUNK	BRIDGER	L.E.
NOISE FIGURE	9.5	10.5	11.0
CTB OUTPUT CAP	33.0	50.0	50.0
CTB RATING(-dBmv)	-93.0	-59.0	-59.0
XMOD OUTPUT CAP	33.0	50.0	50.0
XMOD RATING(-dBmv)	-92.0	-59.0	-59.0
2nd OUTPUT CAP	33.0	50.0	50.0
2nd RATING(-dBmv)	-85.0	-70.0	-70.0
CHANNEL CAPACITY	42.0	35.0	35.0
MANUFACTURER TILT	3.0	6.0	6.0
HUM SPECIFICATION	-70.0	-70.0	-70.0

SYSTEM SPECIFICATIONS	TRUNK	BRIDGER	L.E.
AMPLIFIER INPUT	12.0	13.0	17.0
GAIN OR BR DC LOSS	21.0	-20.0	26.0
DESIRED TILT	6.0	6.0	6.0
AMPLIFIER OUTPUT	33.0	48.0	43.0
CHANNEL LOADING	35.0	35.0	35.0
CASCADE LENGTH	30.0	1.0	2.0

CALCULATED EQUIPMENT SPECIFICATIONS		TRUNK	BRIDGER	L.E.
	C/N......	-46.9	-61.7	-62.2
	CTB......	-67.6	-63.0	-67.0
	XMO.....	-66.2	-63.0	-67.0
LOG..15.0	2ND.....	-62.8	-72.0	-72.5
	HUM.....	-40.5	-70.0	-64.0

CALCULATED SYSTEM SPECIFICATIONS	FWD. TRUNK	FWD. TRUNK PLUS BRIDGER	FWD. SYSTEM TR+BR +LE(S)	
C/N......	-46.9	-46.8	-46.7	...C/N
CTB......	-67.6	-59.0	-56.1	...CTB
XMO.....	-66.2	-58.4	-55.7	...XMO
2ND.....	-62.8	-61.4	-60.3	...2ND
HUM.....	-40.5	-40.2	-39.6	...HUM

NOTES: CURRENT OPERATING PERFORMANCE.

EXHIBIT 1

CATV SYSTEM DISTORTIONS

```
SYSTEM NAME.                   FWD. BW      4.0  FWD. NOISE        -59.2
DATE          1-Mar 1988       REV. BW    4.000  REV. NOISE        -59.2
------------------------------------------------------------------------
MANUFACTURER
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
NOISE FIGURE         |                    9.5      10.5    11.0
CTB OUTPUT CAP       |                   33.0      50.0    50.0
CTB RATING(-dBmv)    |                  -93.0     -59.0   -59.0
XMOD OUTPUT CAP      |                   33.0      50.0    50.0
XMOD RATING(-dBmv)   |                  -92.0     -59.0   -59.0
2nd OUTPUT CAP       |                   33.0      50.0    50.0
2nd RATING(-dBmv)    |                  -85.0     -70.0   -70.0
CHANNEL CAPACITY     |                   42.0      35.0    35.0
MANUFACTURER TILT    |                    3.0       6.0     6.0
HUM SPECIFICATION    |                  -70.0     -70.0   -70.0
------------------------------------------------------------------------
SYSTEM
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
AMPLIFIER INPUT      |                   12.0      13.0    17.0
GAIN OR BR DC LOSS   |                   21.0     -20.0    26.0
DESIRED TILT         |                    6.0       6.0     6.0
AMPLIFIER OUTPUT     |                   33.0      48.0    43.0
CHANNEL LOADING      |                   35.0      35.0    35.0
CASCADE LENGTH       |                    4.0       1.0     2.0
------------------------------------------------------------------------
CALCULATED
EQUIPMENT
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
               C/N..... |      -55.0    -55.7     -61.7   -62.2
               CTB..... |      -65.0    -85.1     -63.0   -67.0
               XMO..... |      -65.0    -83.7     -63.0   -67.0
 LOG..15.0     2ND..... |      -65.0    -76.0     -72.0   -72.5
               HUM.... |       -70.0    -58.0     -70.0   -64.0
------------------------------------------------------------------------
CALCULATED              | FWD.    FWD.      FWD.
SYSTEM                  | TRUNK   TRUNK     SYSTEM
SPECIFICATIONS          | PLUS    PLUS      TR+BR
                        | FIBER   BRIDGER   +LE(S)
------------------------------------------------------------------------
               C/N.....|  -52.3   -51.8     -51.5               |...C/N
               CTB.....|  -64.2   -57.6     -55.0               |...CTB
               XMO.....|  -64.0   -57.5     -55.0               |...XMO
               2ND.....|  -63.9   -62.2     -61.0               |...2ND
               HUM....|   -56.0   -54.4     -51.9               |...HUM
------------------------------------------------------------------------
NOTES: PERFORMANCE IMPROVEMENT ONLY.
FOUR TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.
```

EXHIBIT 2

CATV SYSTEM DISTORTIONS

```
SYSTEM NAME.                   FWD. BW      4.0  FWD. NOISE        -59.2
DATE          1-Mar 1988       REV. BW    4.000  REV. NOISE        -59.2
------------------------------------------------------------------------
MANUFACTURER
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
NOISE FIGURE         |                    9.5      10.5    11.0
CTB OUTPUT CAP       |                   33.0      50.0    50.0
CTB RATING(-dBmv)    |                  -93.0     -59.0   -59.0
XMOD OUTPUT CAP      |                   33.0      50.0    50.0
XMOD RATING(-dBmv)   |                  -92.0     -59.0   -59.0
2nd OUTPUT CAP       |                   33.0      50.0 .  50.0
2nd RATING(-dBmv)    |                  -85.0     -70.0   -70.0
CHANNEL CAPACITY     |                   42.0      35.0    35.0
MANUFACTURER TILT    |                    3.0       6.0     8.0
HUM SPECIFICATION    |                  -70.0     -70.0   -70.0
------------------------------------------------------------------------
SYSTEM
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
AMPLIFIER INPUT      |                   12.0      13.0    17.0
GAIN OR BR DC LOSS   |                   21.0     -20.0    26.0
DESIRED TILT         |                    6.0       6.0     6.0
AMPLIFIER OUTPUT     |                   33.0      48.0    43.0
CHANNEL LOADING      |                   35.0      35.0    35.0
CASCADE LENGTH       |                    3.0       1.0     2.0
------------------------------------------------------------------------
CALCULATED
EQUIPMENT
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
               C/N......|      -55.0    -56.9     -61.7   -62.2
               CTB......|      -65.0    -87.6     -83.0   -67.0
               XMO.....|       -65.0    -86.2     -63.0   -67.0
 LOG..15.0     2ND.....|       -65.0    -77.8     -72.0   -72.5
               HUM....|        -70.0    -60.5     -70.0   -84.0
------------------------------------------------------------------------
CALCULATED              | FWD.    FWD.      FWD.
SYSTEM                  | TRUNK   TRUNK     SYSTEM
SPECIFICATIONS          | PLUS    PLUS      TR+BR
                        | FIBER   BRIDGER   +LE(S)
------------------------------------------------------------------------
               C/N......|  -52.9   -52.3     -51.9              |...C/N
               CTB......|  -64.4   -57.6     -55.1              |...CTB
               XMO.....|   -64.3   -57.8     -55.1              |...XMO
               2ND.....|   -64.2   -62.4     -61.2              |...2ND
               HUM....|    -58.0   -56.0     -53.1              |...HUM
------------------------------------------------------------------------
NOTES: PERFORMANCE IMPROVEMENT ONLY.
THREE TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.
```

EXHIBIT 3

CATV SYSTEM DISTORTIONS

```
SYSTEM NAME.                   FWD. BW      4.0  FWD. NOISE        -59.2
DATE          1-Mar 1988       REV. BW    4.000  REV. NOISE        -59.2
------------------------------------------------------------------------
MANUFACTURER
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
NOISE FIGURE         |                    9.5      10.5    11.0
CTB OUTPUT CAP       |                   33.0      50.0    50.0
CTB RATING(-dBmv)    |                  -93.0     -59.0   -59.0
XMOD OUTPUT CAP      |                   33.0      50.0    50.0
XMOD RATING(-dBmv)   |                  -92.0     -59.0   -59.0
2nd OUTPUT CAP       |                   33.0      50.0    50.0
2nd RATING(-dBmv)    |                  -85.0     -70.0   -70.0
CHANNEL CAPACITY     |                   42.0      35.0    35.0
MANUFACTURER TILT    |                    3.0       6.0     6.0
HUM SPECIFICATION    |                  -70.0     -70.0   -70.0
------------------------------------------------------------------------
SYSTEM
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
AMPLIFIER INPUT      |                   12.0      13.0    17.0
GAIN OR BR DC LOSS   |                   21.0     -20.0    26.0
DESIRED TILT         |                    6.0       6.0     6.0
AMPLIFIER OUTPUT     |                   33.0      48.0    43.0
CHANNEL LOADING      |                   35.0      35.0    35.0
CASCADE LENGTH       |                    2.0       1.0     2.0
------------------------------------------------------------------------
CALCULATED
EQUIPMENT
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
               C/N......|      -55.0    -58.7     -61.7   -62.2
               CTB......|      -65.0    -91.1     -63.0   -67.0
               XMO.....|       -65.0    -89.7     -63.0   -67.0
 LOG..15.0     2ND.....|       -65.0    -80.5     -72.0   -72.5
               HUM....|        -70.0    -64.0     -70.0   -64.0
------------------------------------------------------------------------
CALCULATED              | FWD.    FWD.      FWD.
SYSTEM                  | TRUNK   TRUNK     SYSTEM
SPECIFICATIONS          | PLUS    PLUS      TR+BR
                        | FIBER   BRIDGER   +LE(S)
------------------------------------------------------------------------
               C/N......|  -53.5   -52.9     -52.4              |...C/N
               CTB......|   64.6   -57.7     -55.2              |...CTB
               XMO.....|    64.5   -57.7     -55.1              |...XMO
               2ND.....|    64.4   -62.7     -61.3              |...2ND
               HUM....|    -60.5   -58.0     -54.4              |...HUM
------------------------------------------------------------------------
NOTES: PERFORMANCE IMPROVEMENT ONLY.
TWO TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.
```

EXHIBIT 4

CATV SYSTEM DISTORTIONS

```
SYSTEM NAME:  FIBER TEST       FWD. BW      4.0  FWD. NOISE        -59.2
DATE          7-Mar     1987   REV. BW    4.000  REV. NOISE        -59.2
------------------------------------------------------------------------
MANUFACTURER                   FIBER    TRUNK    BRIDGER   L.E.
SPECIFICATIONS                          FF       CP        XOLE
------------------- ------------ ------ ----------------------
NOISE FIGURE         |                   11.5       9.5    12.0
CTB OUTPUT CAP       |                   38.0      48.0    47.0
CTB RATING(-dBmv)    |                  -85.0     -65.0   -69.0
XMOD OUTPUT CAP      |                   38.0      48.0    47.0
XMOD RATING(-dBmv)   |                  -85.0     -65.0   -69.0
2nd OUTPUT CAP       |                   38.0      48.0    47.0
2nd RATING(-dBmv)    |                  -87.0     -71.0   -73.0
CHANNEL CAPACITY     |                   77.0      77.0    77.0
MANUFACTURER TILT    |                    6.0      10.0    10.0
HUM SPECIFICATION    |                  -70.0     -70.0   -70.0
------------------------------------------------------------------------
SYSTEM
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
AMPLIFIER INPUT      |                    8.0      18.0    19.0
GAIN OR BR DC LOSS   |                   30.0     -20.0    29.0
DESIRED TILT         |                    6.0       9.0     9.0
AMPLIFIER OUTPUT     |                   38.0      48.0    48.0
CHANNEL LOADING      |                   77.0      77.0    77.0
CASCADE LENGTH       |                    4.0       1.0     2.0
------------------------------------------------------------------------
CALCULATED
EQUIPMENT
SPECIFICATIONS                 FIBER    TRUNK    BRIDGER   L.E.
------------------- ------------ ------ ----------------------
               C/N...... |     -55.0    -49.7     -67.7   -63.2
               CTB...... |     -65.0    -73.0     -64.3   -60.3
               XMO...... |     -65.0    -73.0     -64.3   -60.3
 LOG..15.0     2ND...... |     -85.0    -78.0     -71.0   -87.5
               HUM..... |      -70.0    -58.0     -70.0   -64.0
------------------------------------------------------------------------
CALCULATED              | FWD.    FWD.      FWD.
SYSTEM                  | TRUNK   TRUNK     SYSTEM
SPECIFICATIONS          | PLUS    PLUS      TR+BR
                        | FIBER   BRIDGER   +LE(S)
------------------------------------------------------------------------
               C/N...... |  -48.6   -48.5     -48.4             |...C/N
               CTB...... |  -62.1   -57.1     -52.5             |...CTB
               XMO...... |  -62.1   -57.1     -52.5             |...XMO
               2ND...... |  -64.2   -62.2     -59.8             |...2ND
               HUM..... |   -56.0   -54.4     -51.9             |...HUM
------------------------------------------------------------------------
NOTES: 550 MHz UPGRADE/FIBER BACKBONE.
FOUR TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.
```

EXHIBIT 5

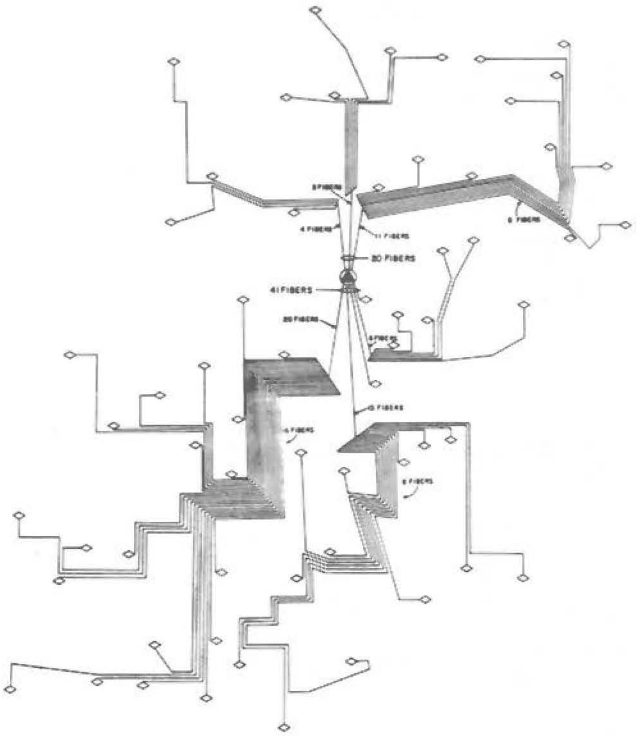


EXHIBIT 6, NODE LOCATION AND FIBER ROUTING FOR TWO IN CASCADE

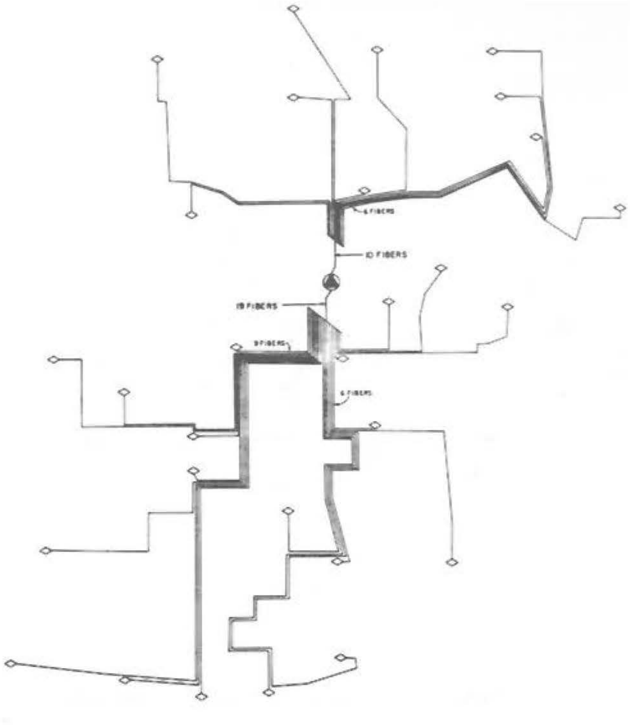


EXHIBIT 8, NODE LOCATION AND FIBER ROUTING FOR FOUR IN CASCADE

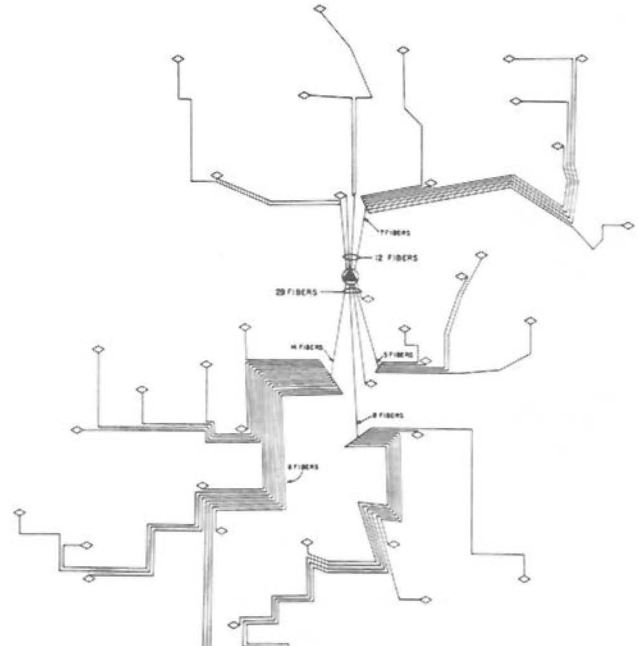


EXHIBIT 7, NODE LOCATION AND FIBER ROUTING FOR THREE IN CASCADE

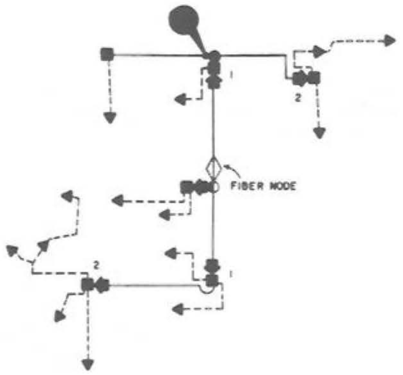


EXHIBIT 9, TYPICAL TRUNK DIAGRAM FOR FIBER NODE PLUS TWO IN CASCADE

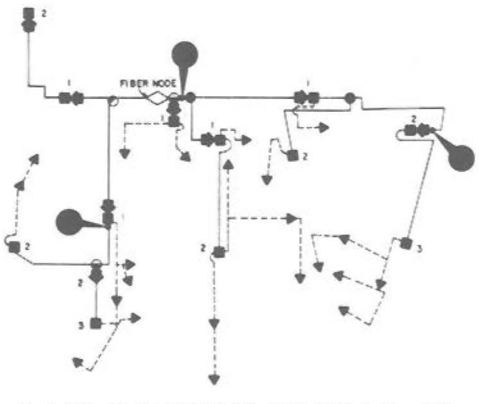


EXHIBIT 10, TYPICAL TRUNK DIAGRAM FOR FIBER NODE PLUS THREE IN CASCADE

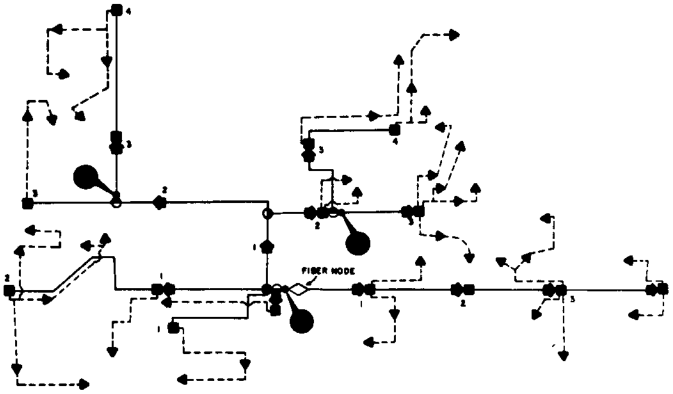


EXHIBIT 11, TYPICAL TRUNK DIAGRAM FOR FIBER NODE PLUS FOUR IN CASCADE

CATV SYSTEM DISTORTIONS

```
SYSTEM NAME:   FIBER TEST          FWD. BW     4.0   FWD. NOISE        -59.2
DATE                7-Mar   1987   REV. BW   4.000   REV. NOISE        -59.2
MANUFACTURER                       FIBER    TRUNK    BRIDGER   L.E.
SPECIFICATIONS                               FF        CP      XCLE
--------------------------------- ------ ---------------------------
NOISE FIGURE         |                      11.5       9.5    12.0
CTB OUTPUT CAP       |                      38.0      48.0    47.0
CTB RATING(-dBmv)    |                     -85.0     -65.0   -69.0
XMOD OUTPUT CAP      |                      38.0      48.0    47.0
XMOD RATING(-dBmv)   |                     -85.0     -65.0   -69.0
2nd OUTPUT CAP       |                      38.0      48.0    47.0
2nd RATING(-dBmv)    |                     -87.0     -71.0   -73.0
CHANNEL CAPACITY     |                      77.0      77.0    77.0
MANUFACTURER TILT    |                       6.0      10.0    10.0
HUM SPECIFICATION    |                     -70.0     -70.0   -70.0
SYSTEM
SPECIFICATIONS                     FIBER    TRUNK    BRIDGER   L.E.
--------------------------------- ------ ---------------------------
AMPLIFIER INPUT      |                       9.3      19.3    19.0
GAIN OR BR DC LOSS   |                      30.0     -20.0    29.0
DESIRED TILT         |                       6.0       9.0     9.0
AMPLIFIER OUTPUT     |                      39.3      48.0    48.0
CHANNEL LOADING      |                      77.0      77.0    77.0
CASCADE LENGTH       |                       3.0       1.0     2.0
CALCULATED
EQUIPMENT
SPECIFICATIONS                     FIBER    TRUNK    BRIDGER   L.E.
--------------------------------- ------ ---------------------------
                C/N......  |       -55.0    -52.2     -69.0   -63.2
                CTB......  |       -65.0    -73.0     -64.3   -60.3
                XMO......  |       -85.0    -73.0     -64.3   -60.3
 LOG..15.0      2ND......  |       -65.0    -78.6     -71.0   -67.5
                HUM......  |       -70.0    -60.5     -70.0   -64.0
CALCULATED                 | FWD.    FWD.      FWD.
SYSTEM                     | TRUNK   TRUNK     SYSTEM
SPECIFICATIONS             | PLUS    PLUS       TR+BR
                           | FIBER   BRIDGER   +LE(S)
                C/N......  | -50.3   -50.3     -50.1               |...C/N
                CTB......  | -62.1   -57.1     -52.5               |...CTB
                XMO......  | -62.1   -57.1     -52.5               |...XMO
                2ND......  | -64.2   -62.3     -59.8               |...2ND
                HUM......  | -58.0   -58.0     -53.1               |...HUM
NOTES: 550 MHz UPGRADE/FIBER BACKBONE.
THREE TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.
```

EXHIBIT 12

CATV SYSTEM DISTORTIONS

```
SYSTEM NAME:   FIBER TEST          FWD. BW     4.0   FWD. NOISE        -59.2
DATE                7-Mar 1988     REV. BW   4.000   REV. NOISE        -59.2
MANUFACTURER                       FIBER    TRUNK    BRIDGER   L.E.
SPECIFICATIONS                               FF        CP      XCLE
--------------------------------- ------ ---------------------------
NOISE FIGURE         |                      11.5       9.5    12.0
CTB OUTPUT CAP       |                      38.0      48.0    47.0
CTB RATING(-dBmv)    |                     -85.0     -65.0   -69.0
XMOD OUTPUT CAP      |                      38.0      48.0    47.0
XMOD RATING(-dBmv)   |                     -85.0     -65.0   -69.0
2nd OUTPUT CAP       |                      38.0      48.0    47.0
2nd RATING(-dBmv)    |                     -87.0     -71.0   -73.0
CHANNEL CAPACITY     |                      77.0      77.0    77.0
MANUFACTURER TILT    |                       6.0      10.0    10.0
HUM SPECIFICATION    |                     -70.0     -70.0   -70.0
SYSTEM
SPECIFICATIONS                     FIBER    TRUNK    BRIDGER   L.E.
--------------------------------- ------ ---------------------------
AMPLIFIER INPUT      |                      11.0      21.0    19.0
GAIN OR BR DC LOSS   |                      30.0     -20.0    29.0
DESIRED TILT         |                       6.0       9.0     9.0
AMPLIFIER OUTPUT     |                      41.0      48.0    48.0
CHANNEL LOADING      |                      77.0      77.0    77.0
CASCADE LENGTH       |                       2.0       1.0     2.0
CALCULATED
EQUIPMENT
SPECIFICATIONS                     FIBER    TRUNK    BRIDGER   L.E.
--------------------------------- ------ ---------------------------
                C/N......  |       -55.0    -55.7     -70.7   -63.2
                CTB......  |       -65.0    -73.0     -64.3   -60.3
                XMO......  |       -65.0    -73.0     -64.3   -60.3
 LOG..15.0      2ND......  |       -65.0    -79.5     -71.0   -67.5
                HUM......  |       -70.0    -64.0     -70.0   -64.0
CALCULATED                 | FWD.    FWD.      FWD.
SYSTEM                     | TRUNK   TRUNK     SYSTEM
SPECIFICATIONS             | PLUS    PLUS       TR+BR
                           | FIBER   BRIDGER   +LE(S)
                C/N......  | -52.3   -52.2     -51.9               |...C/N
                CTB......  | -62.1   -57.1     -52.5               |...CTB
                XMO......  | -62.1   -57.1     -52.5               |...XMO
                2ND......  | -64.3   -62.3     -59.9               |...2ND
                HUM......  | -60.5   -58.0     -54.4               |...HUM
NOTES: 550 MHz UPGRADE/FIBER BACKBONE.
TWO TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.
```

EXHIBIT 13

CATV SYSTEM DISTORTIONS

```
SYSTEM NAME:   FIBER TEST          FWD. BW     4.0   FWD. NOISE        -59.2
DATE                7-Mar 1988     REV. BW   4.000   REV. NOISE        -59.2
MANUFACTURER                       FIBER    TRUNK    BRIDGER   L.E.
SPECIFICATIONS                               FF        CP      PD
--------------------------------- ------ ---------------------------
NOISE FIGURE         |                      11.5       9.5    13.0
CTB OUTPUT CAP       |                      38.0      48.0    45.0
CTB RATING(-dBmv)    |                     -85.0     -65.0   -67.0
XMOD OUTPUT CAP      |                      38.0      48.0    45.0
XMOD RATING(-dBmv)   |                     -85.0     -65.0   -67.0
2nd OUTPUT CAP       |                      38.0      48.0    45.0
2nd RATING(-dBmv)    |                     -87.0     -71.0   -73.0
CHANNEL CAPACITY     |                      77.0      77.0    77.0
MANUFACTURER TILT    |                       6.0      10.0    10.0
HUM SPECIFICATION    |                     -70.0     -70.0   -70.0
SYSTEM
SPECIFICATIONS                     FIBER    TRUNK    BRIDGER   L.E.
--------------------------------- ------ ---------------------------
AMPLIFIER INPUT      |                       8.0      18.0    15.0
GAIN OR BR DC LOSS   |                      30.0     -20.0    29.0
DESIRED TILT         |                       6.0       9.0     9.0
AMPLIFIER OUTPUT     |                      38.0      47.0    44.0
CHANNEL LOADING      |                      77.0      77.0    77.0
CASCADE LENGTH       |                       4.0       1.0     3.0
CALCULATED
EQUIPMENT
SPECIFICATIONS                     FIBER    TRUNK    BRIDGER   L.E.
--------------------------------- ------ ---------------------------
                C/N...... |        -55.0    -49.7     -67.7   -56.4
                CTB...... |        -65.0    -73.0     -66.3   -58.8
                XMO...... |        -65.0    -73.0     -66.3   -58.8
 LOG..15.0      2ND...... |        -65.0    -78.0     -72.0   -66.8
                HUM..... |         -70.0    -58.0     -70.0   -60.5
CALCULATED                | FWD.    FWD.      FWD.
SYSTEM                    | TRUNK   TRUNK     SYSTEM
SPECIFICATIONS            | PLUS    PLUS       TR+BR
                          | FIBER   BRIDGER   +LE(S)
                C/N...... | -48.6   -48.5     -47.9                |...C/N
                CTB...... | -62.1   -57.9     -52.3                |...CTB
                XMO...... | -62.1   -57.9     -52.3                |...XMO
                2ND...... | -64.2   -62.5     -59.8                |...2ND
                HUM..... | -56.0   -54.4     -50.9                |...HUM
NOTES: 550 MHz UPGRADE WITH THREE PD LINE EXTENDERS.
FOUR AMPLIFIERS IN CASCADE FROM FIBER NODE.
```

EXHIBIT 14

CATV SYSTEM DISTORTIONS

```
SYSTEM NAME:   FIBER TEST     FWD. BW      4.0  FWD. NOISE          -59.2
DATE           7-Mar 1988     REV. BW    4.000  REV. NOISE          -59.2
MANUFACTURER                  FIBER      TRUNK  BRIDGER   L.E.
SPECIFICATIONS                             FF      CP
- - - - - - - - - - - - - - - - - - - -  - - -  - - - - - - - - - - - - -
NOISE FIGURE           |                  11.5      9.5    9.5
CTB OUTPUT CAP         |                  38.0     48.0   46.0
CTB RATING(-dBmv)      |                 -85.0    -65.0  -59.0
XMOD OUTPUT CAP        |                  38.0     48.0   46.0
XMOD RATING(-dBmv)     |                 -85.0    -65.0  -59.0
2nd OUTPUT CAP         |                  38.0     48.0   46.0
2nd RATING(-dBmv)      |                 -87.0    -71.0  -70.0
CHANNEL CAPACITY       |                  77.0     77.0   78.0
MANUFACTURER TILT      |                   6.0     10.0   10.0
HUM SPECIFICATION      |                 -70.0    -70.0  -70.0
SYSTEM
SPECIFICATIONS                FIBER      TRUNK  BRIDGER   L.E.
- - - - - - - - - - - - - - - - - - - -  - - -  - - - - - - - - - - - - -
AMPLIFIER INPUT        |                   8.0     18.0   16.0
GAIN OR BR DC LOSS     |                  30.0    -20.0   28.0
DESIRED TILT           |                   6.0      9.0    9.0
AMPLIFIER OUTPUT       |                  38.0     47.0   44.0
CHANNEL LOADING        |                  77.0     77.0   77.0
CASCADE LENGTH         |                   4.0      1.0    3.0
CALCULATED
EQUIPMENT
SPECIFICATIONS                FIBER      TRUNK  BRIDGER   L.E.
- - - - - - - - - - - - - - - - - - - -  - - -  - - - - - - - - - - - - -
                C/N...... |      -55.0   -49.7    -67.7  -60.9
                CTB...... |      -65.0   -73.0    -66.3  -52.9
                XMO...... |      -65.0   -73.0    -66.3  -52.9
  LOG..15.0     2ND...... |      -65.0   -78.0    -72.0  -64.8
                HUM...... |      -70.0   -58.0    -70.0  -60.5
CALCULATED                | FWD.    FWD.       FWD.
SYSTEM                    | TRUNK   TRUNK      SYSTEM
SPECIFICATIONS            | PLUS    PLUS       TR+BR
                          | FIBER   BRIDGER    +LE(S)
                C/N...... |  -48.6   -48.5      -48.3              |...C/N
                CTB...... |  -62.1   -57.9      -49.0              |...CTB
                XMO...... |  -62.1   -57.9      -49.0              |...XMO
                2ND...... |  -64.2   -62.5      -59.0              |...2ND
                HUM...... |  -56.0   -54.4      -50.9              |...HUM
NOTES: 550 MHz UPGRADE WITH THREE PD LINE EXTENDERS.
FOUR AMPLIFIERS IN CASCADE FROM FIBER NODE.
```

EXHIBIT 15

A UNIQUE CABLE ADVERTISING INTERCONNECT

Norman Weinhouse

Norman Weinhouse Associates
Woodland Hills, California

ABSTRACT

A partnership venture between several cable companies is currently implementing an interconnect for the Greater Los Angeles Area of Dominant Influence (ADI in advertising terminology). The system is unique, but could be cost effectively applied to other markets.

The method employed combines existing technologies in a unique manner to achieve the desired end result. Operation of the system is totally automatic and requires no manpower from the cable company affiliates. Available inventory is shared between the cable company and the interconnect. This sharing of inventory is flexible. Breaks can be alternated or shared within an available time slot.

INTRODUCTION

The Los Angeles ADI represents a huge market for television advertising. It is estimated that over a billion dollars is spent by advertisers in this market annually. Within this ADI there are a large number of cable systems of various size. In the City of Los Angeles alone, there are 14 separate franchises. Regional advertisers have been reluctant to use cable because of this fragmentation and, in general , cable advertising has not been done in a professional manner compared to broadcasters.

Furthermore, this ADI covers an immense geographical area. Figure 1 shows the five counties of Los Angeles, Orange, San Bernardino, Riverside and Ventura. The topography ranges from extremely high urban population density to remote desert and rugged mountain areas. It is obvious that a terrestrial interconnect would be extremely expensive to implement. A solution utilizing the distance insensitivity of satellites is employed in this interconnect. The satellite is used sparingly. Only the spots to be aired are transmitted at off hours for only a few hours a week, thereby reducing the cost of transportation.

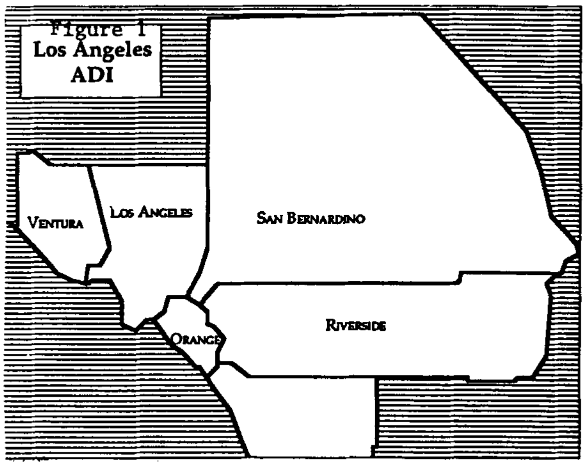


Figure 1
Los Angeles
ADI

SYSTEM OVERVIEW

Figure 2 shows how various elements of the system are connected to form the interconnect.

A Central Hub station is established as business and control center for the interconnect. Each affiliated cable system is equipped with a Commercial Insertion System (CIS) located at the cable company head end. This CIS is in addition to the CIS which may exist to provide ad insertions by the cable company. The Central Hub and remote CIS's are connected by telephone land line. The interconnect CIS's are equipped with Record/Player VCR's rather than Play Only VCR's.

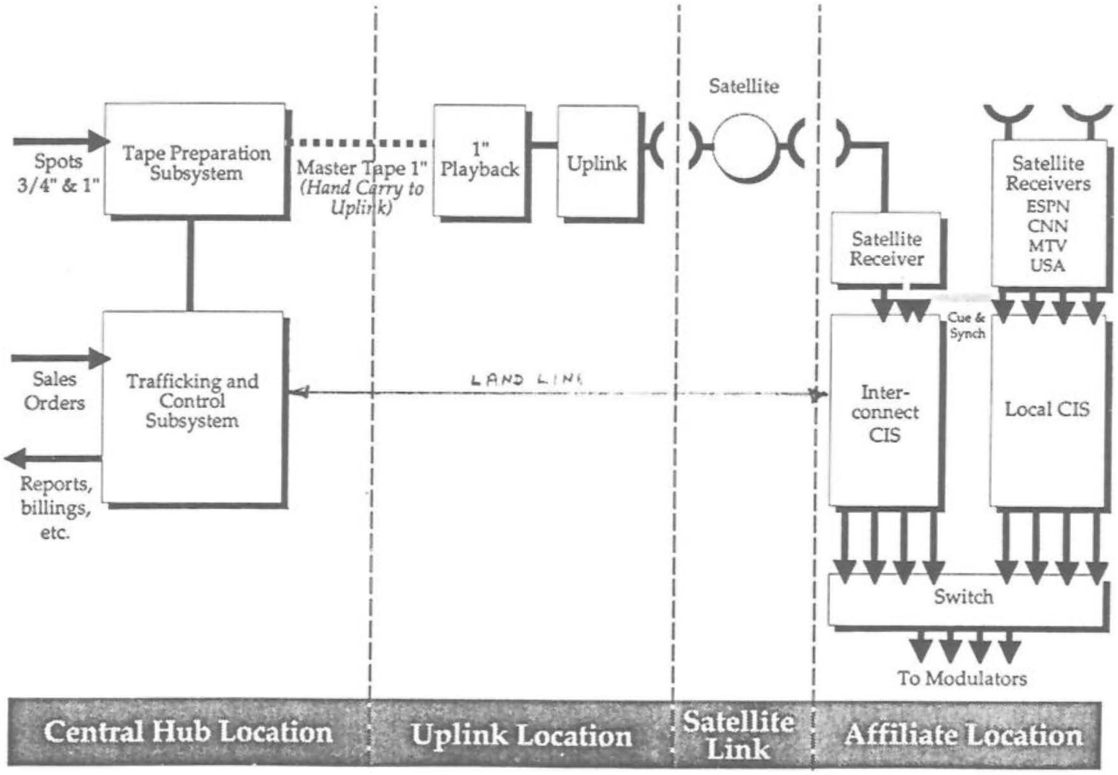


Figure 2 - Interconnect Overview

The Hub compiles a master 1" tape from spots which are supplied by ad agencies or the advertisers. Periodically, as schedule dictates, this master tape is transmitted by satellite, and recorded by the remote CIS's. This transmission and recording session is done at off hours that doesn't conflict with either normal satellite programming on that transponder or with the commercial insertion schedule. Insertion into the programs providing availabilities is done automatically on cue in the usual manner. The telephone line(s) are used to download schedules, provide status and verifications in the recording process, provide verification of spot play, and a host of other communications functions.

Initially, four programs for commercial insertion (ESPN, CNN, USA, and MTV) will be implemented. The system software can accommodate up to 20 programs. Additional programs will require additional hardware. The initial hardware is contained in a single rack of equipment.

SYSTEM DESCRIPTION

Central Hub Facility

The Central Hub contains two major subsystems. They are: Tape Preparation and Traffic and Control. Figure 3 is a sketch of the equipment layout. Professional equipment containing the necessary editing, compiling, library, control and business functions are included. A high degree of automation is employed, such that it is expected that only a single operator will be required, although multiuser software will allow expansion if required.

The Control and Trafficking Subsystem contains two separate 386 class computers for each of the functions. Under normal conditions, one computer is used for system control and the other for trafficking function. In case of a failure in either computer, the other one can perform both functions albeit at a slower rate. A measure of redundancy is thereby obtained.

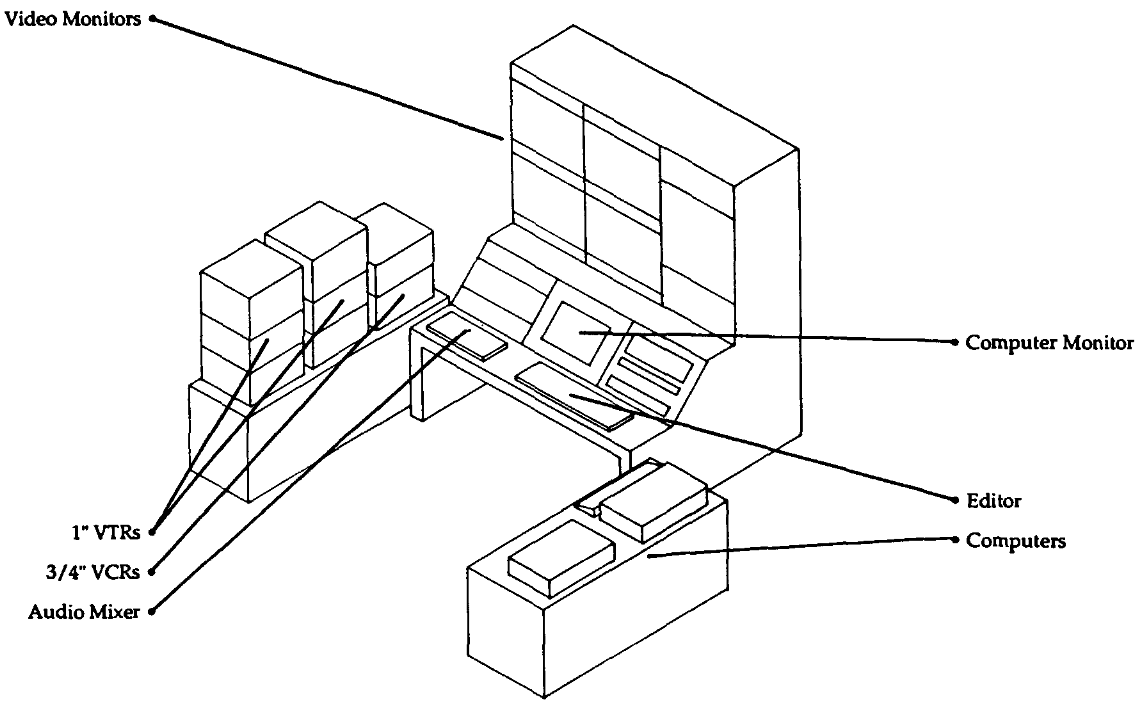


Figure 3 - Central Hub Facility

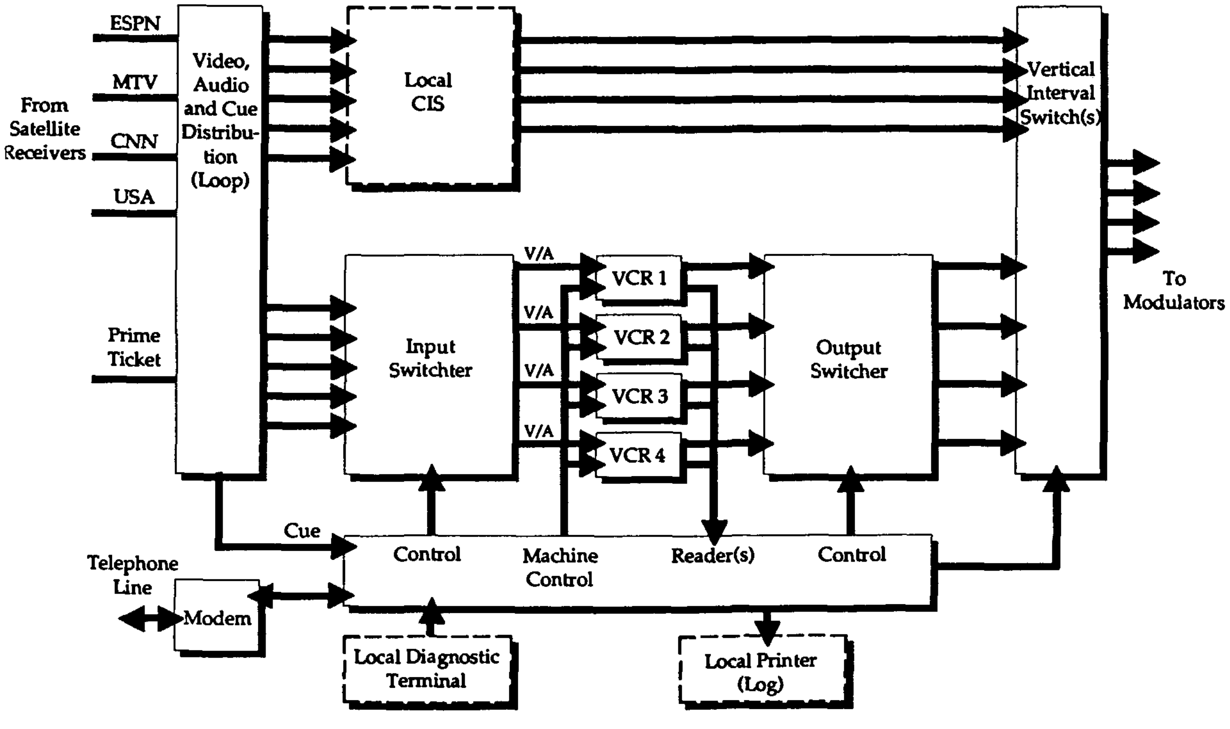


Figure 4 - Block Diagram, CIS

The tape Preparation Subsystem will accept 1" and/or 3/4" spots with either mono or stereo audio from advertisers or agencies and compile a master 1" tape for subsequent transmission by satellite. At the present time, the uplink is separated from the Central Hub, and the master tape is hand carried to the uplink station. The master tape is coded with a header (two minutes maximum) containing a directory of spots with frame code information on the location of the spots. This directory is FSK modulated with error correcting codes on the tape. The frame code data is a numerical designation placed in the video vertical interval at the start and stop frames of each spot. The frame codes are subsequently used at the affiliate location for verification of recording and playback (air).

Commercial Insertion System (CIS)

Figure 4 is a functional block diagram of the Interconnect CIS, and Figure 5 is a rack layout sketch. The VCR's used are the Sony 9600 which have a number of performance enhancements over the previous U Matic machines. This machine has a faster roll/sync time as well as a faster slew time than earlier machines. In addition, there are the following improvements:

- Improved video performance (SP)

  330 Line horizontal resolution (4.2 MHz response)

  46 db (min), S/N-color

- Improved audio performance

  70 db S/N, using Dolby C encoding - will be used

  2% total harmonic distortion

  balanced audio - 600 ohms, input and output

- Improved wow and flutter

  .18% RMS

- Sync input

- Frame coding in vertical interval

The interconnect CIS operates totally independent of any other CIS which the cable company may have for local commercial insertion. A protocol is established such that if a failure occurs in either interconnect or local CIS, signal will revert to the other CIS or to program video. Program video always has priority.

The main functions of the interconnect CIS is given in the following description of the recording and playback process.

Recording Process

The following sequence of events describes the recording session of the interconnect:

- Log of schedule and an approximate time of recording start is sent to all CIS's by land line and entered into the CIS database.
- CIS's confirm and acknowledge Record Sequence Command over land line.
- Cue from satellite feed orders all machines to record mode, rewind and prepare to record.
- Cue from satellite feed orders machines to roll.
- Time code or frame code in vertical interval containing log is stored in CIS memory.
- At conclusion of recording session, a comparison of the recorded tape and the database is made.
- If a malfunction is denoted, a discrepancy report is submitted to the Hub via the land line.
- Hub has the option of re-recording on a selective basis to those CIS where a discrepancy is noted.

Playback Features

- Unattended playback - 4 channels (initially), using normal cue from program.
- Insertion instructions (log) from Hub are stored in Non Volatile Memory.
- Spot length flexibility - 1 second to 1 hour.
- No loss of sync.

- Sharing of breaks and/or split alternate breaks with affiliate.
- Insertion log maintained as completed and transmitted to Hub on demand.
- Positive (Frame Accurate) readers for start/stop run of spots for verification.

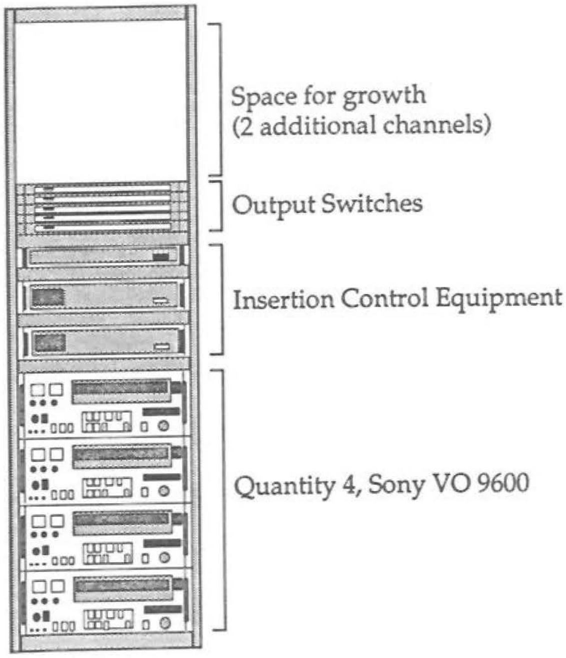


Figure 5 - CIS, Rack Layout

TELEPHONE LINE USE

Telephone lines play a very important function in the interconnect, as can be seen from the description of the recording session and playback operation. After a careful study, a decision was made to use dedicated tie lines between the Hub and Affiliates rather than dial up lines. The modems used are smart modems (up to 2,400 baud rate), and use a communications software package with error correcting protocols.

SUMMARY

An advertising interconnect which will inure to the benefit of the cable company partners and the cable company affiliates has been described. Every attempt has been made to use state-of-the-art technologies in a thoroughly professional manner in the implementation. This interconnect should get the attention of advertisers and agencies who are accustomed to dealing with broadcasters.

Agile Modulator Characteristics and Their Effects on CATV Systems

William Woodward

Scientific Atlanta

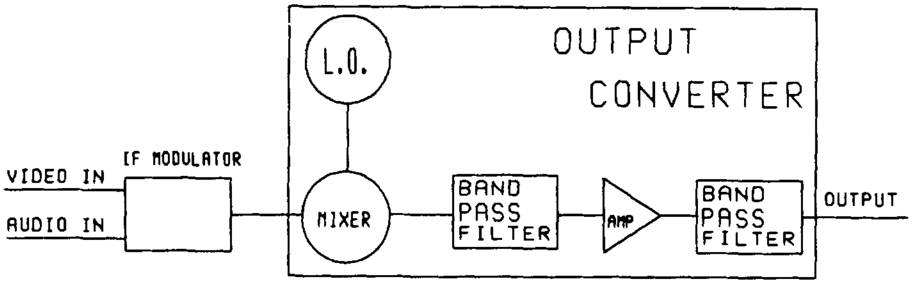
Over the past few years numerous video modulators which allow the user to select their output frequency have been introduced to the CATV market. Initially these frequency agile modulators were only used for back up of fixed channel modulators in CATV Headends, because they were significantly more expensive than fixed channel modulators. With increased interest in SMATV systems, numerous inexpensive frequency agile modulators have been introduced. Some of these "SMATV" modulators made their way into CATV applications, which precipitated the introduction of several cost effective "CATV Quality" frequency agile modulators intended for general Headend use. The CATV operator now has a large field of modulators to choose from. While frequency agile modulators offer numerous advantages, it is important to consider some additional performance parameters that have not historically been reflected in the specifications used to characterize fixed channel modulators. It is possible for two modulators to appear to have the same performance but actually have radically different performance. To understand the causes of these differences, it is necessary to understand how the fixed channel and frequency agile modulator differ in construction.

Basic Modulator Description

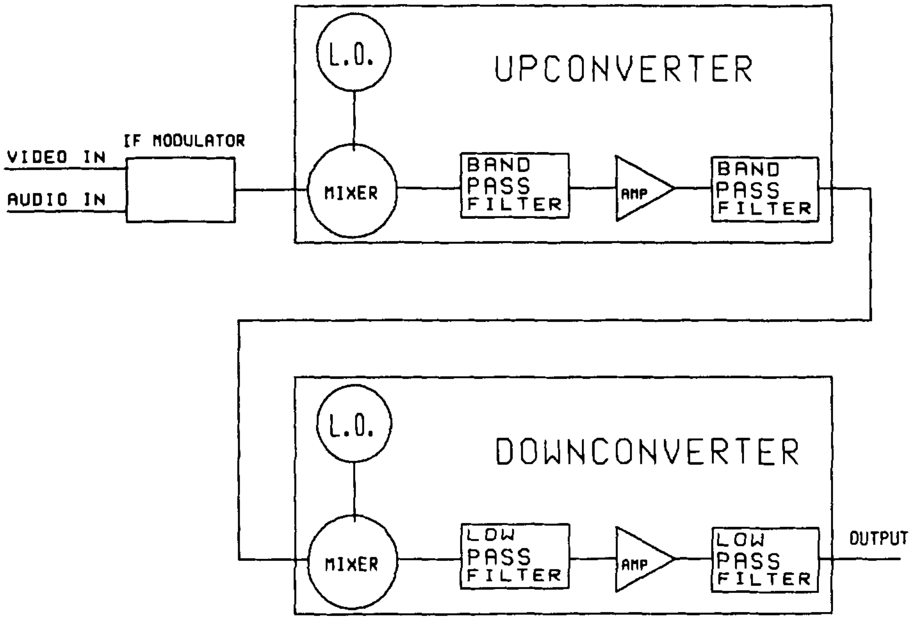
Most fixed channel modulators have a topology similar to that shown in Fig. 1. The baseband video signal is AM VSB modulated onto a 45.75Mhz carrier in the IF modulator block. This signal is typically run through a variable attenuator which ultimately provides the output level control. The 45.75Mhz IF signal is then processed in the output converter where it is hetrodyned in a mixer with a local oscillator which has a frequency 45.75Mhz above the desired output frequency. The output of the mixer is filtered and amplified to provide the final output signal.

The vast majority of frequency agile modulators have a topology similar to that shown in Fig. 2. In this system the IF modulator block is very similar to the IF modulator block of the fixed channel system, with the exception that the level control has been moved to the output converter block. The reason for this will be discussed later. The output from the IF modulator block is then hetrodyned in a mixer with a high frequency local oscillator (typically 600Mhz to 900Mhz). The mixer product which is the sum of the two signals is filtered and amplified. This produces a high frequency second IF signal. From the output of the upconverter the signal goes to the downconverter block where it is hetrodyned with a high frequency local oscillator which has a tuning range equal to the modulator output tuning range. The difference product produced in the output mixer is the desired output frequency. Different channel frequencies are obtained by changing the downconverter local oscillator frequency. The signal from the mixer is lowpass filtered, sent through a variable attenuator and amplified to produce the modulator output. Both of these block diagrams are typical of their type of modulator and may not exactly describe any particular modulator on the market.

Since the IF modulator block of the fixed channel modulator and the frequency agile modulator are essentially the same, specifications which describe the functions of these blocks for a fixed channel modulator are generally quite adequate for both types of modulators. These include Differential Gain, Differential Phase and Tilt to name a few. The specifications which describe the converter portion of the modulator must be more detailed for frequency agile modulators.



FIXED FREQUENCY MODULATOR
FIGURE 1



FREQUENCY AGILE MODULATOR
FIGURE 2

The following output converter performance parameters will be considered:

1. Spurious Signals
2. Thermal Noise
3. Phase Noise

Spurious Signals

In the CATV industry it is generally accepted that all spurious signals at the output of a piece of Headend equipment should be at least 60 db below the desired video signal. The primary sources of spurious signals in fixed channel modulators are output converter local oscillator leakage and 2-tone intermodulation between the video and audio carriers. The primary reason that these are the only spurious signals which cause a problem in a fixed channel modulator is that the output converter mixer is filtered with a narrowband filter which removes all other spurious signals. Filtering these two signals, however, can be difficult because of the intermodulation product's close proximity to the desired signal and the high power level of the local oscillator leakage coming out of the mixer. It should be noted that these signals change frequency when the channel frequency changes and do not combine with the same spurious signals from other modulators.

In the case of the frequency agile modulator the above mentioned spurious signals are present (they are produced in the upconverter block of the output converter), however numerous others may also be present. Since the downconverter typically has an output passband from 50MHz to 550Mhz, any spurious signals produced in the downconverter mixer or output amplifier chain could be present at the output. This includes harmonics of the desired signal and numerous mixer products. Since all of these spurious signals change frequency as the output changes frequency, they generally do not fall on the same frequencies as the spurious signals from other modulators and should not cause a problem if they are 60db below the desired signal. It is possible, however, to have spurious signals in the output which don't change frequency as the output frequency changes. These fixed frequency signals might, for example, be produced by microprocessor and frequency synthesizer clocks and their harmonics, which fall into the 50Mhz to 550Mhz band. These signals can get into the output portion of the output converter if there is inadequate signal isolation and decoupling on the printed circuit boards and modules which make up the modulator. Since all of the modulators of a particular design will have these spurious signals (if they are present) at the same frequencies, they will add together at the headend combiner. These signals will combine on a power basis so the following equation will determine the spurious signal level at the Headend combiner output:

$$S=K+10\text{Log}(N)$$

where
N=Total number of Agile Modulators
K=Spurious rejection of one modulator (dBc)
S=System spurious level (dBc)

As an example consider a modulator with a fixed frequency spurious signal which is -60dBc. If 50 of these modulators were used in the system the spurious output at the system output would be:

$$-60 + 10 \log 50 = -43\text{db}$$

This demonstrates that spurious signals which do not change frequency when the output frequency of a frequency agile modulator changes, should be much less than -60dbc if multiple modulators are to be used. Furthermore, the acceptable level of these spurious signals depends on how many frequency agile modulators are to be used in the system.

Thermal Noise

The next area where the specifications which have historically been used to describe fixed channel modulators are not adequate is the carrier-to-noise specification. Before dealing with the specifications themselves let us first review the sources of thermal noise in both modulator types. All active devices add to the theoretical noise power of a resistive source which has equal noise energy at all frequencies. Ideally, passive filters limit the bandwidth of these noise sources without adding any noise of their own and thus reduce the overall noise output power of the system.

In the case of a fixed channel modulator the last circuit before the output is almost always a narrow bandpass filter. This filter will usually limit the bandwidth over which the modulator contributes noise to the system to between 12Mhz and 18Mhz. Because of this, the single channel modulator does not make a significant contribution to system noise in any channels other than its own output channel and its adjacent channels.

Unlike the single channel modulator, the frequency agile modulator has no narrowband filter in the output amplifier chain. All of the noise produced in the amplifiers will be present at the output. The only bandwidth limiting occurs in the upconverter. This causes the typical agile output converter to have a noise output spectrum similar to that in Fig. 3. There are some manufacturers who have several filters in their down converters, each of which is wide enough to pass several channels. A particular filter is automatically chosen for any given output channel. This will reduce the wideband noise output of the modulator, however this modulator topology will still have a wideband noise output which is greater than the wideband noise output of a single channel modulator.

To demonstrate this point consider the following. The carrier to noise (C/N) specification is defined as the ratio of carrier power to noise power in a 4.2Mhz bandwidth occupied by the video modulation. In reality, the noise bandwidth of a typical modulator is more on the order of 18Mhz. The total noise contribution from a fixed channel modulator would be to the channel of interest and to the two adjacent channels. From this it can be seen that the system noise of a particular channel would be 3 times the noise of a single channel (The noise from the channel modulator plus the noise from the adjacent channel modulators). The combined Headend output C/N for a system made up of 50 single channel modulators with a 60db C/N would be:

$$C/N(sys)=C/N-10Log(3)$$

$$C/N(sys)=60-10log(3)=56db$$

If a similar system were built with 50 frequency agile modulators with the same C/N specification, and if the broadband noise level of these modulators were the same as their in-band noise level, the combined Headend output C/N would be:

$$C/N(sys)=60-10Log(50)=43dB$$

However, this is not necessarily the case, since a properly designed frequency agile modulator will contribute much less noise as the frequency spacing from the carrier increases. Note that such performance would not be indicated by the C/N specification which has historically been used. A simple carrier-to-noise specification is not adequate to characterize the noise performance of a frequency agile modulator. Frequency agile modulators require an in-band C/N specification and a wide-band specification which characterizes the out-of- channel noise performance of the modulator.

In addition to having a C/N specification, which usually implies a measurement with the output at its maximum level, it is important for the C/N specification not to decrease significantly as the modulator output level decreases. This is a function of where the output attenuator is placed in the modulator signal path. The closer the attenuator is to the output of the modulator the less the C/N decreases as the signal level decreases.

Phase Noise

The third area where fixed channel modulator specifications are not adequate to describe frequency agile modulators is in the phase noise specification. A phase noise specification has never been required in fixed channel modulators because the local oscillators are generally crystal oscillators which have very low phase noise. In the few cases where synthesized local oscillators are used, their tuning range is small enough and their operating frequency low enough that their phase noise is quite low. This might not be the case with frequency agile modulators.

Phase noise in frequency agile modulators can be broken into three categories, oscillator thermal noise, powerline related noise and reference sideband noise. Fortunately, the designs of most televisions make them tolerant to phase noise. Excessive phase noise can however decrease the video signal-to-noise ratio, create audio demodulation and stereo decoding problems, and make it impossible to use a synchronous video demodulator to demodulate the video signal. For these reasons the phase noise performance of a frequency agile modulator should be considered, with preference being given to units with the lowest phase noise.

Conclusions

As has been shown here, frequency agile modulators are a useful piece of equipment for the CATV Headend, however before choosing a modulator it is important to consider the additional characteristics discussed in this paper. It has been shown that frequency agile modulator performance with respect to these characteristics is especially important when multiple units are' operating on the same system.

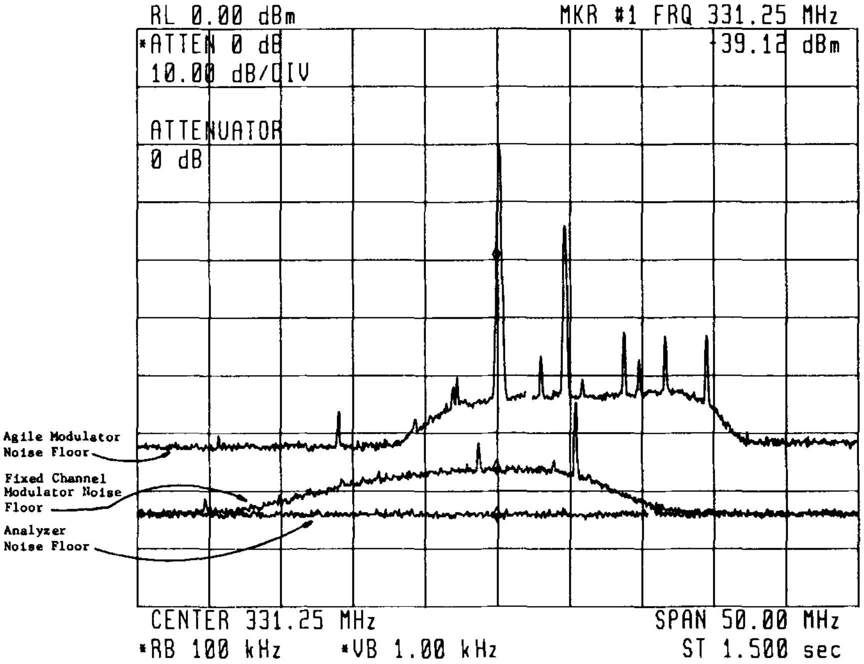


Figure 3

ANI AS A PPV ORDERING TOOL

Jefferson Corbett and Glynda Caddell

Business Systems, Inc.

ABSTRACT

The Cable Television Manager searches for ways to make Pay-Per-View profitable in his cable system; higher penetration at a lower cost per order is his dream. Automatic Number Identification has answered this call with a easy to use, low cost, 24 hour a day method for subscriber ordering. This can reduce the number of CSR's and business phone lines needed, and provide cost effective "impulse" ordering without the need for thousands of dollars of specialized equipment.

INTRODUCTION

I first heard of Automatic Number Identification (ANI) and its applications for ordering Pay-Per-View events three years ago. I was representing Business Systems, Inc. (BSI) at an Addressability Conference for billing system vendors. After hours of discussion about ANI and other PPV ordering methods, the drawbacks of ANI were obvious to most of us:

- a demanding response time requirement for the billing system
- no immediate positive or negative feedback to the subscriber
- no security from unauthorized use by children in the home
- no convenient method for selecting a specific converter

I heard rumors of cable systems experimenting with ANI, but good things rarely make their way into rumors, so what I heard were the problems, the failures, of these first tries. BSI held a steady course in PPV ordering, offering manual and Audio Response Unit (ARU) methods of ordering events. Then, last Spring, BSI agreed to participate in an ANI test with one of its Cable Television Management System (CTMS) customers. I was called in to lead the software development interfacing with the telephone company turning phone calls into authorized converters and line items on cable service bills.

Remembering every (bad) thing I knew about how ANI worked for ordering PPV events, I was not initially excited about the project. However, with the continuous addition of newer, faster, cheaper computers to the product line of Digital Equipment Corporation and the addition of a new, more efficient programming language to our development arsenal, the demanding response time requirement became less of a burden. The thing that really got me excited about ANI as an ordering tool, however, was that the phone company was going to allow us to indicate which of two recorded messages should be given to the caller.

MULTIPLE MESSAGES

With this new ability, we could then indicate to a caller who attempted to order the 5:00 PM movie at 6:30 PM, that his order was not being accepted. He would then be able to check his ordering instructions, dial the phone number for the 7:00 PM event which he really wished to order in the first place, and get a message indicating that his call was accepted. The "reject" message would also be given to those callers:

- whose phone number we didn't recognize as a valid subscriber,
- who don't have an addressable converter in their home, or
- who are behind in their payments (of course).

By informing the subscriber with a "reject" recorded message, the hostility caused when the caller expects to receive the event is alleviated. Then, when the problem is corrected, the caller usually is more likely to order.

ANI IN THE TELEPHONE SWITCHING SYSTEM

A brief description of ANI is probably overdue at this point. An ANI ordering system is much like the new enhanced 9-1-1 systems in use in cities and counties across the country. In this test configuration, which involves a part of the city of Atlanta, special equipment is needed only at one central office where the Modular Services Node (MSN) is located. When the number is dialed, the tandem switch, which connects the exchanges at the caller's central office with the other central offices throughout Atlanta, "knows" from the three digit prefix, or exchange number, both the central office which handles calls with that prefix and that the number of the calling party should be sent with the outgoing call for identification. This function is not much different from what happens when any phone call is made, making special equipment unnecessary in each central office. Also, since the dialing of the phone number is the only subscriber action needed to complete the transaction, a rotary phone will work as well as a "tone" phone.

When the call reaches the MSN's central office, the tandem switch sends the call to the MSN, instead of to another exchange's switching equipment as would happen with a normal phone call. From here the MSN makes a data packet containing the caller's phone number and the phone number he called and sends it via 2400 baud modems over a leased line to the computer at the cable office. The subscriber phone number database is then searched for a match with the caller's number. If the caller can be identified as a valid subscriber, the order is taken; otherwise the reject is logged for later reporting. The same modem link is used to inform the MSN that the call may be completed. The MSN then picks up the phone (usually before the second ring) and plays a recorded message and hangs up. The entire process, from the time the last digit of the phone number is dialed to when the MSN hangs up the phone, takes less than 16 seconds.

SYSTEM TESTING

Since both the telephone company and BSI were developing new software to process the calls, six weeks were allotted for testing the communication between the MSN and the BSI computer. The first three weeks and the last were the busiest testing days. The first problem identified was that the wrong type of leased line had been installed. Our modems both used two wire; four wire had been set up. While we awaited resolution of this problem, we tested over dial up modems between BSI's office at Greenville, SC and the telephone company's development center. After several days of testing the transport protocol (ANSI X3.28-1976) we had worked most of the obvious bugs out. We then moved to checking the information we were passing back and forth. This part worked well almost immediately. The last day before we were scheduled to "go live," one or two minor glitches were isolated and corrected. The phone company also tested our response times under peak loads. After adjusting the priority of the ANI handling software, we were easily within acceptable limits.

The only major outage for the ANI service came as a result of a late summer thunderstorm, which blew an asynchronous communications port which was connected to the Scientific-Atlanta Addressable Transmitter (ATX), the communications port of that ATX, the phone company's four-wire to two-wire converter on the cable company's end and half the power in the cable office. The ANI system was up within a day, after the phone company checked out and repaired their equipment and a spare ATX was put in place until the damaged one could be repaired.

ORDERING DETERMINATION

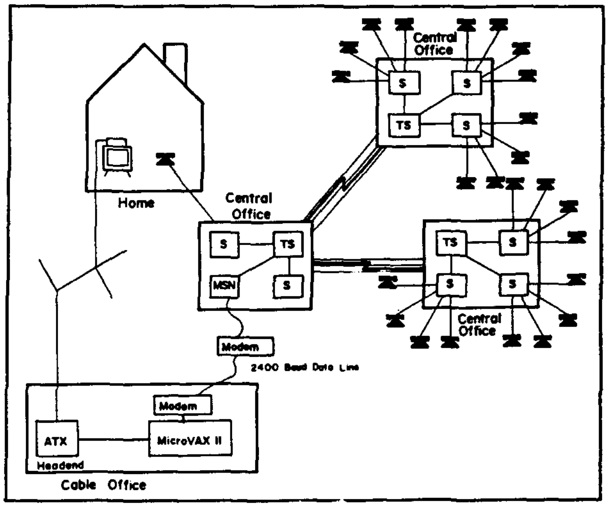
The ANI system determines what the subscriber wishes to order by the dialed phone number. In the numbering scheme designed by the cable company, a block of twenty phone numbers was reserved for each of two pay-per-view channels. The fourth and fifth digits matched the channel number (i.e. 340-53xx for channel 53 and 340-54xx for channel 54). The first three digits were determined by the phone company to indicate the exchange number. The final two digits indicated the particular showing time. Using this method it is possible to order an event several hours in advance. It is also possible to order the event after it has started. The cable system defined limit for ordering, after the event begins, is thirty minutes.

THROUGHPUT

In this configuration, sixteen trunk lines have been dedicated to the service, allowing sixteen simultaneous calls. Each call takes sixteen seconds allowing for an average throughput of 1 call per second. Using the number and length of messages required to complete a call, the average throughput of the data link between the MSN and the CTMS can be calculated at approximately 3 calls per second. The CTMS can handle loads of more than 5 calls per second before system performance significantly begins to degrade, and its worst case response time under these conditions is less than 300 milliseconds.

CONCLUSION

In the ANI test implementation by BSI with North DeKalb Cable TV, customer support representatives reported that ANI was easily and readily accepted by subscribers formerly ordering by manual methods. Further, one month after the ANI system was in full operation, buy rates went from an average of eight previous months at 5.05% to 12.84%. This trend has been reported to be continuing with ANI orders now accounting for an average of 90% of all pay-per-view buys. ANI is providing a major contribution not only to improvement of pay-per-view activity, but also to overall profitability since the ANI operations are handled on an unattended basis running 24 hours each day.



AUDIO CONSIDERATIONS IN SATELLITE TRANSMISSION TO CABLE TELEVISION SYSTEMS

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Group W Satellite Communications

ABSTRACT

Television, by it's name, is usually thought of as the transmission of video images. But much of the information we receive from television comes from the audio portion of the program. As more programming is delivered to cable systems via satellite, it is important for the system engineer to understand the various audio transmission techniques used in the industry. This paper will begin with some backround as to why this subject should be of concern to today's cable system engineer. It will also review some audio basics that the reader should be familiar with. Then the three most common forms of transmission are discussed, pointing out advantages and limitations of each one. Next, we will review the most commonly reported problems and some of the factors that contribute to them. Finally, the paper will discuss types of audio testing normally performed and give a step by step approach to system alignment.

NEW AWARENESS OF AUDIO

In the early days of television, not very much attention was paid to the audio that was accompaning the new pictures being brought into the home. The consumer was too facinated by the new technology to be very critical about it's quality. The TV receivers themselves had small speakers and simple circuitry. And besides that, the only comparison was with the radio or phonograph quality of the day , so all in all television sound was quite acceptable.

The situation today is quite different. Modern day television viewers have become quite aware of the quality of audio they are listening to. The consumer electronics revolution has brought items like high quality stereo systems, CD players, and hi-fi VCR's into a large majority of homes. Even the audio systems in our cars offer sound reproduction far above what was available in the best home stereos 10 years ago. In addition, as the broadcast industry moves rapidly towards implementing BTSC, more stereo capable, and component TV systems are being sold. These consumers, many of them cable subscribers, are becoming more discriminating about the audio signal quality they recieve. Therefore it is imperative that the cable system engineer be as well versed in this subject as possible.

AUDIO BASICS

A sound is produced by waves that cause pressure changes in the human ear. In order to transmit these sounds they must first be changed to electrical signals which we call audio. A transducer, i.e. a microphone, does this conversion and produces a signal that is a complex sinusoidal waveform with a frequency range of 50Hz to 15kHz. This is the range that most humans can perceive. The amplitude of the wave determines how loud or soft we hear it. The goal of any good transmission medium is to allow the signal to be reproduced in as close a quality to the original as possible.

Measurement

Scientific studies show that the human ear's response to sound is not linear, but rather, acts in a logarithmic manner. Thus a doubling of audio power is only perceived as a slight change in volume. In order to handle the math of this relationship, most audio signals are measured using special units. There are two commonly used scales in audio work, the first being dBm. A level of 0 dBm is equal to a power of 1mW delivered into a 600 ohm load. Any good cable engineer should be familiar with the dB measurement system.

The second commonly used scale is the Volume Unit or VU. This is usually measured on a special type of meter that has circuitry to handle the complex waveforms of active audio. It is used to monitor the average program level of an audio signal. While they are related, and often confused with one another, the dBm and the VU are two different measurements.

Average, Peak, and Loudness

We need to understand three other terms used in audio work; Average, Peak and Loudness. Average audio usually refers to measurements over a period of time, as seen on a VU meter. The center of the VU meter is considered 0VU. The "peaks" that are seen on the VU meter are not the peak levels of the audio however. Peak audio level refers to the instantaneous maximum level of an audio signal and is usually measured on a PPM (Peak Program Meter). The scale used is dBm. This is another specially designed audio device that can react fast enough to capture the peak levels of active audio.

Loudness refers to the relative amount of volume that our ear hears. It has a definite relationship to average and peak program level. A program that has been processed to produce a high average audio level will be perceived as louder than one which has higher instantaneous peaks but a lower overall average. Tuning through the FM broadcast band in any major market will demonstate this concept.

Stereo

As the requirement to deliver stereo programming increases, it is important to understand what aspects of stereo can be affected by satellite transmission. In it's most basic form stereo attempts to simulate to the listener the effect of sound coming from two different directions, cleverly refered to as L(eft) and R(ight). Monaural sound is the combination of both, or L+R. Audio engineers spend a lot of time setting up microphones to achieve this perception of Left and Right, known as separation. But the two signals are not mutually exclusive. Part of the Right audio appears in the Left channel and vice versa. As long as both signals remain in the same phase there is no problem. However, should one signal be reversed in phase, a strange effect occurs in the mono channel. The common audio of each channel cancels out, leaving only a very low difference signal. While this reversal can take place at a number of different places in the transmission path, it usually occurs when cabling is connected without regard to polarity.

Distortions

There are three major types of distortion measurement used in evaluating satellite audio transmission.

1) Signal to Noise (S/N) - This is the ratio between the maximum amplitude of the signal and the average noise in the channel, usually expressed in dB.

2) Total Harmonic Distortion (THD) - The amount of harmonics generated by a transmission system as referenced to a pure sine wave. Usually expressed in %.

3) Frequency Response - The amount of output level change from a reference point as the frequency varies from lowest to highest but the input level is held constant.

TRANSMISSION TECHNIQUES

There are three widely used formats for audio transmission in satellite relay to cable systems. These are FM subcarriers, companded subcarriers, and digital. Each will be discussed individually.

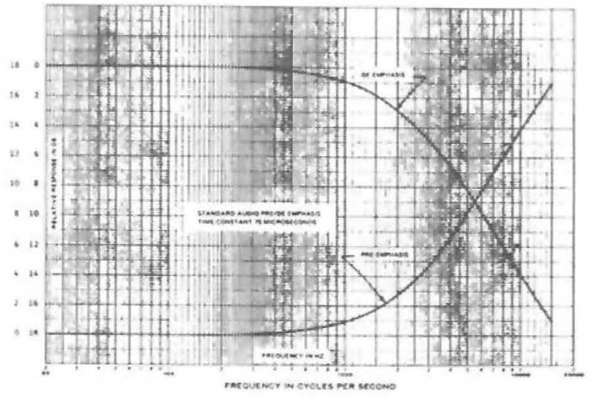
FM Subcarrier

This method is used for carrying the program audio of most non-scrambled cable services. An audio signal is used to frequency modulate a subcarrier located above the video signal, the most common frequency being 6.8MHz. In an FM system, the carrier is deviated from center frequency in relation to the amplitude changes of the modulating signal. Maximum deviation should occur at maximum input level.

Deviation settings used by programmers vary but are typically about 180-240kHz. This converts to an occupied bandwidth of about 400kHz. The total number of subcarriers being used as well as other engineering factors cause this variance. Once the proper deviation is determined, the subcarrier modulators are set up using a Bessel null method. This equipment usually remains quite stable and is monitored closely by the uplink.

An important concept that must be understood in order to evaluate an FM audio system is that of preemphasis. In most audio programming, the higher frequency components occur at lower levels than others, but are very important to the overall quality of the signal. Unfortunately, when these low level frequencies go through a transmission path, they are closer to the noise floor and are therefore received with a worse S/N ratio. The way engineers get around this problem is by boosting or emphasizing the higher frequencies prior to transmission. At the receiving end the signal is then deemphasized by the same amount to get back the original signal. The preemphasis standard most often used is the EIA 75 us curve which produces a boost of 16dB at 15kHz. This curve is also used with the 4.5MHz aural subcarrier of the NTSC TV channel. A chart of that curve is shown below (Fig. 1). What is important to realize is that if your system can only accept a maximum of +10dBm, and there is 17dB of preemphasis at 15kHz, then the highest level test tone you can send at that frequency is -7dBm. There will be more about this in the testing section.

Fig. 1



Companded Subcarriers

While the FM approach uses time tested and well understood techniques, it requires a relativly wide bandwidth and a large injection level into the uplink exciter. This limited early video services to only one or two possible audio channels. However, a requirement arose within the satellite industry to offer more high quality audio services on a single video transponder, both for the programmer's own use as well as to create an additional revenue source. A technique was developed in which the audio is companded using a unique adaptive preemphasis process. This creates an improvement in S/N which allows use of lower deviation and a reduced subcarrier power requirement. As a result, more audio channels can be sent with the video on a single transponder. This technique was pioneered by Wegener Communications, who continue to be the major supplier of both transmit and receive systems.

The major drawback of this technique is that special demodulators must be used that have appropriate circuitry to compliment the processing done at the uplink. Due to the unique systems involved, best results are usually obtained by using a demodulator from the same manufacturer who provides the transmit equipment.

Digital systems

Digital transmission of program audio on satellites is primarily done in conjunction with encryption of the signal. Basically, the audio is sampled at a high rate and each sample is converted to a digital value. This data stream is then scrambled by some algorithm and combined with the video during vertical blanking. At the receive end, the descrambler decrypts the data stream and a digital to analog converter recovers the audio signal. The major advantages of this method are it's immunity to noise and ease of encryption. It also frees up transponder spectrum for other uses, since subcarriers are not necessary. However, it does require a sophisticated demodulation device, in this case, the descrambler.

Combinations

Oftentimes, a programmer may choose to utilize all three techniques on a single transponder. For example, a service that is encrypted offers it's program in stereo via the digital method. They may also use the 6.8 MHz subcarrier for an announcement channel as well as having companded subcarriers for cue tones, second language, or other auxilary uses.

PROBLEM AREAS

The majority of satellite uplink sites used by cable programmers today are high quality, well designed facilities, staffed with trained personnel. The complexity of the systems involved demands that people have a high level of expertise. Most uplink sites and playback operations have audio monitoring equipment at a number of points in the transmission path. They also have available a complement of test equipment to ensure that proper operation is maintained. Again, the dollars being spent to get the signal out demands this kind of attention. In my experience of providing technical support to users of satellite services, I have found that most complaints can be traced to some other source besides the uplink. The two problems most commonly reported are different audio levels between services and distortion or sibilence. We will look at each one separately.

Levels

There are three things that can affect the received audio level at a headend. First, audio level into the transmitter. Second, the modulation setting of the subcarrier modulator (or digital encoder). And last, the output level adjustment of the demodulation equipment. In addition, the deviation control of the cable channel modulator will have an effect on the level the listener at home receives.

As mentioned before, most program origination personnel are quite concious of the need to maintain proper operating levels. Also, the modulation parameters of the companded subcarrier and digital techniques are pretty much set by the manufacturer so not much variation occurs there.

Unfortunately, there is not a hard and fast standard as to what deviation should be used with FM subcarriers. But, with the deviations being used by the major programmers, the variation should be no more than a maximum of 3 dB. This leaves the receiving equipment. The last section of this paper will cover a systematic approach to calibration.

Another important factor to consider regarding the varying level complaint it that of loudness, or the ear's perception of audio strength. This can best be illustrated by an example. A transmission path is aligned for unity gain from end to end. Using the same VCR, two pieces of program material are transmitted and monitored at each end. A steady tone at the beginning of each piece is measured at the same level on the output. The Peak Program Meters indicate that both programs have audio peaks that are just below the maximum allowable. However, after listening to each of them, one tape is noticeably louder. What did we adjust incorrectly?

Nothing! If we also had VU meters to monitor this feed we would have seen that during one program the meter needle was varying widely with the changes in content. However the other one, while having similar content, never seemed to let the needle fall very far down. This material sounds louder because of the higher average program level. This loudness effect is determined in the program's production by the amount of signal processing (compression) that is employed. We will talk about how to handle this in the calibration section.

Distortion

The second most commonly reported problem about satellite reception of audio is that of distortion. And the most frequently described symptom is sibilence. This is a type of high frequency distortion that is manifested as a hissing sound, especially on the "s" sounds. This, and other types of distortion, can come from a variety of sources including defective equipment. But it is usually traced to a situation where the subcarrier is deviated beyond the bandwidth of the reciever. A similar effect can occur if the digital audio modulator is overdriven.

Starting at the beginning of the path, the uplink could be allowing the subcarrier (or digital encoder) to be overmodulated. While this does occur, the rash of complaints from a large number of downlink sites usually causes the problem to be quickly corrected. A second cause can be misadjustment of the downlink receiver, allowing excessive input to the cable modulator. A third cause that has surfaced recently involves the inherent design of some "economy" satellite receivers when used with FM subcarriers.

In an effort to improve audio S/N when used with small antennas, some designers have reduced the audio IF bandwidth by as much as 50%. For example, where a bandwidth of 400kHz is used in most broadcast and cable quality demodulators, some receivers are being sold with bandwidths in the 200kHz range. This means that any modulation beyond this will be sharply removed by the filtering, resulting in distorted audio. Programmers are usually reluctant to compromise their technical parameters to accomodate the users of this equipment.

SYSTEM ALIGNMENT

This section will explain the most often performed audio transmission tests, with descriptions of the measurement equipment needed as well as the test signals used. Then it will outline a step by step approach to system alignment. However, before attempting any audio evaluation it best to check the physical installation of the receiving equipment and it's connection to the cable system headend.

Proper Installation

Wiring - Whenever possible, use shielded audio cable, grounded at one end, to reduce stray pickup. Grounding at both ends can create unwanted ground loops.
Impedance - Most receivers today are designed to operate into a 600 ohm balanced load, such as a cable modulator. A balanced load is one in which neither side is grounded while an unbalanced load has one side connected to ground. Unterminated devices, as well as very high or low impedance loads can cause false readings during testing. If necessary, use matching pads or buffer amplifiers to achieve the proper match.
Phaseing - As was discussed earlier, it is important to keep the phase of the two stereo channels in the proper relationship. Almost every receiver and descrambler is manufactured to maintain proper phase up to it's output terminals. The system engineer must then verify that proper polarity is observed when attaching the connecting cables.

Test Equipment

In order to perform the tests outlined here it is necessary to have some test equipment that is not normally found in a headend, but should be. First, a reliable, accurate method of measuring peak audio levels over a range of at least 70 dB. This can be a good quality Peak Program Meter with built in attenuation or a more sophisticated audio analyzer. A quality VU meter should also be on hand. In order to measure THD however, there are no real shortcuts. You have to have an audio test set that has that function.

Transmission Tests

As part of an ongoing trend of improving service to affiliates, a number of programmers schedule regular test periods. The audio portion usually deals with four areas; calibration of levels, S/N ratio, frequency response, and THD.

Connect the PPM or the audio analyzer to the audio output of whatever device you are testing. Check that impedances are correct.

Level setting- A fixed tone is sent at a reference level, usually 10-14db below maximum modulation. The idea is for each downlink site to adjust for the reference level they need. Set your receive levels as specified by the manufacturer. For most cable modulators, a 0 dBm level from the receiver or descrambler works well.

S/N ratio - For this test a tone is sent at a level that causes maximum modulation. This level is recorded, and then the uplink removes the audio and terminates the line. Remove attenuation as neccessary until a reading is obtained. This is the system noise floor. The two readings are added algebraicly to obtain the audio S/N ratio. For example, if the maximum level is +10dBm and the noise reads -45dBm, the S/N is 55dB.

Frequency Response - This test is designed to measure the flatness of the audio channel throughout the frequency range. A lower than normal input level is used to avoid the effects of preemphasis on the higer frequencies. At the source, a tone is sent at this lower level, typically 20dB below maximum. Then a series of tones are sent at this same level starting at about 50Hz and ending at 15kHz. The level is recorded at each step and then compared to the reference. A desired goal in this test is keep variations within 1 dB.

Total Harmonic Distortion (THD) - This is one test that is simple to perform with the right equipment, but nearly impossible correctly without it. Assuming that an audio analyzer with a THD function is available, it should be connected to the device under test, again verifying the proper impedance matching. When a reference tone is sent, select the THD function and read directly from the meter. A reading of 1-2% is acceptable.

Overall System Alignment

After performing the above tests on a number of services, it is possible to use the PPM and VU meters to adjust the other receiving equipment you have so that the peak levels of all sources are fairly close. When making these adjustments, use the five minute rule. That is, monitor the program for that long to make sure that the signal levels are typical. Remember, a three dB change is just barely noticable. Next, each modulator should be adjusted with a test tone for a peak deviation of 25kHz (NTSC aural carrier; use BTSC deviations where applicable). A number of modulation meters are on the market now to make this adjustment. Also, some modulators have built in metering to set correct deviation.

The combination of matched receive levels and equal deviations should now produce somewhat equal sounding audio as you step through the channels of your cable system. If not, listen to those that are markedly different, and use your VU meter to determine if the problem is program loudness. If most of the programming is that way, you will have to adjust the cable modulator, or the input level from the receiver to get it to match.

ACKNOWLEDGMENTS

Wegener Communications - " Optimzing Subcarriers for Satellite Transmission"

EIA RS 250B
- "Electrical Performance Standards For Television Relay Facilities"

CATV LEAKAGE AERIAL SURVEYS

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Over the past few years the date of July 1990 has been deeply etched on the minds of CATV operators as the date when the FCC will begin to enforce the provisions of Part 76.611 regarding annual qualification of cable systems to the cable leakage standards. Compliance with this section was delayed in the rule making of late 1984 in order to allow cable systems to "clean up their leakage act". When enforcement of this section begins the Commission has threatened severe consequences including forfeitures and cessation of operation for lack of compliance. Not to dwell on this well known area, suffice it to say that the consequences are highly undesirable for the cable operator.

FLYOVER vs. CLI

Qualification under Part 76.611 can be accomplished in either of two ways; 1) compliance with the limits of the Cumulative Leakage Index (CLI), compiled from ground based measurements or 2) flyover measurements in the airspace above the cable system. Ground based measurements, which require the location and measurement of every leak in excess of 50 microvolts per meter (uV/m) in at least 75% of the cable system, are time consuming, tedious, and expensive, consuming weeks, if not months of time. In the process of these measurements, ample time is allowed for new leaks to develop before the measurements are complete. Flyover measurements, on the other hand, are quickly done, usually within a few hours or days, and provide much more of a "snap shot" view of the cable system leakage situation.

Flyover measurements directly address the basic "protection from interference" purpose as established by the FCC. This applies to protection primarily of aeronautical radio services and secondarily, other over-the-air radio services. FCC and industry studies (see Report of Advisory Committee on Cable Signal Leakage - 1977) indicate that leakage fields not exceeding 10 uV/m in the airspace do not present a significant interference hazard to aeronautical communication and navigation radio services. A flyover survey directly measures these leakage fields along the flight path, and compares them to the 10 uV/m threshold. In contrast, the two methods for determining CLI (I of infinity and I of 3000) estimate the total leakage field strength in the airspace by summation of the probable effects of the leaks measured on the ground. In the report of the Advisory Committee on Cable Signal Leakage the CLI thresholds were established by comparison of ground and airspace measurements in but a few systems. The actual mechanism of summation of distributed cable system leaks is quite complex involving not only distances but radiation patterns, polarizations, and phase addition of signals, making precise analytical determination extremely difficult. Flyover measurements are direct and to the point thereby eliminating much estimation.

This paper describes the efforts of Dovetail Systems Corporation to develop hardware and software to automatically gather data in an aircraft and subsequently process that data to produce results which are useful to the cable operator for evaluation and refinement of his monitoring and maintenance procedures and to the FCC for evaluation of system leakage performance.

THE MEASUREMENT PROCESS

Paragraph 76.611 of the FCC Regulations is fairly brief but does specify a threshold of 10 uV/m at 450 meters above the average ground level below which leakage levels are permissible as well as certain requirements and guidelines for calibration and measurement. In consideration of the altitude of the overflight we find that it is exactly 150 times the distance specified for the standard ground based leakage measurement (450 meters (1500 feet) versus 3 meters (10 feet)). On this basis one can say that a single leak which would equal the airspace threshold would measure 150 times 10 uV/m at three meters from the leak. In other words, it requires a single leak of 1500 uV/m at 3 meters to produce the 10 uV/m threshold at 450 meters. This indicates that single leaks in the few hundred uV/m region are not expected to be the problem in failing the flyover measurement test.

Part 76.611 specifies a horizontally polarized antenna on the aircraft but it does not specify any further restrictions. Assuming the practical orientation of a horizontal dipole on an aircraft to be either longitudinal or transverse to the fore and aft axis, two general types of search patterns are indicated. If the antenna is oriented transverse to the fore/aft axis of the aircraft the main dipole lobes are directed fore and aft producing a pattern with nulls to the left and right and maximum response within perhaps + 45 degrees of the flight path. With orientation parallel to the fore/aft axis of the aircraft, the coverage tends to be to the sides and beneath the aircraft thereby producing a main lobe coverage of roughly ± 45 degrees fore and aft of the vertical with a fairly broad pattern to the left and right. In either case the coverage patterns are quite broad and the aircraft antenna accepts maximum energy from ground signals which present horizontally polarized fields to it. A receiving dipole orientation diagram is given in Figure 1. With the receiving antenna oriented parallel to the fore and aft axis of the aircraft, as has been chosen in our configuration, horizontally polarized signals generated to the sides of the aircraft by horizontal radiators parallel to the receiving antenna are readily detected, while those generated by transmitting elements orthogonal to the receiving antenna are not sensed at all. This is shown in Figure 2. In the fore/aft direction the same is true but it is clear that even if all radiating elements are horizontal (parallel to the ground) there will be all variations of coupling to the receiving antenna depending upon the orientation of the radiating elements relative to the receiving antenna rather than their orientation to the ground.

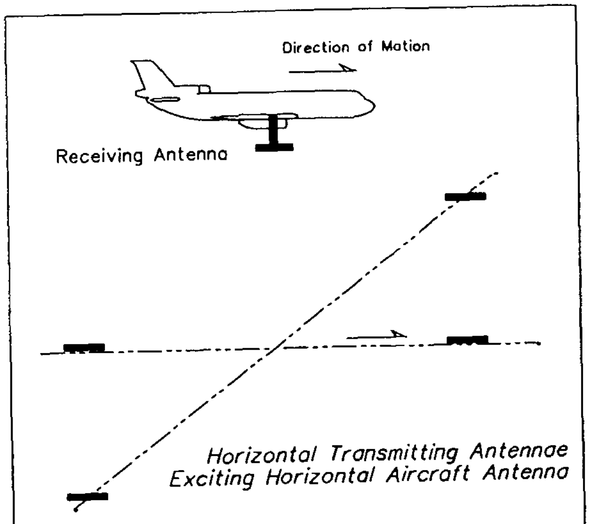


Figure 1

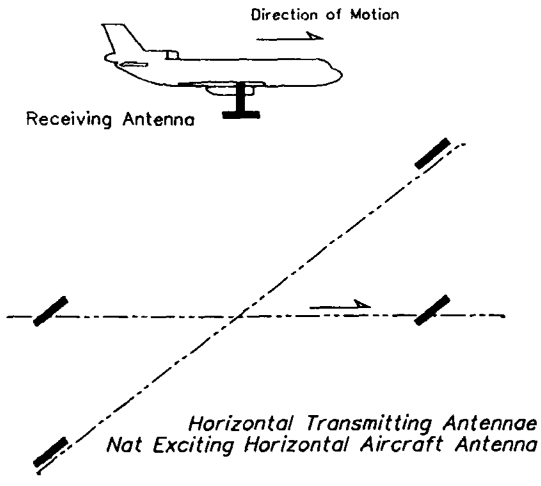


Figure 2

Let us, for a moment, assume that there are also elements in the cable system which produce vertical polarization with respect to the ground. These might be caused by leakage currents flowing on drops, system grounds, etc. In the case chosen in Figure 3, vertical elements to the left and right of the aircraft, will be orthogonal to the receiving antenna on the aircraft and therefore coupling would be minimum. Vertical elements fore and aft of the aircraft will have projections in the plane of the receiving antenna and will be received to the degree that the projections of these elements intercept the receiving antenna on the aircraft. The bottom line is that in three dimensions, specification of polarization as simply "horizontal" or "vertical" does not completely define the energy received by the measurement antenna, particularly when the reception is accomplished by use of a linearly polarized element.

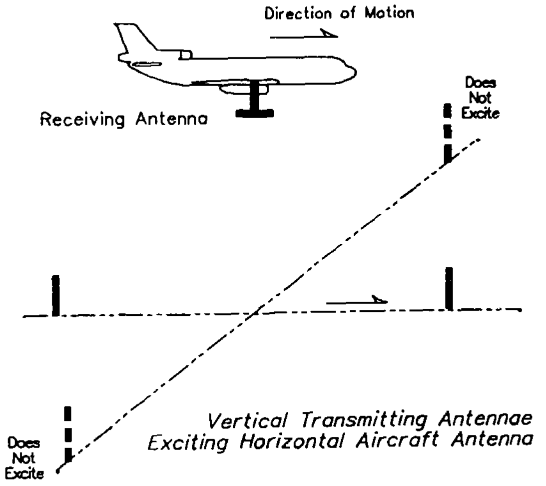


Figure 3

A number of solutions for this dilemma can be conceived. First, if an antenna were given higher gain and its coverage thereby restricted to a smaller angle, it would be possible to restrict the angles of reception and thereby reduce the polarization ambiguities. The problem with this solution is that increase of antenna gain with its commensurate decrease in angle of reception, requires a larger receiving antenna array. A single dipole element is already large relative to the dimensions of a small or even medium sized aircraft so that utilization of an array becomes particularly unwieldy in terms of size and projections from the aircraft structure. It would also be a step forward if a circularly polarized antenna were employed, especially one which maintained its circularity over a wide range of look angles. This also is somewhat impractical due to size.

At this point it makes sense to appeal to the basic reason for making the measurements in the first place. This is to try to quantify the amount of energy which would be received by an aircraft receiving system flying through the airspace. In the scope of all aircraft which might fly in the airspace, any one of a large number of antenna configurations might be employed. Each of these configurations could have a differing response which is further altered by varying aircraft shapes. It would appear that the best which can be said about the leakage survey system is that it attempts to measure field strengths in a way "similar" to a "typical" aircraft receiving system where "typical" seldom corresponds exactly to a specific antenna and its configuration on the aircraft.

Due to the polarization confusion generated in three dimensional space previously described, one might use an antenna which was vertically polarized and which would probably produce an equally valid measurement of the fields in the airspace. Vertically polarized antennas can be conveniently installed and usually produce less impediments to flight and are often used in actual aircraft communications and navigation installations. The program for measurement of signal leakage in the airspace above the cable system, which has been instituted by Dovetail Systems, has made provision for some "research" in these areas. We hope to fly simultaneous horizontal and vertical measuring systems comparing the data. If there is reasonable correlation it will probably prove to be far more practical to use low profile, vertically polarized antennas for reception rather than the somewhat awkward horizontal dipole which now clears the ground by but a few inches on landings and take-offs.

THE MEASUREMENT EQUIPMENT

In the system described a multi-purpose receiver has been employed. This receiver has a bandwidth in the 25 kHz region and can be programmed to receive AM or FM signals. In either case some AGC is used which has the effect of low pass filtering the data and producing an analog measurement. The computer receives the detected analog signal and records the data in successive samples. Many samples are taken each second allowing measurement at speeds in excess of 150 mph. Selection of AM or FM modes on the receiver is largely a function of modulation detection. AM modulation affects the average power in the carrier and therefore requires a correction if such modulation is used for identification. Narrow band FM modulation, on the other hand, as long as it does not at any time move the carrier out of the passband, does not change the average power and requires no correction factor.

Modulation is applied to the test signal to make it audibly identifiable. This is the only area of the data acquisition process which requires operator attention. Whenever the received signal level on the channel is above a certain threshold (well below the 10 uV/m) the distinctive tone(s) can be heard and recognized by the operator. Should a substantial level reading be encountered but the identification not be audible, the data is flagged as being suspect, probably the result of some interference phenomenon. This data is not used in the final analysis since the absence of modulation indicates that the leakage is not the predominant signal being received. In our flight tests we have encountered occasional interference of this type, however, these occurences have been infrequent and have not represented a significant fraction of the total data taken. If such interference were regularly encountered the test frequency should be changed to avoid it.

In addition to the basic receiver selectivity a relatively narrow RF bandpass filter is inserted ahead of the receiver to prevent overloads from out-of-band signals such as television and FM broadcast stations, aircraft transmitters and the like. The receiver with its preselector, is calibrated in the laboratory generating a curve relating microvolts input to the output level indication. In this way the receiver is characterized over the entire range of signal levels encountered in the measurements. A calibration of the measurement system (receiver, bandpass filters and installed receiving antenna) is flown over a "well characterized antenna..." and signal source as specified by Part 76.611. This ties the microvolts input versus output curve of the receiver to the actual 10 uV/m signal threshold in the airspace thus providing an absolute calibration of the entire system. The calibration factor obtained (uV/m in the airspace to microvolts input to the receiver system) is then used to relate the receiver output level indication directly to the field strength in the airspace.

In the DSC system an industrial digital computer is employed. This unit is of rugged construction and high stability and has served very well in our tests to date. It employs both

AC and DC supplies so that it can be run on 24 volts DC in the aircraft and 110 volts AC for calibration in the lab and even for data reduction after the flight. Although the data reduction function may be performed on another similar computer in the laboratory environment. The existing system employs extensive RAM plus a hard disk and a single floppy disk drive. All data recorded is saved. In the process of data reduction (to be covered later) all data points may not be used. Since there are a number of optional routines for data reduction, the original files are preserved and can be reprocessed in the future if a re-run or processing with another algorithm is desired. In the current version of the equipment, a nine inch CRT and a keyboard are also employed. These allow maximum flexibility of configuration and can be of great benefit when "researchy" ideas occur during the flight.

The present equipment is configured to take inputs from multiple receivers so that multi-frequency measurements are possible if the proper antennas to cover the desired frequencies are present. Ground measurements by others have shown occasional heavily frequency dependent results. We are anxious to, over the next few years of measurements, investigate multi-frequency effects whenever possible.

Data in the computer is taken simultaneously with LORAN position indications. The LORAN updates approximately once per second and its data is recorded along with the field strengths. The resolution of LORAN is basically .01 nautical miles or about 60 feet. In the non-precision atmosphere of airborne measurements employing collection of the radiation from numerous leaks simultaneously, it is unnecessary to interpolate these LORAN readings. We occasionally experience intermittent LORAN failures due to either propagation anomalies or actual cessation of transmission from one or more LORAN stations. We have developed procedures for recovery whose efficacy depends primarily on how long the system went without location data.

Flyover paths are preplanned to provide the most efficient flight patterns. It can be seen that a long narrow segment with only a few parallel passes wastes a minimum of time in turnarounds, etc. After establishing a reference path along the edge or through the center of an area, parallel flights are conducted at offsets usually of 0.4 nautical miles (0.4nm equals 0.46 statute miles). This is a convenient method using the LORAN instrumentation. Heading and correction information is fed back from the LORAN, either to the auto-pilot or displayed for the pilot so that the flight paths, although not perfect, approximate parallel traverses one half mile apart. Observation of the latitude/longitude plot, illustrated as part of our report, will show the precision of these passes (or lack thereof). However, it must be remembered that the LORAN at all times gives the actual position whether exactly on the desired flight path or not, therefore the data is accurate in this respect.

It is well to note that flyovers such as this are concerned with coverage of "square miles" of a CATV system and not with "strand miles". The relationship between square miles and strand miles varies greatly between systems and between parts of single systems. In order to properly setup and organize for an overflight the extremities and boundaries of the CATV systems must be located by latitude and longitude. The easiest method to do this is not by use of strand maps nor even Geodetic Survey topographic maps, but simply the use a standard road map which has latitude and longitude information on it. The easiest way for a cable operator to get us started is to simply list these specific points in latitude and longitude and lay out the extremities and boundaries on the road map. From this we construct the optimum flight paths and feed the proper waypoint information into the LORAN system.

Parts of the report which we assemble, are illustrated in Figures 4 through 7. Much of the information is self explanatory. There are tabular and graphic histograms which show the distribution of the data points in order of leakage levels, either as a fraction of the total points within a certain uV/m range (Fig. 4) or the cumulative distribution (Fig. 5) which shows the fraction of the points in and above each particular range. These plots do not provide primary information on the actual leakage conditions but do present a basis for comparison of subsequent flyovers. Similar to a CLI, these presentations can indicate the trends towards (or away from) better leakage control and can thereby be used as a measure of the efficacy of the leakage maintenance program in the particular CATV system.

The latitude and longitude plot of the flight path and the signal intensities (Fig. 6) is very informative. Specific landmarks are indicated on the lat/long chart by the use of alphabetic characters referenced in the accompanying "Position Labels" list (Fig. 7). These may include extremities of the system, headends, hubs, City Hall, major intersections or whatever is of benefit to relate the data to actual landmarks. Over this is plotted the exact flight path of the aircraft as indicated by the recorded lat/long data. In our standard report this plot is in color and various selectable field intensity ranges are indicated by different colors so that it is easy to see at a glance where the areas of maximum leakage are and their extent. This type of presentation was chosen since plotting contours with single line data as is acquired during these runs, is difficult since the resolution along the flight path is very high; so high as to make meaningful interpolation between adjacent flight paths of questionable value. Hence, the representation of the leakage levels received in varying colors has proven to be quite informative. The presentation of this plot in this paper, which can only here be reproduced in black and white, is much more difficult to interpret than the actual color plots in the reports. Figure 7 includes a list of locations where the levels exceeded the 10 uV/m threshold. In addition to this lat/long plot it is possible to present the same data scaled to overlay virtually any map. Such overlays can be provided but require an exact knowledge of the scaling in order to perfectly match the map or chart.

One additional analysis plot can be produced for analysis purposes. In this plot a small section of the lat/long traverse is displayed as a heavy line. An additional plot shows the fine structure of the leakage in that part of the flight path. After some experience is gained in analyzing these plots, it becomes quite easy to pick out responses which are due to interference such as radio transmissions. These detailed plots can be provided when such a problem needs to be resolved.

In the present system data reduction and plotting of the report takes a considerable amount of laboratory analysis time but is deemed to be the most important and necessary part of the survey.

CONCLUSION

In conclusion, we have presented the rationale for and the implementation of an automatic data gathering and analysis project to observe CATV leakage by aerial survey. A good number of systems have been flown to date. We have encountered systems with excessive leakage as well as some with very little. It is our observation that leakage can be controlled, even in large systems, but not without consistent well planned monitoring and repair efforts.

Development of flyover measurement equipment and techniques continues. Not so much in terms of implementation but, in terms of data correlation with actual system parameters and investigation of secondary phenomenon such as multiple frequency and polarization effects. We expect the next several years to be years of development and progress and would not be surprised to find many interesting and perhaps unexpected conclusions as the result of a large volume of flyover and ground measurements plus the evolution of new techniques and instrumentation to achieve more meaningful results.

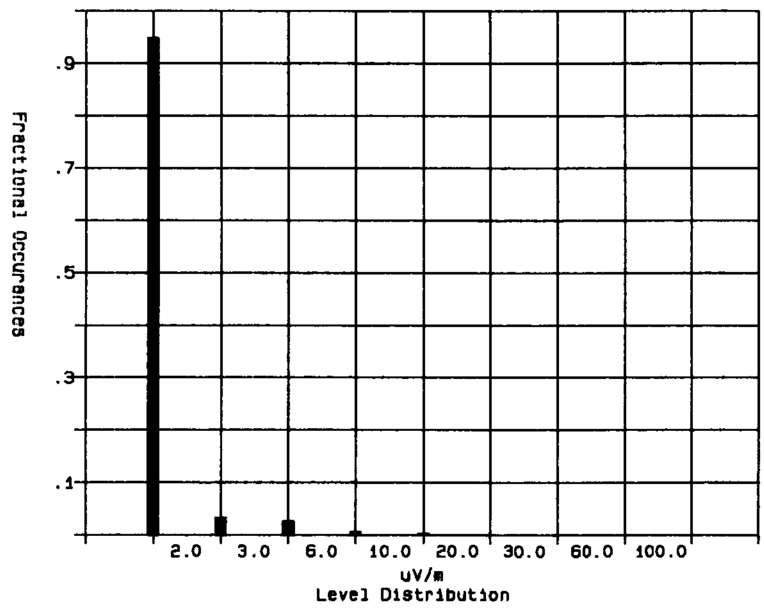


Figure 4

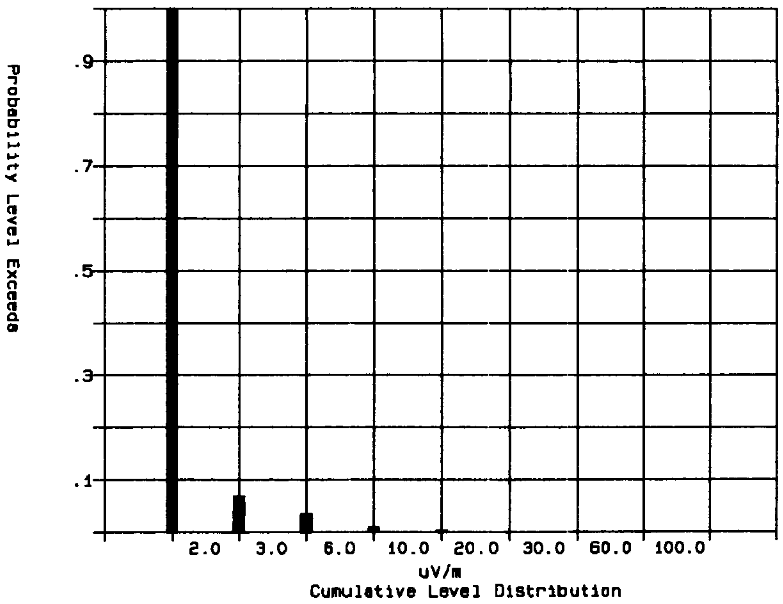


Figure 5

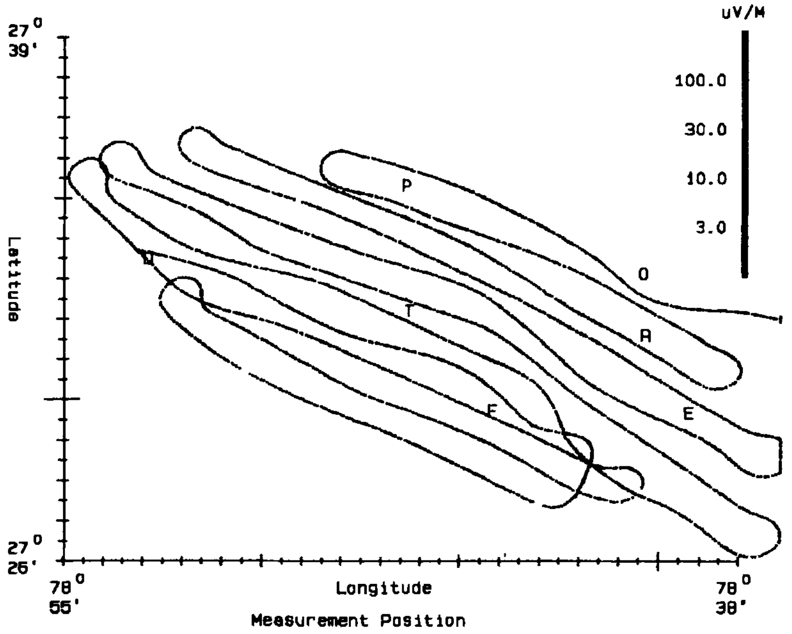


Figure 6

POSITION LABELS

Key	Position		Description
D	N27 33' 16"	W78 53' 21"	WEST HIGHWAY
E	N27 29' 30"	W78 40' 14"	RURAL AIRPORT
F	N27 29' 33"	W78 44' 58"	BEACH SITE
O	N27 32' 54"	W78 41' 18"	TOWER (415 FEET)
P	N27 35' 04"	W78 47' 05"	RAILROAD
R	N27 31' 24"	W78 41' 15"	URBAN AIRPORT
T	N27 32' 00"	W78 47' 00"	DOWNTOWN

LEVELS IN EXCESS OF 10 uV/m

uV/m	Position		Time
15.28	N27 31' 55"	W78 32' 19"	15:30:44
17.19	N27 29' 04"	W78 38' 21"	15:50:36
17.57	N27 29' 22"	W78 40' 43"	15:52:06
16.39	N27 29' 33"	W78 42' 14"	16:02:22
33.42	N27 31' 29"	W78 46' 16"	16:07:54
20.37	N27 29' 53"	W78 45' 46"	16:15:24
12.17	N27 29' 17"	W78 45' 59"	16:18:51
29.29	N27 29' 20"	W78 46' 07"	16:18:54
11.61	N27 30' 32"	W78 45' 23"	16:27:25

Figure 7

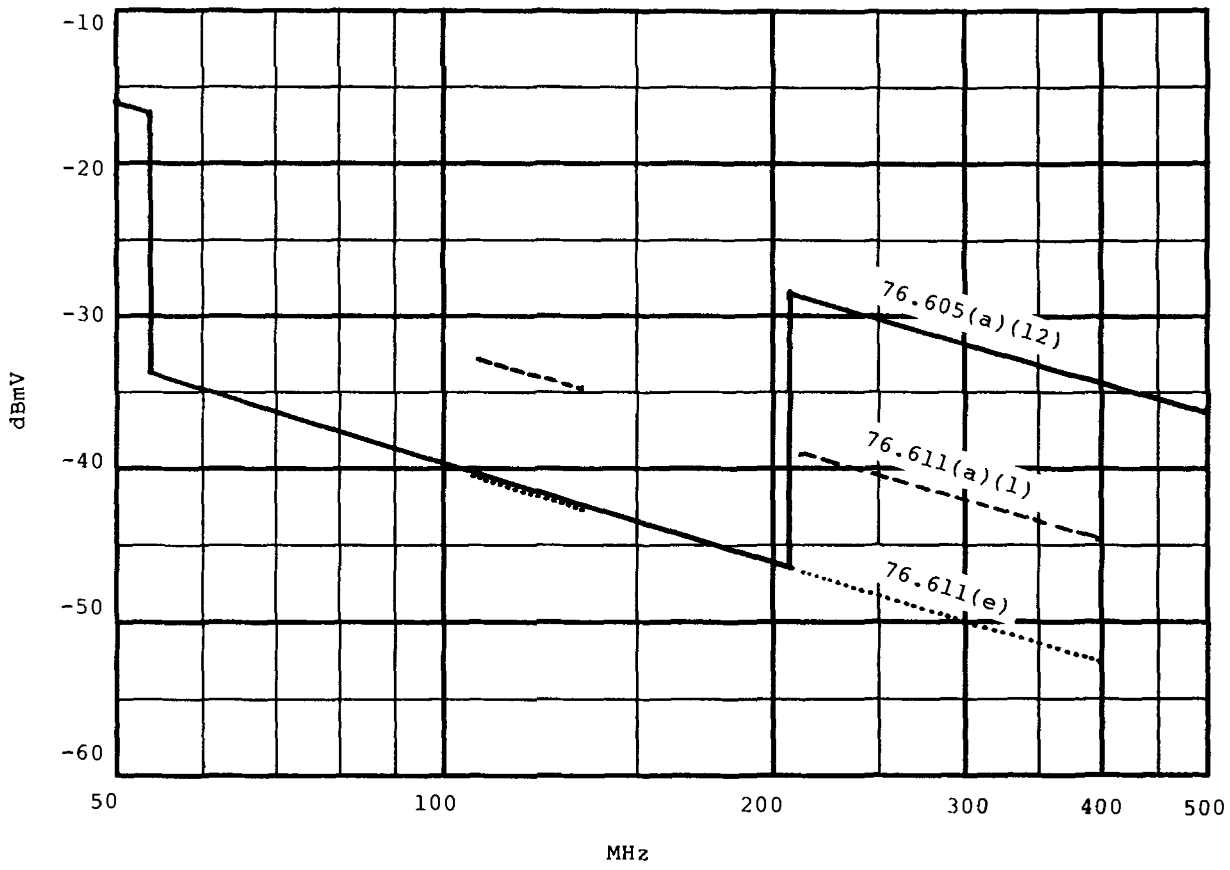


FIGURE 7

FCC Radiation Specifications for CATV
76.605(a)(12) = general system limit
76.611(a)(1) = limit of leaks to be included in CLI requirements
76.611(e) = CLI - limit for new construction

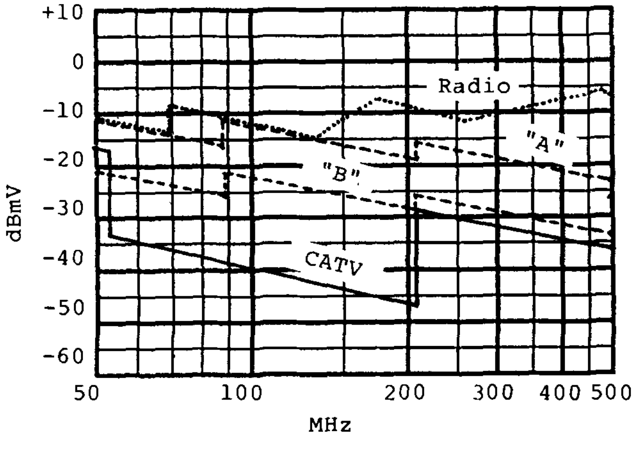


FIGURE 8

FCC Part 15 & Part 76 limits

SOURCES OF ERROR

Following the above steps and arriving at a value for measured radiation level seems deceptively simple, but in an actual situation several factors that are not easily predictable can cause erroneous results. However, if we can analyze the source of the errors and predict their maximum magnitude, we will be able to establish a safety margin for worst case conditions.

Ground reflections

Ground reflections are by far the most prominent factor in altering the measurement results of a free space test site. They affect the readings in two

TABLE I

Sensitivity of Measurement System

Noise Floor, dBmV

Analyzer Bandwidth	Preamplifier Noise Figure 3dB	6dB	9dB	12dB
4 Mhz	- 56	- 53	- 50	- 47
300 KHz	- 67	- 64	- 61	- 58
100 KHz	- 72	- 69	- 66	- 63
30 KHz	- 77	- 74	- 71	- 68
10 KHz	- 82	- 79	- 76	- 73
3 KHz	- 87	- 84	- 81	- 78
1 KHz	- 82	- 89	- 86	- 83

elements. To cover the CATV frequency range of 50 to 450 MHz each element (constituting 1/2 of the dipole, or 1/4 wavelength) should be extendable from about 6.5 to 55 inches. Fig. 1 shows the element length for any resonant frequency (including average corrections for practical element thickness dimensions). But the dipole adjustment for each frequency to be measured need not be too exact, as indicated in Fig. 2, which plots the relative gain of a dipole vs. normalized frequency. In fact, three fixed dipoles will cover the frequency range of 54 to 440 MHz to a 3 dB accuracy and six discrete lengths will measure 50 to 550 MHz to within 1 dB (see Table II).

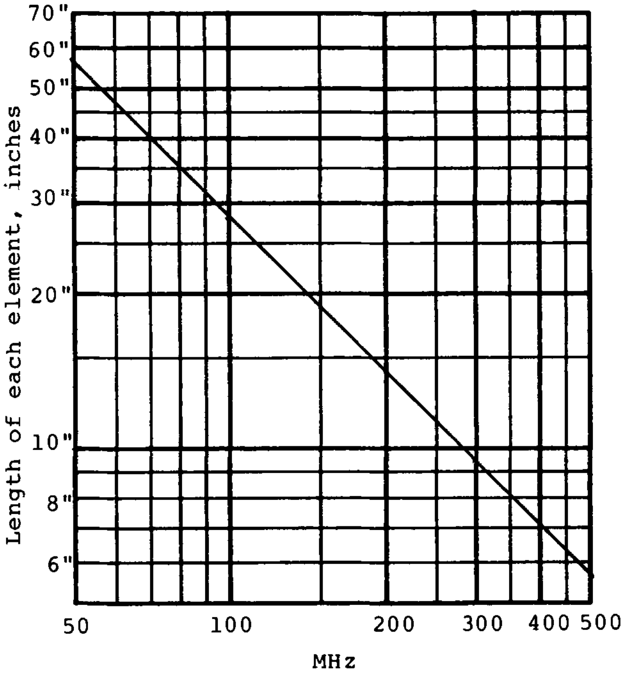


FIGURE 1

Length of each dipole element

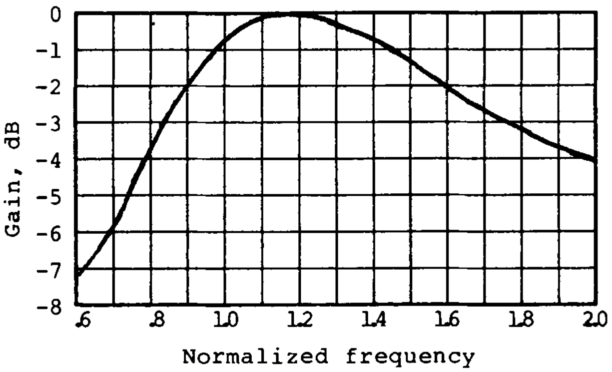


FIGURE 2

Normalized dipole gain

TABLE II

Fixed Dipole Ranges

Element Length Inches	Frequency Range MHz	Gain Flatness dB
43	54 - 109	3
21	109 - 219	3
11	219 - 440	3
49	50 - 75	1
33	75 - 112	1
22	112 - 166	1
15	166 - 247	1
10	247 - 368	1
6½	368 - 550	1

Connections and Calibration

The dipole output impedance is close to 75 ohms, balanced; the preamplifier input is also 75 ohms, but unbalanced. A miniature 75-ohm balanced twinlead (available from several sources), about 15 feet long, should be used as the downlead. At the preamplifier input a balance-to-unbalance transformer (or "elevator" coil") is constructed by winding several turns of the 75-ohm twinlead thru a toroidal ferrite core, of the type used in many CATV passives. Placing the transformer at the dipole end and running a 75-ohm coaxial line to the preamplifier is not recommended because of the unpredictable reflections that can occur between the dipole and the grounded coaxial shield.

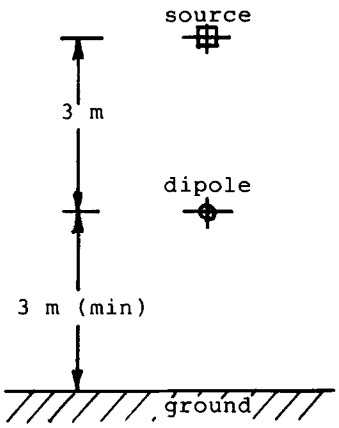


FIGURE 3

Preferred FCC test configuration

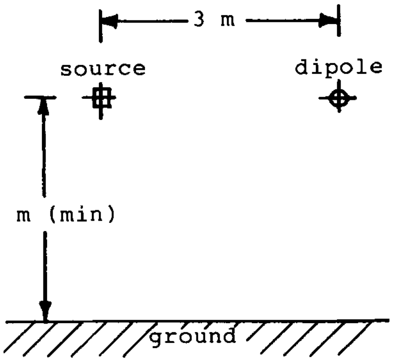


FIGURE 4

Alternate FCC test configuration

After completing the above interconnections, the total system gain from the dipole output to the analyzer input should be measured and recorded at a number of frequencies across the spectrum. These are the calibration values that will have to be subtracted from the analyzer reading in order to establish the true voltage levels reccived by the dipole. If the preamplifier has a variable slope control, it can be set to somewhat equalize the gain vs. frequency characteristic. The downlead loss not only reduces system gain, but adds directly (dB for dB) to the preamplifier noise figure, thus reducing available sensitivity.

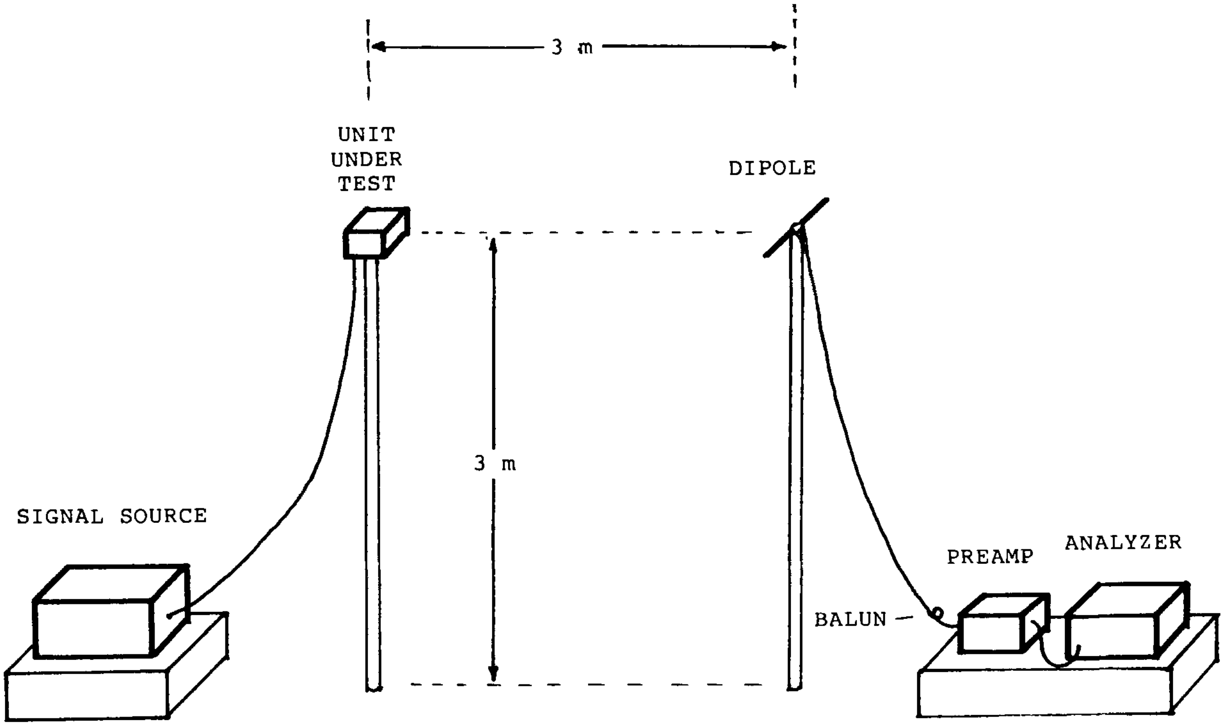


FIGURE 5

Radiation test site - Block Diagram

SET-UP

The FCC procedure outlines both a vertical (preferred) as well as a horizontal (permitted) placement between the dipole and the CATV components to be measured (Fig. 3 & 4). When monitoring an installed system, the placement will be of course predetermined, and only the dipole will have to be positioned. But when setting up a specific measurement site, the horizontal (permitted) placement is more convenient and in this case both the unit under test and the dipole should each be attached to the top of a non-metallic pole (a 3-inch diameter or thicker PVC pipe is suitable), at least 10 feet (or 3 meters) high and exactly 3 meters from each other. The tripod or other structure supporting the poles should also be made from non-metallic material, such as wood. If at all possible, the chosen measurement site should be in the open, far away from all possible interfering signal sources and also remote from structures that could be the cause of unwanted reflections. The ground should be reasonably level (but not mirror-flat or paved) and the drier the topsoil, the better (dry sand is the best). Avoid thick grass or other heavy vegetation.

The coaxial cables carrying signals and perhaps power to the unit under test should be double-shielded and sleeved radiation-proof connectors are a must. If the signal source is an actual CATV feed, route it in the shortest possible manner from the side furthest away from the dipole. If using a signal generator, make sure it is well shielded and located at least 30 feet from the test site.

The signal level reaching the input of the unit to be tested must be adjusted to correspond to the maximum that it would see in an actual installation at the frequency in question.

Fig. 5 is a block diagram of the complete test setup.

MEASURING FIELD STRENGTH

Identify the signal to be measured and received by the dipole on the analyzer display, then rotate the horizontally mounted antenna about the vertical axis (by turning the supporting pole) until the signal reaches a maximum value. Read this level on the analyzer, and using the previously obtained calibration numbers for the appropriate frequency (see "Connections") determine the actual signal level, in dBmV, received by the dipole. Then use this value to calculate the field strength :

$$E = 20.69\ f\ \log^{-1}(e_r/20)$$

where : E = field strength (uV/m)
f = frequency (MHz)
e_r = received signal level by a resonant dipole (dBmV)

Fig. 6 is a graphic plot of the above equation and Appendix A traces its mathematical derivation.

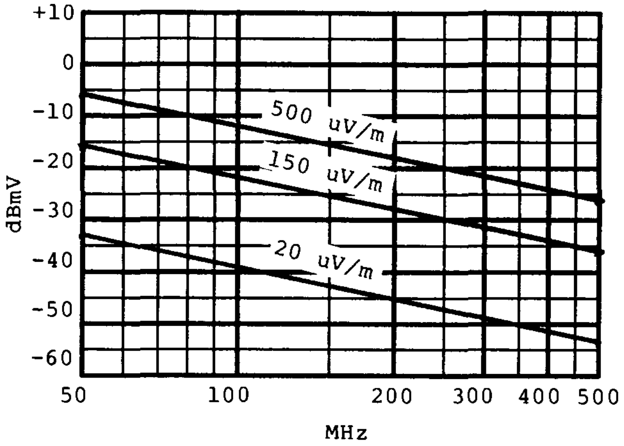


FIGURE 6

uV/m vs. dBmV

FCC Compliance

Having established a method of measuring the received signal level directly in dBmV and calculating the intercepted field strength in uV/m, it is a simple matter to compare the results to the FCC limits.

Fig. 7 shows the radiation limits (normalized to a uniform measurement distance of 3 meters or 10 feet) directly in received dBmV vs. frequency. Any reading above the level of the solid line is in violation.

Other Standards

Just to indicate how stringent the present FCC limits really are, Fig. 8 compares Part 76 (CATV) ceiling to those that are imposed under Part 15 on : (1) Commercial (Class A) Computing Devices, (2) Personal (Class B) Computing Devices and (3) Radio Receivers. FCC General Docket 87-389 which proposes to unify the requirements for all devices under Part 15 (but not CATV), coincides with Class B Computing Device requirements.

CLI - A TOTAL PROVEN APPROACH

Victor B. Gates
and
Clayton A. Collins

MetroVision, Incorporated

ABSTRACT

The Murphy's Law of RF transmission in a shielded unbalanced cable states that:

1) Signal will leak out
2) Signal will leak in

Signal leakage from CATV systems has always been a problem. However, prior to the general use of mid-band and super-band channels, our concerns were usually based on interference to the non-subscriber's television reception. the Harrisburg, PA incident of 1976 reminded us of the real possibility for hazardous interference to aircraft communications and navigation. The Cable Television industry was forced to take the issue of Signal Leakage more seriously.

INTRODUCTION

In the following pages you will read about a computer-aided program to effectively monitor, log, repair and file leaks. To this end, we gather important data as to the cause of the leak and the best method for repair, and we provide a preventative maintenance program to keep the levels acceptable.

MetroVision systems use a ground-based procedure to effectively monitor, log, repair and document leaks. We compile data showing the cause of the leak and method of repair. The procedures have been used in MetroVision's 1100 miles of plant in the Detroit area systems since January 1, 1987. All MetroVision systems now utilize these procedures to control signal leakage.

FCC REQUIREMENTS

Signal Leakage is like lust; we all have it - just don't let the FCC catch you with it!

1. Current FCC rules require leakage measurements to be taken 3 meters from the cable with a field strength meter of adequate accuracy and a horizontal dipole antenna.

2. Systems operating in the frequency bands of 108-137 MHz and 225-400 MHz must be in compliance with a cumulative leak index by July 1, 1990. The Cumulative Leak Index (CLI) measurement technique was developed several years ago to assure cable television operators that leakage from their system would not present a hazard to the safety of aircraft operating overhead.

3. Ground-based CLI is calculated using all leaks equal to or greater than 50 microvolts per meter. The value of each reportable leak found is squared. The squared values of all leaks are summed. This sum is multiplied by the result of total plant mileage divided by the driven mileage to compensate for partial drive-outs. CLI is equal to 10 times the log of this number. The maximum allowable legal limit is 64.

4. All individual leaks found of 20 microvolts per meter or greater must be logged showing the date found, the location of the leak, the date of repair, and the cause of the leakage. The log must be kept on file for 2 years and be made available to authorized FCC representatives upon request.

5. The current FCC regulations are that the entire cable system must be monitored once

each calendar year. (Non-grandfathered status systems must monitor substantially all their plant every three months).

6. We use a large three ring binder labeled FCC Signal Leakage Records for each drive-out. At the end of each drive-out the unrepaired leak file is purged and the repaired leak information is retained in the FCC public file for 2 years. The new Repaired Leak Report is added to the existing file and kept in the 3-ring binder. The binder is used as a current reference should there be an inspection by the FCC.

7. The cable operator shall annually notify the FCC of their calculated CLI on Form 325.

In our program we don't specifically measure each leak at 3 meters on a monitoring basis. We use the computer program to do the calculations based on an estimated footage from the leak and the direct reading of the meter. If we limited ourselves to a 3 meter measurement on each leak during the first drive-out, we wouldn't complete the first drive-out until June 30, 1990. But, as will be shown, we meet the 3 meter measurement requirement as the repairs are completed.

GETTING STARTED

The key to any good maintenance program is getting your schedules, tools, forms and people together.

1. Personnel. We use existing personnel; a team of 1 CSR, salesperson or installer and 1 technician. The technician records the leaks while the other person drives.

2. Time. Although this seems to be the only commodity impossible to make available, it can be done relatively quickly on a Saturday or in slow time. We have found a team can drive 8 miles of plant per hour with a 6 hour time limit due to fatigue.

3. Set up a schedule (See Figure 1 - calendar). This has to be a practical schedule - one that can be attained and maintained.

4. Get detection equipment. We use Augat/LRC-Vitek's leakage detection meter, model TR-1, with a cut dipole at 139.25 MHz (1 meter per 68 miles of plant). The antenna is on a magnetic base and mounted on the top of each vehicle. The meter is sensitive and should be used at a temperature as constant at possible. Calibration is absolutely necessary all through the day of the drive-out. When a leak is detected the meter has to be peaked.

5. Get system prints. We use size 11 x 17 prints in plastic covers. (These will be used for tracing the route while the drive-out is being performed.) The prints have to be updated as the plant grows or changes are made.

6. Signal Leakage Logs (see Figure 2). These logs are the most important source for field information and will have to be treated as such. Careful attention to detail is not only easy, but very important.

THE DRIVE-OUT

On the day of the drive-out, the coordinator puts the prints in groups of 48 miles per team. The technicians calibrate their meters to a known signal in the head end. They use non-permanent markers to follow their route and when a leak is detected, the technician instructs the driver to slow down from 10 miles per hour to 5 miles per hour. At the strongest indication on the meter, the driver stops to write down the level and estimate the footage to the cable plant (the leak level is calculated by the computer for the 3 meter intensity). He then records the nearest address or the system print location on the Signal Leakage Log. He continues this until his 48 miles is complete. At the end of each day the coordinator gathers all of the logs and system prints to verify that all the assigned prints were driven out, the logs are legible and all blanks are filled in. This is done to ensure that the data entry person can enter accurate information. This also ensures that the equipment is working properly and that the drive-out team was paying attention. At this point it's Millertime (refreshments). We make sure there is plenty of pizza and other refreshments for everyone taking part in the drive-out.

Seeing the results of the drive-out is clearly the most discouraging part of the process. However, in Figure 3 you'll see a graph that indicates our service call ratio before the introduction of this program and after the first drive out and repair period (CLI & service calls vs. time). Figure 4 shows our current CLI & service calls vs. time graph after 1 year with this program.

COMPUTER

We use an IBM PC/AT compatible computer and custom software to manipulate and store all leakage data gathered during the drive-outs. The computer is equipped with a 20 megabyte hard disk and 640K of RAM memory and a dot-matrix printer. The software is entirely menu-driven and will provide all reports necessary to control and document leakage repairs and calculate CLI for all or part of a cable system.

Leak information is input into the computer in terms of TR-1 meter reading and estimated footage from the TR-1 antenna to the probable leak location. The computer calculates the leak's intensity in microvolts per meter at 10 feet. The drive-out personnel need not be concerned with determining the field strength.

The computer software provides a listing of all leaks sorted by intensity for the entire system or a portion of the system. The software also provides CLI reports for the entire system or a portion of the system.

As repairs are completed, the repair data is stored with all information required to meet the FCC's rules for

CLI PLANNER FOR 1988

* JANUARY *	FEBRUARY	MARCH
2) **Begin new drive out** 4) **Purge old data** **Enter new data** **Update binder** 5) Print work orders 13) Input repairs Print CLI reports Assign work orders 20) Input repairs Print CLI reports Assign work orders 27) Input repairs Print CLI reports Assign work orders	3) Input repairs Print CLI reports Assign work orders 10) Input repairs Print CLI reports Assign work orders 17) Input repairs Print CLI reports Assign work orders 24) Input repairs Print CLI reports Assign work orders	2) Input repairs Print CLI reports Assign work orders 9) Input repairs Print CLI reports Assign work orders 16) Input repairs Print CLI reports Assign work orders 23) Input repairs Print CLI reports Assign work orders 30) **Complete assigned work orders**
* APRIL *	MAY	JUNE
2) **Begin new drive out** 4) **Purge old data** **Enter new data** **Update binder** 5) Print work orders 13) Input repairs Print CLI reports Assign work orders 20) Input repairs Print CLI reports Assign work orders 27) Input repairs Print CLI reports Assign work orders	4) Input repairs Print CLI reports Assign work orders 11) Input repairs Print CLI reports Assign work orders 18) Input repairs Print CLI reports Assign work orders 25) Input repairs Print CLI reports Assign work orders	1) Input repairs Print CLI reports Assign work orders 8) Input repairs Print CLI reports Assign work orders 15) Input repairs Print CLI reports Assign work orders 22) Input repairs Print CLI reports Assign work orders 30) **Complete assigned work orders**

Figure 1

leakage logs. Printouts of all available reports are stored in a binder that is available for review by visiting FCC inspectors.

We keep the following reports in the public file for FCC inspection:

1. FCC CLI Report (correct CLI to lower than 64 (see Figure 5)).
2. Maintenance CLI Report (see Figure 6).
3. Unrepaired Leak Report (see Figure 7).
4. Repaired Leak Report (see Figure 8).
5. Area Information file (see Figure 9).
6. Repaired Leak Statistics report (see Figure 10).

ADMINISTRATION

The data entry person needs to dedicate time to CLI on a part-time basis; we use a CSR. Emphasis on this position must be the same as other more traditional CSR activities, such as balancing cash.

The CSR gets the drive-out information from the coordinator and then enters each leak individually. We have found we can enter approximately 4 leaks per minute.

After the leaks have been entered an Unrepaired Leak Report is generated. This report may be retrieved either by leak intensity or by leak number. The Unrepaired Leak Report by leak number is used by Dispatch to log the completion

* JULY *	AUGUST	SEPTEMBER
2) **Begin new drive out** 4) **Purge old data** **Enter new data** **Update binder** 5) Print work orders 13) Input repairs Print CLI reports Assign work orders 20) Input repairs Print CLI reports Assign work orders 27) Input repairs Print CLI reports Assign work orders	3) Input repairs Print CLI reports Assign work orders 10) Input repairs Print CLI reports Assign work orders 17) Input repairs Print CLI reports Assign work orders 24) Input repairs Print CLI reports Assign work orders 31) Input repairs Print CLI reports Assign work orders	7) Input repairs Print CLI reports Assign work orders 14) Input repairs Print CLI reports Assign work orders 21) Input repairs Print CLI reports Assign work orders 28) **Complete assigned work orders**
*** OCTOBER ***	**NOVEMBER**	**DECEMBER**
1) **Begin new drive out** 3) **Purge old data** **Enter new data** **Update binder** 4) Print work orders 12) Input repairs Print CLI reports Assign work orders 19) Input repairs Print CLI reports Assign work orders 26) Input repairs Print CLI reports Assign work orders	2) Input repairs Print CLI reports Assign work orders 9) Input repairs Print CLI reports Assign work orders 16) Input repairs Print CLI reports Assign work orders 23) Input repairs Print CLI reports Assign work orders 30) Input repairs Print CLI reports Assign work orders	7) Input repairs Print CLI reports Assign work orders 14) Input repairs Print CLI reports Assign work orders 21) Input repairs Print CLI reports Assign work orders 28) **Complete assigned work orders**

* Months with the drive out will require additional help (peoplepower)

of repaired leaks as called in by the technicians. The Unrepaired Leak Report by leak intensity is used by the Chief Technician to assign work orders (see Figure 11) by leak intensity.

The CSR will also, at that time, print work orders based on intensity, picking the highest level leaks as well as the number of leaks that can feasibly be repaired in one week. A copy is given to the Dispatch Department and the original is given to the Chief Technician of each system. We review this at our weekly regional Chief Technician meeting.

MetroVision

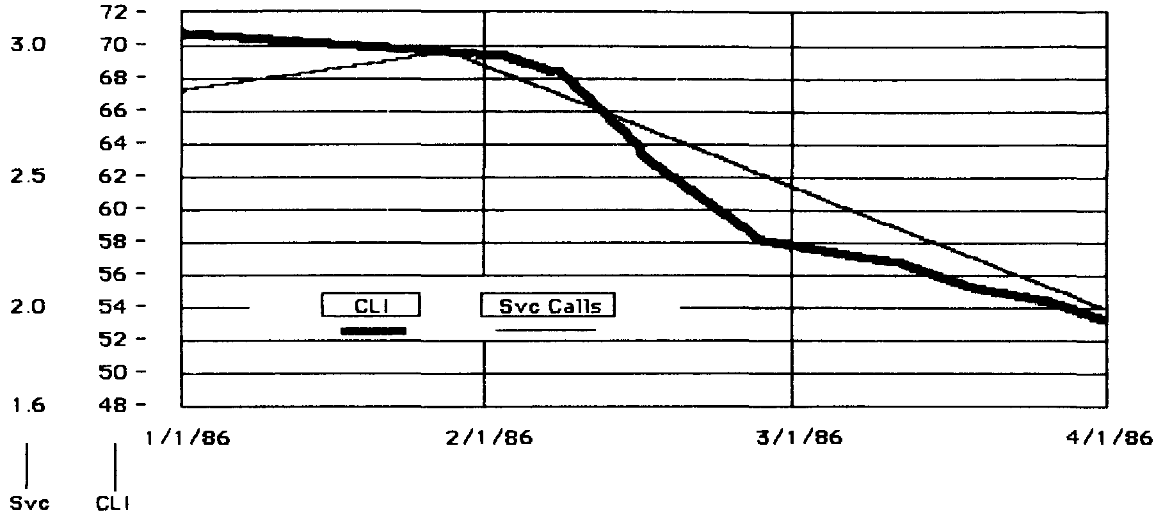
SIGNAL LEAKAGE LOG

FOR DRIVE-OUT ONLY

____
SYSTEM NAME

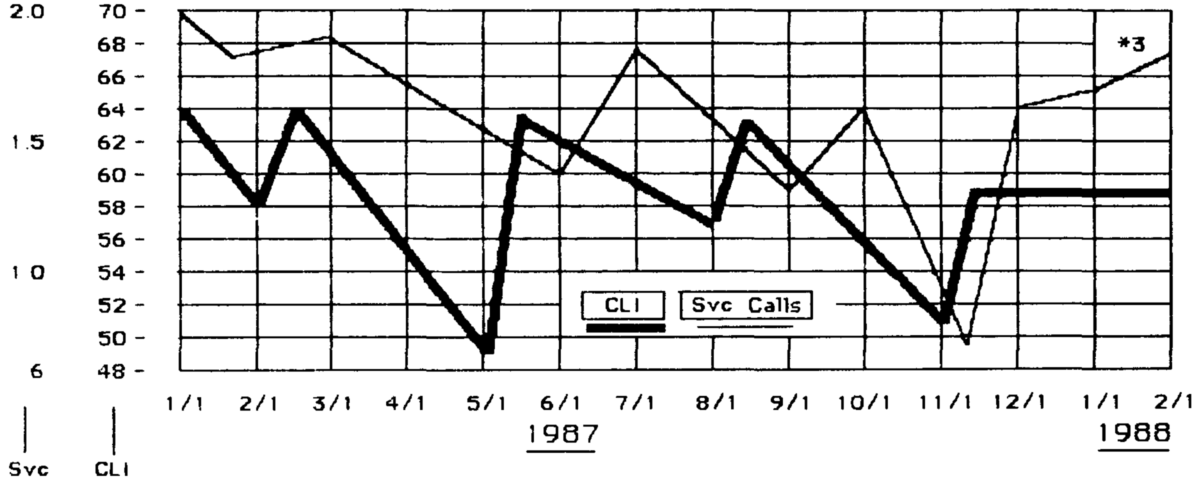
MAP NO.	LEVEL IN dB	ESTIMATE DISTANCE	REPORTED BY TECH #	DATE REPORTED	LEAKAGE LOCATION

Figure 2



1) CLI - The first drive-out period will indicate your most dramatic changes.
2) The overall trend for this drive-out period indicates that service calls per 1000 subs is directly proportional to our CLI.

Figure 3



1) SERVICE CALLS PER 1000 SUBS - You'll see an overall down trend in service calls as CLI is maintained.
2) CLI - You'll see a rise and fall as driveouts are completed. After service has been done, there is an overall decline in CLI to an average of 59.
*3) Indicates an increase in service calls when no leaks have been repaired over a period of a month.

Figure 4

```
=======================================================
=                                                     =
=    Cumulative Leak Index Report                     =
=    METROVISION; DETROIT REGION          03/04/88    =
=    Subsystem-REDFORD                    Ver-1.17D   =
=                                                     =
=======================================================


              All Areas

              FCC Report


         Mileage                 178.650
         Miles Driven            178.650
         Percent Driven          100.0
         Total Leaks              27
         Leaks per Mile            0.15
         Largest Leak            203     uV/M at 10 ft.
         Smallest Leak            51     uV/M at 10 ft.

         Leaks greater than 1500 uV/M -  0
         Leaks between 1000-1500 uV/M -  0
         Leaks between  500-1000 uV/M -  0
         Leaks between  200-500  uV/M -  1
         Leaks between   50-200  uV/M -  26

         Cumulative Leak Index     51.8     (Pass)
```

Figure 5

```
=======================================================
=                                                     =
=    Cumulative Leak Index Report                     =
=    METROVISION; DETROIT REGION          03/04/88    =
=    Subsystem-REDFORD                    Ver-1.17D   =
=                                                     =
=======================================================


              All Areas

              Maintenance Report


         Mileage                 178.650
         Miles Driven            178.650
         Percent Driven          100.0
         Total Leaks             150
         Leaks per Mile            0.84
         Largest Leak            203     uV/M at 10 ft.
         Smallest Leak            11     uV/M at 10 ft.

         Leaks greater than 1500 uV/M -  0
         Leaks between 1000-1500 uV/M -  0
         Leaks between  500-1000 uV/M -  0
         Leaks between  200-500  uV/M -  1
         Leaks between   50-200  uV/M -  26
         Leaks between   20-50   uV/M -  112
         Leaks less than 20      uV/M -  11

         Cumulative Leak Index     53.8     (Pass)
```

Figure 6

```
      UNREPAIRED LEAK REPORT                         Page- 1      Ver-1.17D
      METROVISION; DETROIT REGION                    03/04/88
      Subsystem-REDFORD / AREA-All                   By: Leak Intensity

=========================================================================
 Leak    uVM   TR1  Est  Date      Rep
  No    @10'  dB   Ft.  Reported  By   Leak Location                Area
=========================================================================


  16    202    0   100  02/20/88  107  BEST WESTERN                  024
 139    113   -5   100  02/20/88  103  26720 JOY ROAD                093
  45     80   -8   100  02/20/88  309  15789 WOODBINE                044
  95     64  -10   100  02/20/88  108  12730 TECUMSEH                073
  86     64  -10   100  02/20/88  303  14201 CROSLEY                 064
  74     64  -10   100  02/20/88  303  26900 LYNDON                  063
```

Figure 7

```
      REPAIRED LEAK REPORT                      Page- 2       Ver-1.17D
      METROVISION; DETROIT REGION               03/04/88
      SUBSYSTEM-REDFORD                         AREA-Global (all areas)

  ====================================================================

  Leak Location: 16806 FIVE POINTS                          File No:  7
  Leak Intensity (at 10'):  160 uV/M  TR-1 Reading: -2 dB   Est Dist: 100 ft.
  Date Reported- 02/20/88    Reported by- 309               Area: 044
  Date Repaired- 02/29/88    Repaired by- 309
  Leak Source: LOOSE FEEDER CONNECTOR                       Source Code: 400
  Repair Action / Comments:
  ..........................................................................

  Leak Location: 9060 INKSTER                               File No:  8
  Leak Intensity (at 10'):  202 uV/M  TR-1 Reading:  0 dB   Est Dist: 100 ft.
  Date Reported- 02/20/88    Reported by- 103               Area: 093
  Date Repaired- 02/29/88    Repaired by- 309
  Leak Source: LOOSE FEEDER CONNECTOR                       Source Code: 400
  Repair Action / Comments:
  ..........................................................................

  Leak Location: 17398 GARFIELD                             File No:  9
  Leak Intensity (at 10'):  360 uV/M  TR-1 Reading: +5 dB   Est Dist: 100 ft.
  Date Reported- 02/20/88    Reported by- 309               Area: 034
  Date Repaired- 02/29/88    Repaired by- 309
  Leak Source: LOOSE FEEDER CONNECTOR                       Source Code: 400
  Repair Action / Comments:
  ..........................................................................

  Leak Location: 27357 CATHEDRAL                            File No:  10
  Leak Intensity (at 10'): 2026 uV/M  TR-1 Reading: +20 dB  Est Dist: 100 ft.
  Date Reported- 02/20/88    Reported by- 103               Area: 093
  Date Repaired- 02/29/88    Repaired by- 309
  Leak Source: LOOSE FEEDER CONNECTOR                       Source Code: 400
  Repair Action / Comments:
  ..........................................................................
```

Figure 8

Other reports printed at tnat time include the FCC CLI Report and the Maintenance CLI Report. As you can see in Figure 2, the FCC CLI report only uses leaks above 50 uV/M at 3 meters in its calculation and the Maintenance CLI Report uses all reported leaks. All of these reports are copied and given to the Chief Technician and filed in the FCC binder, with the exception of work orders.

The Chief Technician accesses the information for leaks above 150 uV/m and these are repaired immediately. They are assigned from his Unrepaired Leak Report by intensity and the technicians are given the original copy of the repair work order. When these repairs are completed, he continues to hand out more repair work orders by intensity until all work orders are complete or until the next drive rolls around.

```
          METROVISION; DETROIT REGION            Page- 1
          Subsystem REDFORD Area Information     03/04/88

=====================================================
               Area     Miles       Tech
=====================================================

               013       6.840      108
               014       5.490      108
               023      11.830      108
               024       8.540      108
               033      10.390      108
               034       8.820      108
               043       8.000      108
               044       8.700      108
               053       7.790      108
               054      13.900      108
               063       7.320      107
               064      14.160      107
               073       6.990      107
               074       6.580      107
               075       0.590      107
               083      11.330      107
               084      15.990      107
               085       5.460      107
               093       7.090      107
               094       9.400      107
               095       3.440      107

          End of File- 21  records selected
```

Figure 9

```
    =======================================================
    =                                                     =
    =              REPAIRED LEAK STATISTICS               =
    =                                                     =
    =   METROVISION; DETROIT REGION       03/04/88        =
    =   Subsystem-REDFORD     Page- 1     Ver-1.17D       =
    =   Area-All Areas                    Miles- 178.650  =
    =                                                     =
    =======================================================

                     Total Repaired Leaks -  17

================================================================
Code  Leak Source                                   Leaks    %
================================================================


 100  STAPLED INSIDE WIRING                             0   0.00
 110  CABLE SHIELD STRIPPED                             0   0.00
 120  INSIDE CABLE BURNT                                0   0.00
 130  IMPROPER CABLE SPLICE                             0   0.00
 140  SQUIRREL/RODENT DAMAGE                            0   0.00
 150  DEFECTIVE CABLE                                   0   0.00
 160  INSTALL CRAFTSMANSHIP                             0   0.00
 170  DROP NOT DISCONNECTED                             0   0.00

                              Category Total            0   0.00

 200  DEFECTIVE GROUND BLOCK                            0   0.00
 210  DEFECTIVE SPLITTER                                0   0.00
 220  DEFECTIVE FM SPLITTER                             0   0.00
 230  DEFECTIVE A/B SWITCH                              0   0.00
 240  DEFECTIVE GAME SWITCH                             0   0.00
 250  F CONNECTOR THREADS STRIPPED                      0   0.00
 251  F CONNECTOR CRAFTSMANSHIP                         0   0.00
 252  BROKEN F CONNECTOR                                0   0.00
 253  CORRODED F CONNECTOR                              1   5.88
 254  DEFECTIVE F CONNECTOR                             0   0.00
 255  LOOSE F CONNECTOR                                 0   0.00
 260  DEFECTIVE TRAP                                    0   0.00
 261  LOOSE TRAP                                        0   0.00
 270  DEFECTIVE SHIELD/TERMINATOR                       0   0.00
 271  LOOSE SHIELD/TERMINATOR                           0   0.00

                              Category Total            1   5.88

 300  TELEVISION/VCR LEAKAGE                            1   5.88
 310  UNAUTHORIZED OUTLET                               3  17.65
 320  UNAUTHORIZED STEREO HOOK-UP                       0   0.00
 330  UNAUTHORIZED DROP                                 0   0.00
 340  INFERIOR CUSTOMER EQUIPMENT                       0   0.00
 350  INFERIOR CUSTOMER CABLE                           0   0.00

                              Category Total            4  23.53
```

Figure 10

```
    =======================================================
    =                                                     =
    =              REPAIRED LEAK STATISTICS               =
    =                                                     =
    =   METROVISION; DETROIT REGION       03/04/88        =
    =   Subsystem-REDFORD      Page- 2    Ver-1.17D       =
    =   Area-All Areas                    Miles- 178.650  =
    =                                                     =
    =======================================================

                   Total Repaired Leaks -  17

================================================================
Code  Leak Source                                     Leaks    %
================================================================

 400  LOOSE FEEDER CONNECTOR                              8  47.06
 401  DEFECTIVE FEEDER CONNECTOR                          0   0.00
 402  CORRODED FEEDER CONNECTOR                           1   5.88
 410  BROKEN TAP PORT                                     0   0.00
 411  BROKEN TAP PLATE                                    0   0.00
 412  BROKEN TAP HOUSING                                  0   0.00
 413  CORRODED TAP HOUSING                                0   0.00
 414  LOOSE TAP PLATE                                     0   0.00
 415  MISSING RFI GASKET                                  0   0.00
 420  SHIELD BROKEN FEEDER CABLE                          0   0.00
 421  BURNT FEEDER CABLE                                  0   0.00
 422  CUT FEEDER CABLE                                    0   0.00
 423  DEFECTIVE 500 CABLE                                 0   0.00
 424  FEEDER CABLE SUCK-OUT                               0   0.00
 425  FEEDER CABLE RF SHORT                               0   0.00
 426  SQUIRREL/RODENT DAMAGE FEEDER CABLE                 0   0.00
 430  DEFECTIVE FEEDER ACTIVE DEVICE                      0   0.00
 440  DAMAGED FEEDER TEMPORARY CABLE                      0   0.00

                               Category Total             9  52.94

 500  LOOSE TRUNK CONNECTOR                               0   0.00
 501  DEFECTIVE TRUNK CONNECTOR                           0   0.00
 510  SHIELD BROKEN TRUNK CABLE                           0   0.00
 511  BURNT TRUNK CABLE                                   0   0.00
 512  CUT TRUNK CABLE                                     0   0.00
 513  DEFECTIVE TRUNK CABLE                               0   0.00
 514  TRUNK CABLE SUCK-OUT                                0   0.00
 515  TRUNK CABLE RF SHORT                                0   0.00
 516  SQUIRREL/RODENT DAMAGE TRUNK CABLE                  0   0.00
 520  DEFECTIVE TRUNK ACTIVE DEVICE                       0   0.00
 530  DAMAGED TRUNK TEMPORARY                             0   0.00

                               Category Total             0   0.00

 600  NO LEAK MEASUREMENT FOUND                           3  17.65

                               Category Total             3  17.65
```

```
                    METROVISION; DETROIT REGION

                      LEAK REPAIR WORK ORDER

                         Subsystem - REDFORD
Version-1.17D                                                03/04/88
===================================================================

Leak No. -  1                          Area Designator -013

Leak Location - 20029 MAC ARTHUR

Leak Level (TR-1 Reading) - -22 dB     Est Distance - 100 ft.

Calculated Leak Intensity at 10 ft. -   16 microVolts/Meter

Date Located - 02/20/88                Reported by - 107

===================================================================

Date Repaired - ____ / ____ / ____


Repaired by   - ________ (Tech Code)


Leak Source Code _______


Repair Action / Comments - _________________________________________


____________________________________________________________________


TR-1 Reading (at 10 ft.) after completion of repair - _______ dB (*)

          (*) If 'No Leakage Measured', enter 'NLM'




                                      _________________________________
                                             Repair Technician
```

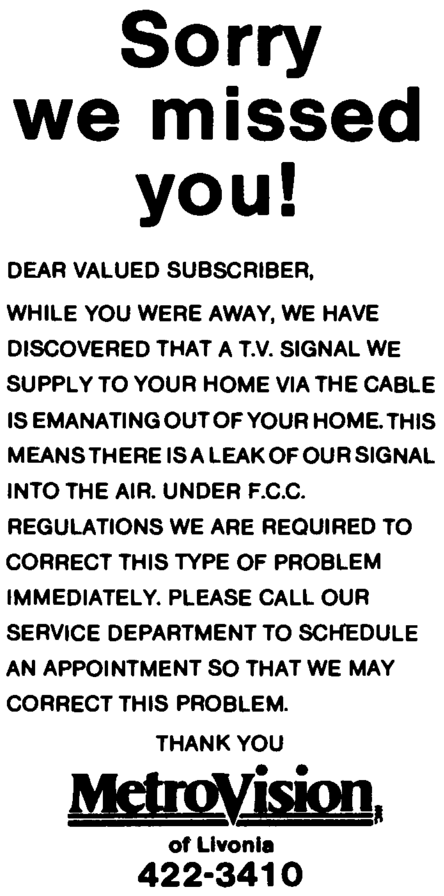
Figure 11

The technician repairs each leak and records it on his work order, being sure to record a measurement at 3 meters or indicating "no leak measured." We've found that after a number of large leaks are fixed, there are no leaks where a minor leak was recorded. The technician then calls in the repair to Dispatch with the fix code, date of repair and level at 3 meters. Dispatch records this on their copy of the work order. The technician, at the end of each day, turns in his copy of the work order to the Chief Technician.

Sometimes a technician is unable to complete an assigned work order because the leak is emanating from a subscriber's home. This can occasionally be quite a frustrating problem, especially when your subscriber works days with no one at home. We alleviate this problem with a door-hanger (see Figure 12) and a series of letters that always resolve the problem. We place the door-hanger on the technicians' first attempt to correct the problem. If we get no response, we send a series of three letters (see Figure 13) resulting either in the repair of the leak or the disconnecting of the subscriber.

Weekly, the CLI CSR gathers the repaired work orders from the Dispatch Department and verifies the information against the Chief Technician's work order. The leak repairs are then logged in the computer and new reports are generated. At this point, the Repaired Leak Report and the Repaired Leak Statistics report are copied for the FCC file and the Chief Technician. We do not file the Repaired Leak work orders.

At the end of the drive-out period all reports are generated and the new drive-out information replaces it.



Sorry we missed you!

DEAR VALUED SUBSCRIBER,

WHILE YOU WERE AWAY, WE HAVE DISCOVERED THAT A T.V. SIGNAL WE SUPPLY TO YOUR HOME VIA THE CABLE IS EMANATING OUT OF YOUR HOME. THIS MEANS THERE IS A LEAK OF OUR SIGNAL INTO THE AIR. UNDER F.C.C. REGULATIONS WE ARE REQUIRED TO CORRECT THIS TYPE OF PROBLEM IMMEDIATELY. PLEASE CALL OUR SERVICE DEPARTMENT TO SCHEDULE AN APPOINTMENT SO THAT WE MAY CORRECT THIS PROBLEM.

THANK YOU

MetroVision
of Livonia
422-3410

Figure 12

INGRESS LETTER #1

March 1, 1988

John Doe
12345 Fallow Lane
Anytown, BE 67890
092302-2

Dear John Doe:

{Cable System} has determined that the TV signal we supply to your home via the cable is emanating out of your home. This means there is a leak of our signal into the air. There are several possible causes to this condition, some of which are: a cracked cable, an unterminated end, a frayed or loose connector, or external equipment that has been installed by someone other than a {Cable System} employee.

It is after an attempt to reach you at your home that we send you this letter. We need to take the necessary steps to correct and ensure that the equipment installed in the home by {Cable System} employees has been installed correctly. Our request, at this point, is that you call our office at the number below within one week of this letter for an appointment to have it corrected. Under FCC regulations we will be required to terminate service to your home if the leak is not stopped.

Please call our Repair Service Department at 555-1111 between the hours of 8:30 a.m. and 5:30 p.m. Monday thru Friday.

Thank you for your cooperation,

{Cable System} Repair Service Department

INGRESS LETTER #2

March 1, 1988

John Doe
12345 Fallow Lane
Anytown, BE 67890
092302-2

Dear John Doe:

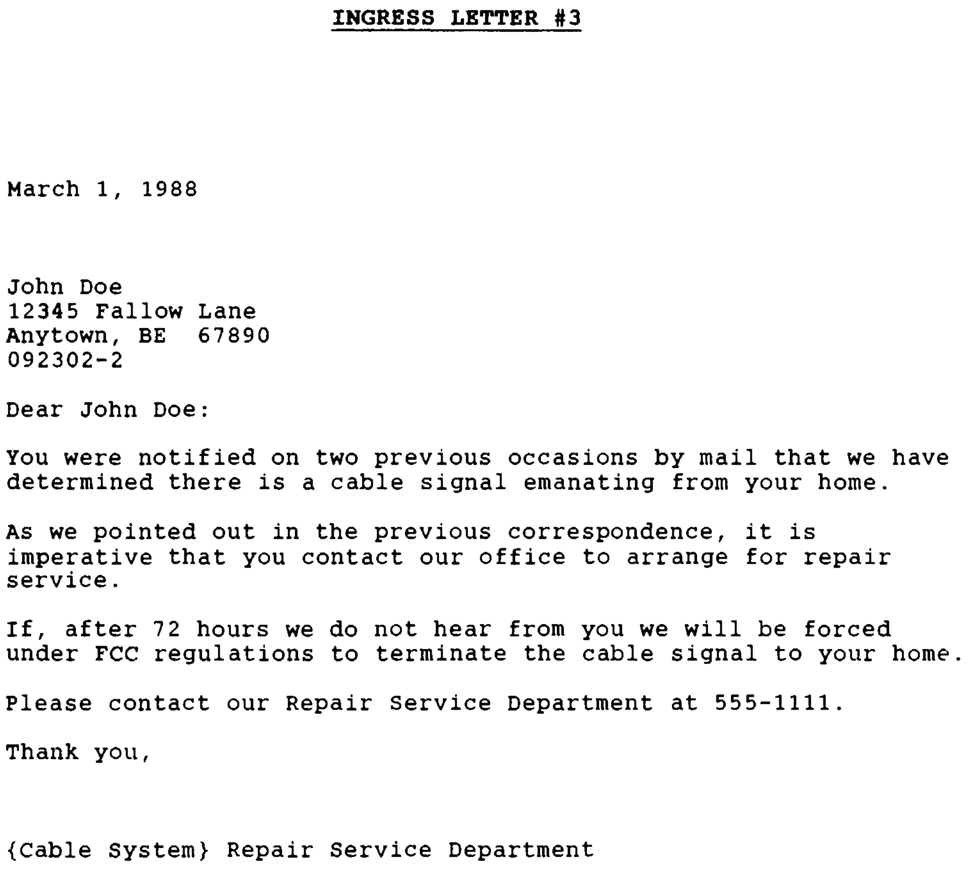
You were notified previously by mail that we have determined there is a cable signal emanating from your home.

As pointed out in the previous correspondence, it is imperative that you contact our office to arrange for repair service.

If, after 5 days we do not hear from you we will be forced under FCC regulations to terminate the cable signal to your home.

Thank you,

{Cable System} Repair Service Department



INGRESS LETTER #3

March 1, 1988

John Doe
12345 Fallow Lane
Anytown, BE 67890
092302-2

Dear John Doe:

You were notified on two previous occasions by mail that we have determined there is a cable signal emanating from your home.

As we pointed out in the previous correspondence, it is imperative that you contact our office to arrange for repair service.

If, after 72 hours we do not hear from you we will be forced under FCC regulations to terminate the cable signal to your home.

Please contact our Repair Service Department at 555-1111.

Thank you,

{Cable System} Repair Service Department

Figure 13

CONCLUSION

CLI is not one of those things where bigger is better.

What we've tried to show you here is a time tested method that we have found to work for us. However, as with any maintenance program we find ourselves constantly improving and streamlining the system.

We have shown that you can effectively drive out your system 4 times per year and stay within FCC standards with the use of available peoplepower.

REFERENCES

R. Amell, "CLI," Amell, 510 S. Kimberly Ct., Roswell, GA 30376, Version 1.17D (c) Copyright 1987

Code of Federal Regulations, Title 47 - Telecommunication, Federal Communications Commission, Parts 70 to 79, "Part 76 - Cable Television Service," October 1, 1986, pp. 450-517

Augat/LRC-Vitek Electronics, Inc., 9223 Billy The Kid Street, El Paso, TX 79907

COMMERCIAL INSERTION TECHNOLOGY:
WHAT TO DO WHEN YOUR AD SALES STAFF BECOMES REALLY SUCCESSFUL

Gregory Davis
Director of Video Operations

Oceanic Cablevision

ABSTRACT

This paper evaluates 5 commercial insertion technologies: manually edited tapes manually inserted, manually edited tapes used in sequential automation, single-spot-per-cassette playback automation, random access automation, and automatic compilation systems with sequential insertion automation. It evaluates those technologies from the perspective of a large and sophisticated ad sales operation, and identifies a critical criterion that random access systems cannot meet. It demonstrates that automatic compilation is the only approach that meets that criterion.

EVOLUTION OF LOCAL AD SALES

Like most, if not all, cable companies that sell local advertising, Oceanic Cablevision started simply. At first, a few commercials were inserted into only one network. Since then, a combination of market forces have allowed Oceanic's ad sales to grow to the point that commercials run throughout the day on 10 channels.

This growth was accompanied by a change in the way advertising time was sold. That change, from run-of-schedule (ROS) selling to selling by time of day or program, along with the volume of spots being scheduled, proved to be more than the two main commercial insertion automation technologies available could handle. After thoroughly testing both linear (or sequential) and random access insertion systems, Oceanic adopted a less common alternative: automated commercial compilation.

ROS

Most, if not all, cable systems begin their ad sales efforts by offering ROS: clients buy a minimum number of exposures but aren't guaranteed specific time slots or programs. ROS offers a limited number of clients an efficient buy because they make up what they lose in specificity with volume. By keeping the spot traffic simple, ROS eliminates the need to produce custom logs each day and keeps the on-air operation very simple.

Sell By Time Or Program

Some cable systems decide to offer more specificity to their clients by selling particular programs or times of day. Oceanic found it necessary to sell by program and/or time in order to compete with the 10 TV and more than 20 radio stations in Honolulu. Agencies and national rep firms shopping for advertising time wanted the same flexibility from Oceanic that they were accustomed to from the other media. In addition, Oceanic became interested in using its own inventory of advertising time for tune-in promotion of its programming. To effectively support pay-per-view and other specific programming meant insuring that promos would not run after the program in question was over.

As the number of clients and promos increased, the volume of traffic changes increased. New clients started and new spots were added to existing contracts throughout the week. Coupled with daily programming changes, these factors required a unique commercial log for each channel, every day.

DIFFERENT INSERTION SYSTEMS

The importance of automation to the cable advertising sales industry cannot be overstated. Automation equipment makes running commercials on multiple channels a whole lot easier. It keeps costs down and delivers clean, reliable insertion of the clients' ads. But the automation system must be chosen to match the cable operator's needs; the wrong approach can be too inflexible or more flexible, and expensive, than necessary.

There are five basic approaches to running commercials:

1. Manually editing sequential reels and manually inserting the commercials.

2. Manually editing sequential reels and automating the commercial insertions.

3. Systems with multiple playback decks per channel that play one commercial cassette per deck.

4. Random access systems that have multiple spots per reel and multiple playback decks per channel. They search and cue to the spots needed for each break.

5. Automatic editing systems that create daily break reels that run in sequential insertion automation systems.

MANUAL SEQUENTIAL INSERTION/ MANUAL ASSEMBLY

Description

Like many cable companies, Oceanic started its ad sales business by manually editing weekly commercial reels and manually inserting them on one channel.

Advantages

This is the fastest and simplest way to get started: all it takes is an editing system, a playback VCR and a switcher.

Disadvantages

The drawbacks are the cost of dedicating a person to inserting the ads and the inaccuracy of relying on human reflexes to start the ads. Frequent changes in the commercial reels become expensive, too.

AUTOMATIC SEQUENTIAL INSERTION/ MANUAL ASSEMBLY

Description

We bought our first sequential insertion system (rather than pay an additional on-air operator) when we began selling ads on additional networks. Sequential systems play clusters of commercials in the sequence they appear on a commercial reel. An entire day's commercials are on a single 3/4-inch tape for each network, and each tape is manually assembled. Each break airs upon receipt of network cue-tones. After the break airs, the tape parks at the next cluster of commercials on the tape. At the end of the day, the reel rewinds and the same breaks run in the next day's programming, or a new tape is loaded.

Advantages

This system works very well for an ROS environment that requires little editing. The insertion technology is very reliable because each break is a single event instead of a collection of 2 or 4 events. One playback machine per channel means lower costs and less to go wrong. Sequential automation systems in an ROS environment work well unattended. Adding automation and VCR's for additional networks is relatively cheap.

Disadvantages

Manual editing becomes very expensive if logs change daily. Our manually-assembled, sequential, automation insertion system was so labor-intensive as to significantly reduce the profitability of our advertising sales effort. It cost us between 25 and 30 man-hours per day to assemble new tapes for each of 8 advertising supported channels, for an annual labor cost in the neighborhood of $75,000.

SINGLE SPOT PER REEL CART SYSTEMS

Description

The broadcast industry historically used single-spot cartridge systems to play back commercials. These systems would have either enough transports to run each spot in a break without reloading, or a means of reloading each transport during a break. As the first 2-inch cart machines reached retirement age, new versions have been developed that use component 1/2-inch cassettes and robotics to change tapes. On a simpler level, some stations have used banks of 3/4-inch VCR's to play back single-spot tapes, manually reloading each VCR after each break.

Advantages

Either single-spot approach is extremely flexible because last minute changes can be made right up to air time.

Disadvantages

That same flexibility can be a liability. The need to manually load tapes leaves open the possibility of error, and if several channels are involved it can keep an operator very busy. Robotic systems will handle the tapes for you, and most current systems use bar-code identification schemes to insure the right tape is loaded, but they're extremely expensive. With or without robotic tape handling, adding channels to single spot systems is hugely expensive: additional controllers and additional VCR's aren't cheap.

The need to provide many copies of each spot, one for each channel, is expensive and complicated. The system is also vulnerable if the automation should break down: it's hard to cue and run individual spots.

RANDOM ACCESS

Description

Random access playback systems use multiple players loaded with identical reels, each containing copies of all active spots. Prior to each break, each player cues to a different spot. At the break, each VCR plays a single spot in turn, then re-cues for the next break. The normal random access configuration would have one VCR per each 30 seconds of the longest local avails on each network. For example: CNN offers 2-minute avails, requiring 4 VCR's; Headline News offers 1-minute avails, requiring 2 VCR's.

Advantages

Random access uses the same spots over and over again instead of requiring daily construction of tapes. This makes it very easy to accomodate log changes (if they don't involve new spots; more on those difficulties shortly) because changes simply mean cueing to different spots.

In addition, many of the random access systems on the market capitalize on their computer sophistication to offer integrated traffic, verification and billing features. This simplified, integrated, purchasing option appeals to many users.

Disadvantages

The most obvious drawback to random access insertion systems is the need for multiple transports on each network. (This problem can be partially ameliorated by sharing VCR's between networks that have local avails that always run at different times, but not many networks would qualify for sharing.) In addition to the capital costs of having all these VCR's, there is the on-going maintenance cost, and some operators would have trouble finding room for that many VCR's.

Keeping all those VCR's filled with tapes is another big issue to consider in evaluating random access systems. If a network offers 1-minute avails, you will need 2 copies of every spot; those that offer 2-minute avails require 4 copies. The multiple copies allow any combination of spots to run during any given break. Starting a new spot running on all networks will mean dubbing that spot onto 2 reels for some networks, 4 reels for others. If you are running ads on 8 networks, this can easily mean making 20 or more dubs of each spot.

The Critical Weakness of Random Access

After using random access automation on 2 networks for several months, Oceanic concluded that it would never be able to comfortably handle more commercials, promos, IDs, and PSAs than would fit on a single 60-minute tape (roughly 100). This proved to be a critical problem for us; our active inventory averages around 250 items.

Having more spots than will fit onto a single 60-minute tape means having to continually change tapes or installing additional VCR's. Rather than changing tapes all day, we could triple the number of transports per network to allow all spots to be loaded at all times. (250 spots, with 100 spots per tape, works out to 3 sets of tapes for each network, and 3 times the VCR's. See Table 1 for Oceanic's VCR requirements under either scenario.) Each VCR would take up space, consume power, generate heat and cost $40-$50 per month in maintenance.

With either approach (constantly changing tapes or installing extra VCR's), every new spot would need to be dubbed once for every playback VCR on every channel. With more than 200 active spots, we would have to keep 63 tapes current, organized and readily available. We

RANDOM ACCESS VCR REQUIREMENTS

	RE-LOADING TAPES	WITHOUT RE-LOADING
MTV	3	9
VH-1	2	6
ESPN	2	6
USA	2	6
FNN	4	12
Nickelodeon	2	6
CNN	4	12
Headline News	2	6
	---	---
	21	63

Table 1

receive from 5 to 10 new commercials and promos per work day to add to the active inventory. With that many sets of tapes, it would take 2-3 hours to make all the dubs necessary to add a new commercial to all channels.

Assuming we used the fewest possible on-air playback VCR's to conserve space and reduce costs, the operators would be overwhelmed by the need to correctly re-load the 21 VCR's once or twice an hour, and commercials would likely be missed. If the operators have to constantly change tapes, we might just as well use the single spot per tape approach. At least it wouldn't need such a complex automation system.

Additionally, the need to play back tapes from multiple VCR's for each channel makes it almost impossible to manually run commercials if the automation should fail. The operator would be unable to cue and roll all spots without the help of the automation.

With multiple transports per channel and sophisticated controllers, random access systems have high incremental costs for adding additional networks.

Finally, while many operators may be interested in integrated traffic, insertion and billing systems, others may prefer the flexibility of picking out these systems a la cart.

SEQUENTIAL/AUTOMATIC COMPILATION

Fortunately, Oceanic found a more practical solution. Rather than automating the playback of several tapes per channel, we chose a system that edits daily tapes automatically. Automatic compilation combines features of random access with sequential insertion systems.

Description

. An automatic compilation system uses library reels, similar to the spot reels in a random access system, to create daily tapes for each channel. The logs are loaded into the system, becoming edit lists. The end result of an automatic compilation system is a daily tape for each channel, which is loaded into its respective sequential insertion system for on-air playback.

Minimum Requirements

An effective compilation system must meet certain criteria:

1. It must use SMPTE time code for frame-accurate editing (see next item).

2. It must compile the breaks on the daily tape out of sequence, checker-boarding the tapes until all positions in all breaks are filled in. This allows the system to transfer all the needed spots from each library reel before requiring a library reel change.

3. It must allow for the use of multiple players and/or recorders. Multiple players reduce the number of library reel changes, and allow one machine to cue while another is editing. Multiple recorders allow spots to be transferred to different daily reels simultaneously.

4. It must allow direct down-loading of commercial logs from the traffic system, avoiding the need to type in logs manually.

5. It must automatically re-try edits that abort due to mis-matched time code. (With SMPTE time code, edits will occassionally abort when the controller is unable to get the machines to sync up properly. This is a random occurrence; the edit is almost always successful on second or third attempts.)

Advantages

Unlike random access systems, each spot need only be transferred to a library reel once.

By retaining the sequential insertion system, the number of VCR's is kept to 1 per network, reducing capital costs, maintenance costs, space, power and cooling needs.

Sequential insertion technology has proven reliable and simple to operate. (Oceanic is still using the first Channelmatic inserter ever sold.)

Reliability is higher than manual editing, thanks to time code. Frame-accurate editing insures that frames aren't cut off of commercials or frames from old commercials don't show at the edit points. The computer is also less prone to careless editing errors than people are.

Labor costs of an automatic compilation system are limited to adding new spots to the library reels (once for each new spot, unlike random access) and the usual housekeeping involved in maintaining quality control of the video tape stock. Compilation itself doesn't require operator supervision. The time of the library tape changes can be accurately estimated in advance, and the system can be left unattended until the tape needs changing.

Perhaps the most significant advantage of an automatic compilation system is that it is very forgiving of problems or failures. Small glitches don't affect the airing of commercials because the system is operating off-line, preparing daily tapes a day or so in advance. Problems can usually be resolved in time to complete the required editing and air all spots as scheduled. The on-air operation, being a collection of stand-alone sequential inserters, is immune to catastrophic failures that might disable all networks.

Disadvantages

As may be apparent, one disadvantage of automatic compilation systems is the difficulty of making last minute changes to the logs. These systems build the tapes in advance, so any late changes mean interrupting work in progress to re-edit daily reels that had been finished earlier, or manually editing the changes. (This is also true of manually edited sequential insertion systems. While random access systems do have an advantage in being able to quickly substitute one current spot for another, getting new spots on the air requires hours of dubbing.)

The start-up cost for acquiring an adequate compilation system is likely to be high due to the sophistication required; at its core, the system should be a multiple-VCR editing controller with time code capability.

The cost will depend on the editing workload. It's indirectly related to the number of networks served: when there are more breaks than can be assembled in one day, then additional VCR's must be added to speed up the compilation process. (Oceanic's current system compiles the daily tapes for 18 hours' worth of avails on 8 networks, using 2 players and 3 recorders, in about 12 hours.)

A final drawback to automatic compilation is the extra generation lost in dubbing spots first onto library reels then onto daily reels. It should be noted, however, that this same generation loss can occur when mass-producing identical library tapes for a random access system (each version of the library tapes would be dubbed to provide copies for all networks' VCR's.) This degradation of the video quality can be elminated by using SP recording technology, or minimized by using the dub video connections between VCR's.

SUMMARY AND CONCLUSIONS

Oceanic Cablevision's Experience

Oceanic has shown that converting 8 channels to an automatic compilation system, even with the expense of modifying 5 VCR's for time code capability, was cost-competitive with converting to random access equipment and acquiring additional playback VCR's.

In our case, we calculated that random access would have eliminated 4 or 5 part-time editors, but 3 or 4 would have been needed to handle the dubbing of newly arrived commercials and promos. Furthermore, reliability would be reduced by the need to constantly change tapes in the control room.

Converting to an automatic compilation system has eliminated 8 part-time positions. The editing of the daily reels is unattended. (Whomever is in the vicinity takes care of changing the source tapes about every 45 minutes.) The amount of editing needed to add new spots is low enough that the former editing supervisor (who no longer has a staff to supervise) can handle all compilation and library tape housekeeping chores. With the cooperation of our ad sales and traffic personnel, last-minute changes have been kept to a minimum. Based on labor savings, system pay-back will come in about 18 months.

Reliability has not been a problem. We have taken advantage of the off-line nature of automatic compilation: we've chosen a system configuration that allows us to complete daily compilation, add new spots and perform general housekeeping in around 18 hours, leaving up to 6 hours a day as a cushion if problems crop up.

Changing tapes only once a day has kept our control room operation simple and avoided a lot of tape inventory management problems. We've added additional commercial insertion channels cheaply by purchasing a single VCR and low-cost sequential inserters.

Lessons For Other Operators

Though they are more dependent on automation than broadcasters, cable operators are still looking for the right technology for multi-channel commercial insertion. Virtually everything has been tried, or at least considered, but the industry has yet to embrace the one technology that can simplify complex operations.

To sum up our conclusions, based on our experiences at Oceanic:

1. Manual insertion using manually assembled tapes only works for the simplest ad sales efforts; for multiple networks and/or in case of frequent traffic changes, the labor costs become prohibitive.

2. Sequential insertion using manually assembled tapes are cheap, simple and reliable, but only suitable for ROS sales practices. Again, the labor costs of frequent traffic changes are prohibitive.

3. Single spot per tape cart systems work well for broadcasters, who only have one network to deal with (and who can afford to invest heavily in their only source of revenue), but become expensive and unwieldy when applied to multiple channels.

4. Random access systems work well in medium-sized sales environments, but use too many VCR's and too many tapes, and don't reduce labor costs enough for larger ad sales environments.

5. Automatic compilation systems keep tapes and VCR's to a minimum, use cheap and proven insertion technology, and keep labor costs lower than any other system. For large ad sales efforts, with more than 100 active spots, automatic compilation is the only way to go.

Recommendations

Cable operators need to adapt technology to their ad insertion needs, rather than vice versa. Those with the most sophisticated ad sales efforts will find that automatic compilation technology can make them more competitive by increasing their operating efficiency. If more operators ask for compilation automation, automation manufacturers will respond with a wider variety of products, improving the breed.

COMPOSITE SECOND ORDER: FACT OR FANTASY

MARK ADAMS

SCIENTIFIC-ATLANTA, INC.

ABSTRACT

Distortion parameters have always been the limiting factor within a CATV system, but as the bandwidth has increased from 12 channels to 60 and 77 channels, the characteristics of the limiting distortions have changed. At the beginnings of CATV, cross modulation and noise limited the number of amplifiers an operator could run in a cascade. As the number of channels increased, cross modulation gave way to composite triple beat as the limiting factor, with noise still a prominent element. A strange thing has occurred however. As the number of channels increased further so did the importance of a distortion parameter that caused little if no concern before. This distortion parameter is called "second order" and in its discrete form still presents no problem to the CATV operator. But when this parameter is taken in its composite form, composite second order can compete with composite triple beat as the limiting factor for cascade length and feeder levels, especially in a 77 channel system.

This paper will re-investigate the causes of second order distortion. It will also provide insights into calculating which composite second order beats are present from discrete second order numbers. In addition, it will provide an analytical analysis of a trunk amplifier, bridging amplifier and line extender for composite second order and how this distortion can be a limiting factor within a cable system.

INTRODUCTION

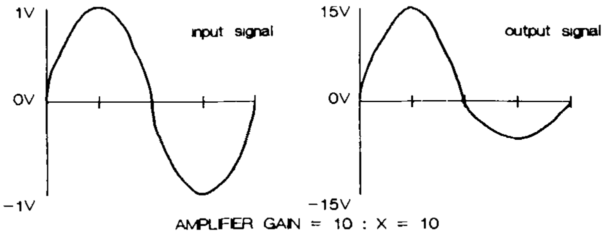
The CATV industry has seen a tremendous amount of change in the last 15-18 years. Systems that in the early 1970's carried 12 or so channels have now progressed to a point where today, 60 or even 77 channels are reaching consumers' homes. This represents approximately 5 times the number of channels that once were present. Along with this growth however, additional problems have presented themselves to the industry. This paper looks into one of these problem areas. It must be understood however, that the data used to calculate the amplifier models and the distortion numbers within this paper are in their worst case situations. In reality the effects of offset headends, modulated carriers and many other combinations can contribute improvements in the numbers presented.

CAUSES & EFFECTS OF SECOND ORDER BEATS

In a CATV system, amplifiers and cable are the medium used to transport TV signals from the point of origin to the viewer's home. If things were perfect, the amplifiers would provide <u>only</u> signal amplification and there would be no limit to the number of amplifiers that could be cascaded. However, in the real world there is no such thing as a perfect amplifier and they provide not only the desired signal increase or gain but they also introduce several unwanted elements commonly known as distortions.

Distortions can take many forms, but in this discussion, only the distortion parameter known as second order will be addressed. Second order distortion is created when the amplifying transistors are not biased in balance. This imbalance creates the non-linear transfer characteristic in the amplifier. This non-linear relationship results in the compression and expansion of the peaks of the sine waves of the amplifier output signal in relation to its input signal. This non-linear transfer characteristic can be expressed mathematically by eout = Xein + 1/2X (ein) 2 and is characterized by Figure 1.

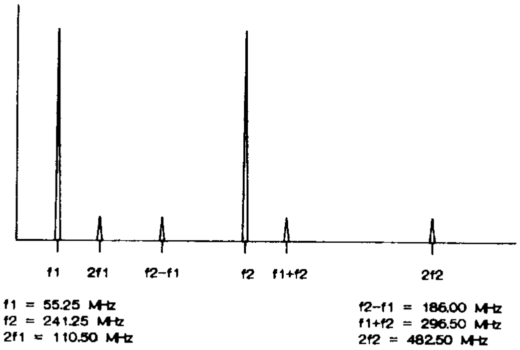
FIGURE 1.
AMPLIFIER TRANSFER CHARACTERISTIC
$e_{out} = Xe_{in} + 1/2Xe_{in}^{2}$



This diagram shows how the output signal is distorted with compression and expansion of the sine wave peaks when a 2.0 volt peak-to-peak input signal is inserted into an amplifier that exhibits the form of eout = Xein + 1/2X (ein) 2. This non-linear effect is known as a square law transfer characteristic.

This square law characteristic, when present in amplifiers with two input signals, will present beats within the spectrum as the phase relationship of the two input signals changes with time. These beats will be evident at 2 times f1 (1st frequency); 2 times f2 (2nd frequency); f1 + f2 (1st frequency + 2nd frequency) and f2 - f1 (2nd frequency - 1st frequency). Figure 2 shows this relationship of beats for an amplifier with f1 = 55.25MHz (Channel 2 - IRC headend) and f2 = 241.25MHz (channel N - IRC headend).

FIGURE 2.
SECOND ORDER BEAT SPECTRUM

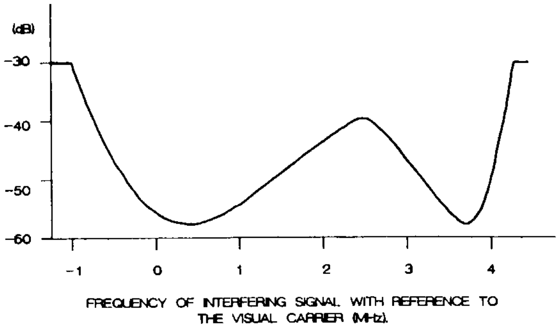


As can be seen in Figure 2, beats fall at 2f1 = 110.50MHz; 2f2 = 482.50MHz; f1 + f2 = 296.50MHz and f2 - f1 = 186.00MHz

The beat relationship depicted in Figure 2 holds true for whatever input signals are inserted into amplifiers that exhibit the square law transfer characteristic. Such beats can affect the picture quality of TV signals if the amplitude of the second order beat product is great enough.

Second order is evident to viewers as a herring-bone pattern that appears to be floating across the picture. The viewability of this phenomenon is highly subjective, and ranges of susceptibility have been as great as 9dB. Recommendations for the levels of discrete second order interference are -60dBc by the NCTA and Figure 3 shows the permissible limits for interfering signals in relation to visual carriers.

FIGURE 3.
RELATIVE SENSITIVITY OF A VISUAL CARRIER TO INTERFERING SIGNALS.

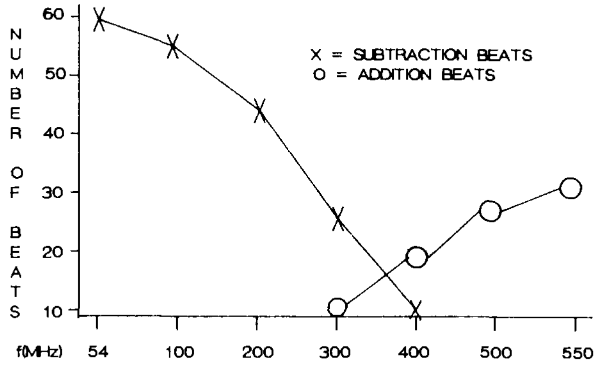


As can be seen by Figure 3 only the signals that fall at a frequency of fref +1.25MHz (fref = reference frequency) will present possible interference problems. The level of interference to visual carriers must be greater at this point than that of fref - 1.25MHz. If the beat products taken from Figure 2 are applied to the graph of Figure 3, then the only beats that could possibly present problems are those at 110.50MHz; 296.50MHz and 482.50MHz. For this reason beats that are generated as a subtraction (f2 -f1) are not considered as problems to the CATV operator. Even beats that fall into the fref + 1.25MHz category present no problems to systems with a small number of channels present. But now consideration will be given to the second order beats in systems that carry 77 channel loading.

COMPOSITE SECOND ORDER NUMBERS

Composite Second Order occurs when many combinations of signals beat together. The once unimportant discrete second order beat, when summed with many other discrete second order beats falling on the same frequency (due to other channel pairs), results in a composite second order distortion which may have a level large enough to interfere with the visual carrier. This presents problems since amplifier manufacturers and CATV equipment manufacturers at present only specify what Discrete Second Order (DSO) numbers should be-not those of Composite Second Order (CSO). Composite second order numbers can be calculated however, by the equation CSO = DSO + 10 log X, where X = number of beats on fref + 1.25. The unknown now is the number of beats that make up X. In a 550MHz system (77 channel) there are 29 beats that fall on 548.50MHz, the relationship of the number of beats to frequency can be seen in Figure 4.

FIGURE 4.
NUMBER OF COMPOSITE SECOND ORDER BEATS IN A 77 CHANNEL SYSTEM



As can be seen, the maximum number of CSO addition beats falls at 548.5MHz. Experiments have been performed on 10 samples each of a 550MHz 19dB gain push/pull hybrid; a 550MHz 19dB gain parallel hybrid and a 550MHz 24dB gain feedforward amplifier to determine how accurate the equation CSO = DSO + 10 log (X) is. The average of each group of amplifiers is given in Tables 1 thru 3.

TABLE 1: 550MHz 19dB Push/Pull Amplifier

Discrete Second Order Spec =
-66dB at +50dBmV
Calculated Composite Second Order Spec =
CSO = DSO + 10 log X where X = 29
= -66 + 10 log 29
= -66 + 14.6
= -51.4

	Average Measured DSO	Average Measured CSO
Freq. 548.50MHz	67.0	51.6

TABLE 2: 550MHz 19dB Parallel Hybrid Amp.

Discrete Second Order Spec =
-65dB at +50dBmV
Calculated Composite Second Order Spec =
CSO = DSO + 10 log X where X = 29
= -65 + 10 log 29
= -65 + 14.6
= 50.4

	Average Measured DSO	Average Measured CSO
Freq 548.50MHz	70.0	58.0

TABLE 3: 550MHz 24dB Feedforward Amplifier

Discrete Second Order Spec =
-80dB at +50dBmV

Calculated Composite Second Order Spec =
CSO = DSO + 10 log X where X = 29
= -80 + 10 log 29
= -80 + 14.6
= 65.4

	Average Measured DSO	Average Measured CSO
Freq 548.50MHz	85.0	71.0

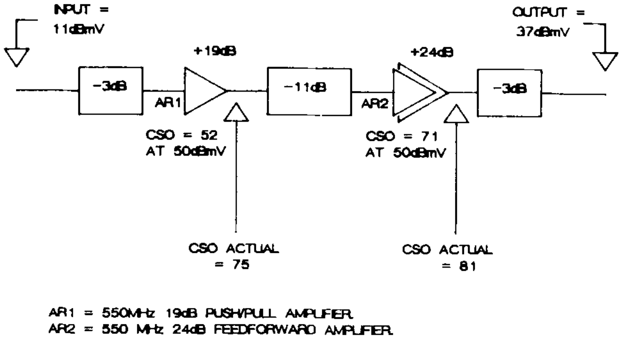
As can be seen from the data, all three amplifiers exhibited better DSO performance than specified: the push/pull by +1dB, the parallel hybrid by +5dB, and the feedforward by +5dB. However the relationship that needs to be looked at is that of the discrete second order beat to that of the CSO beat. In the case of the push/pull and feedforward amplifiers, the 10 log X with X = 29 holds very close to being true (difference = .6dB in both cases). Only in the case of the parallel hybrid amplifier did this relationship break down. These amplifiers showed only a 12dB degradation instead of the 14.6dB that was calculated.

Explanations to this might come from the fact that just as transistors within amplifiers are not biased in balance, the two separate amplifier sections that make up a parallel hybrid amplifier may not be balanced and the square law transfer characteristic of the gain block might be out of phase. Now that the relationships of DSO to CSO has been established, an analysis can be made as to how this affects trunks, bridgers and line extenders used in a CATV system.

AMPLIFIER ANALYSIS

As mentioned previously, amplifiers are used to transport TV signals from one point to another. The most common of these are called trunk amplifiers. These units are built to better distortion specifications than bridgers and line extenders due to the fact that several (most cases up to 20) may be cascaded together to transport these signals. When distribution of signals is required to neighborhoods, units known as bridging amplifiers and line extenders are used. These units, while not exhibiting as good of distortion performance, operate at higher levels than trunk amplifiers. In order to see the effects of CSO on a CATV system, models of these amplifiers will be made using the average CSO numbers from Tables 1 thru 3. In the case of the trunk amplifier a push/pull hybrid will be used together with the feedforward block. The bridging amplifier and line extenders will both be parallel hybrid units meaning that the push/pull hybrid will be used as the input with the parallel hybrid device used as the output. Levels for the units will be +11dBmV input; 37dBmV output for the trunk; and the outputs for the bridger and line extenders will be +46dBmV.

CASE # 1
FEEDFORWARD TRUNK AMPLIFIER
BLOCK DIAGRAM



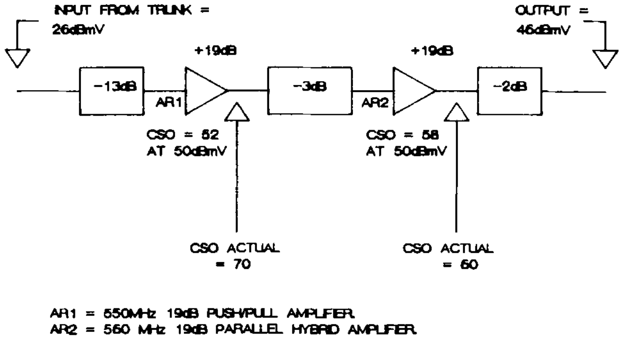
CASE 1:
CSO for unit =

$$10 \log \left(10^{\frac{x}{10}} + 10^{\frac{y}{10}}\right)$$

$$= 10 \log \left(10^{\frac{-75}{10}} + 10^{\frac{-81}{10}}\right)$$

$$= -74$$

CASE # 2
PARALLEL HYBRID BRIDGING AMPLIFIER
BLOCK DIAGRAM



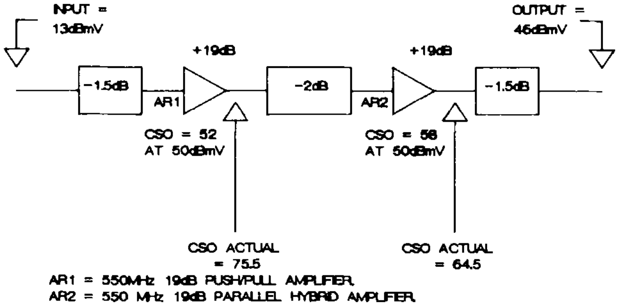
CASE 2:
CSO for unit =

$$10 \log \left(10^{\frac{x}{10}} + 10^{\frac{y}{10}}\right)$$

$$= 10 \log \left(10^{\frac{-70}{10}} + 10^{\frac{-60}{10}}\right)$$

$$= -59.5$$

CASE # 3
PARALLEL HYBRID LINE EXTENDER
BLOCK DIAGRAM



CASE 3:
CSO for unit =

$$10 \log \left(10^{\frac{x}{10}} + 10^{\frac{y}{10}}\right)$$

$$= 10 \log \left(10^{\frac{75.5}{10}} + 10^{\frac{64.5}{10}}\right)$$

$$= -64$$

A review of the preceding cases shows that in trunk amplifiers, the input hybrid is the limiting component in determining CSO, while in the bridging amplifier and line extender, the output device is the one that contributes the most to CSO.

SYSTEM ANALYSIS

Now that models have been generated for trunk, bridging and line extender amplifiers, the numbers derived from these models can be used to determine the consequences of CSO on the cable plant. If a typical system of 20 trunk amplifiers, a bridging amplifier at the 20th location, followed by 2 lines extenders is analyzed, the following CSO numbers can be calculated. From Cases 1-3:
Case 1 Trunk amplifier CSO = -74
Case 2 Bridging Amplifier CSO = -59.5
Case 3 Line Extenders CSO = -64

TABLE 4

Trunk contribution = -74 + 10 log 20
where 20 = number of identical amplifiers in cascade.
Trunk contribution = -61dB CSO
Bridging Amplifier Contribution =

Trunk Amplifier CSO Number + Bridging Amp CSO Number
therefore,

$$CSO = 10 \log \left(10^{\frac{-61}{10}} + 10^{\frac{-59.5}{10}}\right) = -57dB$$

Line Extender Contribution =

Trunk & Bridging Amp CSO Number + Line Extender 1 CSO Number
therefore,

$$CSO = 10 \log \left(10^{\frac{-57}{10}} + 10^{\frac{-64}{10}}\right) = -56dB$$

This is added to a second line extender whose CSO number is also -64 therefore,

$$CSO = 10 \log \left(10^{\frac{-56}{10}} + 10^{\frac{-64}{10}}\right) = -55dB$$

This -55dB CSO number represents the end of the line performance and is 5dB below what the NCTA recommends for DSO performance. When this -55dB CSO is compared to the minimally acceptable interference graph of Figure 3 it can be seen that CSO is right on the threshold on acceptability.

CONCLUSIONS:

While the data presented in this paper is that of an absolute worst case situation, (IRC headend - no offsets; CW carriers, no system tilts etc.) care and consideration must be given to CSO. No longer can operators afford the luxury of ignoring this phenomenon if 77 channel and larger systems are to be built. Additionally, both the amplifier and CATV equipment manufacturers must start specifying equipment with CSO numbers.

ACKNOWLEDGEMENTS:

The author would like to thank Martin Cowen for his help in making distortion measurements and my secretary, Wendy Bonardi, for typing this paper.

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COMPOSITE TRIPLE BEAT AND NOISE IN A FIBER OPTIC LINK USING LASER DIODES

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ABSTRACT

Using a Laser diode in an analog multichannel fiber optic link Composite Triple beat and Carrier to Noise ratios are calculated as a function of laser parameters as well as of the number of channels. Two models for the nonlinearities of a laserdiode are used. The results are applied to multichannel Vestigial Sideband transmission.

INTRODUCTION

The low loss of optical fibers (0.5 dB/km versus 30 dB/km of coax) makes them an attractive choice for multichannel TV transmission. Single mode fiber technology offers up to 1 GHz transmission bandwidth at reasonable cost. Modal noise problems that plagued older multimode systems are non existent in single mode designs. The choice of the modulation format for the transmission of multichannel video is heavily dependent on the parameters of an optical link in terms of noise, intermodulation distortion, and loss budgets. Frequency modulation has been successful when noise levels were high (because backreflection problems were not fully understood and because of high RIN in the lasers themselves). Improvements in laser technology and the capability to avoid backreflection noise allow the use of a Vestigial Sideband modulation format. This approach is very attractive, because no modulation conversion (which is costly or of limited quality) has to be done.

The optical link seen as an RF communication link

Every RF link (microwave, coaxial CATV trunk or supertrunk etc.) can be analyzed for analog transmission, when the following parameters are known:

- The noise figure
- The intermodulation characteristics
- The compression power

It is interesting to ask if these parameters can be found for a link including optical components (lasers, PIN detectors etc.) too.

Noise

The few laser manufacturers that specify noise for their lasers do this by using the RIN number (Relative Intensity Noise) [1, Guekos 1983]. RIN can be considered to be the noise floor, measurable with a spectrum analyzer after light to current conversion with an optical detector.

To find the carrier to noise ratio we consider the following: We talk about 100% depth of intensity modulation of the light when an RF signal that is superimposed to the bias reaches the lasing threshold with its peaks (see figure 1). RIN can therefore be considered a peak carrier to noise density ratio.

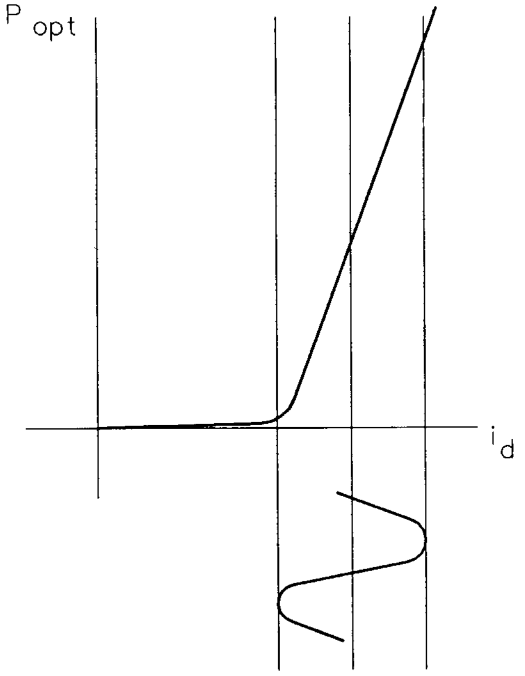

Figure 1: 100% intensity modulation of a laser diode

The carrier to noise (density) ratio CNR when the depth of modulation is 100 % is

$$CNR = -RIN-3 \qquad (dB) \qquad (1)$$

The noise figure F of the laser can be found when the CNR at the input of the laser is known. The RF drive level is determined with the differential quantum efficiency E of the laser, which is

$$E = d(P_{opt})/d(i_d) \qquad (2)$$

with P_{opt} : Optical power

i_d : Laser diode current

The RF drive level C for m = 100% is

$$C = (i_{bias}/\sqrt{2})^2 Z \qquad (3a)$$

with i_{bias} : Laser bias current

Z : Resistor in series with the laser diode (75 Ohm)

Using equation (2) in equation (3a) and the bias current as the differential drive current, we find

$$C = (P_{opt}/E)^2 Z/2 \qquad (3b)$$

The noise power N_L referred to the input of a laser diode exceeds kT_0 by the noise figure of the laser:

$$N_L = -174 + F \qquad (dBm) \qquad (4)$$

With the definition of the CNR

$$CNR = 10 \cdot \log(P_C/P_N) = C-N \qquad (dB) \qquad (5)$$

we find that

$$N = C - CNR \qquad (dB) \qquad (6)$$

With $10 \cdot \log(kT_0) = -174$ dBm/Hz and using equation (4) and equation (3) we find F to be

$$F_L = 10\log[(P_{opt}/E)^2 Z/2] + RIN + 207 \qquad (dB) \qquad (7)$$

A good laser diode can have a -145 dB/Hz RIN number. With a typical differential efficiency of 0.04 W/A and an output power of 1 mW we find the laser noise figure to be 46 dB in a 75 Ohm system.

Intermodulation Distortions

The nonlinear distortion of the laser transfer characteristic produces intermodulation products in an analog multicarrier system.

To determine distortion levels in a weakly nonlinear region around the bias point it is sufficient to specify the 2nd and 3rd order input intercept point (IP) of a laser. The third order IP can be found by driving the laser with two RF carriers with a total depth of modulation of less than 50%. A PIN detector will show the following spectrum (figure 2):

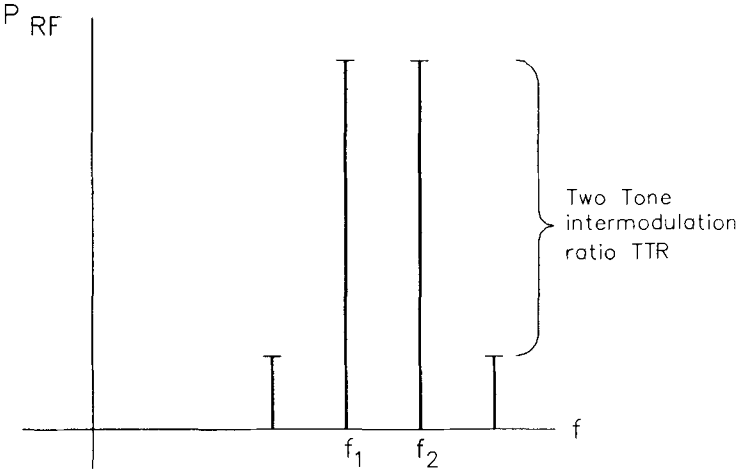

Figure 2: Two tone third order intermodulation test of the laser.

The 3rd order Input Intercept point $IP3_{in}$ is defined [2, Hayward 1982] as

$$IP3_{in} = C_{in} + TTR/2 \qquad (dBm) \qquad (8)$$

The Triple Beat Ratio (TBR) is 6 dB lower than the Two Tone Ratio (TTR), shown in figure 2. Equation (9) shows how to find the TBR when an Intercept point is known:

$$TBR = TTR-6 = 2(IP3_{in} - C_{in})-6 \qquad (dB) \qquad (9)$$

A Dynamic Range figure D allows the comparison of different RF link components with respect to CNR and channel loading. It is insensitive to the input level into the device under consideration:

$$D = IP3_{in}/2 - F \qquad (dB) \qquad (10)$$

Let us compare a laser diode to a cascade of 20 coaxial amplifiers (each at a gain of 20 dB to compensate the loss of a coaxial cable):

	Laser	Coax Amps
F:	46 dB	22 dB
$IP3_{in}$:	25 dBm	11 dBm
D :	-33.5 dB	-16.5 dB

This laser(RIN = -145 dB/Hz, $IP3_{in} = 25$ dBm, E = 0.04A/W, and $P_{opt} = 1$ mW) has a dynamic range of 17 dB less than a standard coax amplifier cascade with 20 dB of gain per amplifier. Distributed Feedback Lasers (DFB's), can have RIN's as low as -155 dB/Hz. Their Dynamic Range is therefore only about 7 dB lower than that of the above mentioned coax amplifier cascade. The conclusion that today's lasers are becoming as good as coax amplifiers is not necessarily correct. First we have to answer the following questions:

- Is the 3rd order intercept point a sufficient description of 3rd order nonlinearity?
- What about second order distortions?
- Under what conditions do we really get the low noise of the latest laser diodes?
- How do systems architectures compare between fiber and coax?

Here are possible answers:

Is the 3rd order intercept point a sufficient description of 3rd order nonlinearity?

The answer is no when a multichannel CATV signal is used. Let's first look at a typical bridger amplifier. Some manufacturers recommend to operate them at a 51 dBmV level with 54 channels. At one (very improbable) time all 54 carriers will be at maximum amplitude. The peak to peak sum voltage at one output transistor is then 2·54·355 mV or 27V. Those hybrids operate from 24V. Therefore, at times that are statistically very rare, this hybrid amplifier is driven into saturation. The same could be true for a laser. When the RF drive current hits the lasing threshold or when it hits the high power region where the differential quantum efficiency rolls off, we leave the weakly nonlinear region described by the third order intercept point. Figure 3 compares the two devices.

How to deal with this quantitatively? Coaxial CATV amplifier manufacturers measure intermodulation distortion (composite triple beat) under real life conditions or with a Dix Hill signal generator. The same can be done with a laser. Nevertheless, it is possible to make some predictions of the distortion products of a laser when two laser models are used:

Model 1: The laser has no compression and is adequately described by its third order intercept point (and other laser data).

Model 2: The laser is perfectly linear with the exception of the compression at the lasing threshold.

The distortion products of both models can be calculated:

Model 1

It is generally agreed that the correct way of specifying third order distortion in CATV is the Composite Triple Beat Ratio (CBR) [3, Jeffers 1980]. Let's derive a CBR when the 3rd order intercept point is known:

The Composite Triple Beat Ratio (CBR) for multiple carriers is

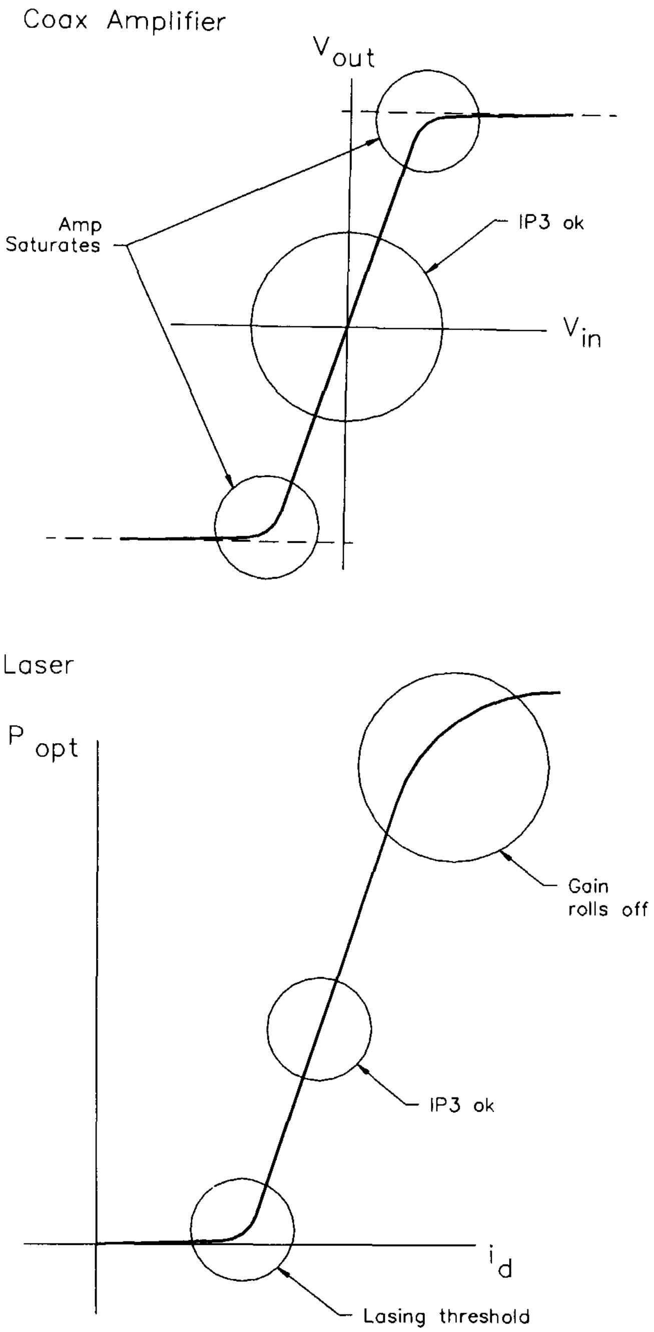

Figure 3: Nonlinear regions of coax amplifier and laser

$$\begin{aligned} CBR &= TBR - K \log Ch \\ &= TTR - 6 - K \log Ch \qquad (dB) \qquad (11) \end{aligned}$$

with Ch: Number of channels

TBR: Triple Beat Ratio

TTR: Two Tone Inermod. Ratio

K: Constant

The constant K is equal or less than 23 [4, Afsar 1987]. Using the Intercept Point number, we find with equation (9)

$$CBR = 2(IP3-C) - 6 - K \log Ch \qquad (dB) \qquad (12)$$

It is useful to ask for the carrier to noise ratio for a varying number of channels when composite triple beat is below the limit of perceptibility ($CBR \cong 60$ dB). Using equation (5) ($C = CNR + N$) in equation (12) we find

$$CNR = IP3 - F + 108 - (CBR + 6 + K \log Ch)/2 \qquad (13)$$

With the above laser, CBR = 60 dB, K = 18, and 10 channels we get a CNR of 45 dB.

If these carriers are amplitude modulated (vestigial sideband) with a 50% APL video signal, then their average power is 6 to 8 dB lower than their power at sync time. We can therefore drive the laser 6 dB higher and now get a CNR of 51 dB for 10 channels.

Model 2

We assume that the laser is totally linear with the exception of the threshold region (we neglect compression at high optical power levels). From the considerations on RIN we know that

$$CNR = -RIN - 3 \text{ dB}$$

for 1 carrier and 100% depth of intensity modulation. If the sum RF current must not exceed the threshold region then we have to reduce the RF drive level by 20logCh (Ch = number of channels). Therefore

$$CNR(Ch) = -RIN-3-10\log 4.2MHz-20\log Ch \qquad (14)$$

The above laser with an RIN of -145 dB/Hz will therefore have a 10 channel CNR of

$$CNR(10) = 145-3-66-20 = 56\text{ dB}$$

when this model is used.

Figure 4 shows CNR for Model 1 and Model 2 as a function of the number of channels. The upper curve is for the case that the modulation is Vestigial Sideband (or AM), the lower trace is for unmodulated carriers.

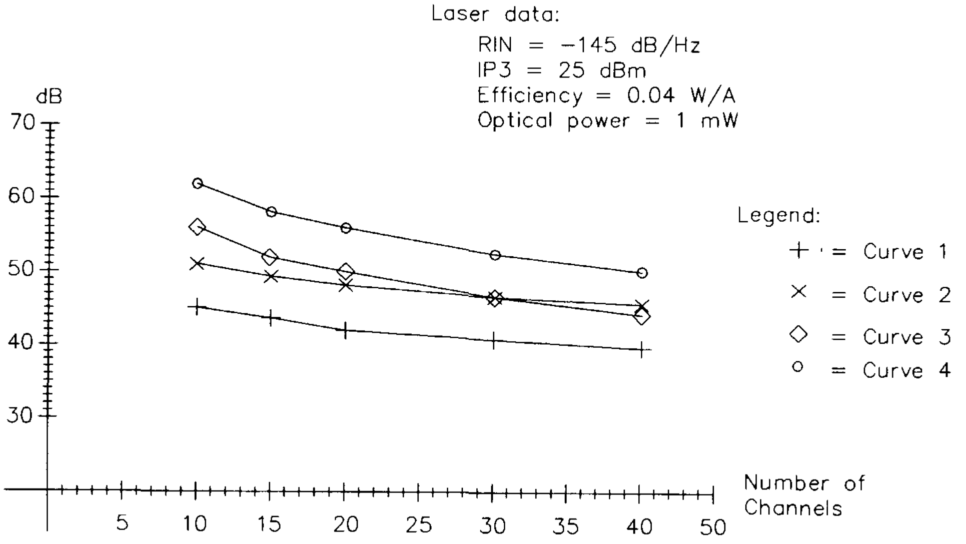

Figure 4: CNR for Model 1 and Model 2 as a function of the number of carriers (channels)

<u>What about second order distortion?</u>

When standard frequencies for Vestigial Sideband transmission are used the second order difference products fall 1.25 MHz below other visual carriers and cause therefore no visible impairment. The second order sum products fall 1.25 MHz above other visual carriers and cause very visible luminance interference.

In the late 60's increasing numbers of channels made second order products of single ended amplifiers the biggest limitation of CATV. The introduction of push-pull amplifiers solved that problem [5, Lambert 1970]. Lasers suffer from the same second order distortion. Lasers can be designed to have low third order distortions but this does not necessarily affect second order products. Push-pull lasers are unknown and it seems that we have to live for some time with those distortions. Two approaches can be used to solve this problem:

- The Octave System
- The Split Band System
- HRC

In the Octave System, the channels are converted to a higher frequency where they do not exceed an octave anymore. Second order products fall then above or below the frequency range occupied by the channels.

In the Split Band System one laser can transmit the Low Band (54...88 MHz) and the High Band (174...216 MHz). All second order products fall above, below, or between the two bands. A second laser transmits the Mid Band (120...174 MHz), which is less than an octave. And a third laser transmits the Super Band (216...294 MHz). If more channels are needed, a fourth fiber might be used for the Hyper Band as is shown in Figure 5.

When HRC (Harmonically Related Carriers, all carriers are phase locked to a common frequency reference) is used second as well as third order products fall with no frequency offset on top of visual carriers. When phase noise is low the visibility of such an impairment is very low. HRC has been used to fight composite triple beat but it can also be very useful to reduce second order interference in a single ended system like a laser diode.

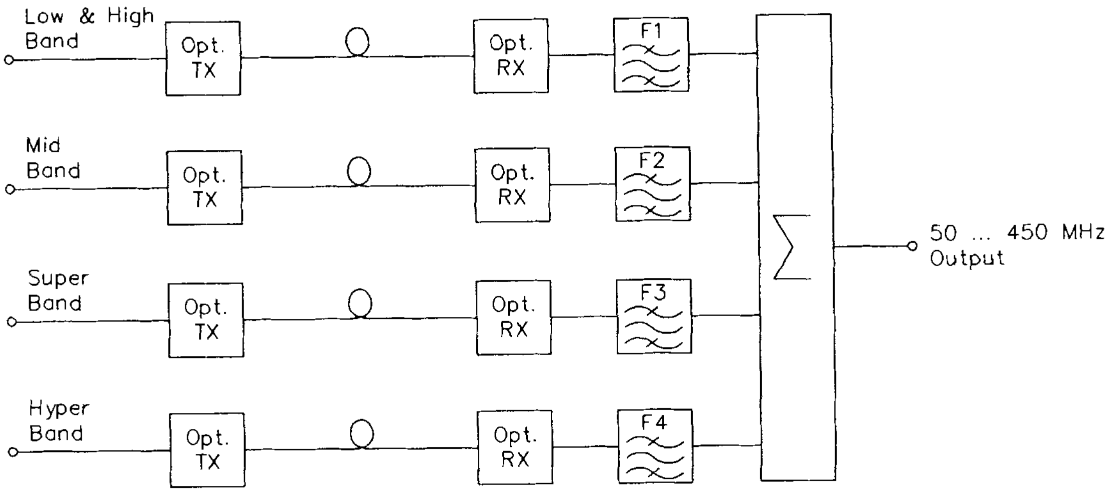

Figure 5: A CATV fiber optics link for Vestigial Sideband modulation avoiding second order distortion

Under what conditions do we really get the low noise of the latest laser diodes?

The RIN of a laser is highly dependent on the amount of light that is reflected back into the laser [6, Ohnishi 1983]. The following sources of back reflections can be found:

- Reflections inside the laser
- Reflections in the connectors
- Reflections in the splices
- Reflections in the detector

Reflections inside the laser are out of our control. Reflections in connectors can be kept low if special high return loss connectors are used. The state of the art is a 55 dB return loss. Principles as described in [7, Rao and Cook 1986] are used. Another method is to avoid connectors totally and fusion splice the entire system. Reflections in splices can be avoided when fusion splices or low loss rotary splices are used. Reflections in detectors are hard to avoid, unless the manufacturer takes special measures to couple the light from the pigtail to the photodetector like antireflective coating and polishing the fiber at an angle. All reflection problems can be solved when an optical isolator is used directly after the laser [1, Guekos 1983].

Another problem is receiver noise. We can ask at what optical receive power the contribution of receiver quantum noise is equal to RIN. At this power level video SNR will be degraded by 3 dB.

When RIN is predominant CNR is in a 1 Hz bandwidth and for 100% depth of modulation:

$$\mathrm{CNR} = -\mathrm{RIN} - 3 \qquad \mathrm{(dB)}$$

When quantum noise is predominant CNR is for the same bandwidth and modulation [8, Keiser 1983]:

$$\mathrm{CNR} = R_0 P_r / 4q \qquad \mathrm{(dB)} \qquad (15)$$

with R_0: Detector Responsivity

P_r: Received optical power

q: 1.610^{-19}

We get a 3 dB systems CNR degradation when

$$-\mathrm{RIN} - 3 = 10\log(R_0 P_r / 4q) \qquad \mathrm{(dB)} \qquad (16)$$

Solving equation (16) for P_r:

$$P_r = (4q/2R_0 10^{-\mathrm{RIN}/10}) \qquad \mathrm{(dBm)} \qquad (17)$$

With $R_0 = 75\%$ and RIN = -145 dB/Hz, we get

a receive power of 0.135 mW or -9 dBm.

With the above laser diode (1mW optical output power) we would therefore get a 51-3 = 48 dB CNR after 9 dB of optical loss for a CBR of 60 dB and for 10 channels.

It becomes apparent that today's 1 mW lasers are not powerful enough for high optical loss budgets.

Another question is: How does a calculated CBR compare to a measured one? Here we open a door to misunderstandings. Nobody measures CBR's with a true power meter for the reason that a spectrum analyzer is a more convenient tool. This instrument contains a logarithmic amplifier followed by a peak detector.

Therefore, correction factors can be calculated when the statistics of the noise are known. For Gaussian noise and for Bessel IF filters this is 2.5 dB. If we assume that composite triple beat noise has a similar correction factor (it is essentially narrowband noise), then we can measure a 1.3 dB higher CNR for a given (rms-power) CBR.

Comparison of theoretical results with measured results

We have experienced that measured results are normally better than what theory predicts. Possible reasons are:

- The constant K in equation (11) can be lower than 23, resulting in a lower CBR than predicted by equation (11).

- Some lasers are operated around their inflection point of the laser transfer characteristic (the third derivative is zero and therefore third order products are zero). Hire an inflection point finder when you plan to use those lasers.

-RIN's are better than -145 dB/Hz. RIN's as high as -155 dB/Hz have been reported. A 10 dB better RIN allows a 10exp(10/23)≈3 higher number of channels.

How about the usefulness of HRC?

HRC is in fact very useful in an optical link. When [9, Switzer 1975] was phase fideling in the 70's, he expected a somewhat higher HRC gain than was found later to be feasible in practice. A good explanation for that can be found in [10, Krick 1979]. An HRC signal has a peak envelope that is a function of the phase relationship between the individual carriers. Krick shows that the worst case peak envelope of a multichannel CATV signal can be 5 times higher than under optimum phase conditions. In a normal coax system this phase pattern changes along the trunk and so does the peak envelope, causing different amounts of intermodulation distortion along the trunk. In a cascade of amplifiers an optimum phase pattern or a minimum envelope can therefore hardly be maintained.

Since repeaters are very unlikely in an optical system using AM, one laser can take full advantage of an optimum phase pattern, therefore achieving full HRC gain.

What has been done so far in AM on fiber?

The Japanese have reported AM on fiber systems [11, Fujito 1985] and [12, Fujito 1988]. [13, Koscinski 1987] talked about linearisation principles. Similar methods have been published in [14, Straus 1977] also. Ortel showed a 40 channel system at the Western CATV Show 1987 in Anaheim. In 1988, more reliable data can be expected in regards to this subject.

What progress can be expected in AM on fiber?

Predistortion networks allow a substantial improvement of the linearity of the optical transmitter. It is not clear if improvements of the lasers themselves can not do the same. The goal will be to come as close as possible to an optical transmitter that behaves like the above mentioned model 2.

External modulation of the light intensity will become an issue when distortions of an external modulator are lower as when a laser is directly modulated. The insertion loss of an external modulator has to be small as long as the laser power is a limiting factor in systems architecture. See [15, Stephens 1987] about external modulators.

How do system architectures compare between fiber and coax

The newest developments in laser technology and in the use of single mode fiber have shown that substantial numbers of AM (vestigial sideband) or FM channels can be transmitted over fiber. The CATV operator should be aware of the difference between AM on fiber and AM on coax. It is improbable that AM on fiber can use repeaters in the same way as it is common practice with coax amplifiers. Therefore the architecture might be more in the direction of a star form. Today's lasers have too little power to allow branching as would be required in a tree network. This might change in the future.

Conclusions

Looking at a fiber optic link from an RF standpoint allows us to predict Composite Triple Beat and Noise with a reasonable degree of accuracy when multichannel VSB/AM signals are transmitted.

Semiconductor lasers have reached performance levels regarding linearity and low noise that make them a feasible choice for video multichannel VSB/AM transmission on fiber. Second order distortion levels are often a limiting factor. The frequency plan has to be chosen so that second order products do not produce visible interference. Higher optical transmit power levels than 1 mW will be needed, when optical loss budgets have to exceed a few dB and when CNR's close to 50 dB have to be achieved. Cost effective 450 MHz Vestigial Sideband fiber optic links using up to four fibers can be expected to be successfully installed in the near future.

Acknowledgements

The author would like to thank the Synchronous team for making this paper possible, especially Vince Borelli for his contributions regarding frequency planning for second order distortion problems and fiber optics, John Folkesson for his extensive measurements, and Al Johnson for many helpful discussions.

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CORRELATING MEASUREMENT RESULTS MADE WITH A HORIZONTALLY POLARIZED DIPOLE AND A VERTICALLY POLARIZED MONOPOLE IN A CABLE TELEVISION ENVIRONMENT

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ABSTRACT

When making absolute measurements of radio frequency field intensity, the most important criterion is to establish an undisturbed field pattern at the point of measurement. Unfortunately, in the quest to quantify the magnitude of signal egress from a cable television plant source, the engineer is faced with a situation which is far from ideal. This paper will explore a few of the possible equivalent transmitting antenna configurations that make up the real cable world, how these hardware models affect propagation parameters and finally how the results are viewed by commonly used receiving antennas. A method of simulating a leakage field for dipole/monopole measurement correlation will be disclosed.

INTRODUCTION

Signal leakage—a term preferred by the cable television industry to describe the emission of energy from the imperfectly shielded environment which transports entertainment and commercial information in a point to multipoint manner—is the single remaining cable television technical parameter enforced by the Federal Communications Commission (FCC) as defined in Part 76 of the rules.

The task of maintaining leakage limits below the maximum specified by the Commission falls on the shoulders of industry engineering personnel. Providing leakage quantification within or close to the aeronautical bands of interest following measurement procedures provided in CFR 76.609(h) can result in the use of a receiving half-wave dipole which becomes quite cumbersome, i. e., about four and one-half feet at 108 MHz, particularly if the intent is to monitor the plant condition from a vehicle.

Aerial construction practices, in particular, place the coaxial system within close proximity to other conductors and structures, each of which provides the mechanism for potential field pattern disturbance. Such interference with the theoretical propagation phenomenon promotes the idea that the prediction of the plane of radiation may be arbitrary.

Given that the last idea has merit, it becomes far more convenient to use a quarter-wave vertically oriented whip (monopole) antenna as a monitoring tool. As will be shown later, results obtained through the use of this device can be equally accurate with those obtained through the use of a horizontal half-wave dipole.

Field strength patterns from fundamental antennas will be explored briefly, followed by a more comprehensive discussion of the disturbances caused by close proximity objects and their effect on typical patterns.

The study will conclude with a discussion of a test site and equipment used to provide dipole/monopole signal interception correlation, along with supporting tabular data.

TYPICAL UNDISTURBED ANTENNAE PATTERNS

Two antenna types, typical to the pursuit of signal leakage minimization within the cable television industry, have already been mentioned; the horizontal half-wave dipole and the vertical quarter-wave whip or monopole. Because of the physical properties involved, pinpointing the source of leakage requires yet a third pick-up device, the operation of which is very different from that used for signal leakage level quantification.

Within the plant, of course, are the transmitting antennas which are more obscure and thus less simple to define. Most all have at their root, however, the long wire antenna type.

The Near-Field vs The Far-Field

Before beginning more detailed discussion of field patterns from the various antennas types associated with CATV plant signal leakage control, it is necessary to briefly touch on electromagnetic fundamentals. The engineer is faced primarily with two problem types; to quantify the magnitude of the leakage signal and to locate the point source of this undesirable bi-product of cable television system operation in order to bring the first element to within specified boundaries. Effective solutions to the described problems require working within both the *far-field* and the *near-field* environments. Proper field intercept for the respective types involve the use of very different tools.

It is a fact that any time current passes through a conductor, an electric and a magnetic field is created some of which is radiated. Radiated electromagnetic energy is self-perpetuating by virtue of the alternating collapse and build-up of electric (E) and magnetic (H) fields comprising the energy unit that has broken loose from its parent. It is, therefore, no longer dependent upon or influenced by any **subsequent** energy emitted from the parent fields. That notwithstanding, even though the energy has become independent, it is subject to loss in the form of heat, generated because of the perpetually alternating interaction between the E and H fields. As a result, the radiated field eventually becomes infinitesimal.

From the point that radiation occurs, the magnitudes of electric and magnetic fields, theoretically and practically, follow rather rigid rules. If the two field energies necessary for signal propagation are provided names, the progenitor could be called the *induction* field and of course the free spirit will be called the *radiation* field.

The induction field loses intensity very rapidly (proportional to between the third to the fifth power of the distance) at points much less than one wavelength from the conductor and at intermediate distances, the intensity drop is less dramatic but still proportional to the square of the distance. Figure 1 demonstrates that by the time several wavelengths are reached, the induction energy remaining is so small that the radiation field intensity becomes dominant and remains that way until the signal becomes undetectable. The radiation field disburses at a rate of half the intensity for each distance doubling.

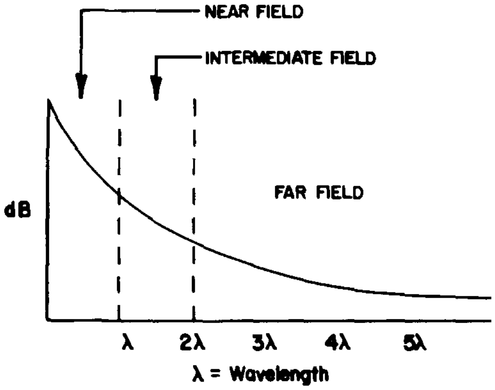


Figure 1 - Near-Field and Far-Field Attenuation

Several important things to note:

There is no magic, single point boundary delineating the near-field from the far-field zones. At the point where the drop in field intensity is sufficiently close to the rate of one-half per frequency doubling, a far-field condition exists;

Accurate quantification of field intensities can be made only with appropriate far-field receiving antennas;

Devices made to intercept near-field energy **do not** provide accurate indication of far-field absolute intensities, regardless whether such devices are used in the far-field **or in the near-field**. Attempts to quantify the absolute intensity value of the near-field energy surrounding an emitter requires the insertion of a probe directly into the flux with a special aperture designed for this purpose. In this manner, this tool is used to locate the source of the energy.

<u>The Horizontal Half-Wave Dipole</u>

The half-wave dipole is a fundamental antenna type which, when segmented into very small unit lengths, is often used to define the current distribution and related electrical characteristics along the entire length of other linear antennas.

When a half-wave dipole is suspended in free space such that no external factors infringe upon its ability to radiate freely, the field pattern appears as shown in Figure 2a and Figure 2b. It is difficult to do justice to the actual appearance of the pattern on the simplistic two dimensional view offered by the page on which it is drawn. However, a mental three-dimensional image might be described as a doughnut with a hole no larger than the diameter of the dipole element at the center. The items are oriented such that the dipole has been thrust into the hole in a manner allowing the doughnut to spin on the dipole element with the dipole element parallel to the surface of the Earth.

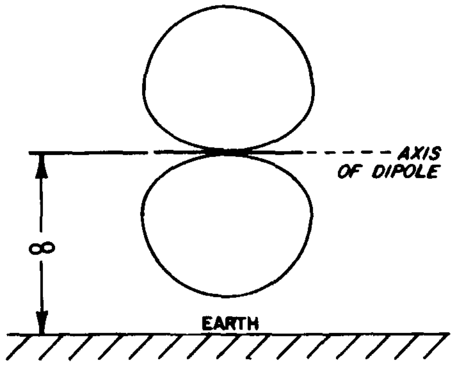


Figure 2a - Field strength pattern of half-wave dipole as viewed perpendicular to the axis of the dipole

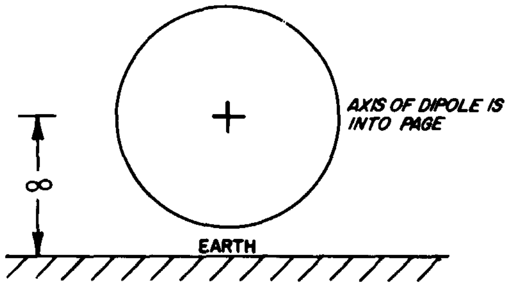


Figure 2b - Field strength pattern of half-wave dipole as viewed parallel to the axis of the dipole

The horizontal half-wave dipole transmits and is most sensitive to the reception of horizontally polarized waves (Figure 3).

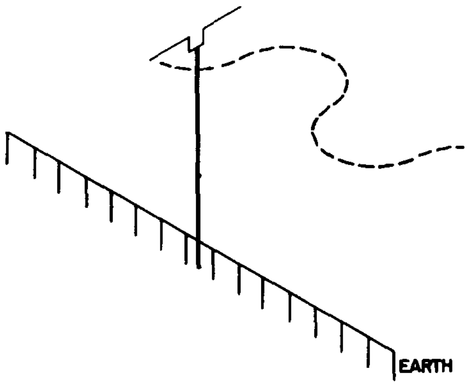


Figure 3 - Horizontally polarized waves emitted or received by a horizontal half-wave dipole

The Vertical Half-Wave Dipole

Rotating the horizontal half-wave dipole so that the elements are perpendicular to the Earth's surface creates a vertical half-wave dipole. The pattern created precisely duplicates that shown in Figures 2a and 2b except, of course, the doughnut is now parallel rather that perpendicular to the Earth's surface.

It follows that the vertical version transmits and is most sensitive to the reception of vertically polarized waves.

The Vertical Quarter Wave Whip (Monopole)

A more practical variation of the vertically oriented dipole, the radiation pattern of the quarter-wave whip antenna is again very similar to its parent. There are, however, several significant differences which affect the performance.

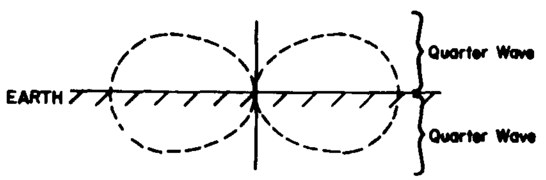


Figure 4a - Field strength pattern of a quarter-wave monopole as viewed perpendicular to the axis of the dipole

In order for the quarter-wave antenna to behave like its parent, the shorter counterpart must be closely associated with earth, whether natural or artificial. The earth then acts as the missing quarter wavelength to again reconstruct a half-wave antenna with one significant difference; the image does not contribute to overall power and sensitivity for transmitting and receiving, respectively. Figures 4a and 4b demonstrate the radiation pattern and Figure 5 provides an image of the vertically polarized transmitted or received signal.

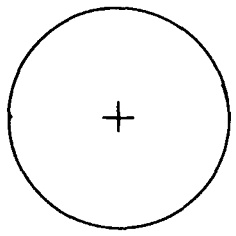


Figure 4b - Field strength pattern of a quarter-wave monopole as viewed parallel to the axis of the monopole

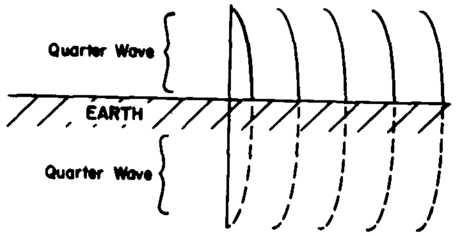


Figure 5 - Vertically polarized waves emitted or received by a vertical quarter-wave monopole

The Long-Wire Antenna

As the name implies, in its most primitive form, the long wire antenna can be made from any length conductor. There are some advantages if the length happens to correspond to a wavelength or some multiple thereof, particularly if the multiple is odd, i. e., 1, 3, 5, etc. Considering that the cable industry makes use of frequencies from 5 MHz to 600 MHz (wavelengths of 197 feet to 1.6 feet), the probability is high that, at some point in the system, this condition will be satisfied for one or more operating frequencies.

Consider a few of the long wire antenna transmitting possibilities which exist within real world aerial CATV construction. Figure 6 is a condensed segment of a situation which occurs frequently in the typical plant.

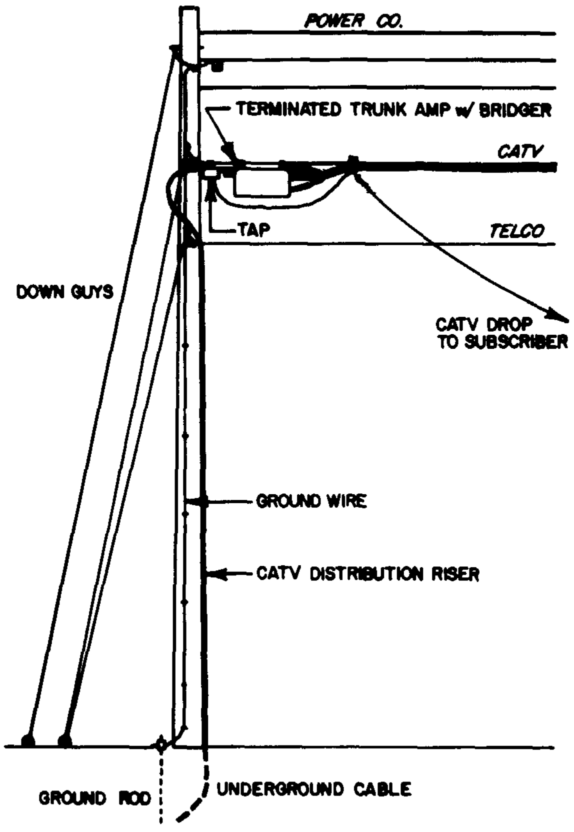


Figure 6 - Typical CATV construction with non-exclusive pole use

The lashed feeder/strand combination, the house drops, the grounding wire and the down guy each serve as examples of individual long wire antennas. Adaptations are easily constructed: The down guy, in reality, is a grounded *inclined* antenna, the lashed feeder/strand in combination with any one of the house drop wires can form a "*V*" antenna, as can any two house drops or the strand/grounding wire pair, so long as each combination contains a common angle.

Each segment deals with propagated currents in a different manner and the radiation effectiveness in any particular instance is totally dependent upon the configuration. Giving no regard to the conductor lengths and other factors such as included angles, etc., general radiation patterns for each segment type are provided in Figures 7a, 7b, 7c and 7d.

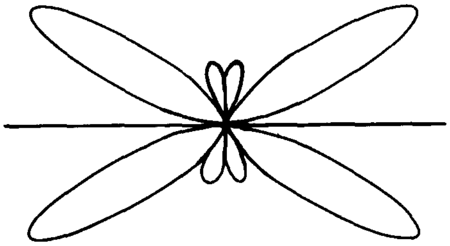


Figure 7a - Radiation pattern of an unterminated long-wire antenna

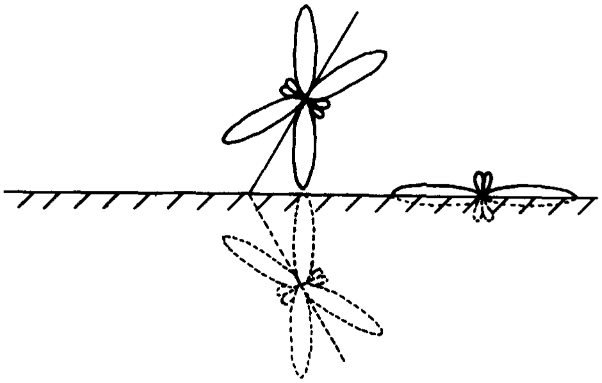


Figure 7b - Radiation pattern for a grounded inclined antenna

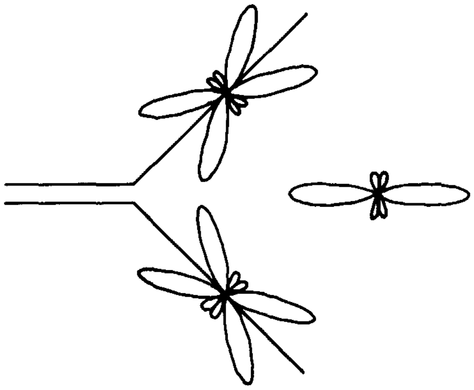


Figure 7c - Radiation pattern for an unterminated "V" antenna

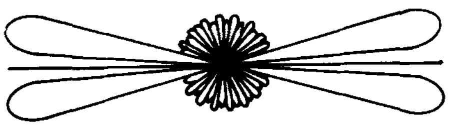


Figure 7d - Radiation pattern for extended length, unterminated long wire antenna

Figure 7a shows the radiation pattern of the fundamental element of the series, the simple straight wire which, if oriented horizontally, produces horizontally polarized wave propagation and if arranged vertically, produces vertically polarized waves.

A slight variation is considered in 7b which makes use of the Earth to create an image of the above ground inclined antenna. The geometrical summation of the field strength values individually occurring on each incline causes the resultant pattern drawn to the side.

Much the same response is achieved with the "V" antenna configuration (Figure 7c), except that the emitted energy is higher when compared to the incline due to the reality of both elements constructing the "V." In all cases, extending the length of the radiating element will cause the main lobe to narrow and more tightly hug the radiating element as well as cause a larger number of narrower sidelobes as shown in Figure 7d. Keep in mind that drawings provided are simple, two dimensional views. Under ideal conditions, when sighting along the axis of the radiating element, the lobes form a symmetrically conical pattern.

Even though it has been mentioned earlier, it is also important that antennas unintentionally assembled as a result of normal plant construction practices propagate both horizontally and vertically polarized wavefronts. The dominant polarity is determined primarily by the physical angular rotation of the radiating element(s) about an axis parallel to a surface which appears as an infinitely conducting earth. This may take the form of Earth itself or any surface in any plane which is sufficiently reflective to act as a ground plane, i. e. some buildings, vehicles, etc. The difficulty to predict the magnitude or the polarization of the field pattern at any given frequency increases with normal field disturbance obstacles.

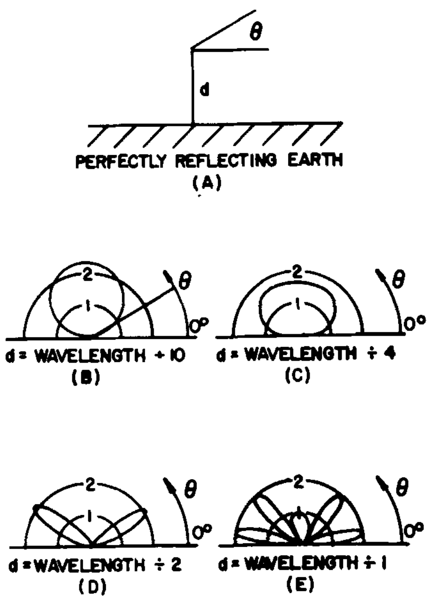
DISTURBANCES TO NORMAL RADIATION PATTERNS

There are many causes of disturbance to the normal radiation patterns of intentional and unintentional antennas. Perhaps the most dominant effect is that caused by the position of the conductors with respect to the earth and with large conductive structures (buildings, vehicles and the like). In addition to antenna configurations, Figure 6 also illustrates that typical cable plant is normally in close proximity to other conductors that are either **virtually** coupled (no direct electrical connection) as in the case of primary and secondary power lines or **directly** connected as power and telephone neutrals

The Effect of Earth and Equivalent Infinite Ground Planes

For those antennas which require grounding, i. e., vertical monopoles and inclined antenna, the effects of the Earth or other suitable ground plane is essential for proper operation and have already been discussed. Recall that the free space pattern of a half-wave, horizontal dipole was described as a doughnut, completely surrounding the element in a vertical plane (if given a push, the doughnut would roll down a street and the dipole element would become the axle). Figure 8 examines the effects of the Earth on the ideal doughnut, **assuming the Earth is a perfect conductor**.

Figure 8a defines the ground plane as earth but could be equally effective in any plane while "d" defines the distance the dipole element rests from the surface. Tracing through the various distances (Figure 8b - 8e), it becomes apparent that as the distance (d) increases, the number of lobes surrounding the dipole element increases thus dividing the available power equally among them and reducing the overall



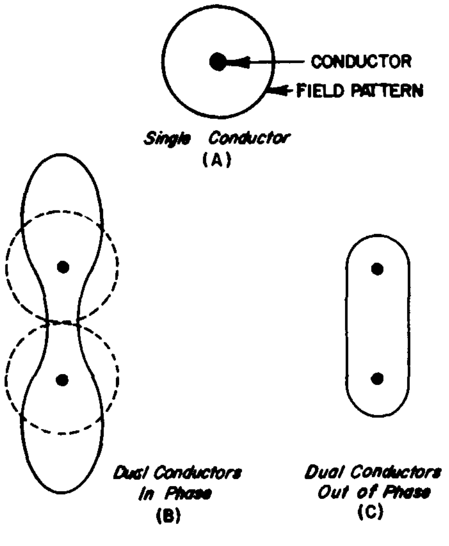
Figures 8 a-e - Ground plane effect on half-wave horizontal dipole pattern field strength in any given direction. As the distance (d) eventually reaches about 10 wavelengths, the free space value is reached.

Results of measurements made with a horizontal dipole are, in varying degrees, subject to the effects pointed out in this section. In most cases, the dipole is held at a position three meters (approximately 10 feet) from the ground while measuring normal distribution plant. At 108 MHz, 10 feet is 0.91 wavelengths which would very nearly duplicate the condition in Figure 8e. Given a perfect ground plane, the nulls shown do reach zero albeit they are very, very sharp allowing the field strength to increase quite rapidly when moving from them. At the peak of a lobe maxima, the field strength is actually double that of the dipole in free space.

In geographical areas where the Earth's conductivity is high, i. e., boggy coastal plains and over water, large excursions in signal level readings may occur. At the opposite end of the spectrum, measurements made in dry desert would tend to act much more as though the antennas were in free space. And then there are all the variations in between. In all cases, the basic pattern remains essentially the same but suffers sensitivity reduction.

The Effect of Parallel Conductors

Those conductors which are bonded directly to the coaxial cable plant sheath circuit are treated as variations of the long line and "V" type antennas. Signals propagated onto adjacent conductors through mutual coupling act as either reflecting or directing elements of an ordinary antenna.



Figures 9 a-c - Extreme effects of phase related, parallel conductors

The extent to which the radiation patterns are affected by these conductors in both cases depends entirely upon the phase relationship of the offending signal which must be computed on a case-by-case basis. Figures 9a, 9b and 9c show the extreme effects from any **single parallel conductor**. Doubling the field strength at a given monitoring location would represent the worst case. Signal cancellation would provide the best case, significantly reducing the field strength.

The probability of either single conductor pair being completely in phase or out of phase is very low resulting in a practical effect which falls somewhere between the two extremes. Geometric summation of two individual field patterns will result in a composite which is fairly broad nosed and therefore probably will not contribute to overall measurement inconsistency. However, when dealing with a larger number of parallel conductors, each with a slightly different phase, the summation at any point is nearly impossible to predict. The situation is further complicated if multiple transmitting points (leaks) are uncovered within close proximity.

DIPOLE AND MONOPOLE CORRELATION

Logistically, it is more practical to use a whip antenna than a horizontal dipole when making measurements from a vehicle. But more importantly, for electrical reasons which have been explored in earlier paragraphs, the use of a quarter-wave monopole is desirable.

The Arguments

Review for a moment the field patterns of the two respective antenna types **as they are used**. Since the leakage monitoring task will be ground based, both antennas will be operated in fairly close proximity with earth. Indeed, if the procedures in CFR 76.609(h) are followed, the maximum height achievable with a horizontal dipole is three meters (≈10 feet) directly above the cable under test which is typically six meters (≈19 feet) from the Earth or nine meters (≈ 30 feet) from the Earth. At that distance, the antenna is about three wavelengths above the earth, increasing the number of lobe maxima and minima shown in Figure 8e. True, the pattern peaks and valleys will probably be less intense than those shown depending upon the tangential loss associated with the Earth or ground plane recognized by the antenna at the point of measurement, thus reducing the overall error possibility. But the possibility does exist.

In the case of the grounded vertical monopole, the ground plane, whether natural (Earth) or artificial (vehicle), is an essential part of the electrical circuit as opposed to a disturbance. The field pattern illustrated in Figure 4a is normal for this antenna while operating in close proximity to a ground plane.

There are no perturbations to cause questionable measurement accuracy.

Two valid variables must be contended with in order to further justify the feasibility for use of the quarter-wave antenna as a measurement tool. First, by its very nature, the grounded quarter-wave whip antenna has a power sensitivity which is one-half that of the half-wave dipole, thus creating a possible error of 3 dB. Second, the quarter-wave whip is far more sensitive to vertically polarized signals.

The Cases

Making a case for the last item first, it is abundantly clear from previous discussion that the vast majority of a cable television plant is built within an environment where the polarization of the unintentionally propagated signaling is at least unpredictable. Adding to the case, the highest signal levels are carried within these plant segments and therefore represent the geographical areas of greatest uncertainty. Given these factual uncertainties, it is equally difficult to defend one method over the other therefore neutralizing the notion of unipolar signal leakage from the vast majority of a CATV plant.

A reasonable evaluation of the difference in sensitivity between the two antenna types is still required. Theoretically, the three decibel difference in power sensitivity is more than offset by an average measurement made with a half-wave dipole whose field pattern is undeniably distorted by the Earth or any other ground plane and perhaps a combination of both.

To provide evidence that there is some degree of substance to this hypothesis, practical tests were conducted.

The Test Site

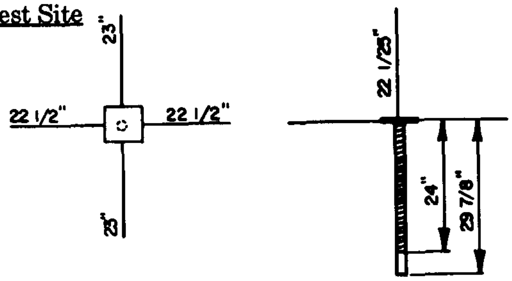


Figure 10 - Modified turnstile antenna

A transmitting antenna was constructed as shown in Figure 10. The purpose of the device is to produce a field pattern which closely approximates that of unintentional fields produced as a result of signal leakage within a cable television plant environment.

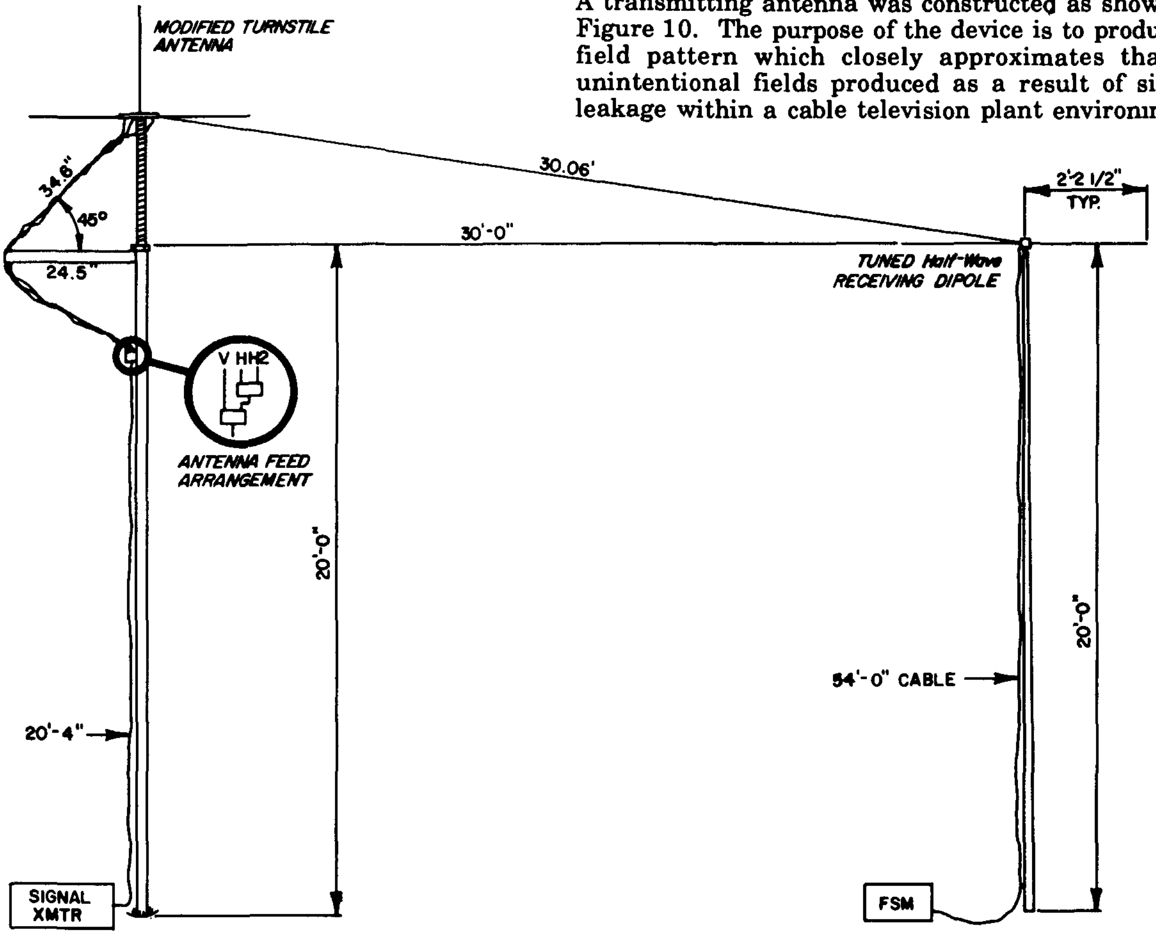


Figure 11 - Antenna test site

As closely as is practical, the modified turnstile antenna models this environment in that it produces a field pattern which is nearly spherical. By delivering equal power to the orthogonal pair of horizontal dipoles and the stub-grounded vertical monopole, nearly equal power is produced in both the horizontal and vertical planes.

The Measurements

Conformation of this was discovered during field measurements on a site described in Figure 11. Having anchored the test transmitting antenna, a tuned, horizontally positioned half-wave dipole was rotated about a 30 foot perimeter, making incremental measurements.

Relative Angle (°)	Horizontal Polarity (dB)	Vertical Polarity (dB)
0	3.4	3.0
45	3.2	2.8
90	3.5	3.0
135	3.5	3.0
180	3.5	3.0
225	3.2	2.9
270	3.5	3.0
315	3.4	3.0

Table 1 - Data recovered from Figure 11 site measurements

The process was then repeated with the half-wave dipole in the vertical plane. Results of the measurements are provided in Table 1.

Having qualified the transmitting source, one final set of measurements were made at the test site shown in Figure 11. A field strength reading was made using a typical service vehicle alternately equipped with a magnetically mounted quarter-wave whip antenna and a directly mounted quarter-wave whip at a distance about 36 feet from the transmitting source. There was no noticeable difference between the two whips. To close the loop, the vehicle was removed from the field and a horizontal half-wave dipole substituted at the same height and rotated about a vertical axis for maximum pick-up. The measurements were within one decibel of those recovered with the vertical quarter-wave monopoles.

Theoretically, there should be a 3 dB difference between the two readings since the receiving sensitivity of the quarter-wave antenna is one-half that of the half-wave dipole. As can be seen, data taken under previously described conditions does not confirm this theoretical difference.

CONCLUSIONS

Given the architecture of typical aerially constructed cable television systems, the polarization of propagated leakage signals is usually mixed. In addition, the disturbance caused by the Earth and/or any other apparently infinite ground plane acting upon the field sensitivity pattern of a half-wave dipole affects the absolute magnitude of a perceived signal. Further complications arise for horizontal half-wave dipole measurements because seldom are ground planes perfect thus providing a loss which can vary from one day to the next, depending upon the weather.

As a result, there appears to be substantial evidence to support the premise that leakage signal magnitude measurement uncertainty exists. This is particularly true when using a horizontally polarized half-wave dipole. Therefore, it is advantageous, both electrically and mechanically, to use the more pattern stable vertically oriented quarter-wave monopole for ground based measurements and it is shown that doing so will not significantly sacrifice intercepted signal accuracy.

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COST FACTORS RELATIVE TO THE FIBEROPTIC BACKBONE SYSTEM

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ATC Engineering & Technology

(Note: This paper should be examined in conjunction with the other papers dealing the fiber backbone presented during the 1988 NCTA Technical Sessions. Overall descriptions and technical details covered therein are not repeated in this work.)

Abstract - This paper summarizes the costs involved in constructing a fiberoptic backbone trunk network in a typical suburban cable system. The assumptions and analytic process are included to allow the numbers to be translate into terms appropriate to the company of the reader.

I. Introduction

The purpose of this effort is to perform the cost analyses required to ascertain the economic viability of the fiber backbone venture in the context of typical suburban cable systems. Since this concept has not yet been deployed in an actual operating system, hence lacking the certainties gained from practical experience, all known assumptions and background data impacting the models have been included.

In this effort we have not attempted to include a benefits analysis with its associated discounted cash flow models since this paper is intended for a universal cable industry audience, and there is no universal agreement as to the value of certain cable enhancements. Rather we have shown the cost to install such a system as we propose, and subsum the system enhancements in terms of increased system overhead. How the cable operators utilize that advantage, whether in increased channel capacity, enhanced signal specifications, or greater system reach is a matter of personal choice.

II. Assumptions

In this analysis, we have attempted to qualify each entry in order to remove uncertainty factors from the results. The following list of assumptions represent the minimal number possible, considering the scope and state of readiness of the technology being examined. The assumptions fall into two major catagories:

o Pricing projections on hardware items which are either not yet available in production quantities, or those having rapidly changing or unstable price structures.

o Operational issues relating to the system being modeled, such as number of channels carried, value of those channels, signal quality standards, specifications of some hardware items whichare not yet available in production form, and maintenance and customer service enhancements resulting from the backbone.

Pricing Assumptions

1. The price used on aerial and underground fiber cable is based upon current quotes ATC has on file from qualified vendors. The price of fiber optic cable has a history of a downward trend as production yield and demand increases. It can be safely projected that fiber will be significantly cheaper by the time the backbone is implemented in exisiting divisions. Using today's pricing is a very conservative approach to this issue.

   Current quotes on fiberoptic cable run between 6-1/2 and 7 cents per fiber foot, which includes the cost of sheath, strength member and internal structures, for cables with over a dozen fibers. The cost goes up slightly for cables with fewer fibers to recover the apportioned sheath costs.

2. The conversion node is an AGC equipped feed-forward amplifier station with a fiber detector front end. We have assumed that early production units will be assembled in just that fashion. Therefore, the price of the conversion node has been derived by combining the costs for the amplifier, with the cost of a fully assembled detector package, with an additional factor added for vendor labor, overhead, and profit. As demand increases for this unit, a more cost effective solution will be the design of a custom card, incorporating the detector front end, the gain block, the 75 ohm interface, with associated power supplies, environmental housings, etc. We believe our approach to the price of this unit is very conservative, but benefits us by being highly quantifiable at this

time. Together with some miscellaneous hardware and installation labor, the total unit cost comes to $2,180.00. In the conservative approach used to generate the financials for this paper, there is a one-to-one relationship between the number of laser assemblies at the hub and the number of conversion nodes.

3. The launcher modules in the cable headend area are priced based on current quotes from qualified vendors.

   The Laser transmitters located in the hub are totally self-contained and require typical headend temperature control and 120v60Hz power. The units occupy about three inches of rack space and at present cost $4,000.00 each. In quantity, these units are expected to be reduced in price to about $2,500.00 each. However, for this analysis, we have assumed the current price.

4. All construction costs are as currently quoted by ATC's construction division. ATC currently uses a cost of 50 cents per foot on route milage for construction costs for fiber cable. This is the cost to overlash the fiber cable onto existing plant.

5. We are currently using an assumption of one to one routing. That is, one fiber eminates at the hub and travels to one conversion node. As can be noted from Figure III-1, the average fiber trunk run for, say, the 4 amplifier cascade case, is 4.4 miles. The shortest trunk is 1.13 miles and the longest 8.99. With the power budgets available from today's lasers, we could route such as to hook in series two or more of the closer conversion nodes, perhaps those under 3.0 miles distance from the hub, thus directly saving fiber and laser costs. This kind of design is exactly what a cable operator would do when addressing a specific application. For the purposes of this analysis, we have assumed no finessing of this sort. However, based on the Pinehurst hub, we have estimated that perhaps a per sub savings of 15 to 20% might be realized with optimized routing.

Operational Assumptions

1. It is assumed that sufficient power budgets exist with the lasers driving the backbone trunks to deliver signals of appropriate specifications to the conversion node after having traversed 15 Kilometers of passive single mode fiber.

2. It is assumed that the laser/detector pair selected will be capable of transmitting 75 VSB-AM video channels with signal specifications at the back of the detector in the conversion node of:

C/N	55dB
2nd Order	-65dB
CTB	-65dB
Intermod	-65dB

3. It is assumed that the lasers will be located in an environmentally controlled area with protected and conditioned power, such as a cable headend, and that the conversion node will meet all of the same specifications for environment, lightning surges, power fluctuations, etc., as currently met by typical active coaxial plant equipment.

III. The Analytic Process

When attempting to qualify technically and financially a new system element, there are two basic approaches to modeling, neither of which are perfect. The first approach selects portions of actual existing and operating cable plants and injects the new item into that environment and examines the results. This approach has the advantage that considerable high-confidence data is available on the existing system. The downside risk, is that there may be unobvious factors in that system selected which make it unlike most other systems, therefore limiting the general applicability of the model.

The second technique is to build on paper a generic cable system which incorporates all design elements typically found in operating divisions. The advantage to this approach is that the base model is completely controllable by the analysis team, and all system factors impacting the outcome can be easily included. The problem with this approach, is that there is no way of qualifying the generic model against the real world, since no such system exists. This also means that the results may have limited applicability against actual systems.

In general,experience has taught us that technique one is far superior when attempting to develop numbers on a new and singular system item, and that technique two may be better when doing comparisons between two or more items having the same functionality. Since in this effort, we are trying to determine the financial viability of a new, singular architectual element for cable systems, the first method appears to be more appropriate. It was the sense of the team assembled to assist in this effort that the model should be derived from actual ATC plant.

For the purposes of this analysis we have chosen a portion of the Orlando, Florida cable system as being representative of typical suburban plant. Specifically, we have chosen to convert the entire Pinehurst node to the backbone architecture. This hub is currently fed via AML microwave and delivers 36 channels of video over 375 miles of 270 MHz plant. There are a total of 10,000 subscribers served by this distribution node.

AMPLIFIERS IN CASCADE	NO. OF CONV. NODES REQ'D.	NO. OF AMPS REMOVED	TOTAL FIBER FOOTAGE REQ'D	FIBER TRUNK ROUTE MILES
2	61	135	1,309,250	44
3	41	102	922,000	45
4	29	69	679,000	51

FIGURE III-1. System Model Summary

Table III-1. summarizes the important factors relating to the system model, indexed according to our assumptions of 2,3, or 4 amplifiers in cascade beyond the optical conversion node. Please note the following items relative to that table. The number of amplifiers removed includes those trunk units bypassed by the fiber, plus the station replaced by the conversion node itself. Also, the fiber footage numbers refer to the total lineal feet of fiber required. There may be up to 24 fibers in a single sheath when it leaves the headend. The number of fibers per sheath will be optimized according to the design.

Figures III-2,3, and 4 show the node locations and fiber routing for the three cascade instances mentioned above.

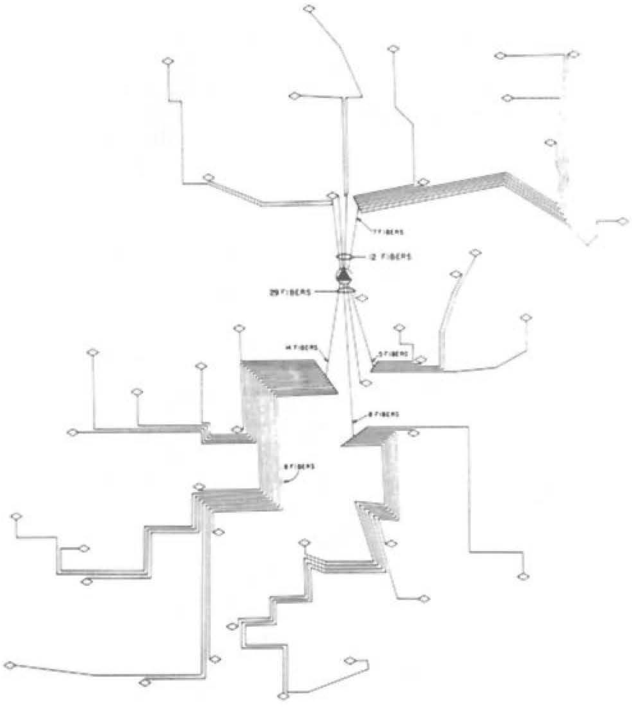

FIGURE III-3. Node Location and Fiber Routing for Three Amplifiers in Cascade

FIGURE III-2. Node Location and Fiber Routing for Two Amplifiers in Cascade

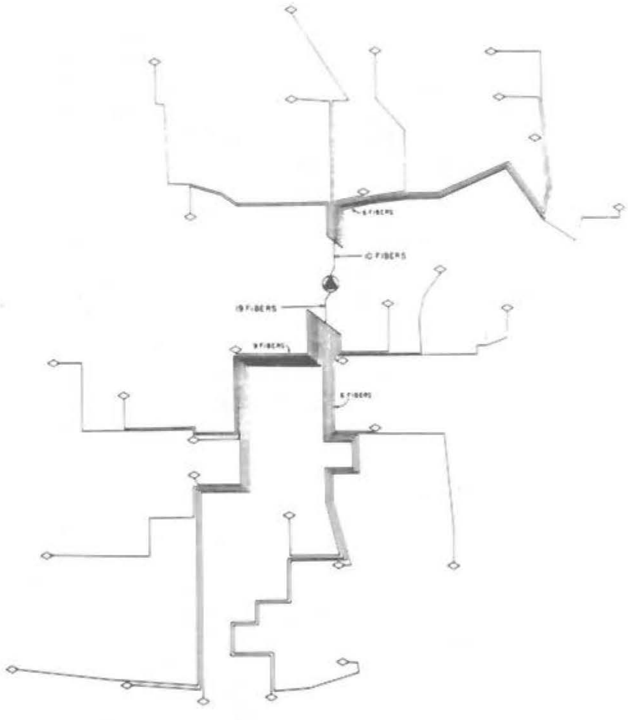

FIGURE III-4. Node Location and Fiber Routing for Four Amplifiers in Cascade

COST ITEM	COST PER UNIT	NUMBER OF UNITS 2 AMP CASCADE	TOTAL COST 2 AMP CASCADE	NUMBER OF UNITS 3 AMP CASCADE	TOTAL COST 3 AMP CASCADE	NUMBER OF UNITS 4 AMP CASCADE	TOTAL COST 4 AMP CASCADE
HEADEND COSTS							
LASER XMITTERS	4,000.00						
MISC. HARDWARE	Included						
LABOR	Included						
TOTAL PER TRUNK	4,000.00	61	244,000.00	41	164,000.00	29	116,000.00
CONVERSION NODES							
STATION COST	2,000.00						
MISC. HARDWARE	30.00						
LABOR	160.00						
TOTAL NODE	2,180.00	61	132,980.00	41	89,380.00	29	63,220.00
FIBER TRUNKING							
CABLE COST	.07 /fiber foot	1,309,250	91,647.50	922,000	63,540.00	679,000	47,530.00
MISC. HARDWARE	Included						
CONST. LABOR	.50/route foot.	230,736	115,368.00	239,184	119,592.00	268,752	134,376.00
TOTAL COST			583,995.50		436,512.00		361,126.00
COST/FIBER NODE			9,573.70		10,646.63		12,456.62
COST/TRUNK MILE			13,363.74		9,636.03		7,094.81
COST/SUBSCRIBER			58.40		43.65		36.11

FIGURE IV-1. Fiberoptic Backbone Cost Summary

IV. SUMMARY OF RESULTS

Figure IV-1 summarizes the costs for the fiber backbone for each of the three cases, 2,3, and 4 amplifiers in cascade beyond the conversion node.

This does not include the cost of rearranging the coaxial plant beyond the conversion node, nor wrecking out the replaced trunk, if desired. The distribution rearrangement depends on the decision of the cable operator as to how the gained system overhead is utilized and is not a function of this exercise. It is our feeling that wrecking out the replaced trunk is not useful, since the bypassed trunk may be utilized for other purposes or as backup to the fiber. Also, wrecking out the trunk adds needless expense to the project.

Once again, it must be noted that the costs in each instance represents a worse case number. Our understanding, based on this admittedly small, but very typical, sample, indicates that the costs can be reduced by 15 to 20% by using optimum routing and daisy-chaining conversion nodes on those fiber runs of less than 3 miles. The bottom line is that in the four amplifier cascade instance, it appears that the per subscriber cost will be closer to $30.00 than the indicated $36.11.

V. CONCLUSIONS

In conclusion, the value of this kind of plant upgrade cannot be ascertained in a global fashion, but each operator must assess its value on a case by case basis. Some value must be assigned to the increased system overhead in order to examine the benefits through the usual discounted cash flow and internal rate of return models.

From the ATC standpoint, we are reasonably convinced that the $30.00 approximate investment required to add this capability to our systems is well justified when considering the results. ATC will expend the gained overhead in a different manner in each of its systems, based on need. However, a factor we are well advised to keep in mind is the need to provide increased signal quality to the subscriber home. This is to address three cable industry problems, one long standing, the other two not yet having reached reality.

o A long term need to enhance signal quality in order to increase our penetration numbers and to reduce churn.

o Some uncertainty regarding the quality of signal required to accomodate HDTV, when it arrives in full force in the next few years.

o The need to enhance quality in order to be in a more competetive position should our competition continue with their plans to run high-quality digital video into the home of the future.

It is not anticipated that these three factors will require all of the gained overhead, but should be figured into the equation by any prudent operator.

Finally, there are many within ATC who believe that fiber will certainly become a franchising issue in the next few years, and an unwillingness or lack of history in using fiber in this manner will put the system operator in a disadvantaged position.

So what kind of an investment are we anticipating if the whole cable industry should decide to adopt the fiber backbone into all systems. With approximately 712,000 miles of plant in the United States serving some 38,800,000 subscribers, and using the 4 amplifier cascade option as the most cost effective, a total investment of just under $1.2 Billion is indicated, based on the $30.00 per subscriber number. This represents the installation of just over 100,000 route miles of fiber trunking, with a varying number of fibers per trunk, as required.

This task has primarily resided in the Engineering and Technology Department at the ATC Corporate offices. It consists of an approximate three month effort beginning in January, 1988. The list of contributors in Engineering and Technology include, alphabetically, Claude Baggett, Jim Chiddix, Mavis Dooley, Barb Lukens, Dave Pangrac, Perry Rogan, George Salvador, Raleigh Stelle, and Jay Vaughan.

FIBER BACKBONE: A PROPOSAL FOR AN EVOLUTIONARY CATV NETWORK ARCHITECTURE

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Abstract **- A hybrid optical fiber/coaxial cable CATV system architecture is described. The architecture is intended to be an evolutionary one, building on existing coaxial CATV networks. A variety of approaches to the electro-optical equipment needed to realize such a system are described. Both short term operating benefits and longer term strategic advantages to the approach are explored and the conclusion is drawn that the approach meets both technical and economic needs of the CATV industry.**

INTRODUCTION

The transmission of information on optical fibers has become commonplace in many areas of telecommunications. The medium's great bandwidth, ruggedness, exceedingly low loss, and light weight make it a worthy candidate for use in any high capacity physical transmission system. The CATV industry has been relatively slow to adopt optical fiber as a major element of its networks. This arises in part because coaxial cable has suited CATV's needs relatively well, and because CATV's basic task of delivering scores of video signals has posed some difficult economic and technical challenges for fiber technology. Nevertheless, fiber optic transmission offers the promise of significant benefit to the CATV industry, and it is important that we explore this potential.

FIBER OPTIC SUPER-TRUNKS

Super-trunks are used in the CATV industry for point-to-point delivery of video signals. This is often necessary in large CATV systems to provide high quality signals to major processing points feeding broadband signals to traditional CATV networks. In the past, super-trunks were often constructed using coaxial cable. A common practice was to frequency modulate (FM) video signals at a variety of RF frequencies for carriage on such a trunk in order to minimize the effects of noise and intermodulation distortion on those signals from the broadband amplifiers necessary to compensate for coaxial cable losses. An alternative was often microwave distribution. Other applications for super-trunks are the delivery of video signals from remote earth station locations or between CATV systems sharing common signal sources for local advertising insertion.

In recent years, a number of optical fiber super-trunks have been built by the CATV industry [1,2]. These super-trunks generally use frequency modulated video and frequency division multiplexing (FM/FDM) of a number of signals onto a laser feeding a single fiber and have proven cost competitive with other techniques. They are also highly reliable, provide very little signal degradation, and have been shown to be capable of providing transmission for more than twenty miles without the need for repeaters. Figure 1 shows data on a number of typical fiber optic super-trunk installations in use today.

The use of optical fiber video transmission technology in super-trunks has opened the door to the possibility of further uses. It has demystified the technology for CATV engineers and has provided practical experience with the design, construction, and operation of fiber systems. It is natural that the CATV industry should look for additional applications where fiber optics may be of use.

LIMITATIONS OF CURRENT CATV SYSTEMS

In order to understand ways in which fiber may be useful in CATV, it is important to focus on the limitations of present system architecture. Figure 2 illustrates the kind of "tree and branch" architecture used in current coaxial CATV systems. All of the signals which are to be delivered to subscribers are gathered at a central "headend". Typical sources are satellite earth stations, off-air antennae, videotape playback facilities, and super-trunks providing delivery of signals from remote locations. At the headend the various video sources are vestigial sideband amplitude modulated (AM-VSB) at various frequencies, are combined into a single broadband signal, and are transmitted over a single coaxial cable. This coaxial cable undergoes repeated branching until it passes down each street in the community. Broadband amplifiers are required every one to two thousand feet in order to overcome cable and branching losses.

This architecture is quite straightforward and practical and is the historical basis of the CATV industry. Nevertheless, it has a number of inherent problems and limitations. Fundamental to many of those problems is the fact that a number of brandband

Date	Location	Company	# channel	Max. Path Miles
4/85	Indianapolis, IN	ATC	8	7.5
9/85	Rockville, MD	Hauser	33	12
12/85	Louisville, KY	Storer	24	11.9
1/86	Honolulu, HI	ATC	32	14
7/86	Toledo, OH	Buckeye	30	8.5
7/86	Flushing, NY	Warner	60	4.5
10/86	Van Nuys, CA	United	60	9.7
6/87	Woodside, NY	ATC	12	8
9/87	Manhattan, NY	Paragon	10	6
12/87	St. Petersburg, FL	Paragon	54	12
1988	Cleveland, OH	Ohio Bell	60	9.5

FIG. 1 SOME CURRENT FIBER SUPER-TRUNK INSTALLATIONS

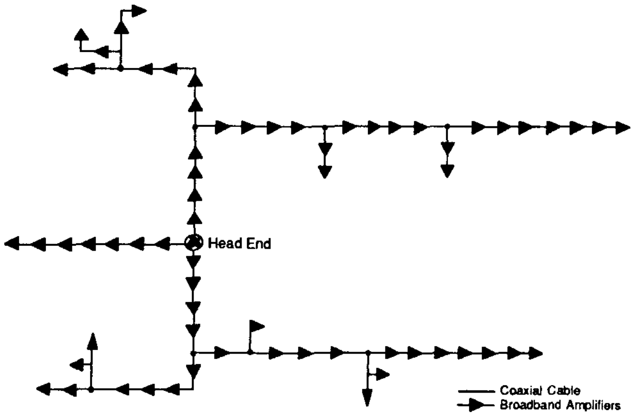

FIG. 2 TYPICAL CATV SYSTEM

amplifiers are required to operate in series, or cascade, in order to transport signals to system extremities. Each of these amplifiers contains active components and must be provided with power, both providing limits to the reliability which can be attained. In addition, each amplifier adds noise and intermodulation distortions to the signals passing through it. The addition of these phenomena over long cascades of amplifiers gives rise to systems which have real limitations in the achievable reliability and quality of the service delivered to subscribers.

Another effect of tree-and-branch systems with long amplifier cascades is on system operating tolerances. In order to realize design specifications, each amplifier in such a system must be adjusted to provide very flat gain over a wide range of frequencies, and must provide rather precise signal output levels. Such close operating tolerances require frequent alignment by highly trained technicians.

Another obstacle arising from this system architecture is a practical limitation on channel capacity. The types of coaxial cables used in CATV systems have a relatively wide potential bandwidth, perhaps approaching lGHz. Such cables have, in fact, been used for many years in small MATV systems to carry UHF channels, often at frequencies above 700 MHz. Typical cable systems operate with the highest frequency of only 300 to 400 MHz, however, with a few recent systems operating to 550 MHz. The difficulty in realizing the potential bandwidth of coaxial cable arises with the limitations of the broadband amplifiers themselves, particularly when those amplifiers are operated in cascade. It is expected that it will be difficult to push channel capacity dramatically further than today's numbers as long as CATV systems employ long cascades of amplifiers.

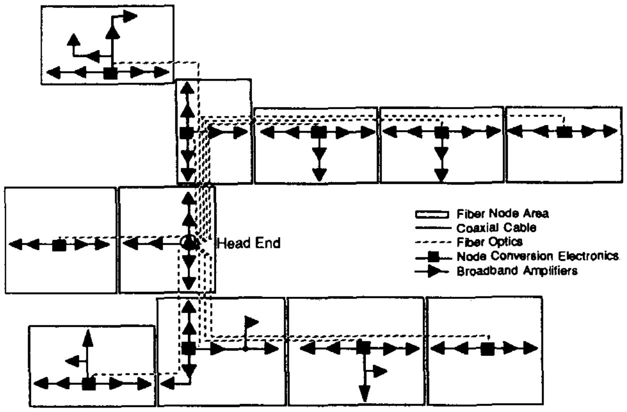

FIG. 3 HYBRID FIBER OPTIC BACKBONE/COAXIAL DISTRIBUTION SYSTEM

If there is a pressing problem with today's CATV systems which might be addressed through the application of fiber optics, it is that posed by long cascades of broadband amplifiers in coaxial tree-and-branch structures. One constraint which must be recognized, however, is that of embedded investment. Most communities have been wired for CATV, and the enormous investment this represents is not one which can be causally discarded with the arrival of new technology. Thus, it seems logical that we should search for ways to apply new technology to a hybrid fiber/coaxial system which makes use of at least some existing plant structures, but which focuses the use of fiber technology on relieving the most serious weaknesses of today's systems.

THE FIBER BACKBONE

In view of the shortcomings of today's CATV system architecture, and the practical constraints on outright network replacement, we have developed an evolutionary concept for the intergration of the fiber into our systems. We have termed this approach "fiber backbone". The approach is illustrated in Figure 3, and essentially consists of overlashing some percentage of the existing trunk system with optical fiber cables. Thus, a direct optical fiber path is established from the headend to "nodes", a number of feed-points in the CATV distribution system. From that point on, the existing coaxial plant is utilized, with some amplifiers being reversed in direction and some

Opitical Link Power Budget	10 dB
Channel Capacity	42 (50-330 MHz)
Carrier-to-Noise (C/N)	55 dB
Composite Triple Beat (CTB)	65 dB
Composite Second Order	65 dB
Cross Modulation	65 dB
Output Frequency Response	+/- 1 dB
Output Video Carrier Level	+40 dBmV
Max. Terminal Equipment Cost	$5000/node

FIG. 4 MINIMUM LINK SPECIFICATIONS

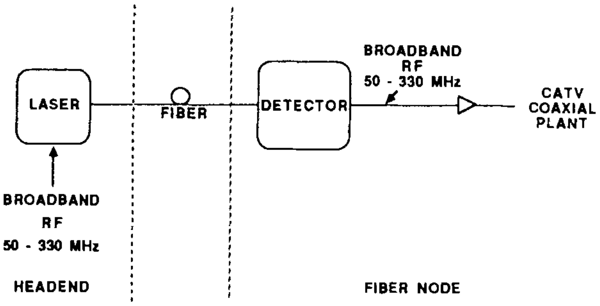

FIG. 5 DIRECT MODULATION OF BROADBAND SPECTRUM

spans of trunk cable between node areas being abandoned. The effect of this is to break up the CATV system into a number of very short systems. The length of those systems can be described by the maximum trunk amplifier cascade which will be allowed. At one extreme, fiber could be taken to each existing bridger amplifier location and the resulting coaxial system would consist only of distribution cable and line extenders. At the other extreme, a maximum trunk amplifier cascade of eight or ten might be defined, breaking a typical cable system into a few node areas. To illustrate, if present power supply locations were used as fiber node feed points, the maximum trunk amplifier cascade would be 2, with a maximum of 3 or 4, and the average node would serve several hundred subscribers.

The selection of the maximum trunk amplifier cascade is constrained by trade-offs between the cost of the fiber backbone with its associated electronics, and the benefits to be gained by the degree of shortening amplifier cascade and coaxial plant. Regardless of node area size, however, the effect of this approach is to break the existing tree-and-branch coaxial plant into many small tree-and-branch systems, with each fiber node feeding anywhere from a few homes to a few thousand homes.

ELECTRO-OPTICAL COMPONENTS OF A FIBER BACKBONE SYSTEM

In examining implementation of a fiber backbone system, the least problem is provided by the installation of the fiber cables. Single mode fiber has become relatively inexpensive in recent years, and is available in a variety of cabled packages, containing from 1 up to 144 fibers in a physically rugged cable 1/2" or less in diameter. "Field-enterable" cable packages have been developed which allow the extraction and splicing of one or a few fibers from a multi-fiber bundle within a cable without the need to splice the other fibers. This type of cable would be particularly helpful in routing a single fiber to each node location in the fiber backbone approach.

The more challenging part of fiber backbone system implementation lies with the electro-optical components. These consist first of a laser diode transmitter feeding each fiber (or split to feed several fibers) leaving the headend. At each node location, an environmentally rugged optical receiver must be installed, capable of converting optical signals back to a broadband RF spectrum suitable for coaxial distribution. The optical link must be relatively transparent to the CATV signals if the advantages of the fiber backbone approach are to be realized. For the sake of investigation, we have postulated minimum performance specifications for such a link. They are illustrated in Figure 4.

While better performance might be desirable, an optical transport system meeting such specifications would enable a CATV operator to construct a useful fiber backbone. While there exists today no economically feasible off-the-shelf equipment meeting these requirements, there are a variety of design approaches which have potential to provide the desired result.

Figure 5 illustrates the simplest possible approach to the problem. In such a system, the laser transmitter would be directly modulated with the entire CATV spectrum, complete with video channels, scrambling (if present), FM radio services, and pilot and data carriers. The output of the detector would be this same broadband spectrum, ready for amplification and delivery to the coaxial portion of the plant. While highly attractive because of its simplicity, this approach is also relatively challenging because of the linearity and noise requirements established by necessary system specifications. A laser capable of meeting these requirements might need a Relative Intensity Noise (RIN) specification approaching -160 dB/Hz and a 3rd order intercept of +38 dBm or better. These are ambitious performance levels in today's off-the-shelf devices. Nevertheless, laboratory measurements of systems using selected lasers approach the system requirements closely enough to be encouraging. Far greater emphasis to date has been placed on digital than on analog performance by the electro-optical

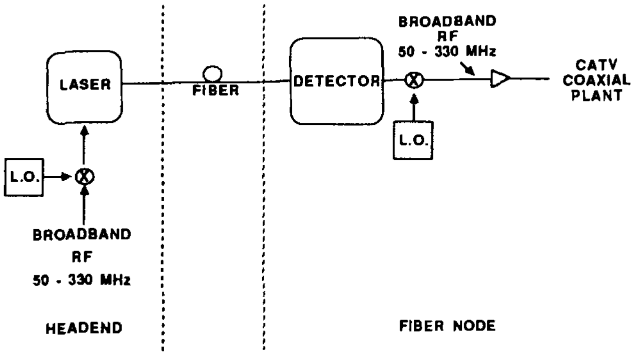

FIG. 6 DIRECT MODULATION OF BROADBAND SPECTRUM WITH BLOCK CONVERSION

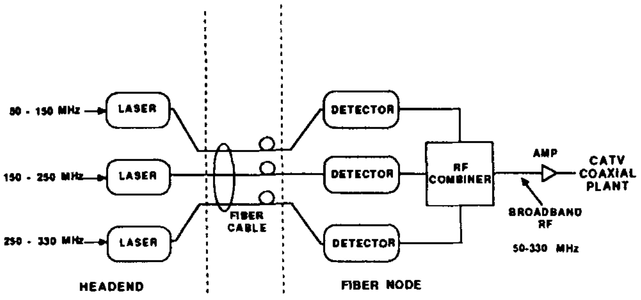

FIG. 7 DIRECT MODULATION USING MULTIPLE LASERS AND MULTIPLE FIBERS

component industry because of telecommunication industry needs. It appears that there is room to revisit device optimization with new applications in mind.

Figure 6 illustrates a variation of the direct modulation approach, with the input RF spectrum being mixed to a higher frequency to take advantage of potentially better laser performance in the 1 to 2 GHz range, as well as avoiding second order intermodulation products by keeping all carriers within a single octave. A corresponding down-conversion would be required at the receiving end.

Figure 7 shows a variation of the direct modulation scheme with several lasers, each modulated with a segment of the total RF spectrum. This should improve performance and require less expensive, more readily available lasers. This approach has been demonstrated in the laboratory, but the investment in additional fibers provides significant system cost penalties.

Figure 8 shows the same approach, again using multiple lasers, but combining their optical outputs onto a single fiber. This approach has two constraints. The first is the additional link loss created by the passive combining device. The second is the necessity of insuring that the optical wavelengths of the lasers are sufficiently separated so that frequency beats are not present in the RF spectrum of interest. At the operating node receiver, a single detector responds to the sum of the intensity variations in the received light. It thus effectively recombines the various segments of spectrum back into a continuous one. One advantage of this approach is the possibility of using a star coupler for the combining of the laser outputs. This would provide multiple outputs which could feed fibers going to multiple nodes.

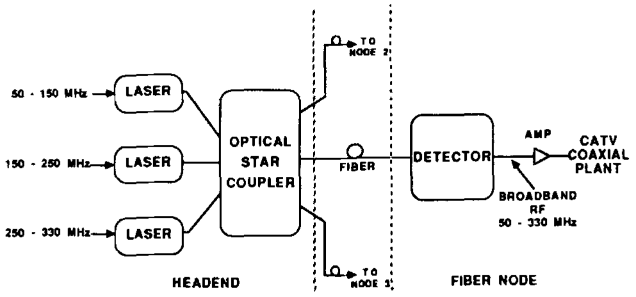

FIG. 8 DIRECT MODULATION USING MULTIPLE LASERS, SINGLE FIBER TO NODE

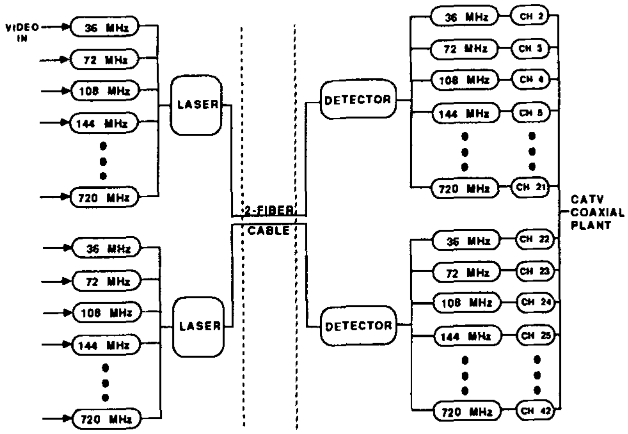

FIG. 9 FM/FDM VIDEO FIBER TRANSMISSION

Figure 9 shows the FM/FDM system of the type used in today's fiber optic super-trunks. Such a system is capable of very high quality video transmission and, were the node equipment sufficiently compact, inexpensive, and environmentally rugged, could be applied to a fiber backbone application. To be economically interesting, however, such a system would have to cost no more than $100 to $200 per channel at the receive end (because of the large power budget available with FM, a single laser could feed a number of nodes through splitting at the headend, and a single bank of modulators could drive a unlimited number of laser transmitters). It is possible that this goal is achievable through large scale intergration (LSI) of demoduator and modulator circuitry. A high level of reliability and stability would also be operationally important for node link electronics using this approach. The system would also need to accomodate video signal scrambling.

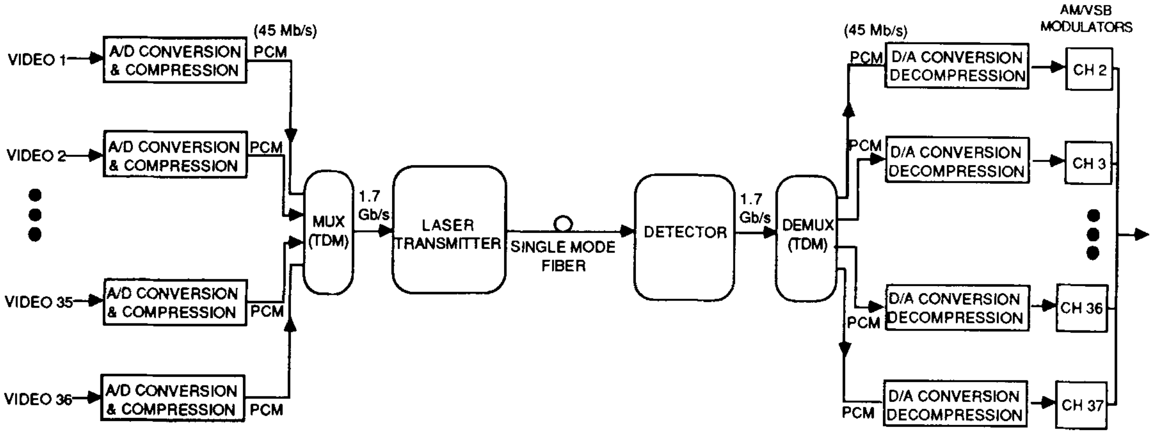

FIG. 10 DIGITAL (PCM/TDM) VIDEO FIBER TRANSMISSION

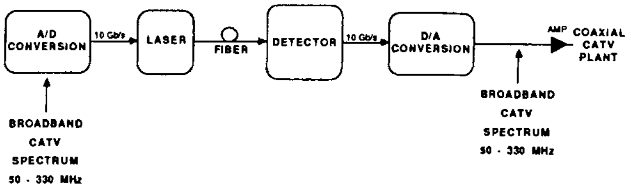

FIG. 11 DIRECTLY ENCODED DIGITAL TRANSMISSION OF CATV SPECTRUM

Figure 10 shows a digital pulse-code modulation, time division multiplexed (PCM/TDM) system for delivery of video to fiber backbone nodes. Several manufacturers have demonstrated the practicality of coding and compressing full motion video to a DS-3 (45 Mb/s) channel. It is conceivable that 36 such channels could be time division multiplexed onto a single 1.7 giga-bit/sec (Gb/s) data stream and transported using optical systems which are commercially available for telecommunications applications. This approach may become practical in the future, but would provide severe economic challenges today.

Figure 11 shows a highly speculative digital solution to this problem; one which is not workable today. In such a system, the entire CATV RF spectrum would be directly converted to digital form through sampling at a frequency some multiple of the highest RF frequency of interest. The sampling rate would certainly be in the 1 GHz-plus range. The resulting exceedingly high bit-rate data stream would then be applied to a single laser. A corresponding decoding process at the receive end would yield the broadband CATV spectrum as an output. While the electronics to do such high speed encoding and decoding are not available, it is possible that high speed gallium-arsenide chip technologies may offer this capability in the future. Laboratory work is under way at Bell Labs and in Japan on optical links in the 7-10 Gb/s range. Such links would be required to transport these signals. There may be variations on this approach which could make digital transmission a practical mode for transporting signals to fiber backbone nodes with relatively simple reconversion to broadband RF. Systems implemented today with other types of terminal electronics could easily take advantage of such developments without the need for costly replacement of the fiber itself.

OPERATING ADVANTAGES

There are a number of direct operating advantages to be derived from a hybrid fiber backbone/coaxial tree-and-branch delivery system architecture. They can all be viewed as direct outgrowths of two facts. First, the worst-case length of the coaxial portion of such a distribution system would be dramatically shortened, eliminating the majority of the amplifiers as well as power supplies, connectors, and directional couplers to be found in the signal path between the head end and any given subscriber. The second is the fact that each small area of the community served by a node would be delivered signals via a dedicated connection to the headend, with the capability of delivering a separate mix of signals to each node area, rather than having to broadcast all signals to the entire system, as in traditional CATV architecture.

Reliability

Under the fiber backbone scenario, there would be essentially the same number of active components in the distribution network as in a traditional CATV system. It is likely that some trunk transportation amplifiers (without distribution bridging circuitry) could be discarded from the system completely. On the other hand, while it is foreseen that most node locations would replace a trunk amplifier, there would be the addition of optical transmitters at the headend. Thus, the number of components which could fail is not likely to change dramatically. On the other hand, from the standpoint of each subscriber, the network would be substantially more reliable because there would be far fewer active and passive network components between the subscriber and the headend. Thus, the impact of any given equipment outage would be substantially reduced in terms of the number of subscribers affected. This should give rise to the perception on the part of cable subscribers that the network had become substantially more reliable. While this is a highly desirable end in itself, it also gives rise to the effect that massive system outages, with their tendency to overload the resources of a cable operation, should become less common.

Signal Quality

Most of the degradation of signals in current CATV systems is the effect of cumulative noise and intermodulation contributions from broadband amplifiers in cascade. Significant reduction of the number of active components in cascade would certainly yield quality benefits, assuming that the optical link portion of the hybrid system was relatively transparent by comparison with the broadband coaxial amplifiers. Since the majority of the intermodulation contribution to degradation occurs, however, in the feeder portion of the system, there would be limitations to the degree of improvement unless and until the coaxial portion of the system underwent some degree of redesign. Nevertheless, overlay of the backbone, by itself, would provide some immediate quality improvement stemming directly from the reduction in amplifier cascade. Full quality benefits would be harvested when system design was rethought, with reoptimization of the balance between noise, intermodulation, and channel loading.

Operating Tolerances

Current trunk amplifier cascades can be as high as 30, 40 or even 50 amplifiers. Such systems necessarily must be operated within very tight operating level and response flatness tolerances if design specifications are to be realized. Maintenance of these specifications is a significant operating challenge, requiring the attention of highly trained technicians. A dramatic reduction in maximum amplifier cascade through construction of a fiber backbone should result in the opportunity to operate the system within wider tolerances, offering some degree of cost savings and operational simplification. This is based on the assumption of very stable and reliable operation of the optical link portions of the system. It must be recognized that such a loosening of tolerances is only one way to "spend" the improvements arising from the construction of a fiber optic backbone and must be balanced with allocations resulting in improved signal quality or increased channel capacity.

Channel Capacity

As previously discussed, the potential bandwidth of the coaxial cable in use in today's CATV systems (including many of the cables installed over the last 10 to 15 years) is significantly greater than we are currently able to use, given our present architecture. The move to a hybrid fiber backbone/coaxial distribution system would ease some of the current constraints on channel capacity. A small number of amplifiers in cascade and broader system tolerances should make it possible to significantly push channel capacity with relative economy. In addition to the construction of the backbone itself, it is assumed that most or all of the active and passive elements of the coaxial portion of the system would be replaced, except for the coaxial cable itself. A new system design would take advantage of the short cascade, and would seek the optimum balance between channel capacity and signal quality. Indeed, preliminary design studies (to be presented in a companion paper) indicate that a current 270 MHz system (30 channels) could be upgraded to 550 MHz (80 channels) through the construction of a fiber backbone allowing no more than 4 trunk amplifiers in cascade, and by fully replacing all active components with high performance wide-bandwidth amplifiers. All passive components (couplers, taps, etc.) would also be replaced, but the enormous investment in coaxial cable and its construction would be reused. While this undertaking would still represent substantial capital investment, that cost would be some fraction of the cost of building a new 550 MHz plant. It is possible that with wider bandwidth CATV distribution amplifiers, the fiber backbone/coaxial hybrid approach may make it possible to upgrade existing systems even more aggressively, or to build new plant with truly spectacular channel capacity.

The history of the CATV industry is a never-ending quest for more channels driven by new types and varieties of programming sources. There are indications that fiber backbone technology may provide a way to deal with the next phase of this challenge.

Network Flexibility

Because a hybrid fiber backbone/coaxial system would no longer automatically broadcast the same signals to every point in the community, there is an opportunity to rethink signal strategy. Different combinations of channels could be delivered to different areas to meet local community needs, or to target advertising. Clusters of hotels could be fed with entirely different channel line-ups than residential sections. Scrambling could be used in ohe neighborhood with plant security problems, a high rate of turnover, or a good market for pay-per-view, while unscrambled signals could be delivered and controlled using traps in other types of areas. Different types of scrambling could be used in different areas as new kinds of addressable set-top converters were phased in. System upgrade and maintenance work would be far less disruptive than today, and could be approached on a node-by-node basis. Ultimately, a hybrid system could provide a certain number of channels in each node area would be reserved for pay-on-demand signal delivery to an individual subscriber. This would require a degree of switching at the headend and addressable delivery at each home, but begins to be practical if the pay-on-demand business opportunity is real. This flexibility begins to shift our focus to the longer term advantages of a hybrid fiber/coaxial network.

STRATEGIC BENEFITS

In addition to the relatively immediate operating benefits cited above, there are a number of longer term strategic benefits which would accrue to a hybrid fiber backbone/coaxial distribution system architecture.

Two-Way Services

The CATV industry has yet to reach consensus on new businesses which make effective use of the two-way capabilities of CATV plant. Current systems are technically capable of providing some degree of return services, although because of noise-summing and the reliability constraints of today's architecture, there are significant challenges to maintaining such a system. In addition, there is a relatively small amount of return bandwidth available within most CATV system designs.

To the extent that two-way services begin to provide genuine business opportunities, hybrid fiber backbone/coaxial architecture could provide significant advantages. The short cascade of the return plant and the relatively small number of branches being summed at each node point should yield a substantially more reliable and tolerant return signal path. In addition, because of the relatively large number of discrete node areas in a given network and the ability to reuse the same upstream frequency spectrum to return signals to each node, the effective return bandwidth of the overall network would be greatly increased. This is all based on the assumption that the same fiber providing downstream services to a node area could also be used for return signals, using wavelength division multiplexing (WDM) or other techniques allowing for transmission of signals in both directions on the same fiber. In our thinking about long term strategy, this potential to provide significantly more effective two-way services is a significant consideration.

Commercial Services

The CATV industry has been experimenting with a variety of commercial services in recent years. Most of these consist of providing data links for businesses. Should this prove to be a significant opportunity for the cable industry, the existence of a fiber backbone network could facilitate its expansion. The availability of single mode fiber at neighborhood "node" points throughout the community could provide a significant amount of capacity beyond that required for a residental coaxial distribution system. That capacity could relatively easily be applied to commercial types of services, either by extending fiber from node points to commercial customers, or utilizing short links of two-way coaxial plant for that purpose. There is also an opportunity to build in a degree of route-redundancy and switching between key nodes to provide the levels of reliability which commercial customers expect.

Competition

The CATV industry faces a broad variety of potentially competitive video delivery systems in coming years. These include direct broadcast satellites, multichannel MDS microwave, overbuild by other CATV operators, and video delivery via the kinds of switched fiber-to-the-home voice and video networks now being experimented with by telephone operating companies, as well as video tape and video disk sales and rentals. The keys to meeting such competitive challenges lie in providing excellent service (including signal quality and reliability), reasonable pricing, and a large number and wide diversity of programming channels. These goals, while straightforward, pose significant challenges given today's CATV networks. The fiber backbone architecture described here provides an opportunity to significantly improve both quality of service and channel capacity in a gradual way, with reasonable economics. This gives it the potential of being a significant tool in the strategic planning of the CATV industry as it faces a competitive future.

High Definition Television

It appears probable that High Definition Television (HDTV) will develop as a significant home entertainment force over the next decade. While all the implications of this are not yet clear, it appears likely that HDTV will provide significant challenges in terms of signal transmission and channel capacity requirements for CATV systems. While NTSC compatible enhanced television systems are in the development stage, it appears likely that services which must be delivered to both standard NTSC receivers and to full quality high definition receivers will require the equivalent of at least 2 to 3 standard 6 MHz channels. If such services become widespread, the magnitude of pressure on channel capacity is apparent. A movement toward a fiber backbone type of architecture over this same period should put the CATV industry in good position to be a high quality provider of these new signals because it helps address both transmission quality and channel capacity issues.

Evolutionary Change

In thinking strategically about its future, it is critical that the CATV industry seek a series of evolutionary steps, moving its plant in directions which will satisfy the needs of coming decades. In order to maintain business health, it is important that these steps be of a relatively gradual, pay-as-you-go nature. The enormous investment in completely new plant necessitated by a radical change in system architecture would be highly imprudent unless off-set by huge new revenue streams.

Business caution, as well as our belief that the most expensive portions of the existing plant (the coaxial cable and its placement) have a significant amount of additional potential, encouraged us to look hard for the kind of hybrid architecture we have outlined. It is possible to envision a carefully orchestrated scenario whereby fiber backbone would first move into the neighborhood as described here, then move to bridger amplifier locations, and next to the tap, increasing channel capacity, improving system operation and customer satisfaction, and enabling new services each step along the way. Complete replacement of plant with fiber all the way to the home is an attractively dramatic concept. We believe, however, that there is a far more practical approach, with each step being taken when it makes business and economic sense, which can enable the CATV industry to improve its business and meet the array of challenges which the future holds.

IMPLEMENTATION

There are several steps required for effective implementation of a hybrid fiber backbone/coaxial distribution system. The first is the achievement of cost-effective optical link electronics which meet the technical demands of such an architecture. A variety of approaches are under investigation by ATC and a number of component and system vendors. These general approaches were outlined earlier. The second step to implementation is developing an understanding of economic and technical trade-offs leading to a decision on the maximum size of the coaxial subsystems which should be fed by a given fiber node. The technical benefits involved must be defined not only in terms of immediate system improvements with the addition of fiber backbone, but also the channel capacity upgrade-ability which is desired of the resulting system. The economic and technical issues involved are quite complex, and it is hoped that work on these issues will continue to emerge in coming years as the backbone concept itself is proven valid. An initial approach to both economic and technical issues is presented in two companion papers.[3,4] Broadly stated, these works indicate the cost of overlaying a fiber backbone on an existing CATV system should be somewhere in the $30 to $60 per subscriber range, depending upon depth of fiber penetration. Further, they indicate that a fiber backbone overlay may make relatively dramatic channel capacity upgrades feasible. In the typical network examined, a system upgrade from 270 MHz (30 channels) to 550 MHz (80 channels) was achievable, maintaining current system specifications, and using off-the-shelf coaxial cable equipment in addition to a fiber backbone performing to the specifications outlined in this paper.

IMPLICATIONS

The architecture of the fiber backbone system is such that many small, unique cable systems are created out of one large operation. As a result, several implications resulting from its implementation can be seen.

The short amplifier cascades created by this architecture provide us with an opportunity to enhance the performance of our plant. The additional operating overhead that results from the short cascades can be used to improve the quality of the signal delivered to the home, to increase bandwidth, or a combination of the above.

If we are trying to position the system to handle such new technology as HDTV without having to rebuild the plant to accommodate the first one or two HDTV channels, with a requirement for better system specs, then this might be provided by the fiber backbone.

Later, as HDTV and other needs for expanded bandwidth advance, a system upgrade becomes a good alternative to a complete rebuild. An upgrade assumes, of course, that the coax in the plant is capable of carrying additional spectrum.

A system could be expanded in bandwidth a number of times. This is a result of the relatively short distances between the fiber distribution point (node) and the end of the plant that the node feeds. To understand this point, we must consider that we have broken our large cable plant into many small plants with short cascades. When we upgrade, it may be necessary to not only change the electronics and passives, but to add additional amplifiers as well to make up the losses of the higher frequencies needed. While doing this while maintaining specifications in a system that may be thirty amplifiers or more in cascade could be impossible, it could be a relatively easy task within a fiber backbone system.

The small "neighborhood cable systems" created by the fiber backbone allow a CATV operator to consider new concepts in advertising. While cable can now "narrow cast" ads on selected stations such as MTV and CNN, one could, using a "neighborhood cable" approach facilitated by backbone architecture, produce neighborhood specific advertising. Neighborhood merchants rarley want, or can afford, city-wide advertising, but could be interested in ads reaching a few system nodes serving their potential customers. The fiber backbone makes this possible because of its unique feature of having a direct feed from the headend to each "neighborhood".

The "neighborhood cable system" lends itself to new approaches to programming as well. Since each system has a direct fiber feed from the head end, we may wish to consider providing different programming to selected areas. For example, in some cities there may be ethnic communities that would like specific programming. Once the primary boundaries were defined, additional ethnic channels could be delivered to the nodes serving that area.

We might find a large concentration of hotels and motels in another area, requiring a completely different channel mix. The flexibility of the backbone architecture opens up many options with regard to targeted program delivery.

The hotel/motel possibilities of a fiber backbone-fed system lead us into some enhanced commercial services possibilities. For example, the ability to use the reverse band on our cable plant starts to look more attractive. We can now look at the short cascades which equate to less noise addition on the reverse system and see that it becomes a much more reliable data path than before. This path could be used for pay-per-view signaling, interactive programming like home shopping, etc. Because we are dealing with "neighborhood systems" we might consider using our more reliable reverse path for local area networking in business areas.

Metropolitan area networks may become practical. In a metropolitan area network, we would be able to provide data communications between points located anywhere in the city. This is a result of having a node that is in every neighborhood connected directly to the headend with fiber which is passive and two-way. As a result, we would have established a very reliable communications path throughout the city.

Operating a cable system today can be a complex venture. Implementing a fiber backbone system might help reduce some of the day-to-day problems that exist. Because of the short cascades, we would probably see a reduction in the need to sweep the cable plant. That means a potential reduction in labor. In addition, we may see a reduction in phone traffic that would normally be caused by large system outages. Often, system failures overload the capability of our phone systems. For example, if the first amplifier in a thirty-two amp cascade fails, it can effect seven or eight thousand subscribers (based on studies of actual systems). If only one third of the affected customers were to call in, the phone system and customer service department would be unable to handle the load in an efficient manner. The result is that subscribers often feel that they are unable to contact the cable company when they need it the most. The phone system overload will often effect all lines going to the cable company office.

With backbone architecture, there will still be amplifier failures, but those failures will effect fewer people and create fewer calls. Thus, there is the potential for improved customer relations and a better image within the city.

Another use for the fiber backbone system could be in new construction. If we consider the rural and low density areas we would like to serve, but find conventional coaxial systems to be too costly, we might look at a fiber backbone-fed node feeding a "tapped trunk" system. We could benefit from the use of passive, low maintenance fiber to transport the signal and maintain reasonable quality to the start of such a system. It is probable that the cost of such a system would be less than traditional architecture.

Still another variation of the backbone could be a system that has no trunk at all, only a distribution system. That would say that the node would be at a bridger location and would feed line extenders rather than trunk amplifiers. It could be possible to cascade a few high quality distribution amplifiers with AGC circuits and still maintain the node performance quality without the need for trunk cable or amplifiers.

Overall, the implications of implementing a fiber backbone system are far-reaching, from marketing to operations to customer relations as well as improved image in the community. The system has the potential for assisting in solving, or at least reducing, a number of problems that exist in most cable systems today.

There is also the opportunity to increase revenues through the "neighborhood cable system" concept that lends itself to new advertising sales and marketing ideas.

CONCLUSION

In summary, the hybrid fiber backbone/coaxial distribution architecture outlined here is one which meets an array of needs within the CATV industry. It provides a means of significantly improving the operation of CATV plant, while laying the foundation for future evolution. It is foreseen that the introduction of optical fiber technology into CATV systems in this way opens the path for the industry to grow and survive in a competitive world well into the next century.

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Chiddix also has an extensive background in the development of a variety of tape automation systems. As a founder of CRC Electronics in Honolulu, he contributed to the development and manufacture of video playback systems for pay television, automated videotape delay systems, and systems for automated commercial insertion. CRC Electronics was sold to Texscan-Compuvid in 1982.

Chiddix was born in Easton, PA., taught courses in computer and radar electronics maintenance in the U.S. Army and studied electrical engineering at Comell University.

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Pangrac is a member of the Society of Cable Television Engineering and past president of the Hart of America Chapter.

Pangrac is currently involved in ATC's effort to develop the use of fiber optic technology in cable television plants.

FIBER OPTIC CABLE CONSTRUCTION AND INSTALLATION

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ABSTRACT

Once the decision has been made to utilize fiber optics as the medium for communications transmission, the next question is in what form should the fiber be cabled (loose tube versus tight buffer), and how should it be installed. The application for both loose tube cables and tight buffered cables is addressed. Also, considerations for direct buried, duct, and aerial installations will be described. In addition, the differences in the two primary fiber manufacturing methods will be discussed. The concern is to insure the correct cable construction and installation are combined to provide the fiber with the necessary long term reliability beginning with the rigors of installation through the cyclic changes caused by its permanent environment.

INTRODUCTION

Fiber optic cable is being utilized by cable television companies to carry signals from sattelite downlinks to headend; headend to headend; headend to hub; and potentially deeper into the cascading system. Some of the reasons for using for fiber optics are 1) reduction of amplifiers in the cascade, 2) elimination of signal leakage, 3) lower maintenance costs, 4) higher reliability 5) increased bandwidth/ channel capacity. The method of cable installation and the corresponding cable construction are critical to insure, as a minimum, the standard 15-year life expected by most cable TV companies is achieved.

In numerous communication industries, fiber optics have been utilized consistently and successfully for the past 10-15 years. Most manufacturers will discuss cable life in terms of 20-40 years. The inherent properties of the fiber optic glass are such that, if properly cabled and installed, the product life could be in excess of 20-40 years. The limiting factors are the materials used to house the fiber and the external stresses that may be applied during manufacturing, installation and under environmental loading.

The vast majority of cable TV applications will call for singlemode (as opposed to multimode) fiber due to its low loss and high bandwidth/channel capacity characteristics. A short description of the two most common methods of singlemode fiber manufacturing will be followed by a description of loose tube cables and tight buffered cables, and a discussion on the application of each. The final area of discussion is methods of installation with special emphasis on self-supporting aerial cables. The reason for emphasis on the self supporting aerial method is its unique combination of being one of the fastest and least expensive methods of installation while also being the most demanding on the fiber optic cable, based on environmental loading.

SINGLEMODE FIBER MANUFACTURING

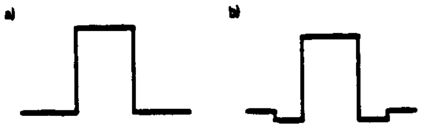
There are several methods of manufacturing high quality optical fibers. For the sake of argument, "high quality" fibers will be defined as singlemode fibers with attenuation less than or equal to 0.5dB/km at 1300nm and 1550nm, bandwidth in excess of 2GHz•km at 1300nm, and dispersion less than or equal to 3.5 ps/nm•km from 1285nm to 1330nm and typically 17 ps/nm•km from 1500 to 1550nm.

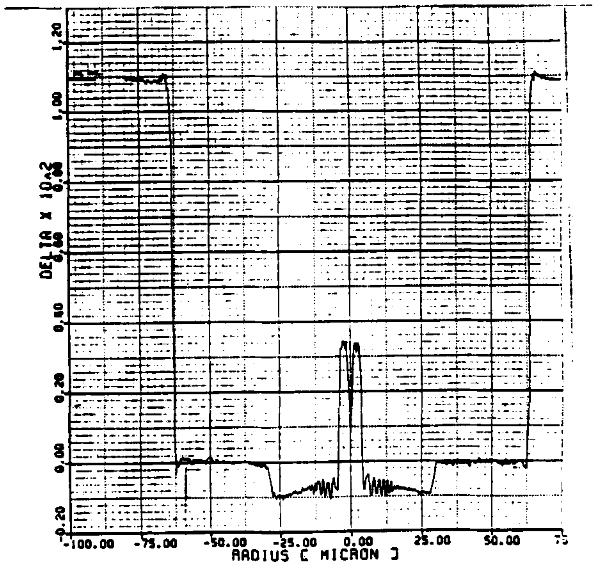
The two primary methods used for manufacturing the fibers are Outside Vapor Deposition (OVD) and Inside Vapor Deposition (IVD). Simplistically, vapor phase despositon is a method of doping fused silica glass with metallic halides in order to establish a desired refractive index profile. The refractive index profile depicts the change in the refractive index across the fiber to include the core, the core cladding interface, and the cladding. The refractive index is the ratio of the speed of light in a vacuum to the speed of light in the glass. For light to propogate properly in a singlemode fiber, the refractive index of the core glass must be slightly greater than the refractive index of cladding glass at their interface. The net result is what is referred to as a step-index profile.

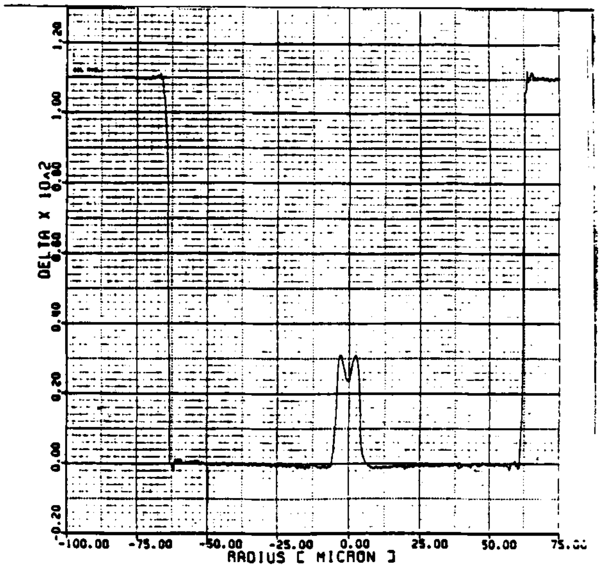
Figure 1 shows the profiles associated with the OVD and IVD processes. The matched cladding index profile is the result of a fiber manufactured by the OVD process. The depressed cladding index profile is the result of a fiber manufactured by the IVD process. Both processes produce fibers that perform equally well. The primary reason for the depressed clad profile associated with the IVD process is to overcome the difficulties associated with this manufacturing process in maintaining the uniform refractive index profile critical to quality performance. Figure 2A shows an actual refractive index profile of a depressed clad singlemode fiber. Figure 2B shows an actual refractive index profile of a matched clad singlemode fiber.

Figure 1.
a Standard step index profile (simple step index or matched cladding)

b Step index profile with reduced refractive index in the cladding (depressed cladding)







The key element regarding fiber is how it will perform once cabled and installed. Bending losses and strain applied to the fiber can degrade its performance and life expectancy. Corning Glass Works, a major fiber manufacturer holding patents for both the OVD and IVD processes, recommends a minimum bend diameter for the fiber of 50mm. At bend diameters below 50mm, there is potential for substantially decreased expected fiber life. At bend diameters of 50mm and above, the loss associated with the bend is negligable for both matched and depressed clad fibers with slightly superior performance of the matched clad over the depressed clad for bend diameters encountered in typical splice trays (60-80mm).

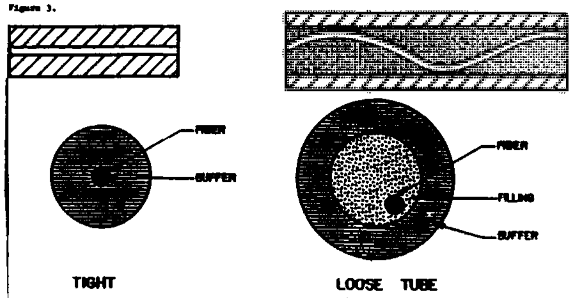
Regarding fiber strain, Corning Glass Works states that a fiber can withstand strain up to one-third of its proof test, long term, without degrading its expected life. The typical proof test after manufacturing is 50 kpsi for fibers intended for loose tube construction and 100 kpsi for fibers intended for tight buffered construction.

LOOSE TUBE AND TIGHT BUFFERED CABLES CONSTRUCTION AND APPLICATION

The difference between loose tube and tight buffered cables is the basic premise of how the fiber should be treated regarding strain. A tight buffered design accepts the fact that some amount of strain will be coupled to the fiber during manufacturing, installation, and due to environmental exposure. It makes the further assumption that the strain will not degrade the long term optical performance of the fiber. A loose tube design makes the assumption that the best way to assure maximum performance of the fiber over time is by isolating it from the majority of strain associated with manufacturing, installation, and environmental conditions.

Figure 3 depicts the buffering techniques applied to the fiber by tight buffer and loose tube designs. As shown, the loose tube design provides a percentage of fiber overlength relative to the loose buffer tube and decouples the fiber from the buffering material, whereas the tight buffer design does not.

Figure 3.



BUFFERING TECHNIQUES

The reasons for decoupling the fiber from its buffer is to isolate the fiber from the strain associated with expansion and constraction of the cable components, and the strain induced during installation. In a loose tube design, the fiber or fibers in the individual tubes are given the freedom to remain in a strain-free state relative to the other cable components. This is particularly important when the cable is to be placed in a non-environmentally controlled environment (i.e. outdoors).

Generally, fiber optic cable manufacturers with the capability of manufacturing both loose tube and tight buffered cables will specify the loose tube cables for use in outdoor applications to include direct buried, duct and aerial installations. In aerial applications, it is particularly important to utilize the loose tube design due to temperature cycling, ice loading, and wind loading. The tight buffered cables are normally specified for use indoors in environmentally controlled areas. Siecor Corporation, a major manufacturer of fiber optic cables, can also recommend a new tight buffered cable design for use outdoors, in ducts, buried below the frost line for short haul applications.

Numerous other cable construction issues such as jacket material, types of armoring, buffer tube materials, etc. could also be discussed at this point. However, this paper will not address them because they are not directly fundamental to the concern of fiber strain versus fiber life, nor particularly important to installation techniques.

CABLE INSTALLATION

Three broad terms capture the types of installations utilized for the outdoor placement of fiber optic cables. They are 1) duct installations, 2) buried installations, and 3) aerial installations. The methods, techniques, and equipment utilized for the installations would be extremely difficult if not impossible to list. However, upon inspection it is clear that by following a few fundamental guidelines, the installation of fiber optic cable in any application is analagous to the installation of coaxial cable. In fact, the size, weight, and flexibility of fiber optic cable should make cable installation faster, easier and less expensive to install.

Duct Installations

Fiber optic cables can be pulled into ducts and innerducts using conventional cable techniques with minor modifications. The two most important guidelines to follow are 1) to not exceed the cable manufacturer's specified maximum pulling tension and and 2) do not exceed the manufacturer's specified bending radius. The industry standard for maximum tension on fiber optic cable is 600 lbs. during installation. This number can be increased or decreased by the cable manufacturer as requried. Generally, the minimum bending radius for a cable during installation, under tension, is 15 to 20 times the diameter of the cable.

In order to pull a cable through a duct, the cable is typically attached to a pulling eye by its strength member(s). The strength of the cable should not necessarily be confused with the central member. Some manufacturers rely wholly or in part on the central member for strength. However, the most commonly used cables utilize aramid yarns applied over the cable core and directly under the jacket as the primary cable strength member. The pulling eye is composed of a wire mesh pulling grip, a kevlar tie-off loop, and is attached to the pulling rope or winch line via a swivel. The purpose of the swivel is to allow the rope to rotate naturally without twisting the fiber optic cable.

In order to reduce friction and increase pull lengths, a pulling lubricant compatible with the particular cable sheath may be utilized. At all times, the pulling tension being applied to the cable should be monitored to insure maximum tension is not exceeded. The distance a cable can be pulled in one direction can be increased by utilizing figure-8 techniques (backfeeding or center pulls).

As an example, if the intent is to pull in a four km reel of cable and after 2km the maximum tension is reached, the cable can be pulled out of the duct at the nearest manhole back from the point of maximum tension and layed on the ground in large figure-8 loops. (The purpose of the figure-8 is to allow for easy handling of the cable and to prevent kinking.) Once all of the cable is formed into a figure-8, it is turned over so that the pulling eye of the cable is on top. The pull can then continue through the duct from this new starting point. In some cases, it may be necessary to hand assist the cable at an intermediate manhole in order to reduce the tension enough to pull the cable out of the manhole to form the figure-8.

Center-pulling of cable can be performed as an alternative to backfeeding for long cable lengths. This technique involves the placement of the reel near the center of the duct run to be pulled. The cable is pulled in one direction to a predesignated splice point. The remaining cable is unreeled, figure-eighted on the ground, and pulled in the opposite direction.

It is conceivable that with proper "housekeeping" either technique could allow cable pulls of 4-6km of continuous cable. Some manufacturers are capable of manufacturing singlemode cables up to 12km in length without fiber splices.

It is recommended that in manholes, flexible conduit be utilized to house and protect the cable. Enough conduit should be used to allow it to be secured to the manhole wall and extend approximately one meter into the duct on each side. Enough cable slack must be left in each manhole for this purpose also.

Buried Installation

The cable utilized for a buried installation would be the same as that used in a duct with the exception that it would be housed in innerduct or, more commonly, it would contain its own armoring such as a corrugated steel tape. The purpose of the armor is to protect the cable against rodent attack and potential crushing forces. The cable is typically buried at depths of 30-48 inches in utilizing a conventional cable laying plow. Depending on the ruggedness of the cable, many manufacturers do allow their cables to be installed with vibratory plows. A warning tape may be buried along with, or above the fiber optic cable for the purpose of forewarning ground excavators.

Trenching is an alternative method for burying fiber optic cable. For short distances, it may prove to be more economical than plowing.

In the event the soil is particularly rocky and there is a concern about cable damage, it would be wise to prepare the area prior to installation. In the case of plowed cable, the ground can be pre-ripped. In the case of trenching, the trench can first be backfilled with approximately one foot of sand.

Aerial Installations

As indicated earlier, aerial installations tend to subject the cable to its harshest environmental conditions over time. This is due to several environmental factors. First, temperature cycling will occur which may cause dissimilar movement between the fiber optic cable and its host supporting messenger. Second, for heavy ice and wind loading areas, seasonal loads of 1/2 inch radial ice with 40mph winds can be anticipated. Third, areas of heavy wind load can produce wind loading up to or in excess of 110mph. In all cases, these factors will place increased stress and strain on the fiber optic cable. If properly designed and installed, a loose tube cable design can insure the fibers remain in a relatively stress-free state eliminating concerns of reduced service life.

As with a duct installation, the two rules of thumb to follow when installing fiber optic cable aerially are: 1) do not exceed the maximum pulling tension and 2) do not exceed the minimum bend radius as specified by the cable manufacturer. The construction of the cable will normally be the same as a cable used in a duct installation.

A minority of users opt to install an armored cable aerially. In some cases, it is for ease of inventory and in a few cases, it is as a precaution against squirrel or rodent damage. Other customers may opt to utilize an all-dielectric cable due to its non-conductive properties and associated concern regarding lightning damage.

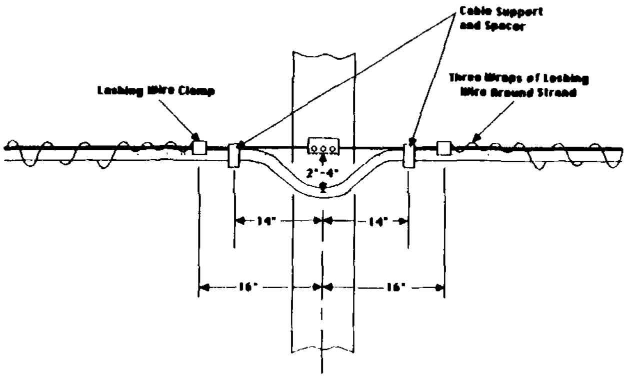
The most common aerial installation involves lashing the cable to a dedicated steel messenger utilizing standard lashing techniques. Either a "pull-in" or "drive off" method may be used. Because of the reduced "make ready time," the drive off method is quicker and more economical. Again, it is critical that the recommended minimum bend radius and maximum tensions as specified by the cable manufacturer are followed. It is critical that the aerial cable blocks and cable guide are large enough to insure the cable's minimum bend radius is not violated. For short spans, one-quarter inch extra-high-strength steel wire messenger has become fairly standard.

Overlashing the cable to existing plant is also an option. In this case, all procedures are the same as with a dedicated messenger. For installation, again, the keys are maximum pulling tension and minimum bend radius. In an overlashing situation, the fiber optic cable is coupled to the copper cable which can sustain more strain than the fiber optic cable. In most cases, the design engineer should consult with the cable manufacturer to discuss the variables which determine the fiber optic cable strain involved in an overlashed situation. The design engineer should also take into consideration the additional potential load to the existing cable and structure just as he/she would in the case of overlashing copper cables.

In the case of dedicated and overlashed aerial installations, most manufacturers suggest that drip loops be left at each pole to allow for expansion of the messenger. The loops are generally 2 to 4 inches below the lashing wire, depending on cable size, with the limiting factor being minimum cable bend radius. The lashing line is clamped to the pole and spacers are generally used.

Siecor

Recommended Drip Loop for Aerial Siecor Fiber Optic Cable



Another method of aerial installation which is growing in popularity is the use of self-supporting cables. The primary reason is ease of installation and significant time/labor savings. When compared to installing a dedicated messenger and lashing a fiber optic cable, a self-supporting system will normally be more economical. In addition, newer designs provide superior relief for the fiber from environmental forces.

To install a self-supporting cable, the same procedures would be followed that are utilized for installing a messenger. Again, tension and bend radius are limiting factors. The Rated Breaking Strength (RBS) of most self-supporting cables runs from 4000 lbs. to 35,000 lbs. The recommended RBS should be specified by the manufacturer based on span length, maximum sag allowed, and ice and wind loading. The recommended installation tension will vary, but will generally be between 10-20% of RBS. As with previously described procedures, if a pulling rope is used as with the "pull-in" method, a swivel should be placed between the pulling rope and fiber optic cable.

The key elements to a self-supporting cable design are 1) ease of installation, 2) a strain-free fiber environment under worst case loading, 3) no effect on the fiber by hardware attachments, 4) resistance to wind induced vibration and 5) the flexibility to preplan the cable construction to accomodate overlashing in the future, if requested.

The three most common self-supporting cable designs satisfy these requirements to greater or lesser degrees. The designs are figure-8, concentric or circular, and pre-stranded or helically wrapped. Of the three, the pre-stranded most completely satisfies the above stated parameters.

The figure-8 design consists of a fiber optic cable clipped or bonded to a messenger. The messenger is normally poly coated and can be fiberglass reinforced plastic (FRP), steel, or aramid yarn. The FRP designs are most common. The figure-8 typically installs easily, but due to the rigid messengers commonly used, may pose handling problems. The fact that there is a physical coupling between the messenger and cable reduces the effectiveness of maintaining the fibers in a strain-free environment. Loads applied to the messenger will be mechanically coupled to the fiber optic cable. Since the cable has a separate messenger, hardware can be attached without the danger of compressive forces applied to the fiber optic cable. The cable design also exhibits resistance to wind forces because the disimilar harmonic motions of the messenger and cable will help to dampen wind induced movement.

The concentric or circular design is simply a standard aerial cable with an increased rated breaking strength and crush resistance. The strength of these cables is found in layers of aramid yarn. By increasing the cross sectional area of aramid yarn, the manufacturer can design a cable capable of aerial installation without an external messenger. These designs provide the lightest weight, most flexible design for installation. The disadvantage is the reduced ability to isolate the fibers from strain during tensioning and under load. Also, hardware must be applied directly to the fiber optic cable increasing the possiblity of placing compressive stress on the fibers. Because of the circular construction, dampeners may be required in some cases to reduce wind induced vibration.

The pre-stranded or helically wrapped design utilizes a poly jacketed messenger with a fiber optic cable stranded around the messenger. The stranding process is zero torque so as not to induce a twist to the fiber optic cable during manufacturing. The messenger is normally a poly jacketed aramid yarn to give the cable low elasticity, high strength, and flexibility for handling. The pre-stranded design incorporates all of the positive points associated with a figure-8, the greater ease of handling found with the concentric, and reduces the mechanical coupling of strain from the messenger to the fiber optic cable because there is no physical bonding.

In all cases, the manufacturer should supply the user with sag/tension information for specific applications. This information should include installation sag and tension, horizontal displacement and vertical sag under worst case loading, and tension under worst case loading. In addition, the manufacturer should be able to guarantee the system will not see any increased attenuation under worst case loading conditions.

To be able to overlash the system in the future, the manufacturer needs to plan for the increased cross-sectional area and weight during the installation design. Both the concentric and pre-stranded designs are capable of being overlashed. The profile of some figure-8 cables may preclude the ability to overlash.

Summary and Conclusions

Reliability of fiber optics has been proven over the last 10-15 years in several communications industries. In order to insure the same success and long term reliability is acheived in the Cable Television Industry, it is important that the design of the cable match the application. Reduction or elimination of fiber strain over time is an essential element to insuring expected life cycles are achieved.

If properly cabled, both matched clad singlemode glass and depressed clad singlemode glass will meet or exceed performance expectations. By utilizing cable constructions compatible with the installation technique specified, the Cable Television Industry will benefit from the reliability, long life, and superior performance afforded by fiber optic cable systems. Acceptance of fiber optic cable as a viable transportation medium for transmission of Cable T.V. signals has occurred.

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FIBEROPTIC CABLES
INSTALLATION AND MAINTENANCE

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General Instrument
Comm/Scope Division

INTRODUCTION

As we all know, fiberoptic technology is beginning to find appropriate applications in CATV. As this technology comes out of the laboratories and into use over the next decade, the local system technical people will learn to deal with it on a daily basis. One aspect of this technology is the installation and maintenance of the fiber cable plant itself. During the next few minutes, we will discuss the fundamental physical characteristics of glass fiber and the resultant cable designs, installation practices and maintenance practices that will yield success.

CABLE DESIGNS

Your casual observations of most fiberoptic cables will discover that they differ in construction from traditional coaxial and twisted pair metal cables. The nature of glass has presented the cable manufacturer several challenges. First is the size of the fiber which is several orders of magnitude smaller than typical metallic conductors. Mechanically, glass exhibits very high tensile strength but very low elongation which means particular attention must be paid to bending of the fiber to prevent breakage; whereas, copper and aluminum have relatively good bending characteristics. However, perhaps the most challenging characteristic is fiber's performance sensitivity to mechanical strain. Under even very small sustained strain loads, the transmission characteristics will be altered and the life of the fiber may be shortened.

The first requirement of good cable design is to furnish finished product which has the intended life and performance under the installed conditions. Communications fiberoptic cables have followed the design life objectives of our traditional coaxial and twisted pair products. Thus, materials and environmental protections applied should under most conditions exceed 20-30 years excepting physical damage. Careful attention must be applied to construction techniques and to unusual environmental conditions so as not to compromise the design life.

Cable designers have been successful in developing cables which can be installed by conventional means with very few exceptions or changes. In fact, the areas of concern in construction practice for fiber cables mirror those of our traditional CATV coaxial lines. Materials and geometric design elements are chosen to combat severe bending, tensile elongation and impact loads. All construction techniques can be utilized including aerial lashed, aerial messengered, plowing, trenching and duct.

As with metallic cables, the most destructive environmental element is water in its several forms. Fiber cables intended for outdoor use, whether aerial or underground, must be protected from water ingress. For this reason, you will find flooding materials and bonding between cable elements commonly used in all cables. Glass is attacked by water in a process called hydrogenation. This results in microcracks which will propagate over time ultimately resulting in fiber failure.

Three basic cable designs have evolved, all of which are successful in obtaining the objectives set out. These are known as loose tube, slotted core, and ribbon cables.

Several implementations of basic loose tube design are available. One generally representative sample is shown in Figure 1.

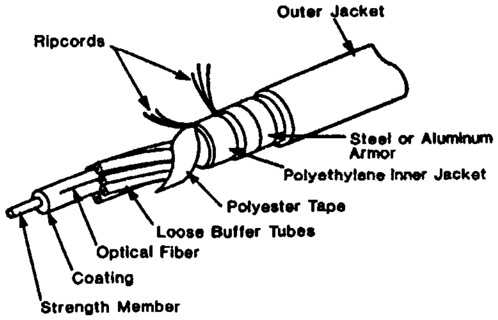

Figure 1

All of these designs utilize the concept of buffering and incorporate a strength member. Buffering simply means that the cable design attempts to mechanically isolate the fiber from all adverse conditions including impact, crushing, bending, tensile and thermal stress.

Figure 2 shows one of several variations in slotted core (open channel) construction.

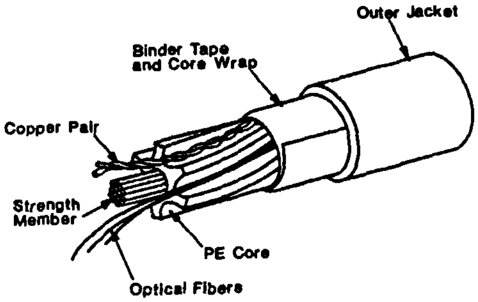

Figure 2

Strength members are available as either steel or a dielectric such as Kevlar or FRP. Both materials produce cables which meet all the mechanical, physical and optical requirements set forth. In cable designs which place the strength member in the center surrounded by fibers, the use of a dielectric is advantageous to prevent the possibility of an electrical potential between the strength member and outer steel armor or aerial strand. Also use of all dielectric designs for duct and buried plants may be particularly advantageous in higher lightning areas of the country. The marginal increased cost of dielectric materials are worthy of consideration particularly with higher fiber count cables which carry proportionately higher revenue traffic.

A very high density fiber design available from AT&T is the ribbon cable, shown in Figure 3. In many respects, this design is similar in concept to a loose tube construction.

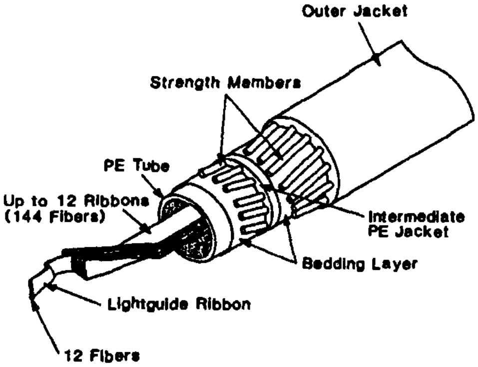

Figure 3

AERIAL INSTALLATIONS

All of the general techniques and methods of aerial installations which have been successfully used with coaxial cables can be applied to fiberoptic cables.

In order to have a successful install, the fiber must be protected from stress. If a fiber is subjected to a stress equal to 30% or more of its breaking strength, there will be a reduction in the life of the fiber. Such excessive stress produces microcracks in the glass which over time will propagate resulting in failure.

Cables have been designed and are specified for maximum tensile load strength such that the fibers are sufficiently protected. It is vital that the cable specifications are adhered to. Most cables carry a specification of at least 600 pounds maximum pulling strength. Observing this limit strictly during pulling will prevent fiber damage. It is recommended that a tensiometer, fusable link or other device be used during the pulling process so as to guarantee that the maximum pull strength specification is not exceeded.

All cable designs incorporate one or more strength members. Their purpose is to absorb the tensile load applied during installation and during the life of the cable. Attaching the pulling devices to the cable properly is essential to transferring the load to the strength member rather than to the fiber. Kellums® grips, pulling eyes, etc. should be effectively attached to the central strength member.

Back Pull (stationary reel)
Installation Method

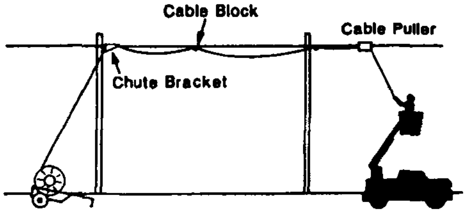

Figure 4

One characteristic of fiber cable is its light weight. In most cases the cable is lighter than coax. Even so, rollers and other support devices must be used along the spans to support the cable during a backpull. The size, number and spacing should be equivalent to good coaxial cable installation. Failure to use sufficient support may result in excessive drag or exceeding the minimum bend radius.

Drive Off Installation
Method

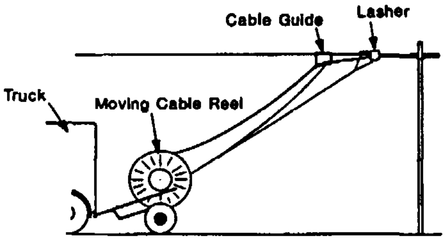

Figure 5

Cable designs have been chosen to give minimum bend radius essentially equivalent to other types of cables. This is usually specified at about ten (10) times the cable diameter. Thus, the standard practice with regard to corner blocks should be followed. Obviously every additional corner encountered during the pull will increase the pulling tension.

The splice case will contribute substantially to the overall life of the installation. First of all, it must be environmentally qualified for the installation. Water entry into the case will create a significant problem. The internal structure of the case must be designed with the bending characteristics of the fiber, the type splice to be used, the type cable and convenience of the splicer in mind. The case must be designed to contain excess fiber lengths up to several meters. This allows the fiber ends to be brought out to the splicer for easy effective work. The excess length also allows the fiber to be coiled back into the case with large enough radiuses to avoid damage to the fibers or excess attenuation. Specific coil frames are usually provided to hold the fibers. The case should also contain some mechanical means of holding the splice after the job is finished. The splice cannot be allowed to hang free. All of these requirements are usually fabricated into what is generally called a fiber organizer inside the splice case.

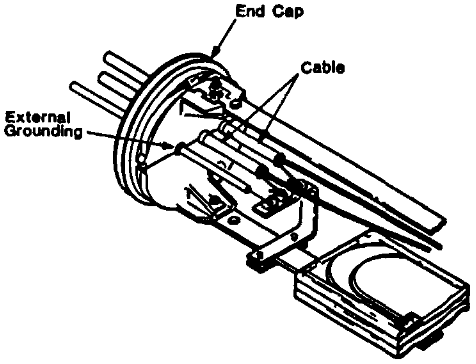

Figure 6

All splicing techniques are relatively sensitive requiring some equipment and a convenient work space for the splicer. As a result, common practice is to do the splicing at ground level as shown in Figure 7.

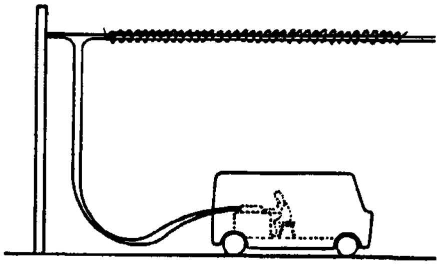

Figure 7

After splicing is complete, the splice case and excess cable is lashed up to the strand as shown in Figure 8. Care should be taken to place the case and cable away from the pole to prevent damage by other pole occupants.

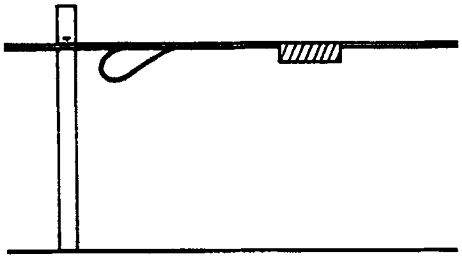

Figure 8

Fiber cables have a need to be as longitudinally dimensionally stable as can be reasonably accommodated. Thus, unlike coaxial cable sag and tension practices, a tight span is preferrable to a loose span. The objective of the cable design and installation is to minimize the chance of stressing the fiber. A very loosely sagged strand will exhibit more differential length movement due to temperature, ice, wind and snow which in turn increases the chance of applying stress to the fiber. In practice, sag conditions will usually be restricted by other cables installed on the poles. Whenever possible, place the fiber cable in the uppermost available space on the pole.

Overlashing of a fiber cable to existing cables is acceptable with a single precaution. The strand must be of sufficient size and installed correctly so that the finished installation of fiber cable and other cables will meet the sag and tension needs of all the cables.

Standard practice in CATV coaxial cable construction requires expansion loops periodically to accommodate the difference in thermal coefficients of expansion of steel and aluminum. In fact, specific care must be given to the geometric configuration of the loop to prevent premature failure of the cable. The materials used and the configuration of fiber cables present a different situation and in fact, the requirements may differ between cable types and even between implementations of the same cable type. For example, loose tube cables can be designed such that expansion loops are not required. This is achieved by carefully constructing the cable in such a way as to accommodate the expansion and contraction of the strand. It is best to consult your cable supplier for a specific recommendation. Conservative practice may be to install a minimum number of loops. Because of the flexibility of fiber cables, and their lack of susceptibility to stress concentrations, the natural shape of an expansion loop is quite adequate.

DIRECT BURIAL

Fiber cables are suitable for direct burial using either the trenching method or plowing. All of the precautions considered in aerial installations apply here with a few additions. For plowing operations, special attention is needed for the plow design and for the entry of the plow into the ground. In both cases, precautions must be taken so that severe bend stress is not put on the cable. For added strength, bend protection, and environmental protection, an armored cable design is recommended for underground.

DUCT INSTALLATIONS

These are quite common with fiber cables and should present no problems. Some precautions should be observed to prevent over tensioning of the cable. The duct should be cleared before pulling the cable. An inner duct may have to be pulled in to assure sufficient clearance. Never attempt to fill a duct over 60% of its cross sectional area. Excessive filling will create excessive tension. Use of lubricants is recommended to reduce tension.

IN GENERAL

The success of a fiber cable installation is planning and careful attention to stress. The cable runs should be well planned for clearances, avoidance of obstructions, location of splice points and the ability to place long lengths of cable. All conditions which will create difficulties should be eliminated or accounted for in the planning stage.

One of the advantages of fiber optics is to utilize long lengths of cables and in fact, splicing should be minimized. For particularly long runs, whether aerial or duct, there is potential for generating excessive stress or in the case of aerial construction, having to go above other facilities perpendicular to the run. A technique which can help in these situations is to start the cable placement in the middle of the run and work in both directions reducing the run by half. To accomplish this, it will be necessary to take the last half of the cable length off the reel in order to access the bottom end. The cable can be laid on the ground in a figure eight configuration. By using the figure eight, the cable will pull out into the last half of the cable run without kinking. This avoids the natural twist which would be induced if a simple coil were used.

To clear obstacles along the route of an aerial placement, one can use the figure eight technique. After figure eighting the cable on the ground, the cable end is pulled over the obstacle and the cable can then be rewound on to the cable reel by hand.

RESTORATION

Repairing a fiber cable which has been damaged will be a necessary part of the system maintenance. Unlike the initial installation which will usually have been done by specially equipped contractors, restorations may be done locally due to time and to cost.

The first step is to have extra cable on hand. Usually some extra length is added to the initial order to have on hand for repair purposes. Since fiber cables at this time are generally made to order, obtaining a repair length from the factory may require several weeks. If necessary, long jumper cables can be used as a temporary repair. If a length of the original cable is not available but a length of a different cable containing sufficient fibers is available, then it can certainly be used. Under emergency conditions, even splicing together fibers from a different manufacturer is acceptable temporarily (for multimode fibers they must be equal core sizes).

For the permanent repair, two splice kits and a length of appropriate cable will be needed. The type of splices chosen and the splice cases chosen should be consistent with the objectives originally set out for the entire cable run. Some factors to be considered are splice loss, cost, reliability and local expertise.

How much cable should be removed to be assured that all damaged fiber is eliminated? One concern is that all fiber which has been overstressed and would as a result have a reduced life be removed. It is probably impossible to know with any certainty the answer due to the variability of installations and type of damage incurred. One rule of thumb which is commonly proposed is to cut back ten (10) meters each side of the damage. A second factor to consider is the introduction of modal noise due to locating two splices close together. The importance of this factor is dependent on the particular manufacturers' fiber used. Avoidance of this situation requires separating the splice by twenty (20) meters. From a practical point of view then it seems that whenever practical, a repair section should be about twenty (20) meters long. If the particular situation makes this difficult, you should consult your cable supplier.

Another approach is to install an accumulated excess of cable at points along the cable run. These points could be chosen for their proximity to likely damage locations such as an area which is expected to see significant construction and development in the near future. The accumulation of excess cable can be done as in Figure 9, always keeping in mind minimum bend radius and tension.

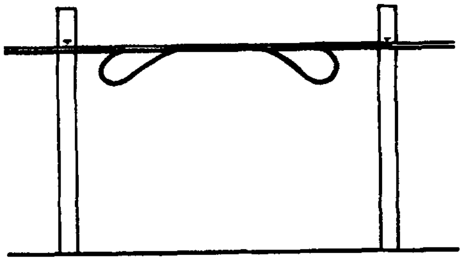

Figure 9

This excess cable can then be pulled out and relashed so that the restoration can be done with a single splice.

FIBER SPECIFICATIONS

Single mode fibers being provided for telecommunications today have parameters which in most cases are standards.

Attenuation
0.40 to 0.70 dB/km @ 1300 nm
0.30 to 0.70 dB/km @ 1500 nm

Fiber Mode Diameter (µm) ≈ 9.0

Fiber Outer Diameter (µm) 125 ± 3

Coated Fiber Diameter (µm) 250 ± 15

Other physical characteristic differences between fibers are generally artifacts of the manufacturing process employed. While these do produce some operational differences, they are of secondary importance and with accepted cable design, installation practice and splicing practice, should not significantly impact the installed system operation.

CABLE SPECIFICATIONS

The objectives of designing a cable fall broadly into the categories of protecting the fibers and providing ease of use by the user. Protection specifications are relatively standardized because they are quantitative and the requirements are well understood due to the long history of building and installing metallic cables. On the other hand, ease of use, convenience, adaptability, etc. are more qualitative attributes and vary depending on the needs of the specific installation.

Typical physical specifications for single mode telecommunications cables include:

Operating Temperature Range	
- 50°C to + 70°C	
Crush Resistance	
Armored	460 lbf/in.
Non-armored	400 lbf/in.
Impact Resistance	
Armored	20 times @ 3.7 lbf/ft.
Non-armored	20 times @ 2.2 lbf/ft.
Minimum Bend Radius	
depends on fiber count	
≈ 10 times cable outer diameter	
Maximum pulling tension	600 lbf

The specific geometric configuration and materials used in the cable may bear on the convenience to the user. Single tube, multitube, open channel or ribbon cable designs each have their own strengths and weaknesses from a user perspective. The choices may depend on individual preferences, installation, etc.

CONCLUSION

Fiberoptic cables are finding use in CATV systems today and many are predicting much wider use in years to come. The CATV operator can be assured that the cable manufacturers have the ability to provide products and accessories that can be installed and maintained in a practical sense. Some understanding of the characteristics of fibers and the design philosophy of cables by the user will help make the deployment of fiber cables successful. The objective of the cable manufacturers is to provide product which will minimize the need for special treatment.

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FIBER-OPTIC DELIVERY OF ADVANCED TELEVISION

Donald Raskin

Hoechst Celanese Advanced Photonics

ABSTRACT

Fiber-optic technology can be expected to play an increasingly important role in TV transport because of its essentially unlimited bandwidth, along with its potential for reducing operating costs and service interruptions. While a variety of fiber-optic TV transport options have been demonstrated in the laboratory and in actual field trials, the principal barrier to advanced TV distribution over fiber is the first-cost of cable installation.

A number of commercial scenarios are discussed which could lead to optical fiber implementation. The technical attributes of fiber-optics and their relevance to advanced TV transport are discussed, as well.

INTRODUCTION

In just the past 10 years, fiber optics has emerged from a laboratory development to become a major industry, as is evidenced by the more than 50,000 route-miles of fiber-optic long-distance telephone cable in-place in the US, with an additional 20,000 route-miles planned for installation by 1990 [1,2]. It is important to note that although much of the public awareness of fiber optics has focussed on transmission quality and reliability [3], the attribute that has propelled this technology with such unprecedented speed to its critical position in the major arteries of the telephone system is its dramatic reduction of installation and operating costs for telephone service providers. Because of the widespread use of fiber-optic equipment in long-distance telecommunications, the costs of the fiber, cable and certain key components have dropped sharply and there is a clear extension of the fiber system closer and closer to the end-user [4]. In particular, there is intensifying interest of both the cable TV and the telephone industries in utilizing fiber-optics for transport of video signals to their customers.

This paper will describe the attributes of fiber-optic transport, discuss its relevance to advanced television (ATV) signals and explore the prospective issues. An overview of on-going field trials and experimental work will be given, as well.

ATTRIBUTES OF FIBER-OPTIC TRANSPORT

In fiber-optics, the central core of a glass fiber one-eighth millimeter in diameter carries light signals that are produced by electrically modulating a semiconductor electro-optic device -- generally a laser diode. At the distant end of the fiber these optical signals impinge on semiconductor photodetectors, where they are converted back to electronic signals.

The keys to the technology are the extremely low signal attenuation and the nearly unlimited bandwidth of the glass fiber. In long-distance telecommunications, for instance, these capabilities of optical fibers have enabled commercial transmission at information rates presently as high as 1.7 gigabits per sec (1.7×10^9 bps), with repeater spacings of 40km. Such communications trunks carry the equivalent of over 24,000 simultaneous voice channels. An overview of lightwave technology is given in reference [5].

In telephone and data communications over optical fiber, digital techniques have been used exclusively since the signals and the switching in these networks are digital. Additionally, in long-distance communications, digital techniques offer immunity to error build-up as the signal passes through a series of repeater stages. In television production, ABC News has been transmitting segments from its Washington, DC studio to its main operation in New York City over the AT&T fiber-optic telephone network. Digital coding at 45Mb/s is used to make the video signal compatible with the standard telecom DS-3 bit-rate. Bellcore, the research organization of the regional telephone holding companies, is coordinating a nationwide trial for a customer-controllable DS-3 network to distribute contribution-level television signals between broadcasters and affiliates [6]. That trial, which will involve broadcast networks, local and long-distance telephone companies and numerous vendors, is scheduled to begin later in 1988.

Optical fiber has advantages in analog transmission, as well, which in the near term, at least, appears to hold high commercial promise for local delivery of TV signals. The clearest assets of such fiber transport are increased video quality and reliability, along with decreased maintenance costs, since fewer (or no) repeaters are required. In certain cases the installed first cost of a fiber-based system is lower, as well. This is true of the initial service examples: fiber supertrunks from CATV antennas to distribution hubs in Honolulu (Oceanic Cablevision) and Dallas (Heritage Communications). American Television & Communications (Englewood, CO) is making plans to recable one of its urban operations to bring optical fiber backbones from the antenna to several local hubs, with the final delivery to customers by conventional coax. That installation is likely to employ VSB-AM analog signals and one or two low-cost lasers per fiber to deliver approximately 40 NTSC TV channels. Since no subscriber would be more than four (coax) repeater-spans away from the fiber hub, the renewed system is expected to improve the quality and reliability of the delivered TV picture and to reduce maintenance costs.

An additional attraction of fiber for future cable TV systems is the relative ease of upstream transmission in a fiber network, again resulting from the low signal attenuation and the absence of repeaters.

It should be noted that, for the most part, it is anticipated that fiber-optic TV delivery systems will terminate at the home or apartment building. Copper-based cabling is likely to be used within the dwelling units.

Recent developments in fiber-optic systems and devices for telecommunications are reviewed in reference [7]. A brief summary of aspects of fiber delivery of ATV compared with alternative transmission media is given in Appendix 1.

RELEVANCE OF FIBER-OPTICS TO ADVANCED TELEVISION

It is a well-demonstrated fact that optical fiber technology can provide sufficient transmission bandwidth to permit the emission of a multitude of advanced television signals. In addition, new levels of picture reception quality can be achieved, due to the noise immunity and the low attenuation of fiber-optics. The principal concerns relating to the implementation of fiber-optic local access networks are costs of the electronic and opto-electronic terminating equipment and of the installation of the optical fiber.

Cable installation costs are, of course, the major barrier, especially since copper coaxial cable already exists in much of the country, while fiber installations to residential end-users are only beginning (see Appendix 2). The magnitude of this cost barrier would decrease or possibly even disappear if a coax system is ready for rebuild or, more generally, if the costs eventually required for upgrading copper coax systems to true high definition TV capability turn out to be considerable.

There are indications that -- aside from cable installation -- the first-costs of fiber CATV systems may be commercially tolerable. GTE Laboratories (Waltham, MA) has demonstrated an FM analog system carrying 60 NTSC TV channels with 56dB signal-to-noise on a single 18-km long fiber [8]. The basic technique -- subcarrier multiplexing -- is similar to that used in satellite TV transmission, with the multiplexed microwave (electrical) signal driving a fiber-connected laser, rather than a satellite antenna. At the receiver a photodiode changes the optical signal back to electronic form and a block converter (one per building) shifts the microwave signal down from microwave to RF bands. As in satellite home receivers, an additional converter stage is needed to transform the FM signals to AM [9]. One company has announced low-cost FM-AM converters suitable for cable TV use [10].

Subcarrier multiplexed fiber-optic systems can also transmit information in digital form by frequency-shift-key modulation of a subcarrier. Combined digital and analog transmission has been demonstrated by GTE Labs, as well, which makes this type of optical system compatible with both telephone <u>and</u> cable TV operations. GTE estimates that with subcarrier multiplexing there is sufficient capacity within the 2-6 GHz band to carry 50 analog NTSC channels (2 GHz), 4 digital video channels (800 MHz), 4 HDTV channels (800 MHz) and 25 digital audio channels (200 MHz) -- with 200 MHz remaining for narrowband services, such as voice and data.

A 21-channel digital version of the GTE Labs system is to be part of a planned demonstration by General Telephone in Cerritos, CA, if legal and regulatory concerns can be overcome.

The need for signal security (e.g., scrambling or encryption of pay services) does not appear to raise any distinctive problems for fiber, either in analog or digital embodiments.

ISSUES RELATING TO FIBER DELIVERY OF ADVANCED TV TO END-USERS

The technical issues relevant to the use of fiber-optics for transport of advanced TV to residential and other end-users will be discussed initially. This will provide some timing context for the commercial issues, which will then be discussed.

Technical issues

SYSTEM SELECTION: As can be seen from the foregoing (and Appendix 2), there are a number of quite different types of systems presently under development and evaluation.

If digital techniques are to be used, there are a number of fundamental system options:

A. Switched star networks, where a limited number of TV signals could be carried simultaneously over the fiber that leads to a given household. The viewer would send a message upstream to request the specific programming to be transmitted. Switched systems are particularly natural for telephone companies, thus a laboratory development and evaluation of a four-channel, 600Mbps switched system is presently underway at Bellcore [11].

B. Multiplexed systems carry all of the TV signals simultaneously, with channel selection done essentially at the TV receiver, as is the case in present coax TV cable systems. Multiplexing can be done either by using different laser wavelengths (wavelength division [12]) or by assigning different time slots (time division [13]) for each TV channel. In the former, tunable filters will be needed; in the latter, very high bit-rate devices will be required.

C. Coherent systems, a special class of multiplexed systems, use heterodyning techniques analogous to those common in radio, but extended to the optical domain. These systems truly access fiber's enormous bandwidth, but will require stable, tunable devices that exist at present only in the form of relatively bulky and expensive laboratory objects [14].

If analog techniques are deemed preferable for ATV delivery, there is still the question of FM vs AM signal type. FM appears to permit a larger number of high-quality channels (appropriate for ATV) to be transmitted, but is not directly compatible with the existing receiver base, if this is required.

INTERFACES AND STANDARDS: For digital transmission, three issues must be addressed:

A. What coding/decoding scheme is to be used for fiber transport. This determination is necessary before low-cost codecs can be developed.

B. What are the specific characteristics of the digital bus inside the ATV receiver. Since all of the ATV receivers will be based on digital signal processing, digital transport could be compatible with direct access of the selected TV channel signal to the digital bus.

C. If it is determined that an ATV emission system should be compatible with switched telephone systems, then broadband telecommunications standards are needed, as well, to define the nature of the digital data stream on the fiber.

For analog emission, a receiver interface standard will be needed, perhaps including an FM-to-baseband converter.

Commercial issues

COMPETITION: The principal questions to be resolved are: who will install a fiber-optic TV delivery system and who will provide the TV program services. Regulatory issues aside, both telephone companies and present cable TV companies are capable of installing and operating a fiber-based TV system. Other types of private companies and public utilities could play those roles, as well. Additionally, a telephone company could install and maintain the fiber system, to provide tariffed transport of programs assembled by a "cable TV" company [15].

It is conceivable, as well, that a cable operator could install fiber all the way to end-users. In that event the cable company could provide residences and businesses with alternative access to interexchange carriers (in partial bypass of the local telco). Since telephone companies have traditionally been highly effective at operating and maintaining large, complex, high-quality networks and at providing sophisticated billing functions, however, it might eventually make commercial sense for the cable company either to sell the fiber plant to the telco, with long-term guarantees for transport of the cable company's TV programming or to contract with a subsidiary of the telco for maintenance and billing services. Of course, other scenarios are possible, as well (Appendix 3).

Subsidiary, but critically important questions relate to (1) the regulatory and legal barriers to telephone company involvement in broadband services like TV and (2) the role of broadcasters.

INVESTMENT: The installation of fiber-optic local networks nationwide will clearly require major capital investments. It is important to analyze the situation from a national viewpoint to better understand how that investment could be achieved and to determine if significant efficiencies can be obtained. Some facts appear to be emerging:

A. At least two of the regional telephone holding companies (Bell South and Southwestern Bell) have stated publicly that by the early 1990's they expect fiber to be the cost-justified medium for new installations <u>based on basic telephone services only</u>. Thus we can expect that -- even with no other incentives -- local telephone connections by fiber-optics in the US will grow at the new-home rate (1-2 million households per year) beginning in the 1990's.

B. The cost of a fiber <u>over-build</u> to existing end-users, on the other hand, would be justified only if there were reasonable expectations for sufficient additional revenues that would accrue to the phone companies, resulting either from provision of or transport of the new broadband services made possible by fiber-optic systems (e.g., high definition TV, interactive video, video games, video reference services, etc).

C. Thus, if the telephone companies are prohibited from participating in any of these additional revenue opportunities, local fiber telephone networks will grow in the US, but at a relatively slow rate.

D. Other countries are making commitments to install nationwide fiber-optic networks. In particular, NTT of Japan has programmed a national fiber overbuild (at a cost estimated at $80B in 1987); several European countries are building fiber overlay networks. Two aspects of this international effort are particularly threatening to US competitive stature:

In the course of these constructions, considerable technical and commercial expertise will be acquired that will benefit these countries' domestic producers in the massive fiber-optic installations that will be taking place throughout the world during the next two decades.

The inherent operational utility of these nationwide broadband networks will be of great competitive advantage to these countries, as well.

Since any rebuild of the existing copper coaxial cable TV system to permit transport of ATV will entail considerable expenditures, when viewed on a national scale, it is clearly worth investigating the efficacy of applying that same investment toward a US broadband fiber network.

It should be noted that if the telephone companies are barred from providing TV program services, there still remain considerable revenue opportunities for them in other video services, as well as in TV transport. On that basis, fiber overbuilds could be cost-justified. If, on the other hand, telephone companies are denied any revenues from broadband services, then it is likely that for the foreseeable future they will be able to install fiber only for new residential installations and for larger commercial users, thus delaying by decades the availability of an integrated broadband network in the US.

APPENDIX 1: COMPARATIVE SUMMARY OF TRANSMISSION MEDIA FOR ATV

Table 1 lists the basic advantages and disadvantages of each of the alternative media for transmission of ATV signals. In many cases, there will be exceptions to these generalized statements. Thus this appendix should be viewed as merely a starting point in comparative evaluations.

APPENDIX 2: FIBER/TV TRIALS

Telephone companies on three continents have either initiated or announced trials of fiber networks to deliver both telephony and TV signals to residences, as listed in Table 2. In the US trials -- excepting the one case noted -- the telephone company provides only transport of the TV signals from an independent CATV operator.

Table 1. General comparison of transmission media for advanced TV

MEDIUM	**ADVANTAGES**	**DISADVANTAGES**
BROADCAST	In-place Compatible with installed base of receivers	Spectrum limits Interference Picture quality
FIBER-OPTICS ANALOG	High bandwidth Low cost optical components EMI immunity Few, if any repeaters Possible connection to phone system	Little experience Cable installation cost Set-top converter, if FM Limited distance (<20km)
FIBER-OPTICS DIGITAL	High bandwidth Noise immunity No noise build-up Easy integration with telephone system Nationwide distrib'n network	Little experience Cable installation cost Higher component costs Needs digital port in ATV receivers, converter for NTSC rcvrs
COAXIAL CABLE	Installed cable system Residence access base	Wideband amplifiers Repeater maintenance Noise build-up System reliability
SATELLITE (DBS)	Available bandwidth Low-cost electronics	Requires dish antenna Possible power limits

APPENDIX 3: SCENARIOS FOR IMPLEMENTATION OF FIBER-OPTICS FOR ATV

I. Cable TV company installs optical fiber local distribution network

I-A. Cable company retains ownership and operates system

A local cable franchise holder sees that he will have to make a substantial investment to re-equip his coax system to carry high definition TV with suitable picture quality and a sufficient number of channels. The prospective investment might include new broadband amplifiers, reduction of reflections, possible FM-to-AM converters, etc. He is aware of the long-term promise of fiber-optics and he knows of certain CATV installations where fiber has reduced operating costs and increased customer satisfaction. He decides to invest in fiber, so that he will never again need to upgrade his cable plant.

Because his distribution is repeaterless, he is able to offer bidirectional services [16], such as interactive video, for his customers by providing a point-of-presence for an interexchange carrier on his network. He receives additional revenue from this extra capability and his customers enjoy new forms of recreation, communication and learning.

I-B. Cable company sells the fiber system to the local telephone company, with lease-back agreement for transport of CATV signals

The local telephone company sees an opportunity for additional new revenues in broadband services over its switched net-

Table 2. Fiber to-the-home trials that include video services

Telephone company	Location	Equipment supplier	Start date	Comments
UNITED STATES				
Southern Bell	Hunters Creek, FL (Orlando area)		1987	New housing devel; Switched CATV
Southern Bell	Heathrow, FL (Orlando area)	Northern Telecom	3/89	Upscale new devel; 3 simult TV chnls, 54 chnls avail, ISDN
General Telephone	Cerritos, CA (5000 units)	GTE, others	late'88	20 chnl CATV transport; Video-on-demand*
Bell of Pa.	(New develm't, 2000 units)	Alcatel Sitcom		Multimode fiber, LED's for local drop
OTHER COUNTRIES				
MITI (Japan)	Higashi-Ikoma	NEC,Hitachi others	1978	HI-Ovis; 2-way
Bell Canada	Yorkville, Ont	No. Telecom	1978	Multimode fiber
Manitoba Tel (Can)	Ste Eustache & Eli, Manitoba	No. Telecom	1981	Canadian Dept of Communications
Deutsche Bundespost (W. Germany)	6 major cities	Siemens,SEL others	1983	BIGFON; fiber overlay
France Telecom	Biarritz	SAT	1984	Includes 2-way video

* Planned by General Telephone, subject to regulatory approval.

work, but it knows that these revenues cannot support the construction of a second fiber network in the locality. It offers cash to the CATV operator, takes over the operating and maintaining of the physical network, provides a long-term agreement to the cable company for transport of the TV signals to his customers, and includes billing and collection services. The cable operator ends-up with a television business without many of the headaches; the telephone company obtains a fully-connected fiber loop plant [17].

II. The local telephone company builds and operates the fiber network

II-A. Telco provides only transport of television signals

Legal and regulatory barriers may continue to prohibit telco's from providing broadband services, but the transport of such services over a telco's fiber network at tariffed rates may be permitted. Thus, if a tariff can be established that is attractive to the local broadband and cable TV service providers, a fiber overbuild (or a partial overbuild, such as fiber supertrunks) by the telco may be justifiable. The telco is more likely than a CATV company to have the large financial resources for such an investment, but its local regulators will need to be convinced that the investment will not burden the basic telephone ratepayers. Fiber delivery of high definition TV and other broadband services could provide that justification.

It is important to note that -- once a telephone company provides a broadband pathway between its residential customers and the national public network -- then a number of programming providers (e.g., premium entertainment channels, motion picture studios, even TV networks) can sell programming directly to these households by a dial-up telephone connection. Needless to say, this would radically change the nature of the "cable TV" industry.

II-B. Telco's are permitted to provide broadband services

If there are no restrictions on the services that can be delivered by the telephone company, then it should be able to justify the costs of the fiber network installation. This would result either in head-to-head competition with the local CATV operator, possibly including double network builds, or some accommodation between the two parties. In this scenario, it is difficult to envision self-supporting roles for all three of the present participants: broadcasters, cable operators and telco's.

III. Alternative network implementers

There are other industries or individuals who could possibly start construction of fiber local networks. Included among these would be:

Local private service companies and utilities (electric companies, teleports)

Private investors, forming a "new industry"

Broadcasters, not wanting to allow themselves to be closed out from the opportunities in true high definition TV.

ACKNOWLEDGEMENTS

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2. Generally, each of these cables carries from 24 to 36 fibers.

3. Telephone companies guarantee bit error rates one-thousand times better on fiber routes that on copper.

4. Many major industrial plants and corporate offices are already connected directly by fiber to public and private networks. In lower and midtown Manhattan, fiber loops are in operation both by New York Telephone, the local phone company, and by independents.

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15. In Cleveland, Ohio the cable TV system is being installed by Ohio Bell, the local telephone company, according to the system implementation plan of a cable TV MSO (Viacom), with eventual purchase or lease-back of the system to a group of local investors who hold the cable TV franchise.

16. It must be pointed out that these interactive services could not be provided in a fiber system configured in the conventional CATV tree-and-branch architecture with passive taps -- some form of switching would be required.

17. In order for this system to be potentially attractive to the telco, it would have had to have been constructed to some approximation of telephone company standards, including, for instance, at least the provision for controlled environment vaults at major junctures.

FM DEMODULATORS FOR BTSC STEREO

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ABSTRACT

Of the many kinds of FM demodulators, two types have been commonly used to demodulate television aural carriers modulated with BTSC stereo: quadrature demodulators and pulse-count demodulators. These two types of demodulators are described. Waveform plots are used to illustrate the operation in a qualitative and intuitive way. The relative advantages and disadvantages are discussed. In particular, cost/circuit complexity, noise, and sources of distortion are considered in some detail. The effect of these parameters on BTSC stereo is discussed.

INTRODUCTION

Through the history of FM, several different types of circuits have been used for FM demodulation. Some, like discriminators and ratio detectors, were particularly appropriate to times when passive circuits were less expensive than active circuits. Others, such as phase-locked-loops, quadrature demodulators and pulse-count demodulators became practical with the availability of inexpensive transistors and integrated circuits.

The low FM threshold of the phase-locked-loop demodulator has made it popular in applications where carrier-to-noise ratio is marginal. In television transmissions, however, carrier-to-noise ratio is limited by video quality long before the audio approaches threshold.

Two types of FM demodulators have been widely used for recovering BTSC stereo; the quadrature demodulator and the pulse-count (or pulse-averaging) demodulator. This paper will concentrate on these two types of demodulators.

QUADRATURE DEMODULATORS

Figure 1a. shows a block diagram of a quadrature demodulator. The name quadrature comes from the fact that a network with a 90 degree phase shift at the carrier frequency is used. At the input of the demodulator, the signal is split into two paths. Part of the signal goes directly to one input of an AND gate or multiplier. The rest of the signal passes through the phase shift network before getting to the other input of the AND gate. The output of the AND gate is passed through an integrator to average the signal (low-pass filter it) and recover the baseband.

The effect of the phase shift network is shown in Figure 1b. The signal passing through the network is shifted in phase by an amount depending on its deviation ($\Delta\omega$) from the carrier center frequency (ω_0). A carrier at center frequency ($\omega - \omega_0 = 0$) is shifted by 90 degrees. A carrier at higher than center frequency is shifted by less than 90 degrees, and so on.

To illustrate how AND'ing the original signal with the phase shifted version provides FM demodulation, we consider three separate cases. Square waves are used for clarity.

- Figure 1c shows the case in which the instantaneous frequency (ω) is at the carrier center frequency (ω_0). The phase shift between the two AND inputs is the nominal 90 degrees. The output of the multiplier is HIGH whenever both inputs are HIGH as shown in the output pulse-train. After integrating we get the average voltage of the pulse-train as shown by the dashed line in the output waveform.
- Figure 1d shows the case in which the instantaneous frequency (ω) has been deviated to less than the carrier center frequency (ω_0) until the phase shift between the gate inputs is > 90 degrees. The pulse-train out

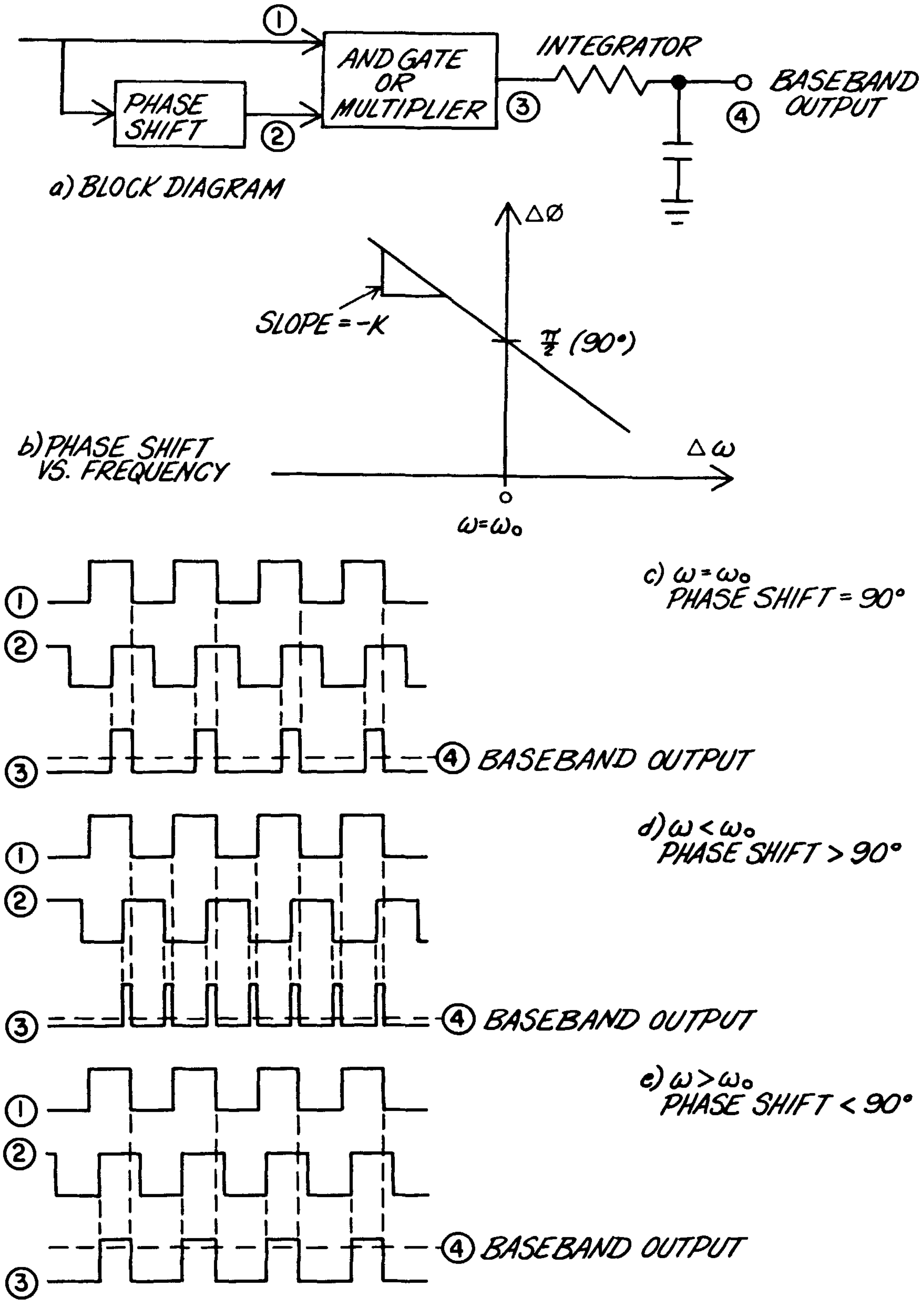


FIGURE 1. QUADRATURE DEMODULATOR

of the gate has a duty cycle that is lower than the previous case, and consequently the average voltage decreases.

- Figure 1e shows the remaining case, in which the instantaneous frequency (ω) has been deviated to greater than the carrier center frequency (ω_0), until the phase shift is < 90 degrees. After integrating, the average voltage is seen to be increased over that in the previous two cases.

We see that as the carrier deviates below and above the carrier center frequency the output voltage swings lower and higher than the nominal value. This provides the frequency-to-voltage conversion required for FM demodulation.

Advantages

Low cost is a major advantage of quadrature demodulators. Specialized integrated circuits are available that have built-in intercarrier detectors, limiters, quadrature demodulators and audio amplifiers.

The output level from a quadrature demodulator is proportional to the "steepness" of the phase slope, or k in Figure 1b. This allows a high output level from the demodulator itself. This high demodulator output level aids in overcoming device noise from the active components. Thus quadrature demodulators usually provide good output signal-to-noise ratio. Passive networks can be built which can provide steep phase slopes at 4.5 MHz, making further downconversion unnecessary. Circuit complexity is consequently reduced even further when compared to most pulse-count demodulators.

Disadvantages

The one significant disadvantage of quadrature demodulators is their somewhat higher distortion when compared to pulse-count demodulators. There are two causes of this distortion. The first is less significant, but fundamental to the operation of the quadrature demodulator. To show this let the phase shift at the shifted multiplier input be represented by the slope-intercept formula for a line

$$\Delta\phi=-k(\omega-\omega_0)+\frac{\pi}{2}$$

$$\Delta\phi=-k\Delta\omega+\frac{\pi}{2} \qquad (1)$$

where

ω_0 is carrier center freq.
ω is instantaneous freq.
$\Delta\Phi$ is phase shift relative to unshifted input
$-k$ is slope (units:seconds)

This is the equation for the plot of Figure 1b.

At the multiplier, for sinusoidal inputs

$$\begin{aligned}Vout&=A\sin(\omega t)\times A\sin(\omega t-k\Delta\omega+\frac{\pi}{2})\\ &=A^2\sin(\omega t)\times\cos(\omega t-k\Delta\omega)\end{aligned} \qquad (2)$$

Carrying out the multiplication yields a baseband component

$$Vout=-\frac{A^2}{2}\sin(k\Delta\omega) \qquad (3)$$

At this point an approximation is used

$\sin\theta\cong\theta$ for small θ

to get the ideal transfer function for an FM demodulator.

$$Vout\cong-\frac{A^2}{2}k\Delta\omega \qquad (4)$$

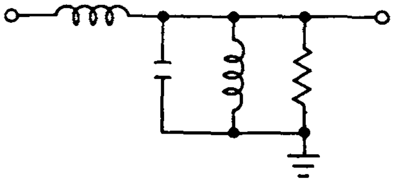
Note that even if k is exactly constant, (i.e. slope is perfectly linear) some distortion is inherent in this technique due to the sine approximation.

But the phase slope k is not constant, as we shall now show. Figure 2a shows a typical single-tuned 90 degree phase shift network. Figure 2b shows the phase response of the network. Note the slight curvature of the phase slope. Group delay is the first derivative of the phase, and as such gives a convenient measure of phase curvature. If the phase slope were perfectly linear, group delay would be a constant. Figure 2c shows the group delay of this network to have a peak-to-peak variation of about 280 nsec.

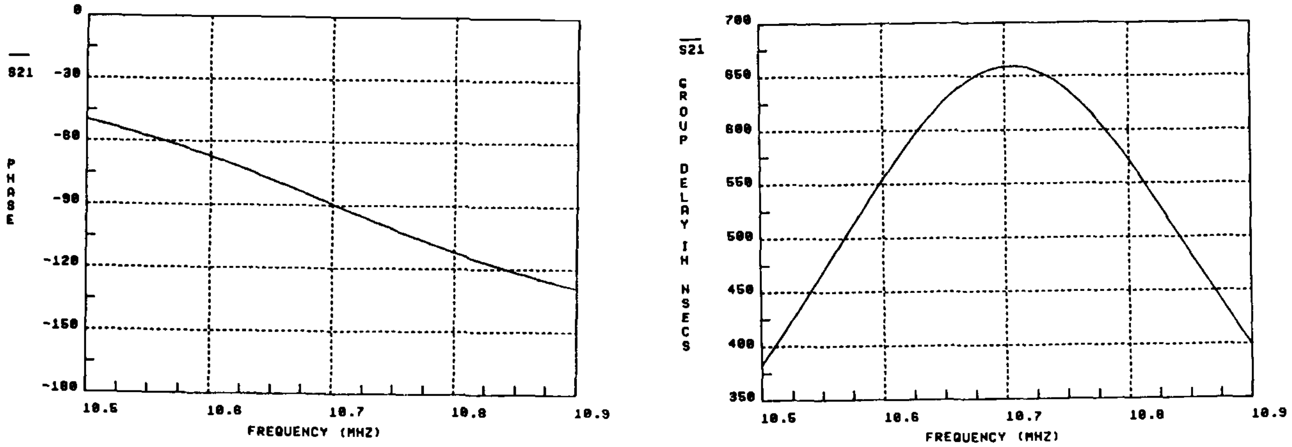
In order to linearize the phase, improve the distortion and increase the output level, a double-tuned network could be used. Figure 3 shows one such network. Note that the phase slope has now increased and become more linear. The group delay has been reduced to about 55 nsec peak-to-peak. Inductive coupling instead of capacitive coupling between the tanks was used to flatten the group delay.

Equation (4) gave the ideal transfer function of a FM demodulator. We would now like to examine the distortion resulting from the phase shift network nonlinearity. An analysis will be done

FIGURE 2



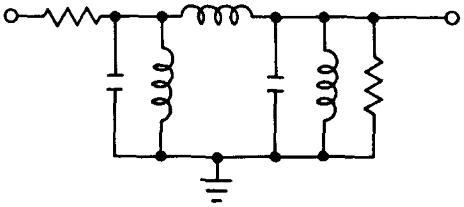
a) Single-Tuned Phase Shift Network



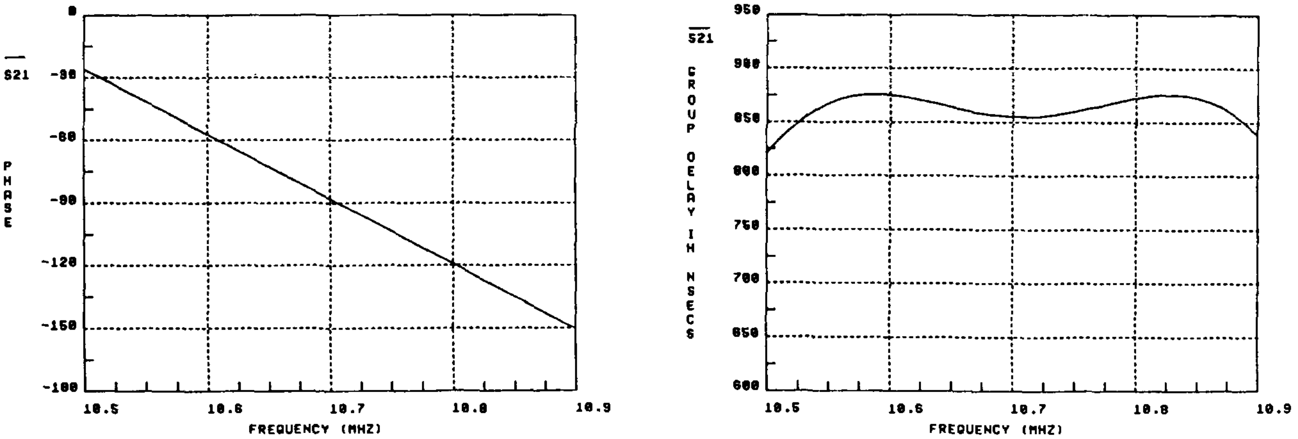
b) Phase Response

c) Group Delay

FIGURE 3



a) Double-Tuned Phase Shift Network



b) Phase Response

c) Group Delay

that is very similar to that in reference [1]. In that paper the effect of amplifier nonlinearity was studied in the presence of three carriers. The input was a voltage and the output was a voltage. We will generalize this approach to the case of a nonlinear FM demodulator, where the input is a frequency deviation ($\Delta\omega$) and the output is a voltage.

We can express the transfer function for the quadrature demodulator in a different way.

$$Vout=k_1\Delta\omega+k_2\Delta\omega^2+k_3\Delta\omega^3 \qquad (5)$$

where, rather than using a constant k, as we did in equation (4), we use a power series expansion to model the nonlinear phase response.

Now, as an input to this network, let us use an expression for the instantaneous frequency deviation of the carrier as a function of three individual input signals.

$$\Delta\omega=A\cos\omega_a t+B\cos\omega_b t+C\cos\omega_c t \qquad (6)$$

where the term in
- A represents a signal in the sum channel,
- B represents the pilot, and
- C, in a simplified way, represents a signal in the difference channel.

This composite input is substituted in the transfer function in (5). The resulting expression is expanded, and if we collect terms by order, we get the results shown in Table 1. This table should look somewhat familiar to CATV engineers accustomed to dealing with distortion products in high level distribution amplifiers.

Note the frequency column in Table 1. This column gives the frequency of the distortion products. The important point to be made here is that due to nonlinearities in the FM demodulator transfer function, signals are produced that fall in channels other

TABLE 1

DISTORTION PRODUCTS

ORDER	FREQUENCY	PEAK AMPLITUDE	DESCRIPTION
1st	fa	k_1A	desired
"	fb	k_1B	"
"	fc	k_1C	"
2nd	dc	$1/2\ k_2(A^2+B^2+C^2)$	dc shift
"	2fa	$1/2\ k_2A^2$	2nd Harmonic
"	2fb	$1/2\ k_2B^2$	"
"	2fc	$1/2\ k_2C^2$	"
"	fa+/-fb	k_2AB	Beat Products
"	fa+/-fc	k_2AC	"
"	fb+/-fc	k_2BC	"
3rd	3fa	$1/4\ k_3A^3$	3rd Harmonic
"	3fb	$1/4\ k_3B^3$	"
"	3fc	$1/4\ k_3C^3$	"
"	2fa+/-fb	$3/4\ k_3A^2B$	Intermodulation
"	2fa+/-fc	$3/4\ k_3A^2C$	"
"	2fb+/-fa	$3/4\ k_3B^2A$	"
"	2fb+/-fc	$3/4\ k_3B^2C$	"
"	2fc+/-fa	$3/4\ k_3C^2A$	"
"	2fc+/-fb	$3/4\ k_3C^2B$	"
"	fa+/-fb+/-fc	$3/2\ k_3ABC$	Triple Beat Products
"	fa	$3/4\ k_3A^3$	Self Compression/Expansion
"	fb	$3/4\ k_3B^3$	"
"	fc	$3/4\ k_3C^3$	"
"	fa	$3/2\ k_3AB^2$	Crossmodulation
"	fa	$3/2\ k_3AC^2$	"
"	fb	$3/2\ k_3BA^2$	"
"	fb	$3/2\ k_3BC^2$	"
"	fc	$3/2\ k_3CA^2$	"
"	fc	$3/2\ k_3CB^2$	"

than those where they originated. Thus pilot and sum frequencies can cause signals in the difference channel. Sum and difference frequencies can cause products in the SAP channel, and many other combinations. Dr. J. James Gibson [2] has compiled a comprehensive table of the possible combinations and the channels that they affect. Suffice it to say that distortion of a composite signal such as BTSC stereo has a more convoluted effect than distortion in single channel audio.

This discussion on distortion due to nonlinearity of the phase shift circuit applies equally to other FM demodulators that depend on a network to establish a linear transfer function. This can be the frequency slope in a discriminator or the frequency-vs-control voltage function in a phase-locked-loop FM demodulator.

The availability of encompassing "jungle" IC's with most of the components necessary for a full demodulator makes the quadrature demodulator difficult to ignore for consumer applications, despite the somewhat higher distortion.

PULSE-COUNT DEMODULATORS

Figure 4a shows a block diagram of a pulse-count demodulator. The term pulse-count is probably a misnomer, because no counting actually occurs. The name "pulse-averaging demodulator" is sometimes used and is more descriptive of the operation of the circuit. A one-shot is triggered on every rising edge of the limited FM carrier. The output of the one-shot is a pulse that lasts for one half-cycle of the unmodulated carrier. To illustrate the operation we again consider three separate cases.

- Figure 4b shows the case in which the instantaneous frequency (ω) is at the carrier center frequency (ω_0). The output of the one-shot is a pulse-train of 50% duty cycle. After integrating we find that the average voltage of the pulse-train is halfway between the top and the bottom.
- Figure 4c shows the case in which the instantaneous frequency (ω) has been deviated to less than the carrier center frequency (ω_0). The pulses out of the one-shot are the same width as before, but now the time between them has increased. After integrating, we find the average voltage to be less than in the previous case.
- Figure 4d shows the remaining case, in which the instantaneous frequency (ω) has been deviated to greater than the carrier center frequency (ω_0). Now after integrating the average voltage is seen to be increased over that in the previous two cases.

Advantages

Again we see that as the carrier deviates below and above the carrier center frequency the output voltage swings lower and higher than the nominal value, thus providing the required frequency-to-voltage conversion for FM demodulation. In theory significant distortion does not occur until the carrier is deviated to twice the center frequency. Effectively, all the distortion in a carefully designed demodulator using a pulse-count demodulator is due to group delay in the preceding filters. This makes the pulse-count demodulator an excellent choice for applications involving high percent deviations or in very low distortion applications.

Disadvantages

Unfortunately, even with the relatively wide deviations of BTSC stereo, the percent deviation at 4.5 MHz is somewhat low at

100 x 73 kHz/4.5 MHz = 1.6%.

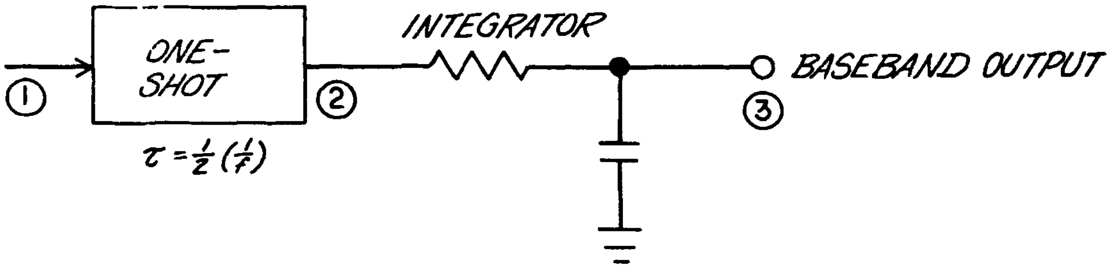
This normally results in a low output level from the demodulator. More baseband gain is required, and whatever noise accompanies the signal is also amplified.

The usual solution (not the only solution) to this problem is to further downconvert to a lower IF frequency, often about 1 MHz. This increases the percent deviation to

100 x 73 kHz/1 MHz = 7.3%

which is somewhat easier to deal with.

This solution is not without significant penalty, however. Circuit cost and complexity is increased by the requirements for another mixer, oscillator and IF bandpass filter. A less obvious problem is that the baseband filter now has to reject the much lower IF at 1 MHz while passing the composite BTSC waveform out to 110 kHz. Maintaining the recommended flatness of +/- .05 dB for monitoring and measurement equipment through such a filter becomes a more difficult task than with a final IF at 4.5 MHz.



a) BLOCK DIAGRAM

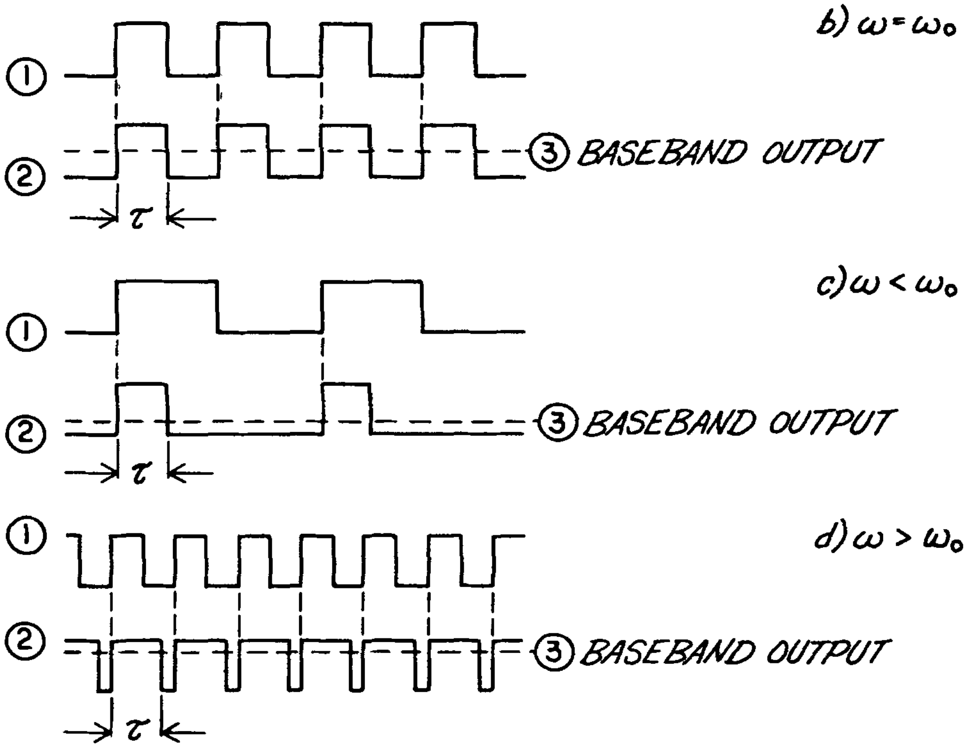


FIGURE 4. PULSE-COUNT DEMODULATOR

The very low distortion but higher cost and complexity of the pulse-count demodulator makes it better suited for applications in professional monitoring and measurement, as opposed to consumer equipment.

FURTHER CONSIDERATIONS

Although noise is always an important consideration, two factors combine to make it less significant in BTSC stereo than one might expect. The carrier to noise ratio required for the video usually puts the audio well above FM threshold. Also, the dbx[1] noise reduction used in the difference channel effectively masks an otherwise objectionable noise floor in marginal reception conditions.

Buzz is normally a much more significant concern in BTSC stereo than noise. Sources of buzz in television audio have been covered in the literature [2],[3]. This paper has concentrated on the FM demodulator itself and not on the associated circuitry and receiver architecture. It is mostly up to the associated circuitry and system and architecture choices to reject buzz and phase noise.

But it is also important that the FM demodulator not contribute to the buzz problem. Good AM rejection in the limiter and demodulator is important here, particularly in the presence of audio carrier tag and timing pulses often used in cable security systems. The pulse-count demodulator, being essentially a digital circuit, has inherently good AM rejection. Phase-locked-loop demodulators can also provide good protection against AM.

The importance of maintaining good frequency response flatness and good phase linearity in the demodulator and subsequent circuits cannot be overstated. For monitoring and measurement applications a flatness of +/- .05 dB and phase deviation < +/- .5 degree from linear is required to maintain sufficient stereo separation in the system [4]. In some cases the internal audio amplifier in an IC may limit the achievable response.

CONCLUSION

Quadrature demodulators and pulse-count demodulators are commonly used to demodulate BTSC stereo carriers. These two types of demodulators were described. Waveform plots were used to illustrate their operation. The effect of different performance parameters on BTSC stereo was discussed.

Low cost, good noise performance and integrated circuit availability combine to make the quadrature demodulator a good choice for consumer products, despite its somewhat higher distortion. For the ultimate in low distortion at the price of increased circuit complexity and cost, the pulse-count demodulator is difficult to equal. For this reason pulse-count demodulators are found in professional monitoring and measurement equipment.

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1. dbx is a registered trademark of dbx inc.

HDTV: Cable's Opportunity for the Future

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American Television and Communications

Paul Heimbach
Home Box Office

Abstract

High Definition Television (HDTV) will be available within this country by the early 1990's. All broadcast media including terrestrial broadcasters, cable operators, DBS and telco are formulating plans on how to best accommodate HDTV in their environments. At American Television and Communications (ATC) and Home Box Office (HBO) efforts are being made to encourage the development of HDTV systems that are optimized for CATV carriage. A cable aware HDTV system must take into account existing practices within the cable industry including satellite delivery, interconnect systems, scrambling and security concepts, in addition to the basic coax system and its inherent signal transmission characteristics[1].

What is HDTV?

High Definition Television (HDTV) has the potential to be the most significant development in the home-entertainment arena since the introduction of color television. A large-screen video medium, HDTV will be able to deliver a TV picture vastly superior to any picture on the air today, with multi-channel, digital-quality sound to match. The introduction of this advanced video technology will undoubtedly lead to new technical standards of quality in broadcast and cable.

Perhaps the best indication of the scope of HDTV's recent development can be measured by tracking the 35 equipment manufacturers currently selling second-generation HDTV production and studio display equipment, the adoption by the Advanced Television Standards Committee (ATSC) and the Society of Motion Picture and Television Engineers (SMPTE) of a HDTV Production standard, the ongoing work of at least a dozen transmission standards, and the FCC Advisory Committee on Advanced Television Systems (ATS). And if we track the evolution of the VCR and CD player, it appears likely that an HDTV system, composed of an HDTV television and VCR/optical disk player, will be introduced into the consumer marketplace within one to two years. Accordingly, some form of HDTV programming will be in consumer homes within two to three years, with software delivered via the same combination.

The potential impact of this new medium on the cable industry is largely in the hands of the industry itself. Clearly, the choice for the cable industry is to grow with the new medium or lose customers to it. Without the cable industry's involvement in the early developmental stages, HDTV technology will be defined by manufacturers or agencies not sensitive to cable's needs, which ultimately will result in the same kind of incompatibility problems we as an industry experienced with "cable-ready TVs," connection of VCRs in scrambled systems, and delivery of BTSC-MTS stereo.

To develop uniform TV standards, the first National Television System Committee (NTSC) was formed in 1940, and by mid-1941, the committee recommended to the FCC the basic black-and-white television format in use today: 1) 525 lines per frame, 2) 30 frames per second, 3) 2:1 line interlace of fields to frames and 4) a 4:3 aspect ratio of picture width to height.

In 1953 a second NTSC proposed to the FCC a color-television system that was compatible with the then existing black-and-white television transmission standards and the existing base of 25 million black-and-white television sets. To achieve compatibility, black-and-white television sets experienced a small loss in resolution and picture degradation. The FCC approved this compatible standard and 34 years later it continues to be the standard.

With the unexpected, rapid emergence of HDTV on the horizon, the FCC issued a Notice of Inquiry (NOI) on Advanced Television Services in July 1987 and formed the FCC Advisory Committee on Advanced Television Systems. The Advisory Committee has an 18 month life, during which it is to explore all issues relevant to improved television service and, if possible, specify the characteristics and attributes to be included in a such a system. It is possible that a standard to which broadcast ATS systems must be built will evolve through this process, or perhaps a single proposal will be chosen. It is very important to remember that the NOI and the FCC Advisory Committee are addressing transmission or delivery issues as they relate to the over-the-air broadcasters and Alternative Media Technologies such as Cable, Satellite, Fiber, Microwave (AML, FML, MDS) and VCR/Disk. The question of a single standard or multiple standards (one for each media) is also being considered.

Although the FCC and other organizations will be studying a possible range of ATS system performance, the ultimate goal is that of achieving what is commonly referred to as "HDTV". As one engages in discussion of what constitutes HDTV, it often seems as if HDTV stands for Hard to Define TV! However, to justify the expense of this service to programmers, consumers, and equipment manufacturers, it must offer substantive and highly visible improvements over the 34-year-old NTSC color system in use today. This distinction must be a least as dramatic as the difference between black-and-white television and color-television in 1953. These differences can be categorized as follows:

1. Increased horizontal and vertical detail and resolution: Increased horizontal and vertical resolution allow better image reproduction by displaying more detail and truer color rendition. The viewer experiences a sense of reality as if watching a live scene through a clean window. Picture detail is also important when the image is displayed on a large screen such as a home-projection television system or in a movie theater.

2. Aspect ratio or screen shape: NTSC televisions' pictures are almost square, with an aspect ratio (picture-width to picture-height) of 4:3. This shape is a carry over from television's early development when movie theaters showed films with that frame shape. The aspect ratio of films today is about 1.85:1. By incorporating this aspect ratio into the HDTV system, existing film product can be displayed in its original composition without the need to make editorial judgements, such as pan and scan, over the product. What's more, this aspect ratio opens up interesting possibilities for today's programming - particularly sports - by providing a more compelling view of the event.

3. Large television screens: The emergence of large-screen television has virtually dictated demand for HDTV. The current NTSC system displays a fuzzy, less than ideal image when displayed on a large screen. In contrast an HDTV image can be expanded considerably before detail is lost, which makes it particularly well suited for consumers' large-screen televisions, theatrical display and audience presentations.

4. High-quality multi-channel sound: High quality multi-channel sound enhances the viewing experience. Surround sound concepts are already available for advanced quality consumer VCR and Disk systems. With the popularity of digital audio, as the Compact Disc and the upcoming Digital Audio Tape systems have illustrated, the consumer will expect digital audio in the next generation TV system.

5. Reduction of artifacts found in the current television system: The current NTSC system is plagued with image degradation called "artifacts", which greatly reduces the picture quality. These artifacts result from the NTSC 1953 requirement to have compatible color and black-and-white systems. Some of these artifacts, such as the rainbow effect seen on plaid jackets, are visible to the untrained viewer. Today's technology coupled with the overall movement to improve television transmission systems provides an opportunity to recover from the compromises made in 1953.

Market Research

Market research regarding US consumers general interest in HDTV systems has been conducted by several organizations, such as MIT, over the period of the last few years. Recently, cable customer oriented research has been conducted by ATC and HBO. HBO conducted a series of demonstrations coupled with specific questions during October 1987, with ATC conducting focus groups in February 1988. Both these efforts must be considered preliminary because, as with any new consumer technology, appropriate testing methods are still being understood by the research community. It is particularly difficult to separate variables such as screen size and picture brightness from the overall perceived quality of the image. Sound reproduction also plays an important role in the quality of the viewing experience.

HBO has analyzed its side by side test of very high quality NTSC vs. the MUSE HDTV system, displayed on the same height screens (26" NTSC and 28" HDTV). The following trends were determined based on viewer perceptions of two "new" television formats:

- Interest in HDTV was high
- Possible pay cable lift
- The price must be right (<20% increase)
- Males rate HDTV higher than females
- Picture viewing size plays an important role

ATC conducted focus groups with side by side comparisons between studio quality NTSC and the SMPTE HDTV production standard, once again as viewed on the same height screens. The groups were separated into basic, pay, former and never subscribers to cable. The members of the group were encouraged to interact and move around the room during approximately one half hour of demonstrations. At the end of the session they were shown a 110" HDTV projection system. Similarly, there were trends evident in these groups:

- Amazement at HDTV quality
- Growing awareness of HDTV
- Pricing is a major issue

The results of these initial research results support our belief that HDTV will have a positive impact on consumers, and therefore cable must take a leadership role in its development.

Transmission Issues

The transmission of HDTV from the origination point to the viewer is the component of the introduction of HDTV into the U.S. that will have the greatest impact on the cable industry, as well as most other media. Once originated, the HDTV signal may be delivered to the final user in one or more of the following ways:

- Over-the-air broadcast
- Cable delivery
- Satellite delivery
- Fiber
- MDS
- VCR or video-disk player

The transmission format is still to be defined. Various agencies in the U.S., most notably the FCC and ATSC supported by many industry associations are attempting to resolve the following issues:

- Should an HDTV format be compatible with the existing NTSC standard?
- To what extent should the format approach the absolute quality of the SMPTE HDTV production standard?
- How much bandwidth is acceptable in the transmission of HDTV signals?
- Due to bandwidth compression techniques required, how much degradation (due to motion, etc.) will the viewer accept?
- Is one standard required across all distribution media?

We believe that one point is clear - each distribution medium must be allowed to deliver the best possible HDTV service it is capable of delivering[2]. This may imply a family of HDTV transmission standards with a corresponding multi-standard HDTV receiver.

Cable HDTV System

It appears reasonable to assume that a family of distribution media optimized HDTV standards will be developed. If this does happen, the following attributes should be considered for a Cable HDTV delivery system (C-HDTV).

1. Provide at least 850 lines of Horizontal and Vertical resolution in both static and moving images. The C-HDTV format shall be designed and implemented so that it does not present a limitation to the quality of the HDTV signal the cable subscriber will receive. Particular attention needs to be paid to the tradeoff of resolution which occurs in moving images when using bandwidth reduction techniques. While initial implementations may not completely achieve this level of performance, the system should be designed with the expectation of delivering this level of clarity in more advanced designs.

2. Occupy one 6 MHz RF channel. Although a cable plant is a closed circuit system and its use of frequencies and bandwidth are not as restricted as that of the over-the -air broadcaster, it does not generally have significant available bandwidth, nor is it electrically transparent to the signals it is carrying. Whatever bandwidth might be available is not likely to be located in a contiguous band, and may have limitations as to its signal carrying quality capability. Cable systems are configured around 6 MHz RF television channels that carry both the visual component and the audio component of a standard television transmission. Various channelization plans (IRC and HRC) were developed to reduce the effects of amplifier distortions in the delivered signals. A HDTV transmission system that does not operate in the existing 6 MHz plan can potentially create distortions in the remaining conventional television channels as well as being degraded itself by distortion products from conventional channels falling into the HDTV signal.

3. Operate in typical U.S. cable systems with little or no rebuild of the system. If the C-HDTV format is to be accepted and used by the cable industry at large, it must be designed to operate in typical U.S. cable systems without requiring major cable rebuild or modification.

4. Co-exists with NTSC and other C-HDTV channels. The envisioned C-HDTV format shall 1) not require a redefinition of the cable channelization plan, 2) not require readjustment of cable signal parameters, 3) not require existing NTSC channels to be removed for technical reasons, and 4) will allow the replacement of any number of NTSC channels with C-HDTV channels.

5. Provides "hooks" to allow future evolutionary improvements of the system. It is reasonable to assume that technological improvements over the next 10-20 years will allow even better HDTV signals to be delivered by cable than possible with the C-HDTV format. C-HDTV shall be developed and implemented in such a manner that allows upgrades to any such advanced HDTV systems with ease and with no disruption to the existing base of HDTV receivers.

6. Allows real time transmission of programming. The C-HDTV system must accommodate real time, live, HDTV programming. Bandwidth compression or conservation techniques that require non-real time processing are not acceptable. While this point may seem obvious, it is not a constraint placed on all media (for example tape and disk).

7. Easily interfaced to the SMPTE approved production standard or to an intermediate satellite transmission format. The SMPTE approved 1125 line, 2:1, 60 HDTV production format is gaining acceptance in North America for film and tape applications. In fact, to date, there have been no other HDTV production

standards successfully demonstrated and supported with readily available hardware. Therefore, it is reasonable to believe this format will be the system of choice for HDTV programming, whether originating live, from film, or videotape. The C-HDTV format must allow an easy interface to this production format directly. In addition, the C-HDTV format must allow an easy interface to an intermediate satellite distribution format which is used for program delivery to cable headends.

8. Uses scan rates and other parameters that allow reasonably priced multi-standard NTSC/HDTV television sets to be produced. For HDTV to be successful, consumer equipment must be readily available and reasonably priced. Furthermore, the consumer HDTV set must readily interface with all television formats it will be expected to receive. The formats include: 1) NTSC, 2) C-HDTV, 3) VCR-HDTV and 4) Broadcast EDTV. Therefore, it is a necessity that the developers of the HDTV formats and the consumer electronics industry maintain close contact to ensure feasibility.

9. Provides 4 CD quality audio channels. At least 4 high quality digital audio channels are needed. The channels should be dynamically reconfigurable to allow any of the following configurations: 1) 4 independent channels, 2) 2 stereo channels, 3) 1 stereo,1 surround, and 1 independent and 4) a 4 channel surround system.

10. Includes a "built-in" high security audio/video scrambling and addressing system. The C-HDTV format shall include a method of high video security and very high audio security. Complete addressability is needed, including access from the program origination point and/or the cable headend. Of course, an intermediate satellite format will also require full security and addressability.

11. Capable of being delivered by satellite to a variety of receive locations. The C-HDTV format or its intermediate satellite format shall not require a total C/N of more than 15 dB to perform satisfactorily. Since a variety of satellite transponder configuration exist, the design of the system must address the typical transponder bandwidths of 27 MHz, 36 MHz and 54 MHz.

12. Recordable on VCRs and optical disks. It is required that the C-HDTV format, and any intermediate satellite formats, be capable of being recorded on consumer VCRs and optical disks. Further, it is desirable that professional VTRs also be capable of supporting C-HDTV.

R&D Efforts

HBO and ATC are jointly investigating methods of HDTV delivery as they relate to cable. These efforts include supporting programs which conduct R&D towards development of C-HDTV and NTSC compatible HDTV systems. We are also participating in NCTA Engineering Committee work characterizing cable equipment and systems.

One R&D effort, funded by HBO and ATC through the Center for Advanced Television Studies (CATS), is occurring at the Advanced Television Research Project facilities of MIT. This program is intended to determine the feasibility of the C-HDTV transmission system as described above. This effort, expected to take 2 years, will produce computer simulations by the end of the first year and implementable designs by the end of the second year. At that time, a decision to go forward will be based on the level of success in reaching the C-HDTV goals and consideration of the results of the FCC ATS process.

A second effort is being planned in cooperation with the David Sarnoff Research Center (DSRC), with respect to the single channel Advanced Compatible Compatible TV (ACTV) system they developed for GE/NBC[3]. This system provides a wide screen improved resolution display by adding augmentation information to the present NTSC system. HBO and ATC are working with DSRC to ensure that ACTV is compatible with satellite and cable distribution. The concern is that, given the additional complexity of the ACTV system over conventional NTSC, it will not be able to withstand the rigors of cable and satellite delivery. This is a defensive project for HBO and ATC. It is in our best interest to ensure that any advanced transmission system that has the potential of broadcast industry acceptance is cable compatible. Beyond fundamental compatibility, it is necessary to investigate how to best carry this transmission format in the cable environment, with any corresponding receiver design requirements identified at this early stage in the development. We have also initiated discussions with DSRC with regard to including signal encryption as an inherent feature of their system.

The NCTA Engineering Committee has appointed a subcommittee, headed by Nick Hamilton-Piercy to investigate cable system performance as related to HDTV systems. Both headend equipment and plant electronics are being considered in this effort. It is expected that knowledge will be gained which can improve performance of our current systems as well as provide valuable insight for HDTV system developers. As both part of an internal quality program and as a contribution to this effort, ATC intends to visit all of its major systems (>30) and measure headend signal characteristics by 3Q88.

Finally, HBO and ATC are active members in the NCTA, FCC, ATSC and CATS organizations as they promote the development of HDTV systems. We encourage all cable industry organizations to play an active role in supporting these efforts.

Conclusion

In summary, ATC and HBO believe that consumers will perceive HDTV as a significant enhancement to the television viewing experience, and therefore it is critical that cable participate in the emergence of the technology. There are major issues currently under debate in anticipation of the availability of consumer HDTV equipment within the next few years. Perhaps the most significant of these is how to transmit HDTV to the home. Cable must work actively with the pertinent governmental and industry committees considering the development of HDTV. Further, we believe it is necessary to work directly with R&D groups to look at opportunities for cable optimized HDTV systems.

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[1] "Cable System Overview - 1988" available from the authors.

[2] Time Inc. Comments and Reply Comments submitted for the FCC NOI on ATS.

[3] "A Single Channel, NTSC Compatible Widescreen EDTV System", David Sarnoff Research Center, HDTV Colloquium, October 1987.

HEADING FOR CONVERTER OVERPOPULATION

Shellie Rosser

Anixter Manufacturing

ABSTRACT

Converters have done a lot for the cable television industry in the last 20 years. By enabling subscribers television sets to receive more than twelve channels, they have opened up tremendous revenue opportunities as new services have become available. By incorporating programmable descramblers into converters, it became possible to secure the increasing revenues from theft of service. By adding addressability to the converter descramblers, we can now offer additional revenue-generating services, such as pay-per-view. Over the last twelve years, cable systems have purchased more than 60 million converters from equipment manufacturers, and are expected to buy another 6.4 million units per year through 1991, for a total of 85.6 million converters. With industry projections for a 1991 subscriber base of 50 million, an inventory surplus is mounting.

How did we get here? With so many more converters than subscribers, why are new converters still being purchased? And, perhaps most importantly, what can the cable operator do to reduce surplus inventory, yet keep pace with the state of the art?

Technological Advances (The Genealogy of the Converter)

One reason for the current overpopulation is the rate at which technology progresses. Remember the block converter? It was widely used in the mid 70's, and can still be found in subscribers' homes today. The block converter took a "block" of channels carried on the cable system outside of the TV set's range (generally in the mid-band) and converted the entire set of 7-21 channels to another range of frequencies that the set could receive-often in the UHF band, where poor quality of the set's UHF tuner would wreak havoc on the signal. But the boxes sold for \$15-\$22, and significantly increased the number of channels a cable operator could offer subscribers. "Soft security" protected the system's revenue stream; if the subscriber didn't have a block converter, the signals weren't received by the set.

By the late 70's (only 5 years later) varactor-tuned converters had already rendered block converters obsolete. With enhanced frequency stability and adaptability to scrambling techniques for signal security, a new standard emerged. Now the TV set constantly looked at only one frequency - the converter's output channel - and a wide range of functions and processes could be imposed on the signal before it was passed on to the set for viewing.

Early versions of these converters simply converted from 2 to 26 channels to the same ouput frequency (2, 3, or 4), and functionally increased the bandwidth of the television set. Mechanical push-buttons, slide switches, and rotary dials were all used for channel selection on the converter.

Later versions came on the market with bandwidth capability to 42 channels, and some incorporated programmable decoders. These units were highly popular in the early 80's and are still widely used, although addressability is steadily replacing them. With a decoder built into the converter, specific channels to be decoded are programmed into the unit (encoders are matched with the corresponding channels' modulators at the head end).

So when a subscriber selects a pay (scrambled) channel that the unit has been programmed for, the channel will be automatically decoded and a viewable picture presented to the TV set. If an unauthorized channel is selected, the decoder simply passes the scrambled signal through, and presents an unviewable picture to the television.

The programmable decoder can be reprogrammed to descramble and (or all) scrambled channels, so a black market quickly developed for these converters. Cable operators had bought them from manufacturers at $60-75 each, and consumers were now buying the same product for $100-200 on the pirate market and receiving "free" cable service. Loss of hardware and loss of revenues (often from subscribers who dropped service, but kept their converter/decoders) prompted many system operators to move into addressability in the early to mid 80's.

With addressable systems, digital technology facilitated deactivation of the entire converter when a subscriber disconnected. Addressability brought remote control of the subscriber's device to the cable operator, so service level changes could be implemented from a customer service rep's keyboard (rather than relying on retrieval of the box from the home and replacement with a reprogrammed unit). And in the late 1980's, a new revenue stream has emerged, that only addressable technology can deliver: Pay-per-view. Now subscribers can buy more programming from their cable systems than they have before. In addition to regular subscription service, they can also buy individual movies or events, and be remotely authorized to view single segments of programming. Addressability has thus become cable's answer to the videotape rental industry.

Technological advances have moved so quickly and the industry's needs changed so dramatically over the last decade, that cable systems have often been faced with a converter's depreciated life (7-8 years) far exceeding its life as a state of the art device (2-3 years). New units are often purchased to replace converters that are still quite serviceable, but not adequate for maximizing the revenue potential of subscribers in that particular system. And the older converters are delegated to excess inventory status, often necessitating substantial write offs.

Changing Customer Needs

In addition to the new wave of addressability, another trend is developing, which demands that subscriber devices be "consumer electronics-friendly". In other words, if the subscribers' TV sets have wireless remote, we can no longer give them pushbutton electromechanical boxes that make them walk across the room to change channels. If they already have volume control on their television sets, they want volume control on their converters. A subscriber with a VCR now must have a compatible program timer in the addressable converter.

Recent changes in consumer electronics have contributed as much to the continued demand for new converters, as the addressable evolution has. Even in systems where trapping is used for security, rather than scrambling/addressability, older (electromechanical) converters are being replaced by digital converters that offer consumer-friendly features.

So what happens to the "clunkers" of today that 4 years ago were brand new, state of the art technology?

Management of Assets

As cable operators upgrade their systems to satisfy subscribers' demands for additional programming (through increased channel capacity and pay-per-view offerings), older converters are being displaced by new addressable or digital products. These displaced converters are sometimes used in a less sophisticated sister system, or in non-addressable subscribers' homes, or even on additional outlets in addressable homes. Under these circumstances, the older converters continue to generate revenues, to "earn their keep" at least until they are fully depreciated.

But more often, when a wholesale system upgrade is undertaken thousands of converters are taken out of homes to end up in one of two places:

1. Cable system inventory - converters will sit idle, in a warehouse corner, until another system lets it be known that there is a requirement for them.

2. Equipment brokers - brokers often buy "lots" of unused or obsolete converters for resale.

Each scenario merits further examination.

Cable System Inventory:

When converters are in a system's warehouse, not only do they not earn revenues, they incur significant costs in space, material management, and in some cases, interest charges on the original purchase. Often, the excess inventory is not properly accounted for, so that when a requirement for the product does surface in a sister system, no one knows that the units are available. Additional products are purchased, and the excess converters remain idle.

Equipment Brokers:

Sale of the excess converters to equipment brokers is preferable to the costs of maintaining unused inventory for extended periods of time, but another set of issues must then be considered.

1. The broker's credibility and reputation is a primary concern, especially if the converters include descramblers. The pirate market has been fed by less than reputable brokers and many pirate boxes have resurfaced in systems owned by the same companies originally selling the product.
2. The market value the broker can offer is often well below the product's book value, and may not be easily collected.
3. Brokers operate in a "spot market" with pricing that fluctuates widely with supply and demand cycles. It is generally necessary to shop several brokers for the best price, which will undoubtedly be quoted by the one who has a buyer already lined up. Shopping to sell off inventory is simply a distraction from the main business of a cable system's operation.

A Solution For Enhanced Utilization of Assets

The Anixter Converter Exchange (ACE) program was developed to offer cable operators a safe, convenient and valuable outlet for unused converters as they upgrade to new technology. Aimed at eliminating the system's costs of carrying inventory in excess or unused converters, the program facilitates immediate removal from the cable system as converters are taken out of service, with a guaranteed price for the product that is held firm for the duration of the upgrade.

When a system buys new converters a trade-in value is given for the old ones in "as-is" condition, and credit is issued against new converter purchases. Where the product's depreciated value exceeds fair market price, the ACE program can offer full book value for a large portion of the product traded. The credit issued substantially reduces the system's net capital outlay for state of the art technology, and remains constant for the entire upgrade period.

Anixter then remanufacturers the old converters and places them in inventory at distribution centers throughout the country to make them readily available to systems that have use for working, like-new product. The remanufactured converters are discounted substantially below the price of new products, and are covered by a 12 month limited warranty.

Anixter's distribution network, with sophisticated inventory and materials management systems, is highly efficient at finding legitimate outlets for what had been unused converters. Systems need not hold or account for non-revenue producing inventory, nor be concerned with feeding a pirate marketplace that undermines the industry's revenues, since purchasers of the remanufactured product are qualified as cable operations before shipment is made.

The ACE program may not single-handedly absorb all of the industry's obsolete and excess converters, but it can certainly have a tremendous impact on individual systems where excess inventory of older product is impeding growth into digital and addressable technology. By converting idle surplus to revenue-producing assets, the ACE program serves as a catalyst for lower-cost system upgrades, while accelerating reallocation of product throughout the industry. Surplus inventory from one system can enhance cash flow in another, with the proper vehicle in place.

HIGH QUALITY TELEVISION DELIVERY SYSTEMS

Clyde Robbins

General Instrument Corporation
Jerrold Division

ABSTRACT

Looking forward, signal quality will be increasingly important. A minimum performance target of 50 dB C/N is suggested. A method of improving cable system performance is outlined. Two alternate modulation schemes are presented for extended definition and picture quality over existing cable systems.

INTRODUCTION

The advent of Super VHS (S-VHS) VCRs has caused many people in the cable TV industry to take a renewed interest in picture quality. S-VHS VCRs are capable of delivering substantially better picture quality than the original VHS VCRs. Soon the same movie titles will be available to rent in the S-VHS format as are carried by cable operators on pay per view and premium channels. This will provide the discriminating cable subscriber with a direct A/B comparison of picture and sound quality over cable vs. rented tape. Unless steps are taken, the cable quality will most likely be the clear loser in this comparison.

Although the growth of S-VHS owners in the next year may not be cause for great concern, the longer term trend of improved signal quality is certain. Sony will enter the high end video market this year with ED-Beta, which promises to provide significantly higher quality than S-VHS. Laser discs, another medium capable of very high picture and sound quality, could make a comeback.

S-VHS vs. VHS

Table 1 compares performance characteristics of S-VHS and VHS. S-VHS is clearly better in terms of luminance resolution (detail). Note that the chroma S/N is nearly equal in the two systems and is nothing to boast about. The VHS chroma S/N problem may be more a result of mechanical limitations than electronics. The poor chroma S/N results in poor color purity. Chroma bandwidth is also not changed in the S-VHS format, resulting in soft color edges, but some of Faroudja's (1) techniques may be incorporated by manufacturers in the future to enhance the sharpness of chroma transitions.

	VHS	S-VHS
Weighted Luminance S/N	52 dB	51 dB
Chroma S/N		
AM	38 dB	38 dB
PM	37 dB	40 dB
Resolution	200 lines	400 lines

Table 1: Measured Video Performance Parameters

Y/C vs. NTSC

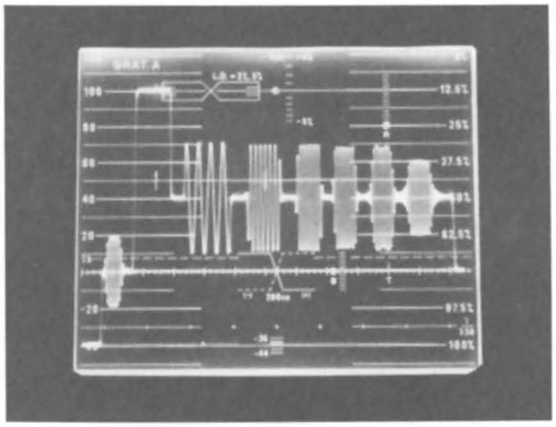
The Y/C (luminance/color modulated) connector feature of S-VHS VCRs and monitors has been widely publicized. It should be noted that the new connection is not in itself a reason for superior picture quality. If an NTSC composite signal is properly encoded (combined Y and C) and then properly separated, the artifacts (i.e., cross color and cross luminance), are minimal and do not significantly degrade picture quality. A properly encoded NTSC signal (with proper decoding) on a monitor is nearly indistinguishable from a Y/C presentation on the same monitor. However, not all monitors with Y/C connections have good NTSC decoding.

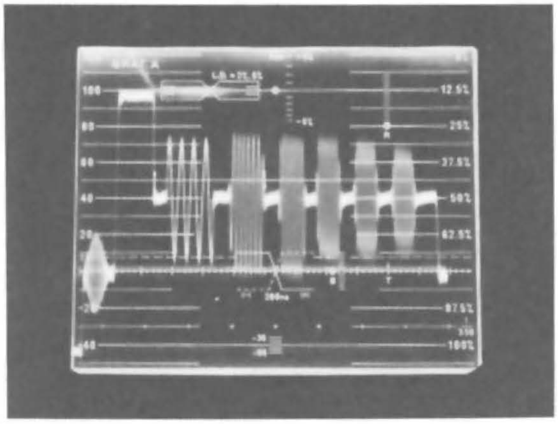
VSB-AM NTSC vs. S-VHS

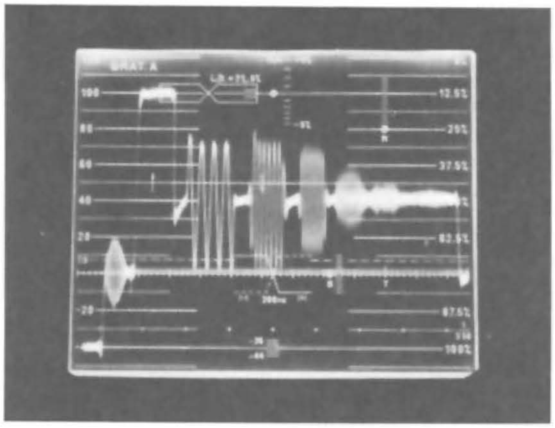
The 6 MHz spaced AM vestigial sideband system for transmitting NTSC pictures and sound limits resolution to 330 lines or less, depending on receiver and display performance. Already available on the market are TV Monitor/Receivers with Y/C connections which have display capabilities of only 330 lines, regardless of whether the NTSC or Y/C video input is used.

A clean 330 line picture can be an excellent and pleasing display, even on large screen CRTs (25 to 36 inches). The difference between a 330 line and 400 line picture is not a dramatic difference, but a subtle improvement. If the 330 line picture is clearer (higher S/N) than the 400 line picture, then the choice of better picture quality will go to the 330 line version. In a broadcast environment, a properly encoded/decoded and displayed NTSC picture is truly an excellent picture.

Photograph 1 shows a multiburst video test pattern AM-VSB modulated and demodulated. Photograph 2 shows the same pattern recorded and played back on an S-VHS VCR, and Photograph 3 shows original VHS. The AM Mod/Demod pair is clearly more transparent than the VCRs. These photographs show that cable TV has been using a modulation and channel allocation format which is capable of providing superior pictures than that of new S-VHS VCRs for many years. The question then is "what quality of pictures and sound is actually being delivered"? A further question is "what can be done within the constraints of existing cable TV systems to improve the delivered picture and sound quality"?. It is beyond the scope of this paper to discuss new distribution system design approaches. Techniques which can be applied to existing systems to deliver better quality signals will be presented.







Boosting C/N

Cable system operators and equipment manufacturers have historically been conservative on signal levels for distortion parameters at the expense of noise. Signal levels at the input of trunk amplifiers and converters are often too low. A simple and effective means of improving trunk and converter noise performance is to reduce system AGC pilot signal levels by 3 dB or more. The effect on S/N can be substantial and make a dramatic picture improvement. Boosting system levels should not be done indiscriminantly. An experimental approach to finding the best system operating levels can be used to "fine tune" the system for minimum noise with acceptable distortion. Observing pictures at the end of the longest system cascades and decreasing pilots until distortion is just noticeable on live pictures, then increasing the pilots back about 3 dB for a safety margin will yield the optimum picture quality.

Low Noise Pre-Amplifiers

As system C/N is improved the converter noise performance becomes more important. In situations where the C/N is relatively high (i.e., 47 dB) and the drop level is low (i.e., 0 dBmV) a low noise pre-amplifier installed before a converter can improve the C/N presented to the TV by 3 dB. If in this example the converter noise figure were 12 dB, then the system cascade length would actually be doubled by the converter. A low noise amplifier built into the converter solves this problem. AGC is required to prevent overload of the converter mixer where input levels are normal or high. Fixed gain pre-amplifiers suffer from the problem that they shift the dynamic range lower, but do not extend it. AGC'ed pre-amplifiers built into the converter can widen the input operating range over which high C/N pictures can be presented to the TV receiver.

The Rebuilding Decision

If a cable TV system has an end of cascade C/N less than 40 dB and the C/N can not be improved by raising signal levels because of already visible distortion, pictures comparable with S-VHS and other new sources will not be delivered without more major changes. It should be kept in mind that along with improved resolution displays comes the need for higher C/N ratios. Current S-VHS machines measure a weighted luminance S/N of 50 dB. It is reasonable to assume that further improvement will be forthcoming in S-VHS performance. If a cable operator desires to deliver comparable quality and is faced with a 40 dB C/N system, there are two possible approaches which can be considered. One is to redesign and rebuild the system. In this case, 50 dB C/N should be taken as an absolute minimum C/N design target, including the converter contribution. This type of performance target will require a reconsideration of all signal processing aspects of a system. A final resulting picture is the product of all system components, not just the cascade of cable and amplifiers. The antennas, LNA/B/C, satellite receiver and modulator, transportation via cable, microwave or fiber optics, all have a cascading effect.

Non-Standard Modulation Plans

An alternative solution to rebuilding is to use non-standard modulation techniques. If premium picture quality on premium services is desired, an exchange of bandwidth for signal quality can be made. The approach would be to use either a demodulator adapter box connected to a wideband auxillary IF port on a converter, or a self-contained converter/demodulator.

Either AM or FM modulation may be useful, depending on the desired level of signal improvement and the available bandwidth.

AM-DSB

An AM approach which requires a lower adjacent channel, but offers extended definition and 6 dB of S/N improvement is as follows:

1. Synch suppress both horizontal and vertical intervals at composite video.
2. Decode NTSC to Y/C.
3. AM modulate the Y signal and filter with a special DSB filter.
4. Up-convert C and filter at 42.17 MHz.
5. Up-convert BTSC sound to 41.25 MHz.
6. Combine the signal and convert to the desired two cable channels.

Figure 4 is a block diagram of this DSB-AM modulator with a composite two channel IF output. Figure 5 shows a typical modulated spectrum. Figure 6 is a block diagram of the receiver which receives Y, C, Mono and Stereo Audio, all separately. The S/N improvement of the Y signal is as follows:

1. The IF level is boosted by 3 dB so that peak channel power matches adjacent channels (+3 dB).
2. DC to 2 MHz is received as a double sideband signal (+6 dB).
3. From 2 MHz to 6 MHz the sidebands are single, but at twice voltage (+6 dB).
4. The Y receiver bandwidth is 8 MHz (-3 dB).

   S/N (DSB) = S/N Adjacent + 3 dB (IF level) + 6 dB (sideband power) - 3 dB (BW).

   S/N (DSB) = S/N Adjacent + 6 dB.

AM–DSB Backward Compatable Extended Definition IF Modulator

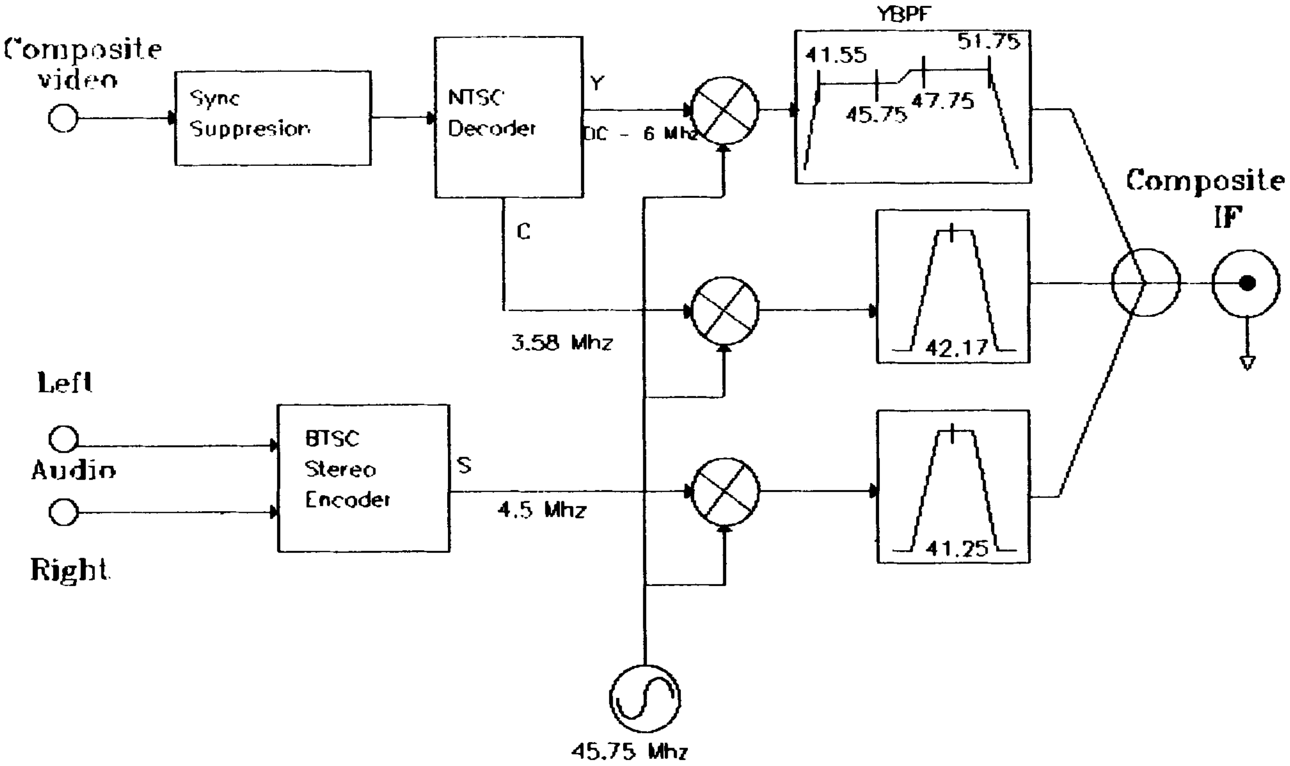


FIGURE 4

Modulated Composite IF Spectrum

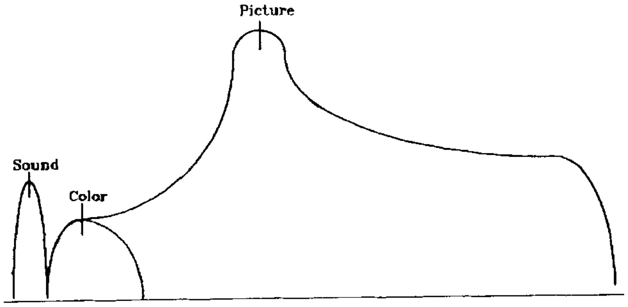
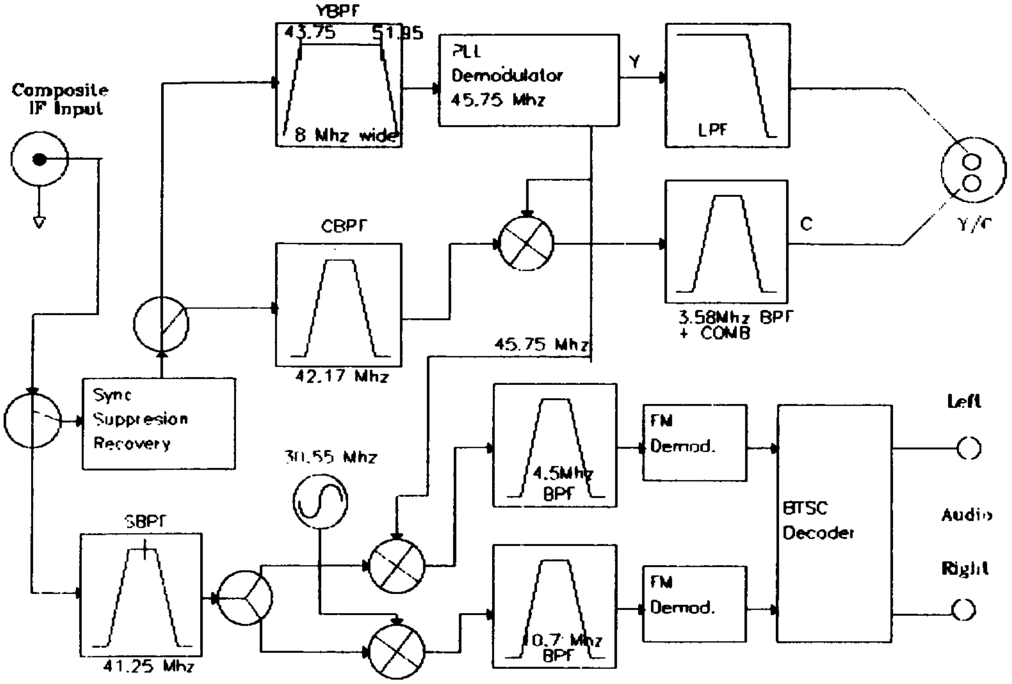
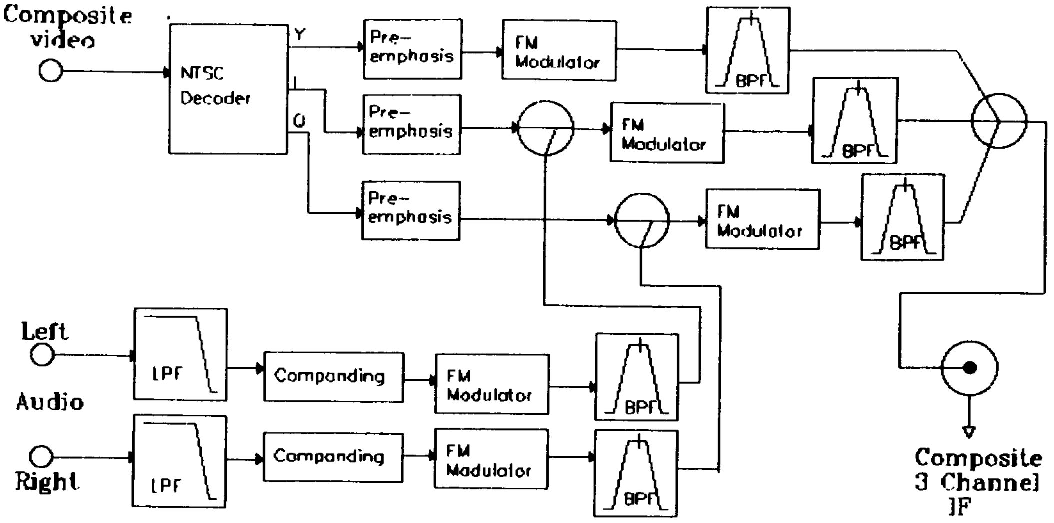


FIGURE 5



Extended Definition AM IF Demodulator With Super MTS Decoding

FIGURE 6



3 Channel FM Component IF Modulator

FIGURE 7

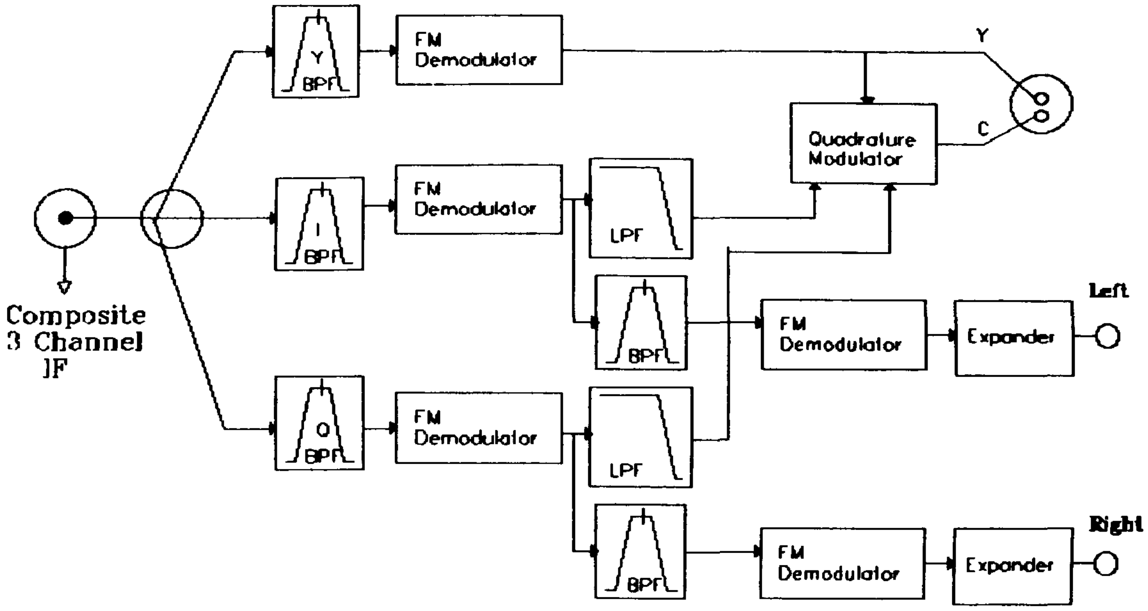

3 Channel FM Component Demodulator System

FIGURE 8

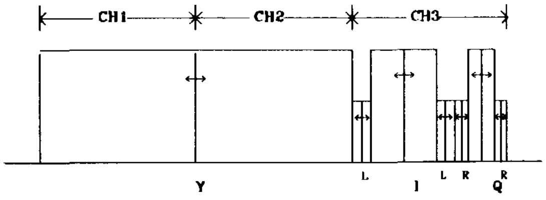

3 Channel Component FM Composite Spectrum

FIGURE 9

FM Component Modulation

If 6 dB S/N improvement is inadequate, FM modulation can be employed. An approach which could yield at least 15 dB S/N improvement is shown in Figure 7. The key features are the optimally matched pre-emphasis curves for each component and separate FM carriers for Y, I and Q with FM subcarriers for L and R which are companded. A further refinement would be to make the Y, I and Q pre-emphasis adaptive. Figure 8 shows the receiver for this FM scheme which must include a chroma encoder to generate the desired Y/C output. Figure 9 shows the 3 channel allocation. Although this FM component modulation concept is bandwidth intensive, it is a feasible means for providing excellent picture quality over systems which provide poor pictures in the normal format. Looking at this FM format from a different perspective, extremely long cascades could be built with this very robust modulation in mind. Note that this method could have optical fiber applications, such as fiber trunking with short multi-cable runs, without a format conversion. Signal security could be provided by line rotation or other baseband means.

CONCLUSION

Picture and sound quality of competing video mediums are rapidly improving. Depending on the design and condition of individual cable systems, operators may choose to "fine tune" for best picture performance or rebuild in order to provide comparable quality pictures. If spectrum space is available, non-standard modulation formats could provide both extended definition and improved S/N. A DSB AM approach with moderate S/N improvement is backward compatible and requires the lower adjacent channel. For more severe cases, an FM approach is proposed which requires 3 channels and which is compatible with fiber transmission.

(1) "Improving NTSC in a Cable Television Facility", Yves Faroudja and Joseph Roizen, NCTA Technical Papers, 1987.

IMPROVED OUTAGE CONTROL
USING A NEW AND UNIQUE TRANSIENT ELIMINATOR

Roy Ehman
Jones Intercable

Tom Osterman
Alpha Technologies

ABSTRACT

Outage control is an area of major concern throughout the cable television industry, not only from the standpoint of maintaining customer revenues, but also for insuring reliability and longevity of CATV system hardware.

Power problems can plague a CATV system. Transient voltage surges and spikes induced by lightning or caused by sheath currents and utility switching operations are a very serious threat to reliable cable system operation.

This paper will describe a new method for protecting the 60 volt plant. A design using extremely rugged semi-conductors to shunt surge currents to ground, enables active and passive devices to become essentially immune to damage caused by high voltage transients.

We will present the technical results of initial laboratory research, as well as actual cable system tests. A detailed description of how spikes and surges are created in the CATV environment provides a basis for evaluating effectiveness and reliability of this approach. Several illustrations supporting the research data are included.

Our paper proposes a unique solution to several of the contemporary problems facing all CATV system operators: Outage control, hardware protection and customer satisfaction.

INTRODUCTION

Numerous surveys have confirmed that interruption of service (after picture quality) is the second-highest cause of customer dissatisfaction. Technically, the reason for these long and short-term outages can be classified as follows:

HUMAN ERROR
*Under-fusing.
*Self-induced interruption during maintenance or equipment change-out.
*Disinterring of underground plant or driving fence posts through it.
*Oversized vehicles tearing down overhead plant.
*Poor installation causing "pull-outs" during large temperature drops.
*Inadequate batteries or battery maintenance to support standby power.
*Vandalism.

NATURE
*Wind-related storm activity causing trees to fall on plant.
*Electrical Storms (Lightning).
*Ice

POWER PROBLEMS
*Blackouts
*Brownouts
*Surges
*Transients/Spikes (Dirty Power)

EQUIPMENT FAILURE
*Semiconductor Heat Prostration
*Catastrophic Failure

Apart from the obvious, the frequent mechanism of equipment failure is caused by lightning and dirty power. Note: Direct lightning hits, fortunately, are quite rare (and preventable). Amplifiers and other CATV equipment actually survive the majority of surges, spikes and other transient phenomena; however, they are injured in the process and slowly deteriorate until they "unexplainably" die, causing a surprise outage.

OUTAGE CONTROL

During the spring and summer months, many articles are published on Outage Control. From these come ideas that provide solutions to alleviate electrically-related problems. In general, these references include:

1) Drive unbonded grounds at separate poles. This provides a divider network that drains-off some of the energy under fault conditions, but there are limits. One-ohm grounds, which are created by coupling-up ground rods (to 32 feet in depth) and hitting underground water, do not completely solve the problem. Also, it should be noted that this technique can create large potentials between conductors on the pole.

2) Bridge the amplifiers with at least AWG #6 copper wire. This is intended to shunt the approximate 1000 Amperes flowing in the strand/cable during fault conditions and prevent a potential from developing across the entire assembly, including input and output connectors.

3) Increase fuse ratings incrementally. This is especially true where the equipment is sufficiently robust, such as the secondary of ferroresonant-type, 60 Volt power supplies which are short-circuit proof and "indestructible."

4) Institute Outage Tracking, Quantifying and Post-Mortem Analyses. A step-by-step procedure needs to be established which provides exact details of how each type of outage is to be managed, who is to be called, and under what circumstances. This type of management can help to reduce outage *duration*.

5) Attack surge and spike problems at the center-conductor. The one, single-step, safe and legal way to overcome power-related problems where the damage occurs, is by using a fast-responding, rugged, transient protector.

THE CROWBAR APPROACH

During the summer of 1986, I received a call from a 1000-mile system in Virginia which was repeatedly receiving electrical storm damage. This was a sizable county system and spread over a very large area. It was possible to determine the broad path of storms as they moved through the system by the trail of burnt fuses and modules left in their wake. The problems were further compounded by the fact that the power tended to be intermittent during the storms, as well as losing regulation. Fortunately, the power company was able to provide valuable information for the study. In the case of the direct influence of the storm, lightning would strike the primary, arc-over to the secondary/neutral and be followed by as much as 10,000 Amperes of AC fault-current flowing back to the substation. This traveled by whatever route it could find, for as long as 160 milliseconds, before the substation breaker could stop the flow. It was discovered that the fault-current was divided about equally between neutral and strand/cable, which was then equally divided again between the strand and cable. This gave rise to a cable sheath-current in the order of 2,500 Amps. It's not surprising that their amplifiers and fuses were blowing. (See figure 1)

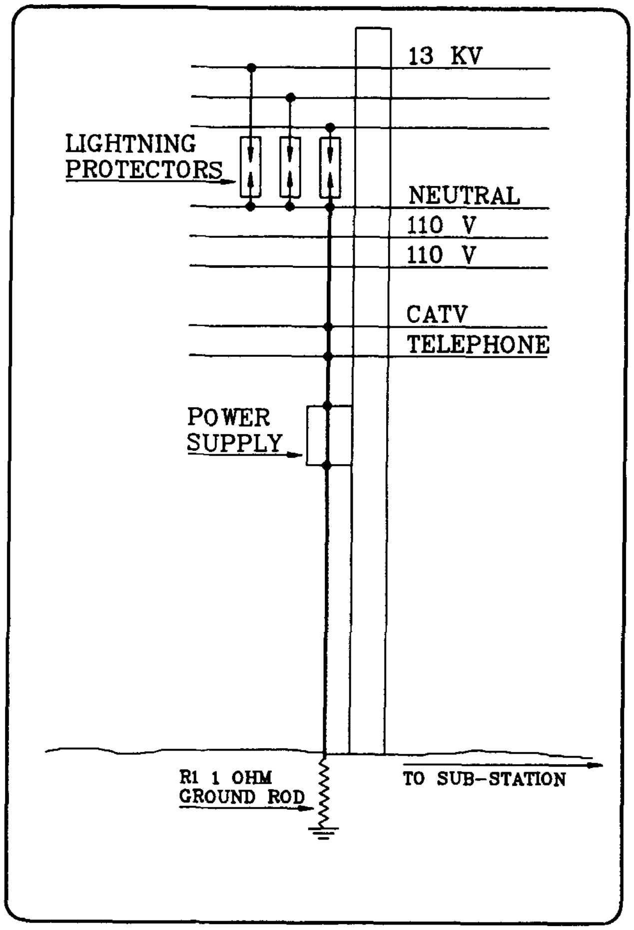


Figure 1

Even on normal, calm days during low-loading in residential areas, there will be at least 5 to 10 Amperes or more flowing in a strand/cable. It's an eye-opening experience to go around a plant with a clip-on ammeter and take strand/cable current-flow readings. Frequently, it is the areas with high, idle-currents that blow the plant away.

When contemplating the magnitude and duration of these currents, it is easy see why the small, ionized spark-gap pellets are inadequate for this type of service. They will either blow open, or closed, under prolonged high-current over-voltage conditions. When they are open, a false sense of security is created. When shorted, they are difficult to find and fix.

Since I had no access to a lab, I asked Tom Osterman at Alpha Technologies to build several heavy-duty transient-protection devices into power inserters. In my opinion, it was necessary to design a circuit capable of taking damaging fault currents to ground for several AC cycles. To be effective, the device required a response time of less than one microsecond. Trying to remove the transients by clipping, as in the case of M.O.V.'s and zener diodes, wasn't acceptable due to the high I^2R losses and low power dissipation capabilities. The best approach was to overcompensate for the energy rise by shunting everything, including the 60 Volt power supply to sheath ground.

Some purists may ask "What happens to the active devices during the three or four cycles when peak voltage is near 0?" The answer is that the power supply certainly doesn't care and the 18 to 22 Amperes that it can deliver to the semi-conductors is insignificant, compared to the main surge coming directly down the coax.

As for the active devices, they will typically stay up for approximately 100 milliseconds, by which time, a four to five cycle surge has ended or the power company breaker has terminated the surge; in which case, the question becomes academic. Standby power is available and full voltage will be returned on the first half-cycle when the fault overvoltage has ended. At worst, customers may see a one-frame roll. Is this not better than burnt fuses and modules, outages of an hour or more, and above all, techs performing repairs under inclement conditions?

The final requirement of this device was to insure high-reliability. The solid-state components would have to be extremely rugged and offer an almost indefinite life span, unlike MOVs with their ultimately self-destructing, tunneling phenomena.

Of the four units that we made for the Virginia system, one was installed directly in the storm path. No more damage was sustained in that area during the next five successive storms of the season. Interestingly, the plant surrounding and adjacent to the crowbar-protected plant was severely damaged as before. The second unit was installed in a pedestal enclosure at a new development where the 15 Amp supply was loaded to only 2 Amps. Everything connected to the power supply was being wiped out with every storm. After installation of the modified power inserter with the crowbar circuit, there have been no more problems on that leg.

I kept one unit and sent the other to a cable lab in Florida where they tried to test its survivability. Lab boss, Rick Miller put a flash capacitor charged to 1,500 Volts onto the device, which dissipated the energy without damage. Other tests included putting 120 VAC from a Variac into a crowbar unit, but the Variac got hot and repeatedly blew its fuse. Next, they applied 120 VAC from a 20 Amp breaker into it. The breaker tripped, but the device was unharmed. In desperation, we put 220 VAC on it from a 40 amp breaker. Again, the device sustained no damage. That was the extent of testing they could perform with their limited resources. After some minor improvements to the design, we sent one of the newer models to a system in Little Rock, Arkansas, experiencing a problem with very dirty power (VDP) coming from an adjacent, high-voltage power switching center. Fuses and equipment were blowing repeatedly. After installing the crowbar, no more equipment was lost, but fuses still blow on occasion. It may take two of the devices, several spans apart, to completely eliminate the problem. Fortunately, a power inserter with the crowbar circuit can be dropped-in anywhere; you don't have to actually insert power!

By this time we had missed the rest of the 1987 storm and lightning season. Since then, we have installed a few Crowbars in Central Florida (The "Lightning Capital" of the USA), awaiting the summer storms of 1988. It was then up to Tom at Alpha Technologies to perform the more sophisticated testing and analysis.

TESTING AND ANALYSIS OF THE "AMP CLAMP"

Identifying the exact nature of transient phenomena and developing a fail-safe solution required re-thinking the age-old problem of power protection. Following some of Roy Ehman's suggestions and practical field expertise, we approached the development of the "Amp Clamp" from the ground up.

Transients can occur randomly, or repeatedly. Repeatable transients, such as commutation voltage spikes, inductive load switching, power factor correction, etc., are easier to observe and eliminate than random disturbances. In the CATV AC power environment, transients can sometimes be traced to local industrial operations where large motors, compressors, welders, and other forms of heavy electrical equipment conduct dropouts, or produce "load dump" inductive-voltage flybacks onto the AC power line.

Most ferroresonant-based CATV power supplies will do a consistent job of protecting their AC loads from damage. Excellent common mode rejection and spike attenuation is inherent in the ferroresonant transformer topology. With most of the repeatable utility AC transients filtered out by the CATV power supply, the focus shifts to random events, such as lightning-generated transients on the CATV cable.

The device we developed to provide the voltage-triggered, low impedance short circuit to ground, consists of two, high-current SCRS (Silicon Controlled Rectifiers) connected in opposite polarity across the center conductor and sheath of the CATV cable. The most effective, and convenient, location for this device turned out to be inside of a standard, Jerrold Power Inserter which provides a weather-proof enclosure, as well as access to the cable conductors. (See figure 2) The SCR's are triggered into their conduction state by a voltage sensitive, bi-directional trigger diode. The diode provides a fast voltage level-sensor that gates the proper SCR into conduction which corresponds to the polarity of the voltage transient presented to the circuit. (See figure 3) The SCR's have a steady-state current rating of 35 Amps and a one-cycle (8ms) pulse rating of 500 Amps. When an SCR is triggered into conduction by a voltage spike exceeding the threshold of the trigger diode, it will conduct current only until the current source falls close to zero. On the next AC half-cycle, the SCR that was conducting will become reverse-biased and turn off. If the transient re-occurs during this half-cycle, the opposite SCR will conduct until zero cross. (See figures 4 - 7)

The SCR's are extremely rugged devices in the pulse current mode. Voltage spikes will be clamped to ground without damaging the SCR because of the limiting effect of series resistance and inductance between the voltage source and the clamp circuit. This reactance will limit the maximum current flow through the clamp circuit. It's important to note that there is a forward-conduction voltage drop of 1.8 Volts across the device.

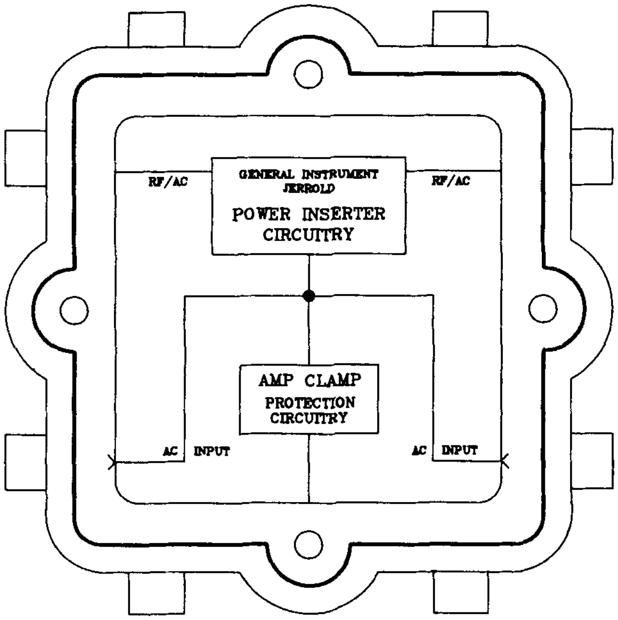


Figure 2

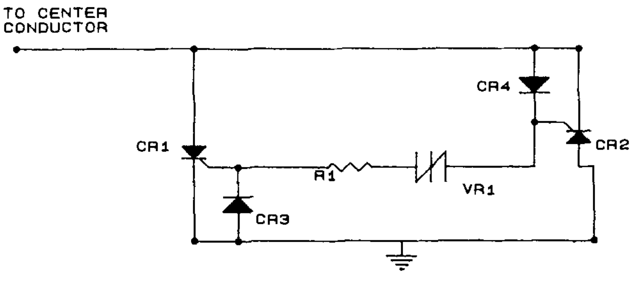


Figure 3
Amp Clamp schematic diagram.

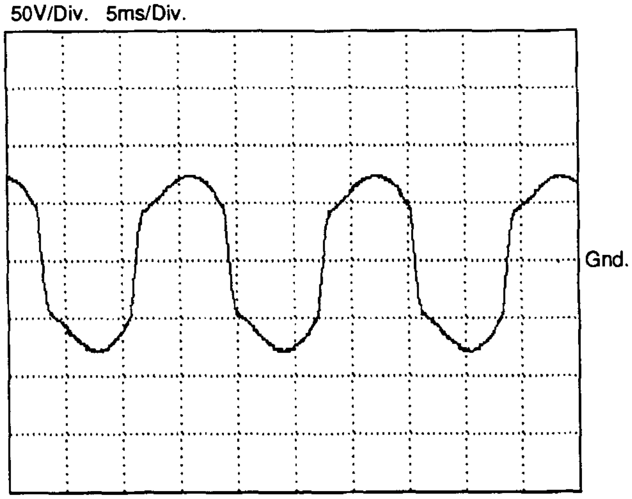


Figure 4
Normal 60V power supply output waveform.
(full load 16A)

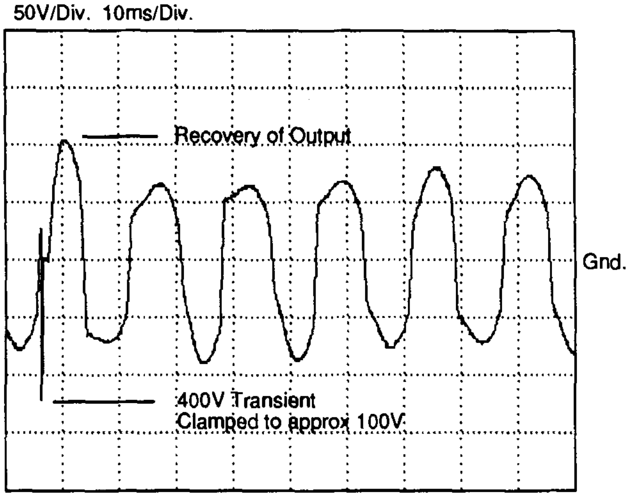


Figure 5
60V power supply output waveform
with 400V transient applied.

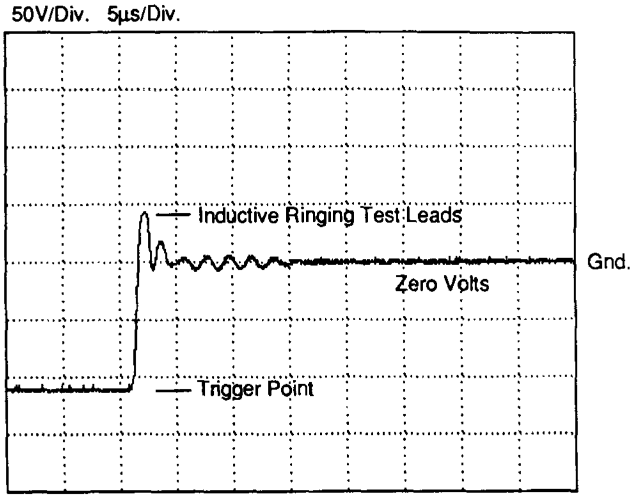


Figure 6
Enlargement of clamp action
(from figure 5).

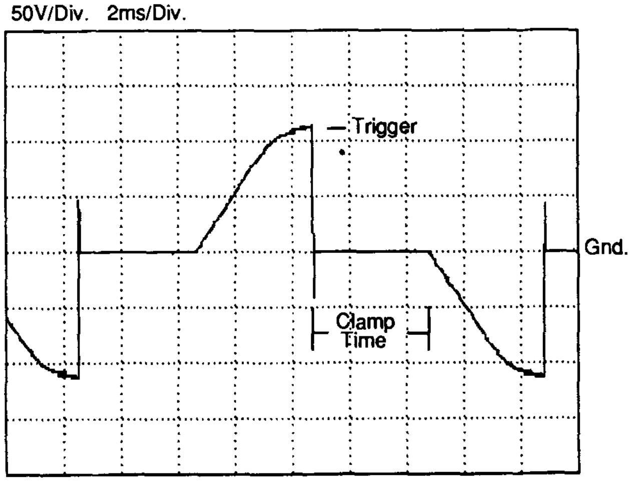


Figure 7
Amp Clamp subjected to 120VAC
Note: Trigger point and resulting
clamp to ground.

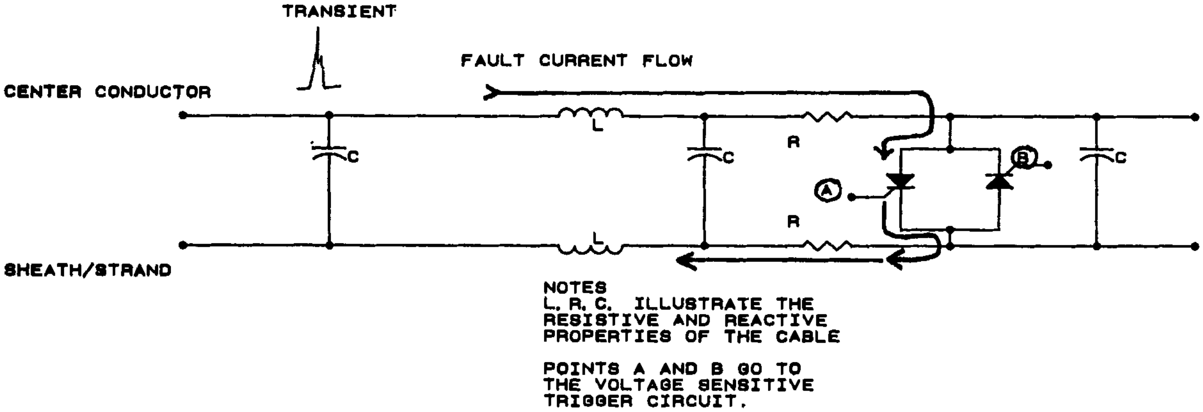


Figure 8
Equivalent Cable Circuit Description

The minor disadvantage of this circuit is the phenomenon called "power follow". Once the clamp is triggered into conduction mode, current provided by the local AC power supply will be clamped close to ground, as well as the fault current. This will cause a maximum AC interruption of 8.3 milliseconds or 1/2 cycle (60Hz). This occurrence will not harm any ferroresonant-type power supply and will not cause most trunk amplifiers to drop out due to the approximate 100 milliseconds of "hold-up time" resulting from the large DC input filter capacitor located in the internal 24 VDC power supply.

To fully test this device and determine its effectiveness and survivability, we embarked on a program of component stress analysis and "real world" transient simulation. In the fall of 1987, we took several prototypes to an independent high-current test laboratory for IEEE 587 surge voltage protection compliance testing. We used a Keytek high energy surge generator to produce surges specified by IEEE 587, Part A (6,000 Volts - 200 Amps) and IEEE 587, Part B (6,000 Volts - 3,000 Amps). Other aspects of our test program included direct connection to 40 Amp 220 VAC power circuits, high current discharge from multiple capacitor banks, continuous operation in conduction mode at 30 Amps, and thermal cycling of the clamp components. With repetitive hits, we were unable to cause a single failure to ANY of the active components in the power inserter or the Amp Clamp circuity. The unit clamped the high energy spikes faster and with a lower amplitude than any of the M.O.V. surge arrestors that we took along for comparison!

One unique feature of the circuit layout is the press-fit heatsinking of the SCR's to the die-cast power inserter case. Any potential heat generated by the fault current flowing through the SCR's is quickly dissipated by the large mass and surface area of the power inserter case. This function minimizes the thermal stress on the SCR's when they are conducting, thereby greatly increasing the reliability of the device.

As a result of this new design, transients can be quickly and safely clamped to ground, thus protecting active and passive devices in the CATV system, without interruption of service or degradation of equipment. To date, the feedback from system operators that have installed Amp Clamps in areas that consistently experience outages and equipment damage due to lightning strikes has been very positive.

The "Amp Clamp" (See figures 2 and 3), can be easily built in time to protect your plant from this summer's storms. This is an exciting application because of its significant contribution to industry-wide outage control.

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3. Roy Ehman CED Nov/Dec 85
4. Jeff Geer Alpha Technologies
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INTERACTIVE ELECTRONIC HOME SHOPPING
AN UPDATE ON THE TELACTION APPROACH

Dom Stasi

Telaction Corp.

INTRODUCTION

Projections of CATV systems as the likely vehicle for the large scale introduction of interactivity to the TV viewing experience have been with us for about as long as CATV itself. The fact that most interactive endeavors, while meeting their technical objectives, have been eluded by economic success has not lessened that likelihood.

In fact, for the first time in the 20 odd years of interactive capability, the market, not the technology, is responsible for renewed interest. For this reason more than any other, the outlook for the economically successful inclusion of interactive service(s) to CATV program fare is brighter than at any previous time. An indication of this trend is in the nature of the interactive services themselves. While early efforts tried to provide as wide a range of uses as the technology would support, current fare has concentrated on specific services, i.e., home shopping, <u>or</u> pay per view <u>or</u> games, etc. A reactive rather than proactive position indicating a market need rather than responding to a market potential.

This paper will describe the current state of one such specific interactive service, "random access electronic home shopping".

One year ago, the J.C. Penney Company announced that it had formed a subsidiary - Telaction - to assess and develop a fully interactive electronic home shopping system (IEHS) for application to cable television.

At the time of announcement, the system was described in a paper entitled "Selective Electronic Home Shopping", by this author.

Over the ensuing 12 months, the system has been subjected to the rigors of both environmental and system assurance testing to determine reliability. It has further undergone consumer field trials in operational CATV systems to assess its suitability to the medium. The results of these tests, their implications, and a technical overview of IEHS architecture will be discussed.

CAPABILITY

Of the many and varied uses of interactive technology considered to date, none has the apparent potential for both revenue generation and subscriber satisfaction as that represented by electronic home shopping. However, if we are to exploit this potential to its fullest extent, an interactive electronic home shopping system must offer the user substantially improved functionality over systems previously available.

Shopping systems currently in use rely upon a stimulus-response relationship between viewer and presenter. Items are displayed in serial fashion, relying on the presenter's ability to hold viewer attention until an item of interest is displayed. At that time, the viewer interacts by operating whatever response mechanism is at his disposal, thus consummating the transaction.

The amount of time a purchaser must dedicate to a serial presentation varies over a wide range. To date, only limited progress has been made to refine the process by program segmentation. This, however, excludes the user looking for a cross section of products or services.

To that end, programmers are offering a degree of choice, such as five sizes of an apparel item or four pay per view movies, etc.

The limitation, however, remains that as choice and selectivity improve, so must the hardware complement at the user interface. Increases in intelligence and/or memory capacity at user stations necessary to provide a tangible increase in functionality remain substantial. Systems become costly and intrusive long before achieving a level of capability approaching random access.

Of the interactive system architectures available, those most frequently encountered fall into one of four control categories:

1. Polled-Real Time
2. Store and Forward
3. Hybrid Distributed
4. Contention Based

The selective use of a combination of these architectures with control and processing highly centralized has been shown to yield a very large increase in selectivity with adequate response times under most operating conditions. The system imposes no user interface hardware and operates in real time. Access to potentially 50,000 items is fully random-interactive.

A block diagram of the Telaction system is shown in Figure 1.

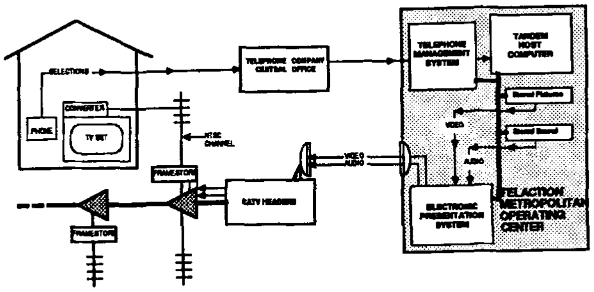

Figure 1

The intent is to provide, through the cable television interconnect, the electronic analogue of a shopping mall, with functionality approaching that of a brick and mortar mall, i.e., random access to a cross section of stores; the ability to enter those stores and examine a cross section of products again, through random access; and finally, to optionally purchase products, store products for future purchase or simply examine products at leisure without the necessity of visiting a conventional brick and mortar store, free of the intervention of a sales person. When and if human intervention is desired, the shopper has at his/her command a simple bridge to customer service representatives from any of the stores participating in the "electronic mall".

All of the capability described above is accessible through simple, touchtone strokes to cable subscribers at systems affiliated with Telaction. The system - a four year, sixty million dollar development effort, exists in hardware and is undergoing market introduction in the Chicago area.

Technology notwithstanding, the implications of so powerful a service are, of course, enormous.

Conceptually, the system operates as follows:

The cable subscriber, tuning to the Telaction channel, will observe a "welcome screen". The screen, a still frame graphic, will advise him in lower one-third (1/3) script ... "to begin shopping dial the phone number".

Following these instructions, the consumer removes the phone from its cradle, dials as instructed and within two seconds of closure a menu will appear on screen with its associated prompt. This menu will consist of product categories. Following the prompt, now reduced to touchtone keystrokes, the consumer may "navigate" the catalogue inventory of some 40 national and international stores, displayed in full NTSC video with aural accompaniment. This activity may now continue until such time as the consumer chooses to terminate the interaction by purchase, storage, customer service bridge, or simply hanging up the telephone.

Simply stated, the viewer need not be subjected to the rigors of computer operation or any sort of incremental hardware. Interaction is via telephone and television. Specifically, cable television.

ARCHITECTURE

Metropolitan Operating Center

This level of interactivity, albeit with a far narrower range of products and services, has been achieved to date only through use of home personal computer or point of purchase (mall) kiosk devices. In order to deliver such functionality while limiting user hardware requirements to CATV and phone, transaction processing and control must be accomplished externally. This is provided on a regional scale through a facility known as a Telaction Metropolitan Operating Center.

When an interactivity is initiated, i.e., a subscriber dials into the Telaction Network via the local toll, the call will be routed to the most local metropolitan operating center.

Placement of this center within the telephone network heirarchy is critical if acceptable levels of concurrent use are to be achieved.

Public switch convention at present

would preclude placing the sort of telephone management system (TMS) necessary to handle multiple-sequential-response interactivity at a cable system head end.

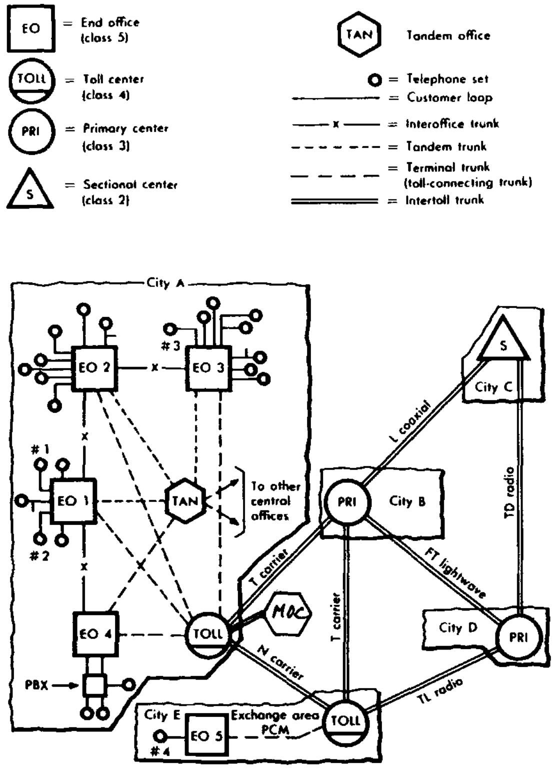

Figure 2
A simplified telephone system

A headend location would, in the vast majority of instances, be limited to end-office loop service to the subscribers it serves. The local loop would saturate far short of target levels for concurrent use. This sort of congestion has given rise to the widespread use of store and forward technology. A shopping system, however, must operate in real time. Consequently, MOC locations will be placed within access to toll grade service or greater. Traffic may then be diversified and concentrated on adequate trunk facilities.

1,800 incoming lines appear at the input of the Chicago MOC telephone management system. Incoming traffic will process via ATT conversant telephone management system (TMS). Voice grade circuits will direct incoming calls at the Chicago metropolitan operating center from the telephone management system, to a host computer system for data entry and control.

The host computer systems, in the interest of reliability, are Tandem Systems VLX multiple processor mainframes, characterized by full redundant hardware.

While essentially transaction process computers, the VLX systems are sufficiently fast to respond to the level of activity generated by electronic home shopping. A generally accepted measure of transaction processing power is the ET-1 Benchmark. The ET-1 is an amalgam of various commonly encountered processing tasks such as banking transactions, in an effort to quantify the operations of a transaction. It is an arbitrary unit representing the rough equivalent of some 1000 COBOL instructions. Relevant measures are cost and elapsed time.

Each four processor Tandem VLX in the Telaction system is capable of 32 ET-1 transactions per second.

Our source limited input traffic of 210 concurrent users each performing an average of one transaction every seven seconds yields a probable processor load of 30 ET-1/second. Of greatest importance, however, is the fundamental architecture of Tandem systems - complete hardware duplicity, each computer is a dual system, each running duplicate programs and interconnected in a failure deferral hierarchy.

Simply stated, should a host computer experience a catastrophic failure in hardware, the system will sense the failure, shift output to the operable duplicate and continue running valid data, virtually undistributed.

A system architecture characterized by its inherent ability to balance processor loading (Figure 3) is essential to orderly growth of the network. The Tandem system is capable of "bolt on" expansion to accommodate multiple processors.

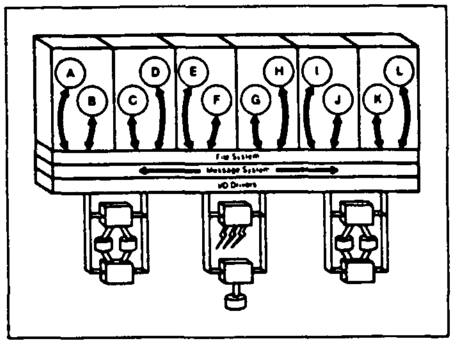

Figure 3

Video Display Subsystem

Following data base query as to the validity and identification of the incoming transaction, the host computer outputs a command to the video display subsystem.

The video display subsystem consists of a video display unit, (VDU), an audio distribution unit (ADU), intelligent controllers; VBI, address inserter, and a nxl matrix switch, interconnected via high speed LAN.

Video access is random read only as well as multiple write to accommodate dynamic data such as graphics or product change.

The entire EHS system is characterized by the output of the VDS.

The output, a series of television frames, are electronically conventional NTSC, 30 frames per second.

The frames, however, are concatenated, i.e., each is an individually fetched and addressed slide, bearing no apparent relationship to the previous or subsequent frame, but instead lifted from a laser disk in response to user commands and multiplexed serially.

This system of distribution allows for a very large transfer of information without stressing CATV system bandwidth or linearity.

Each information display requires only as much system time as is needed to fetch, replay and address a single 1/30 second NTSC frame.

Electromechanical limitations of playback equipment when used in random access fashion require that some thirty-six (36) video players be dedicated to the task of fetching single frames to achieve a 30 FPS rate reliably. The video display system controller (VDSC) will memorize each stylus location among the thirty-six (36) players. It may then assign that available device who's most recent frame location most nearly accords with the subsequent frame request thereby limiting stylus travel time. Further efficiencies can be realized through placement of frames. If those images most frequently requested are concentrated at disk center and distributed outward according to frequency of use and affinity, stylus exclusions can be further limited.

Some one-third (1/3) of all frames stored on disk for playback contain aural accompaniment. This can take the form of narration, music or product purchasing instructions. In all cases, audio is limited to less than forty (40) seconds of continuous output per frame of video.

To achieve the same level of playback efficiency realized in playback of video, a time compression technique is employed for audio storage and retrieval.

Audio is encoded and recorded onto individual video frames of the same laser disk used for video storage. The encoding technique used converts the analogue audio input to a format similar in waveform characteristics to NTSC video. Each such image is an analogue representation of audio sound, but is meaningless to view on a picture monitor. Instead, a digitally quantized sample of each ten (10) second audio segment is recorded during the active line period of the "video" frame, thus allowing a 300:1 time compression of aural information without significant compromise of linearity or fidelity.

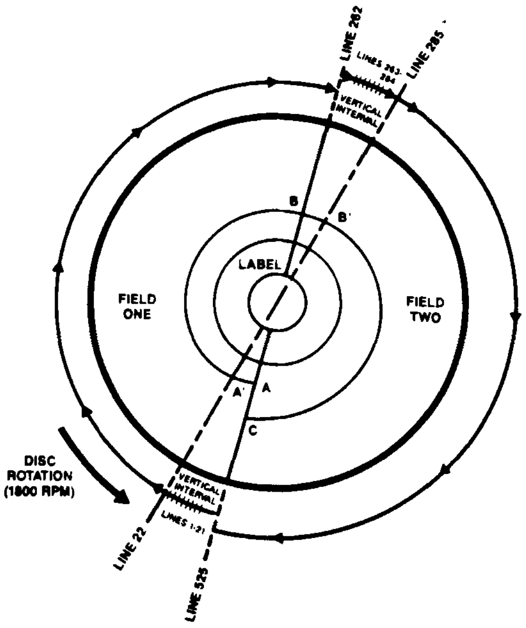

Figure 4
Laserdisk Format

Audio is stored on disk adjacent to its accompanying video frame in the interest of retrieval speed. (Fig. 4)

Audio Distribution Unit (ADU)

Following retrieval from disk, each audio "frame" is routed to the audio decoder. The audio decoder performs an analogue to digital conversion of the time compressed waveform. Digital to analogue conversion recovers the original 3.4 KHZ audio baseband signal for amplitude modulation upon a carrier in real-time. Carriers are selected according to availability from 210 discrete frequencies available.

Audio carrier distribution is via 10.75 KHZ spaced frequency division multiple access (FDMA). Each carrier is synchronized with its associated video frame according to an addressing scheme described in a subsequent section of this paper.

Network Configuration

The Telaction system is characterized by an NTSC output of thirty (30) video frames per second transmitted in concatenated fashion for distributed storage. It is anticipated that each stored frame will be held by the viewer for an average of seven (7) seconds. This yields a need for real time audio accompaniment of 210 parallel audio channels. Additionally, addressing and variable text overlay information are consolidated into the composite video output.

Transmission to affiliated cable systems is via terrestrial microwave or suitable I-Net.

The recovered baseband signals are modulated on cable system trunk channels usually above viewable spectrum. Aural carriers distribution requires three (3) continuous megahertz of bandwidth. Signals are injected at -20 db video.

Since trunk distribution will route the signals through the CATV plant, selectivity and conversion to subscriber usable format must take place externally.

These functions are accomplished in an original engineering device known as the dual-node frame store unit (FSU).

FRAME STORE UNITS

While the system is designed to accommodate end user devices, such as dedicated set top frame store units, usage profiles encountered during field trials do not support this level of distribution.

For example, if 75 percent of all basic subscribers served by the 120 home feeder access the Telaction system twice monthly for a twenty minute shopping session, this would average one hour and twenty minutes of system access per feeder population per day distributed over a thirty day period. This is not considered an impediment to access.

This same level of activity, 75 percent of all basics, twice monthly, would require that each basic household have at least one dedicated FSU device installed. This would result in only two minutes of usage per device per day and is considered less than economically nominal hardware usage.

Therefore, frame store units are designed for installation at off premise aerial or underground locations generally co-located with similar population to existing bridger amplifiers. This level of distribution optimizes hardware use while limiting access costs.

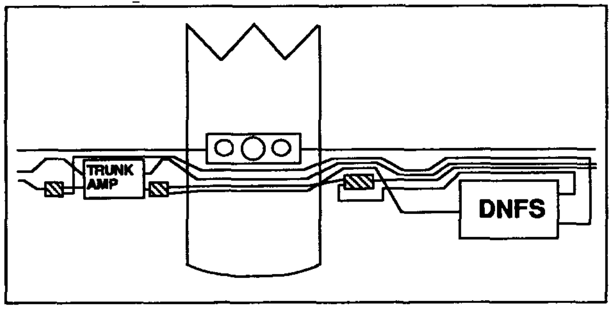

Figure 5

In its simplest form, the frame store system consists of a combination of circuit components that 1) recognizes a video frame addressed to it, stores that frame for subsequent transmission as a video signal to the subscriber addresses it serves, and 2) receives and transmits the audio signal related to the video image being transmitted.

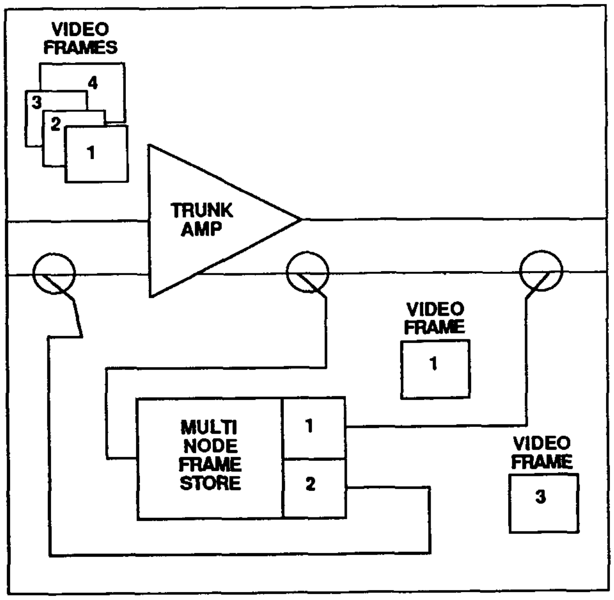

Figure 6

The external appearance is similar to that of a conventional CATV trunk amplifier and should exhibit similar environmental immunity and RF radiation properties consistent with a single channel device.

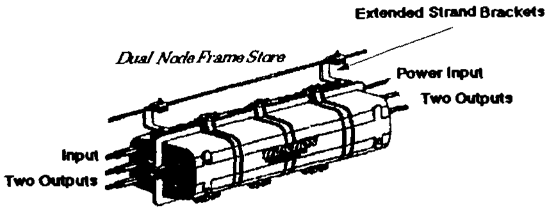

Figure 7

The circuit components include a dual audio receiver, a video demodulator, an analogue/digital converter, a digital frame store, a digital/analogue converter, a channel modulator, and a controller which reads and interprets the addressing information in the incoming vertical blanking interval and activates the other components as required.

In its dual-node configuration, the FSU system (Figure 5), will accept an input signal, comprised of NTSC video and frequency divided multiple access (FDMA) audio.

By virtue of address, the system will detect, A/D convert, discriminate, store, D/A convert, remodulate and amplify two specific video and associated audio "frames". Stored signals will appear simultaneously at two parallel feeder maker outputs of the FSU.

Output video levels are continuously variable over a 20 db range, up to a maximum of +65 dbmv continuous.

When a subscriber initiates a transaction call to the M.O.C., the requested frames are routed to and through the CATV trunk system. All frames appear at the input ports of all FSU's, and are selected by address for display by the FSU associated with the initiating subscriber.

Audio is routed via frequency division multiple access technique throughout the trunk system as well. The appropriate carriers are selected for feeder distribution by address and modulated on subcarrier 4.5 MHZ above video by the targeted FSU.

Simply stated, in the CATV trunk line a channel of concatenated frames, as well as narrow channel of FDMA audio, are routed. At the feeder level, those frames (A&V) requested by homes served by each feeder are selected by the FSU and routed only to that feeder.

Each interaction taken by the subscriber results in an additional VDS subsystem output. Each will be discriminated by that subscriber's FSU for display. Telaction's design target for response time is two (2) seconds, from key stroke to video display at the drop.

Since all frames distributed to and through each cable system will appear at the inputs of all frame store units in that system, the dual-node FSU will recognize, discriminate and redirect user specific frames determined by three message types appearing at its input.

Message Type 00

When an FSU is initially activated (or following a power outage), it will tune its input to a pre-selected default channel. It will detect a pre-determined vertical blanking interval (VBI) line in that channel. This control data will communicate and enable the FSU to retune its input to that channel allocated as the channel of interest and containing the concatenated video frames.

Additionally, this address identifies the input audio band of interest and enables the FSU aural input to tune accordingly.

Message Type 01

Once tuned to the video channel of interest, a series of FSU specific VBI messages will appear at its input. When the FSU detects and decodes an address match, it will capture the subsequent video frame and tune its audio input to the appropriate 10.75 KHZ FDMA audio carrier within the audio band of interest associated with that video frame. This message will also indicate which output modulator will receive the captured audio and video information for distribution to subscribers and that modulator's frequency.

Message Type 11

Under certain operating conditions, it may be necessary to change an FSU's channel configuration. In this instance, a type 11 message containing operational data will be acted upon only after being detected three times in succession. This capability is intended to provide improved subscriber access in instances of unusually heavy use.

All messages employ 16 bit cyclic

redundancy (CRC-16) error detection.

The frame store output carrier frequency is phase locked to its input and variable over a 20 db range.

Spurious emissions at the FSU output will be at least 60 db below output levels in any 10 KHZ band from 5 to 550 MHZ.

Output carrier frequencies can be any 12.5 KHZ increment between 5 and 550 MHZ according to any commonly used protocol (HRC, IRC, STD).

CONCLUSION

The Telaction system is intended to provide an eminently practical interactive system offering broad selectivity. It is compatible with all commonly encountered CATV system architectures and imposes no user intrusive incremental equipment.

A contention basis was selected as an economically feasible method of providing this level of interactivity to all of a system's basic subscribers.

Actual contention has been minimally encountered in feeder populations of between 60 and 240 households during field trials and is not considered an impediment to system use. Telaction's design target remains 86% availability during the peak traffic periods (busy hour) on a system basis.

International Dimensions of Cable Television

Patrick K. McDonough

United Cable Television Corporation

ABSTRACT

This paper will discuss current activity in Cable TV in several countries in Western Europe and other areas. Based on the author's personal experience, the following topics will be included:

* Current State of the Art of European Cable.
* Differences in system configuration (ie. switched star in United Kingdom systems)
* Technical comparison of European and American systems
* Technical considerations for European applications.
* European construction methods and approximate costs.
* Labor and training requirements.
* Operational considerations (importing, taxes, rate of exchange problems, billing systems).

A discussion of the future potential of CATV in Europe will include recent developments in DBS, HDTV and fiber applications.

CURRENT STATE OF THE ART

The widespread use of Cable TV as a delivery medium is a relatively recent development in Europe. Cable has been available in some countries, such as Ireland, for many years but only in the past two years has Cable really become viable in most of the European area. The reasons behind this change are somewhat complex and can have an effect on the type of system which is required in a particular country. Whatever the motivation behind the change, the fact is that Cable is becoming an increasingly visible medium in many areas around the world.

Existing systems range from very small SMATV type applications to large city size systems with most of the bells and whistles associated with modern American plants. Systems carry anything from two or three channels up to forty. Newer plants are being designed with bandwidths of from 450 to 860 MHz. European operators take full advantage of the technical advances which have been made in the U.S. and Canada over the past twenty years and managed to avoid a good number of the mistakes domestic Cable operators had to struggle with as CATV developed here. This, of course, is a tremendous advantage as new systems come on line and programming choices increase.

An important consideration in any foreign country is the perception of television by the residents. It must be pointed out that in many countries TV has been a State owned or State controlled medium. Reception in a lot of nations has been limited to only one or two channels for many years. As a result, the people who live there do not always perceive a need for additional television programming. Many times they cannot conceive of how they might be able to use more than a half dozen or so channels. Beyond this, there is a vast difference in the way Americans and Europeans use TV. Here in the U.s. we are conditioned to having a large number of channels twenty-four hours a day, even in areas not served by Cable. We are also quite used to being entertained by television and most Americans also rely on TV as their primary source of news. In the main, though, it is the way TV is perceived as a method of recreation in America that sets us apart from Europe. European subscribers are, at first, a little stunned by the sheer number of programming choices they suddenly have after decades of having only one or two channels. They literally do not know how to take advantage of Cable. It thus becomes part of the operator's job to educate the subscribers in this regard.

One of the most dramatic recent changes in the European situation is the advent of satellite delivered programming. Similar to American Cable systems, the introduction of additional programming has been the key element in fostering the growth of Cable. For the first time, system operators can offer product beyond the available off-air channels and locally produced efforts. Further increases in satellite capacity are planned and the addition of still more channels will give another boost to Cable in Europe.

To summarize the current situation in Europe, and other areas of the world as well, one would see a wide mix of old and new technologies operating in almost every imaginable configuration. Increases in available programming and the use of both American and Continental electronics has brought about changes which will drive the existing systems to become more like their American counterparts, in function if not in form. Cable in Europe can be compared to the industry as it existed in the States back in the early seventies, just on the verge of explosive growth in both system size and area coverage.

SYSTEM CONFIGURATIONS

There are three basic system configurations in use in the European plants. These are tree and branch, switched star and a variation of the switched star which is built in the star architecture but does not employ active switches at the node points. Again, government regulations have a great deal to do with the type of plant configuration which is employed in specific areas. Beyond this, the density of the housing and existing infra-structure are determining factors in how systems are designed and built.

Some countries, most notably the United Kingdom, actively promote the use of one configuration over another. The reasons for this can range from the pragmatic to a reliance on what outside "experts" have claimed to be the best system architecture. In the specific case of Great Britain, as an example, the story started with British Telecom (BT), the government owned telephone company. As part of a growing trend in Europe, the British decided to denationalize the phone company and let it compete on the free market as an independent entity.

At the same time, however, the government decided that there was a need for something for the BT to compete with. Thus, they created a structure governing the development of alternate telecommunications systems such as Cable TV. The idea behind all of this is to foster the growth of independent systems which can compete with the phone company and avoid monopoly control of communications within the country. In their desire to promote alternatives to BT and to avoid the situation where only TV service is being offered, the governing rules are structured so as to promote the use of a switched star type system. The hope being that operators will eventually offer services other than just television such as telephony, data communications and so forth. The incentive for this is an eight year extension to the fifteen year license, or franchise, for operators who build and active, switched system.

The switched star configuration, for those not familiar with it, is based on the use of neighborhood nodes which feed the subscribers. This is similar in configuration to the off-premise converter systems which have been tried in the States but with more capacity. Again, the intent of the regulators is to encourage the type of system architecture which will facilitate active telecommunications services beyond television delivery.

Systems built in the star configuration, whether switched or not, offer a great deal of flexibility to the operator and can, if properly built and maintained, provide an extremely reliable plant.

The other factors mentioned, density and existing infrastructure, also have a good deal to do with the final build structure. Densities in many areas of Europe are quite high when compared to the States. Homes passed on a per mile basis can often exceed three hundred and in some instances be in the neighborhood of one thousand or even more. It should be noted that per mile comparisons can be somewhat misleading in the cases where star configured plant is being used. Star systems have about thirty percent less active plant than tree and branch topology so per mile figures are skewed upwards. However, the fact remains that the overall densities are quite high when compared to most American systems. The star configuration is particularly well suited to very high density situations, especially when the vast majority of construction is extremely expensive underground build. For example, let us say we will install nodes so that, on average, there is one node per two blocks of houses. This can be visualized by imagining a capital H with the node at the center of the crossbar. The legs of the H represent the drops which run down the streets past the homes. In this configuration there is only one pedestal or cabinet, which houses the node equipment. The bulk of the plant is conduit for future drop feeds. There is no need to install taps and pedestals at many locations and expensive street crossings are minimized. There are problems with this approach too, subscriber installations become more difficult and time consuming for instance, but overall the star configuration is a very efficient method of serving high density areas.

The existence or non-existence of usable conduit, the complexity and location of the other utilities and the accuracy of underground structure maps also contribute to the determination of how a plant is built. In most of the areas that this author has seen all of the services, electric, phone, gas, etc., have been one hundred percent underground. There are exceptions to this but they are rare and in any case, all new service is required to be underground anyway. Because the existing infra-structure has been in place for a very long time and has been rebuilt, modified and changed along the way, it is not unusual to find that there are no records which will allow the operator to determine exact locations for the existing services. In some instances this is complicated by the fact that many service feeds, even natural gas, are enclosed in plastic pipe which means metal detectors are useless for locating underground structure. It may be that the best an operator can do is determine that phone and power are both on one side of the street, in which case he can build on the other side. The location of the other utilities is even partially known, can be the deciding factor in determining where CATV facilities need to be placed and thus become the ultimate method of fixing on a system architecture.

In other areas, notably, Sweden, the topography and demographics of the cities themselves will determine how a system must be constructed. Many Swedish cities consist of large areas of MDU's, sometimes three or four thousand units, separated by relatively small areas of single family dwellings. In these cases the structure of the system will be determined by the most efficient method of reaching the greatest number of passings, the MDU's and picking up the rest later. This can lead to plants with fairly long supertrunk runs followed by relatively short feeder systems supplying signal to a small area with a large number of dwelling units. This kind of layout falls naturally into a tree and branch type of design for the system backbone.

The MDU's are fed from centralized splitter locations, a type of star configuration. Television drop wiring is in place in most of these large apartment buildings in internal conduit systems. The normal method of connecting the units is a loop system, where each unit is connected in series, rather than individual homerun type drops. This can impose limits on the options available to the operator to provide tiered service levels and/or pay channels. Because of government regulations requiring that each unit be able to receive the National channels, the operator is usually faced with providing a universal service to all dwellings programming as well.

One other unusual aspect, at least to most American engineers, is the way systems are defined by layers or networks. The best analogy to describe this feature is to use typical U.s. terminology to illustrate the different plant categories. Typically, a European plant is described as being composed of three separate networks called D-1, D-2 and D-32, plus the headend and hubs. (In some areas the headend itself is considered a distinct layer of the system and supertrunk or other interconnect methods can constitute an additional layer. The most common description is for three layers). The D-1 network is roughly analogous to the main trunk system in a U.S. system. The D-2 network can be compared to the feeder system, and the D-3 net is the subscriber system. There are specific points identified as being the turnover spot between networks. The most important issue here is that in many countries, Sweden is a good example, the D-3 net is owned by the subscriber, not by the Cable operator. The operator is responsible for the signals only up to the point at which they are placed on the D-3 net. It is interesting to note that the subscribers usually have to pay for the D-3 net themselves. The fact that the subscribers (or apartment house owners) own the final part of the system is another limiting factor in Cable design in Europe.

TECHNICAL COMPARISON OF EUROPEAN AND AMERICAN SYSTEMS

There are very few countries outside of North and South America which use the NTSC system of television transmission. Most European and Middle East countries have adopted either the PAL (Phase Alternation Line) or SECAM (Sequential with Memory) systems. The PAL system utilizes 625 lines interlaced two to one at a rate of fifty fields per second. It uses a four to three aspect ration and the sound carrier is the same as NTSC. Most commonly, PAL signals are either seven or eight MHz wide, depending on frequency. PAL and SECAM systems differ mainly in the way color signals are processed. Both systems are alike in that they separate the chrominance and luminance information and transmit the chrominance information in the form of two color difference signals which are used to modulate a color sub-carrier which is transmitted within the bandwidth of the luminance signal. In the PAL way of doing thins, the phase of the color sub-carrier is changed from line to line. This necessitates sending a line switching signal along with a color burst. In the SECAM system, the color subcarrier is frequency modulated, alternately, by the color difference signals. This also requires the inclusion of a line switching signal within the channel. Both of these systems produce picture quality which, as a rule, is superior to that of the NTSC signal. Signals in many areas also include teletext information in the vertical interval.

The main difference as far as Cable is concerned is the wider bandwidths of European signals. As a general rule (although this is not entirely accurate) channels at lower frequencies, comparable to the VHF band, are 7 MHz wide. Higher frequency channels, UHF band, are 8 MHz wide. There are five bands of broadcast signals arranged to include both TV and FM radio signals. Band I goes from 41 to 68 MHz, Band II from 87.5 to 100 MHz (FM radio), Band III which goes from 582 to 960 MHz. Cable systems utilize bandwidths starting at 40 to 50 MHz and extending to 450 or 550 MHz. There are some cable systems which have been designed to operate up to 860 MHz but these are the exception.

Both VHF and UHF frequencies are utilized for broadcast, although in Great Britain only UHF is allowed. Because there were, until recently, only a few channels available most of the older TV sets are limited in the number of channels they can receive through their tuners. Newer sets, made in the last five years or so, can receive more.

The combination of UHF only reception and limited tuner capacity in the United Kingdom presents the Cable operator with the need to provide a UHF input signal to the receiver. In switched star systems this can be handled by either sending a low frequency UHF signal down the drop or by sending down a VHF signal and installing a VHF-UHF upconverter in the subscribers home. Systems which use converters must install an upconverter on the output of the box. The use of the upconverter is complicated by the fact the U.K. signals contain teletext information which must be delivered to the set in a usable state. The specifications of the upconverter are therefore fairly strict. The operators who have chosen to send UHF signals down the drop avoid the use of upconverters but find drop lengths limited by attenuation factors. This, in turn, can place restrictions on the node locations.

System operating specifications are generally comparable to those dictated by good engineering practices here in the States. Composite Triple Beat and CrossModulation are usually expected to be in the -53 or -54 dB range. Carrier to Nose is specified for a -44 to -46 ratio. Group delay, differential gain and differential phase, system response, hum modulation and other parameters are also very similar to U.S. standards. Some differences arise in radiation specifications, which tend to be a little stricter in Europe and in some specific areas such as port to port isolation in subscriber taps. Isolation requirements in some countries can place severe restrictions on the tap values available to the system designer and complicate amplifier placement and levels.

The other factor that must be included in considering the European systems is the layer or network distinctions. As noted above, the systems are often defined in specific networks. The operator must be aware that each portion of the network has its own related set of technical specifications. These standards are specific to each layer and are generally not additive. That is, the D-2 net is expected to meet certain criteria regardless of how the D-1 net is operating. The only point where a general set of spec's apply is at either the subscriber outlet or at the defined turnover point to the D-3 net.

In general, European technical specifications are reasonable and a well engineered system will meet these standards easily. The fact that there are fewer channels carried, due to the higher bandwidth per channel, means that engineers can define system specifications to run at the high levels necessary to meet noise and isolation regulations without running into severe distortion effects usually associated with high level operation. From an overall, technical standpoint, the European systems, if built according to the standards, will compare quite favorably with those in America.

TECHNICAL CONSIDERATIONS FOR EUROPEAN APPLICATIONS

As in any system, here in the States or overseas, the principles of solid, well understood engineering practices apply. Systems should be designed so that the end user receives the highest possible quality picture available. There should be extremely little or no degredation present and the system, taken as a whole, must have a very high degree of reliability.

European systems differ from their American counterparts in several areas. Governmental regulations apply one set of considerations to system design as noted previously. System topography, as dictated either by regulation or demographics, applies another layer of consideration. Local conditions, such as the UHF requirement in England, add yet another aspect to the whole situation.

A good example of the type of complexity that can arise from a combination of all of these factors may be illustrated by looking in detail at a typical application in Sweden. The example area is a group of MDU's numbering 2,000 units which will require about 4 km (2.5 miles) of plant to feed all the buildings. Construction must be done underground and the headend will be located within the complex. In this area, as in many areas in Sweden, there are three off-air channels available, all of which are must carries. There are also several satellite channels available, ranging from Russian broadcast TV to a French language channel and a couple of English language channels. The apartment owners recently (within the last two or three years) rewired all of the apartments in accordance to the Swedish regulations. The internal wiring, the D-3 net, is all looped from unit to unit with the feeds coming from the basement.

The operator wants to offer a basic tier of service, consisting of the three must carry channels, to all of the units. He also wants to offer a second tier, an expanded basic level, to subscribers willing to pay for it and a movie service. The headend and earth station installation will be fairly straight forward and familiar processes. The first decision comes in deciding which trunk cable to use. Swedish standards call for these cables to have a copper outer conductor and a solid copper center conductor. The reason for this requirement is the feeling on the part of the authorities that copper cable will not corrode as much as aluminum cable will in similar circumstances.

There are a number of cables available, commonly built in a fused disk construction. The next decision involves the routing of the D-1 and D-2 cables to feed the forty or so buildings in the complex. Strict attention must be paid to the spec's for each portion of the plant up to the point where it is turned over to the D-3 net. Most of this process is familiar CATV type engineering and design. However, once inside the buildings the differences become more significant. The typical subscriber outlet in use in Sweden contains an FM splitter so that there are actually two feeds into the apartment, one for TV and the other for radio. The drop, coming from the apartment or basement below, is connected to the outlet and then loops on the next apartment. Because of the FM trap it will be difficult to use an American type addressable converter which, typically, needs data which is carried in the FM band, the data will have trapped out before it can reach the box. Likewise, traps present problems. Negative traps, which might be used to protect the upper tier and pay channel, can only be installed in the apartment itself, because of the loop system. Obviously, this is not the most secure situation to have. Positive traps could be used on the pay channels, but not for more than one or two because their size will soon become objectionable behind the set. The operator does not won the D-3 net so he cannot change the configuration to homerun and the owners will be reluctant to do so since they just rewired a few years ago. Since he must provide the three must carry channels to every unit the operator must find a way to secure his services without spending huge amounts of capital. One of the solutions to this dilemma is to use a modified addressable box which will receive data at a lower frequency. Another possible approach might be to use a combination of a block converter, for the expanded basic tier, and a positive trap for the pay channel. This last solution would certainly be viable and may represent the most economical approach but what happens when additional programming becomes available or the operator wants to try PPV? Again, the addressable converter seems to be the best bet. The issue of PPV also runs into complications. A two-way converter could be used, but the subscriber outlet again causes problems. This piece does not use F connectors, instead the connections, internally, are made with screw contacts on the center conductor and shield.

These devices have higher losses and are more prone to ingress/egress than similar parts in America. This means that the return data may not have the strength to get back to the system at a reasonable level or in a non-corrupted state. Faced with this, the operator still has a couple of options available. He can rely on a phone-in type approach to PPV event ordering or use a phone return type of two-way converter. He might even consider a converter which can be downloaded with pre-paid credits which are used up as events are watched. The problems, while numerous, are not such that with a little ingenuity and thought cannot be overcome.

CONSTRUCTION METHODS

Most, if not all, of current CATV construction in Europe is underground. Actual construction methods are very similar, as they must be, to those used in America. The use of concrete saws, trenchers and rock saws is common. In some instances, because of the uncertainty about other utility locations or extreme congestion, hand digging is employed to minimize damage to other facilities.

Construction in the streets is rare. Most of the underground in the U.K. for instance is placed underneath the sidewalks in front of the dwellings. Density and traffic play a large role in the complexity of construction in urban areas like London. A good deal of time is spent in clearing parked vehicles, controlling pedestrian and traffic flow and maintaining a safe construction site. Local regulations can add to the complications. Some municipalities require that all the spoil removed from trenches be hauled off site. Trenches are then filled with a slurry mix and the sidewalks refinished. Restoration of the sidewalks can be quite complicated as well. Asphalt sidewalks merely need a hot asphalt fill, sometimes following a cold patch. Sidewalks which are made up of flagstones need to have a layer of sand put down and the paving blocks reset (or replaced if they have been damaged). Some sidewalks are made of concrete topped with a mastic coating. In these cases the concrete must be poured and, when cured, the mastic must be redone. This requires hand finishing of the hot mastic substance and is not only time consuming but expensive as well.

The age and density of the areas leads to a good deal of congestion in the underground plant. The lack of accurate records indicating utility locations, as noted earlier, can lead to incredibly complex coordination problems. Damage to existing underground structure is not uncommon and must be considered as part of the cost of construction.

The capital required to build plant is higher because of all of these factors. In relatively clean areas, costs should be in the neighborhood of $70,000 to $80,000 per mile. Areas with extremely high density or unusually difficult construction can experience even higher costs. Because of the density, even very high per mile costs can translate into pretty reasonable costs on a per passing basis.

LABOR AND TRAINING

Because CATV is relatively new in most areas of Europe there is not a pool of experienced people to draw from to build, maintain or operate a system. There are a few people who have worked with earth stations, SMATV systems and who have done MDU wiring but often they are unfamiliar with the stricter requirements of cable. European operators are basically starting from scratch in building up a work force. This includes all of the various job functions from installer to CSR to salesman to manager.

The operator faces a decision regarding the makeup of workers. Should he import experienced people or try and train local workers? The exclusive use of expatriots is often resented and can serve to the operator's disadvantage. On the other hand, trying to make a system successful with inexperienced people can also lead to severe problems.

A system operator can use one of several courses to resolve this dilemma. The most obvious is to import a small number of experienced cable people and utilize their experience to train a local work force. This has the benefits of keeping overall costs down (it is very expensive to move people in Europe and keep them there) and building up a good community identity. Once local workers have been trained and have gained some practical experience they will be in high demand because of the scarcity of such personnel. Fair labor practices and good wagfes become a must to retain qualified people and avoid the costs of constant retraining. One other training method can be considered. This involves sending a small group of local people to the United States, or another country with a lot of cable systems, and having them train there. These people can then return and train others with the knowledge they have acquired. Either method practical and the approach used by an operator will depend on his resources and the timing involved for his situation.

OPERATIONAL CONSIDERATIONS

Doing business in Europe can be extremely complicated. There are numerous currencies to deal with, fluctuating rates of exchange and high taxes to deal with. Importing hardware from outside of any country is a complicated process with many potential pitfalls along the way. Operators must think in terms of twenty or forty foot containers of material and planning is necessary several months in advance to insure that needed equipment is received on schedule. Cost planning must take into account the import duties for each nation. Depending on the type of equipment being imported, and classifications vary from country to country even for the same gear, import duty can range anywhere from 15 to 150% of the value of the equipment. Naturally, the rates of exchange also affect this process. If possible an operator should attempt to lock in a rate of exçhange for some period, such as a year or 18 months.

The operator is also faced with starting up or somehow modifying existing billing systems for use in European systems. The whole area of computerized billing service, and addressability as well require a detailed analysis of local requirements. For instance, some people prefer to pay bills monthly by coupon at their bank (this is common in the U.K.). In other countries, quarterly or even annual billing is common. The operator must develop his own billing system, either by adapting existing software or writing the software himself (or having this done for him). It may be possible to contract with domestic U.S. companies who specialize in this area of business to rework their software and equipment to conform to European needs.

Future Trends

The future of CATV in Europe can be viewed from a number of standpoints. There appears to be a need for additional services in most areas but penetration levels, at least in some newer systems, are somewhat disappointing. This relates to the cultural differences in how TV itself is used and the subscriber's perception of the new services. The high density of many areas is a compelling reason to investigate European CATV but this must be balanced by realistic expectations in penetration and a full realization of high construction costs involved.

Europe as a whole is much more interested in DBS than i8s the U.S. Several DBS satellites have been planned and at least one has been launched. DBS could pose a real threat to the development of CATV as could MMDS, potentially. The opinion of European operators is that the greater diversity and lower cost of cable will eventually prove t5o be the deciding factors.

Newer technology, are also beginning to make themselves felt in Europe. France has done a tremendous amount of research and development in the area of fiber optics plant. The end results of their experiences could affect future cable system configurations in a major way. Likwise, the development of HDTV is of concern to operators. They will be faced with the same questions which now confront American CATV systems. What bandwidths will be needed to accomodate HDTV channels? How much will system technical criteria need to change ? Will shorter cascades be necessary? How will converters be adapted to handle the new signals? At the same time, HDTV could present additional revenue opportunities so the questions are all valid and require well thought out analysis very soon.

To summarize, the European CATV scene is beginning to show signs of tremendous potential. However, optimism must be coupled with caution because of the risks involved. Europe is on the verge of explosive growth in CATV but competing technologies also have a window of opportunity which could negatively affect this potential. All in all, watching our European counterparts develop their systems should prove to be most interesting over the next several years.

KEEPING MAINTENANCE RECORDS

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ABSTRACT

A preventative maintenance program requires adequate records to be succuessful. Keeping records can save your system money and can be accomplished with existing personnel. Intended for those involved in the management of cable systems, this paper discusses why records are important, lists six ground rules to be aware of before beginning a record keeping program, and presents a three-tiered system of record keeping for trunk lines that can be adapted to meet the needs of most any system. Sample forms are included for you to use in your own system.

INTRODUCTION

Is your cable system benefiting from a preventative maintenance program that uses a solid base of records to plan work? If so, congratulations; you are ahead in one of the toughest battles facing us in the cable industry. If, however, preventative maintenance and its associated recording tasks are things you support in theory but find impossible to fit into daily practice, take comfort in knowing you are not alone.

Why is it that few cable systems manage to run a successful on-going preventative maintenance program? Certainly, most systems possess the tecnical know-how and test equipment necessary to mount a successful campaign. What, then, gets in the way? Often, keeping system records is a large stumbling block that trips-up preventative maintenance efforts. Records are a mandatory component of any preventative maintenance program. Without records, it is impossible to spot and correct potential system problems before they become serious. In other words, without adequate records, the most genuine effort at preventative maintenance is doomed to failure.

What is the current overall state of the records kept at many systems today? Often poor and usually not too helpful, according to the five field engineers who work with me.

Just opinions you might say, but opinions worth listening to. Together, the six of us have a combined total of 89 years experience in the cable industry, and in our jobs we travel around the world visiting a total of about 175 systems each year. On the main points we all agree: Most systems do not keep adequate records. Some systems do not even keep any records. Many systems that do try to keep records, fail to record "useful" information or fail to turn to the records when they might be helpful.

WHY BOTHER?

No one would say they were just plain opposed to maintaining system records. It is fitting this activity into busy schedules already filled meeting immediate demands that creates the problem. Many would agree that in their day-to-day system activities keeping records is on the bottom of the priority list. It may even be considered something to do "in your spare time." Do many of your employees have spare time? So, why should you, as part of your system's management team, bother to make record-keeping a genuine priority on your system's daily to-do list? There are a few reasons.

To Meet Government Requirements

Requirements set by the FCC and other regulatory boards governing system performance are becoming tighter. Stricter monitoring requirements of Cumulative Leakage Index is one example. Keeping and using records will decrease your chances of not meeting regulations. And if you should fall short of the standards, complete and accurate records will probably make you able to locate and correct the problem more quickly. In addition, if your system's performance does not measure up, records that document your regular efforts to meet requirements are convincing proof that you are doing all you can to meet the parameters established by the regulatory boards.

To Retain Subscribers

Subscriber requirements have also gotten tougher. Other affordable substitutes for the entertainment service you offer--VCRs and home satellite dishes--are real options to which unhappy subscribers can turn. And once they have been disconnected chances are these subs will not return.

Other members of your client base are even more demanding. Local Area and Information Networks will not tolerate degradations in signal quality, let alone a complete outage; burglar alarms and medical alert services depend upon a coaxial system that can consistently provide high-quality signals.

To Save Money

Efficient use of staff, equipment, and inventory costs you less. A good base of records will make it possible for you to plan maintenance work when it is most economical and convenient for you and decrease the number of un-planned, expensive, emergency calls. Further, when you can control the time and conditions under which repairs are performed, the quality of the work will improve. You will have fewer follow-up visits, fewer truck rolls overall, and less unscheduled overtime to pay.

ESTABLISHING THE GROUND RULES

If you are ready to seriously consider making a genuine effort at keeping system records, read on. This paper offers some practical suggestions about the types of records you probably need to keep and suggests procedures to help you maintain these records.

To start us off on common ground, I have listed six strongly-held beliefs upon which my program of record keeping is based.

1. Any cable system that wants to make a profit and stay in business must be performing not only the maintenance necessary to keep the cable system going, but it must also be performing preventative maintenance. The entire record-keeping system exists to track both "trouble call" and PM work , with a goal of reducing the number of trouble calls.

2. You must be keeping records for a practical purpose: to use as a tool. State-of-the-art test equipment is only valuable to you when it can be applied in your system to help you accomplish your goals. The same is true of system records. They only have value if you can use them. Keep this in mind when establishing your recording-keeping system. Think of the types of information that would help you attack your problems, and then make up forms that ensure that the information gathered will be useful to you and that it is gathered in groupings convenient for your use.

3. A sincere committment to preventative maintenance and record keeping must be felt throughout your organization. You must truly see benefits for yourself and each member of your staff asked to participate or you will receive a half-hearted effort at best. To be successful, you need system-wide support. If you clearly do not have support or question your ability to whip-up support, save your time, energy, and money. Why set yourself up for failure?

Be sure you have the type of support that will manifest itself in actions. Can you make your subordinates allocate time to record keeping and check on the quality of the records they keep? Will your superiors say they support a maintenance/record keeping program, but then unconsciously undermine it by making staff assigned to maintenance/recording tasks abandon their work to add a new drop at the mayor's house or clean up around the office? Unfortunately, it happens.

Force yourself to maintain and use the records. If you do not intend to regularly examine and record the activities in your system, again stop reading now. A beautifully bound set of perfect sweep sheets never updated or never referred to is useless. In fact, if this is the case, you threw away money by paying a qualified technician to generate them in the first place.

Would you ever approve a cash outlay to acquire a piece of test equipment you had no intention of using? Would you invest in a piece of test equipment and never maintain it? Learn to look at your system records like another piece of test equipment. Do not make the intial investment unless you intend to use the records, and once the investment is made, be prepared to meet the demands of record up-keep.

System records can be maintained without increasing staff--if a system is appropriately staffed to begin with and if that staff is wisely allocated. Many people find this hard to believe, but it is true. Granted there will be an uncomfortable month or maybe even two at the beginning when you are still receiving enough trouble calls to keep your staff completely occupied and feel you cannot afford to "waste" time on maintenance and record keeping activities. But if you set aside a fixed percentage of each day for maintenance/recording tasks, in about a month you will see the number of trouble calls decrease.

Don't believe it? A program designed and implemented by Jones Intercable in 1984 at a system in Castro Valley reduced monthly service calls by 20% (from about 360 calls to 290 calls) in just several months. This reduction in service calls saved the system an estimated $21,000 annually and was accomplished without adding new employees.[1]

Regardless of system size some version of the basic three-tiered approach to record keeping for the trunk line described in this paper can be adapted to fit the needs of most systems.

A BASIC PLAN FOR TRUNK LINE RECORD KEEPING

Certainly you will benefit from keeping records on all the segments of your system (headend, feeder lines, trunk lines). However, to make this discussion managable, I have focused on a basic framework for maintaining records on just the trunk line of a cable system.

Although it is not mandatory, I strongly suggest that if possible you gather and store your system data on a computer. A simple personal computer and any software package that allows you to build up a data base and sort it according to different variables that you can name--like model numbers, attenuator values, or fault codes--will help you get the most mileage from your records. For example, sorting your data base by outage codes allows you to easily generate a report delineating the amount of down-time for any given time period. Of course this information could still be gathered using a manual method of record keeping, a computer just makes it possible to complete the task more efficiently.

With or without a computer, you should keep a master hard-copy of your records. The master copy should never leave your office, so I suggest you compile your master in binders that can be opened and closed. This way when a technician needs to take a copy of the record into the field, he can take a photcopy.

No matter how large or small your cable system, the key person involved in the record keeping system is the individual in charge of the cable plant's technical performance. This person will develop, institute, and oversee the maintenance program and its associated record keeping activities. This does not mean that he will have to generate and maintain all of the records personally. He will, however, have to determine who should be recording what, ensure that the approproiate recording is completed, and analyze the results to plan future maintnenace work.

At a minimum, you should be maintaining three types of records on your system's trunk line: 1) sweep sheets including proof-of-performance records 2) location logs, and 3) serial number logs.

Where to Begin

If you are fortunate enough to be developing the records for a new system or re-build, you can start with the system maps and accurate measurements of equipment performance taken at initial bench inspection and at initial installation.

If you are starting with existing records that are inaccurate and inconsistent, do not despair. Break the job down into managable bites. Begin with your backbone trunk line. Update this line on your map, and be prepared to keep your map up-to-date. You will be working to create "as-built" maps, a section at a time.

Sweep Sheets

Generate your sweep sheets first. A sample sweep sheet is shown in Figure 1. Each sweep sheet records the performance of a freshly-swept loaded mainstation at a particular location in your system. When pulled together, these sheets provide you with all the pertinent information you need on the daily operation of your system. In the future as work is performed at a mainstation, its performance should match that recorded on the sweep sheet. Having a clear record of the necessary performance to match is helpful, since the desired performance for each mainstation will vary. Being able to compare changed values to the original values for particuilar specifications can tip you off that a problem is developing before service is actually affected.

Regularly matching the performance listed on the sweep sheets will lenghten the life of your sweep. A sweep should last about one year. A crew dedicated to sweeping and collecting this information should be regularly working its way through your system. Establish a schedule to spread your sweeps out evenly over the year.

On each sweep sheet, include the installation date and ambient temperature at the time of installation. List the model number, model name, and serial number of every component in the mainstation. Include the number used to identify the location of this mainstation on your maps along with a street location. Record any pertinent information about each individual module in the station. For example, model number and value of any plug-ins installed. For the trunk amplifier, be sure to include input and output levels, reserve slope and gain range, peak-to-valley, and a response picture. Also record bridger module output levels along with the number of feeder lines served, number of feeder lines fused, and number of line extenders served. You will also find a record of the AC input voltage to the mainstation's power supply and the DC output voltage it creates useful. Finally, don't forget to include the location of the line power supply feeding this mainstation.

Along with sweep sheets, you should keep a proof-of-performance record for each trunk line. A sample proof-of-performance record is shown in Figure 2. This record helps you monitor trunk lines between sweeps by documenting the end-of-line performance once each month at various locations throughout the system. Establish several key test spots in your system, and once each month measure and record the composite-triple-beat, carrier-to-noise, and composite-second-order figures for each test location. Also, photograph the response at each test location. Like the individual sweep sheets, these proof-of-performance records can indicate potential trouble before it erupts.

This may seem like a lot of information, and it is. But taking the time to gather it all in one book now will save you time and money later, since it is cheaper, faster, and easier, to look through your sweep sheets than it is to send your crews out to open up mainstations.

Location Log

You will also need to establish and maintain a location log. This record enables you to develop a picture of performance at a particular location over time. Tracking and recording performance trends in this manner helps you spot problems specifically linked to location. Again, this record need not be elaborate to be useful; your location log can have just two columns: date and events. All you want to know is specifically what is happening at each manistation and when the events occur. For example, frequently struck poles or "killer locations" frequently affected by electrical storms become apparent in this log. Knowing that location and not equipment is the cause of a problem can save you a great deal of wasted time servicing amplifiers that are not at fault.

Useful information for your location log is probably already being generated in your system through "Outage Report Forms" and "Trouble Call Report Forms." Make use of these documents by requiring that they all be submitted to the person in charge of your record keeping system. This individual should read each form and then add it to his permanent records in the location log.

Further, I suggest that all staff members be coached on how to make meaningful comments on their reports. Meaningful does not necessarily mean long or formal. But a note that says "trunk amp broken" is not worth the effort it took to write. More useful comments would list specific symptoms, the on-the-spot diagnosis, the action taken, and the result of that action. For example, "trunk amp broken" could be replaced with "low output/correct input levels/could't adjust for proper output/ customer complaint-picture distortion." This note gives you much more to go on when diagnosing a problem.

Serial Number Log

Finally, you will want to develop a separate record tracking the performance of individual plug-in components that are being moved about in your system. The serial number log is your mechanism for doing this.

The first time a module is removed from your system because of a problem, that module should be added to your serial number log. Individual entries here are arranged by serial number and will tell you the module's previous location, date of removal, and reason for removal.

Then, when the module is examined and worked-on you should document its performance on such characteristics as composite-triple-beat, composite-second-order, cross modulation, and noise factor. Plots of the unit's frequency response and input/output return loss should also be included. A sample serial number record is provided in Figure 3.

Taking, recording, and examining these measurements ensures that the modules going back into your system meet factory specifications. For example, if a module is repaired with inferior substitute parts causing its performance to be degraded, you will see the degradation in your serial number log. And you will see it before the degraded module is re-introduced into your system. Monitoring the performance of the components in your system is an effective way to ensure your entire system operates to specification.

In addition, the serial number log helps you isolate modules with intermittent problems. Say, for example, that a module is removed from your system because of low gain. You should immediately turn to your serial number log. If no page exists for this particular serial number, then you know it has not been considered a problem source in the past. Proceed by adding the module to your log; then having the module examined. If, however, a page does exist on this serial number, take a few minutes to look over the existing entries. If previous entries list that this module has been examined twice before for the same problem and both times checked-out fine, you can conclude that the problem is intermittent, and you can adjust your testing and repair practices accordingly. Cycling modules with intermittent problems throughout your system is expensive; the serial number log helps you work to reduce this expense.

If you make entries to the serial number log each time a piece leaves and re-enters your system you will also develop an accurate account of how particular models perform over time. You can use the unit degradation you have tracked to project reasonable system degradation to expect, and then plan maintenance and upgrade work accordingly.

CONCLUSION

Maintaining accurate system records makes it possible for you to run your system, rather than having your system run you. If you are willing and courageous enough to deem preventative maintenance and record keeping "real" and worthy work in your system you will enjoy many rewards. You will have fewer expensive fires to fight and instead be able to intelligently schedule work that heads-off problems before they occur.

Like the saying goes, those who do not examine the past are doomed to repeat it. Why choose to repeat old problems? Record your system's history; study it; then take action so that old problems do not return.

REFERENCE

[1] Ron Hranac, Corporate Engineer, Jones Intercable Inc., "Establishing a PM Program," Communications Technology, December 1985, pp. 94-102.

Mainstation Sweep Sheet

System: ______________________ Date: ______________________

Franchise ______________________ Ambient Temperature: ______________________

Amplifier #: ______________________ Map # ______________________

Location: ______________________ Cascade ______________________

Voltage AC ________

Voltage DC ________

Location of Line Power Supply feeding mainstation ________________

Power Direction In Out Thru

Power Program Card Lo Med Hi

Test Channels	Trunk Input Level (dBmV)	Trunk Output Level (dBmV)	Bridger Output Level (dBmV)
______	________	________	________
______	________	________	________

Pad ____________ Equalizer ______________ Response Equalizer ________________

Reserve Range

Slope ________ dB Up ________ dB Down

Gain ________ dB Up ________ dB Down

Trunk Module ________ Serial Number ________

AGC/ASC Module ________ Serial Number ________

Bridger Module ________ Serial Number ________

Return Module ________ Serial Number ________

Power Supply ________ Serial Number ________

Chassis Model/Serial Number ____________/____________

Housing Model ________________

Place P/V Photo Here

Bridger Splitter model name/number ____________

Number of line extenders the mainstation serves ________

Number of lfeeder lines served ________

Check feeder ports fused 1 2 3 4

Peak-to-Valley ________ dB

Comments ____

____

____

____

____

Technician's Signature

Figure 1. Sample Sweep Sheet Form

System End-of-Line Performance Sheet

System	Amplifier Serial Number	Date
Amplifier Model No. & Name (If line extender, note number in cascade.)	Amplifier Map Number	Time
	Amplifier Location	Temperature

Input Levels			**Output Levels**		
Low Ban	CH	dB	Low Ban	CH	dB
Mid Ban	CH	dB	Mid Ban	CH	dB
High Ban	CH	dB	High Ban	CH	dB
Super Ban	CH	dB	Super Ban	CH	dB
Hyper Ban	CH	dB	Hyper Ban	CH	dB

(Place an asterisk next to channels used as pilots.)

Flatness Photo

Distortion Report

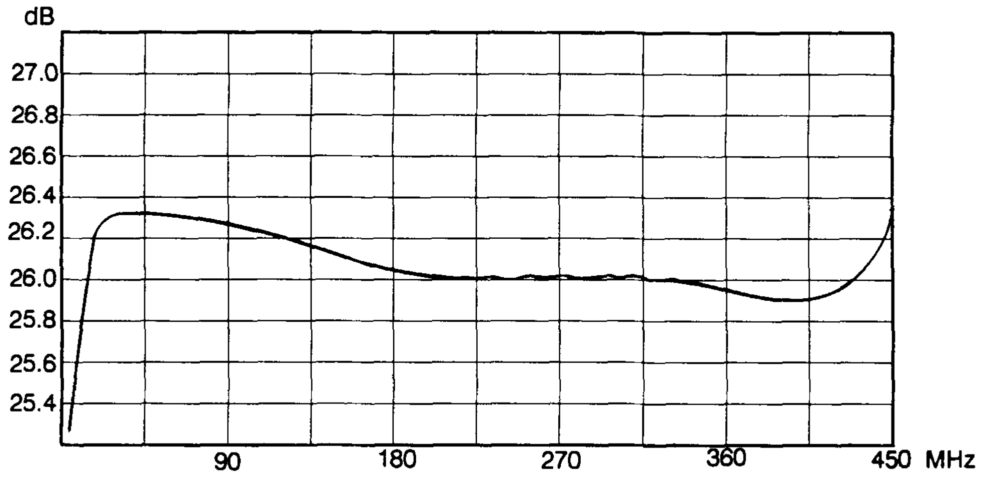
	Low Ban	Mid Ban	High Ban	Super Ban	Hyper Ban
Measured Frequency					
Carrier/Noise					
Composite-Triple-Beat					
Carrier/Cross Mod					

Figure 2. Sample Proof-of-Performance Record Form

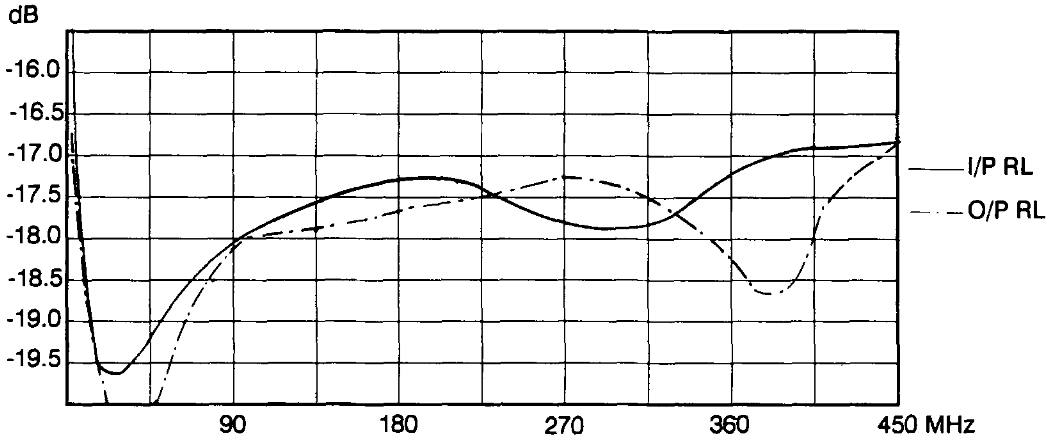
AMPLIFIER ANALYSIS SHEET

Model No. 6-T450 Trunk Amplifier
Serial No. 1232488
Date 3/8/88

Frequency Response



Input and Output Return Loss



Distortion Report

	CH 2	CH 13	CH R	CH HH	CH WW
CTB*	75	69	67	65	63
CSO*	82	81	81	78	74
XMOD**	72	78	70	72	73
NF**	7.5	6.3	6.1	5.9	6.0

*Test performed with 6 dB slope and 45 dBmV output.
**Test performed at operational gain.

Figure 3. Sample Serial Number Record

LAUNCHING A STATEWIDE ANI PASSING IMPULSE PPV SYSTEM

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ABSTRACT

Pay-Per-View is an important source of revenue for the cable television industry. The challenge is in launching this new service in a customer-friendly manner over a wide variety of system architectures.

The answer can be found by taking advantage of an existing customer accepted technologies: the telephone, 92% of the homes in America have an in-home telephone; this with the cable television industry's use of addressable converters, provides the solution.

Both of these existing technologies, the telephone and the addressable converter, can be merged together on a statewide basis to become a low cost and reliable means of implementing a statewide ANI based IPPV network.

The ANI based IPPV viability has been proven on the system level in the Centel Traverse City , Michigan system. The next logical step would be to implement a network that would link multiple systems together. The basics of how an ANI system works and network design considerations will be covered. Among the factors discussed are:

- Telco Switch consideration
- Peak system loading
- Throughput and trunk requirements
- Interfacing with the billing system
- Remote scheduling of controllers
- Network design considerations

Experience gained through the operation of an ANI passing IPPV system since May 1, 1986, will be discussed, along with other non-traditional means of gathering ANI information.

INTRODUCTION

IPPV has gained wide acceptance as a valuable source of revenue for the cable television industry. Of the variety of transaction technologies available, ANI has proven to be one of the most customer friendly and economical approaches to impulse order taking. ANI can be used with either rotary or touch tone telephones and requires no additional in-home hardware. A PPV event is ordered by the subscriber viewing the barker channel, which has a list of events available and the times they are shown. Once a selection has been made, the corresponding telephone number is dialed. After the automated "thank you" response, the subscriber hangs up without having to speak to anyone or enter additional digits. Total off-hook time less than fifteen seconds.

ANI OVERVIEW

Automatic Number Identification (ANI) has been in use in the telephone industry for many years. It's main use has been in the identification of subscribers placing a call for automatic billing purposes in 800 and 900 prefix applications.

The ANI information originates from the local telephone switching center or switch where each telephone subscriber has his own individual pair of wires connected. The switch recognizes when a subscriber picks up his phone and waits for the dialed digits to route the call to the appropriate equipment.

In an ANI passing system, some software modifications called translations, are made to the switch so that the PPV call is routed differently. These modifications allow the call to be placed on a different set of trunks that route the call outside, and thus

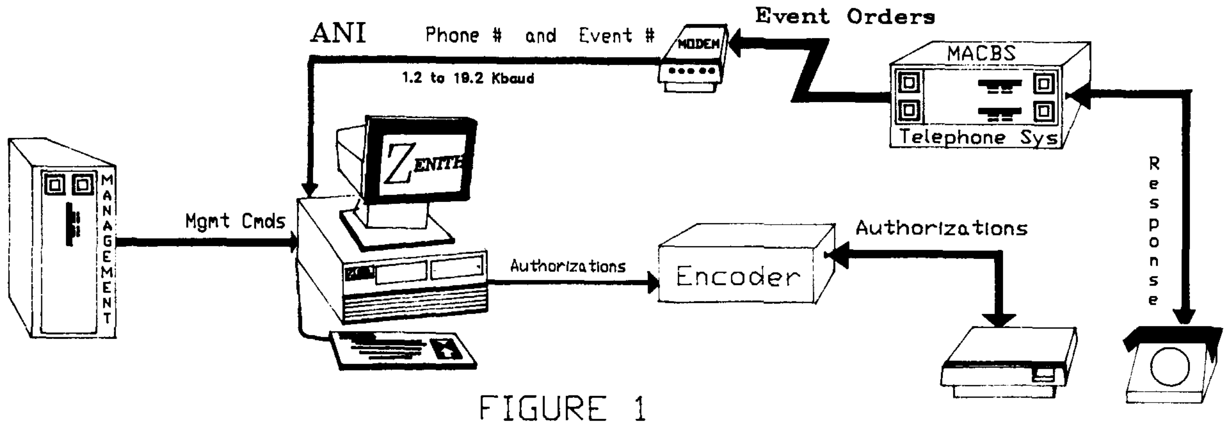


FIGURE 1

bypassing, the normal telco switching equipment, and directly connecting to the Science Dynamics Multi-Access Cable Billing System [MACBS]. A simplified block diagram is shown in Figure #1.

The routing of the call out of the normal telco network is an important factor. This means the telco network is not subject to peak loading, that could overload or crash the local switch network, should a high volume of calls occur in a short period of time.

When the PPV call reaches the MACBS, it is held in a buffer while the MACBS requests the calling number or ANI from the originating switch. Once the ANI has been received, both the called number [identifying to the event] and the calling number [identifying the subscriber] are sent in an asynchronous ASCII data packet, via a modem to the CATV company. When verification has been received that the modem at the CATV company is available to accept the order, a response is given to the calling subscriber. The response is a digitally synthesized message, thanking the caller for the order and requesting the caller to please hang up.

NETWORKING SWITCHES

The first step in designing a ANI passing IPPV network is determining which switches are involved. This is best assessed through a list of the number of subscribers by prefix or NNX you wish served.

The list will indicate to the telephone company which switches are involved and the probable call volume that will be processed. The telephone company will then design a network that will link the switches together into one or more MACBS.

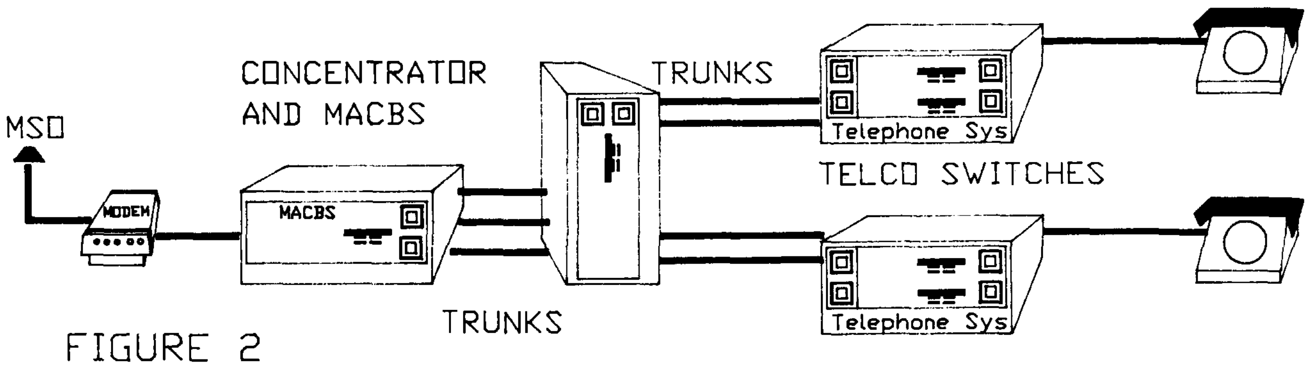


FIGURE 2

This is most commonly done through a series of ANI sending trunks called TSPS trunks, linked together into a Tandem computer, acting as a concentrator. The output of the Tandem will be trunked in to the MACBS as shown in Figure #2 .

The number of trunks needed to link the switches into the MACBS is dependent on three factors:

- the call volume
- the peak loading
- the holding time per trunk

Many of the newer electronic and digital switches can be fairly easily converted to pass the ANI to the MACBS by entering new translations. The older electro-mechanical switch may require physical re-wiring but in some cases even if rewired may not be capable of ANI passing.

The telephone company is the only one who can determine what equipment changes and networking is required. Only after a timetable has been given can the true potential of an ANI network be explored.

PRIVATE BRANCH EXCHANGES

Many organizations today are using their own internal telephone exchange or private branch exchange [PBX]. The PBX can route calls within the organization to other extensions, as well as connect them to the public telephone network, to place outgoing calls.

When an outgoing call is dialed, the PBX will select one of a group of trunks that connects the caller to the public telephone network. This random selection of outgoing trunks created a problem for an ANI system, since the ANI would only identify the trunk group. To identify the specific phone or customer in the PBX network that placed the request, an additional identifier needed to be added.

For the hotel industry using an in-house PBX, a separate Barker Channel would be needed to reflect the PBX PPV order number and the increased cost of the event.

When the PBX order number is dialed, the MACBS will route the call through a separate interface. A voice response will request the customer to enter their PPV number on their touch-tone phone. The MACBS will respond back, repeating the PPV number and requesting they press the star [*] key if the number was correct or the pound [#] key if the number was incorrect.

If the star [*] key is pressed the MACBS will thank the customer and request they hang up. A pound [#] key entry will request they re-enter the number again.

The ANI indicates the trunk group for the MACBS, which in turn translates the prefix of the calling number into the identity of the hotel, along with its four digit PPV number. This information would then be processed in the controller in the same manner as a standard ANI data packet and authorizes the descrambler for the requested event.

The PBX in the hotel would note the PPV order number in much the same way as it handles long distance in room calls. A translation would be entered into the PBX so the proper charge and description would be noted on the guests room bill.

Once each month, the cable company would send the hotel a bill, with backup of each transaction, for the buys made during the month. This same scenario could be used for any PBX application to gather the ANI identification.

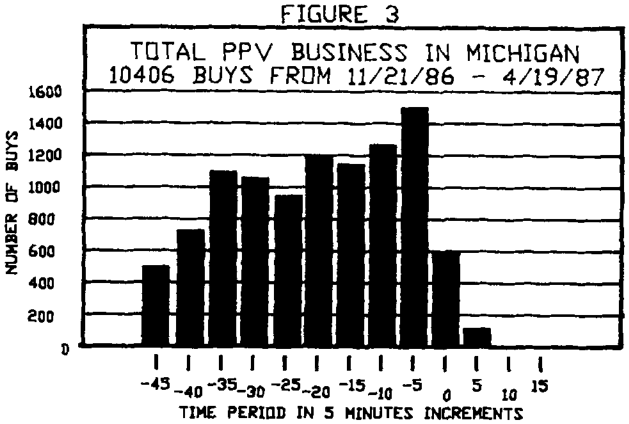
NETWORK THROUGHPUT

The throughput of an ANI network or the number of transactions a network can process, is determined by:

- number of trunks
- holding time per trunk
- peak loading
- controller processing capability

To some extent peak loading is influenced by the length of the order entry window, customer familiarity, confidence in the system, and the popularity of the events.

FIGURE 3

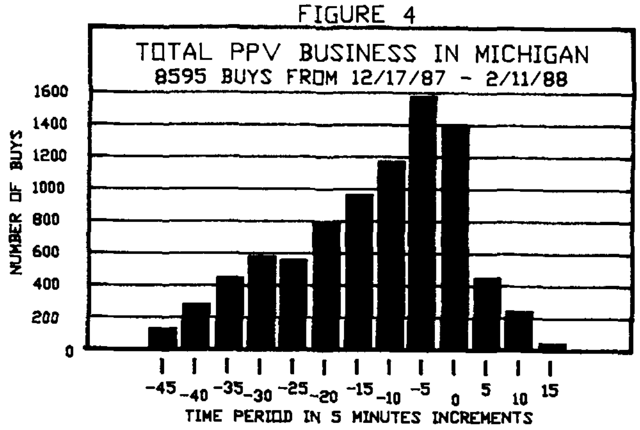


The first order entry window Centel used was 45 minutes prior to the start of the event. Six months after the system was launched, a peak loading study was done see Figure 3. The findings revealed a more level ordering pattern than expected. We also found that 18% of the subscribers tried to place an order after the event started. With this in mind, we extended the order entry window to include the first 15 minutes of the event.

Between December 17, 1987, and February 11, 1988, a second peak loading study was done see Figure 4. This study demonstrated a substantial increase in orders just before the event, which we attributed to the customer's increased confidence and familiarity with the ANI order entry system.

Throughput of the MACBS is proportional to the number of trunks that terminate into it and the holding time that each customer remains on line during a transaction. The holding time is affected by the length of the audio response given the customer. We presently use "Your order has been accepted. Thank you. Please hang up". This message results in an average of 16.5 seconds of holding time per trunk, or 3.6 calls per minute per trunk. Shortening the message to "Thank You" and automatically disconnecting the customer would reduce the holding time to 10 seconds per transaction. Ten seconds of holding time per trunk allows six calls per trunk per minute. Using the buying curve in Figure 4, the throughput for a 24 trunk system with a 10 second holding time would be approximately 3,900 calls per event.

FIGURE 4



When designing an ANI network, Some assumptions need to be made regarding the maximum volume of calls anticipated and the peak loading you will experience. From those assumptions, the number of needed trunks can be determined. There is no practical limitation on the number of trunks into the MACBS.

AUTHORIZATIONS

There are two ways of authorizing the PPV customer's converter for the requested event:

- Through the billing system
- Directly to the addressable controller

There are both advantages and disadvantages of routing the ANI through the billing system prior to the addressable controller. The tradeoffs are increased flexibility versus reliability.

If the billing system processes the transactions prior to the addressable controller, several options are available.

- Compatibility with a wider variety of addressable converters.
- Instantaneous credit checks.
- Flexibility in packaging and discounts for multiple events.
- Controllers with less on-board memory and speed could be used.

The addressable controller maintains the subscriber database in active memory. With the ANI sent directly to the controller there are several advantages gained.

- Nearly instantaneous look-up, processing, and authorization of events.
- No interruptions due to loss of data communication with the billing system.
- No loss of events due to nightly procedures on the billing system.

In Centel's Michigan systems, it was decided to implement a statewide IPPV network by delivering the ANI directly to the controller. This decision was made to gain the maximum reliability.

It is believed that if the more crucial links in the chain of events were in Centel's control, the less likely a failure would occur and more likely that timely repairs could be made.

It has been Centel's experience that a lack of system reliability reduces customer confidence. This lack of confidence reduces the buy rate and increases the number of duplicate order requests. In the event that you are paying for ANI services by the number of requests delivered to the CATV system, there could be a significant increase in transaction charges.

BARKER CHANNEL

To be in a position to take advantage of an impulse buying decision, the PPV offerings need to be readily available. A method that has proven to be one of the most accessible and economical is a character generated Barker Channel.

This channel, as shown in Figure #5, has a list of currently showing events, the price, associated time, and order number.

CENTEL CINEMA
Each Movie is $3.95
Monday's Movies:
7:00 pm - Title
9:00 pm - Title
11:00 pm - Title
1:00 am - Title
3:00 am - Title
To Order, Dial: 999-9090

From 45 Minutes Before until
15 Minutes after each event

FIGURE 5

In addition to the screen shown in Figure 5, there are screens that give a brief description of each movie, the rating, and it's duration.

Networking of the Barker Channel throughout the state from one central location, is done with dial-up data lines and addressable character generators made by Video Data Systems. This allows the same central location that schedules the remote addrssable controllers to also control the remote Barker Channels.

VIDEO PROGRAM SCHEDULING

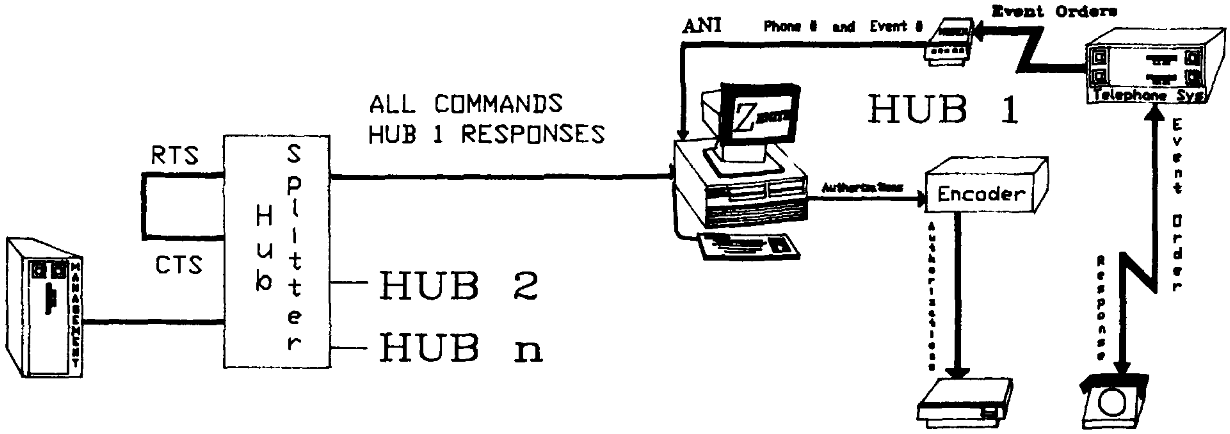
With the complexity of the PPV event schedule, having one central control point provides consistency, reduces labor cost, and reduces human errors.

The video supplier downloads the time schedule of programming to a single location. The central location converts the time schedule to management computer interface commands. These commands are multiplexed with the management computer commands and downloads the program time schedule to all controllers using the same data distribution system.

MANAGEMENT COMPUTER INTERFACE

The decision to connect all controllers to a single management computer interface, while providing local control of new installations, background global refresh, and ANI input, gives Centel the reliability of local control and the economy of centralized customer service, billing and scheduling.

FIGURE 6



This is accomplished by feeding the entire state through one box driver port. This port is sent through a multiport expander which transmits to all controllers. The controllers are addressable by hub number. Only the controller whose hub number matches the hub number embedded in each command will execute the command and respond to the management computer. Each controller supports RTS/CTS hardware handshake. The multiport expander uses the RTS signal to connect the responding controller to the management computer. The port expander issues a CTS to the controller permitting response. See figure 6.

In those cells where there are clusters of small cable systems, a single controller is used for multiple headends. It is possible to implement the statewide ANI system using only two addressable controllers. The addressing data is distributed via leased line synchronously to the local headends. This economical approach works with either Z-TAC baseband or PM rf addressable converters. A separate controller is needed for each type of converter. They are controlled by the single management computer interface port. See figure 7.

The ANI information is sent to all controllers via a multiplexing modem. The controllers will process ANI information only for those phone numbers in its data base. The management computer polls each controller for an upload of the ANI Pay-Per-View transactions.

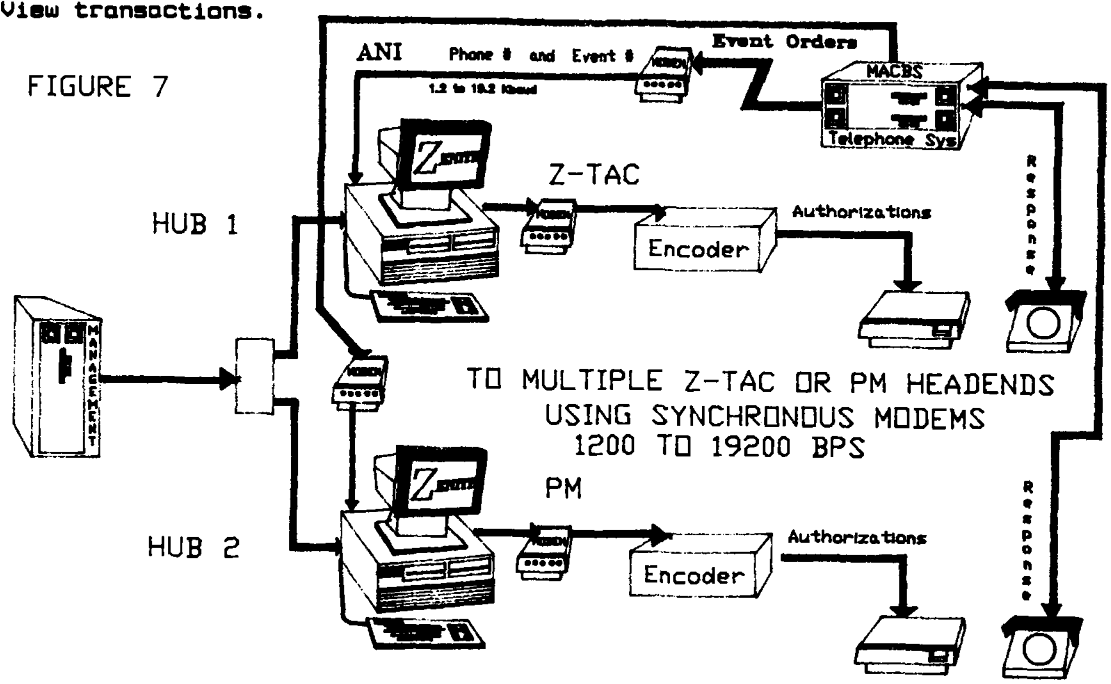
STATEWIDE ANI NETWORK ARCHITECTURE

The ANI PPV network will be initially launched in eight systems around the state. These systems are already linked together with multiport asynchronous data modems. These lines are used to carry the CableData billing information. Additional ports on these same data multiplexers will also carry the ANI, and management computer interface to the Zenith addressable controllers. The time scheduling of program control will be multiplexed with the management computer interface data. See Figure # 8 .

The scheduling of both addressable controllers, as well as the Barker Channel character generators, will be done from one central location. A conversion utility will take the video program schedule and convert it to management computer interface commands. These will then be downloaded to all hub controllers by time sharing the interface link.

Each of the initial systems, with one exception, will have their own addressable controller. This will break the network into separate, yet linked, individual cells, or hubs. Therefore, it will allow most of the network to operate independently in the event of a failure in any link in the chain. Although the ANI information shares the same phone line, a separate phone line would be no less susceptible to outage.

FIGURE 7



The second input to the controller will be used for the ANI data packets from the MACBS. The output of each area MACBS is sent to all local hub controllers. Each controller has its own systems data base downloaded into its memory. When the ANI from another hub reaches the controller, it is unable to match it with the information in its own data base, so it is rejected. Overloading is not a problem because of the speed and capacity of the Zenith 200 series controller.

The Zenith controller can accept an average of 50 ANI transactions per second with bursts of 100 per second. The database capacity can be expanded to in excess of 300,000 decoders with additional memory, and supports 15 area codes and unlimited NNX numbers.

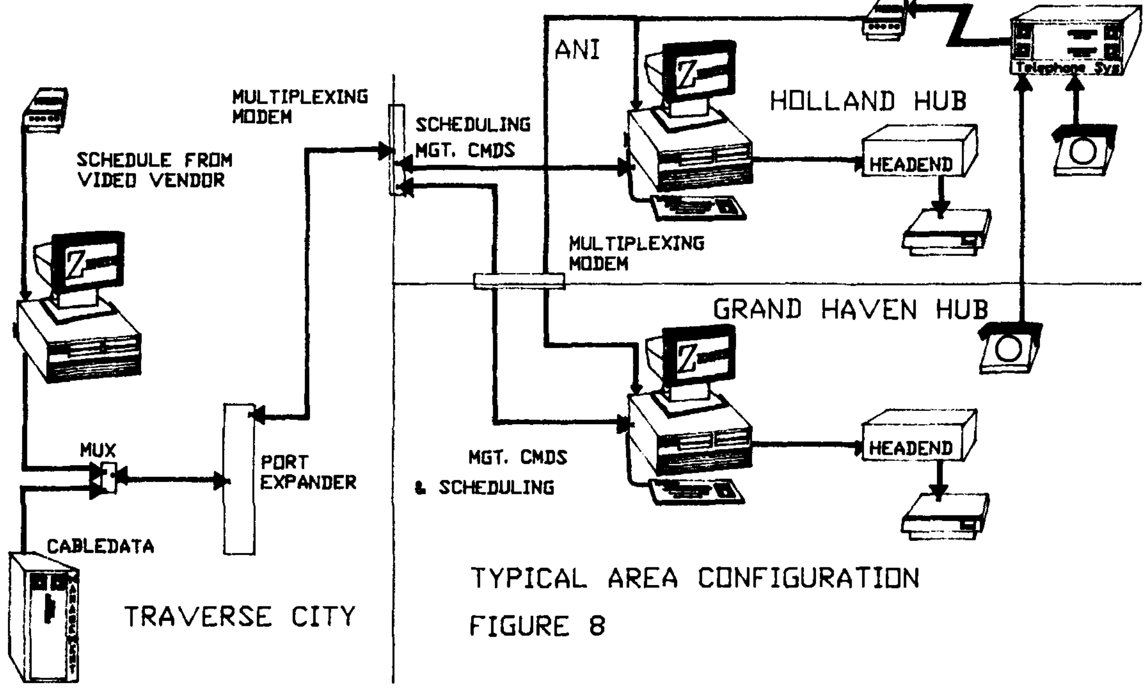
With the burden of sorting the ANI being placed on the controller rather than the MACBS, the same order number can be used by one MSO for all area systems. This method was selected for three reasons:

- The same controller schedule could be created for all systems
- The cost of the MACBS can be spread over many cable operators reducing the per transaction charge.
- The same marketing materials can be used for an operator with many CATV systems is the same area.

Each of these factors reduce the operating costs of the ANI network.

ACKNOWLEDGEMENTS

The authors would like to express thanks to Mark Bowers, Tom Roach, and Karen Briggs of Centel, Bill Courry and Russ Spranger of Michigan Bell, Vito Brugliera, and Jeff Huppertz of Zenith.



TYPICAL AREA CONFIGURATION
FIGURE 8

MANAGING SERVICE CALL REDUCTION

BY

ROBERT A.LUFF, GROUP V.P./TECHNOLOGY JONES INTERCABLE, INC.
DON SUTTON, EXECUTIVE DIRECTOR OF ME/U JONES INTERCABLE, INC.
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DANA EGGERT, PRESIDENT, PERFORMANCE PLUS TRAINING PROGRAMS.

ABSTRACT

CATV service calls have grown to a staggering one million dollar per day cost. Various MSO studies confirm that nearly 80% of all service calls fall between the pole and the TV - that is, within the drop system. And, of these, nearly 40% are the result of poor training, workmanship, or accountability of the field installation work force. A unique installer qualification and performance tracking program concept called Performance Plus was created to address this costly and subscriber frustrating problem. This paper details the Jones Intercable specific installer quality and performance tracking QIP program.

INTRODUCTION

Based on the industry average of 3% per month service call ratio of 60 million subscribers at an average cost of $30 per service call, the cable industry now experiences a service call expense of nearly one million dollars per day - and this expense continues to grow.

Research by several MSO's show that 80% of all service calls are caused by problems between the pole and the back of the TV set, i.e., the drop system and in the domain of the installer. The research also shows that of this 80%, nearly 40% of the problems are the direct result of poor training, workmanship, and accountability of the installation work force.

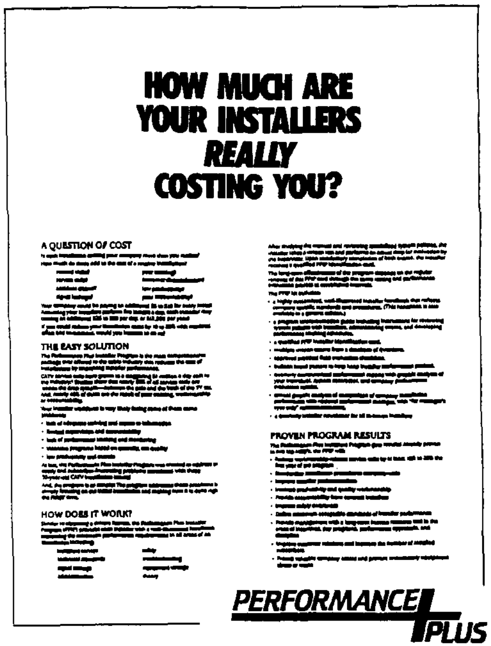
As an example, a large MSO with nearly one million subscribers has documented that its service call ratio is just at the industry average of 3%. Records show that it averaged a little over 30,000 service calls per month. Previous analysis by several MSO's assigns an average cost of $30 per service call. (Most industry experts believe $30/service call to be, if anything, conservative. The telephone company uses $72 per service call in their analysis.) This means that service calls cost this MSO at least $900,000 per month, every month. This equates to $10,800,000 per year.

If the same assumed ratios and costs were used, typical cable system with 10,000 subscribers would result in $9,000/month and $108,000/year service call expense respectively.

In both examples, a large sum of money!

The Performance Plus Concept

An industry expert in installer training and productivity tracking, Dana Eggert, introduced the Jones Technical Department to a unique and promising concept to effectively address service call reduction called the Performance Plus Installer Program (PPIP) (Fig. 1).



HOW MUCH ARE
YOUR INSTALLERS
REALLY
COSTING YOU?

A QUESTION OF COST

THE EASY SOLUTION

HOW DOES IT WORK?

PROVEN PROGRAM RESULTS

PERFORMANCE PLUS

FIGURE 1

This unique approach addresses the service call problem by focusing on insuring that the initial installation or service call is done right the first time and establishes an effective performance tracking and feedback system.

This performance monitoring and feedback process is key to the effectiveness of the Performance Plus Installer Program. Unlike traditional training programs where performance peaks immediately after the training session then rather quickly falls back, the PPIP offers a long-term approach to performance management through the ongoing performance monitoring process.

Initially, performance expectations are established and clearly communicated by a strong policy statement from the user company for quality workmanship and a complete installer handbook including all company practices and policies on installations. An evaluation of those performance standards is achieved through a written exam and field evaluation. Performance continues to be monitored, then, by periodic field evaluations.

The program in its complete form provides computer analysis of the initial and periodic tests, and field evaluations which are graphically represented to show performance trends and improvements by system, team, contractor, or individuals, in summary or by specific item (e.g., loose F-fittings, unlocked pedestals, and grounding). Such graphic and quantitative output serves as feedback to the individual installers and to the supervisory level as well.

THE JONES QUALIFIED INSTALLER PROGRAM

Jones leadership is both quality minded and concerned about managing service call cost reduction. Jones was intrigued by the fundamental concept of the Performance Plus Installer Program and commissioned its own company-specific version to be developed and implemented.

The Jones Qualified Installer Program (QIP) was designed to address the 80% of service calls that are caused by problems between the pole and the TV set, and more specifically, the 40% that are caused by poor training, workmanship, and accountability of the field installation work force.

Using the Performance Plus approach, the Jones QIP program is not a training program, per se. Nor is it just a manual, although a well written and illustrated generic or company-specific installation manual, which is an integral part of the final Jones QIP program. Further, the QIP program is not just based on an SCTE-type BCT/E written or field evaluation. The QIP program is <u>all</u> of the above. The Jones QIP Program is a complete but simple installer/management integrated approach founded on the basic philosophy of "doing it right the first time".

The Jones QIP program has six essential parts: 1) a well written and illustrated installer's manual printed in a manner that is easy to use in the field; 2) a strong statement of commitment from the President and Chairman of the Board, Glenn R. Jones, regarding the priority for quality installations and quality customer service; 3) a written self-evaluation of the manual's practices and policies; 4) a written proctored skill evaluation when the installer is ready; 5) initial and recurring field skill evaluations; 6) a formal method to include the QIP results in the personnel record in a manner that insures that they are considered during salary and promotion reviews.

THE QIP MANUAL

The heart of the QIP program is the QIP manual (Figure 2). How can we expect accurate execution of very complex installations if we do not define our practices and policies in a manner easily understood by installers? Included in this manual is everything the installer should know about a company's installation practices and procedures. So what's so new about an installation manual?

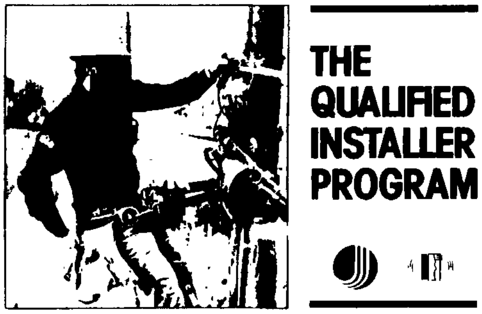


FIGURE 2

The authors of the Jones QIP manual, Bob Luff, Don Sutton, Pam King, Dana Eggert (Consultant), Paul Schauer, Charles Turner, collectively have had considerable experience in writing manuals for various industries and applications. A review of CATV installation manuals in general found many common shortcomings. First, many companies and systems surprisingly do not even have a written installation manual for their employees. Everyone agreed with the need but just could not find the time. Many companies and systems who thought they had installation manuals were surprised with field results that showed no installers, and only a few of their highest technical level employees, could produce one. Also, even when a company or system could be found with an installation manual in the field, it fell into one or a combination of the following benefit-robbing situations: 1) so out-of-date most employees ignored it as a serious reference or guide; 2) written at such a high level (by senior technical personnel) that most field personnel, especially installers, found it above their level and too difficult to read; 3) the manual itself was printed in a format impractical for convenient day-to-day use in the field - usually a hard three-ring binder that may work well on a book shelf but hardly suitable for a back pocket or glove box.

The Jones QIP manual was designed to address each of these possible shortcomings. It was decided to make the manual contain every practice and policy the installer was expected to follow so that this manual would be the only manual. Further, it was decided to make the QIP manual very readable for its intended audience. After the Company's official practices and policies were all reviewed and updated (not at all an easy task), they were re-written and each important point amply illustrated.

The manual is styled very much like a typical State Drivers Manual. It is printed in a 6" x 8" format with soft covers allowing easy fit in the glove box or back pocket. An effort was made to keep the illustration to text space ratio to about 50% (Figure 3). The text was checked repeatedly for readability and understanding at the eighth grade level (eighth grade is a common target level for manuals of this type). The manual was also checked by qualified professions to insure that there were not ethnic, age, or gender bias in either the text, illustrations, or skill evaluations.

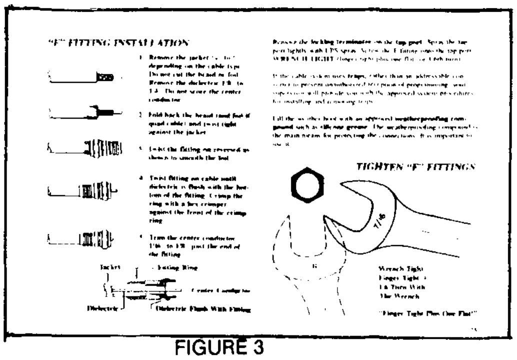
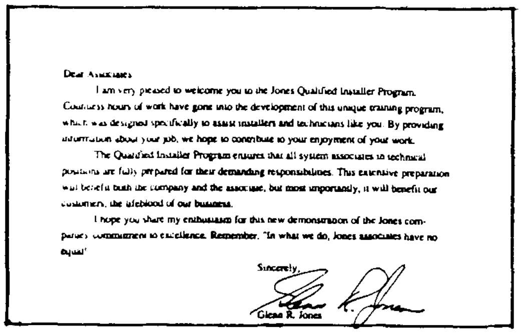


FIGURE 3

Statement of Commitment

A strong statement of commitment to quality workmanship and to the highest standards of customer service by the President of the Company is one of the most important guarantees of success for a quality-oriented installer program (Figure 4). Too often the field personnel hear guidance regarding only the quantity of daily work.



Dear Associates:

I am very pleased to welcome you to the Jones Qualified Installer Program. Countless hours of work have gone into the development of this unique training program, which was designed specifically to assist installers and technicians like you. By providing information about your job, we hope to contribute to your enjoyment of your work.

The Qualified Installer Program ensures that all system associates in technical positions are fully prepared for their demanding responsibilities. This extensive preparation will benefit both the company and the associate, but most importantly, it will benefit our customers, the lifeblood of our business.

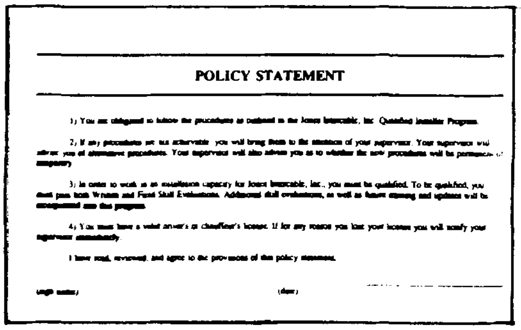
I hope you share my enthusiasm for this new demonstration of the Jones companies' commitment to excellence. Remember, "In what we do, Jones associates have no equal."

Sincerely,

Glenn R. Jones

FIGURE 4

The Jones Statement of Commitment includes both the company's pledge to quality performance and the individual installer's pledge to quality performance (Figure 5). The statement of commitment appears in the very first few pages of the QIP manual and requires all company or contract installers to sign the commitment indicating that they



POLICY STATEMENT

1) You are obligated to follow the procedures as outlined in the Jones Intercable, Inc. Qualified Installer Program.

2) If any procedures are not achievable, you will bring them to the attention of your supervisor. Your supervisor will advise you of alternative procedures. Your supervisor will also advise you as to whether the new procedures will be permanent or temporary.

3) In order to work in an installation capacity for Jones Intercable, Inc., you must be qualified. To be qualified, you must pass both Written and Field Skill Evaluations. Additional skill evaluations, as well as future training and updates will be incorporated into this program.

4) You must have a valid driver's or chauffeur's license. If for any reason you lose your license you will notify your supervisor immediately.

I have read, reviewed, and agree to the provisions of this policy statement.

(sign name) (date)

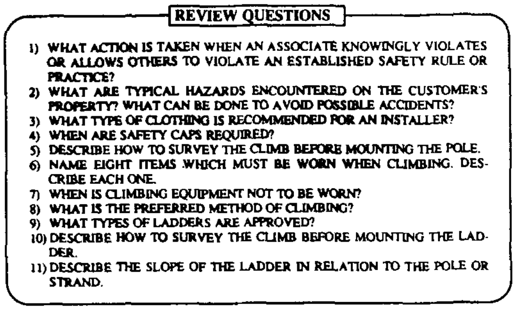
FIGURE 5

understand that quality workmanship and high customer service standards are desired at all times, and that by their signatures they are agreeing to follow the specific Jones installation procedures, standards, and policies. They also agree to cheerfully accept guidance and constructive comments from supervisors and make every attempt to address their points as quickly as possible. And lastly, the installers agree to have the results of the recurring skill evaluations entered into their individual personnel files and acknowledge that they are an important part of the performance evaluation process.

There was concern that such a radical change from virtually no direct link between actual field workmanship and the evaluation process to a very formal and direct link would cause employee concern or backlash. In fact, the installers very much welcomed the process. It seems that lacking such a formal process, installers have felt that salary increases and promotions have been based on friendships or at best random. This process took the all important merit and promotion consideration from under-the-table to on-the-table in their eyes, and they liked the change.

Self-Evaluation

Perhaps the strongest factor in early enthusiastic acceptance of Jones QIP Program to both company and contract installers is the self-evaluation feature of the manual. Every two or three pages in the text there are three to five "bullet questions" covering the important procedures or policies of the immediate text and illustrations (Figure 6). The reader is able to immediately determine whether he fully understands that section before going on. The answers are given in full on the next page so there is no frustration, waiting, or misconceptions allowed to develop. At the end of each chapter is a chapter quiz - again with the answers on the next page.



REVIEW QUESTIONS

1) WHAT ACTION IS TAKEN WHEN AN ASSOCIATE KNOWINGLY VIOLATES OR ALLOWS OTHERS TO VIOLATE AN ESTABLISHED SAFETY RULE OR PRACTICE?
2) WHAT ARE TYPICAL HAZARDS ENCOUNTERED ON THE CUSTOMER'S PROPERTY? WHAT CAN BE DONE TO AVOID POSSIBLE ACCIDENTS?
3) WHAT TYPE OF CLOTHING IS RECOMMENDED FOR AN INSTALLER?
4) WHEN ARE SAFETY CAPS REQUIRED?
5) DESCRIBE HOW TO SURVEY THE CLIMB BEFORE MOUNTING THE POLE.
6) NAME EIGHT ITEMS WHICH MUST BE WORN WHEN CLIMBING. DESCRIBE EACH ONE.
7) WHEN IS CLIMBING EQUIPMENT NOT TO BE WORN?
8) WHAT IS THE PREFERRED METHOD OF CLIMBING?
9) WHAT TYPES OF LADDERS ARE APPROVED?
10) DESCRIBE HOW TO SURVEY THE CLIMB BEFORE MOUNTING THE LADDER.
11) DESCRIBE THE SLOPE OF THE LADDER IN RELATION TO THE POLE OR STRAND.

FIGURE 6

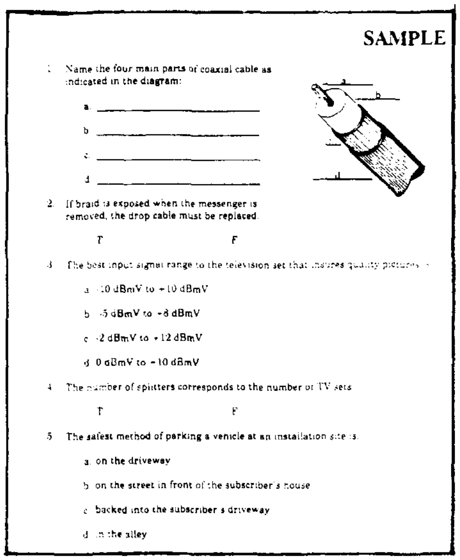
The comments from the field have been very positive on the self-evaluation bullets and chapter quizzes. Installers (everyone) likes to know where they stand as they proceed.

There is an important element to successful training theory working here as well. "Fear of failure" robs everyone of a fully positive attitude toward something new that involves a testing process. It is only natural to doubt one's own ability or the fairness of the exam which can also dampen the enthusiasm and momentum of even the highest charged program. The self-evaluation bullets and chapter quizzes quickly help to show the installer knows the material and can easily pass.

The chapter self-evaluation quizzes presented in the same format as the final written exam further builds confidence in the installer's ability as well as to the fairness of the questions.

Proctored Exam

No element of the original Performance Plus or Jones specific QIP programs was debated more than whether this program would work best (or at all) with or without a final written proctored exam (Figure 7).



SAMPLE

1. Name the four main parts of coaxial cable as indicated in the diagram:

a. ____________________

b. ____________________

c. ____________________

d. ____________________

2. If braid is exposed when the messenger is removed, the drop cable must be replaced.

T F

3. The best input signal range to the television set that insures quality pictures is

a. -10 dBmV to +10 dBmV

b. +5 dBmV to +8 dBmV

c. +2 dBmV to +12 dBmV

d. 0 dBmV to +10 dBmV

4. The number of splitters corresponds to the number of TV sets

T F

5. The safest method of parking a vehicle at an installation site is:

a. on the driveway

b. on the street in front of the subscriber's house

c. backed into the subscriber's driveway

d. in the alley

FIGURE 7

The arguments against an exam centered around the fear that the installers, particularly contract employees, would object to the requirement and that there was so much obvious benefit from the rest of the total program - why risk it?

The arguments for the exam centered around accountability of the program itself as well as the installation work force, including the supervisory level.

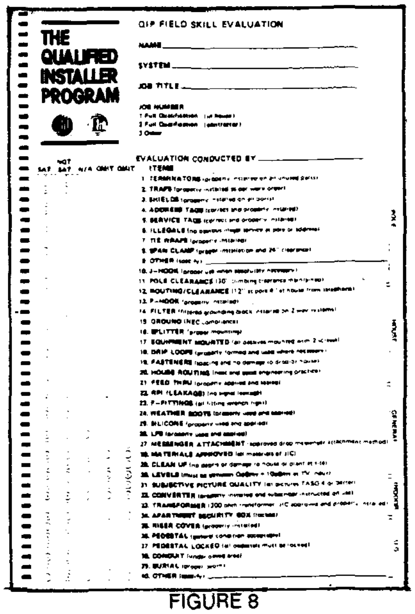
One of the strongest fundamental elements of the parent Performance Plus concept that intrigued Jones was that the program had an automatic "self driving factor" and an automatic "self healing factor" built in. The Performance Plus concept included a policy statement "that no one is allowed to perform installations or service calls unless they are 'qualified' to do so by successfully completing both written and field evaluations". The intent as far as desired impact on the installation work force is obvious, but the full purpose of this policy was to insure the company had a means to focus daily on the program and that it could not slowly erode into inexistence or ineffectiveness like so many "voluntary" programs. The theory is that by making the testing a company requirement and making the field evaluations very much part of the employee evaluation process, the program, once started, would remain in a state of "spontaneous combustion" without continuous support from the distant corporate office. Once the program was up and running, employees involved in the process would not sit back and allow "less qualified" employees to enter their same QIP status. Further, if an employee or contractor's employee was ready to take the written exam and the supervisor delayed the process excessively, the employee or contractor would cause a review of the situation. And lastly, if company practices or procedures change (as they do frequently) and either the text, illustrations, or exams fell out of date, the employees would again cause a review.

In short, the written exam decision was made to insure that the program is scrutinized by all those involved so that it remains fair, accurate, up-to-date, and carefully administered.

Field Evaluation

The last major element of the Jones QIP Program is actual field evaluation of installer workmanship quality. To become a Jones Qualified Installer the associate must pass an initial field evaluation, and must pass recurring field evaluations to maintain that status.

When the installer is ready, he simply requests a field evaluation. His supervisor accompanies him on a regular installation work order, and with a formal computer check sheet observes the installer perform an installation without interfering with the job (Figure 8). During the installation the installer is rated on the defined performance standards in all areas including safety, customer service, drop procedures, etc. When the installation is over, the supervisor more closely inspects the drop for mechanical and electrical integrity and completes the evaluation form. The results are shared and discussed with the installer immediately at the site to provide more effective feedback with concrete examples.


THE QUALIFIED INSTALLER PROGRAM

QIP FIELD SKILL EVALUATION

NAME ____
SYSTEM ____
JOB TITLE ____

JOB NUMBER
1 Full Qualification (in house)
2 Full Qualification (contractor)
3 Other

EVALUATION CONDUCTED BY ____

SAT NOT SAT N/A OMIT OMIT ITEMS
1. TERMINATORS (properly installed on all unused ports)
2. TRAPS (properly installed as per work order)
3. SHIELDS (properly installed on all ports)
4. ADDRESS TAGS (correct and properly installed)
5. SERVICE TAGS (correct and properly installed)
6. ILLEGALS (no obvious illegal service at pole or address)
7. TIE WRAPS (properly installed)
8. SPAN CLAMP (proper installation and 24" clearance)
9. OTHER (specify) ____
10. J-HOOK (proper use when absolutely necessary)
11. POLE CLEARANCE (30" climbing clearance maintained)
12. ROUTING/CLEARANCE (12" at pole & 1' at house from [illegible])
13. P-HOOK (properly installed)
14. FILTER (filtered grounding block installed on 2 way systems)
15. GROUND (NEC compliance)
16. SPLITTER (proper mounting)
17. EQUIPMENT MOUNTED (all passives mounted with 2 screws)
18. DRIP LOOPS (properly formed and used where necessary)
19. FASTENERS (spacing and no damage to drop or house)
20. HOUSE ROUTING (neat and good engineering practice)
21. FEED THRU (properly applied and sealed)
22. RFI (LEAKAGE) (no signal leakage)
23. F-FITTINGS (all fitting wrench tight)
24. WEATHER BOOTS (properly used and applied)
25. SILICONE (properly used and applied)
26. LPS (properly used and applied)
27. MESSENGER ATTACHMENT (approved drop messenger attachment method)
28. MATERIALS APPROVED (all materials of JIC)
29. CLEAN UP (no debris or damage to house or plant at site)
30. LEVELS (must be between 0dBmv + 10dBmv at TV input)
31. SUBJECTIVE PICTURE QUALITY (all pictures TASO 4 or better)
32. CONVERTER (properly installed and subscriber instructed on use)
33. TRANSFORMER (300 ohm transformer JIC approved and properly installed)
34. APARTMENT SECURITY BOX (locked)
35. RISER COVER (properly installed)
36. PEDESTAL (general condition acceptable)
37. PEDESTAL LOCKED (all pedestals must be locked)
38. CONDUIT (under paved area)
39. BURIAL (proper depth)
40. OTHER (specify) ____

FIGURE 8

The Jones QIP Program requires all supervisors to perform at least five random field evaluations for each installer under his supervision every quarter. The installations selected must be current installs that were done by the installer during that same quarter. These evaluations can be done after the fact without the installer actually present.

This requirement serves several important functions. First, it insures continual focus on the program. It also provides an important mechanism for the supervisor to "schedule in" field visits in his own calendar for the express purpose of reviewing his installers' performance - a function that too often gives way to other seemingly important tasks.

Also, by requiring quarterly evaluations of all installers on the same standardized sheet, the supervisor and the installer are able to observe through graphic representation any positive or negative performance trends in as little as six months and have the opportunity to have several feedback/result sessions within the first year of the program.

Indeed, from the company's standpoint, this quarterly review of all workmanship in the field provides invaluable data on the overall effectiveness of our training, recent changes in important practices, and changes in system technical or management leadership. Because the field data evaluation sheets are optically scanned into a computer, any amount of analysis and comparison are easily done and graphically represented.

Beta Test

The primary reason for a controlled and limited Beta Test was to evaluate the attitudes and receptiveness to the QIP from field personnel. While Jones was confident that the program would be well received, the technical department exercised some degree of caution by introducing it to one system at a time in a total of six systems of varying size and installation complexity (in-house vs. contract installers, and known high quality field work vs. known areas of needed performance improvement). Any unforeseen employee concerns or backlash could be analyzed and addressed at a single system level. Also, but to a lesser level of concern, the Beta Test provided a small forum to "tweek" the manual text and illustrations.

As it turned out, employee reaction and acceptance was enthusiastic. And, as expected, the text, illustrations, and particularly the test questions quickly revealed areas requiring further change as a result of the careful review by the installers who were now agreeing to be held more closely accountable to the stated requirements. Each system added valuable recommendations. In fact, the comments were so insightful and valuable that it was decided to form a formal, annual QIP Review Committee from our "Gold Medalist" installers to insure their input is built into future revisions.

The systems selected for Beta testing were Broomfield, CO; Albuquerque, NM; Green Bay, WI; Independence, MO; Ft. Myers, FL; and Saratoga Springs, NY. A typical launch included descriptive memos to the manager and chief engineer and a scheduled date where all field associates, including contract installers and their supervisors would be present for the roll out briefing.

At this briefing our corporate engineering technical training coordinator and often the regional engineer would explain the whole scope and intention of the QIP program, especially including the specific benefits to the system, subscribers, and individuals.

This cushioned the next event which was a pre-QIP quiz and field evaluation of recent installation workmanship and practices.

The system associates were given the QIP manual, and a local QIP facilitator was selected and given additional background and support material.

The associates were then challenged to improve their understanding of the important company installation practices, procedures, and policies, and field workmanship and productivity. A contest between the Beta Test systems was developed to reward the team with the most improved written test scores and most improved field evaluation scores.

This team concept as well as individual achievement was purposely developed to foster positive peer pressure. In addition, the team concept helped the associates recognize the fact that the public perceives the Company as a "team" or single entity, and that poor driving habits in a service vehicle, rude attitudes, or poor workmanship of any one member reflects on the entire team.

The corporate engineering training coordinator would schedule a return trip to the system in 30 days and host a second QIP briefing. At this visit a second written exam was given as well as second field evaluation of workmanship and practices. The second exam as with the first was graded on the spot. Exam improvements and field evaluation improvements were discussed in full.

In addition, a thorough discussion of the system's comments about the QIP program occurred with all suggested changes carefully recorded right in the master QIP manual. The managers, chief engineers, and supervisors were asked to participate in the general sessions as well as in private discussions regarding the QIP Beta Test.

The same procedure was followed in each Beta Test launch, and except for the excellent feedback and comments given, each launch proceeded nearly identically.

Perhaps the only surprise was the initial reluctance by contract installers to attend the general sessions. We initially incorrectly jumped to the conclusion that the contract installers saw no long-term benefit to them, considering their possible relatively short-term association with the system. Much anxiety and brainstorming occurred before learning that the reason for the contract installers' reluctance was due to their piece work (per install) salaries. Sitting in a conference room for an hour was, in effect, "work without pay". In fact, some contract installers would have been exposed to "penalties" for fewer installation completions that day. The situation once understood was quickly corrected.

Waiver Policy

Jones is committed to the philosophy of having one strong, well-documented set of installation practices and procedures to insure that all our subscribers benefit from the best possible picture quality, reliability, and customer service. But, one of the most important findings during the Beta Test period was the need to have a formal Waiver Policy of specific practices and procedures that were unsuitable to a particular system for one reason or another.

Just as State Rights have served to relieve the pressure on everyone being forced to agree to a single federal set of laws, the Jones QIP Waiver Policy allows for these same regional variances. Climate differences between systems is one such justification for regional procedural waivers.

For example, long periods of significant snow cover prevents burying of drops for many months at a time. Very dry climates eliminate the need for a system to provide the extra boots and silicone gel weather protection -- and, there are many more examples.

However, to just allow systems to drop or substitute various QIP requirements without review or formal change to that system's standards was seen as a "little hole that over time could deflate the program". There would be a breach in accountability on which the very essence the QIP program is built.

This Waiver Policy simply requires the chief engineer and manager to make a formal request for a variance on a specific form stating the reasons for the variance as well as a draft of the specific changes to the text, illustrations, test questions, and field evaluations. The self-mailing form is returned to the manager and the chief engineer upon approval by corporate engineering for implementation and permanent filing.

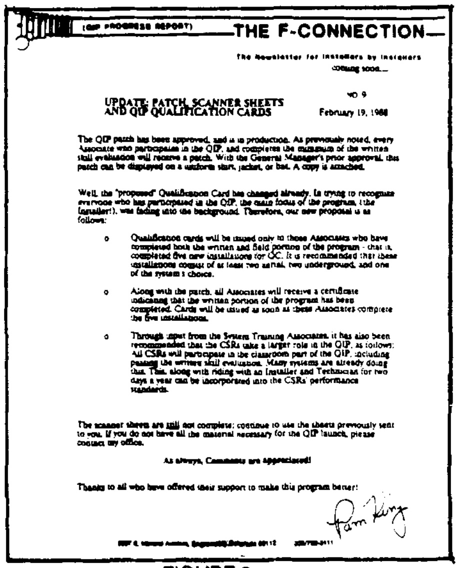
The easy Waiver Policy is probably one of major factors of quick acceptance by even the most strong-willed managers or chief engineers who have long-standing feelings on certain issues.

Implementation

The QIP program implementation began in late November of 1987. The process is proceeding very smoothly and similarly to the Beta Test launches. New systems continue to be launched at a rate of several a month. With over 78 systems, program implementation is projected to be completed by the end of 1988.

Initially systems were brought "on-line" one or two at a time to be sure the corporate facilitators could schedule the trips and be totally available for follow-up questions and discussions. It was decided that a twenty minute video tape explaining the QIP program and a strong facilitator's guide would allow all remaining systems to implement the QIP program totally on their own and at their own pace in a uniform, highly organized manner. With 78 separate systems, this was indeed a welcome labor-saving approach. In fact, the QIP launch tape and the facilitator's guide have proven to be very effective, and many systems have implemented the QIP totally on their own.

Also, throughout the process, a bi-weekly newsletter called the F-Connection was written to insure everyone in the company was fully aware of the QIP implementation process (Figure 9). This newsletter also reported on text or illustration changes, and highlighted which systems and individuals had made program improvement suggestions. The success of this newsletter suggests its continuation even after the QIP program is 100% implemented.


(QIP PROGRESS REPORT) THE F-CONNECTION

The Newsletter for Installers by Installers
coming soon...

NO 9

UPDATE: PATCH, SCANNER SHEETS AND QIP QUALIFICATION CARDS

February 19, 1988

The QIP patch has been approved, and is in production. As previously noted, every Associate who participates in the QIP, and completes the minimum of the written skill evaluation will receive a patch. With the General Manager's prior approval, this patch can be displayed on a uniform shirt, jacket, or hat. A copy is attached.

Well, the "proposed" Qualification Card has changed already. In trying to recognize everyone who has participated in the QIP, the main focus of the program, (the Installer!), was fading into the background. Therefore, our new proposal is as follows:

- Qualification cards will be issued only to those Associates who have completed both the written and field portion of the program - that is, completed five new installations for QC. It is recommended that these installations consist of at least two aerial, two underground, and one of the system's choice.
- Along with the patch, all Associates will receive a certificate indicating that the written portion of the program has been completed. Cards will be issued as soon as these Associates complete the five installations.
- Through input from the System Training Associates, it has also been recommended that the CSRs take a larger role in the QIP, as follows: All CSRs will participate in the classroom part of the QIP, including passing the written skill evaluation. Many systems are already doing this. This, along with riding with an Installer and Technician for two days a year can be incorporated into the CSRs' performance standards.

The scanner sheets are still not complete; continue to use the sheets previously sent to you. If you do not have all the material necessary for the QIP launch, please contact my office.

As always, Comments are appreciated!

Thanks to all who have offered their support to make this program better!

Pam King

[illegible]

FIGURE 9

Lastly, during the implementation, the company quickly realized how significant the QIP program was in terms of positive individual and team morale. For the first time, installers were observed during lunch and breaks actually discussing company practices and procedures. It was also recognized that reaching the full Qualified Installer status was a highly sought and prized accomplishment by the installers. The company felt that this attitude was indeed valuable to individual morale and to the program, and that we should develop a suitably more visible indication of an installer reaching the full Qualified Installer status. A handsome diploma was first considered but installers do not have offices and, hence, walls to display their accomplishment. Instead, a special patch was designed and our company's standards for installer dress requirements were modified to specifically assign a specific location for this patch to be worn (Figure 10).

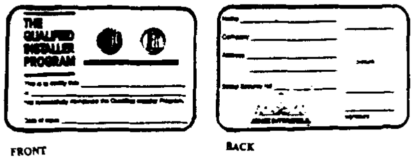


FIGURE 10

Along with the patch, a new Qualified Installer picture ID is issued (Figure 11). Both the ID, which is clipped in full view on the shirt pocket, and the Qualified Installer patch provide a constant valuable visibility of the installer's achievement to all other installers and to our subscribers.

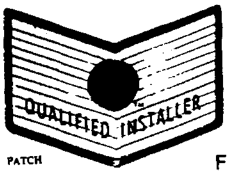


FIGURE 11

Jones Intercable is also rolling out a comprehensive E-mail system to all of its cable systems. The individual system QIP facilitators, plus the corporate technical trainer and senior engineering staff will then be able to communicate via computer network to insure an on-going flow of information, support and feedback on the QIP Program.

<u>Results</u>

The results of the Jones QIP program are already very favorable considering that for many systems the program is just starting. These early results also show that positive impact to the company as a whole will far exceed the initial goals and projections.

Using the same six Beta Test systems, Figure 12 shows a before and after comparison of the written test scores on important installation practices and procedures. A 20+ point average increase has been observed.

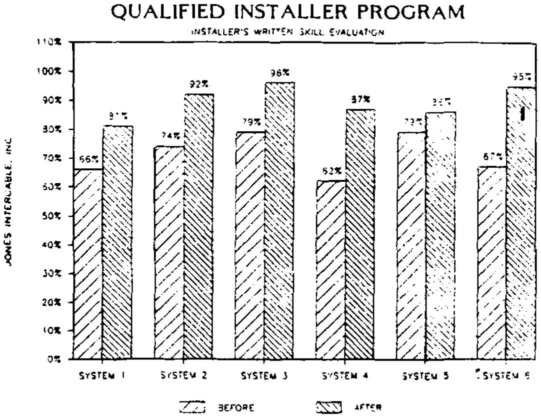
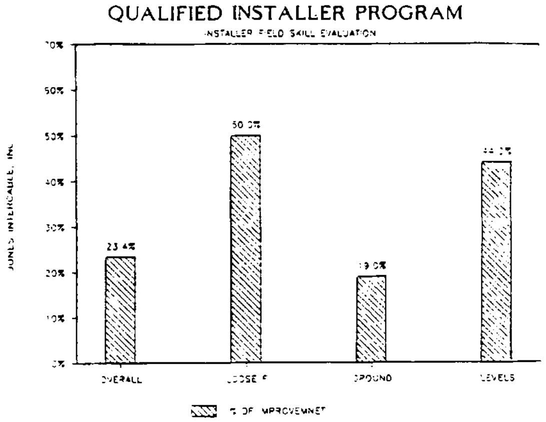


FIGURE 12

Performance improvement on these written test scores is seen as very significant because without a firm understanding of exact performance expectations on important well known service call-producing operations, the installer and Company is doomed, at best, to mediocre execution. While there is still room for improvement in this area, observers agree that the difference between a mid-60's percent score on important installation requirements and a high 80's to low 90's percent score as a Company-wide average is indeed a very significant improvement.

The question then turns to whether the QIP Program is actually producing better workmanship and procedure compliance in the field. Figure 13 shows the percent improvement in installation quality as measured by the fixed Jones standard field evaluation data sheets.



The most impressive result, steady reduction of controllable service calls reported by our billing service, Cable Data, is as yet simply too soon to reliably measure. We must remember that today's service calls are the result of poor practices and workmanship that occurred months or even years prior. It is recognized that even the most successful installation procedures and quality program will take some time to fully address years of less structured performance management.

Conclusions

Service calls are a major expense to the cable industry and cause negative subscriber attitude issues in every cable system. The magnitude of the expense - one million dollars/day for the industry and over $100,000/year for a 10,000 subscriber system requires all systems and companies to focus on better management of service call reduction.

The fundamental concepts of the Performance Plus Installer Program and the nearly full implementation of the Jones Qualified Installer Program with immediate impressive results exceeding expectations, prove that managing service call reduction can be successful, affecting not only the bottom line but subscriber satisfaction as well. And further, such installation performance management programs actually have been proven to improve associate morale and motivating team spirit.

MULTI-CHANNEL COMPACT DISC DIGITAL AUDIO ON CABLE

Joseph L. Stern
President

Stern Telecommunications Corporation

ABSTRACT

The introduction of compact discs has brought a new dimension of sound into the home. A system has been developed which will provide the delivery of nine stereo channels over one CATV channel in full compliance with all compact disc specifications.

SUMMARY OF PAPER

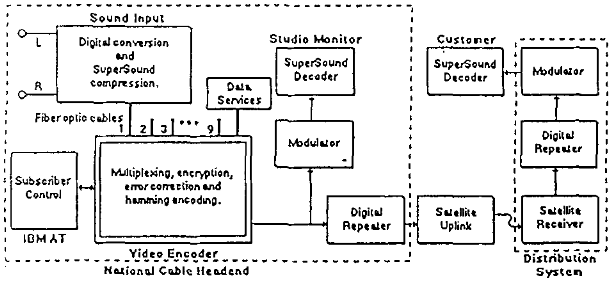
The paper to be presented at Cable'88 will describe CD 8-DM, a new digital audio transmission system delivering nine channels of stereo, plus multiple data channels within a 6 MHz bandwidth. The system will be described and waveforms of the modulation and baseband signals displayed. More importantly, a series of tests of CD 8-DM transmissions over microwave, satellite, and cable systems will be discussed.

CD 8-DM provides for encrypted, addressable delivery of nine stereo channels using a sixteen-bit 44.1 KHz sampling rate. The encryption is performed with a proprietary algorithm and the nine audio channels are combined with forty 9.6 KBPS and twenty-four 19.2 KBPS data channels. This package becomes a 12 megabit data stream. Four-level PAM transmission is used confining the major energy within 3 MHz of bandwidth.

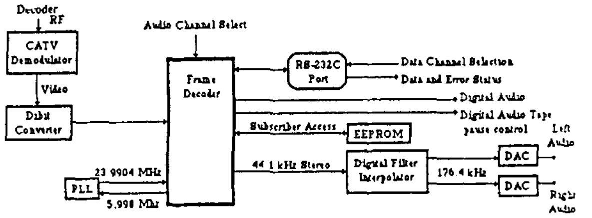
Transmission on the cable is through a modified and patented vestigial sideband modulation scheme. Forward error correction is utilized which allows operation with poor carrier-over-noise and/or operation utilizing small satellite recieving dishes.

The test information which will be presented will show the effect of cable system variations on the signal, as well as the effect of these digital PAM signals on existing cable operations.

Since the tests will be in process between the publication date and the presentation date, copies of the presentation will be made available at Cable '88.



CD 8-DM Transmission System



CD 8-DM Decoder

NCTA ENGINEERING COMMITTEE 1986-88 UPDATE

Walter S. Ciciora, Ph.D.
Vice President, Technology
American Television & Communications
Englewood Co, 80112
1986 & 1987 NCTA Engineering Committee
Chairman

Wendell H. Bailey, Jr.
Vice President, Science and Technology
NCTA, Washington, D.C. 20036
NCTA Staff Liaison

INTRODUCTION

During 1986 & 1987 several issues dominated the committee's work. Included among them were the A/B Switch, HDTV, Cumulative Leakage Index (CLI), The EIA Multi-port, Consumer Interconnection with cable, and Competitive Technologies (including Telco). Numerous other issues arose and were dealt with. Routine work requiring constant attention from the committee also received expeditious handling.

The A/B switch posed serious problems for the cable industry. The most obvious aspect of the difficulties was the cost of installation and materials. However, a much more serious consequence could be seen by the Engineering Committee. Improper installation of the switch could result in significant radiation of cable signals. In fact there is only one correct installation configuration and several erroneous methods. The hazard of interference with aircraft communications and navigation was increased by the fact that these signals would be connected to antennas all pointed in roughly the same direction. A mechanism of efficient, focused radiators was created at a time when cable engineers were struggling with ways to reduce leakage. Special thanks go to Dave Large who worked to investigate and inform the committee and the FCC of the technical issues.

The Subcommittee reports which follow provide a review and status report of the Committee workings.

The December meetings in both 1986 and 1987 were held in Denver. This resulted in greater attendance from Colorado and West Coast engineers. This may become a traditional site for the last meeting of the year. A meeting attendance record was set at seventy five for the first meeting of 1988.

The sections below repeat the information from the 1985 report by then chairman Robert A. Luff. They are repeated here for the convenience of the reader.

BACKGROUND

The National Cable Television Association (NCTA) has, since 1952, represented the diverse and growing cable industry before Congress and Federal agencies, in courts of law and before state regulatory agencies. As the principal trade association of the U.S. cable television industry, its members comprise cable television system operators, equipment manufacturers, program suppliers and several ancillary service providers.

Members are provided with forums--newletters, committees and an annual convention/exposition, where they may exchange information on developments in the industry and maintain liaison with other industries, societies and groups. The NCTA Engineering Committee is one such forum. Two-day, bi-monthly meetings held mainly at NCTA's Washington, DC headquarters, attract 50-75 top level member and non-member cable engineers from all over the country. Subcommittee chairmen reports form an important segment of each agenda.

STAFF AND SUBCOMMITTEE FUNCTIONS

To the extent that it is able to identify issues of common concern to members, NCTA strives to propose or recommend ways to address these issues. The NCTA Engineering Committee, its subcommittees and staff liaison department -- Science & Technology -- play a vital role in this continuing process. When an area of concern has been pinpointed, the Engineering Committee often turns to or creates a subcommittee to address the concern. Following the compilation and analysis of a combination of original testing, research, literature reviews and survey results (every effort is made to solicit technical input from all affected interests) subcommittees report their findings to the Engineering Committee. The Committee then reviews and approves final documents and/or recommendations before NCTA acts on them -- in some cases, publishing and distributing a printed product -- though, as you will read in the following reports, often a subcommittee fills an educating, liaison or monitoring function for the Committee and no published documents result.

CHARTER

The policies of the National Cable Television Association are determined by the Board of Directors. To assist in policy formulation in technical areas, the Board establishes an Engineering Committee. The duties of the Engineering Committee are:

1) To respond on a timely basis to Board requests for advice and recommendations on technical matters.

2) To forward to the Board advice and recommendations on technical matters which the Committee perceives as having an effect on the policies of the Association.

3) To advise the Board of technical developments and innovations which the Committee perceives as having an effect on the policies of the Association.

4) To advise the Board of technical developments and innovations which the Committee perceives as having an effect on the future courses of the cable business.

5) To assist the technical staff of the Association as requested.

6) To represent NCTA by establishing liaison with international and national technical groups.

The activities of the Committee shall include, but not be limited to:

1) Regular review of FCC dockets, Notices of Inquiry, Notices of Proposed Rulemaking, etc., having impact upon the technical operation or construction of cable television systems.

2) Liaison with appropriate outside technical organizations, associations and professional societies.

3) Liaison with international organizations, associations and professional societies whose work may have an impact on the industry.

Membership on the Committee shall be open to all technically oriented employees of members of the National Cable Television Association who are interested in the work of the Committee. The Chairman of the Board of NCTA appoints the Chairman of the NCTA Engineering Committee. Individual voting members are then appointed by the Chairman of the Board of NCTA after consultation with the Chairman of the Engineering Committee.

Notice of meetings shall be sent to all members of the Committee and also sent to interested, qualified parites. Attendance is open to all members of the cable industry's engineering community who are NCTA members.

ACKNOWLEDGMENTS

Participation in subcommittee work and Engineering Committee meetings are some of the cable engineering community's most challenging but rewarding endeavors, requiring unusual professional dedication and acumen. NCTA's Science & Technology department joins Engineering Committee chairman Walt Ciciora in applauding subcommittee chairmen and members for unstinting and outstanding service to the cable industry.

- 1988 NCTA Technical Papers editor, K. Rutkowski-

For further information about the NCTA or Engineering Committee, call (202)775-3637

SUBCOMMITTEE AND LIAISON UPDATES

CONSUMER INTERCONNECT SUBCOMMITTEE

David Large, Chairman

CHARTER

The Consumer Interconnect Subcommittee was formed by the NCTA Engineering Committee in 1985 for the purpose of exploring short-term solutions to the problems of interconnecting various combinations of consumer video equipment to cable television systems. The Engineering Committee felt that longer-term solutions were being dealt with by such groups as the EIA homebus group, the EIA/NCTA Joint Committee, and the EIA Decoder Interface group, but that such solutions would be years in coming because they only affected future production of products. The Consumer Interconnect Subcommittee has limited its scope to dealing with the currently installed base of consumer equipment, with its thrust being the instruction of cable operators and suppliers in appropriate solutions and adequate specifications for cable-supplied interconnection equipment.

ACCOMPLISHMENTS

The major accomplishment of the Subcommittee to date has been the submittal of an extensive tutorial report to the parent committee (late 1986). This tutorial was published in CED Magazine in three removable sections in the period April-June, 1987 and is available from either CED or NCTA as a reprint. In response to a call to extend our reach beyond the technical community to management, Mr. Large presented a management session paper at the 1987 NCTA Convention based on the business consequences of following the recommended solutions in the tutorial. This paper will be published in the December (Western Show) edition of Cablevision Magazine.

FUTURE ACTIVITIES

Two addendums to the original report are currently planned. The first recognizes that there is a move in some parts of the cable industry away from set-top converters and towards outside-the-home signal denial schemes. Since the cable company need install no unique equipment within the home, the customer assumes, by default, the major responsibility for in-home wiring. While such schemes, based on some form of positive or negative trapping, have advantages in "friendliness" to cable-ready consumer hardware, they raise issues of signal leakage control. That is the subject of a report authored by Roy Ehman for the Subcommittee.

An area not explored in the original report was baseband interconnections. Most VCR's, many television sets and several converters and descramblers offer video and/or audio connections. Use of these signals may result in increased switching flexibility and will almost certainly result in better quality pictures. More importantly, it may be the only way to realize the benefits of stereo sound under certain circumstances. A second addendum, authored by Dave Large, covers this area.

HIGH DEFINITION TELEVISION (HDTV) SUBCOMMITTEE

Nick Hamilton-Piercy, Chairman

CHARTER

This subcommittee on HDTV was formed by the NCTA Engineering Committee in 1987 to closely follow the rapid developments taking place in HDTV technology; to interpret what impact the transmission of HDTV signals would have on cable television distribution networks; to determine what is needed to accommodate these signals; and to liaise with the various proponents of HDTV systems on the unique requirements of cable/microwave/satellite transmission.

BACKGROUND

Television set technology is making a substantial leap forward as a consequence of the introduction of digital processing circuitry at the consumer level. At moderate incremental cost television sets can be made intelligent enough to overcome many of the short comings of the North American (NTSC) television transmission standard and can accommodate new standards such as that associated with high definition television (HDTV).

Evolution within the traditional analogue circuits and display technologies is also taking place which enables the conventional television receiver to produce quite handsome television images with resolutions approaching the theoretical obtainable from standard NTSC signals.

The full potential of these new technology receivers becomes clearly evident when they are directly connected to video cassette source material, however, the transparency of the traditional cable distribution network may sufficiently compromise delivery of improved NTSC or HDTV signals to the extent that the consumer may be inclined to adopt other program distribution infrastructures for their entertainment fare.

Recent customer attitude surveys have already shown a general dissatisfaction in the quality of cable distributed signals even though substantial improvements have been made to these networks over the last few years. One reason for this growing dissatisfaction is that customers now have a daily comparison against which they can assess cable television signal quality. Over 50% of the cable customers have in-home video cassette players and an A/B comparison occurs every time it is used. The industry is fortunate in that much of the video cassette material is worn rental tapes of questionable quality.

These same customers are often exposed to high definition video images at the work place, school or during leisure hours. The word processor, the desk top computer, the computer control of industrial machinery, and the video arcade present this group with a barrage of video images all substantially better in quality than can be provided by present cable distribution networks. Customers often ask why they cannot read the credits for a television movie yet the text is not smaller than the capital letters on their word processor or home computer. Should this dissatisfaction with quality truly be a result of this day to day comparison, then the industry could find itself with a severe problem following the introduction of super VHS/Beta video cassette formats, or other sources of enhanced quality video programming (direct to home satellite, MMDS, video disk, even new off-air broadcast transmitters, or off-air signals viewed through the A/B switch, etc., etc.)?

The problem is being considerably exacerbated by the recent presence of the new technology large screen televisions which tend to emphasize cable's transmission shortcomings, especially at the closer than ideal viewing distances found in the smaller home. In the older television sets the images were sufficiently soft and blurred that echoes, beats and certain types of noise were not really noticeable. Their audio systems and minute loud speakers compromised the sound to the extent that the cable added distortions and noise were just not noticed. Many of these same customers are now using state of the àrt comb filter equipped 25 inch or larger television receivers with stereo sound and good quality speakers.

WORKING COMMITTEES

Recognizing the foregoing concerns and recognizing the timeliness of providing input to the various HDTV proponents on the requirements of cable retransmission, the Engineering Committee of the NCTA decided the issue was of sufficient importance to form a sub-committee whose mandate is to address the whole subject area. There are a multiple of unknowns and many of the answers are needed soon if they are to be useful in influencing the HDTV transmission standards formation or to assist cable operators in their preparation of their distribution networks for these new signals.

Early answers are also needed for improving the transmission transparency of the existing networks to help stem the current growing customer dissatisfaction with picture quality. Whether it is improving the present system for the present NTSC signal and enhanced NTSC signal or a full HDTV signal many of the problems are common, therefore at last initially there seems no need to have separate committees addressing the concerns of each standard. However, it does appear productive to address the subject area through three interrelated groups.

Group 1, Transmission Channel Characterization, Group 2, Liaison and Group 3, Super Cable.

The Group 1 activities (under the guidance of Dan Pike) are to examine the transmission aspects of video signals of both present and future standards through mediums such as co-axial cable plant, AML systems, FML systems (narrow band and wide band) and satellite. The question that faces this group is why do even well designed cable systems compromise the quality of a normal NTSC signal (softening of the resolution, busyness of the background, etc.) even though measurement of the usual parameters would indicate the network as being transparent? The extension of this question is whether the mechanisms causing this degradation will have equal or worse effect on an HDTV signal. Once the cause is understood then the task is to provide guidelines on how to minimize these effects.

The end goal of Group 1 is to provide a comprehensive "transfer function" of the transmission media for each part of the distribution chain be it the satellite link, terrestrial microwave, the AML system, or the cable network itself. The findings of Group 1 are passed to Group 2 for dissemination and discussion with the HDTV proponents and consumer electronic suppliers. Initially, work will be the characterization of the effects of some of the less traditional distortion mechanisms such as phase noise and micro-reflections, etc. Other work will include a reevaluation of the subjective effect of discrete echoes in a progressive scan scenario, the subjective effect of beat noise in the increased band widths associated with high definition transmissions and so on and so on.

The Group 2 focus is directed more towards providing a very tight liaison with the developers of enhanced and high definition television systems and equipment as well as ensuring a continuous dialogue is maintained with other groups such as NAB, ATSC, SMPTE, etc., etc. It will be the responsibility of Group 2 to take the findings from Group 1 and ensure these are disseminated to the developers of these new systems and equipment. It will also be the responsibility of Group 2 to provide the status reports and information pieces necessary to advise the industry on the progress of HDTV developments and the necessary steps to prepare for its introduction.

It can be anticipated that once Group 1 has characterized the distribution infrastructure and the requirements for successfully distributing high quality NTSC and HDTV signals then the two groups will merge into one body whose main focus will be the implementation steps towards HDTV.

The Group 3 Super Cable activities (under the guidance of Paul Perez) is focusing its attention on ways and means of taking a component style signal such as "Super VHS" and transmitting it through the existing cable distribution network with the aim of providing a superior quality picture to those customers with appropriately adapted luminance/chrominance input monitors. This is seen as an interim scenario for quality picture transmission while the various advanced television systems develop.

ACCOMPLISHMENTS

The major accomplishment of the Group 1 working committee is the identification, measurement and characterization of phase noise. This distortion is one of the principle contributors to the background busyness effect seen in many cable systems pictures. Two comprehensive dissertations are contained in the 1988 NCTA Technical Papers showing results of this testing and the causes of this unique distortion. Other preliminary testing activities in the area of reflections and in-channel fine grain transmission responses have also taken place.

The liaison group, Group 2, has focused most of its attention on developing an industry input in response to the FCC's Notice of Inquiry and subsequent analysis of other organizations submissions. The group also developed a comprehensive response in comment to the FCC on the various submissions. Other Group 2 accomplishments included the development of a draft cable transmission test plan for use by the Advance Television Systems Committee's transmission and Distribution Specialist Group T3S4 and the description of a generic cable system (tutorial narrative and schematics) for dissemination to ATS developers, broadcasters and others unfamiliar with cable television distribution networks.

Group 3 (Super Cable) was formed in the latter part of the reporting period and is focusing its attention on planning and feasibility investigations into cost effective technologies to distribute the component signal.

FUTURE ACTIVITIES

The immediate future focus will be on the continuation of cable transmission characterization. As soon as any of the competing ATV system hardware is available testing will be conducted by subjecting the system to the characterized transmission distortions to determine the sensitivity to these impairments. Guidelines will be developed on the minimum transmission standards necessary for successfully distributing HDTV signals and disseminated through the industry. This will likely be an iterative process with ATV system promoters presenting further evolutions of their hardware and the group feeding back results. Once the "final" version of ATV hardware is available from each promoter the group in conjunction with the ATSC will subject each to a side by side evaluation and qualify each as to its merits and disadvantages in the cable transmission environment.

Close liaison with program originators and ATV system manufacturers will continue to ensure both are kept fully appraised of the cable operators concerns and technical distribution capabilities while obtaining from them latest details of their origination and reception equipment developments.

Should the developments of HDTV emission systems not follow a path appropriate for retransmission through cable of a superior picture, then focus will be directed in establishing alternate technologies/formats more suitable for cable transmission.

MULTIPORT COORDINATION

Joseph Van Loan, Chairman

CHARTER

Coordinate implementation of the EIA Multiport Standard Baseband Interface within the Consumer Electronics and CATV industries.

ACCOMPLISHMENTS

With support from ATC provided a neutral testing facility in ATC's Denver laboratory. Arranged for manufacturers to make TV receivers, scramblers, descramblers and other equipment available to the lab for testing by manufacturers developing EIA Multiport products. Arranged and staffed EIA Multiport exhibits at NCTA and Western Shows. Conducted a survey of top 50 MSO's willingness to use EIA Multiport products when they become available. Held meetings with MSO's using baseband interface, TV receiver and VCR manufacturers and with CATV decoder manufacturers to make them aware of the benefits of the interface and the industry's willingness to support it once it becomes available. Give presentations to management, marketing and technical groups to acquaint them with the advantages of a standard decoder interface.

1988 PLANS

Plans for 1988 include a survey of signal ingress in "cable ready" TV receivers among the top 50 MSO's. Conduct the first field trials of EIA Multiport using production TV receivers and pre-production decoder units. Continue exhibiting at major trade shows. Continue to give presentations to groups concerning the use of the decoder interface standard.

SATELLITE PRACTICES SUBCOMMITTEE

Norman Weinhouse, Chairman

There were several issues addressed by the Satellite Practices Subcommittee in 1987. Two issues involve comments before the FCC, and three issues which were undertaken to assist satellite programmers and the cable operators who receive those programs.

A. ISSUES BEFORE THE FCC

1. Modification of Part 25 of the Rules. cc. Docket No. 86-496

   In this docket, the FCC proposes to make extensive changes and additions to part 25 of the Rules. Administrative and licensing matters which had previously been treated on an ad-hoc basis are codified in these proposed rules. In addition, the Commission proposed operational procedures which are intended to reduce alien interference between satellite systems. In some cases, these procedures are detrimental to cable's interests. Some of the proposed technical standards needed clarification.

   The subcommittee provided extensive inputs to the staff. Comments were filed by NCTA on June 8, 1987. The Commission has not taken further action in this docket.

2. Automatic Transmitter Identification System (ATIS) - General Docket No. 86-337

   The Commission instituted a Further Notice of Proposed Rulemaking (FNPRM) on ATIS of Satellite Video Carriers, based on digital modulation of the energy dispersal signal in a satellite transmission. Earlier (in 1986) the Commission instituted a NPRM for ATIS based on digital modulation in the television vertical interval.

   In the earlier NPRM, NCTA and others made comments which deprecated the use of vertical interval for ATIS, prompting the FNPRM. In its comments to the FNPRM, NCTA was generally supportive of the energy dispersal method, but cautioned the Commission that it was an untested technology which needed further refinement and extensive testing. NCTA and most other commenters suggested delay in implementation until this technology could be completely tested in a real world environment.

   The Commission has not yet taken further action in this docket.

B. SATELLITE PRACTICE ISSUES

The subcommittee started work in December of 1987, with the object of generating "Good Engineering Practice" bulletins for the following items:

1. Audio levels (monaural and stereo) for Videocipher II transmissions.
2. Use of subcarriers with Videocipher II transmissions.
3. Use of a "more reliable" method of signalling (cue tones) and communication by programmers offering advertising availabilities to cable operators.

Items 1 and 2 have been generated and will be reviewed by the subcommittee. It is expected that these two documents will be submitted to the main engineering committee at its next meeting in April. It is further expected that a document dealing with item 3 will be submitted to the main engineering committee in either the June 1988 or the August 1988 meeting.

MULTI-CHANNEL TV SOUND

Alex Best, Chairman

CHARTER

The Multi-channel TV Sound Subcommittee was formed by the NCTA Engineering Committee in 1983 for the purpose of evaluating compatibility between three proposed broadcast television stereo systems (Zenith, EIAJ, and Telesonics) and existing cable technology. The Engineering Committee felt that the BTSC (Broadcast Television Systems Committee) committee guided by the Electronic Industries Association had failed to consider the impact of cable carriage on any of the proposed systems. At this time the EIA was advocating a selection of one of the three systems by voting members of the BTSC (the NCTA represented one of the 13 votes to be cast).

ACCOMPLISHMENTS

The accomplishments of the subcommittee to date have included written test procedures to the EIA which was one factor in creating a one-year extension on testing of the three stereo systems. The NCTA then decided to perform its own tests. During the summer of 1984 a detailed test procedure was written and an engineer was hired (Brian James) to conduct cable related tests of the BTSC systems. A report on the results of these tests was made available to the office of the NCTA. The results were also made known to other interested parties through presentations at various national, regional, and state association meetings. As a result of this effort, the NCTA was successful in winning a non-must carry status from the FCC on the stereo portion of a broadcast television signal.

FUTURE ACTIVITIES

The Multi-channel TV Sound Subcommittee was reactivated in 1986 with a charter to define and document a series of test procedures to assist cable operators in evaluating stereo encoders. In addition, an error budget (separation) will be developed to aid cable operators in achieving an overall level of quality by knowing the contribution of each component. It is anticipated that the end product of this effort will be a document similar to the NCTA Recommended Practices for Measurements on Cable Television Systems.

AD HOC 75 OHM STANDARDS SUBCOMMITTEE

Ron Hranac, Chairman

CHARTER

The ad hoc 75 Ohm Standards Subcommittee was formed in late 1987 to investigate the feasibility of establishing National Bureau of Standards (NBS) traceability in 75 ohms. 50 ohm NBS traceability has existed for some time, but these standards do not directly support 75 ohms. Advances in CATV technology, industry deregulation, and the increased availability of 75 ohm test equipment suggest that such standards be established to assure measurement accuracy and repeatability.

ACCOMPLISHMENTS

Due to the creation of the ad hoc subcommittee so late in the year, major accomplishments have centered around three areas; recruiting individuals to serve on the subcommittee; securing the unofficial support of a number of test equipment and product manufacturers; and making initial contact with NBS.

NBS officials have indicated that standards development usually begins one of two ways: lobby Congress to obtain funding for research, a process that takes several years. Or, obtain private sector (eg., CATV and related industries) support and research funding. The second approach will be the most feasible for 75 ohm standards work, since much footwork can be accomplished by the CATV engineering community.

FUTURE PLANS

The subcommittee plans to collect information on existing 75 ohm standards, and develop parallels, where possible, with 50 ohm standards and traceability. The subcommittee will then determine the cost to establish basic NBS 75 ohm traceability, and recommend how the CATV industry can pursue standards development.

SIGNAL LEAKAGE SUBCOMMITTEE

Ted Hartson, Chairman

During 1987 the signal leakage subcommittee assisted the NCTA in providing input for FCC filings regarding A/B switches, set-top devices and more recently in the pending docket on Part 15 standards. The subcommittee provides assistance to state associations and operators, by providing speakers and information to assist in the formulation of aggressive signal leakage programs.

As we approach the June 1990 deadline for aeronautical offsets and CLI compliance, signal leakage, its investigation and containment will become even more important to the industry. The subcommittee welcomes inquiries and participation by interested parties. Further information may be obtained from the NCTA Office of Science and Technology.

1988 TECHNICAL PROGRAM SUBCOMMITTEE

Wendell H. Bailey, Chairman

CHARTER

To choose topics, moderators and panelists (speakers/authors) for ten ninety-minute technical sessions and authors for papers printed in NCTA's annual convention proceedings, NCTA Technical Papers.

ACCOMPLISHMENTS

The five-member team choosing participants for the 1988 show selected thirty four technical paper proposals from a field of eighty five responses to the "Call for Papers".

Joint EIA/NCTA Engineering Committee

1987 Subcommittee Annual Report

Walter S Ciciora, Ph.D., Chairman
Vice President, Technology
American Television and Communications
Englewood Colorado 80112

Charter

To establish and maintain dialogue between the cable and consumer electronics industries for the purpose of studying and resolving engineering matters of common interest.

Background

The Joint EIA/NCTA Engineering Committee was formed in 1982 under the leadership of Bob Rast, whose many years of experience with RCA and whose position at ATC facilitated the construction of a bridge between the cable and consumer electronics industries. Many loyal souls have served the purposes of the committee over the years. 1987 saw serious economic difficulties in the consumer electronics industries and the transfer of ownership of major assets. This brought early retirement to several of the committee's strongest contributors. Tom Mock of the EIA continued his invaluable services as facilitator. To all of these, both industries offer their thanks.

While the primary purpose of the committee is communication between the two industries, a secondary and perhaps more visible role is the creation of voluntary technical standards to improve performance of consumer electronics products when used on cable systems. These standards do not have the force of law but depend on the good will of the participants for there efficacy. This approach has been successful in the past.

Accomplishments

The committee's first major accomplishment was the creation of a frequency channelization interim standard, IS-6. A significant part of this standard is the definition of an orderly procedure for numbering increased channel capacity on cable systems and adding new tuning capability to consumer electronics products. This work has subsequently achieved full standard status and is designated as EIA 542.

The second accomplishment was the agreement on IS-23, the RF cable interface interim standard. The standard was subsequently tabled until further research into quantifying the need for stronger direct pick up, DPU, requirements was completed. Simultaneously, an investigation on the practicality of better DPU hardware techniques was carried out.

The third accomplishment was the ratification of IS-15, the baseband decoder interface interim standard and agreement on an intermediate frequency interface recommended practice. Several manufacturers of TV receivers have introduced product with IS-15 plugs on the back. Most of the manufacturers of cable descramblers have developed prototype units and some are working to bring them to production. Cable operators have placed purchase orders for these units and are awaiting delivery.

Some difficulties over detailed interpretation of the IS-15 specifications have been experienced and, as of this writing, appear to have been resolved. A consequence of this has been a careful review of the interim specification with the goal of tightening up the language.

Since the creation of IS-15, a major change in direction has been taken by the consumer electronics industry in the methods of transporting video between devices. The advent of Super-VHS and ED-Beta have brought along with them the "S-plug" which embodies a new method for video transfer, the "C/Y" format. The committee is finalizing a procedure for optionally carrying this electrical format. Mechanical conversion is by adapter plug or a cable with appropriate terminations.

Currently, considerable attention is being given to approaches for implementing "pay per view" and other services in an IS-15 environment. Ideally, the subscriber uses only one remote control hand unit to operate all functions including impulse purchase of video or home shopping wares.

Prototypes of TV receivers and decoders have been demonstrated at the 1986 and 1987 Western Cable Shows and the NCTA Convention in 1987. Papers have been presented in both technical and management sessions at these shows. In addition numerous other forums and publications have been used to publicize the work of the committee to both industries. Of special note are cable papers at the IEEE's International Conference on Consumer Electronics (ICCE) and papers at the Montreux Television Symposium in Switzerland.

Future Activities

Two major goals for 1988 are to bring the IS-15 Multiport Interim Standard to full standard status and to make progress on IS-23.

Of course the primary subcommittee goal of maintaining dialogue between the two industries will continue to receive attention. A special effort in this regard is a short course on cable practice for non cable engineers to be presented ahead of the IEEE ICCE in June in Chicago. Consideration is being given to ways of increasing awareness of US cable practice among the consumer electronics designers of Japan and other far east countries.

The EIA Multiport needs a success story. Work continues on putting all the pieces together to demonstrate the full power of the concept.

SPACE WARC

Paul A. Heimbach

1. Represent the NCTA in the preparation for the August, 1988 Conference on the Use of the Geostationary Satellite Orbit and the Planning of the Space Services Utilizing it (SPACE WARC).
2. Maintain a liaison between the NCTA and the United States organizations, private and governmental, that are preparing the U.S. positions to be presented at the SPACE WARC Conference.
3. Ensure that cables' interests from the perspectives of cable operators, program distributors, equipment manufacturers, and other NCTA members are represented in the U.S. positions at the SPACE WARC Conference.

1987 ACCOMPLISHMENTS

Monitored and participated in those SPACE WARC activities that will significantly affect the continued operation of the U.S. domestic satellite service. In particular, the creation of new planning procedures for the currently used C and Ku FSS bands have been the major areas of concern. The U.S. is attempting to fabricate a planning procedure that will provide fair and equitable access to the geostationary arc for all countries while preserving the flexibility and service continuation assurances that exist today.

The SPACE WARC meeting will convene in Geneva, Switzerland in August, 1988.

PLANS FOR 1988

Participation in activities that are a result of the 1988 SPACE WARC Conference.

ARRL/NCTA LIAISON

Robert V.C. Dickinson

There has been very little action in this area in some time. Brian James and Bob Dickinson are the only current active liaisons between NCTA and the American Radio Relay League.

There have been no formal leakage complaints forwarded through the ARRL within the last year. Our periodic checks with ARRL members indicate that the general feeling is that things are more or less under control. ARRL is now more concerned about the Part 15 rewrite and feel that they have a good working relationship with NCTA.

During the coming year we expect to maintain our liaison function while urging continued cooperation of cable operators with local amateur groups, since this has seemed to have been the key to our greatly improved relations. There is a possibility that additional testing of leakage implications in the upstream cable channels will be initiated during the coming year.

IEEE LIAISON

Lawrence W. Lockwood

The Institute of Electrical and Electronics Engineers, Inc. is the world's largest professional engineering society. A few of the 30+ special interest Societies in IEEE address issues in journals, committees and standards-setting groups that affect the cable TV industry.

Due to agreements obtained by liaison with IEEE committee members special reciprocal publishing arrangements have permitted NCTA technical papers to be reprinted in IEEE Communication Society journals.

On the standards front, work on Local Area Network standards, the 802.7, is progressing satisfactorily. It is likely to reach IEEE final approval by the end of 1988. The standard will then proceed to ANSI for concurrence and issuance as a combined standard for the U.S.

ADVANCED TV SYSTEMS COMMITTEE (ATSC) LIAISON

Jud Hofmann

PURPOSE

The ATSC has been the national forum for consideration of a new national TV system(s), and methods of enhancing our existing system. It is important to track the progress made by the ATSC, so that the cable industry can be kept informed of, and influence, events which will shape its future in the next few years.

1987 EVENTS

The ATSC began 1987 with the decision of how to handle the next step in the establishment of a production, or studio, standard for HDTV. The effort in the CCIR to establish the 1125/60/2:1 system as a world standard has run into strong resistance from the European governments: this resulted in a CCIR decision to defer its decision on a single worldwide standard. The decision in the ATSC as to what the next step would be was relatively straightforward: make the 1125/60/2:1 system a US standard in cooperation with the SMPTE.

That activity was one of two focal points for the HDTV Technical Group: in the latter part of 1987, SMPTE finished the document defining the parameters of the signal waveform and the parameters of signal interchange between equipment.

Transmission testing and transmission demonstrations were the second focal point of the HDTV T/G in 1987. Preliminary tests were being made in the UHF to look for differential transmission characteristics between separated channels. Plans went forward for testing at frequencies above 1 GHz. Liaison between the NCTA HDTV Subcommittee and the ATSC T3S4 testing was tightened up.

The demonstration transmissions of MUSE HDTV in Washington DC and Ottawa, Canada went a long way to awaken broadcasters, cable people, Congressmen, and the FCC to the reality of HDTV. Partially as a result of this, the FCC opened an Inquiry into HDTV.

As a result of the sudden awareness of HDTV across the nation, the ATSC is suddenly growing in membership.

1988 ACTIVITY

1988 will be a critical year for the ATSC. The FCC Inquiry is said to exist only to bring forth the critical issues in broadcast HDTV, not to choose a system. Presumably, this means that the ATSC will get that task. The ATSC must organize itself to handle this task, and the cable industry must strongly participate in the process.

EIA CONSUMER ELECTRONIC BUS COMMITTEE LIAISON

Jud Hofmann

PURPOSE

The CEBC is generating standards for residential communications on many media, but the most important is the coaxial bus (CXBus). It is expected that this media will be used to deliver cable signals and the output of converters around the home.

The second most important media is InfraRed (IR), which can be used for universal remote controls.

1987 EVENTS

The topology of the CXBus and the node structure needed to get signals on and off the bus were defined. The primary contribution was from Scientific-Atlanta, and arrangements are being made to build a prototype.

The importance of the prototype, in addition to testing performance factors, is to determine the leakage problems that the CXBus will present and to find methods of solving them.

Coding and modulation method to be used for the IR media have been defined, and prototyping equipment will be built to test the ability of the system to reject interference from present remote control systems.

1988 ACTIVITY

Finish prototyping and testing, begin circulation of draft CEBus Standard.

SCTE LIAISON

William Riker

GOAL

Inform NCTA Engineering Committee membership of current activities of the Society of Cable Television Engineers, Inc., often requesting input concerning specific programs or issues. SCTE representative will also update its Board of Directors on action taken at Engineering Committee meetings and make recommendations as to how the Society can best support the efforts of the Committee.

NESC LIAISON

James Kearney
Brian James, Alternate

The Cable Television industry has been represented on the NESC Committee since the late 70's for the purpose of monitoring and contributing to the code writing process. It has been the practice of NCTA representatives to report on the activities of the NESC and to support the interests of the Cable Television industry throughout the code writing and interpreting process.

UPDATE

Initial Change Proposals to the 1987 NESC are to be Published April 15, 1988.

In November and December, 1987, the first of two series of NESC Subcommittee meetings were held to solicit changes to the 1987 NESC and to record the proposed changes. Change proposals have been submitted for all sections of the Code. This includes sections on Purposes, Grounding, Clearances, and Underground, which are particularly important to the CATV industry. These changes are being printed and will be available to the public on April 15, 1988 for comments. Copies of the change proposal preprint can be obtained through ANSI or through the NESC office in New York after April 15.

Anyone may submit comments in writing, directed to the appropriate sub-committee. Deadline for public comments is September 30, 1988. A series of subcommittee meetings will be held to review and respond to all comments received. The responses will include the text of the subcommittee action and the minutes of the subcommittee meeting. Full details of the procedures for public comment will be made available with the change proposals after April 15, 1988.

Summary of Major Changes

- More than 150 change proposals have been made. An effort is being made to consolidate similar sections and simplify troublesome sections of the code. The new code will be "revenue neutral". This means that present users will realize little or no increased costs as a result of changes in the code.

- The proposed changes include rewritten clearance tables to reduce the extensive and confusing footnoting in the existing code. Changed Sections include 232, 233 and 234.

- Fiber optic cable is better defined. There have been efforts to allow fiber optic cable attachments at less than 40 inches below supply conductors. The 40 inch requirement will not change. Fiber may be defined as a Communications or Supply Class cable but this classification will be made dependant on the classification of the line's service and its maintenance personnel.

FUTURE ACTIVITIES

NCTA members are encouraged to suggest to the Engineering Committee any modifications or additions to the NESC that may be considered desirable for reasons of safety, economy or clarification. Proposals for changes will be submitted through the NESC representatives, with the advice and consent of the Engineering Committee. NESC representatives will continue to report on the code writing process.

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REPORTS NOT RECEIVED BY PRESS TIME

STANDARDS SUBCOMMITTEE

Michael F. Jeffers, Chairman

CHARTER

To determine the best method (or methods) for measuring parameters that can ascertain the proper operation of a cable system and to establish performance criteria for good engineering practice. Further, to publish this information in the NCTA Recommended Practices for Measurements on Cable Television Systems notebook.

NATIONAL ELECTRIC CODE LIAISON

James Stilwell
215/885-6350

SMARTHOUSE PROJECT LIAISON

Wendell H. Bailey, Jr.
202/775-3637

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NEXT GENERATION
C-BAND SATELLITE SYSTEMS
FOR CABLE PROGRAM DISTRIBUTION

Bruce R. Elbert
Director
Galaxy Systems
Hughes Communications, Inc.

Abstract

C-band satellite transmission is the established standard for the delivery of cable TV programming to cable headends. The basic 24 transponder design is used by every cablenet satellite, greatly simplifying ground equipment design and minimizing investment cost. The current generation of cable satellites, including Galaxy I and III, Satcom 3R and 4, will exhaust its fuel supply during the 1992 to 1995 timeframe; therefore, a new generation of C-band satellites will be launched as replacements. The technology to be incorporated into the replacements will add capability but will not cause the existing C-band ground infrastructure of antennas and receivers to be obsolete. The features that we foresee for the replacements include higher power, longer life, improved reliability and interference protection.

Introduction

C-band satellite transmission is the established standard for the delivery of cable TV programming to cable headends. Receiving a wide array of video and audio programming is a ground infrastructure of C-band antennas and associated electronics worth in excess of $500 million. These facilities are standardized on the frequency plan of the current generation of C-band satellites. Antenna diameters in the range of 3 to 5 meters are also part and parcel of cable TV networks, which is consistent with the satellite power levels and benign propagation environment.

This solid foundation provides the motivation for satellite operators to solidify their plans for the next generation of C-band cable satellites. A representation of the geostationary arc serving the United States and the satellites therein is provided in Figure 1. The current generation of cable satellites, including Galaxy I and III, and Satcom 3R and 4, will reach end of life during the 1992 to 1995 timeframe. End-of-life is predictable since it is mainly based on the fuel supply to the on-board propulsion system, which is used to maintain orbit position.

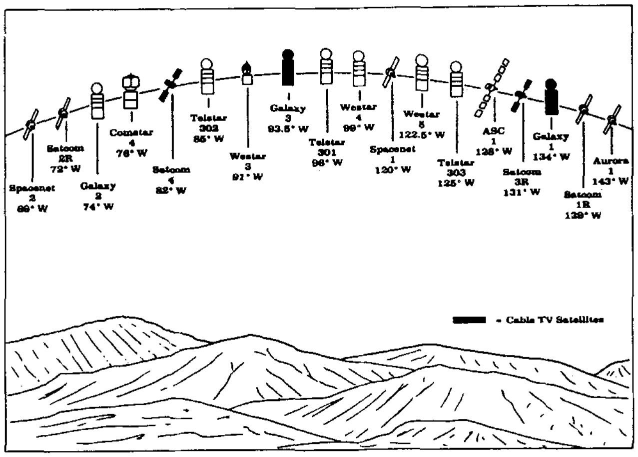

Figure 1. C-Band Satellites Serving the United States

A new generation of satellites will replace that now operating, employing significant technology improvements derived over the past five to ten years.

A key point throughout is that any new characteristic will add capability but will not cause the existing C-band ground infrastructure of antennas and receivers to become obsolete.

Communications Performance

The basic 24 transponder design is used on every cablenet satellite and this arrangement will be maintained in future satellites. In its Two-Degree Spacing Order, the FCC has stated its intention to standardize on this plan, which is illustrated in Figure 2. There are two orthogonal

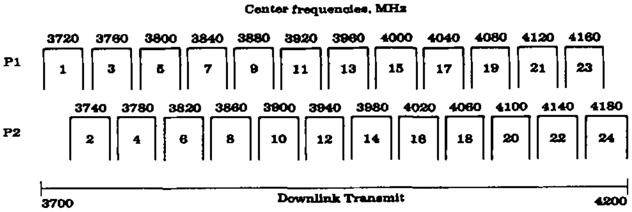

Figure 2. C-Band Frequency and Polarization Plan

linear polarizations, P1 and P2, each containing 500 MHz of spectrum divided into 12 transponders. The sense of P1 and P2 is reversed on adjacent satellites to improve isolation from interference. Consequently, particular orbital slots are designated for a particular sense, e.g., P1 is horizontal for Galaxy 1 at 134°W and it is vertical for Satcom 3R at 131°W. A generalized repeater block diagram of a C-band satellite is shown in Figure 3.

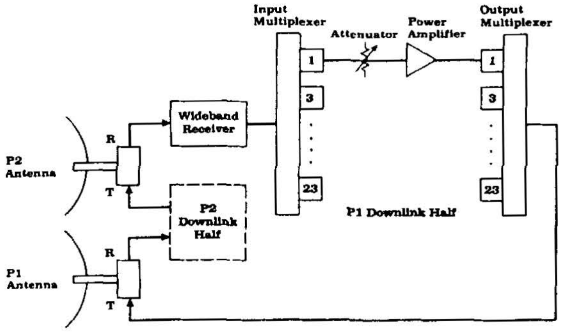

Figure 3. Satellite Repeater Block Diagram

We can expect that the footprint of the next generation C-band cable satellites will remain unchanged, as illustrated in Figure 4. From any of the established cable satellites, coverage of 50 states is possible, including portions of the Caribbean. The aspect that will be modified is the radiated power level of the transponders.

The current generation of Hughes and GE satellites employs power amplifiers with powers in the range of 5 to 10 watts. For a footprint like that in Figure 4, the effective isotropic radiated power (EIRP) over 80 to 90% of the land mass of the Continental United States (CONUS) is approximately 33 to 36 dBW. Experience has shown that at 36 dBW such as Galaxy I transmits commercial quality for cable programming is achieved with a receive antenna of 3.2 meters or greater diameter. This size is considerably smaller than the 5 meter antennas first employed in TVROs. The larger size was dictated by the 5 watt power levels of the first domestic satellites; in addition, early spacecraft antennas were less efficient than current technology and hence provided lower overall gain.

In the next generation of Galaxy satellites, overall EIRP within the footprint will be increased by approximately 3 dB to about 39 dBW (a factor of two in power) by a combination of factors. First, the power output of each amplifier will be increased to approximately 16 watts, representing a change of 2 to 2.5 dB. The types of amplifiers to be employed are the traveling wave tube amplifier (TWTA) and the solid state power amplifier (SSPA). TWTAs have been around since the first geosynchronous satellite was launched in 1963. Their performance and reliability are both well understood. A few of the current satellites employ SSPAs although TWTAs still dominate. A comparison of salient properties of the two amplifier types is presented in Table 1.

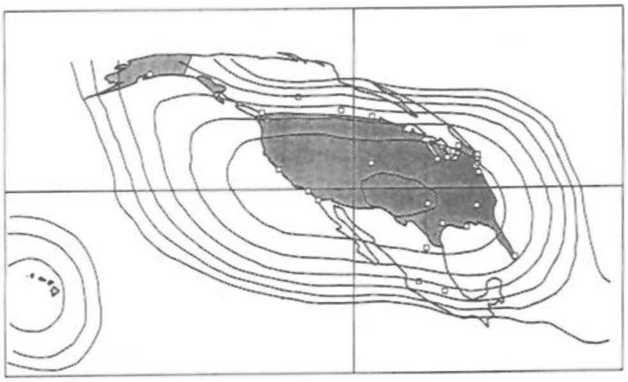

Figure 4. Downlink Footprint of Galaxy I

Table 1

A Comparison of TWTA and SSPA Properties at C-band

	TWTA	**SSPA**
Current power levels (watts)	8 to 16	6 to 9
Efficiency, RF out/DC in (%)	33 to 40	25 to 30
Weight (lbs)	2 to 3	3 to 4
Lifetime, minimum (years)	12	20

The power from space-proven TWTAs is already adequate to meet the needs of the next generation of Galaxy satellites. With regard to SSPAs, power must be increased by a factor of approximately two, primarily by paralleling two amplifier modules. This tends to increase weight while overall efficiency can be expected to decline slightly. In an overall sense, the performance of SSPAs for video transmission from space is less satisfactory than that of TWTAs. However, the TWT itself has a wearout mechanism not present in the SSPA. For lifetimes of 12 years or less, and provided that redundant amplifiers are on board, the TWTA will provide reliable service.

The rest of the increase in EIRP for Galaxy is provided through increased efficiency of the spacecraft antenna. Approximately 0.5 dB of gain enhancement over the footprint results from better antenna beam shaping with an advanced feed horn array. On top of this, a reduction in power loss through the output multiplexer and feed system will increase power delivered to the reflector by another 0.5 dB.

Impact of Higher EIRP

The 3 dB increase in EIRP can contribute measurably to the quality and utility of cable video transmissions. However, careful consideration must be given to the regulatory environment and the potential for interference with adjacent satellites. A primary test for C-band satellite radiation levels is the spectral power flux density which falls in a neighboring country. International and FCC regulations stipulate that the maximum flux density at the earth's surface shall not exceed

$-152\ \mathrm{dBW/m^2}$ for $E \leq 5^\circ$

$-152 + 1/2\ (E - 5^\circ)\ \mathrm{dBW/m^2}$ for $5^\circ < E \leq 25^\circ$

$-142\ \mathrm{dBW/m^2}$ for $E > 25^\circ$

in any 4 kHz band, where E is the earth station elevation angle in degrees. Video transmissions must employ energy dispersal to spread the power of strong spectral components.

The worst case for a satellite with the type of footprint shown in Figure 4 and providing 38 dBW over CONUS is -154.2 dBW/m^2 at the northeast corner of Maine on the Canadian border. The regulatory limit at this point, where the elevation angle is 7.2°, is computed as follows

$$-152.0 + 1/2\ (7.2^\circ - 5^\circ) = -150.9\ \mathrm{dBW/m^2}.$$

The difference between -154.2 and -150.9 represents a positive interference margin of 3.3 dB; therefore, the power flux density limit is met. All other points along the borders have greater margins.

In terms of adjacent satellite interference, Figure 5 summarizes an analysis of the carrier to interference ratio (C/I) as a function of orbital separation. Two cases are examined: one for a 5 meter receiving antenna and the other for the newer 3 meter antenna. The data demonstrates that adequate protection from interference is afforded, even for a receiving antenna of 3 m diameter.

The question naturally arises as to the purpose of raising the EIRP in the first place. Perhaps the most fundamental benefit is an increase in overall link margin, which is quantified in Figure 6. The 3 dB EIRP increase will raise overall link performance for the 3 meter antenna by approximately 2.5 dB. The popularity of the 3 meter class antenna for cable reception is enhanced by this added margin, since both reliability and noise suppression improve. Terrestrial interference in urban areas will be diminished in its effect by the added margin.

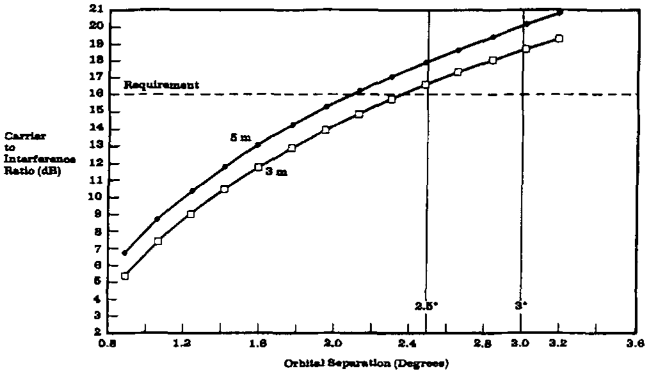

Figure 5. Adjacent Satellite Interference (C-Band)

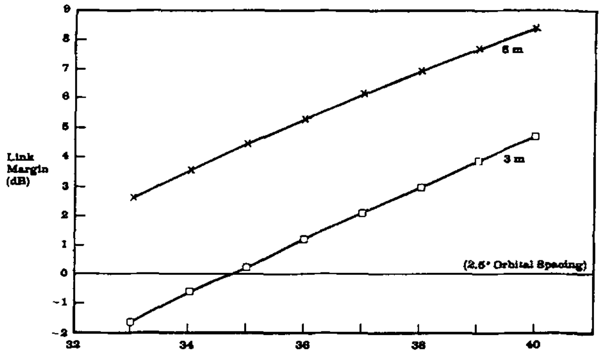

Figure 6. TV Link Margin vs Satellite EIRP

Antennas in the 4 to 5 meter range will produce somewhat higher quality video signals for standard NTSC transmissions. However, the real payoff in the future could be in High Definition Television (HDTV) which will require 3 to 6 dB more EIRP (depending on system finally adopted) than does NTSC. In many cable systems the 3 dB increase would support HDTV without increasing the size of the ground antennas. The standard transponder bandwidth of 36 MHz is adequate to support HDTV signals such as MUSE, the NHK HDTV system.

Spacecraft Characteristics

The communications requirements just described can be supported by spacecraft of comparable design to those now operating. Some upgrade in payload weight and power would be necessary to handle the 50% increase (2dB) in power requirements. The impact on a standard spacecraft "bus" design such as the Hughes HS-376 is quite minimal. The total "dry" weight (exclusive of fuel) increases from 1100 lbs to 1400 lbs, representing only a 25% change. Much larger spacecraft, with their attendant complexity and financial risk, are not required.

The lifetime of the next generation of satellites will increase from 10 to approximately 12 years even though dry weight will increase. This will be obtained through launch vehicle performance improvements and next generation propulsion systems. In Figure 7, the expected lifetime is presented for each of three available expandable launch vehicles: Ariane IV, Delta II and Long March 3. In the future, no space shuttle flights are anticipated for commercial purposes. The Titan rocket, while on the commercial market, is matched to much larger payloads and is not as appropriate for this class of satellite.

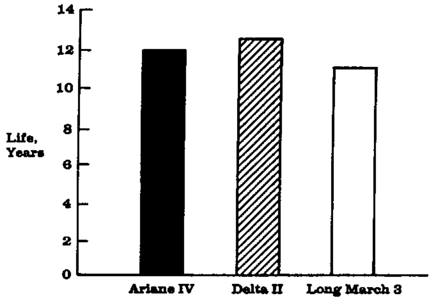

Figure 7. Expendable Launch Vehicle Performance

Other Considerations

Beyond the issues of EIRP and orbital lifetime, there are a few other enhancements that can be foreseen. The reliability of current domestic satellites has proven to be very high once final orbital station is reached. The end-to-end link availability at C-band is typically 99.9%, which is considerably better than can be obtained with terrestrial transmission systems. To obtain this level of availability at Ku band requires higher satellite EIRP and ground antennas of 3 to 5 meters.

The portion of the spacecraft most prone to outage is the same power amplifier used to generate EIRP. Occasional failures of TWTAs and SSPAs have been experienced, and the best remedy is to have spare amplifiers on board the satellite. With an appropriate switching scheme, a failed amplifier can be replaced with a spare in a matter of minutes. The obvious advantage of this approach is that a change of frequency is not required. Current cable satellites have either 1 spare for 4 operating amplifiers (called 5 for 4) or 1 spare for 6 operating amplifiers (7 for 6). There are limitations on how spares can be switched in. In the next generation, we recommend an increase in the number of spares, so that satellites have either a 5 for 4 or 6 for 4 scheme. Also, switching can be improved so a spare can replace any of a number of failed amplifiers and operating amplifiers can be interchanged.

A consideration which gained notoriety in the past few years is double illumination and intentional interference. Some of our worst fears seemed to be confirmed with Captain Midnight. Of course, one or two incidents like this is really minor in the grand scheme. Some control of the threat is possible by including a commandable variable attenuator, illustrated in Figure 3. A low powered intruder can be suppressed be activating the attenuator and increasing the uplink power of the authorized video uplink by the amount of attenuation. Other modes and uses are possible.

Conclusion

Providing these added capabilities of greater EIRP and longer life in the next generation can be done without added technical risk. Cable programmers and system operators can therefore expect continuity of service and even higher levels of quality and reliability. Finally, these benefits can be obtained at costs considerably below those of the class of Ku band satellites need to provide similar service.

OPTIMIZATION OF SUBSCRIBER SIGNAL QUALITY THROUGH LOCAL DISTRIBUTION MICROWAVE

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ABSTRACT

Although the era of high definition television (HDTV) may not yet be quite upon us, there can be little doubt that new CATV system designs and upgrades must increasingly strive to provide improved signal quality to subscribers to enhance the competitive stance of the CATV system. This paper addresses some of the quality criteria that will most likely be required of future CATV systems. As in the past, local distribution service (LDS) microwave can play an important role in achieving this improved system performance. One obvious technique is to reduce the length of trunk amplifier cascades by increasing the number of receiving hubs. However, the improved quality imposes more stringent requirements on the microwave link. It is shown that recent improvements in microwave systems and technology can accommodate these requirements. Specific examples are provided that illustrate how microwave system elements can be configured to meet the needs of CATV systems that will carry the HDTV signals.

INTRODUCTION

One of the primary motivations for the development of LDS microwave in the late 1960s was the potential for improvement in cable system signal quality. The idea was to reduce the length of trunk amplifier cascades, thereby improving carrier-to-noise ratio (C/N) delivered to the farthest subscriber. It was also felt that maintainability would improve if shorter trunk cascades were utilized. This, in fact, has proven to be the case in numerous instances. Bilodeau has provided the example of Suburban Cable in Essex County, New Jersey.[1] That reduction of trunk amplifier cascade lengths tends to improve quality, maintainability, and reduce outages is a fact that has more recently been recognized to potentially apply to other transmission technologies.[2] A key requirement is that each hub site, and the connection to it, be low in cost and simply implemented. The outdoor-mountable, cable-powered Hughes AML® microwave receiver shown in Figure 1 has widely fulfilled this requirement for the cable industry.

Figure 1 Typical CATV system AML hub.

While AML microwave has been utilized since 1971, the quality requirements imposed on the microwave link have become increasingly stringent over the years. Initially, the receiver microwave AGC threshold was set for 45 dB C/N, but already in 1972, this was increased to 48 dB. In 1976, the factory-set threshold was raised to 50 dB, and by 1981, it was again raised to 53 dB. The threshold could, of course, be adjusted in the field to any desired value, limited only by the link margin and distortion considerations, but the above-cited progression of C/N ratio settings is indicative of the increasingly tighter standards imposed by the CATV industry. To accommodate these requirements and still maintain link margins, especially over longer paths, it was necessary to provide 11 dB increased transmitter output capability with a klystron amplifier dedicated to each channel and then to provide a further 3-dB increase through improved upconverter linearity. At the same time, the receiver noise figure was reduced from 13 dB to 10 dB, and then through the introduction of low noise amplifiers (LNAs) to 7 dB and 5 dB.[3] Most recently, the increase of channel loading up to 80 channels necessitated improvement in second-and third-order distortion characteristics.[4] This steady evolution of the AML microwave in response to tighter CATV system needs has also witnessed the introduction of new classes of equipment, such as the active repeater and the microwave feed forward amplifier.[5,6] These past developments have set the stage for further improvements required to meet the future needs of CATV systems approaching the era of high definition television.

SYSTEM REQUIREMENTS

Overall minimum CATV system performance recommendations can presently be found in NCTA Recommended Practices for measurements on cable television systems. Similar information is contained in the Canadian

Technical Standards BP-23. These are minimum standards, and in many cases, cable systems are even today designed to meet tighter requirements. In anticipation of the advent of advanced television systems (ATV), including HDTV, there exist presently ongoing investigations to more fully characterize actual cable systems. At the same time, the various proposed ATV systems are under evaluation with regard to their robustness in the face of nonideal transmission media. The investigation being conducted in support of the HDTV subcommittee of the NCTA Engineering Committee will contribute to a wider study by the Advanced Television Systems Committee, which will formulate recommendations dealing with delivery standards for HDTV.[7]

Although a general consensus exists to the effect that some improvements in the cable plant will be required to accommodate ATV, there are as yet no agreed-upon numbers to provide firm guidance to the CATV system design. The problem is compounded by the fact that different ATV systems will undoubtedly exhibit a varying degree of susceptibility to transmission system impairments. However, it has been tentatively suggested that a 6-dB improvement of C/N (to 49 dB at the farthest subscriber) might be a logical design objective.[8] C/N is, of course, only one of several system performance parameters that are under investigation. Other parameters that are also of potential concern to elements of a CATV system and the LDS microwave are reflections, phase noise, frequency response, envelope delay, and distortion, including quadrature intermodulation.

A scenario that nearly meets the 49-dB C/N objective has been proposed by Switzer.[9] In his Table 3, he allocates 56 dB to the supertrunk, the role which can be played by AML microwave. Although this can represent a challenge when utilizing the lower cost block conversion type transmitters, this C/N requirement can be met in a large number of existing AML systems and is also furthered by recent AML improvements. Other CATV system parameters, although not yet allocated to the subsystems, including supertrunk, can also be improved with new AML developments, which are described in the following section.

If the signal being carried is reasonably robust, there is no intrinsic reason why existing CATV systems cannot provide a satisfactory transportation medium. This was most recently demonstrated at the 1987 HDTV Colloquium in Ottawa, Canada, where side-by-side HDTV display of signals directly received via satellite and satellite signals carried over Ottawa's Skyline Cable, including AML, were essentially indistinguishable. The signal in question was, however, MUSE in FM format, so that close to 30-MHz bandwidth was required. On the other hand, carriage of spectrum-conservative VSBAM television signals over AML microwave need not be associated with any significant degradation in picture quality. Indeed, baseband signal-to-noise ratio in excess of 63 dB has been demonstrated.[10] Other baseband performance criteria were generally in conformance with the rigid short-haul requirements of RS250B. However, cable systems do not normally employ the test equipment type quality VSBAM modulators (and demodulators) used in this demonstration. Nor are the baseband parameters routinely measured in AML production, since, in fact, VSBAM modulators and demodulators are not generally a part of the microwave link equipment. It is nevertheless clear that greater care will be required both in the operation and design of standard AML systems utilized by the cable industry if these systems are to meet the higher standards associated with carrying ATV signals.

AML PERFORMANCE PARAMETERS

1. Carrier to Noise Ratio - The principal source of thermal noise in AML microwave systems is usually noise generated within the receiver. In this case, the microwave AGC circuit maintains a constant C/N once the input exceeds the microwave AGC threshold. Adjustment of the threshold therefore controls C/N, provided sufficient signal is available to reach and exceed the threshold. The receiver parameter that determines the equivalent input noise level at threshold is the noise figure. For instance, an 8-dB noise figure receiver has an equivalent input noise power per 4 MHz bandwidth of -100 dBm. If the AGC threshold is set to -47 dBm input, the C/N will be 53 dB. The recently introduced 550-MHz receiver, which incorporates a single-stage LNA inside the AGC loop, is factory set in just such a manner and provides an 80-channel composite triple beat (C/CTB) of 80 dB. If, instead of a single-stage LNA, a 2-stage LNA is inserted into the AGC loop, the receiver noise figure is improved to under 6 dB. The AGC threshold could then be set for -49 dBm, while still providing the same 53 dB C/N. However, because of the increased LNA gain, the 80-channel C/CTB would be degraded to 70 dB. If then one wished to improve C/N to 56 dB by resetting the AGC threshold to -46 dBm, the resultant 80-channel C/CTB would be further degraded to 64 dB. Although this still allows margin to the 53 dB C/CTB (CW measurement) NCTA CATV system performance objective, it does eat into the overall budget, particularly if the calculation assumes voltage addition of third-order distortion products. Further improvement in receiver linearity was therefore desirable if 80-channel operation at 56 dB C/N was contemplated.

Figure 2 is a photograph of the new compact outdoor receiver (COR), which provides this improvement. Table I summarizes its key performance parameters. The phase-lock receiver block diagram is essentially the same as in the 550-MHz receiver introducted in 1987.[4] That is, it incorporates both an LNA and separate microwave and VHF AGCs. The main change is that the temperature control housing is not used, thus making possible a substantial reduction in weight and power consumption. The new compact housing is designed for optimal thermal transfer under maximum ambient temperature conditions. This permits use of a high-power solid-state source to drive a high-level mixer with improved distortion performance in the dual-stage LNA version of the receiver. The distortion performance thus achieved allows setting the C/N to 56 dB, even with 80-channel loading.

The two COR configurations described by Table I are not the only possible cases. For instance, the dual-stage LNA could be housed within the receiver, but outside the AGC loop as in a tower mounted LNA application. In that case, the receiver noise figure is less than 5 dB, but the receiver is now vulnerable to a signal overload condition. The 3-IM output intercept point of the LNA is specified as a minimum of 24 dBm. From this, and a nominal LNA gain of 15 dB, one can calculate that 80-channel C/CTB would fall below 69 dB for input signals in excess of -44 dBm. Thus, for heavy channel

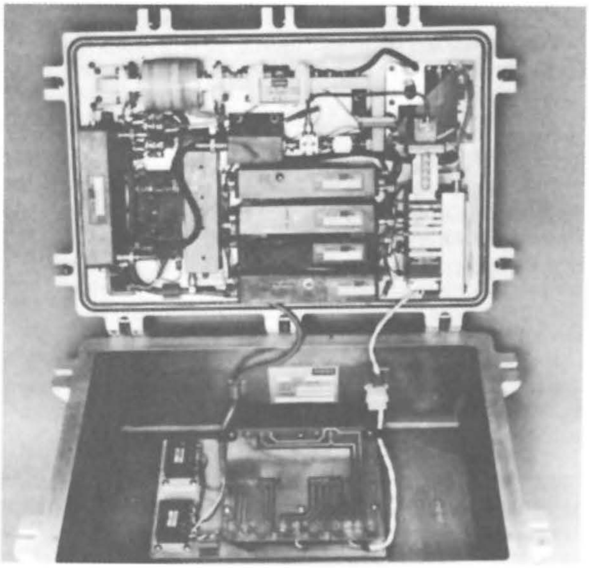


Figure 2 Compact outdoor receiver.

TABLE I

COMPACT OUTDOOR RECEIVER (COR) PERFORMANCE

	WITH SINGLE-STAGE LNA IN AGC	WITH DUAL-STAGE LNA IN AGC
NOISE FIGURE, dB	8	6
C/CTB (dB) FOR C/N = 56 dB		
80 CHANNELS	74	69
40 CHANNELS	80	75
C/CSB (dB) FOR C/N = 56 dB		
80 CHANNELS	63	67
40 CHANNELS	66	70
OUTPUT FREQUENCY ERROR	0 Hz (PHASE LOCKED TO AML TRANSMITTER)	
FREQUENCY RESPONSE, dB		
54-550 MHz OUTPUT	±1.5	±1.5
AGC		
MICROWAVE THRESHOLD (56 dB C/N)	-44 dBm	-46 dBm
VHF RANGE, dB	12	12
NOMINAL OUTPUT, dBmV	+20	+25
COMBINED MICROWAVE AND VHF FLATNESS, dB	±1	±1
WEIGHT (lbs)	45	45
INPUT VOLTAGE(1)	40 - 60 VAC	40 - 60 VAC
POWER REQUIRED (WATTS)	50	60
TEMPERATURE RANGE	-40° TO +120°F	-40° TO +120°F

(1) CABLE POWERED. -48 VDC INPUT ALSO POSSIBLE.

loading and/or strong signal conditions, careful consideration should be given to assess which receiver/LNA configuration is most suitable.

Further improvement in overall receiver performance is possible if the LNA noise figure is improved without degrading the third-order distortion performance. Recent FET technology improvements make a 2-stage LNA noise figure of 2.5 dB readily achievable. Investigation is presently under way to determine whether this can be done while maintaining the 24 dBm 3-IM intercept. If so, the aforementioned overall 6- and 5-dB receiver noise figures would improve to better than 5 and 4 dB, respectively.

The receiver is not the only possible source of thermal noise. The transmitter, particularly a low cost block conversion transmitter in which the output signal must be backed way off to avoid excessive C/CTB, can also degrade overall link C/N. Of course, if a path fade occurs, the transmitter noise is attenuated along with the signal, so the transmitter's contribution to a faded 35-dB C/N is negligible. However, during clear weather, the transmitter contribution (as well as any other headend noise) must be considered. Careful design is required to ensure that no active element within the transmitter operates at a signal level low enough to significantly degrade the microwave system C/N. The problem is really no different than in classic CATV system design, when both distortion and noise need to be taken into account. The situation becomes particularly acute if the microwave link is to provide 56-dB C/N with 65-dB C/CTB. For instance, this level of performance with 40-channel loading of the microwave feedforward transmitter is possible only if the noise figure of the 2-watt amplifier within the OLE-111 drive stage is lowered to 6 dB. Fortunately, a solution seems near at hand so that, even with a heavily loaded feedforward transmitter, the 56-dB link C/N criterion can be maintained. The block upconversion type transmitter link calculation is summarized in Table II, which further illustrates that with average propagation conditions, the feedforward amplifier can support a 6-mile path with less than 1 hour per year fade below 35 dB C/N. Note that the requirement is made tougher, by waveguide losses, in that both transmitter and receiver are assumed to be ground-mounted for ease of maintenance and minimum downtime in the event of a component failure.

If the link calculations indicate that insufficient signal level is supplied to the receiver to obtain the desired C/N, use of an active repeater may solve the problem. Generally, the repeater is used only in situations where direct line-of-sight cannot be established between transmitter and receiver. If the repeater is used to improve C/N, this is usually possible only if the repeater output capability is equal to or greater than that of the originating transmitter. This is because the repeater will itself degrade system C/N (and C/CTB). For instance, consider a repeater at the midpoint of a longer path (a direct antenna pointing between the transmitter and receiver cannot be allowed, since the direct and repeated signal could then interfere with one another at the receiver). The input signal at the repeater is 6 dB higher than what the receiver could receive if transmit and receive antennas were repointed at each other. Assume further that the repeater noise figure is equal to the receiver noise figure and that the repeater output (in AGC) is equal to that of the transmitter. This means that

TABLE II

A HIGH QUALITY MICROWAVE FEED FORWARD LINK

TRANSMITTER OUTPUT POWER	40 CHANNELS (dBm/CH)	0.8
TRANSMIT CIRCULAR WAVEGUIDE	100 FEET	-1.6
TRANSMIT ELLIPTICAL WAVEGUIDE	15 FEET	-0.6
TRANSMIT ANTENNA	10 FOOT	48.8
FREE SPACE LOSS	6.0 MILES	-134.3
RECEIVE ANTENNA	10 FOOT	48.8
RECEIVE CIRCULAR WAVEGUIDE	100 FEET	-1.6
RECEIVE ELLIPTICAL WAVEGUIDE	15 FEET	-0.6
RECEIVER INPUT AGC ATTENUATION		-2.5
FIELD FACTOR		-2.0
RECEIVE CARRIER LEVEL		-44.6
RECEIVER NOISE FIGURE	6 dB	

TRANSMITTER C/N	61.7	TRANSMITTER CTB	65.9
RECEIVER C/N	57.4	RECEIVER CTB IN AGC	72.5
*OVERALL C/N IN AGC [+]	56.0	*OVERALL CTB IN AGC [+]	65.0

STATISTICAL ESTIMATES

MULTIPATH FACTOR (A x B) = 0.25
CCIR CLIMATE REGION = D2

HOURS PER YEAR BELOW 35 dB CARRIER-TO-NOISE: MULTIPATH	0.0
HOURS PER YEAR BELOW 35 dB CARRIER-TO-NOISE: RAIN	0.6
TOTAL HOURS PER YEAR BELOW 35 dB CARRIER-TO-NOISE	0.6
PERCENTAGE RELIABILITY	99.993

[+] DENOTES POWER ADDITION (+) DENOTES VOLTAGE ADDITION
*OVERALL C/N AND CTB TO BE ADDED TO THOSE OF TRANSMITTER INPUT

the signal at the receiver is also 6 dB higher than it would be if no repeater were used. Since, however, both repeater and receiver contribute to C/N, the improvement is at best 3 dB. Note also that repeater gain is critical if both C/N and C/CTB are to be maintained at acceptable levels.

The block diagram of the FFR-123 microwave feed-forward repeater (Figure 3) illustrates the point. The AGC threshold is set to obtain the desired CTB. Table III summarizes the key FFR-123 repeater performance parameters. Consider, for instance, a 40-channel application in which the repeater C/CTB link contribution is 65 dB. The output is then set for 1 dBm per channel. Since the gain is 45 dB, the input level at AGC threshold is -44 dBm. With 6-dB noise figure, C/N must then be 58 dB. Since this must still add to receiver C/N, a repeater with too much gain cannot provide the desired quality signal. Where input signal level to the repeater is always below -42 dBm, the LNA could be taken outside of the AGC loop shown in Figure 3 without excessive degradation of C/CTB, but this would limit the range of possible system application.

TABLE III

MICROWAVE FEED FORWARD REPEATER PERFORMANCE

POWER OUTPUT FOR 65 dB C/CTB, dBm	
21 CHANNELS	+5
35 CHANNELS	+2
60 CHANNELS	-1
GAIN, dB	45 ± 1/2
NOISE FIGURE	6 dB
AGC	
RANGE	25 dB
FLATNESS	1 dB
THRESHOLD ADJUSTMENT RANGE	10 dB
FREQUENCY RESPONSE, 12.7 - 13.2 GHz	±1 dB

Even channelized transmitters can sometimes be a significant contributor of thermal noise when overall 56-dB C/N is demanded from the microwave link. Noise power output of the STX-141 transmitter is determined by the klystron gain and noise figure. After attenuation by the output filter and allowance for spillover from the adjacent channels, noise power is typically -30 dBm/4 MHz. Comparing this to the +33 dBm signal, the C/N is seen to be 63 dB. As the klystron current drops due to cathode aging, both gain and noise figure can be expected to deteriorate. If, then, the klystron is retuned to reestablish 45-dB gain, the output noise may be a few dB larger than when the unit was delivered from the factory. With the introduction four years ago of the long-life klystron, one can expect that the aging process will be stretched out to over 10 years.

One solution for obtaining better C/N in STX-141 type transmitters is to upgrade the unit so that its output capability is raised to 36 dBm. The difference lies in the linearity of the upconverter, which is provided with a higher level local oscillator (LO) signal. A further 3-dB

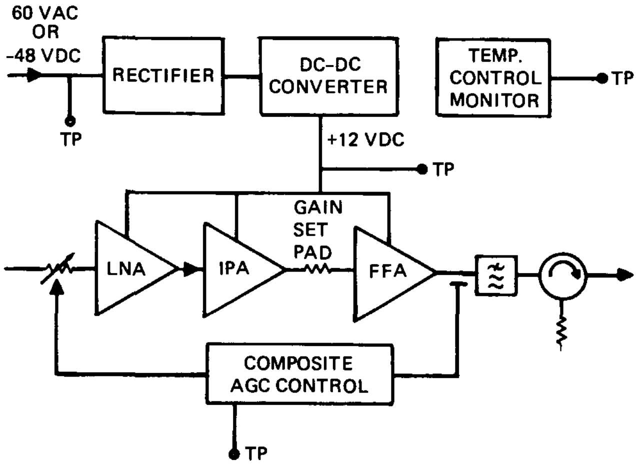


Figure 3 Microwave Feed Forward Repeater block diagram.

increase in output power capability is possible with a predistortion circuit.[11] It is, of course, obvious that increasing transmit output power has the double benefit of increasing link margin and, therefore, the ability to better sustain 56-dB C/N at the receiver, as well as make transmitter noise contribution an all but negligible entity.

Another possible approach to obtaining better C/N in a channelized high power AML is to utilize a high power FET amplifier in place of a klystron in the output stage of the transmitter.[12] The noise figure of the FET amplifier is much lower than that of the klystron, thereby making transmitter C/N contribution as insignificant as it is in the medium powered MTX-132 transmitter. The drawback in the FET amplifier approach is that with currently available devices, one must give up several dB in output power capability (relative to the +33 dBm of the STX-141 transmitter) to maintain good distortion performance. AM-to-PM conversion in FET amplifiers operating close to saturation may be a particular limitation for some types of ATV signals. The primary advantage of this new type of channelized all solid-state transmitter has less to do with HDTV than with floor space and prime power requirement in new or expanding transmitter system installations.

A final thought dealing not so much with C/N as with baseband S/N is that, if the television signals carried by the AML supertrunk are frequency modulated rather than VSBAM, one can, of course, more easily obtain very high quality signals. The drawback, as with any other supertrunk scheme carrying FM video, is the cost and complexity of converting each of the FM signals back to the VSBAM format before delivering the product to the subscriber. Table IV summarizes the various means for achieving very high quality S/N on AML links.

2. Distortion - In the channelized AML transmitters, the distortion is similar to that encountered in other headend equipment. In particular, the rise of third-order intermodulation products limits the output power of the MTX-132 and the high power STX-141 transmitters. Those products fall both in-band (the 920-KHz beat caused by a combination of video, color, and audio carriers) and into the next lower channel (audio-video beat 1.5 MHz above the adjacent video carrier). The transmitter specification for the audio 17 dB below video and color 20 dB below video (cw measurement) is C/I of 58 dBc. Since there is then considerable margin with respect to the "W-curve" specified by BP-23, the 58-dBc specification will presumably also be adequate for most ATV systems. If an even better number is desired, one can back off the transmitter output to obtain a 2-dB improvement in C/I for each dB reduction in output power. Alternatively, high power transmitter linearity can be improved through higher LO power or predistortion.

TABLE IV

MEANS OF ENHANCING AML S/N

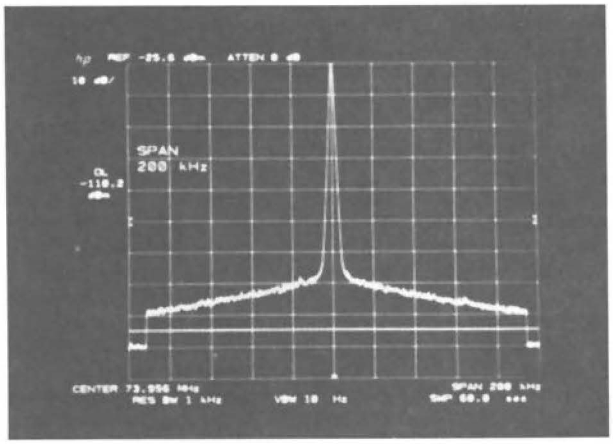
ADJUSTMENT OF MICROWAVE RECEIVER AGC THRESHOLD
COMPACT OUTDOOR RECEIVER WITH 2-STAGE LNA
LOWER NOISE FIGURE LNA
REDUCED OLE-111/FFA-160 TRANSMITTER OUTPUT NOISE
FFR-123 MICROWAVE FEEDFORWARD REPEATER
HIGHER OUTPUT POWER STX-141 TYPE TRANSMITTER
HIGH POWER CHANNELLIZED ALL SOLID STATE TRANSMITTER
FM TV SIGNALS INSTEAD OF VSBAM

Differential gain is typically better than 3 percent and differential phase is under 2 degrees. However, if a significant performance degradation is introduced by overdriving the upconverter or klystron, a phenomenon somewhat akin to differential gain can interfere with proper operation of descrambler units in the home. This is caused by transfer of AM onto the FM audio subcarrier. Normally, the effect is barely measurable, and well below the threshold of greater than 0.5-dB modulation riding on top of the audio signal, at which certain types of descrambler units may begin to experience some problems. Generally, keeping the C/I to 58 dBc will keep AM transfer to audio at a negligible level.

Another type of distortion that occurs in AML systems can be found in the broadband receivers and the block upconversion type transmitters. This distortion is the second- and third-order intermodulation between video carriers. In discussing C/N, reference has already been made to the improvement in C/CTB and C/CSB (composite second-order beat) in the COR receiver with a dual-stage LNA. Second-order distortion does not play a role at microwave, since the percentage bandwidth is only 4 percent, but it does occur in the VHF end of the block upconversion and downconversion process.

In CATV system calculations, such third-order distortions as composite triple beat are assumed to add on a voltage basis in a cascade of amplifiers. If, however, the distortion generating elements in the cascade are not identical, it is not necessarily true that the phase vectors representing the distortion products will all line up with one another. In a careful set of experiments involving a Microwave Line Extender, a Microwave Feedforward Amplifier, a two-stage LNA, a 440-MHz AML receiver, and a CATV hybrid amplifier, it was found that C/CTB did not always add on a voltage basis. Sometimes it added on a power basis (90-degree angle between voltage vectors) and sometimes it didn't add at all (120-degree angle between vectors). Therefore, although it may not be totally rigorous, as a practical matter, the C/CTB performance of a CATV system including AML can be conservatively calculated by first separately voltage-combining the microwave-based elements and then power-combining the microwave resultant with the VHF (i.e., receiver and cable amplifier) resultant.

3. Phase Noise - Figure 4 shows the phase noise on the AML pilot tone signal as it appears at the output test point of the receiver. The performance shown is typical of present production. Note in particular the value at 20-KHz offset from the carrier: better than 70 dBc in a 1 KHz resolution bandwidth. Depending on the phase noise limitation of the spectrum analyzer and the thermal (flat) noise at the measurement point, corrections to the apparent measured value may be required at this low level of phase noise. Thermal noise limit after external amplification of the test point signal is indicated by the display line while the thermal noise of the analyzer itself is shown at the start and end of the trace. The analyzer



VERTICAL SCALE:	10 dB/DIV
HORIZONTAL SCALE:	20 kHz/DIV
RESOLUTION BANDWIDTH:	1 kHz

Figure 4 Receiver pilot tone output spectrum.

phase noise contribution can be calibrated by using a known ultralow phase noise signal, such as the 74-MHz crystal oscillator within the AML transmitter. This crystal reference must be extremely clean, since it is multiplied up in frequency by a factor of 171 before emerging as the microwave LO signal. The multiplication process worsens the crystal phase noise by a factor of $(171)^2$ or 45 dB. The phase noise is also degraded by contributions internally generated within the transmitter solid-state source. The same elements exist in the receiver and, in addition, one has the contribution of the receiver phase-lock loop. The bandwidth of this loop is quite narrow, so only at offset frequencies under 5 KHz is there any hope of tracking out any of the incoming phase noise.

It can be shown that the phase noise of the magnitude shown in Figure 4 would, through conversion to AM by the Nyquist filter of an ideal VSBAM envelope detector, contribute better than 65-dB baseband S/N. With that type of TV receiver, one would expect that phase noise could be worse by as much as 15 dB before becoming visible on the screen. Recent tests with quasi-synchronous type television receivers indicate visibility thresholds on the order of 53 to 60 dBc phase noise at 20 KHz offset in 1 KHz resolution bandwidth.[13] Although phase noise in a CATV system is typically limited by elements other than AML, investigations have been under way to see whether AML phase noise performance can be further improved in case ATV requirements eat substantially into the existing margin.

4. Reflections - It is expected that some forms of ATV signals will be much more sensitive to close-in ghosts than with standard NTSC. In particular, reflections as close in as 30 ns may become a concern. It has been suggested that an overall CATV system echo rating objective of 34 dB may be suitable.[8] To contribute negligibly to this objective, reasonable care should be taken in the design of the microwave system.

Consider Figure 3 again. Note the isolator at the output of the transmitter. Because it is implemented in waveguide, a return loss of 23 dB should be achievable if required. The transmitter must be connected to an antenna, which is typically specified to have a VSWR of 1.1:1. This is equivalent to a return loss of about 26 dB. Thus round-trip return loss with a 15 foot length of elliptical waveguide interconnection would be about 50 dB when waveguide loss is taken into account. Longer waveguide lengths will lead to greater than 30 ns delay echoes, but not necessarily greater round-trip loss, since a circular guide may be used. In either case, microwave return loss should contribute negligibly to the overall CATV system echo rating.

5. Frequency Response - Two types of frequency response are of concern. ATV signals could require greater bandwidth and thus push out the maximum frequency limit on the CATV system. AML equipment can be fully compatible with operation to 550 MHz. As an example, HPOLE-112 transmitters are now designed for 550-MHz operation. Most broadband units, whether they are transmitters or receivers, can be upgraded to 550-MHz operation if they are not presently compatible with this requirement.

If CATV system requirements were to expand to a maximum of 600 MHz, AML systems could conceivably still fit within the broadened 12.7- to 13.25-GHz frequency allocation. Another option, and one which would not be limited by the 550 MHz wide microwave allocation, would be to employ microwave frequency reuse, such as that demonstrated in Dallas.[14] A suitable choice of LO frequency would automatically keep the UHF signals carried on the auxiliary microwave link within the CARS-band limits.

The second question relating to frequency response concerns itself with the limitations of the channelized transmitters. The TE_{011} mode filters used in such transmitters can be designed for bandwidth as large as 30 MHz. Existing transmitters designed for 6-MHz channel plans would require modification for wider band ATV signals.

6. Group Delay - Group delay is of concern only in the channelized transmitters. The MTX-132 type transmitter typically exhibits less than ±15 ns delay. The STX-141 transmitter may have as much as ±35 ns delay. This can, however, be reduced by exchanging the upconverter output filter for a broader bandwidth unit. Since the klystron is typically the primary source of video-audio intermodulation (falling in the next lower channel) and the output multiplexing filter attenuates this product, performance should otherwise be unaffected. With the modification, delay may typically run about ±20 ns.

7. Availability - The calculation in Table II resulted in a predicted path reliability of 99.993 percent. Similar reliabilities are possible over considerably longer paths using channelized transmitters. Since there is no threshold effect with VSBAM, the pictures are still viewable, even below 35 dB C/N. Nevertheless, one can speak of an availability of signal for the indicated percentage taking only rain and multipath into account. One also needs be concerned with the twist of the antenna during high wind conditions. The design must be consistent with the 1/2 degree beamwidth for 10-foot dishes.

Availability is, of course, a key element of the quality of signal provided to the subscriber. If pictures are simply not available, this is the worst kind of quality imaginable. Fortunately, the microwave link service interruption is not influenced by such factors as drunken drivers knocking down telephone poles, intentionally severed cables during labor disputes, and "backhoe fades" resulting from construction activities. If an equipment failure occurs, it can be rapidly localized to either of two sites: the transmitter or receiver.

Since a failure in the receiver will affect all channels, the desirability of a redundancy arrangement has long been recognized. In many systems, a simple headend for local off-air channels (note the VHF antennas in Figure 1) is automatically switched in if the signals are temporarily unavailable over the microwave path. A more sophisticated redundacy arrangement is provided with the receiver redundancy unit (RRU), which monitors the pilot tone output level and phase lock alarms from a standby receiver, as well as a primary receiver. If the RRU logic circuits detect a failure in the primary receiver, the switch is automatically activated to connect the standby unit directly to the antenna. If the problem lies with the microwave path or the transmitter, the RRU will automatically switch to the local headend signals. The RRU has recently been redesigned to make it fully compatible with carriage of signals to 550 MHz.

Another application of the RRU is shown in Figure 5. Here, automatic redundancy is applied to the transmit end of a broadband AML link. Another form of block conversion transmitter redundancy,[6] although not automatic, provides an added 3-dB output capability when the application calls for two or more receive sites.

Fail-soft redundancy of the klystron and high-voltage power supply has long been a standard feature of the MTX-132 transmitter. This was provided because a single failure would affect eight channels. Most recently, a new means of backing up a single channel failure has been developed. This is the frequency-agile upconverter (AUPC) shown installed (Figure 6) in the lower right side of an MTX-132 transmitter rack. The AUPC takes a VHF input and provides a microwave output. If an upconverter failure occurs, the VHF input signal to that upconverter is patched over to the AUPC input. The AUPC output is connected to the bottom of one of the circulator strings in which the standard output multiplex rules would not be violated. The AUPC thus essentially provides for immediate back-up (assuming the transmit site is manned) for any upconverter failure. The AUPC can also serve as a premium channel back-up when carrying a low priority "9th channel" in an MTX-132 rack.

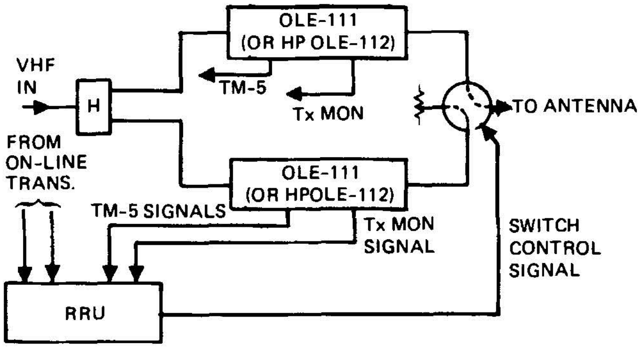


Figure 5 Microwave line extender automatic redundancy arrangement.

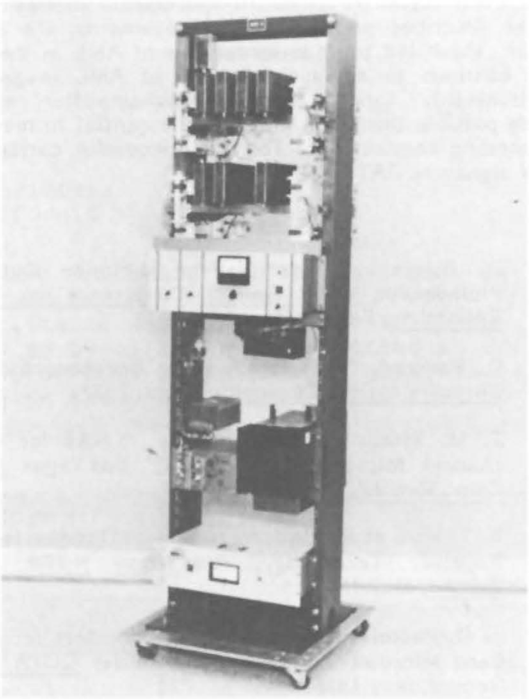


Figure 6 Frequency agile upconverter in MTX-132 transmitter.

SUMMARY

Technology improvements recently incorporated in the AML receiver design enhance the ability of LDS type microwave to fulfill CATV system needs, such as a 56 dB C/N, which may be required by ATV. Noise figure and linearity are the key parameters determining overall capability. Improved output power capability is achieved through linearization techniques, such as those illustrated in the microwave feedforward repeater, and by the application of predistortion to the high-power STX-141 transmitter. The typical AML phase noise of 70 dBc/KHz at 20-KHz offset is well below the visibility threshold in present TV receivers. With reasonable care, microwave reflections should contribute negligiby to overall CATV system echo rating even for ATV systems capable of distinguishing ghosts as close in as 30 ns. Bandwidth requirements of ATV signals can presently be met with broadband AML equipment, and even channelized transmitters can be designed for up to 30-MHz channel bandwidths. Group delay in these transmitters can be kept under ±20 ns. Signal availability in a well-designed microwave link can be better than 99.99 percent if redundancy techniques are employed. Because equipment is located only at the transmit and receive points, catastrophic outages are more easily avoided with microwave than with other forms of signal transportation. In view of the above described performance improvements, the advantages, which led to wide-spread use of AML in the past, can continue to apply to the use of AML in an ATV environment. Indeed, shorter trunk amplifier cascades made possible through AML may be essential to meet the demanding requirements for the successful carriage of ATV signals in CATV systems.

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OSCILLATOR PHASE NOISE AND ITS EFFECTS IN A CATV SYSTEM

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ABSTRACT

Phase noise of oscillators such as local oscillators in modulators, receivers, set-top converters, etc., can introduce noise in TV pictures in a CATV system. Acceptable characteristics and the effects of phase noise are not recognized as readily as other more familiar and routinely measured distortions. The qualitative measure of phase noise is the perceptibility of phase noise in a TV picture. A quantitative measure is the baseband signal-to-noise ratio (SNR) and noise spectral density. This paper presents the theory relating the RF noise spectrum of an oscillator and the resulting video noise spectrum and SNR. Some representative data for oscillator noise in video modulators and set-top converters is given along with results of perceptibility tests.

INTRODUCTION

In recent years, experienced CATV engineers spoke of an effect they had begun to observe in which television pictures appeared to the trained eye to have more noise than standard traditional measurements indicated. In mid-1987 an ad-hoc group consisting of representatives of the NCTA, cable operators, and equipment manufacturers organized to examine the issue. A short time later this group was incorporated by the NCTA Engineering Committee into its HDTV Subcommittee, called Group 1, and charged with the investigation and documentation of signal transfer characteristics in cable systems with particular emphasis on parameters useful in forecasting the transparency of a cable system to various HDTV proposals. Improved quality of present CATV service is also an expected result. This paper, together with the companion paper by Gerald Robinson [1], form the first published results of the Group 1 investigations.

It was determined that the first efforts of the group should be devoted to rigorous investigation of phase noise effects throughout the entire network, including satellite links and through final detection.

In this paper both RF and baseband theoretical and measured results are presented. This paper is concerned with high frequency phase noise and its effect in vestigial sideband television. The perceptually dominant effects of phase noise over thermal noise after detection are isolated and presented.

BACKGROUND THEORY

A general expression for oscillator phase noise as derived by Leesson [2] is

$$L(fm) = \frac{1}{2}\left[1 + \frac{fo^2}{fm^2}\frac{1}{4Q^2}\right]\frac{KTF}{P} \qquad (1)$$

where L(fm) is the ratio of single-sideband noise power in a 1 Hz bandwidth (centered fm Hertz from the carrier) to the carrier power, and

fm = frequency offset from the carrier (modulating frequency),
fo = carrier frequency,
Q = loaded Q of oscillator resonator,
F = noise factor of active drive,
K = Boltzmann's constant,
T = temperature in degrees Kelvin, and
P = available carrier power in watts.

Equation (1) predicts the spectral distribution due to intrinsic noise in the active device, and assumes the AM contribution is negligible, as it is in a well designed oscillator. Low-frequency phase noise, which is usually predominately power-supply related, is not included, nor is low-frequency flicker noise. Furthermore, in CATV equipment, oscillators of concern are often incorporated in a synthesizer phaselock loop which modifies the close-in spectrum. As a result, the close-in spectrum is determined by the particular circuit design and can not be predicted in a general way. Low frequency phase modulation is often caused primarily by insufficient filtering or isolation of the oscillator power supply. The result is frequency modulation at 60 Hz and harmonics of 60 Hz. The clamping action of TV sets tends to suppress the effects of this low frequency FM, and TV sets may respond quite differently to this low frequency disturbance. The effect of high-frequency noise is quite different, and the analysis here will be limited to high-frequency noise, that is, noise modulation approximately 10 kHz or higher in frequency.

From Eqn. (1), the spectral density (noise power/Hertz) is proportional to $1/fm^2$ up to the point at which it "breaks flat" (fm = fo/2Q). In this paper we will consider oscillator phase noise to be that which has a noise power spectrum proportional to $1/fm^2$; i.e., a 6 dB per octave decrease with offset frequency.
Eventually the oscillator phase noise falls below the "noise floor" of the system. The "noise floor" of the system is limited by the carrier-to-noise (C/N) ratio of the distribution system, but the earth station, head-end equipment, set-top converters, etc. are also contributors. The system "noise floor" is caused by amplified thermal noise, and is referred to as thermal noise . It contains equal amounts of AM and PM noise, and upper and lower sidebands are correlated. Here we will consider system noise to be comprised of (1) oscillator phase noise, plus (2) thermal noise. From Eqn. (1), that part we call oscillator phase noise is:

$$L(fm) = 1/(fmQe)^2 \qquad (2)$$

where Qe is a constant ("effective Q") which defines the spectral purity of the oscillator. The equations that follow give phase noise, frequency noise, and video SNR as a function of the parameter Qe.

The term L(fm) is the reciprocal of the more commonly used term C/No, where C is carrier power and No is noise power in a 1 Hertz bandwidth. In this paper we will use the notation C/N_p for the ratio of carrier to phase noise, and C/N_t for the carrier to thermal noise ratio. For noise given in a 1 Hertz bandwidth, the notation is

$$C/No_p = \text{Carrier/phase noise/Hz} \qquad (3)$$

$$C/No_t = \text{Carrier/thermal noise/Hz} \qquad (4)$$

Qe expressed in dB is 20log(Qe). Qe can be obtained directly from the oscillator spectrum measured with a spectrum analyzer by

$$Qe = C/N_p - 1.7 - 20\log(fm) + 10\log(B)\ \text{dB} \qquad (5)$$

where C/N is the carrier/phase-noise sideband ratio in dB, B is the analyzer bandwidth, and 1.7 is the usual analyzer correction factor applied to noise measurements [3]. For example, if an oscillator spectrum measures 56 dB below carrier in a 1 kHz bandwidth 20 kHz from the carrier, then Qe = -1.7 dB.

In analyzing the effects of oscillator phase noise in an NTSC system, it is helpful to convert phase noise to frequency noise since it is FM noise that is directly converted to AM noise by the Nyquist filter in the TV receiver.
For the analysis, it is convenient to make use of the principal that random noise can be approximated by a large number of sinusoidal components all approximately equally spaced and of arbitrary phase [4]. Thus, the oscillator spectrum can be considered to consist of a carrier plus sinusoidal components 1 Hz apart. The ratio of the <u>power</u> of each component to the carrier <u>power</u> is, therefore, L(fm); (refer to the definition of L(fm)). The ratio of the RMS voltage of each component to the RMS voltage of the carrier is $\sqrt{L(fm)}$. The <u>peak</u> phase deviation of the oscillator at a frequency fm is equal to the sum of the upper and lower sideband phasors, or $2\sqrt{L(fm)}$. The RMS phase deviation θn for a 1 Hertz bandwidth is:

$$\theta n(fm) = \sqrt{2L(fm)}\ \ \text{RMS Rad/Hz} \qquad (6)$$

Instantaneous frequency in radians/sec. is the time derivative of phase ($w=d\theta/dt$). Thus, for the above sinusoidal peak phase deviation of $2\sqrt{L(fm)}$, the <u>peak</u> frequency deviation is $2fm\sqrt{L(fm)}$. The RMS frequency deviation due to phase noise in a 1 Hz bandwidth fm Hertz from the carrier is:

$$\Delta f(fm) = fm\sqrt{2L(fm)}\ \ \text{RMS Hz} \qquad (7)$$

$$= \sqrt{2}/Qe \qquad (7a)$$

Thus, the spectral density of frequency noise is constant (white) for $1/fm^2$ spectral phase noise.

The slope of a TV Nyquist filter extends over a nominal range of ± 750 kHz centered around the picture carrier. First assume the Nyquist slope is linear over that bandwidth. A deviation of

750 kHz in this case would theoretically produce 100% amplitude modulation at the output of the Nyquist filter. As a result, the AM depth of modulation is equal to $1/750*10^3$ times the frequency deviation which, from Eqn. (7), is:

$$An(fm) = \frac{fm\sqrt{2L(fm)}}{750\cdot 10^3} \qquad fm < 750\text{ kHz} \qquad (8)$$

$$= \sqrt{2}/750\cdot 10^3\cdot Qe \qquad (8a)$$

An(fm) is specifically the ratio of the RMS noise component that is in phase with the carrier to the RMS carrier voltage. Likewise, $\theta n(fm)$, (Eqn. 6), is the ratio of the quadrature RMS component to the RMS carrier.

Now consider the effects of phase noise for frequencies where the response of the Nyquist filter is flat; i.e, the single-sideband region. The amplitude response of a the Nyquist filter should be down 6 dB at the carrier frequency relative to the response at single-sideband frequencies. As a result, the relative single-sideband noise power is four times greater than at the input to the Nyquist filter; the noise power ratio at the output is 4L(fm). For single-sideband noise, the AM and PM spectral components are equal in power: each is 1/2 the total spectral power. The AM component of noise power is 2L(fm); the RMS noise voltage ratio is

$$An(fm) = \sqrt{2L(fm)} \qquad fm > 750\text{ kHz} \qquad (9)$$

$$= \frac{\sqrt{2}}{C/No_p} \qquad (9a)$$

In this region the noise spectrum at the filter output has the same shape as the input noise spectrum, and the ratio of carrier to noise power density is degraded 3 dB.

Now consider the effects of the Nyquist filter on white thermal noise. For thermal noise, sidebands are uncorrelated, and, as for single-sideband phase noise, half the power is in the AM component and half in the PM component. The effect of the Nyquist filter can be calculated by power addition of AM sideband components at the output of the filter. With the assumption of a linear Nyquist filter, sidebands add to produce a baseband noise spectra that increases quadratically 3 dB to 750 kHz [5]. Above 750 kHz, the output of the receiver filter is single sideband, and the result is the same as above for phase noise.

APPLICATION OF THEORY

The assumption of a simple linear characteristic for the receiver Nyquist filter is useful, but, of course, real receiver filters are not linear. To more accurately calculate noise resulting from slope detection in the Nyquist filter and to better correlate the theory with measured data, this analysis is based on the response of the Nyquist filter in the Teletronix 1450-1 Television Demodulator used in the video SNR and baseband spectra measurements. A plot of the Nyquist filter response is given in Figure 1. Also superimposed is 1/2 cycle of a sine function, and as seen, it is a very good approximation of the actual filter function. With this characteristic and the equations above, good accuracy has been achieved in relating baseband measurements - video noise spectra and weighted and unweighted SNR - to the carrier phase noise spectra and thermal noise.

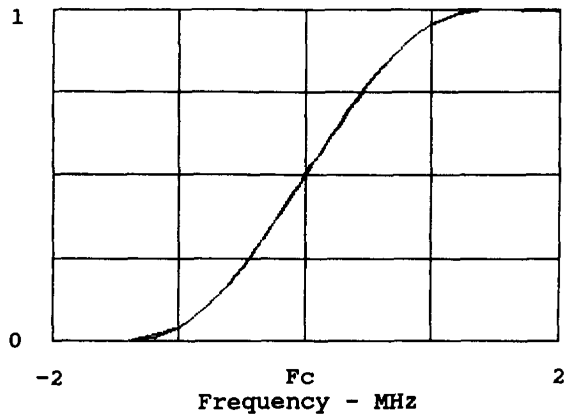

FIGURE 1. Nyquist Filter Response

(a) Measured data
(b) Approximation

Figure 2 is a plot of the AM noise spectra at the output of the Nyquist filter caused by thermal and phase noise. Thermal noise produces a video noise spectrum that increases from DC to the upper limit of the Nyquist filter and is constant above that. For frequencies near carrier frequency, the AM (in phase) component is the same at the output of the filter as at the input since upper and lower sidebands are nearly equal. The thermal noise plot shows, simply, the effect of the Nyquist filter on AM noise.

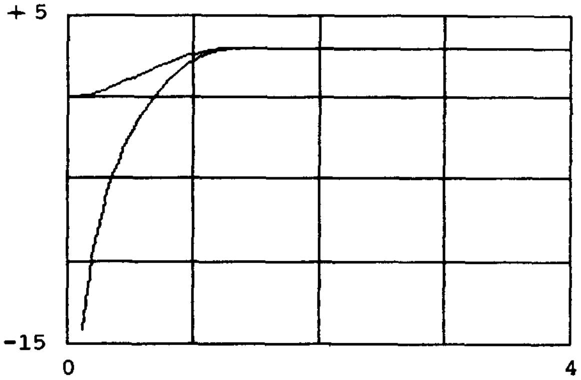

FIGURE 2. AM Demodulation of RF Noise.

Ordinate is C/No : S/No in dB for
(a) Thermal noise
(b) Phase noise

Figure 3 shows the PM to AM conversion of oscillator phase noise. In the frequency range of the Nyquist filter there is some noise roll off; for a linear Nyquist filter the response would be flat. Above the cut off of the Nyquist filter the baseband noise roll off is the same as at RF. Oscillator phase noise contributes primarily to low frequency video noise in the frequency range of perhaps a few hundred kilohertz to a megahertz or more.

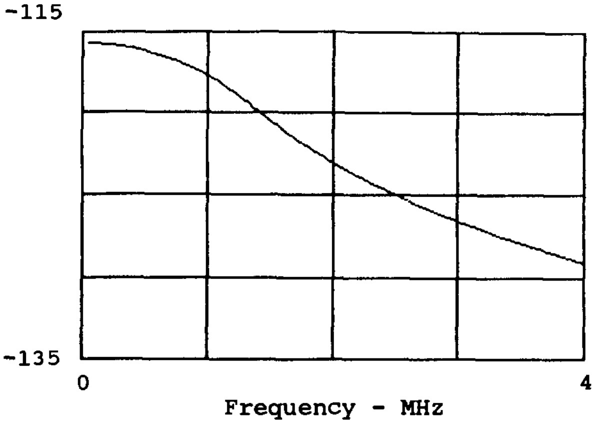

FIGURE 3. Baseband Noise Spectra for Phase Noise = $1/(fmQe)^2$.

Ordinate is No/S in dB for Qe = 1

Oscillator phase noise can be recognized and distinguished from video noise in an examination of the video baseband spectra. For high oscillator phase noise, the noise seen when viewing a TV set in recognizable as low frequency noise and appears different from broadband nose. Data is given in a later section that illustrates these points.

The objective of this paper is to relate RF C/N measurements to video SNR and baseband noise spectra. Weighted SNR is the ratio of the total luminance signal (100 IRE Units) to the weighted RMS noise level expressed in dB. Note, however, that noise due to phase noise is different from thermal noise in that it is directly proportional to the carrier level. If the carrier were to drop to zero percent modulation, there would be no phase noise contribution, of course. Thermal noise is the same (for constant receiver gain) regardless of carrier level. Furthermore, note that noise is more noticeable in dark TV scenes of perhaps 10 to 20 IRE. In our experiments, SNR is determined by measuring weighted baseband noise with the carrier unmodulated in accordance with EIA Standard RS-250-B. The amount of noise caused by phase noise is determined by turning the phase modulation on and off. Phase SNR is the ratio of the signal for 100% modulation (1.143V for 1V/100IRE) divided by the RMS phase noise voltage.

Phase noise can be measured also on a waveform monitor using the Tektronix 147 Test Signal Generator or by the NTC Report No.7 Approximation Technique. With these procedures the amount of phase noise measured will depend on the level of the waveform pedestal at which noise is measured. If noise is measured at a level of 20 IRE, these procedures theoretically give the same results and agree with the above measurement and definition of phase SNR.

For the Nyquist filter data the theoretical AM baseband spectral density is plotted in Figure 3 for Qe = 1. Video SNR can be obtained by a noise power integration of Figure 3. The weighted SNR is obtained by multiplying the spectral density in Figure 2 by the noïse weighting function. For this data and in our tests, the weighting filter given in Report 637-1, Equation 4, "for system M (prior to the introduction of the unified network" was used. This network is in general use for NTSC system measurements. Performing the noise power integration to 4.2 MHz gives

SNR due to phase noise:
SNR unweighted = 54.2 + Qe dB (10)

SNR weighted = 57.7 + Qe dB (11)

In a similar manner, the unweighted and weighted video SNR due to thermal noise is obtained.

SNR due to thermal noise:

$$\text{SNR unweighted} = C/N - 6.9 \text{ dB} \quad (12)$$

$$\text{SNR weighted} = C/N - .5 \text{ dB} \quad (13)$$

From Eqns. (5) and (11) one obtains a fortuitous and very neat identity. By measuring phase noise at 20 kHz offset from the carrier in a 1 kHz bandwidth,

$$\text{SNR weighted} \approx C/Np \text{ dB} \quad (14)$$

where C/N_p is the carrier to noise ratio. This is a simple and possibly very useful measurement for predicting degradation caused by phase noise.

The amount of phase noise relative to that produced by thermal noise in the system can be calculated from Eqn. (11) and (13) and the definitions of Qe and C/N. Given that the phase noise spectrum crosses the thermal noise spectrum (measured in the same resolution bandwidth) at a frequency F, then, for equal contribution of each to the weighted SNR, F is equal to 1.53 MHz. Thus, if the phase noise spectrum crosses the thermal noise spectrum below 1.53 MHz, thermal noise predominates; if it crosses above 1.53 MHz, phase noise predominates.

These equations assume the oscillator spectrum decreases 6dB/octave, and one should observe the spectrum on a narrow and wide span to see if that is the case. Also, the spectrum in the range of 10 to 20 kHz can indicate higher phase modulation in that range than actually is present. Low-frequency high-deviation PM can cause high order Bessel sidebands to extend above 10 kHz and cause phase noise to appear high.

VIDEO DEMODULATOR TYPES & RESPONSE TO PHASE NOISE

The effect of phase noise on NTSC video depends on the type demodulator employed in the TV receiver or TV demodulator. Demodulators may be classified as envelope detectors, such as diode rectifiers, or product demodulators [6][7][8]. Envelope detectors respond to large quadrature modulation and distortion of the amplitude modulated signal can occur. However, the envelope detector is immune to the relative small amount of phase noise considered here. This can clearly be seen when one considers that oscillator phase noise produces low deviation FM which, in this case, may be a deviation of perhaps a few hundred Hertz or even a few kilohertz. Deviation that low would not be detected by a broadband envelope detector except for detection by FM to AM conversion in the Nyquist filter.

Product demodulators or coherent demodulators in principle detect an AM signal by recovering the carrier from the modulated signal and multiplying the RF signal by the recovered carrier (hence the name "product" demodulator.) A mixer (ring diode type or integrated circuit mixer) is effectively a multiplier for this purpose. Product demodulators are realized in different implementations and respond differently to the presence of PM on the desired AM signal. In TV applications, product demodulators are known also as synchronous demodulators and quasi-synchronous demodulators. Furthermore, envelope detectors, as in the Tektronix 1450 TV Demodulator, can be realized as product demodulators. Generally, the synchronous detector recovers the carrier by phase locking a local oscillator to the carrier of the TV signal. The bandwidth of the phase lock loop is low, approximately 50 Hz for the Tektronix 1450 Demodulator and Scientific-Atlanta 6250 Demodulator, and the oscillator may be a crystal oscillator. Certainly, this type of synchronous detector can not handle a large amount of phase noise, particularly 60 Hz power supply noise and low frequency jitter. The advantage of the synchronous demodulator is its good linearity and immunity to quadrature distortion provided incidental phase modulation is low.

Quasi-synchronous demodulators, and envelope detectors realized as quasi-synchronous demodulators, recover a carrier by filtering and limiting the TV IF signal and applying it as the reference (local oscillator) for the IF signal mixer. Since the filtering occurs at IF, the filter bandwidth is relatively wide: 50 kHz for the Tektronix demodulator and about 200-300 kHz or more currently for TV receivers. Within this frequency range, the recovered carrier tracks the signal carrier and the system behaves as an envelope detector. However, in recovering the carrier, if the filter bandwidth is too small and phase noise is high, the detector itself will convert phase noise to AM noise. Theoretically, the output of a product demodulator is proportional to the cosine of the angle between the recovered carrier and the carrier of the input signal. For a small tracking error (small phase error), the cosine of the angle is approximately 1 and negligible error is caused by the detector. If the tracking error is large, the detected signal is modulated by the cosine of the tracking error. Thus, inability of the recovered carrier to track phase noise results in additional PM to AM conversion in the detector itself. This should not be a problem except for very narrow band tracking loops and excessive low frequency phase noise. By integrating the mean square phase noise spectra from frequency f_1 to infinity, the total RMS phase noise is obtained:

$$\delta = \frac{1}{f_1}\sqrt{\frac{2}{Qe}} \qquad \text{Rad RMS}$$

For example, for phase noise that would result in weighted SNR of 46 dB, from Eqn. (12), Qe is -11.7 dB, or a factor of 0.26. The total phase noise in the spectrum above f_1 = 10 kHz is only .016 deg RMS. This small amount of high frequency phase noise should not be detrimental to the quasi-synchronous demodulator.

PERCEPTIBILITY TESTS

Tests have been conducted to investigate the effects of phase noise on TV reception and determine the threshold of perceptibility. In tests reported by Giorgio Allora-Abbondi [9] and Robb Balsdon [10], a Hewlett Packard 8660B Synthesized Signal Generator was frequency modulated by the broadband noise source of a Tektronix 147 Test Signal Generator and the Synthesizer output was substituted for the output convertor LO in a Scientific-Atlanta 6530 TV Modulator. The bandwidth for noise modulation was limited by the synthesizer to about 250-500 kHz. In these and other tests, phase noise was measured by measuring carrier sideband noise level in dBc at 20 kHz offset from the carrier and in a 1 kHz bandwidth. Balsdon reported that phase noise became perceptible at a noise level of about -53 dBc on three TV sets, and at -54 dBc when using a Scientific-Atlanta 6250 TV Demodulator in the envelope detector mode. When operating in the synchronous detector mode, phase noise became perceptible at a much lower level, -67 dBc, due to the narrow bandwidth of the synchronous demodulator (approximately 50 Hz) and its inability to track the low frequency noise.

In a similar test, Allora-Abbondi found the perceptibility threshold to be -52 dBc to -56.5 dBc with -53 dBc to be typical for envelope detectors. With Tektronix and Scientific-Atlanta synchronous demodulators, susceptibility to phase noise was much greater: -57 dBc to less than -64 dBc. Performance in the synchronous mode was best with the fast detector time constant due to better tracking between the reference oscillator and the incoming signal. With no phase noise added, weighted SNR of the system was 54dB.

The tests that follow were conducted at Scientific Atlanta with participation by members of the Group 1 committee. In tests similar to those above and using an HP 8640 Signal Generator as the noise modulated source, the perceptibility threshold was found to be at a phase noise level of -56 dBc. Levels were set for optimum performance; without phase noise weighted SNR measured 66 dB. At the phase noise threshold, weighted phase SNR measured 60 dB.

In another test, an oscillator with 4 MHz modulation bandwidth capability was frequency modulated by the Tektronix 147 noise source and substituted for the Scientific Atlanta 6350 video modulator output converter LO. With this oscillator the background SNR was 64 dB. Phase noise and weighted SNR measured -62 dBc and 60 dB respectively at the perceptibility threshold. Phase noise at 20 kHz offset from the carrier was 6 dB lower than with the HP8640 source due to the narrower modulation bandwidth of the HP8640, approximately 250 kHz, but the resulting SNR's were the same.

Thermal noise was added from a broadband RF source and the perceptibility test repeated for thermal noise only. Weighted SNR measured 58 dB for the same degree of perceptibility. This is within 2 dB of the above SNR's measured for wideband and band limited phase noise. We believe that weighted SNR gives a good quantification of system performance regardless of whether noise is thermal or phase in origin.

Thermal noise was increased to give a weighted SNR of 46 dB. Under this condition, phase noise measured -50 dBc at threshold. Weighted SNR due to phase noise (measured with thermal noise off) measured 50.7 dB.

For the above Scientific-Atlanta tests, test patterns were very closely scrutinized to see any noise effects. Tests were also made with program video obtained from a satellite feed. The HP 8640 Signal Generator was noise modulated and used for these tests. Video SNR from the satellite feed measured approximately 53 dB. For moving program video phase noise became visible generally in highly saturated areas at a phase noise level of -47.6 dBc (at 20 kHz offset from the carrier and in a 1 kHz bandwidth, as before).

Phase noise appears a little different from thermal noise in test patterns and video. Thermal noise appears as fine grain noise; phase noise has more of a streaked, low frequency characteristic which is to be expected from general knowledge of the baseband spectrum. In the Scientific Atlanta tests, plots were made of the baseband video spectra (with the Tektronix 1450 Demodulator operated in manual gain mode to insure that the gain is the same with unmodulated carrier as for normal video). Phase noise was easily distinguished from thermal noise by its shape. Phase noise showed a roll-off with frequency, whereas thermal noise showed a slight rise from dc to approximately 1 MHz and was flat from there to 4 MHz.

REPRESENTATIVE DATA

Figure 4 is data for a fixed-frequency (CH. 5) video modulator. Oscillators in this modulator are crystal oscillators, and, of course, phase noise is very low. The baseband plot is characteristic of a system white noise limited: no phase noise is evident. Spurious responses in the baseband plot are evident, but these are low enough so as not to materially effect the results. Calculated unweighted phase noise is more than 10 dB below measured noise.

Figure 5 is data for an agile modulator. This modulator shows results of oscillator phase noise that is somewhat high. The oscillator spectrum has the classical 6dB/octave roll off up to approximately 2 MHz where it approaches the noise floor of the modulator. Above that frequency, baseband noise is determined by thermal noise; below approximately 2 MHz baseband noise is predominately phase noise in origin.

Figure 6 is data for a set-top converter. The input level was set relatively high - 16dBmV - but not excessive for a single channel in order to achieve maximum dynamic range for the spectrum plots and SNR. Also, the converter output was amplified ahead of the spectrum analyzer for the same reason. Notice that for the 100 kHz RF span, the carrier is several dB below the reference line. The carrier was actually set to the reference line in a wide IF bandwidth (30 kHz), and because of low frequency FM, the carrier appears low when plotted with an IF bandwidth of 1 kHz. At baseband, there is a definite contribution from phase noise below 1 MHz. For no phase noise, there should be a dip in the baseband spectrum below 1 MHz. As shown in the 1 MHz RF span, the oscillator spectrum falls off more rapidly than 6dB/octave, and apparently is below the noise floor of the converter by 500 kHz. This causes a sharper roll-off in the baseband spectrum to 500 kHz as compared with that shown in Figure 3.

CONCLUSIONS

Phase noise is another source of system noise in a CATV system which could result in a discernible amount of noise in the final TV display but should not be noticeable in systems with SNR 45 dB or worse. A general discussion of oscillator phase noise was presented and equations given for the case in which the noise spectrum decreases at a 6dB/octave rate from the carrier. Simple equations enable one to calculate the video SNR from measurements of the phase noise spectrum. Actually, the RF carrier spectrum may vary to a large extent from the assumed 6dB/octave roll off, but an understanding of the principles discussed will help in evaluating and determining the effects of phase noise.

Phase noise in distinguished from thermal noise by its low frequency character. Generally, demodulated phase noise decreases slowly to approximately 1 MHz and follows the roll off in the RF spectrum above that. An examination of the video spectrum will show if the noise caused by phase modulation of the carrier is significant.

Phase noise, if excessive, appears in a TV display generally in low luminance and highly color saturated areas. Phase noise appears different from thermal noise due to its higher low frequency content. Phase noise does not appear as granular as thermal noise and shows some low frequency streaking.

A baseline for phase noise measurement is the sideband level of the unmodulated carrier at 20 kHz offset and in a 1 kHz bandwidth. For an RF carrier with sidebands that generally decrease 6dB/octave, the weighted SNR due to phase noise sidebands is approximately equal to the sideband level thus measured. Also, if the phase noise spectrum intercepts the thermal noise floor (measured in the same IF bandwidth) below approximately 1.5 MHz, thermal noise is likely to predominate. If it intercepts above approximately 1.5 MHz, phase noise is likely to predominate. These are simple tests that should help the operator realize whether phase noise is likely a problem.

Perceptibility tests are reported in which a video carrier is noise modulated with modulation bandwidth approximately 250-500 kHz. In these tests, phase noise became perceptible at a level of about -52 dBc to -56.5 dBc (measured 20 kHz from the carrier in a 1 kHz bandwidth). Video SNR without added phase noise was 54 dB or better. In a similar test with an oscillator with 4 MHz modulation bandwidth, phase noise became perceptible at -62 dBc. With thermal noise increased to make weighted SNR equal to 46 dB, phase noise became perceptible at a sideband level of -50 dBc.

Synchronous detectors respond the same as envelope detectors or quasi-synchronous detectors to low levels of phase noise. Above a threshold narrow band synchronous detectors are much more sensitive to phase modulation and are particularly sensitive to low frequency noise. High frequency phase noise (above 10 kHz) is not expected to be a problem for tracking bandwidths 10 kHz or greater, but low frequency, high deviation noise can cause PM to AM conversion in the detector.

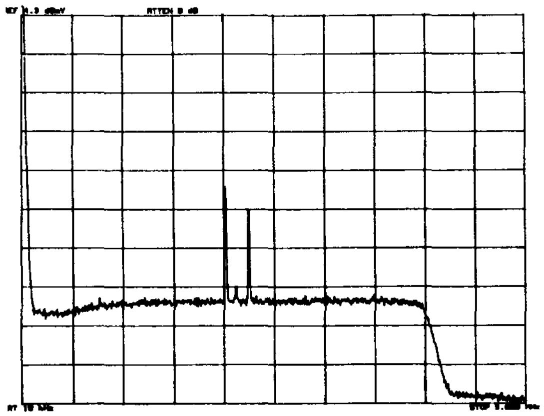

FIGURE 4. Fixed Frequency Modulator Baseband Noise Spectrum.
Start: 10kHz Stop: 5MHz BW: 10kHz
Ref: 4.3 dBmv 5dB/div

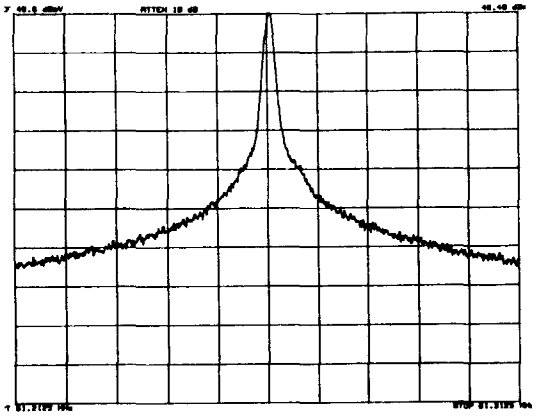

FIGURE 5a. Agile Frequency Modulator RF Noise Spectrum.
Center Freq: 61.25MHz Span:100kHz
BW: 1kHz 10dB/div
Ref: 4.3 dBmv 5dB/div

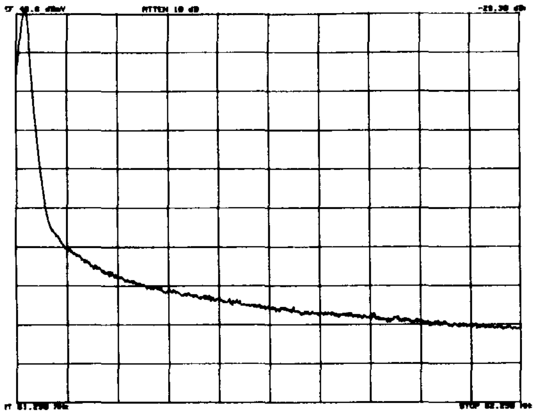

FIGURE 5b.
Span: 100kHz BW: 10kHz 10dB/div

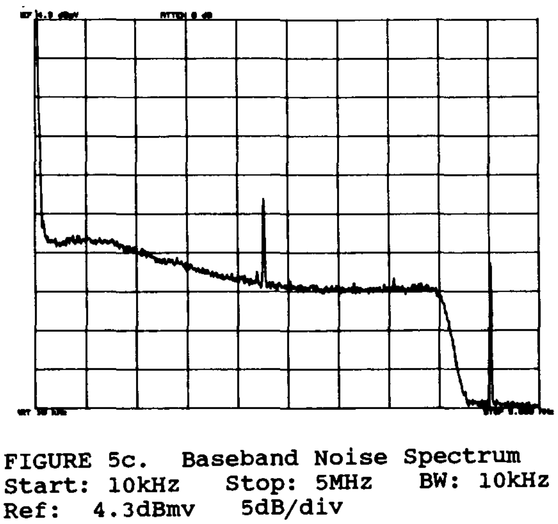

FIGURE 5c. Baseband Noise Spectrum
Start: 10kHz Stop: 5MHz BW: 10kHz
Ref: 4.3dBmv 5dB/div

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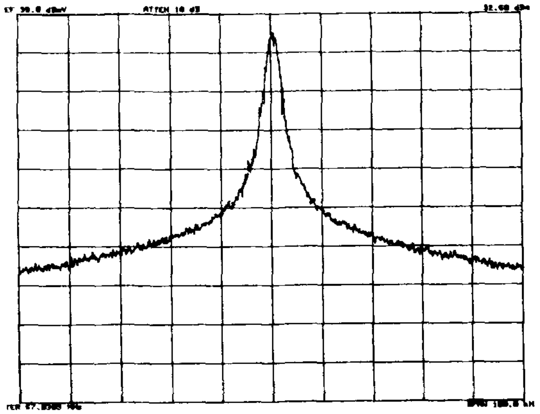

FIGURE 6a. Set-Top Converter.
Center Freq: 67.0MHz Span: 100kHz
BW: 1kHz 10dB/div

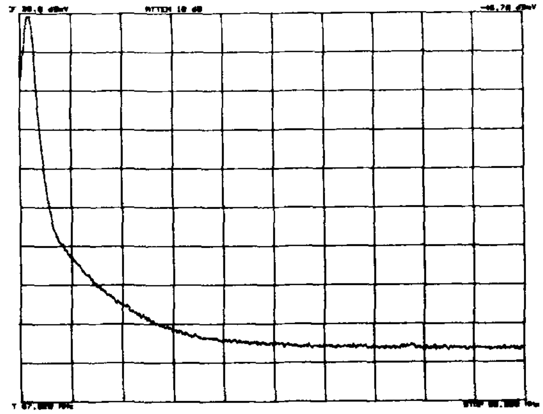

FIGURE 6b. RF Spectrum.
Span: 1MHz BW: 10kHz 10dB/div

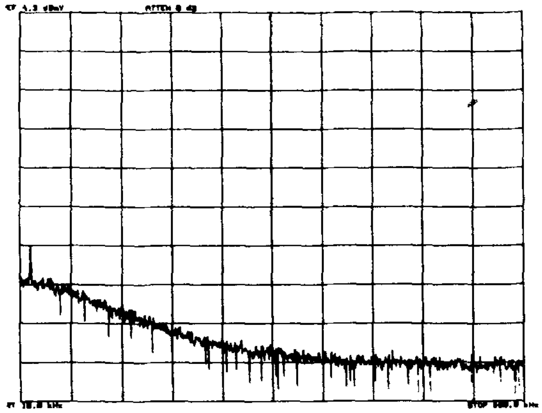

FIGURE 6c. Baseband Noise Spectrum.
Start: 10kHz Stop: 500kHz BW: 10kHz
Ref: 4.3dBmv 5dB/div

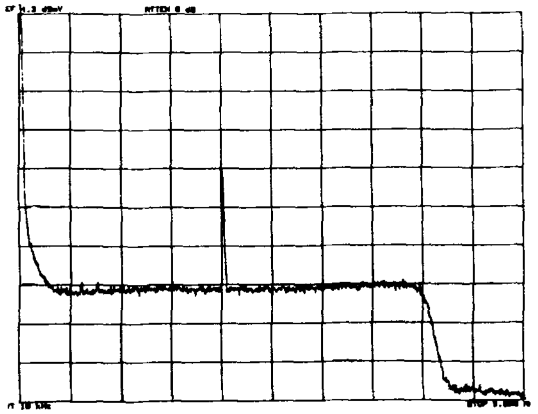

FIGURE 6d. Baseband Noise Spectrum.
Start: 10kHz Stop: 5MHz BW: 10kHz
Ref:4.3dBmv 5dB/div

PREVENTATIVE MAINTENANCE
A NEW LOOK

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ABSTRACT

Current methods of preventative maintenance for CATV systems are based on system sweep response and do not include signal leakage detection as an ongoing part of the program. Many system problems that can go unnoticed by system sweep can be detected by signal leakage activities.

Increasing the amount of sweep work in a system has not been able to reduce service call rates commensurately. Leakage detection and correction work, however, has been found to do so in a field trial. It is proposed that PM programs for CATV systems put more emphasis on signal leakage detection as a method to reduce service calls while improving service and reliability.

INTRODUCTION

Cable television systems have traditionally approached the topic of Preventative Maintenance (PM) with less than enthusiastic commitment. Other things always seem more pressing, and all the best laid plans and intentions seem to slip away in the hectic world of CATV operations.

Changes are underway in the CATV industry now, and competition from VCR's and tape rentals, new "super" tape formats, home TVRO's, DBS, and MMDS are to be reckoned with. The move is to better customer service, quality and satisfaction. To meet the competition, systems need to set goals for customer service that are attainable and measurable, then develop plans that can be used to reach them. PM is a cornerstone for any successful plan to improve quality and service.

A measurable goal for any PM program is a reduction in the number of service calls related to plant performance. Outside of level checks and standby power supply checking, most PM plans in use today are largely based on using system sweep response to monitor plant performance. Many system problems can go undetected by system sweep, and misleading results can be obtained--especially for long cascades.

Work carried out by CUC cable systems could not establish a correlation between increased sweep activity and a reduction in service calls, i.e. more sweep did not mean fewer service calls or increased subscriber satisfaction. It was recognized that if quality improvements were to be realized, new methods and approaches would be needed.

CURRENT PRACTICE

Cable systems are dynamic in nature and require ongoing attention for proper performance. A successful preventative maintenance program should minimize the number of service calls and have an increase in signal quality and system reliability. The best of equipment, cable and components does not guarantee success if ongoing maintenance is not carried out.

Standard preventative maintenance programs generally direct attention to the headend, trunk system, power supplies and amplifiers. Most involve electrical checks as well as an element of physical plant inspection. System sweep--both high and low level--and amplifier level balancing, are the most common forms of electrical preventative maintenance with system test point monitoring being the normal method of assessing a system's performance.

These methods have developed over the years, and with varying degrees of commitment, are undertaken by all systems. Most operators consider system trunk sweep to be the cornerstone of their preventative maintenance program.

THE PROBLEM

The picture on a subscriber's TV is the final measure of the performance of a CATV system. Proper plant design and installation should ensure that adequate S/N and distortion performance can be achieved. Routine maintenance keeps the plant operational, but preventative maintenance is required to limit service calls, increase reliability and improve quality. The reliance on system sweep as the main tool in the PM program to the exclusion of other methods limits the success of the program.

There are three main problems with the heavy use of system sweep for PM:

1. Sweep can overlook many problems that are or would soon visibly affect pictures.

2. Current practices are to sweep only the trunk lines, leaving the distribution lines untouched.

3. Most sweep systems create picture problems by interfering with TV's, VCR's and decoders.

Small cracks in cable sheaths and loose connectors do not usually show in an easily recognizable fashion on a sweep response display. Eventually, these defects become large enough to be seen, but in the meantime, the effects of ingress become apparent in the pictures.

The sporadic nature of mobile radio ingress can cause a large degree of customer dissatisfaction as does the moving video background on local VHF channels. These problems go generally unnoticed with sweep activities and result in service calls.

Typically, a CATV system will have three to four times more distribution plant than trunk. The economic implications of doing sweep work on all the trunk and distribution plant has resulted in the industry generally only sweeping the trunk plant. Usually, it is only the distribution lines feeding the system test points that garner any attention. The distribution plant is unattended except for perhaps a check of levels every few years or when there is a service problem. Hence, the majority of the cable system plant--the distribution network--receives little PM (as do the subscriber drops).

The shear volume of plant makes complete system sweep impractical. The heavy use of high level system sweep will create a large degree of customer dissatisfaction. The recurrent blip that causes some TV and VCR units to lose lock and create broad bands in the picture does not create a favourable impression with subscribers.

Problems with high level sweep and decoders used with premium services are more harmful given the cost of these services being paid by the subscriber.

It is not practical to do all system sweep work in the middle of the night when you consider the amount of 24-hour-a-day programming and the labour costs involved. Increased sweep simply causes more subscriber aggravation without a commensurate reduction in service calls.

LEAKAGE DETECTION AS A PM TOOL

CUC Broadcasting's CATV system at Scarborough, Ontario, has an active preventative maintenance program. Its goals were established to reduce service calls and improve customer satisfaction and service. As per industry norm, the program was primarily based on system sweep along with the usual attention to power supplies, headend and physical plant. Service call ratios were essentially static, and increasing system sweep did not reduce service calls.

In an effort to obtain authorization for the use of channels A-1, A-2, 41 and 42, an accelerated program of signal leakage detection and correction was undertaken to achieve a CLI of 64 dB. Constraints on personnel forced the suspension of the sweep program when the leakage project commenced. As work progressed through the system, it was noticed that service call rates related to plant performance were going down in areas where leakage correction work had just been completed. More surprising were the types of problems uncovered through leakage detection and their significant influence on picture quality. These had not been discovered through normal preventative maintenance and service call requests. Finding these problems was exactly what the existing PM program, based on system sweep, was supposed to do.

Obviously, the leakage program was more successful at reducing service calls. An example of this was a totally severed 412 underground distribution cable which had been "repaired" by the subscriber (who had cut through it) with a piece of aluminum clothesline wire to join the center conductors only. This cable was having an effect on numerous channels, but it had not created any service calls. Apparently, the customers were used to the signal quality, and had developed a negative perception of the signal quality on the cable system. This creates a very negative influence on marketing programs.

Conventional preventative maintenance methods would not have detected this problem. No service calls were initiated, and distribution line sweeping was not feasible, thus, the problem could have gone undetected for a long period of time. The fact that it was readily found through a normal leakage detection program indicates the suitability of enhanced leakage detection activities as a useful, preventative maintenance and fault finding tool.

Since it would be impractical to sweep the total distribution network within a cable system constantly, due to the amount of plant, the use of signal leakage detection as a method of finding plant irregularities is apparent. All the problems uncovered through leakage detection are true system problems that require repairs. They have an effect on the pictures in the system. The efforts undertaken in the detection program are not wasteful of finances because they locate problems. Problems that must be fixed.

Every leak that is fixed prevents at least one and perhaps many service calls at a savings of the cost of these calls. In essence, we find something that needs to be fixed anyway. In the process, we catch problems before the pictures have deteriorated to the point which causes subscriber dissatisfaction.

There is no long-term extra cost with this approach--simply a reallocation of resources from expensive service call activities to appease dissatisfied customers, to preventative maintenance through improving plant performance. It is a net win-win situation with a reduction of service calls and an increase in subscriber satisfaction at the same cost. The ideal preventative maintenance situation.

The spin-off benefits of improved relations with the DOC/FCC over interference to other radio services and the increased channel availability due to A-1, etc., are a bonus.

A METHOD

A method is required to successfully reduce the amount of leakage in a system and then maintain it as part of a new preventative maintenance program. An initial push is needed, and this will require extra staff. A short-term increase in the use of subcontractors to allow experienced and knowledgeable system staff to work on leakage detection has been found to be a successful approach.

The system should be approached in a series of waves with ever-increasing threshold levels of leakage being sensed. It has been found that the first pass should use a leakage threshold of greater than 100 uV/m to isolate the really bad leaks. The second pass then uses a lower threshold limit of about 75 uV/m and the third about 50 uV/m. By breaking the problem down into manageable parts, the possibility of technicians being overpowered by "leaks everywhere" can be reduced.

Experience has shown that it is best to have the personnel detecting leaks do the actual correction at the same time if possible. The equipment used can vary from very elaborate to quite simple. It is the commitment that is most important. A high degree of job satisfaction has been noted in these programs, as the results of the effort are almost always immediate, apparent and positive.

Once the system has achieved a reasonable level of leakage control, the ongoing preventative maintenance plan must carry on the work. Leakage detection and correction work must be given equal footing with system sweep programs if service call rate improvements are to be maintained. It is suggested that systems with a constant sweep program could significantly reduce the sweep resources and invest them in leakage work to obtain superior results.

RESULTS

A concerted effort to work on signal leakage problems in a cable system will reveal a startling number of plant problems that have gone undetected. One has to wonder what it takes for some subscribers to initiate a service call. The effect on the perception of service quality is no doubt significant and of value in the increasingly competitive market for entertainment dollars.

A comparison was made between the service call rates for the Scarborough system for a period before and after the commencement of increased leakage correction work. The Scarborough system has approximately 1,900 Km (1,200 miles) of plant and serves over 150,000 subscribers. The leakage work found over 1,200 faults in the system of which roughly 60 percent were distribution plant related with the remainder split between trunk and drops.

Over a comparable seven month period the average number of service calls per month dropped by almost 16 percent system wide. As the overall system cannot be said to be all at the same level of leakage correction, this number is indicative more of a trend than an absolute. However, in a portion of the system which represents about 25 percent of the total, a more uniform level of leakage performance was measured, and its service call rates for the same period had dropped an impressive 23 percent.

The results of these figures are that the system can operate with at least one service technician less than the year before while offering a higher level of service.

SUMMARY

A major program on signal leakage detection and repair was instituted, and a correlation with service call rates developed. Problems that were having noticeable affects on picture quality which had gone undetected with system sweep were uncovered. As leaks and ingress were eliminated in an area, a reduction in service calls was noted as well as an increase in subscriber satisfaction. The increased investment in personnel time required for leakage detection and correction was offset by a reduction in staff needed for service calls, and the quality of our service was improved.

ACKNOWLEDGEMENTS

The author would like to thank the technical staff of Scarborough Cable TV for their work on this project. In particular, Manny DiLecce and Don Morton for their successful implementation of the CLI program that led to these results. Special thanks to Janice Walter in the production of this paper.

PROPOSED HDTV SYSTEMS AND SOME IMPLICATIONS FOR CABLE

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ABSTRACT

High Definition Television (HDTV) is subject to much debate in the industry. The economic opportunity has prompted a high level of competitive activity. The cable community must appraise the business and technical impact of HDTV amid a blizzard of conflicting information. The brief summary of several systems and discussion of the various techniques presented is intended as some small aid to this effort. Two of the many technical issues raised by HDTV, noise and reflections, are assessed with particular attention to the effects of time compression.

INTRODUCTION

Technological progress has reached a point where significant improvement in television performance is possible. This includes developments in source equipment, digital signal processing and VLSI. Historically, the economic opportunity created by new technology has resulted in the creation of new and, hopefully, more useful and enjoyable products. Television has reached that point. HDTV is coming. Technology is the vehicle but economics is the engine. There are many technical questions to be answered but the factors which are key to determining direction are of strategic business and economic nature.

HDTV can be delivered by a variety of media. The constraints of each are different making a single "best" system design unlikely. Encoding for recorded media is likely to be different just as it is today. For example, available recording bandwidth is increasing while spectral space for terrestrial broadcast is, at present, fixed. In this paper we will consider HDTV from the cable transmission perspective.

STRATEGY FOR INTRODUCING HDTV ON CABLE

The decisions would be simple indeed if picture and sound quality were the only criteria. A standard of performance could be set and each system evaluated against this standard. There are many tradeoffs to be considered between resolution, bandwidth, decoder cost, and transmission system constraints. Since many of these constraints will change with time, the timing of introduction and potential for future development must be considered. Each of the proposed systems have made implicit assumptions about strategy. The cable community should consider the implications of basic choices.

Should every HDTV transmission on cable be available to customers having only NTSC equipment? This is one of the primary strategic questions. Is totally differentiating the HDTV service to command a higher price advantageous or, would the broader initial market represented by adding NTSC customers offer a better economic model? Will NTSC based formats continue well into the future? The answer to these questions will determine some of the technical decisions on compatibility. Compatibility also has potential impact on the quality of the signal which can be delivered. The requirement for quality is considered below.

Should increased transmission bandwidth be considered to achieve higher performance and/or lower decoder cost? This is indeed a complex issue. Future development in optical fiber and reduction in decoder cost will change the model with time. It is quite probable that the level of performance achieved in recorded media will be relatively high. This will serve as a yardstick for the consumer in evaluating alternatives for program sources. It is tempting to say that the quality of the transmitted picture must be equal to that of recorded pictures. The degree to which this is possible within realistic constraints is not clear. Other factors will also be important. Certainly, the introduction of the compact disc has not caused the demise of FM radio, even though compact disc quality is substantially higher. Few cars have TV's, however, and the markets are very different. Quality is important but other factors must accompany quality. Recording time had a large impact on the VTR market. The convenience and durability of compact discs is a part of their market advantage in addition to sound quality.

COMPATIBILITY

We have discussed above the need to define the requirements for compatibility. In comparing the NTSC compatibility of various systems, we will give a value for "Compatible Bandwidth" which is the total transmitted bandwidth required to allow reception directly by NTSC equipment. The quality of the received signal is presumed to have negligible degradation against a purely NTSC signal. This is no small point. The interest in HDTV will very likely increase sensitivity to the quality of all signals. The alternative to increasing bandwidth to transmit a compatible signal would be to require that NTSC customers desiring to receive the HDTV broadcast pay for a transcoder. One aspect of compatibility is independent of the requirement for complete compatibility. This is the issue of field rate and number of scan lines. If there are advantages to be gained by having field rate different from 59.94Hz and a number of scan lines not an integer multiple of 525, then they should be considered along with other tradeoffs. The writer has heard no proposed advantages and none come to mind. Neither are there any apparent disadvantages to invoking these constraints. Transcoding advantages gained by using 59.94Hz and 2X525 interlace or 525 progressive are obvious. Not having to drop frames, for example, eliminates one potential artifact and simplifies transcoding. The fact that transcoding complications occur in going to film or other video formats seems little cause for gratuitous incompatibility with NTSC.

THE SYSTEMS AND THEIR PARAMETERS

There are several proposed systems. We will first present a general description of the various techniques used in encoding, since several are common to more than one system. We will then present a brief overview of several individual systems and a summary of their parameters. The systems included are limited because of time and space.

All of the systems begin with input from standard cameras (or recordings of such) with the exception of those of Dr.'s Glenn & Glen (NYIT) [1,2] and Mr. Iredale (The Del Rey Group) [3,4]. The RGB signals are matrixed into a constant luminance set of luminance and two chrominance signals. The bandwidth of the chrominance channels is reduced to take advantage of the lower resolution of human color vision. In this form, the signals are subsampled to reduce transmission bandwith requirements. The subsampling generally capitalizes on the fact that human visual perception on the diagonal requires less resolution. The systems vary considerably as to the degree of bandwidth reduction (relative to final display resolution) they introduce at this step. The NHK MUSE [5,6], and Del REY systems are the most extreme in this regard. The bandwidth is recovered in the receive decoder by use of line difference information, intra-frame or interframe information processing. The complexity of the decoder increases as the amount of storage increases. The complexity progresses through requirement for line store to frame store to multiple frame store. Quite simply, information required to produce the display resolution is transmitted time sequentially over several frames with an obvious reduction in bandwidth requirement. This works well for static pictures, but moving pictures must either use motion compensation or simply revert to the resolution dictated by the transmitted real time bandwidth. Temporal artifacts can be generated where interframe information is used. (Temporal aliasing artifacts are well known to moviegoers in the form of the backward turning wheels of the stagecoach in westerns). Systems which use intrafield information do not require the complication of motion compensation.

Many of the systems use time compression or expansion of signals before transmission. Where time division multiplexing of the luminance and chrominance is employed, the signals are time compressed so that chrominance and luminance are transmitted time sequentially within one line time. This is the format of the MUSE Time Compression Integration (TCI)signal. Others refer to this as Multiplexed Analog Components (MAC). In any case, the chrominance and luminance are encoded as analog voltage levels time compressed. Time compression raises the transmitted bandwidth required to support a given signal (luminance or chrominance) bandwidth. Since the chrominance bandwidth is lower, it is compressed to a greater extent.

The MUSE signal is shown in Fig. 1. Note that there is no synchronizing pulse extending beyond signal modulation. This offers improvement in signal to noise. Note that two lines are required to send the chroma since there are two such signals.

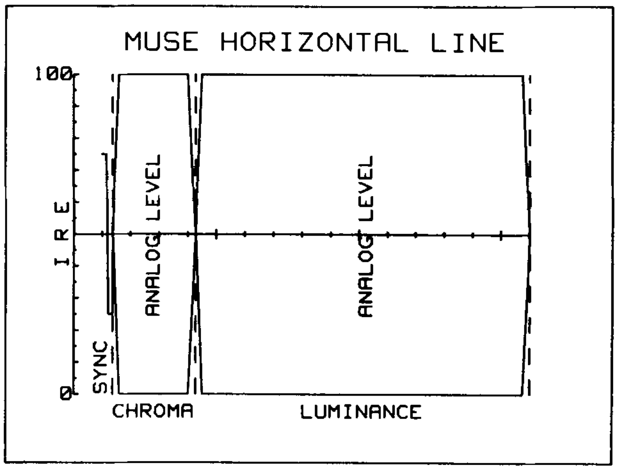

FIGURE 1

Another approach is to take the principles of NTSC encoding to greater lengths. The ACTV [7] system uses an additional quadrature modulated subcarrier and quadrature modulation of the visual carrier to transmit additional information. This allows transmission within one standard channel and provides a signal with NTSC compatibility, albeit with potential artifacts. The use of subcarriers has impact on signal to noise and quadrature modulation of the picture carrier has some implications for phase noise in set top converters.

A remaining difference between systems is the number of separate channels used. The NA Philips [10,11] and Glenn systems propose two separate channels for both terrestrial and cable transmission. Others propose single channels. Some achieve compatibility within the single channel and some do not.

Many systems provide "CD" quality sound. This may well be a key issue in the competition. Often, what may at first seem a side issue will prove vital. Some would hold that wide screen with good sound are really what is needed. Opinions abound, solid market evaluation is imperative.

Table of Parameters

Table 1 presents a summary of some key parameters. Much of the information is derived from Mr. William Schreiber's response to the FCC NOI [12] and Robert Hopkins paper [13]. The resolution numbers are based on scanning standard and bandwidth only. The numbers for resolution are in lines-per-height which, for horizontal,is total horizontal lines divided by aspect ratio. Values for stationary and moving areas are given. Bandwidth is the total transmission bandwidth required, regardless of the number of channels into which it is divided. The "Compatible Bandwidth" is the total transmission bandwidth required to allow an unaided NTSC receiver to display a picture. The number of channels is the number of separate channels transmitted, regardless of bandwidth. Storage is intended to reflect decoder complexity since processing requirements also increase as information is drawn from a wider temporal range.

	MUSE	NAPC	ACTV	NYIT	HDBMAC
	DISPLAY FORMAT				
LINES	1125	525	525	1050	525
FIELD RATE	60	59.94	59.94	59.94	59.94
FRAME RATE	30	59.94	59.94	59.94	59.94
ASPECT RATIO	16:9	16:9	5:3	5:3	16:9
	STATIONARY RESOLUTION				
LUMA-VERT	728	480	480	800	480
LUMA-HORIZ	1007	874	650	1300	420
	MOVING AREA RESOLUTION				
LUMA-VERT	520	480	480	480	480
LUMA-HORIZ	629	494	316	441	420
	BANDWIDTH REQUIREMENTS				
TRANS. BW	10	12	6	9	SEE
COMPATIBLE BW	16	12	6	9	TEXT
CHANNELS	1	2	1	2	
STORAGE	3X FRAME	LINE	FRAME	FRAME	LINE

TABLE 1

The Del Rey system is not shown in the table. The sampling pattern used and methods for recovering data do not permit ready conversion into appropriate scan parameters and resolution. These parameters are addressed in the text on this system.

The MUSE System

The MUSE (Multiple Sub-Nyquist Sampling Encoding) was developed for the single channel direct satellite broadcast of HDTV [5,6]. The signal bandwidth is 8.1MHz. The system is based on 1125 lines 2:1 interlaced at a 60Hz field rate with 16:9 aspect ratio (See Table 1). The input signal would be 1125/60 "Studio Standard" RGB. It provides either 4 channel (15KHz BW) or 2 channel (20KHz BW) digital audio in the vertical interval. The signal format is multiplexed analog components with 1:1.25 time compression of luminance and 1:5 time compression of chrominance (Fig.1).

Chrominance is boosted 3dB to help balance signal to noise compared to luminance. Active line time is 29.25 microseconds. Significant amounts of digital processing is done requiring motion area and vector detection in the encoder. This information is transmitted to the decoder. The synchronizing signal does not extend beyond signal modulation. Clamping level is provided in the vertical interval. For FM transmission, AFC is keyed to this level. Averaging AFC is not considered appropriate for FM modulation of MUSE.

The MUSE format is not well suited to VSB AM modulation. Tests of broadcast in this format were carried out in Washington D.C. in Jan. 1987. Limited tests on cable were performed in Oct,1987 at Alexandria, Va. More data in this regard are needed. A number of public demonstrations of MUSE transmitted via FM have been made. Laser disc MUSE recordings have also been demonstrated. Hardware development on this system is the most advanced of any proposed. It is also the most complex. Development of the required VLSI decoder chips is underway at present. These are very complex, large chips in many cases.

MUSE is not compatible with NTSC. A transccoder is required. Further, it has a different field rate and line count so that transcoding is more complex. Nonetheless, such tsancoders have been demonstrated.

HDB-MAC

This Scientific-Atlanta system has been proposed as an extension of the existing B-MAC [8] system which is in use in several countries for satellite broadcast and private network. HDB-MAC [9] is a 525 progressive system with 10.7 MHz bandwidth, 59.94Hz field rate, and 16:9 aspect ratio (see Table 1). The system has high quality digital stereo sound (as does the existing B-MAC)

The system, as the name implies, is Multiplexed Analog Component and is based on an evolution of B-MAC. Data, chroma, and luminance are time multiplexed within each line. Active line time is 52.5 microseconds with chroma compressed 3:1 and luminance 1.5:1. Sound is carried in the digital data. Clamping level is in the vertical interval and a clamped exciter is recommended for FM transmission. The 525 sequential signal is transmitted as a combination of 525 interlace and line difference. This has the advantage of limiting the transmitted bandwidth without introducing storage cost in the decoder, and without requiring motion compensation. The signal is derived from either a 1050 line interlaced or 525 sequential RGB. The input is sampled and diagonally filtered to make room for line difference signal. Alternate samples are discarded to give the "quincunx" sampling pattern. The next step is to interleave odd and even lines by taking samples alternately from each. This has the effect of transmitting the sum of the odd and even lines at low frequency with the line difference transmitted interleaved at higher frequency.

The HDB-MAC format is a part of a compatible evolution from B-MAC. B-MAC uses 6.3MHz bandwidth and is 525 interlaced. The increase in bandwith to 10.7MHz permits several options, one of which is that described above. A second option is the transmission of 16:9 aspect ratio with horizontal resolution increased to 420 lines-per-height. This system is compatible with present B-MAC decoders which have dual aspect ratio capability with pan and scan. The third option is to transmit a 4:3 aspect ratio signal with horizontal resolution of 560 lines-per-height. A Y/C output from the decoder would make this system compatible with S-VHS recorders and Y/C equiped television sets. Such signals could be carried on cable in two channels, one carrying luminance with increased bandwidth and compatible with current scrambling etc., the other carrying chroma and sound. This would provide an enhanced 4:3 picture free of NTSC artifacts and digital stereo sound.

HDB-MAC has been demonstrated with all features save the line difference to extend vertical resolution, which has been simulated. It is not compatible with NTSC. Decoder complexity is relatively low, having minimal storage requirements.

North American Philips

Philips proposes a system which uses two different formats, one optimized for satellite and another for terrestrial broadcast and cable [10,11]. The satellite format is a Multiplexed Analog Ccomponent format called HD-MAC60. This format, like MUSE, is well suited to satellite transmission. A less complex data reduction method is elected so that motion correction and frame stores are not required. The cable/terrestrial format is two channel, one of which is standard NTSC.

The system is based on 525 line progressive scan with 59.94Hz field rate 16:9 aspect ratio (See Table 1). The input signal would be 525 progressive scan RGB. Active line time is 26 microseconds. As with other systems, chrominance bandwidth is limited. The information is then "repackaged" in the form of several different signals. One is a line differential signal which is a low pass filtered version of the difference between the present line luminance and the average of the adjacent lines (a prediction error). Luminance for every other line (n, n+2, n+4 etc.) is sent alternately uncompressed and 16:9 time expanded. Time expansion lowers the transmission bandwidth required to support a given signal bandwidth,thus increasing resolution. Similarly, chrominance is transmitted for every four source lines alternating between 1:2 and 1:4 time compression. The signal bandwidths and compression are such that each has a common 9.5MHz of transmission bandwidth. In order to have a uniform distribution of temporal and spatial information and to facilitate transcoding, subsequent frames have different content. The total cycle is 4 frames. The information transmitted in the four frame sequence maintains full temporal resolution with a reduction in diagonal detail . This diagonal detail is available at lower temporal rate and can be recovered by added storage provision. Alternately, the higher diagonal detail may be filtered out at the source.

The satellite signal is transcoded to a two channel format for terrestrial use. This format is called HD-NTSC and consists of one standard NTSC channel (Main Signal Package) and an augmentation channel (Augmentation Signal Package). Transcoding is relatively simple and does not introduce artifacts. The NTSC channel contains only standard NTSC information. Adaptive comb filtering would be used to reduce NTSC artifacts. The second channel contains sidepanels to increase aspect ratio from 4:3 to 16:9, information for increased resolution, and digital audio. Several formats for the ASP are being considered. An analog method has been outlined in some detail [10]. The augmentation information includes time expanded line difference VSB modulated onto a subcarrier. High horizontal luminance is time expanded and SSB modulated since it has no DC component. Chroma is handled in similar fashion. Detailed description is beyond the scope of this paper. The modulation format and exact packaging is still being evaluated. The scheme described and those being evaluated fit within a 6MHz channel. Cable would carry this augmentation channel and a standard NTSC channel. A provision is made for selecting the portion of the 16:9 picture to be transmitted in the NTSC channel (commonly called "pan and scan"). The pan and scan control would be established by production requirements and transmitted within HD-MAC60. The transcoder to HD-NTSC will use this information to select the portion of the picture to be placed in the NTSC channel.

The system has been demonstrated with most features. Development is not so advanced as MUSE but the processing is not so complex which may allow more rapid advancement.

ACTV

This system is based on multiple subcarriers with quadrature modulation [7]. The signal is NTSC with one additional subcarrier (quadrature modulated) and quadrature modulation of the picture carrier. It is based on 525 progressive 59.94Hz field rate system with 5:3 aspect ratio (See Table 1). While the 5:3 aspect ratio is preferred and analyzed, it could be 16:9 by modification. A spectrum is shown in Fig. 2.

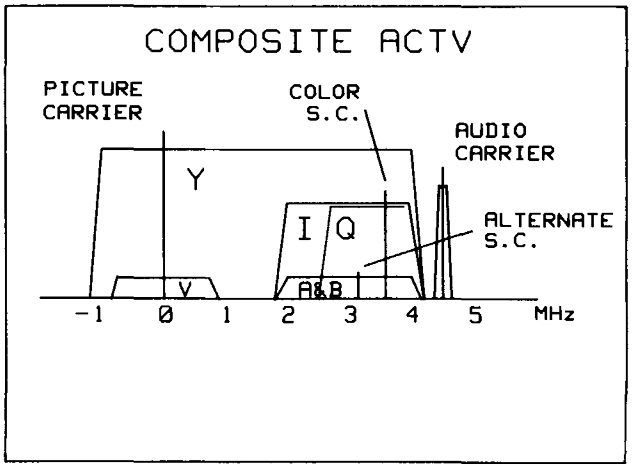

FIGURE 2

The source would be 525 progressive RGB. This is matrixed to YIQ and prefiltered. Active line time is 52 microseconds. The luminance is converted to 4:3 interlace scan by first expanding the center panel of the input signal to 50 microseconds. The remaining sidepanels are separated into low and high frequencies. The low frequency portion is time compressed 6:1 into 1 microsecond at each end of the center panel. The filtering and compression is such that the transmitted bandwidth of this signal is standard NTSC (4.2MHz luminance and .5MHz chrominance). The luminance and chrominance are 3-D filtered to produce little crosstalk between luminance and chrominance. The sidepanel highs are NTSC encoded and time expanded to reduce bandwidth to 1MHz,then quadrature modulated onto a 3.108MHz subcarrier. Horizontal luminance detail related to the main signal (with same expansion/compression) is likewise quadrature modulated onto this alternate subcarrier. A Vertical Temporal helper signal, a temporal prediction error , is quadrature modulated onto the picture carrier. This signal is zero for stationary pictures. The resulting signal package can be transmitted in a standard 6MHz channel.

When received by an NTSC receiver, the compressed sidepanels are decoded in compressed form but are hidden by overscan. The sidepanel highs rely on an interlaced subcarrier and the fact that they should appear as 30Hz complementary color flicker. Such flicker is not normally perceived. It is also important that the level of these added signals be relatively low. This system uses time compression and expansion but transmits components through time parallel modulation techniques instead of time sequential as with MAC signals. Added information is placed "in the cracks" between existing spectral information. Sound would be carried by the NTSC sound carrier.

This system has.been simulated by computer but has not been demonstrated in hardware. Computer simulated television pictures have been demonstrated.

NYIT

Dr's. Glenn and Glenn propose a system which begins with a different source. It is based on 1050 line progressive scan 59.94Hz field rate with 16:9 aspect ratio (See Table 1). There are, in effect, two cameras within one. One scans the image 525 line 2:1 interlace 59.94 Hz with RGB output. The other is a single tube scanned 1050 line progressive 59.94/4Hz and provides high resolution luminance information. Low resolution information is provided by the RGB camera at 59.94 Hz. The high resolution information is provided by the second camera at 1/4 this rate. The high resolution information is digitally processed and the rate further reduced by a factor of two. When received, the high resolution signal is frame stored. The low resolution signal is scan converted to 1050 progressive by line interpolation and added to the frame store information to produce the display. No motion correction is performed. The low frame rate high resolution information will cause elongation of pixels in moving areas. Arguments based on visual perception predict that these effects will not be perceived as degradation.

Transmission is via two channels. One is standard NTSC except for the aspect ratio. A 3MHz augmentation channel contains the low frame rate information. Aspect ratio is dealt with by using a 56 microsecond active line for the NTSC signal, extending from immediately after burst to immediately before sync. The number of active vertical lines is reduced. This eliminates vertical overscan on an NTSC set. Extra width is cropped by horizontal overscan. Sound would be carried on the standard NTSC sound carrier.

Some hardware has been demonstrated.The system uses a totally new camera concept. The decoder is moderately complex.

The Del Rey Group

This system is based on a unique scanning concept which is called tri-scan [3,4]. The camera scans with spot wobble which is different frame to frame to create a three frame sequence (Fig. 3).

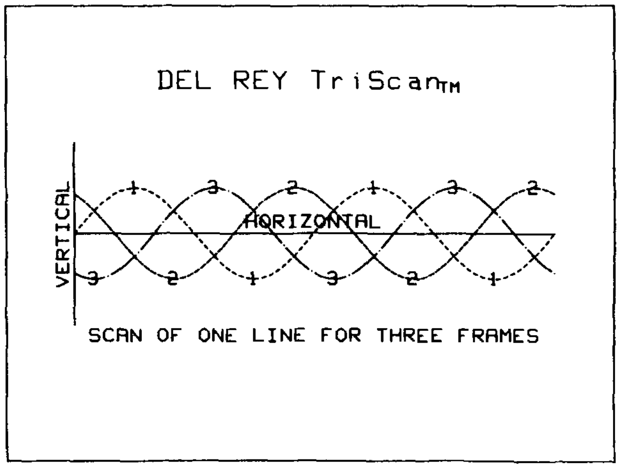

FIGURE 3

The numbered points (scan number) on the scan line correspond to the triplets of pixels making up one NTSC pixel. The resulting scan could be considered as 1050 interlace, 59.94Hz field rate. The spot wobble reduces the horizontal sampling rate and converts vertical frequency into the horizontal. Each frame consists of 440X414 pixels (the system uses 414 active vertical lines). This is based on using the full 4.2MHz bandwidth. There are three frames in a complete sequence, giving 547,000 pixels to be shared between horizontal and vertical. Assuming that the wobble could be viewed as generating 2X414 vertical lines, we have a horizontal resolution of 659 lines. This gives a somewhat simplified view which indicates the system capabilities.

As noted, the spot wobble translates vertical information into horizontal frequency. Consider the case where a vertical black/white transition is spanned by the beam wobble. In the figure, the transition would be at the horizontal line. This generates a large component at the wobble rate. The effect is not unlike the use of a subcarrier and the same care must be used in regard to interference with other components.

Encoding is NTSC. An NTSC receiver would treat all frames the same, displaying lines as transmitted. The "smart" receiver would display with the same wobble as in th original scan. The NTSC receiver would see each of the three scans as information from the same space, even though each scan is slightly offset. Edges would show low temporal rate flicker (10 Hz).

This process basically sends the complete data sequentially over three frames. Rather than use a frame store, a longer phosphor time constant is proposed. The desired result is achieved when static pictures are displayed. Motion causes blurs due to phosphor lag and the blur is in three bands because of the slow refresh rate. Frame storage is proposed as an alternative. A "Dual Resolution Processor" is referred to. Resolution switching would be used rather than motion compensation. A 14:9 aspect ratio is proposed which would be attained by reducing active lines vertically to eliminate vertical overscan and encroach into the display of NTSC sets. The image on the NTSC set would approach the 14:9 ratio while new sets would take full advantage. The possibility of expanding active line time to achieve 16:9 aspect ratio as does Glenn is mentioned. Sound data would be carried in the now unused lines of the vertical scan.

This system is remarkably similar to the MUSE approach in the use of multi-frame sampling. It is quite different in that encoding is NTSC, and a narrower transmitted bandwidth is used.

The elements of this system have not been denonstrated. Some simulation has been performed. The complexity is high. Use of phosphor time constant rather than frame stores has been proposed to reduce complexity. The approach places priority on using one 6 MHz channel for compatible transmission.

The transmission characteristics for this system are the same as NTSC since it is purely NTSC encoded. Noise and reflections would behave in the usual way. All of the enhacement is via frame sequential data.

IMPLICATIONS FOR CABLE

Clearly all systems present some new concerns for cable transmission. The fundamental question of "compatible bandwidth" is key. The ACTV and Del Rey systems place the highest priority on this concern, keeping to one 6MHz channel. Other systems require 9 to 12 MHz in two channels. MUSE places lowest priority on compatibility, requiring two channels totaling 16MHz. MUSE places highest priority on resolution.

Decoder complexity/cost is not easily compared between systems except that MUSE is likely the most expensive and systems requiring only line stores should be near the lower end.

Signal to Noise

It is reasonable to assume that the closer viewing distance permitted by HDTV will require an increased signal to noise ratio in the displayed picture. We can make some effort to relate the carrier to noise to final signal to noise. The perceptibility of noise varies with frequency. This is accounted for by weighting filters which simulate the way we perceive noise. While these functions are specified in Hz, they relate to the perceptual function which is in cycles per height (cph). This is based on the fact that observation is specified at standard ratio of picture height. This relates well to practical viewing conditions. For sake of comparison with well known parameters, I will begin with the well known CCIR weighting function (not the unified).

$$A = \frac{1 + \left[\frac{f}{f3}\right]^2}{\left[1 + \left[\frac{f}{f1}\right]^2\right]\left[1 + \left[\frac{f}{f2}\right]^2\right]} \qquad \text{EQ 1}$$

here A= power ratio
f1= 0.270 MHz
f2= 1.370 MHz
f3= 0.390 MHz

The frequency in Hz is related to the horizontal spatial frequency in cph by:

$$F = \frac{Ta}{AR} \cdot f \cdot \frac{1}{K} \qquad \text{EQ 2}$$

where F= horizontal patial frequency (cph)
Ta= active line time of signal component(sec)
AR= aspect ratio (W/H)
K= compression ratio = Ta/Ts
Ts= occupied time of signal
f= frequency (Hz)

Ta is usually total active line time. However, when the component is a partial line as such as ACTV sidepanels, it is the active line time associated with the partial line.

From the values above and the NTSC parameters one can calculate F1,F2, and F3 to be:

$F1= 10.63$ cph
$F2= 53.95$ cph
$F3= 15.36$ cph

We can now convert to another aspect ratio, line rate or compression ratio. For example, for MUSE luminance:

$Ta= 29.63$ microseconds
$AR= 16/9$
$K= 1.25$

which yields (for MUSE)

$f1= 0.795$ MHz
$f2= 4.050$ MHz
$f3= 1.152$ MHz

These are new values for a weighting filter which would be used for MUSE luminance. This function would be used to integrate baseband noise to determine signal to noise ratio. It should be understood that some modification of the CCIR function for the broader bandwidth may be desirable but the function as is should give reasonable results. This function, with the new frequency values, accounts for the fact that time compression shifts signal frequencies up. In the receiver, time expansion returns these frequencies to their proper value. This expansion also lowers the frequency of noise components, making them more noticeable. We can now determine signal to noise for VSB modulation on cable. If we integrate the CCIR function for NTSC from .01 to 4.2 MHz we get a weighting factor of 6.2 dB for flat noise. Similarly, if we integrate the weighting for MUSE (derived above) from .01 to 8.1 MHz we get a weighting factor of 4.8 dB. Then, for NTSC;

$$\begin{aligned} S/N &= C/N - 6.9\text{db} + \text{WEIGHTING} \\ &= C/N - 6.9\text{dB} + 6.2\text{dB} \\ &= C/N - 0.7\text{dB} \end{aligned}$$

The 6.9 dB derives from the definition of signal to noise and the modulation parameters [14]. For MUSE the signal level will be 3dB higher because there is no negative sync. However, the C/N for a given noise level will be 3dB lower because of doubling bandwidth (from 4.2 to 8.1MHz). Thus, the MUSE signal to noise relative to NTSC for the same noise power density would be:

$$S/N\ (\text{MUSE}) = C/N\ (\text{NTSC}) - 3\text{dB} - 3.9\text{dB} + \text{WEIGHTING (MUSE)}$$
$$S/N\ (\text{MUSE}) = S/N\ (\text{NTSC}) - 6.2\ \text{dB} + 4.8\ \text{dB}$$

$$S/N\ (\text{MUSE}) = S/N\ (\text{NTSC}) - 1.4\ \text{dB}$$

In order to recover the signal to noise, we could increase carrier power. This would seem practical since the broader bandwidth will reduce the number of carriers present on a system. Also, the interference caused by the MUSE modulated carrier may be less due to the greater spreading of energy. By this means, signal to noise might actually be improved several dB. An analysis of the susceptibility of MUSE to interference is also needed. Chroma noise will also need attention.

When interframe information is used, noise effects are reduced because the noise contribution in each sample is uncorrelated and averages over the samples to reduce the net effect. This will occur with certain signals in several systems.

The side panel lows in ACTV are compressed 6:1. This causes almost the entire bandwidth of baseband noise to be lowered into the perceptible range when displayed. An analysis such as above yields a weighting factor of 1.7 dB. This indicates that signal to noise in the sidepanel area would be 4.5dB lower than in the center panel. Information on subcarriers and how they may fare with noise is incomplete. The relatively low levels implied raises some concern.

In the case of the NYIT system, one channel is simply NTSC and will behave as we are accustomed. The second channel is high frequency information time expanded to reduce bandwidth. The 1125 line progressive scan is transmitted at 7.5 FPS. This doubles the line time compared to NTSC. It is time compressed when received, reducing noise visibility. Noise does not appear to be a major concern for this signal.

The Philips case is somewhat different. The sidepanels are transmitted in a separate channel. Matching of noise characteristics is important here. Their transmission characteristics would be the same as the main signal. The high frequency augmentation and line difference signals are time expanded for transmission so that they have a reduction of perceptible noise when compressed after reception. The complex nature of the overall modulation scheme makes complete analysis impractical within this paper. The choices for the second channel encoding are still being evaluated and could involve digital modulation (according to Philips response to the FCC NOI).

Reflections

The subjective effects of reflections have been reported by Pierre Mertz [15]. As is the case with many efforts, his complex analysis is usually reduced to presenting a simplified guideline referred to as the Mertz curve. This curve relates the echo level barely discernible to echo delay. A portion of this curve from 10 to 1000 nanoseconds is shown in Fig. 4. Echoes with coordinates which fall above and to the right of the curve would be visible, while those below would not. Above about 5 microseconds, the level is a constant 40dB.

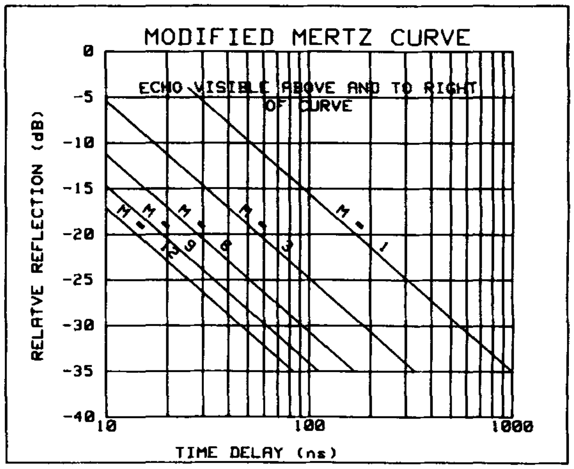

FIGURE 4

The original curve was developed for NTSC with 4:3 aspect ratio. A conversion of this curve is necessary to use the information for other systems.

The echo delay axis really relates to horizontal displacement on the screen. A system using a shorter active line time will cause a given horizontal displacement to relate to a commensurately shorter delay. A wider aspect ratio has a similar effect. Many systems being considered also transmit· information in time compressed form. Echo delay is increased when the received signal is expanded to the proper display time. All of these effects can be accounted for by multiplying the actual delay by a constant and using the standard Mertz curve. Alternatively, the curve can be shifted to the left by this same ratio (as in Fig. 4) and actual delay used. This ratio, M, can be determined by:

$$M = \frac{3}{4} \cdot AR \cdot K \cdot \frac{52.56 \cdot 10^{6}}{Ta} \qquad \text{EQ 3}$$

The parameters of M were defined above.

For example, if we were to halve the halve the active line time and change aspect ratio to 16:9:

$M = 2.7$

Curves for several values of M are given in the figure. Using MUSE luminance parameters:

$Ta = 29.63$ microseconds
$K = 1.125$
$AR = 16/9$

which gives $M = 2.7$

A similar calculation for MUSE chroma gives a value of 11.8. The appearance of echoes in the color signal for a constant luminance signal may not be so clear as echoes in luminance. Another point to be noted is that echoes can cause color signal echoes to appear as luminance information due to the time multiplexing of the components with luminance following color. Both are analog voltages distinguished only by timing.

Cable systems generally have discontinuities located at 50 to 150 ft intervals. For a single pair of reflections, this equates to echo delay of 113 to 339 ns. As MERZ noted, multiple reflections appear as ripples in the amplitude and phase in the frequency domain. The effects of multiple reflections at short delay spacing as encountered in cable are best comprehended in this way. A good way of testing would be response with 2T pulse or bar rising edge. For the broader band signals of HDTV a narrower pulse (along with a broadband modulator and demodulator) would be necessary. For the 8MHz of MUSE, a transmitted pulse with a half amplitude width of 125 ns would be required.

The ACTV system compresses the sidepanels by 6 which gives value of 5.9 for M. However, only very low frequency information is transmitted in this region. As a result, short delay echo will still have little effect.

It is apparent that the reflections in a cable plant can be expected to be of more concern in HDTV. Primarily because short delay reflections which do not have to be suppressed so much presently will become significant. These effects need to be analyzed for each potential system.

CONCLUSIONS

HDTV may be viewed as a threat to cable, an oportunity or simply another format to be dealt with. The threat would be potential bypass by other broadcast or recorded media. The opportunity would be a service of value to the consumer which would command a higher price. The third case assumes that almost everyone will have HDTV sets eventually and cable simply must provide the signal to stay even. Which of these views is proven out will depend at least in part on the degree to which the cable community is active in the decision making process. Regardless of which opinion is held, an informed and prepared position will maximize opportunity or reduce risk.

There will, no doubt, be unforseen technical challenges in carrying HDTV on cable. The systems are different in the priority placed on various tradeoffs. Each presents some different challenge to cable. We have tried to provide some insight into the effects of noise and reflections in some candidate systems. Continuing effort is required to gain a sufficient understanding. A more complete evaluation will become practical as systems are better defined and understood.

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RADIATION MEASUREMENTS - COMPLYING WITH THE FCC

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ABSTRACT

The FCC does not require a manufacturer of CATV equipment to obtain type acceptance or certification, but the equipment, when properly installed, must be capable of meeting the radiation limits imposed on the operator of a cable distribution system under Part 76 of the FCC Rules and Regulations.

This paper will outline some relatively straightforward methods of measurement that can be used to obtain correlation between plant leakage and equipment radiation. Further, major sources of error and their possible magnitude are examined to establish safety margins in order to have confidence that FCC specifications are indeed met.

The application of these methods to determine shielding effectiveness of passives, predict ingress, and help the requirements of CLI are also discussed.

INTRODUCTION

The Code of Federal Regulations, Title 47 ("Telecommunications"), Part 76 ("Cable Television Service", formerly FCC Rules and Regulations, Volume XI, Part 76), Subpart K, stipulates some of the remaining technical operating standards that cable systems have to abide by. Specifically, 76.605(a)(12) gives the maximum permissible RF radiation limit and 76.609(h) outlines the measurement procedures acceptable to the FCC for determining the radiated field strengths from leaks in cable television systems.

The procedures as written are specifically directed to monitoring an aerial cable plant, but since compliance is required from the entire system, upto the subscriber's TV set, they are also applicable to non-strand mounted CATV equipment, including head-end and subscriber premises components. These procedures are especially relevant to the manufacturer of active CATV gear who must ensure that the level of designed-in RF integrity will be preserved when installed in the field and will then be verifiable as measured by the operator according to FCC mandate.

Therefore the manufacturer's test program cannot be limited to laboratory type measurements alone, but must also include realistic simulations of FCC-compatible field tests. The practical implementation of these is the subject of the following discussion.

TEST EQUIPMENT

No specific test equipment is mandated by the FCC, but the rules do advise to use "a field strength meter of adequate accuracy" and "a horizontal dipole antenna".

Field Strength Meter

It should be capable of measuring RF levels down to below -60 dBmV and cover the CATV frequencies upto 450 MHz or higher. The most useful instrument is a spectrum analyzer because it also enables rapid identification of all particularly bothersome or otherwise significant signals. However, most analyzers lack adequate sensitivity and must be used with a low-noise preamplifier. A CATV indoor distribution amplifier or a good line extender is suitable. The actual sensitivity of this combination is dependant on both the noise figure of the preamplifier and the bandwidth setting of the spectrum analyzer. Table I shows the sensitivity that can be expected with various bandwidths and noise figures (it is assumed that the preamplifier has adequate gain, so that the noise contribution of the analyzer is negligible).

Dipole Antenna

An adjustable dipole antenna can be constructed from two telescopic "whip" ways, a) the direct and the ground-reflected signal, on arriving at the receiving dipole, can alternatively cancel or reinforce each other, changing the received magnitude, and b) the proximity of conducting ground can change the impedance and thus the gain of the dipole.

The magnitude of the true direct free space field strength (E_d) is related to the measured field strength (E_m) by :

$$E_m = E_d /(1+B^2+2B\cos A)^{1/2}$$

where : $B = k(d/r)$

$A = ((2\ (d-r))/\lambda)+p$

and :
d = direct distance, source to dipole (m)
r = reflected distance, source to dipole (m)
k = magnitude of ground reflection coefficient (maximum 1.0)
p = phase of reflection coefficient
λ = wavelength (m)

Fig. 9 shows the geometric relationship of d and r.

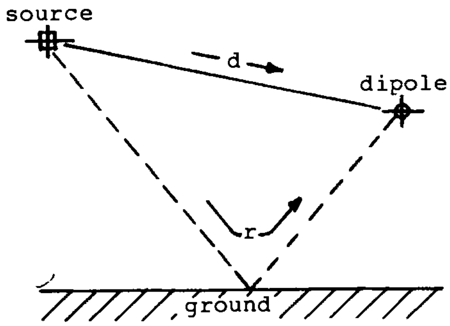

FIGURE 9

Direct and reflected paths

For the reflection angle of the proposed test site (63°) the phase of the reflection coefficient, p, can safely be assumed as 0, but the magnitude k is a function of the dielectric constant, depending on the moisture content and nature of the ground surface. A k=0.6 is an accepted average value for reasonably dry soil (dielectric constant = 15). Fig. 10 plots the expected deviation, in dB, of the measured signal E_m from the direct free space signal E_d, for k=1.0 (solid line) and k=0.6 (dashed line).

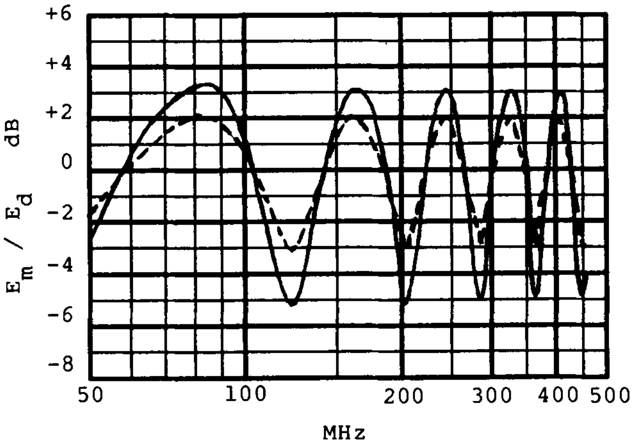

FIGURE 10

Measured vs. true field strength (effect due to ground reflections)

Similarly Fig. 11 shows the maximum deviation, in dB, due to impedance variations (k=1.0).

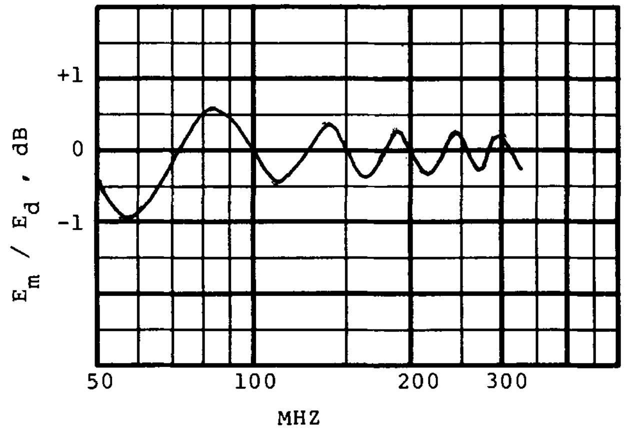

FIGURE 11

Measured vs. true field strength (effect due to dipole impedance change)

Surface roughness

Ironically, unlike laboratory type measurements, where one seeks a perfectly flat and conducting ground plane, in an open field test site the magnitude of reflections will decrease and the accuracy of measurement increase over rougher (within limits) ground. For example, by Rayleigh's roughness criterion, an average ground roughness of 1/2 foot (1 foot peak-to-trough) will result in negligible reflection and thus minimum error above about 275 MHz.

Safety margins

Taking into a cummulative account the maximum excursions depicted in Figs. 10 & 11, and adding possible dipole length and calibration errors, a 10 dB margin of measured signal strength below that of the FCC limits would seem to assure that they are met under all conditions.

SHIELDING EFFECTIVENESS

The same methods as used to measure field strength, can be readily applied in order to determine the shielding effectiveness of passives.

The unit to be measured is mounted as the source on one pole and the dipole on the other in the usual manner. The signal level into the unit should be as high as possible, of the order of + 60 dBmV or higher. Because of the high signal level, proper shielding of all coaxial cables and connectors is especially important. The signal level received by the dipole is read (in dBmV) as before, and, knowing the signal level supplied (also in dBmV) to the input of the unit under test, the shielding effectiveness S (-dB) can obtained from :

$$S = P_r - P_t - 10 \log (103.85/f^2)$$

where : P_r = receiving dipole output (dBmV)
P_t = input to transmitting source (dBmV)
f = frequency (MHz)

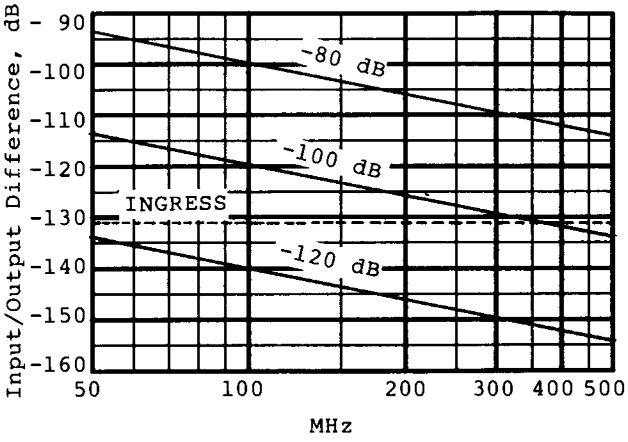

FIGURE 12

Shielding effectiveness &
Ingress threshold

Fig. 12 is a plot of shielding effectiveness as a function of the measured transmitter-input/dipole-output difference in dB. Appendix B traces the derivation of the equation.

INGRESS

Ingress immunity, while not specifically a concern of the FCC, remains a CATV problem. It is proposed (IS-15) that the minimum carrier-to-ingress ratio at a subscriber device be 60 dB in the presence of an ambient field of 1 V/m.

It would be almost impossible to set up such a radiated field in an open air site, not to mention the resultant interference potential over a wide area. However, if we reverse ingress to egress, making the unit under test to radiate (instead of receive) by feeding it a signal level far in excess for which it was designed, we can apply the same reasoning as in measuring shielding effectiveness, and arrive at a representative ingress evaluation.

If the signal fed into and transmitted by the test unit exceeds the signal received by the dipole by more than 131 dB (at any frequency), the ingress criteria are likely to be met (assuming a minimum 0 dBmV operating signal).

A word of caution : rarely, if ever, will signal ingress and egress for a device be exactly the same.

CLI

As far as ground based leakage measurement techniques are concerned, the CLI requirements (76.611) rely on the same procedures that the FCC has outlined (76.609) for general system radiation limits and which form the basis of all the methods discussed here. It is the application of the results of these measurements that require some thought.

The CLI requirements seem to apply over the frequency range of 108 - 137 and 225 - 400 MHz. In the lower of these two bands the present general limits are already more stringent than the CLI threshold level, and therefore a system in compliance would have no contributory leaks. In the higher band, CLI effectively lowers the limit to 50 uV/m @ 3 m (from 15 uV/m @ 100 ft., equivalent to 150 uV/m @ 3 m), and all the way to 20 uV/m for new construction (see Fig. 7).

The maximum number of leaks (each at the CLI threshold of 50 uV/m) that a system could have is 1004. However, a system could also be totally in compliance with the general requirements of 76.605, yet exceed the CLI limit with as few as a total of 112 leaks (each at a level of 15 uV/m @ 100ft., or 150 uV/m @ 3 m, in the frequency range of 225 - 400 MHz.

APPENDIX A.

Converting uV/m into dBmV.

The power density P (W/m) in a field of intensity E (V/m) in free space is :

$$P = \frac{E^2}{120\pi}$$

The effective area (m) of a resonant half-wave dipole is given by :

$$A = \frac{1.64\,\lambda^2}{4}$$

Therefore the power intercepted by this dipole will be :

$$P_r = AP$$

$$= \frac{1.64\,\lambda^2\,E^2}{480\,\pi^2}$$

The equivalent received voltage e, across a dipole impedance Z, is :

$$e = \sqrt{P_r Z}$$

Substituting 300/f (where f is the frequency in MHz) for , and 75 ohms for dipole impedance, we get :

$$e = \frac{48.34\,E}{f}$$

If we express e in dBmV and E in uV/m, then :

$$e = 20\log\left(\frac{.04834\,E}{f}\right)$$

which is the signal in dBmV received by a 75-ohm resonant dipole, and where E is the field strength in uV/m and f is the frequency in MHz.

Conversely :

$$E = 20.69\,f\,\log^{-1}\left(\frac{e}{20}\right)$$

APPENDIX B.

Shielding Effectiveness.

A transmit/receive antenna system has a power transfer of :

$$P_r = \frac{P_t G_r G_t \lambda^2}{(4\pi R)^2}$$

where : P_r = receiving antenna output power (W)
P_t = transmitting antenna input power (W)
G_r = receiving antenna gain (over isotropic)
G_t = transmitting antenna gain (over isotropic)
λ = wavelength (m)
R = path distance between antennas (m)

For a resonant half-wave dipole G_r = 1.64. If the shielded unit to be tested (the transmitting radiator) is regarded as a point source (isotropic) antenna, then G_t = 1.0 . Putting R, the distance at 3 meters and expressing the wavelength as 300/f (where f is the frequency in MHz), we get :

$$P_r = \frac{P_t * 1.64 * 300^2}{144\pi^2 f^2}$$

which gives a transmit-to-receive power ratio of :

$$\frac{P_r}{P_t} = \frac{103.85}{f^2}$$

Converting to decibel terms, we have the relation :

$$P_r = P_t + 10\log\frac{103.85}{f^2}$$

Regarding the shielding effectiveness S (in -dB) as a direct attenuation in the transmit/receive path, we now have :

$$P_r = P_t + 10\log\frac{103.85}{f^2} + S$$

and rearranging :

$$S = P_r - P_t - 10\log\frac{103.85}{f^2}$$

where : P_r = receiving dipole output (dBmV)
P_t = input to transmitting unit (dBmV)
f = frequency (MHz)

Note that S will always be negative (-dB), as shielding effectiveness is commonly expressed.

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REDUCING SERVICE CALLS ON DROPS

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ABSTRACT

This paper discusses the high percentage of drop-related service calls to all service calls. It cites some of the causes of drop-related service calls and suggests possible solutions to those particular problems. Much of the data was obtained from responses to a survey conducted throughout operating divisions at ATC and Paragon.

This paper also describes both the field testing and the laboratory testing of drops which are taking place at ATC. (While the testing is still in the early stages, results are given where available.) It is clear that either the current methods and/or the materials we are utilizing in installations must be revised if we are to reduce service calls and improve customer service.

INTRODUCTION

Most system technical personnel agree that a large proportion of the service calls they receive are due to various problems with subscriber drops and therefore affect a single customer only. Over time the potential exists for an operator to run a service call to each and every subscriber in each and every system. Identifying the reasons for these service calls and finding long term solutions will have a significant and positive financial impact on system operations.

DEFINING THE PROBLEM

We asked our system engineers what percentage of their service calls are related to problems in the drop portion of the plant. Responses ranged from 5% to 90% with the average falling in the 45-50% range. This would imply that resolving drop problems over the long term could reduce the number of service calls by about half.

In an average system* having 50% penetration, 47% of the total plant will be drop wire. It should be no surprise, therefore, that 45-50% of the service calls are drop-related. As penetration numbers improve in the quest for added revenues, more than half of the plant will be drop wire and, at the current service call rate, more than half of the service calls will be drop-related. Any progress which can be made now in reducing truck rolls on drop-related service calls will increase the operating savings as subscriber penetration numbers increase.

Our immediate goal is to study causes and develop solutions for those problems which occur along the drop between the tap and the ground block. We believe that 30-40% of the problems which inspire drop-related service calls occur in this portion of the drop.

CAUSES

Results from a survey of ATC and Paragon operating divisions indicate that approximately one-third (1/3) of the drop-related service calls are caused by problems at the F-connector. These problems typically fall into one of the following four categories:

1) those improperly installed
2) those which have corroded
3) those which have loosened over time
4) those which have manufacturing defects.

We know also that service calls are generated when drops are taken down by storms or other accidental means, or when buried drops are cut, and that drop replacements due to such damage account for 4% of service calls. Another 2% of drop cables are replaced when the service technician is able to confirm that the problem is indeed in the drop but cannot determine that a specific component is causing the problem.

The causes of the remaining 64% of the drop-related service calls have not specifically been identified. It is probably fair to say that they are due to problems within the home stemming from faulty electronic equipment (the subscriber's or the operator's) or the subscriber's inability to properly use the equipment. While this paper does not cover these particular problems, preliminary results from our field test indicate that most of the service calls which have been run in the test area resulted from consumer education issues.

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* An average system is defined for this paper as having 100 homes per mile, an average drop length of 125 feet and a trunk to feeder ratio of 1:3.

TESTING

In order to adequately determine what are the real causes of service problems within the subscriber drop it is necessary to study the methods and tools employed in doing an installation as well as to test the drop materials which are currently available on the market. The test parameters being used for both the field and the laboratory testing of methods and materials were established by ATC's Engineering and Technology Department.

Procedures - Field Testing

The first field test is taking place on a northern coastal island where the environmental conditions are severe and where the test area is well-defined and isolated. Additional test areas in other systems will be identified which will also be relatively small and self-contained for control purposes.

The current test area contains approximately 500 passings and 180 subscribers. (The penetration will increase as we move into the summer months.) The island can be accessed only by boat and has been assigned to one service technician. It was selected because of the harsh environment as well as the ability to control the quality of the installations and follow up on service calls. Having only one system technician directly involved with running service calls also provides a more controlled environment.

All drop wires installed were messengered RG-6 cables with 67% braid coverage. In this particular case, only the cable from one manufacturer was used, but we installed both a regular drop cable and a waterproof drop cable, marking system design maps for later reference and identification.

Two connectors, from different vendors, were used. One was a standard type F-connector and the other was a waterproof type F-connector. Again, system maps were marked to identify locations for each material for later reference and identification.

Drops were installed by a drop contractor in accordance with the manufacturers' specifications, using otherwise standard installation practices. All samples were installed using "boots and grease" on the tap end. Control samples were sealed with RTV sealant on the ground block end with the remaining samples having "boots and grease" at the ground block end. No additional protection was provided for the waterproof connectors. The drops within the test area were post-inspected by system and corporate engineering personnel to verify that proper installation procedures were used.

Each possible scenario was given a code which was to be used on the system design maps to track the various installations. Trouble calls were to be recorded, drop-related or not.

Additional information was to be kept for the drop-related trouble calls, such as:

1) location of the failure
2) symptom as seen by the customer
3) symptom reported by the service technician
4) code type of the drop in question
5) corrective action taken
6) any failed components were to be replaced with the same equipment and procedures as the original install

In addition to the controlled test described above, several systems are experimenting with materials which are newly on the market or which have been used sparingly in the past by ATC or Paragon systems. The system engineers are reporting results as they have them or when they are queried, providing other test beds, albeit without the same controlled environment.

Results - Field Testing

Upon inspection of the initial installations, which took place in September and October of 1987, several were found to have been crimped with pliers instead of the proper hexagonal crimping tool. About 20 connectors have been replaced because of this problem. Not all of the incorrectly installed connectors were replaced before causing a service call, however. Two of these caused problems with off-air pick-up and were corrected by replacing the F-connectors using the proper tool.

To date, there have been no problems resulting in service calls due to the cable itself and no drops have been damaged. Peeling the messenger back on one of the cables, as one does at the tap and at the P-hook, also peeled the cable's poly jacket back exposing the braid. (This happened only on occasion.) All other drop-related service calls (about six) were due to consumer education issues.

Below are some comments received from systems which have experimented with waterproof, extended life drop cable. Comments are:

. fittings were easily installed
. water and salt migration seemed to be slowed when left to the beach environment
. foam dielectric adhered to the center conductor and had to be scraped off
. the messenger sometimes pulled out of the poly covering while stripping it back, exposing bare steel
. stripping the messenger back sometimes left ragged edges on the drop cable
. no noticeable difference compared to non-waterproofed drop cable over a period of a few months
. the key seems to be waterproofing of fittings

Procedures - Laboratory

The laboratory testing will determine how well various drop cables, connectors and protection methods perform. Samples will be placed in a salt spray chamber for a period of 15 days in a spray solution containing salt water and acetic acid (copper-accelerated acetic acid-salt spray testing). The acid is used to speed the aging process, such that one day's exposure in the chamber is equivalent to one year of exposure in a harsh, coastal environment. The samples will be examined for environmental effects at 3, 7, 11 and 15 days, which will represent 3, 7, 11 and 15 years respectively.

The test will contain six (6) connectors from five (5) vendors and six (6) cables from three (3) vendors. All cables will be RG-6 size with 67% braid. All six connectors will be installed on all six cables, (requiring thirty-six (36) samples) in accordance with the manufacturers' installation procedures. Each individual sample will be tagged for identification.

Thirty -six cable samples approximately 24" in length, are attached to a bracket. One end of the cable has an installed F-connector, the other end is capped. The brackets allow the samples to be suspended in the chamber and to be easily removed for inspection purposes. There are a total of five brackets, one for each of the four time periods, and a control sample, bringing the grand total of cable samples to one hundred eighty (180).

Each cable sample will have a knife cut around the perimeter of the cable, cutting the outer jacket, but not cutting the inner braid. All connectors will have "boots and grease" applied except those which are built to be moisture resistant.

After the first three days, the first set of samples will have the outer sheath removed in quarter inch increments on either side of the original cut in order to note the migration of water and/or salt along the cable. The open end will also be cut back in quarter inch increments to determine the depth of water migration.

The boots will be removed to note the effects of the salt spray environment on the connectors. One connector will be removed also, noting the amount of torque required for removal.

Contact resistance will be measured at two locations on the samples. First, from the connector (the back of the ferrule) to the F-81 at the bracket and second from the knife cut (16"-18" along the sample) also to the back of the ferrule on the connector.

The same procedure will be repeated for each of the four (4) periods.

In addition, a pull-out or tensile strength test will be done to determine the minimum strength required to pull the connector away from the cable. Pull-out is defined as slippage of at least one-eighth inch.

Results - Laboratory Testing

To date, there has been some collection of raw data, but the tests are incomplete and therefore the data have not yet been analyzed. The results of the initial pull-out test and the measurement of water migration from the first week in the chamber are available and are shared below.

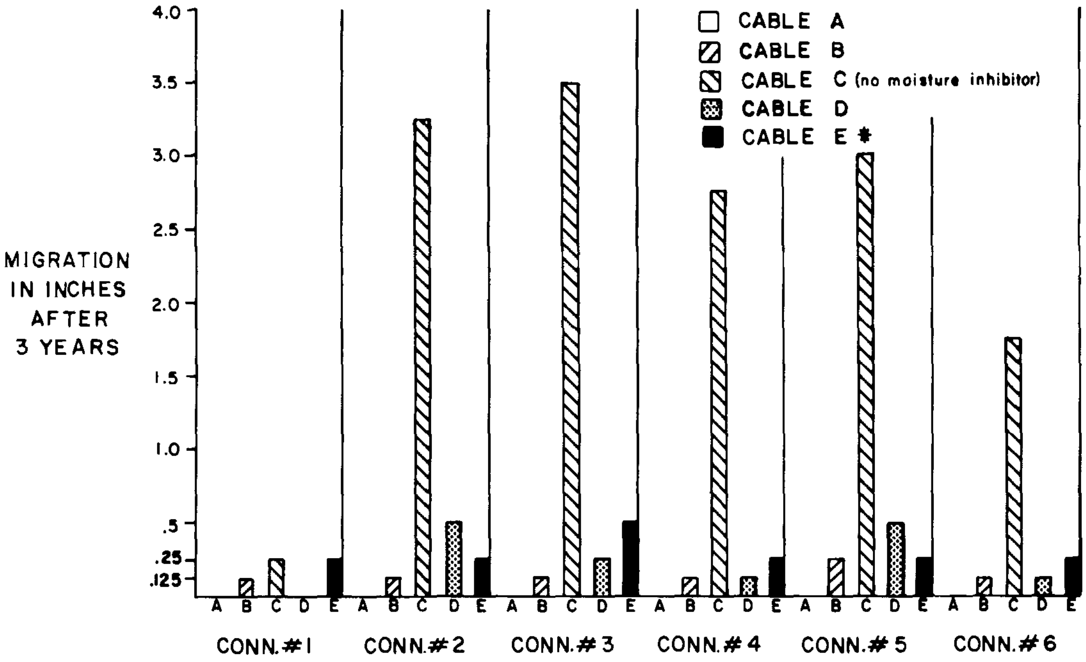
The pull-out testing was done on all 180 samples prior to putting them in the chamber. Of the 180 connectors, there were eighteen (18) which pulled out at tensile strengths below the minimum at which the manufacturers said they should. Of the eighteen (18) failures, twelve (12) could be attributed directly to the connectors and the remaining six (6) to the cables.

There has been insufficient analysis as to why the connectors did not grip well at all times in this test (a 3.3% failure rate of the all brands and types of connectors). No one connector was at fault significantly more than others, although all of the connectors seemed to fail more often on one manufacturer's cables.

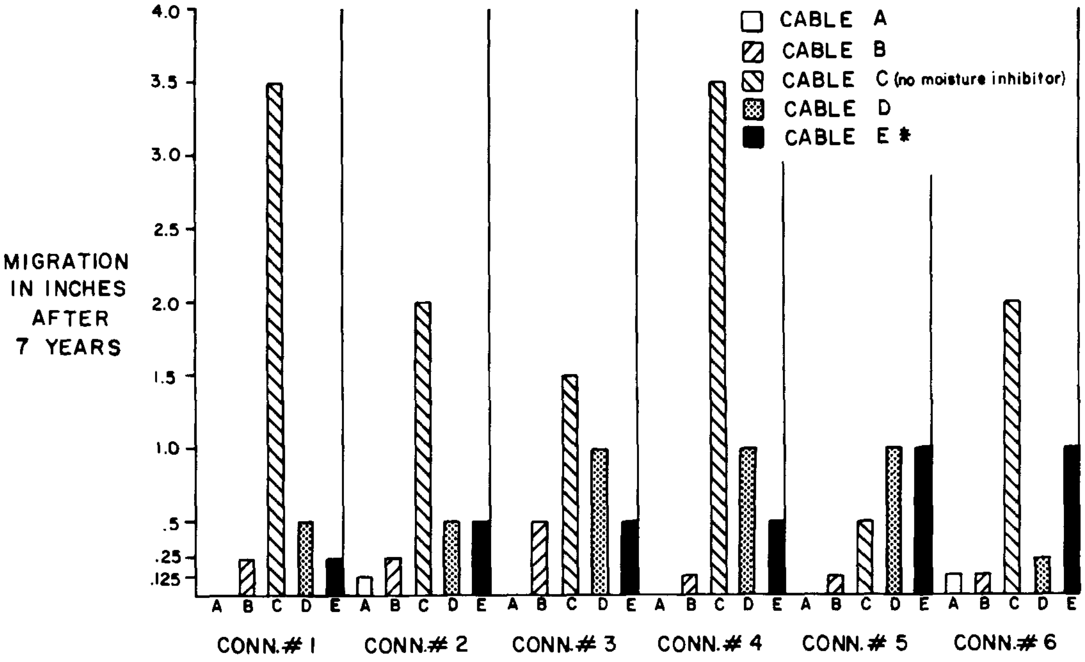
It appears that the cables (all manufacturers) caused the connectors to pull out because they are irregular (i.e. braiding material is sometimes bunched and the poly jacket does not have a constant thickness).

One week in the chamber has been completed as of this writing, an equivalent of seven years due to the age acceleration process. The results of testing contact resistance, removal torque and connector pull-out will not be reported until the completion of a full 15 days in the chamber, as they are not deemed relevant at this point. Water migration was measured at the end of both the 3 and the 7 year periods and is shown below on bar charts.

The graphs show that cable C, which is the only cable without a moisture inhibiting compound, consistently shows the greatest amount of water migration, while cable A has the least amount (usually none at all). Cables D and E allowed significantly more water migration over a seven year period than over the three year period.



* The 6th cable was added on day 7



* The 6th cable was added on day 7

CONCLUSIONS

While testing is far from being completed and therefore there has been no analysis, preliminary results would indicate that the use of drop cables with moisture inhibiting compounds may be of some benefit in reducing water migration. Since water in the cable affects the signal quality, it could perhaps be inferred that the use of drop cables with a moisture inhibiting compound will also reduce service calls.

Insuring that all installers use the proper methods of installing connectors along with the use of the correct tools should also help, although we found that some connectors will pull out even if they are installed with great care in a laboratory setting.*

It is apparent that some loose connector problems are caused by irregular cable diameters, and not because the connectors or installation methods are faulty, although a 3.3% failure rate on connectors with respect to holding or gripping capacity perhaps needs to be improved upon.

SUMMARY

Nearly thirty-six per-cent of drop-related service calls could be eliminated by accomplishing the following:

1) manufacturing cables such that all dimensions are accurately retained throughout the cable length
2) making F-connectors such that they
    a) resist corrosion
    b) prevent moisture from entering the cable
    c) are more easily installed with a minimum of installer training
    d) retain shielding integrity
3) burying drops 6-8" below grade
4) having all installers and service technicians carry the proper connectors for all types of drop cable within the system, and trained to recognize them and use them properly
5) using drop cables which have effective moisture inhibiting compounds
6) developing a special tool for peeling back the messenger so that the remaining cable surface is smooth and will not channel water into the connector.

The remaining sixty-four per-cent of the drop-related service calls are due to problems within the subscribers' homes. Many of these calls could be resolved with better consumer education programs, and could be effected by CSR's rather than rolling a truck. The telephone companies solved this problem by making telephone wiring universal and by allowing homeowners to own the internal system components, thereby being able to charge a customer for a service call which requires in-home repairs or adjustments. While our product is not yet universal in scope, if we as an industry could include installation procedures and workmanship and material specifications in the Uniform Building Code all new housing starts could be prewired. A by-product of this effort would be hardware which could be installed easily by the homeowner (perhaps similar to the wall-plate approach used by the telcos), plus all products sold at local outlets would have to meet the industry's standards of quality. The cable operator could then recover the cost of service calls caused by problems within the home.

In the absence of conclusive evidence, the best approach we can take today is to thoroughly train our employees and contractors in the proper use and application of the connectors and cables currently being used. Proper use of the correct wrench or crimping tool is key. This training in itself is not sufficient to insure quality workmanship. A second effort in the form of an effective quality assurance follow-up program for in-house and contractor installers is also necessary. Both of these must be an on-going effort, but training and motivating employees is key. When we do have test results which clearly direct us to use specific materials and equipment, we can then firmly move in what we will know is the right direction.

I'd like to acknowledge Jim Haag and Raleigh Stelle from ATC's Engineering and Technology Department for their valuable input into this paper.

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* In no cases in the course of this study was there a situation whereby the installer had to choose a connector to fit an older or different size drop cable. In the real world, this can be an issue, and installers must be able to recognize the different cables and the connectors that fit them, and they must have an adequate supply of all necessary components in their vehicles.

SERVICE CALLS ARE NOT SCHEDULED IF CUSTOMERS DON'T CALL. EASY WAYS TO KEEP CUSTOMERS FROM CALLING.

Fritz Baker

Viacom Cablevision

ABSTRACT

Simple procedures, used with preexisting software in our billing computer, allowed us to reduce our service call rate two thirds while adding 25,000 customers to our system. We use our billing computer in real time to analyze customer service requests, identifying specific problems by geographic location within the cable system. Problems are identified, located, and dispatched to the technicians before most customers know a problem exists. Eliminating the reasons customers call for service eliminates reasons for them to downgrade or disconnect.

THE BILLING COMPUTER

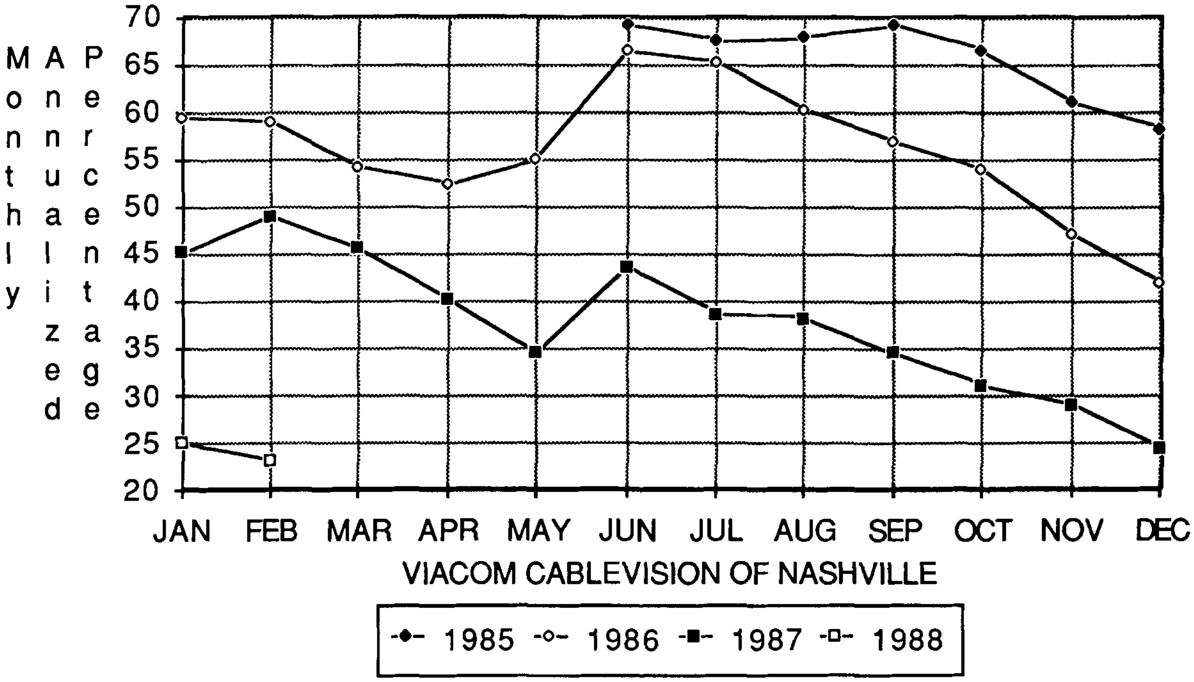
Most billing computers have many useful programs that can help us reduce service calls. They usually can identify: why customers call, what we did when we got to the home, which employees were involved, and which areas of plant have a higher percentage of service calls than other areas. Some billing computers will itemize and compare types of problems found between different parts of the system.

The Data Base

The first step in using the billing computer information to reduce service calls, is to understand how your system was originally set

ANNUALIZED SERVICE CALLS

JUNE 1985 - FEBRUARY 1988



up. If you have been on-line several years, the system was probably divided into segments to accommodate the salesman. One of the most frequent divisions was the "management area". Sales routes were created to track the salesman. Systems were also divided to accommodate franchises, tax codes, zip codes, mail routs, or cities; the list is endless. Often several divisions were used. The smallest division is the most helpful for tracking service calls. We would like to associate these small divisions with either trunk runs or headend hubs.

In Viacom's Nashville system, we use CableData as our billing computer. The system was not originally setup with service calls in mind. It is still not, but we put to use the divisions in the customer base, originally set up for salesmen, to identify areas of plant which record higher than normal service calls. Our system, with 2,000 miles of plant, is divided into about 100 management areas. Seven head ends are represented within these management areas.

Displaying Service Calls in Real Time

Nashville's annualized service call rate is currently 24% with a customer base of 88,0000. We schedule service calls six days per week and complete about 69 calls per day. For the most part, we do next day service calls, but we will vigorously investigate and fix any system problem the same day. To help us do this, CableData provides an on-line visual display of pending service calls sorted by management area.

If a customer's problem cannot be solved over the phone, we schedule a service call. This trouble call order is displayed, on a service representative's CRT, with other trouble call orders taken that day and from from any previous date. Space limitations are inherent in a visual display, so numeric problem codes are used to represent a description of the problem. We chose to have the numbers 1-9, represent customer complaints that have a high potential of being possible system problems, ie., Snowy Picture, Lines, Problem Converter, Ghosting, etc. Problem codes 10 and above, have a low correlation with system problems, ie., Dog Chewed Cable or Bad Remote. The display is sorted by management area, with a second sort by these problem codes.

Because fewer service calls are scheduled each day (69) than there are management areas (100), no more than one call should be scheduled per area. If there are two or more calls in one area, I am interested; very interested if they have problem codes lower than 10. When this occurs, I become pro-active, placing outbound calls to other customers on the same street. I want to see if they have a similar problem. If they do, the search for additional homes experiencing the problem is expanded to amplifiers closer to the headend. When a location is found where the problem no longer exists, a technician is dispatched. We make sure no service calls are scheduled in the effected management areas until we are sure the problem is fixed. Figure 1.

The same procedure works in reverse. When a technician reports he has fixed a trunk or distribution problem, possibly effecting other customers, we use the on-line display to search this management area, looking for customers with similar problem codes. We call any previously scheduled customers to confirm that their problem has been corrected and will cancel those service calls. We reduced our "No Problem on Arrival" calls 80% doing this.

The Service Call Log

We log the number of service call orders taken each hour, to track each group of management areas representing our headends. The log allows us to see orders taken on an hourly, as well as a daily basis. On occasion, calls during one particular hour rise higher than the norm. This prompts us to do a visual check of the number of calls within each of the management areas. Again we are looking for more than one call scheduled with low numbered problem codes. The log is responsible for brining possible system problems to our attention. We have a chance to fix them before a great many customers call and get scheduled for a service call.

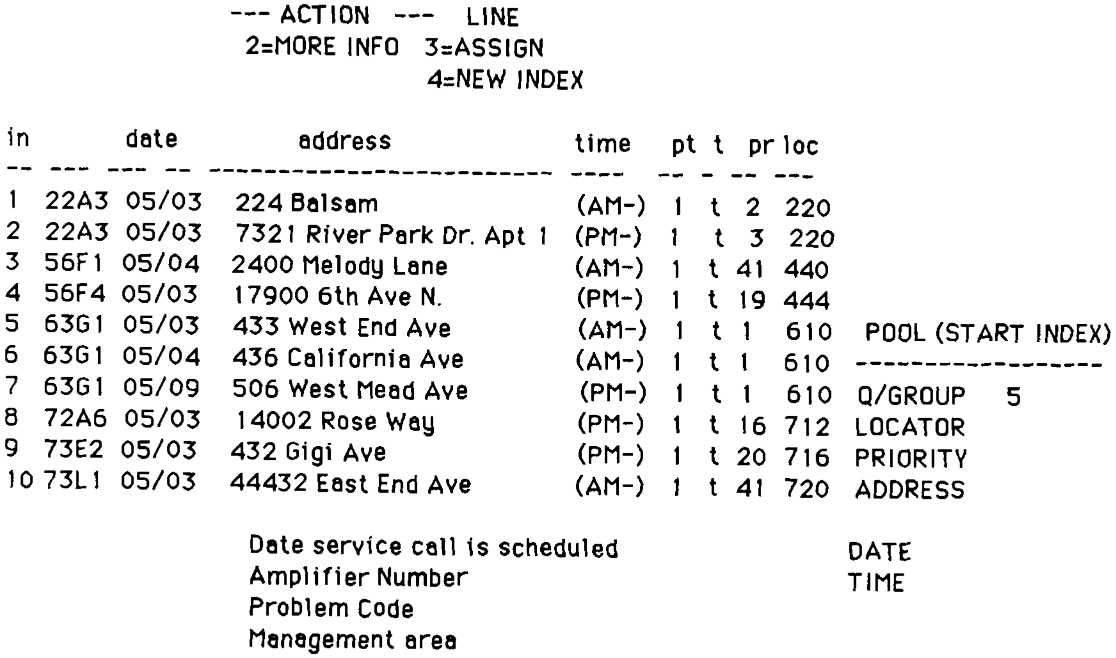
ANNUALIZING SERVICE CALLS

After a service call is completed, a record of that call is maintained within the billing computer. At the end of the month, service calls are totaled, then sorted by headend area and type of call. The number of customers in each area is provided, so its annualized service call rate can be computed. The annualized rate for any fix code such as converters, customer education, system problems, etc., can be done and a comparison between the areas is possible. Figure 2

This comparison, has led us to find ways to reduce service calls previously attributed to bad converters. When areas with a high number of converter swaps were compared to areas with low swaps, we asked why? We did not specifically target bad converters for one area, therefore, we must be exchanging converters due to some other reason. Excessive swaps were traced to other problems such as system alignment, VHF ingress, or the lack of customer education. Fixing these problems lowered the annualized converter service call rate. It would have been difficult to have found and corrected these problems without doing a comparison of problems between management areas.

System Maintenance

Comparing the annualized fix codes related to system problems gave us direction on where to sweep and do signal leakage. When preventive maintenance was completed in these areas, we could see its immediate effect. We also saw the disruptive effects of some types of system maintenance. Service calls in a management area would rise when the system was allowed to go off too many times when changing pads, equalizers, or cutting in new plant. It became obviously cheaper to do system maintenance in the early a.m. hours, than to do the service calls generated by these actions.



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                   --- ACTION  ---   LINE
                    2=MORE INFO  3=ASSIGN
                                 4=NEW INDEX

in        date           address                  time    pt  t  pr loc
-- --- --- -- ------------------------- ----   -- - -- ---
1   22A3  05/03   224 Balsam                   (AM-)  1   t   2   220
2   22A3  05/03   7321 River Park Dr. Apt 1   (PM-)  1   t   3   220
3   56F1  05/04   2400 Melody Lane             (AM-)  1   t  41  440
4   56F4  05/03   17900 6th Ave N.             (PM-)  1   t  19  444
5   63G1  05/03   433 West End Ave             (AM-)  1   t   1   610   POOL (START INDEX)
6   63G1  05/04   436 California Ave           (AM-)  1   t   1   610  -----------------
7   63G1  05/09   506 West Mead Ave            (PM-)  1   t   1   610  Q/GROUP    5
8   72A6  05/03   14002 Rose Way               (PM-)  1   t  16  712  LOCATOR
9   73E2  05/03   432 Gigi Ave                 (PM-)  1   t  20  716  PRIORITY
10 73L1  05/03   44432 East End Ave           (AM-)  1   t  41  720  ADDRESS

                    Date service call is scheduled              DATE
                    Amplifier Number                            TIME
                    Problem Code
                    Management area
```

Pool Calls as seen in CableData

Figure 1

FIX CODE SUB TOTALS ANNUALIZED BY HEADENDS

Run date: Feb. 1, TO Mar. 1

AREA	100	200	300	400	500	600
Converter Total	8.4%	9.8%	7.1%	7.9%	6.3%	7.1%
Drop Total	7.5	5.9	4.0	5.5	7.7	4.4
Customer Ed. Total	2.0	3.2	2.4	2.9	2.4	2.1
Customer Equip. Total	3.5	3.1	2.5	2.5	2.6	2.6
Distribution Total	0.9	0.8	0.7	2.4	1.8	1.7
No Work Done Total	4.0	3.1	2.0	3.6	1.6	2.4
Total Annualized Service Call % by Area	26.3%	25.9%	18.7%	24.8%	22.4%	20.3%

Figure 2

Rebuild Analysis

Tracking service calls by area can help your rebuild analysis. Most of our management areas experience a service call rate of 20-25%. However, one area recorded an annualized rate of 60%. In this area, we found we spent $40,000 in additional truck roll costs above the average. Sorting the several months' of fix codes from the effected area identified the problem. A $25,000 rebuild was the solution; costs were lower by the end of the year and savings in future years will be even greater.

Amplifier Numbers

If you were to go on-line with a billing computer today, I would recommend the divisions within your system equate to customers fed from a trunk amplifier. Using amplifier numbers, rather than loosely fitting sales routes, is an ideal way of identifying system problems. It should be possible to accommodate the needs of marketing and still assign customers to amplifier numbers by planning ahead. I would not recommend associating customers with line extenders. The interpretation of the on-line display is made more difficult when trying to recognize some types of trunk problems. Calls from two different line extender locations can be confusing in this situation.

We are now entering trunk amplifier numbers into CableData. To do this, CableData prints a list of all homes in one management area. An employee spends a half day identifying the address range from streets served off each trunk amplifier. The amplifier number and address ranges are entered into CableData. CableData does what is called a mass correction and fills in the missing addresses for each house assigned to the trunk amplifier. We can do one sixth of the system every four weeks.

CONTROLLABLE CALLS

A key aspect to reducing service calls is monitoring the types of calls scheduled by the service representatives and completed by installers and technicians. We give these employees constructive feedback on the calls they complete.

The Service Representative

CableData provides us with a weekly report that totals the calls scheduled by the service representative and completed by technicians. When completing a service call, the technician will choose from any of 95 fix codes they feel solved the problem. The codes are entered into CableData at the completion of a service call. Twenty of the codes represent problems that could have been solved or "controlled" by the representative over the phone. Some of the 20 codes tracked are: Fine Tuning, Bad Tv, Not Home, Converter Education, No Problem on Arrival, etc.

The report compares the service representatives to each other with respect to these 20 categories. We easily see who is the "best" or "worst" in any of the categories. Representatives high in a category can be given additional training. No longer does the entire group receive retraining for categories such as "Fine Tuning" when only one or two representatives need a refresher course. Figure 3.

A second report gives feedback to the representatives by listing all the calls they scheduled, what the problem was thought to be, and what the technician actually found. This report, used in conjunction with the controllable report, allows the representative to see the cause and effect of their scheduling a service call. As an example I might counsel with the representative saying, "Several customers called and you scheduled the service call as Converter Buzzing. The technician found the problem to be Fine Tuning. Next time a customer mentions 'buzzing', try these fine tuning steps; I'll bet your controllable percentage in this category will become just great."

Installation and Technician Call-backs

We track call-backs for installers and technicians. A call-back is registered any time we return to a home in a 30 day period. As with the service representatives above, we track "controllable" call-backs - Customer Ed., Fittings, Drop, Bad Tv, etc. However, we found that when the installers and technicians were held accountable for all call-backs, then that category was reduced by half. We also spent less time managing the exceptions which the employees felt were not within their control.

The greatest benefit and challenge to holding an employee accountable for all call-backs is that they are going to tell you up front what is wrong with your system and what procedures they feel cause call-backs. More than once an installer slammed an addressable converter on my desk and said, "If you're going to hold me accountable for call-backs, you've got to fix this junk!" He was right, but upon investigation I found it wasn't the converter. An incorrect procedure used in check-in could cause the converter to turn off 10 days after installation. That procedure might still be in

SERVICE REPRESENTATIVE PERFORMANCE REPORT

sample codes tracked

Date range = 2/1/88 to 2/29/88

PROBLEM	TOTAL CALLS IN CATEGORY	**GROUP %**	<-------SERVICE REPRESENTATIVE-------> REP A	REP B	REP C	REP D	REP E
FINE TUNE	54	**3.30**	0.00	11.42	3.03	4.16	4.44
TV PROB	121	**7.43**	7.40	8.57	6.06	0.00	8.88
VCR EQUIP	41	**2.47**	3.70	0.00	0.00	4.16	6.66
NO PROBLEM	36	**2.20**	0.00	0.00	6.06	0.00	6.66
NOT HOME	45	**2.75**	7.40	2.85	6.06	0.00	6.66
additional categories tracked as appropriate							
Service calls Completed	1634		122	156	149	108	203
TOTAL "CONTROLLABLE" AVERAGE		**18.75**	18.50	22.84	21.21	8.32	33.33

Figure 3

use today, but for an installer who did not want to be held accountable for a call-back he attributed to a converter.

Converters

We track converters both with CableData and with stickers inside the converter. Each time a converter is placed or removed from a home, a record of that transaction is recorded as part of the converter's history along with the return code reason given by the technician. CableData generates a list of converters that have had multiple trips to the home, the reasons for removal, and the repair code used in Quality Control when the converter was fixed. With the report, we see trends and problems, ie., a converter is making its sixth trip through QC this year - two times for disconnects; four times the technicians said it did not decode properly and each of these times the tuner was replaced. The report suggests: (a) I am not recognizing the problem in QC as described by the technician; (b) The disconnects may have come from disgruntled customers; and (c) I have an opportunity for reducing truck rolls, converter swaps, and possible disconnects if I fix this problem. The stickers give me the same feedback; however, CableData allows for the sorting of information.

The output quality of QC can be monitored by using the installation call-back report and selecting converter fix codes. With this report, you can see how many converters do not stay in a home 30 days after installation.

In our system, converter call-back percentages dropped more as a result of fixing system problems and holding employees accountable for their work, than from changes in QC procedures. Addressable converter truck rolls are often the symptom for problems caused by other sources. System upkeep, alignment, ingress, customer education, and office procedures play an important roll in unnecessary converter swaps. A way to monitor your system for unnecessary converter swaps is to compare the "bad" converter returns against the number of converters you actually test bad in QC. If you are not happy with the results, your problems may lie elsewhere.

CONCLUSION

The impact of using these reports has been to reduce service calls, and the results work! I am not satisfied with rolling a service truck to fix a system problem I could have identified and fixed yesterday. By fixing system problems within hours of their occurrence, you eliminate the reasons customers call your office to complain. If they don't call, they won't receive a service call. If they're not calling, they cannot use that occasion to request a downgrade or disconnect. Large growths in our customer base came as a result of providing the best possible customer service - We eliminated the reasons for the customer to call.

SuperNTSC FOR SUPER CABLE

-abstract-

Yves C. Faroudja and Joseph Roizen

Cable television executives are currently examining a variety of proposed options for improving the television images delivered by their systems to the cable subscriber in his home. This effort has been catalyzed by the plethora of new TV systems being proposed by others as the solutions to the problem of high definition television in the future.

Such systems as the NHK-developed HDTV system employing 1125 lines, the NYIT-augmented channel system, the Fukinuki EDTV system, the Del Ray pixellized NTSC, the GE/RCA ACTV system, and event the S-VHS dual channel Y-C system have been discussed as potentials for an improved cable TV delivery method.

The authors of this paper will describe a system that retains full compatibility with the existing NTSC receivers in nearly 50 million cable TV households. While providing stepped improvements in picture quality to existing sets, as this SuperNTSC system lays the ground work for very improved NTSC images that would take advantage of newer TV sets built with bi-dimensional comb filter decoders, and line doubling frame stores. The results, which have already been demonstrated experimentally, emulate the performance of an HDTV system, without imposing the burden of extra bandwidth and significant added cost.

SuperNTSC can fit into a cable company's present operations by the addition of a more advanced NTSC encoding process than what is currently being used, and greater care in the handling of component or composite signals at the headend. Once a "clean" NTSC signal is sent down the cable, current viewers will notice some improvements on their present NTSC receivers, the improvement being commensurate with the type of receiver they own.

Future receivers with precision, dual delay line decoders and a line-doubling frame store will display a 1050 line image in which the scanning lines are invisible, and in which the subjective horizontal and vertical resolutions are improved.

The net result of this system is that everyone benefits, and cable TV images will compete favorably from an image quality standpoint with improved VCR or video disk systems, or even with other more expensive HDTV systems via DBS or augmented channels. SuperNTSC is a combination of a variety of present technologies that can be applied to the NTSC system to bring it to its full potential as a high quality television service, while still retaining full reverse compatibility with the huge number of cable TV receivers already in use.

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THE APPLICATION OF NATIONAL ANI TO PAY-PER-VIEW ORDERING

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ABSTRACT

The benefits and architecture of a national ANI pay-per-view ordering system are described. Using AT&T's INFO1 800 service, VIEWER'S CHOICE will make available to all addressable cable operators a high volume, impulse PPV ordering system. Customers call an 800 number and hear an announcement confirming their orders. The AT&T network passes the customer's 10 digit phone number, together with the last 4 digits dialed, to a central node. This data is then transmitted to the cable headend via a satellite data channel. Inexpensive downlink hardware and software screen the data by area code and local exchange. System relevant phone numbers are then passed via a standard protocol to either the billing system or the addressable controller at the operator's discretion.

I. INTRODUCTION

On December 3, 1987, AT&T and Viewer's Choice announced plans to deploy the first national ANI pay-per-view ordering service. Beginning in the second quarter of 1988, cable customers in participating cable systems around the country will be able to order PPV events simply by dialing a toll free 800 number. The customer hears a recorded confirmation message, hangs up his phone, and views the event.

II. WHY ANI?

The national ANI order system is designed to provide cable customers and cable operators with simple, inexpensive, high volume impulse ordering for PPV. The decision to go ahead with the national service was based on successful completion of a trial performed in Milwaukee that began in June 1986 [See: "A Trial Of National Pay Per View Ordering", NCTA Technical Papers, 1986]. In the trial research, over 90% of surveyed cable customers describe ANI ordering as "very easy"(69%) or "easy"(22%).

For the cable operator, ANI automates the entire order taking process. Unlike Automated Response Units (ARU's), ANI orders can be received from both touch-tone and rotary dial phones. ANI also permits the handling of large volumes of calls at the last minute.

Fully automated ANI ordering means cable operators can offer more showings, and also that many more orders per showing can be quickly processed. Furthermore, for operators with an installed addressable base, ANI permits the introduction of impulse ordering with a modest headend expenditure, no in-home investment, and a low $.25 per call charge.

III. WHY NATIONAL?

National ANI will speed the growth of impulse PPV ordering, as well as the PPV business overall.

A national ANI service is accessible from any telephone in the country. It provides operators a turnkey ordering system with a simple customer interface. Requiring very low capital investment (under $10,000) for downlink equipment, national ANI becomes especially attractive for smaller addressable systems with under 25,000 subscribers.

The arrival of national ANI will also hasten the development of industry standards in billing and/or addressable controller interfaces. The availability of comprehensive print and on-air ANI launch and marketing materials from Viewer's Choice, with costs spread across a large national base, is an added plus for many operators.

For some cable operators, local ANI is a good solution to their PPV ordering needs. However, local ANI is readily available in only some areas of the country and often involves substantial capital investment, guarantees or long-term commitments. The need to deal with multiple phone companies sometimes further complicate implementation.

IV. SYSTEM DESIGN

The system design has three principal components:

- Order collection and acknowledgement.
- Satellite uplinking and transmission of order data.
- Downlink screening of order data.

The end-to-end system is shown in Figure 1.

1. Order Collection and Acknowledgement:

Each PPV channel has a specific 800 phone number associated with it. The cable subscriber, using either a touchtone or rotary dial phone, calls an 800 number during a locally defined ordering window prior to the start of a PPV event. Customers are connected to a mass announcement node where they hear a recorded confirmation message.

The subscriber's 10 digit home phone number, and the last four digits of the number dialed, are simultaneously transmitted via the AT&T network to the Viewer's Choice satellite uplink facility. Any calls from exchanges not yet converted to equal access will be routed to live operators for manual phone number input.

2. Satellite Uplinking And Transmission Of Order Data:

At the uplink, a Q.931 communications controller interfaces with the AT&T network via a 2-way protocol. Buffering capability of 30,000 call messages is provided within the controller. The data next passes through an AT&T 6386 work group station where it is time stamped and tabulated for transaction billing purposes.

Satellite transmission is accomplished using a GI 1500P uplink data conditioner and a proprietary simplex data transmission protocol employing extensive error correction and automatic retransmission to assure reliable data delivery. All uplink hardware is fully redundant.

3. Downlink Screening of Data:

Each downlink receives the data via a General Instruments model 1500C downlink card. The data then passes through an AT&T custom screener (AT&T 6312 PC plus custom software) which is pre-programmed to select out orders originating from designated local area codes and exchanges. Minimum screener capacity is a screen rate of 67 messages per second, with buffering capability of up to 3,000 messages. The combined cost of the GI downlink card and custom screener is under $10,000 per headend.

Screened data is then passed to the cable company billing computer or addressable controller using a simple protocol. Within the billing system or addressable controller, customers' phone numbers are matched to their accounts, while the four digit indicator of number dialed is matched to a specific channel and PPV event.

V. CONCLUSION

The nationwide service described here is the product of more than two years of planning, design, and system trial. Throughout, the objective has been to provide cable customers and operators with a simple, effective and economical means to enjoy the benefits of impulse PPV programming. We feel that this system meets our initial requirements of:

- Nationwide Scope
- Very High Capacity
- Ease and Simplicity
- Low Upfront Costs
- Full Automation
- Turnkey Installation and Operation

VI. ACKNOWLEDGEMENTS:

Bringing this system from trial to national rollout has involved close cooperation among people from numerous organizations: AT&T, CableData, Computoll, Viacom Cable, Viewer's Choice, and Zenith, to name a few. Special acknowledgements for the final system engineering as described in this paper should go to the AT&T Adaptive Design Engineering Group led by Steve Calabrese.

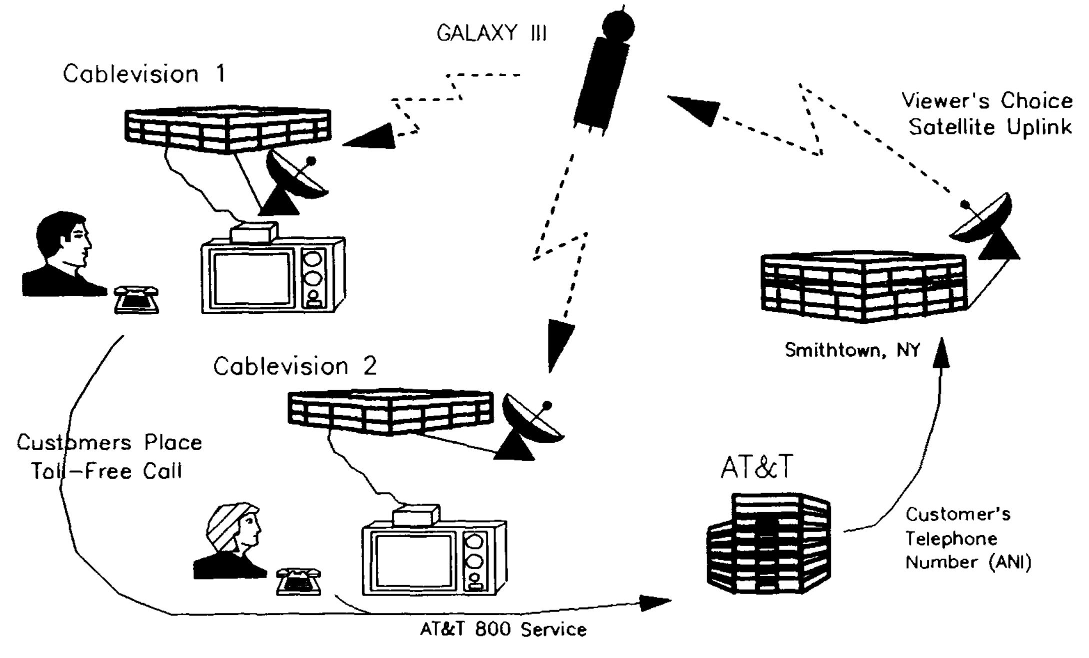

Figure 1

ANI PPV ORDER SYSTEM

THE EFFECTS OF OSCILLATOR PHASE NOISE IN AN FM VIDEO LINK

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ABSTRACT

Phase noise of local oscillators in frequency converters in an FM Video link can introduce noise into TV pictures in a CATV system. The acceptable level of such noise have not been established. The qualitative measure of phase noise is its perceptibility in a TV picture. Baseband signal-to-noise ratio (SNR) is a quantitative measure. This paper presents the theory relating the RF noise spectrum of an oscillator and the baseband noise spectrum and SNR for an FM Video link. Measured results are compared to the theory and conclusions about perceptibility presented.

INTRODUCTION

The NCTA Engineering committee formed its HDTV Subcommittee in the Fall of 1987. Group 1 of that subcommittee is charged with the investigation and documentation of signal transfer characteristics in cable systems, with particular emphasis on parameters useful in forecasting the transparency of a cable system to various HDTV proposals. Improved quality of present CATV service is also an expected result. This paper, together with the companion paper by Rezin Pidgeon [1] form the first published results of the group 1 investigations.

It was determined that the first efforts of the Group should be devoted to rigorous investigations of phase noise effects throughout the entire network, from satellite link through final detection. This paper treats the effects of phase noise in NTSC FM Video links used in satellite transmission of CATV signals. Both RF and baseband theoretical and measued results are presented.

THEORY

FM System Equations

FM modulation is described by the following equation [1]:

$$M(t) = A_c \cdot \cos\left[2 \cdot \pi \cdot f_c \; t + X \cos\left[2 \cdot \pi \cdot f_m \; t\right]\right] \qquad \text{EQ 1}$$

where $M(t)$ = the modulated waveform
X = the modulation index
= peak phase deviation
f_m = modulating frequency

and

$$X = \frac{\Delta f_m}{f_m} \qquad \text{EQ 2}$$

where Δf_m = peak frequency deviation

In the general case, this implies a Bessel series of sinusoids (sidebands) when expanded. When X is small (X 0.5 rad), the process approaches linearity and the series is adequately approximated by the first term. The result is a single pair of sidebands offset to either side of the carrier by wm. By constructing a phasor diagram of the carrier and sidebands one can determine that:

$$A_s = \frac{1}{2}\,\mathrm{ARCTAN}(X) = \frac{X}{2}$$

where V_s = peak voltage amplitude of sideband

Noise can generally be treated with this approximation unless the total noise power is great enough to produce large peak phase deviation. Low frequency noise components may also violate the approximation since phase deviation due to a given frequency deviation increases as modulating frequency decreases (see EQ 2).

Thermal Noise

Consider a carrier with flat thermal noise input to an FM demodulator. By "thermal noise" we mean noise with the statistical properties of that generated by resistors due to thermal effects. The actual source of this noise in an FM video link would include galactic and ground noise entering the antenna, amplifier gain and internal noise etc. It does not include oscillator phase noise. The following parameters will be used for the predetection signal:

C = carrier power (Watts)
N_t = thermal noise power density (Watts/Hz)
V_c = peak carrier voltage (Volts)

The signal at baseband will be:

$$V_s = k_d f_s = k_d f_p \frac{1}{1.4} \qquad \text{EQ 3}$$

where V_s = peak to peak signal voltage
K_d = demodulator constant (V 2πsec/rad)
Δf_p = peak frequency deviation due to 140 IRE total video

Our objective is to calculate video signal to noise which in NCT 7 is defined as the ratio of peak to peak signal volts of 100 IRE active video to RMS noise voltage (for noise above 10 KHz) [3]. The RMS noise voltage at baseband (out of the demodulator) is given by:

$$V_{bbn0} = k_d \Delta f_n \qquad \text{EQ 4}$$

where Δf_n = RMS deviation due to noise input to demodulator

The phase deviation produced by a single 1 Hz wide band of noise offset from the carrier by f_m is:

$$\Delta\phi_{NSSB} = \frac{\text{RMS NOISE VOLTAGE}}{V_c} = \frac{1}{\sqrt{2}}\sqrt{\frac{N_t}{C}}$$

There are two such bands of noise, one above and one below the carrier frequency. The noise in these bands is uncorrelated, and therefore additive in power.The RMS phase deviation due to the combination of both is:

$$\Delta\phi_N = \frac{1}{\sqrt{2}}\sqrt{\frac{2N_t}{C}} = \sqrt{\frac{N_t}{C}} \qquad \text{EQ 5}$$

Referring to EQ 2, 4 & 5, we have:

$$V_{BBNO}\left[f_m\right] = k_d f_m \sqrt{\frac{N_t}{C}} \qquad \text{EQ 6}$$

This is the RMS noise voltage at baseband frequency f_m at the output of the demodulator due to the thermal noise accompanying the carrier at the input. The total noise voltage may be found by integration over the desired baseband frequency range. The voltages at various frequencies are uncorrelated requiring integration of power (voltage squared).

$$V_{BBN} = \int_0^B \left[V_{BBNO}\right]^2 df \qquad \text{EQ 7}$$

$$V_{BBN} = k_d \frac{B^{\frac{3}{2}}}{\sqrt{3}} \sqrt{\frac{N_t}{C}} \qquad \text{EQ 8}$$

Using the previous definition of signal to noise and EQ 3 & 8:

$$\frac{S}{N_t} = \frac{f_s \sqrt{12}}{B^{\frac{3}{2}}} \sqrt{\frac{C}{N_t}} \qquad \text{EQ 9}$$

This gives the signal to noise without pre/deemphasis or noise weighting. It includes all baseband frequencies. In an NTSC FM video link, preemphasis is used to condition the signal for the FM format. After demodulation, the signal is deemphasized to restore the original baseband signal. Preemphasis for NTSC video attenuates low frequencies by 10 dB and increases high frequencies by about 3 dB. This reduces variation of average carrier frequency due to DC variation in the video and improves signal to noise. The latter effect can be seen by referring to EQ 4 and noting that baseband noise voltage due to thermal noise increases linearly with frequency, giving a triangular baseband noise spectrum. The deemphasis will have 10 dB of gain at low frequencies and 3 dB attenuation at high frequencies. Thus the noise is boosted at low frequencies where it is small and attenuated at high frequencies where it is large. The deemphasis function according to CCIR Recommendation 405-1 is:

$$D(f) = 10 \cdot \frac{1 + B \cdot f^2}{1 + C \cdot f^2} \qquad \text{EQ 10}$$

where D(f)= The deemphasis power response function

$$B = 1.306 \cdot 10^{-12}$$

$$C = 28.58 \cdot 10^{-12}$$

The important factor in video noise is how it is perceived by the viewer. Early studies showed that the perceptual effects of noise are very frequency dependent. Generally, the noise is perceived less as frequency increases. Weighting filters have been devised to have a response in frequency which matches the perceptual response of the human visual system. The weighting filter given in CCIR Report 637-1, equation 4 "for system M (prior to the introduction of the unified network)" is :

$$W(f) = \frac{1 + \left[\frac{f}{f3}\right]^2}{\left[1 + \left[\frac{f}{f1}\right]^2\right]\left[1 + \left[\frac{f}{f2}\right]^2\right]} \qquad \text{EQ 11}$$

where W = The weighting power response function

f1 = 0.270 MHz
f2 = 1.37 MHz
f3 = 0.390 MHz

This network is in general use for NTSC system measurements. Taking EQ 3, 6 & 7 and including the power response of the above deemphasis and weighting functions for noise above 10 KHz gives:

$$\left[\frac{S}{N_t}\right] = \frac{2 \cdot f_p \cdot \frac{1}{1.4} \cdot \sqrt{\frac{C}{N_t}}}{\sqrt{\int_{10 \cdot \mathrm{KHz}}^{4.2 \cdot \mathrm{MHz}} H(f) \cdot f^2 \, df}} \qquad \text{EQ 12}$$

where H(f) = D(f) W(f)

Carrying out the integration gives a constant so that:

$$K.t = \sqrt{\int_{10 \cdot \mathrm{KHz}}^{4.2 \cdot \mathrm{MHz}} H(f) \cdot f^2 \, df} \qquad \text{EQ 13}$$

$$= 1.144 \cdot 10^9$$

The units of K_t are the square root of Hz cubed. In all equations frequencies are in Hz and power densities are in 1Hz bandwidth. Change of units can be confusing.

Phase Noise

Now, let us consider phase noise which might be introduced by a local oscillator or carrier generator in the system. Oscillator phase noise is caused by noise voltages in the oscillator tuning circuit which produce frequency variation. These effects are described in some detail in a companion paper [1]. We will consider the phase noise to have a power density spectrum which is proportional to 1/fm^2. Thus the noise density decreases at 6 dB per octave as offset frequency increases. This is true of free running oscillators. Where synthesizers are used, the noise within the control bandwidth is a function of their design. While we will not treat that case here, the information presented is readily applied.

Unlike thermal noise, the phase noise sidebands are correlated since both arise from the same source. We add one new parameter to describe the signal at the demodulator input:

N_p = phase noise power density

Which is exactly that described above. The analysis proceeds as for thermal noise save two points. First, the noise power density is not flat and second, the sidebands are correlated. In this paper I will account for the frequency dependence through use of a reference offset. That is, I will specify phase noise power density at a particular offset frequency. By this means, the carrier to phase noise density can be written as:

$$\frac{C}{N_p} = \left[\frac{C}{N_{pr}}\right]\cdot\left[\frac{f_m}{f_r}\right]^2 \qquad \text{EQ 14}$$

where N_{pr} = phase noise power density at offset fr

or using the notation of REF 2:

$$Q_e = \sqrt{\frac{C}{N_{pr}}\cdot\frac{1}{f_r}}$$

We can now write RMS phase deviation for one sideband as:

$$\Delta\phi_{NSSB} = \frac{1}{\sqrt{2}}\cdot\sqrt{\frac{N_p}{C}}$$

Since the sidebands are correlated, the two add as <u>voltage</u> which gives:

$$\Delta\phi_n = \frac{2}{\sqrt{2}}\cdot\sqrt{\frac{N_p}{C}} \quad \phi_n = \sqrt{2}\cdot\frac{f_r}{f_m}\cdot\sqrt{\frac{N_{pr}}{C}} \qquad \text{EQ 15}$$

Referring to EQ 2, 4 & 15, the baseband noise voltage is given by:

$$V_{BBNO}(f) = k_d\cdot\sqrt{2}\cdot f_r\cdot\sqrt{\frac{N_{pr}}{C}} \qquad \text{EQ 16}$$

We see from this that the <u>baseband</u> spectrum due to phase noise is flat. You will recall that the RF phase noise spectrum (predetection) rolled off at 6dB/octave. Taking EQ 3, 7 & 16 and including deemphasis and weighting we can calculate signal to noise:

$$\left[\frac{S}{N_p}\right] = 20\cdot\text{LOG}\cdot\left[\frac{2\cdot f_p\cdot\frac{1}{1.4}\cdot\sqrt{\frac{C}{N_{pr}}}}{\sqrt{2}\cdot f_r\cdot\sqrt{\int_{10\cdot\text{KHz}}^{4.2\cdot\text{MHz}} H(f)\,df}}\right]$$

Carrying out the integration yields:

$$K_p = \sqrt{\int_{10\cdot\text{KHz}}^{4.2\cdot\text{MHz}} H(f)\,df} = 1.545\cdot 10^3$$

We now have a complete picture of both the effects of thermal and phase noise in an FM video link. The effects are readily combined. Each mechanism is independent and the baseband noise arising from each is uncorrelated. The noise power from the individual effects may be added. The video signal to noise ratio is defined in terms of voltage. From these facts we can determine the overall video signal to noise in terms of the thermal and phase noise. Thus:

$$\left[\frac{S}{N}\right] = 20\cdot\text{LOG}\cdot\sqrt{\frac{1}{\left[\frac{N_t}{S}\right]^2 + \left[\frac{N_p}{S}\right]^2}} \qquad \text{EQ 19}$$

Take as an example the case where:

(C/N_t)dB = 86 dB
(C/N_p)dB = 66 dB
f_r = 20 KHz

then

(S/N_t)dB = 48.6 dB
(S/N_p)dB = 56.9 dB

and

(S/N)dB = 48.0 dB

Summary of Theoretical Results

Fig 1 shows the predetection spectrum using 1 KHz bandwidth and the parameters of the above example. These are computed plots. Actual analyzer display of noise is 1.7 dB less than the true value [4]. The figure shows the thermal and phase spectra separately and the overall spectrum. The rolloff of phase noise and flat thermal noise of the predetection spectrum are evident.

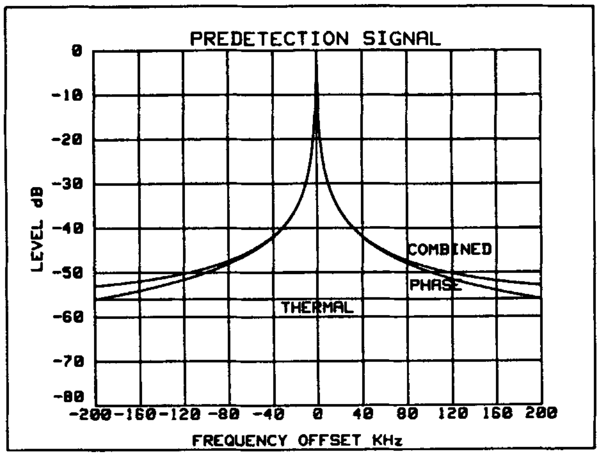

FIGURE 1

Fig 2 shows the baseband spectrum for the same case without deemphasis or weighting. Here, we see the flat baseband spectrum due to phase noise and the rising spectrum of the thermal noise. The thermal noise is dominant except for very low frequencies.

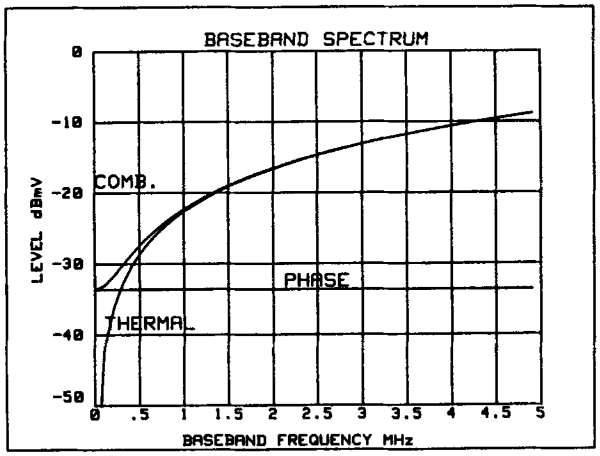

FIGURE 2

Fig 3 shows the same baseband spectra with the added effects of deemphasis and weighting. The relationship of the two types of noise in this plot is representative of the perceived effects. The boost of 10 dB by deemphasis is evident in the low frequencies. Clearly, phase noise dominates the low frequency area. However, the phase noise in this example degrades the overall S/N very little (see above example)

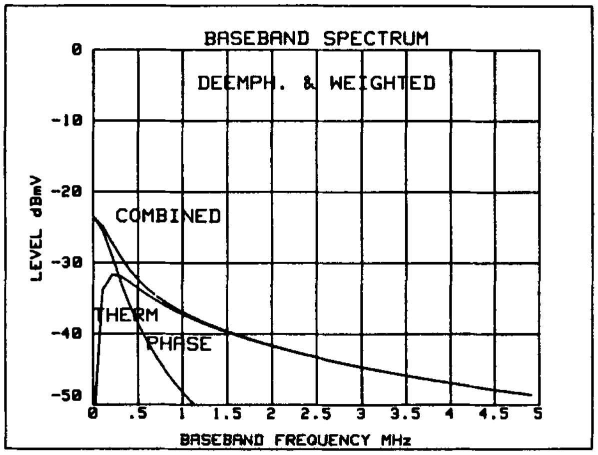

FIGURE 3

Fig 4 presents a family of curves for various thermal and phase noise conditions. All phase noise is referenced at 20 KHz offset and all densities are per Hz. These allow ready determination of system signal to noise for most combinations of thermal and phase noise. With a spectrum analyzer it is not practical to display power density in 1 Hz bandwidth. Other bandwidths may be used by subtracting 10 LOG (BW) from the thermal and phase noise scales, where BW is the desired bandwidth in Hz. For example, Fig 5 is referenced to 1 KHz BW.

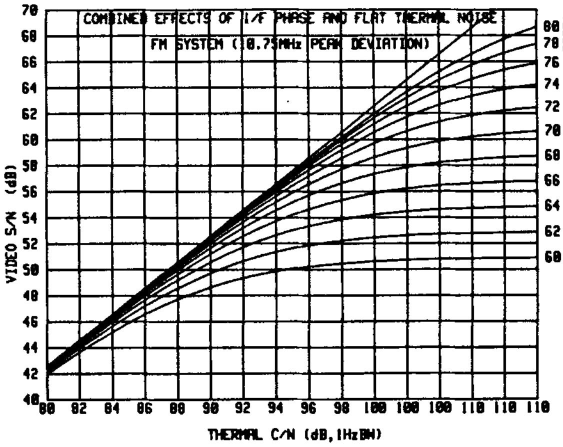

FIGURE 4

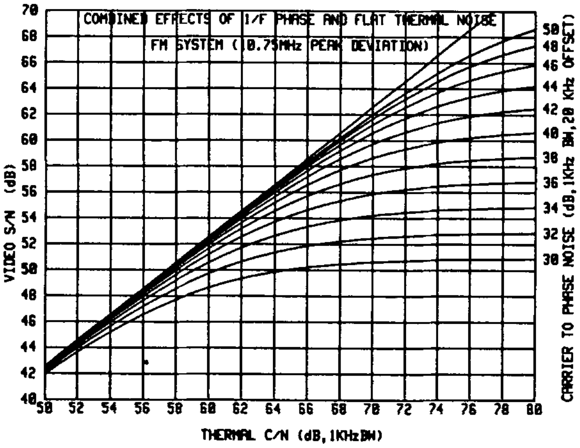

FIGURE 5

MEASUREMENT

A series of tests were run with the objective of determining the subjective effects of phase noise and whether weighted signal to noise adequately describes the effects. These tests were also compared to the above theoretical treatment. The test equipment diagram is shown in FIG 6.

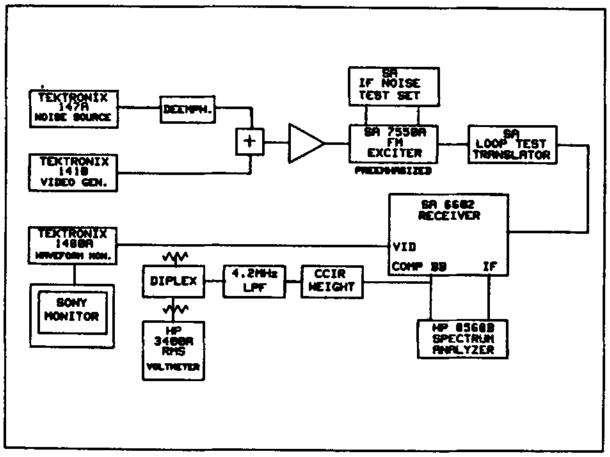

FIGURE 6

This system allowed addition of relatively arbitrary amounts of thermal and phase noise. The results of these tests are summarized in Table 1. Agreement with theory is quite good.

The tests for perceptibility were all run over a relatively short time span with a group of five expert observers. The tests were not intended to establish absolute perceptibility levels but to compare phase noise and thermal noise. Perceptibility was measured by switching between the lowest possible noise conditions and the test condition. Both thermal and phase noise were perceptible at the same weighted video signal to noise.

THERMAL C/N	C/N (PHASE) @ 20 KHz OFFSET	S/N MEAS	S/N CALC	DIFF
110	77.9	79.4	67.3	12.1
95	77.9	57.6	57.2	0.4
90	77.9	52.7	52.5	0.2
88	77.9	50.7	50.5	0.2
86	77.9	48.6	48.5	0.1
84	77.9	45.9	46.5	-0.6
110	69.8	59.5	60.4	-0.9
110	65.0	55.5	55.8	-0.3
110	61.3	51.7	52.2	-0.5
110	51.1	42.0	42.0	0.0
90	69.8	51.9	51.9	-0.0
90	65.0	50.9	50.9	0.0
90	61.3	49.2	49.4	-0.2
90	51.1	41.7	41.6	0.1

TABLE 1

With the noise level high enough to be clearly visible, the appearance of phase noise and thermal noise was different. This was also true when measuring noise using a waveform monitor. The reason for this is due to the difference in the baseband noise spectra as seen in Fig's 4 & 5. The combination of the flat phase noise spectrum and the deemphasis causes the low frequency phase noise to dominate. Thus the appearance of the noise in the picture is more "streaky" with phase noise. On the waveform monitor, the low frequency components cause the noisy line to "wobble" as well as the usual "fuzzy" look of thermal noise.

CONCLUSION

If accurate measurements of the phase noise of various components in an FM link are made and the thermal carrier to noise is known, a very good calculation of the video signal to noise can be made.

While the appearance of phase noise in the picture is generally different from thermal noise, the level of perceptibility occurs at the same Weighted Signal to Noise Ratio. The Weighted Signal to Noise is then a good measure of the effect of phase noise in general. When referring to the literature, conclusions drawn about the observable levels of noise will apply to phase noise as well as thermal noise.

In considering new formats, we must evaluate their differences from NTSC. In particular, where chroma is carried in a different manner and where added subcarriers are used, the effects may well be unlike that observed for NTSC. The deemphasis will also vary with format.

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2. Members of the Technical Staff,Bell Telephone System, Transmission Systems for Communications, Fourth Edition, 1970 Section 5.2

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THE GILLCABLE PRECISION NON-INTERFERING SWEEP SYSTEM

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ABSTRACT

At the 1985 NCTA Convention, Gill Cable described an ongoing project whose objective was the development of a dramatically improved system response test instrument. The report outlined the limitations of current high level and low level sweepers and proposed a new "smart" system which could overcome the limitations of the previous methods.[1]

Gill was motivated in this development by the lack of satisfactory options available to it in doing its own testing. An increasing number of complaints related to the use of high-level sweep made it imperative that less intrusive testing be done. A lack of accuracy available with other products on the market dictated a new approach to response measurement.

In the intervening three years, continued work at Gill has resulted in the development of a successful prototype sweeper with high resolution, fast refresh time and total absence of interference. In field trials it achieved noise-free displays at the maximum cascade of the Gill system (40 amplifiers), electronic error correction, and 0.05 dB of screen resolution. The transmitter generated no complaints of interference in over a month of continuous operation. A patent has been issued in recognition of the uniqueness of the Gill approach.[2]

Although there have been recent product announcements by several vendors in this field, it is felt that there are still serious limitations to all of the newly available approaches. Their dependence on the stability of video carriers at the headend severely limits their usefulness as precision alignment tools in Gill's view.

BACKGROUND

In order to deliver the highest possible quality television signals to consumers, operators must operate cable systems at carefully controlled levels: if carriers are too low pictures will be noisy; if they are too high, various distortion products will become visible. Operating at the ideal amplitudes requires careful level setting at the headend and maintaining the distribution system such that the frequency response is flat and so that the gain of each amplifier is just sufficient to overcome the loss preceding it. Sweep systems are the primary tools for distribution system monitoring and alignment.

Various methods have been developed over the years to allow system sweeping without requiring the removal of television carriers or unduly interfering with reception. Each involves compromises as outlined below.

High Level Sweep

The most common technique in use today is high level sweeping, patented in 1972. In this method a test carrier is inserted into the distribution system at a level approximately 20 dB above that of the television visual carriers (equivalent to adding 100 additional television carriers to the system loading!) The test carrier is rapidly swept from the lowest to highest frequencies of interest. The test receiver can sample this signal at any physical point in the plant.

Since the test signal is highly interfering, a low repetition rate (2-8 seconds) is employed along with a very fast sweep (1-5 milliseconds). Additionally, conscientious operators use communications radio systems to "trigger" the sweep on only when necessary and, further, disable it during prime viewing hours.

Recent changes in the industry have combined to make the high level sweep even less acceptable:

- o High VCR penetration, since VCR servo systems can be affected by the sweep signal more than TV sets.
- o Implementation of addressable systems whose data and channel tagging systems can be affected by the sweep signal.

- An increasing emphasis on PPV whose "one-shot" nature has raised quality expectations among consumers.

Aside from the problems with a properly operated high level system, it is subject to inadvertent abuse from inadequately trained technicians. If the test carrier is set too high, the amplifiers will begin to compress, making the system appear to have a flat frequency response and causing a higher degree of interference because of intermodulation products.

Low Level Sweep

In 1976 Avantek introduced a sweep system which allowed the test signal to be 30 dB below video carrier levels by use of a narrow-bandwidth tracking spectrum analyzer technique. While not truly non-interfering, it was a significant improvement in that respect compared with high level sweep. In addition to interference reduction, it offered simple spectrum analyzer functions.

On the negative side, it did not have the amplitude resolution of high level sweep and all response information was lost in the vicinity of each system carrier. The latter was not a problem in the lightly loaded systems of fifteen years ago, but has become one in recent years.

This product was withdrawn from the market in 1987 and is currently not available.

"No-Sweep" Sweep

A recent innovation requires no test carrier for response testing. In this technique, a spectrum analyzer is modified to measure and memorize the levels of all carriers in the system at the headend. This measurement is repeated at each test point and a smooth curve displayed showing the difference in decibels between the headend levels and the test point levels.

The limitations of this method are:

- Its accuracy depends on the amplitude stability of headend levels.
- Data is available only for those portions of the band in which signals are present.
- Only one or two data points are available for each channel, limiting frequency resolution.

The dependence on headend level stability is probably the most serious. Either high or low level sweep systems can achieve an amplitude resolution of a fraction of a dB, while individual headend signal levels can vary over much greater ranges because of:

- switching between standby carriers and live programming
- channel sharing between two services
- routine headend adjustments
- imperfect AGC circuits in processors
- aging and intermittent components

It is for precisely these reasons that sweep systems were developed in the first place: to allow system response testing to take place independent of system carriers.

Hybrid Systems

A recent entry into the sweeper market uses a hybrid technique to overcome some of the limitations of high level and "no-sweep" sweep methods. Its readout is based on carrier levels in the occupied portions of the band while a method akin to low level (but at much higher test signal levels) is used in the unoccupied portions of the band. It thereby achieves a complete response curve over the entire distribution system bandwidth.

Unfortunately, it has the same dependence on carrier levels as the "no-sweep" technique in the most critical frequencies.

THE GILL PRECISION NON-INTERFERING SWEEPER

Gill's technique differs substantially from existing technology in that it avoids interference by taking advantage of the unique characteristics of television signals. In this system, the test signal is generated by a frequency synthesizer and is inserted into the headend output at approximately the same level as video carriers. Interference is avoided by inserting the test carrier in each channel only during the first few lines of the vertical retrace interval when television sets are blanked.

Aside from the lack of subscriber interference, this portion of the vertical interval is uniquely suited to response testing for two other reasons (see Figure 1). First, it is the only time during the entire field that there is no chroma or burst, thereby clearing out that portion of the spectrum lying between luminance and aural carriers. Second, luminance modulation is limited to 25% downward modulation by equalizing/serration pulses.

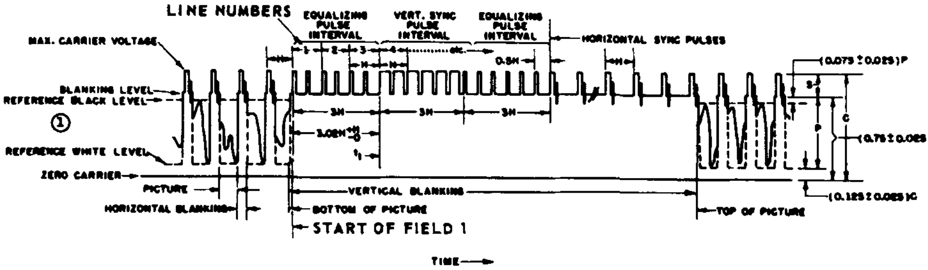

FIGURE 1. VIDEO WAVEFORM DIAGRAM

This level of luminance modulation is equivalent to 14.3% symmetrical amplitude modulation. If the modulation waveform were sinusoidal, this would result in a single sideband down 23 dB from the video carrier. Since the modulation is in the form of narrow pulses (8% duty cycle) however, the sideband energy is distributed among a series of sidebands spaced 31.5 kHz apart and extending to at least 1.38 MHz[3].

Given a test receiver bandwidth of approximately 270 kHz, only about 20% of the sidebands would be received simultaneously, so that the received sideband energy would be reduced another 7 dB below the carrier level or a total of 30 dB. This corresponds to a detected power level of 0.1% relative to the video-level test signal and produces a 0.004 dB reading uncertainty, well below the 0.04 dB resolution of the instrument. Thus very accurate response measurements can be made almost anywhere between luminance and aural carriers.

In summary, advantages of the Gill system are:

- Because the test signal level is comparable to normal video carrier levels, it avoids overloading of amplifiers which can easily occur with the high level system.
- The relatively high test carrier level compared with the low-level system assures highly accurate response even at very high cascade numbers.
- Carefully choosing test frequencies allows resolutions of approximately 2 MHz while avoiding loss of data near video and aural carriers. This resolution is sufficient to resolve "fine-grain" VSWR problems that can confound a lesser resolution system.
- Taking full advantage of the on-board microprocessor allows for full error correction eliminating the need for "grease pencil lines and visual correction of data.
- Since the system is totally non-interfering, the sweep rate can be much higher than high level systems. This translates directly into increased efficiency for sweep crews.
- The receiver can be made in such a way that it also allows very accurate read-out of system carrier levels, eliminating the necessity for the sweep personnel to carry level meters to each amplifier location.

DESCRIPTION OF OPERATION

Figure 2 is a block diagram of the transmitter. Operation in each television channel is as follows. The receiver/sync separator first tunes to the channel and derives vertical synchronization timing (including scrambled channels). The transmit signal generator is tuned to the first test frequency within the channel and, via the telemetry signal, the receiver is tuned to the same frequency. During the first few lines of the vertical interval, the transmitter is gated on for approximately ten microseconds. The transmitter and receiver are then incremented to the next frequency and a test signal briefly inserted into the following vertical interval, and so on until that channel is completed. Then the receiver tunes to the next channel and the entire sequence is repeated.

The keypad on the transmitter allows initial setup for any given cable system: start and end frequencies, frequency plan and any critical frequencies to be avoided.

Telemetry may be transmitted on any convenient frequency as, unlike the low-level system, there is no critical

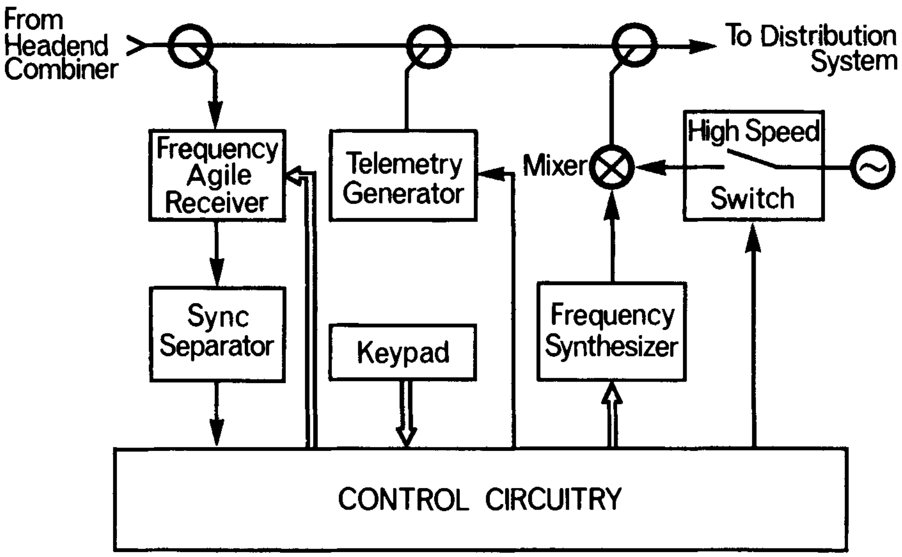

FIGURE 2. TEST SIGNAL GENERATOR

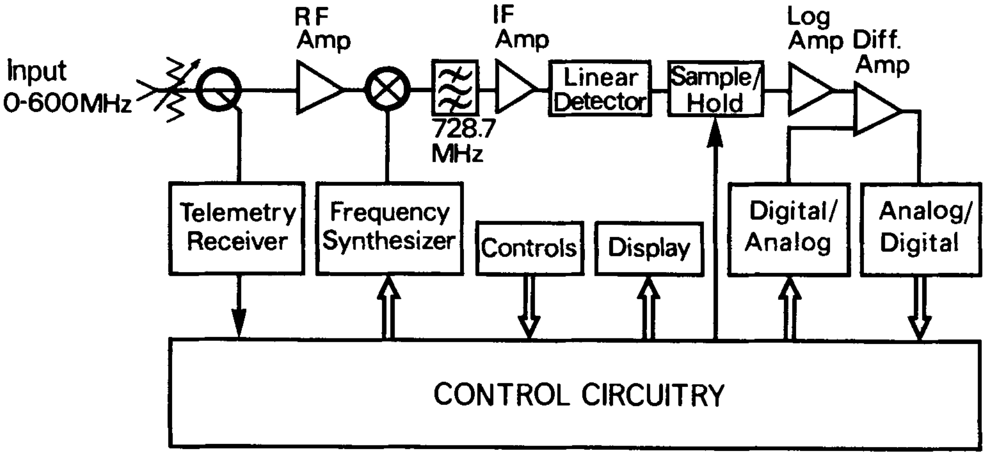

FIGURE 3. TEST SIGNAL RECEIVER

relationship between telemetry and test signals.

Figure 3 is a block diagram of the receiver. The telemetry receiver serves to keep the transmitter and receiver in synchronization and avoids having to specially program the receiver. The test signal receiver is synthesizer-controlled and uses a double conversion scheme to totally eliminate in-band images. This scheme allows a maximum frequency of 600 MHz (potentially up to 700 MHz). The detector uses active linearization to avoid temperature and linearity problems inherent with diode detectors.

A sample-and-hold circuit following the detector captures the brief test signal and a highly accurate log amplifier converts it to dB. Correction for the residual flatness of the transmitter and receiver is derived by making a back-to-back measurement at the headend. These errors are memorized in the receiver and subtracted out at each measured frequency before the data is stored.

The stored data is continuously displayed on the screen. The first prototypes have been built using flat panel electro-luminescent (EL) display screens for high readability under varying light conditions. This also eliminates the cost, size and weight associated with CRT systems. Given the rapid developments in back-lit super-twist LCD displays for computers, future products might well use this technology, allowing dramatic reductions in battery size and weight.

The microprocessor in the receiver also allows for several other features which enhance readability:

- A vertical graticule directly calibrated in dB referenced to the headend is displayed.
- The horizontal trace is adjusted to full screen, regardless of the range swept, for highest resolution. In the future, a calibrated horizontal frequency graticule will also be displayed.
- A digital read-out of the peak-to-valley response in dB is also displayed.
- The instrument can memorize several traces so that a tech can compare the output of a given amplifier with the output of previous amplifiers.
- A smooth curve is presented using a quadratic approximation derived from the sampled data available.

Additionally, a calibrated attenuator will allow offsetting of the trace to allow direct observation of amplifier input levels and bridger or line extender output levels.

STATE OF DEVELOPMENT

The first prototype was field tested in the Gill system in September, 1987 and the patent issued in October. The prototype fully exhibited the expected resolution and lack of interference. The transmitter successfully synchronized to both clear and scrambled channels. Scrambling systems tested included both baseband sync-suppression/video inversion scrambling and RF sinewave sync-suppression scrambling.

Figure 4 shows the front panel and a typical trace display on the first version (which lacks horizontal graticule and frequency scale). Figure 5 shows the receiver packaging with the display on bottom, the microcomputer and control circuitry below that, the RF deck next, and the batteries and power supply on the top.

Figure 6 is a photograph of a waveform displayed on an oscilloscope showing the placement of the sweep signal in the vertical interval. The waveform was taken from the video output jack of a Sony television receiver connected to the cable system with the sweep transmitter operating. As can be seen, the sweep signal is not only at a non-intrusive level, but uses a portion of the vertical interval not used for any other test or data services, including addressing or channel tagging for addressable devices.

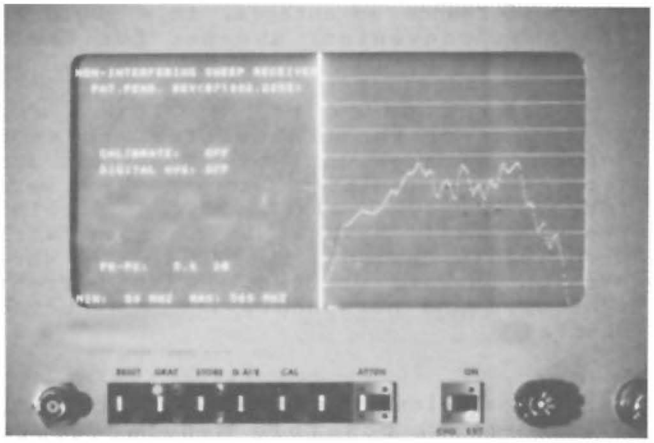

FIGURE 4. RECEIVER FRONT PANEL

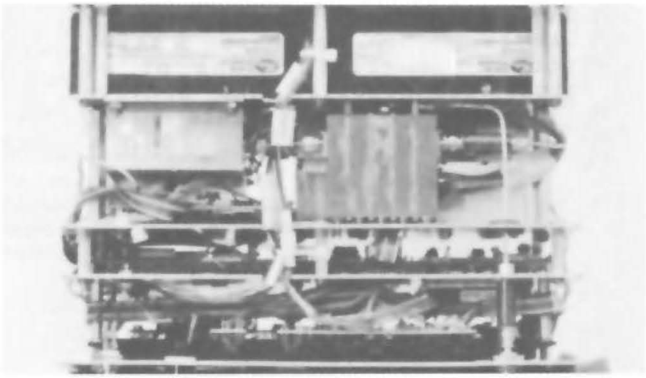

FIGURE 5. RECEIVER PACKAGING

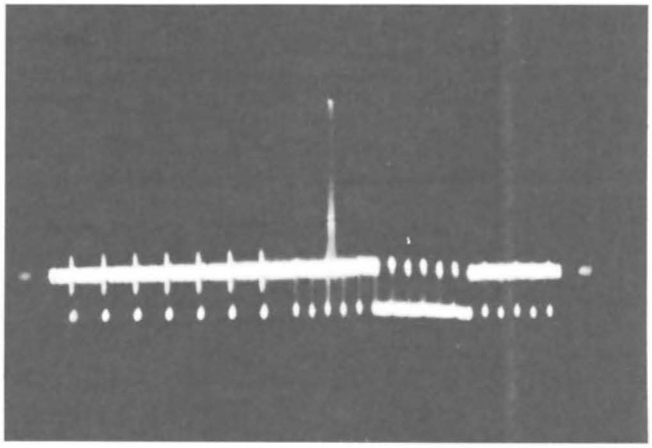

FIGURE 6. TEST SIGNAL PLACEMENT

Even with its relatively crude packaging, the receiver is smaller than any of the products currently on the market. Work is under way to take more than two additional inches off its depth. Additional tooling by a volume manufacturer should allow further substantial weight and size requirements so that, in addition to its performance advantages, this could be the most convenient sweeper for field personnel to use.

Remaining to be completed are packaging of the transmitter and some software features in both transmitter and receiver. Transmitter circuits which were temporarily synthesized using commercial products still have to be replaced with proprietary designs, but this is a very straightforward process. With current schedules and personnel, it is expected that a full prototype will be complete in July.

Negotiations are currently under way with several possible manufacturers regarding licensing of the technology for possible inclusion in commercial products.

CONCLUSION

The sweep system developed by Gill represents the next logical step in cable system frequency response testing. It overcomes the limitations of all the previous technologies and achieves the level of accuracy and non-interference that are needed to optimize cable system performance while not alienating customers. It is Gill's hope that commercial products using this technology will shortly be available to other operators.

ACKNOWLEDGMENTS

The Gill Cable Research and Development group (Bill Kostka, Rich Wayman, Mike Truppa and Jerry Sotirhos) have all spent many hours developing this product. It goes without saying, however, that without the enlightened support of Bob Hosfeldt, president of Gill Industries, the project would not have been possible. The illustrations and text preparation are the work of Gloria Cook.

REFERENCES

[1] Kostka: "Broadband Sweeping: A New Approach", 1985 NCTA Technical Papers, NCTA, Washington, D.C., 1985.

[2] U.S. Patent #4,700,222, issued in October, 1987.

[3] The Fourier transform of a series of narrow pulses into the frequency domain consists of a series of frequencies whose spacing is the repetition rate of the pulse train and whose upper frequency can be approximated by $F_{max} = 0.35/t_r$, where t_r is the rise time of an individual pulse, in this case 0.254 microseconds maximum.

The Trend to Digitization

by

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The Message

The trend to the digitization of electronics is pervasive. Cable technology, which has traditionally had an analog and an RF emphasis, may soon come under pressure from this. HDTV will magnify the problem. The cable technologist should prepare by increasing digital skills. This will at least position him to judge the competition and perhaps, increase cable's competitiveness.

Introduction

There are solid technical reasons for the trend to digitization. In most applications, cost is reduced and quality of the product's performance is increased. Digital components are experiencing the most rapid cost decreases of anything electronic. The cost reductions are caused by a "learning curve" driven by the massive computer industry. Huge R&D expenditures and fierce competitiveness between large international corporations are behind this important trend. Communications technology is also capitalizing on the digital revolution. This adds to the driving forces which are propelling digital technology. The increase in quality comes from the almost limitless ability to regenerate a signal which has suffered modest distortion and noise pollution. A whole science has been created over methods of coding signals so that errors may be completely removed. Signal quality becomes distance and time independent.

Technology by itself is sterile. Marketing makes "digital" come alive in the consumers' mind. Digital is an almost magical word which the consumer has grown to equate with "modern" and "high quality". (The only way to gain marketing impact with things that are analog is to use the spelling: "analogue"!) "Quartz digital", "Digital tuning", "Digital audio tape", "Compact digital disk", "Digital Television" are just some of the phrases which predispose the consumer to be favorably impressed when he first hears "digitally delivered video". "Digital" may become a marketing imperative.

In four short years, the Compact Disk, CD, has revolutionized the prerecorded audio business. The analog vinyl record is history. Digital audio is the standard. Broadcasters are seriously considering digital audio transmission schemes. The audio tape industry is bracing itself for the digital revolution brought by the Digital Audio Tape, DAT.

Yet cable's experience, training, and even culture is analog. The most important danger in this is that most cable technologists are ill prepared to evaluate the impact of the trend to digitization of electronics. It may be that there is little to be worried about. But that is unlikely. More than likely, there are important action steps to be undertaken to prepare for the digital future.

Competitors' Tools

Perhaps cable's two most important competitors are prerecorded video and telco. Both are moving down the digital trail. HDTV plays an important role in both of their plans.

Recording technology is the area of consumer electronics which has made the most dramatic progress over the last decade. It is also the area with the most potential for more progress. As recording densities increase, more and more signals of greater and greater quality will find their way to consumer tape machines. It is very likely that the next major trend in this arena is to digitization. Sony has demonstrated a two hour recording of video on 8mm tape. Special tape formulations and special techniques were used, but the size and form factor was that of the familiar 8mm tape format. The advantages are greater video quality and an almost immunity to tape wear. Digital recording will do for video what it has done for audio; it will significantly decrease the consumers' tolerance for imperfections. Consumer expectations will dramatically increase. This will be especially true when HDTV prerecorded video is digitized. The consumer will be challenged to expect better quality.

The telco trend to digitization of telephony is nearing its end. It is an accomplished fact for most of the network. Its remaining step is into the home. The Integrated Services Digital Network, ISDN, will finish the job. ISDN can be implemented over nearly all of the existing copper twisted pair plant. In this form, ISDN's only threat to cable is for those businesses we tried and abandoned. Included here are residential security, meter reading, videotex, software downloading, etc. If the reason cable did not find success in these areas is because the consumer fundamentally does not want these services, telco will harvest the same bitter disappointment. But if the consumer was not ready when cable tried or if cable's technology or implementation was lacking, telco will reap new rewards. The good news is that if cable is alert and responds quickly, it can rejoin the competition.

The real concern over telco's trend to digitization is over B-ISDN, the broadband version of ISDN. B-ISDN is video capable. It has the bandwidth to handle video and even HDTV. B-ISDN cannot be delivered over the twisted copper pair plant. It requires fiber optic cable. This will significantly delay implementation in areas already served by relatively modern telco plant. However, in just a few years, all new construction to the home will be fiber.

One needs only to look over the roster of the various FCC HDTV advisory subcommittees to be impressed with the telco interest in HDTV. Reading the papers published in telco journals and trades and in the IEEE publications clearly reveals the telco interest in digital delivery of HDTV.

The Rapidly Crumbling Brick Wall

The brick wall separating the analog world from the digital world is made up of two components: cost and spectrum demands. Both impediments are rapidly crumbling.

The general technology is advancing in ways that reduce cost and increase reliability. Cost is being reduced because of the progress made in computers. Specific components such as memory are enjoying dramatic cost reductions. This leads to broader application in communications and consumer electronics equipment. This in turn furthers the cost reduction. The cycle is endless. Digital television receivers and VCR's are transforming digital techniques into consumer electronics product design tools. It would be prudent for cable to find ways to tap into this process and capitalize on the massive development investments made by others.

The bandwith impediment is being attacked on two fronts. Advances in signal processing have reduced bandwidth requirements while the move to fiber optics has increased the bandwidth available for digital transmission. These impediments have been reduced for both telco and cable. Telco is taking advantage of the opportunity. Cable must at least understand the significance of the telco initiatives. If possible, cable must find ways to apply these techniques to its advantage too.

Paperback Movies

There is a digital development which in many ways runs counter to most other trends and in some ways may be the most dangerous of all. The Paperback Movie project at MIT has as its objective the creation of a movie distribution business that closely parallels the paperback book business. The intention is to develop a medium which has costs similar to those of a paper back book. The economics and distribution methods for Paperback Movies would be very similar to those of paperback books. Just as the price of a paperback book is too low for anyone to be motivated to copy it, so the price of Paperback Movies will be to low to tempt copying. In fact the price would be so low that even loaning the Paperback Movie would be more trouble than its worth. Most readers buy their own paperback books. Relatively little loaning takes place.

The vision behind the Paperback Movie is of a digital bandwidth reduction technology which would allow a two hour movie to be placed on a five inch compact disk. This is an ambitious challenge, but not an unreasonable one.

A factor which mitigates the difficulty of compacting two hours of video onto a five inch disk is a willingness to take a reduction in video quality as a trade off in gaining the compression. The willingness to reduce the quality requirement stems from the fact that the Paperback Movies concept is complementary with another important trend in consumer electronics, personal video. Small, portable, battery operated VCR's are already available with three to five inch diagonal measure liquid crystal color displays and TV tuners. The VCR's come in both the VHS and the 8mm formats. The 8mm devices are very small indeed. Portable CD players are also available. When the color liquid crystal display is added to the CD player, the ultimate Paperback Movie playback device is achieved. Personal, portable viewing of movies anywhere, anytime becomes possible. There is reason to be concerned that the way consumers enjoy movies may be changed by this technology.

Digital Downloading

Another digital technique which has received attention over the last few years is "digital downloading." There are two approaches to digital downloading. In one approach, the goal is to compress the video so its bandwidth is minimized, then it is sped up for transmission. The hope is to download a two hour movie in five minutes. The second approach hopes to reduce the video bandwith adequately so it can be downloaded over ordinary twisted pair phone lines during the night in more than two hours if necessary.

While these concepts are technically possible, several daunting problems remain. The most important impediment is the question: "download into what?". At first thought, the ideal would be to download into the consumer's existing VCR. In the case of the five-minute-download, if we are to deliver a two hour movie, the speed-up ratio is twenty four times. The VCR head must rotate twenty four times faster and the tape must fly by the heads twenty four times as fast. Also, if the recording is analog, the bandwith is increased by twenty four times to nearly 100 MHz. No consumer VCR exists which can do that. It is unlikely to be practical to accomplish this in any reasonable time frame. In the case of the phone line down load, the consumer's VCR must be capable of recording one picture at a time while the next is downloaded over an expanded time period. Consumer VCR's simply don't do that now. A special VCR would be required. This second type of VCR is much more practical to consider building. But the usual chicken and egg problem remains. The build up of penetration of the special VCR will take years. Can a business be build on such assumptions? Likely not.

The usual assumption is that the consumer's home computer will provide the computational power to process the compressed signals into the form required for recording. There are several things wrong with this assumption. First the number of home personal computers is a tiny fraction of the number of TV households. Further they are mostly of the wrong kind, more suited to games and very limited in computing power, speed and memory. Secondly, a dedicated consumer electronics product would be more efficient and cost effective. It too does not exist.

In both downloading scenarios, the temptation will be to take a reduction of quality in order to make the time constraints more manageable. HDTV is counter to these approaches because it greatly increases the amount of information that must be downloaded and challenges the consumer to expect high quality. In the case of the phone line download, planning for an overnight downloading is simply not in keeping with the American desire for instant gratification. It is not impulse pay per view.

Conclusion

The trend to the digitization of electronics is pervasive. The cable technologist should prepare for this trend by increasing his digital skills. This will at least position him to better judge cable's competition. Perhaps these new digital skills will also serve to increase cable's competitiveness. HDTV makes this all the more important.

The Vestigial Sideband and Other Tribulations

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Abstract

In 1941, NTSC recommended standards to FCC that specified vestigial sideband amplitude modulation in order to squeeze a 4 MHz video signal into a 6 MHz channel. In 1954, NTSC recommended color TV standards that specified pre-correction at the transmitter for the group delay characteristics of what they believed to be an "average receiver". These two NTSC RF standards create enough mischief in modern TV reception largely to mask the improvement in baseband NTSC performance being pursued so diligently by ATSC and the FCC advisory committee on Advanced TV. FM transmission on cable, with Y/C delivery to the subscriber TV set would by-pass the VSB problem. Low-cost ($25) VLSI chips in the form of FM modulators and demodulators will be needed to achieve this economically. Correction of envelope delay distortions due to the IF sound trap should be made the sole responsibility of receiver designers, by eliminating the NTSC pre-correction standard for transmitters, cable TV processors and modulators, and establishing tight tolerances.

Historical

As early as 1936, five years before the first NTSC developed its monochrome television standards, the 6 MHz channel width had already been set in concrete by the Radio Manufacturers Association (RMA) television standards committees.[1] At that time, 100 MHz was at the frontier of the electromagnetic spectrum considered useful for public purposes. You may laugh, but references even to 75 megacycles as "ultra-high frequency" were commonplace. Frequencies (wavelengths) were measured with Lecher wires (ask some old-timers about those); Barkhausen transit-time tubes and magnetrons were used for power oscillators. The RMA recommendation that seven 6 MHz channels be established between 42 and 90 MHz was considered at the time to be both farsighted, and a little greedy. In hindsight, it is unfortunate they did not opt for 8 MHz channels, like the British did some 25-30 years later. Maybe this is the price of technological leadership.

In the 1936-37 RMA deliberations, there was general agreement on 441-line, 2.5 MHz video bandwidth, using double sideband amplitude modulation (Figure 1). By 1938, however, the RMA committees recommended the recently developed vestigial sideband technology in order to increase the video bandwidth to 4 MHz without expanding the 6 MHz channel width. It was only at the last meeting of the first NTSC, in March 1941, actually two months after its recommendation had been submitted to FCC, and after stormy debate, that

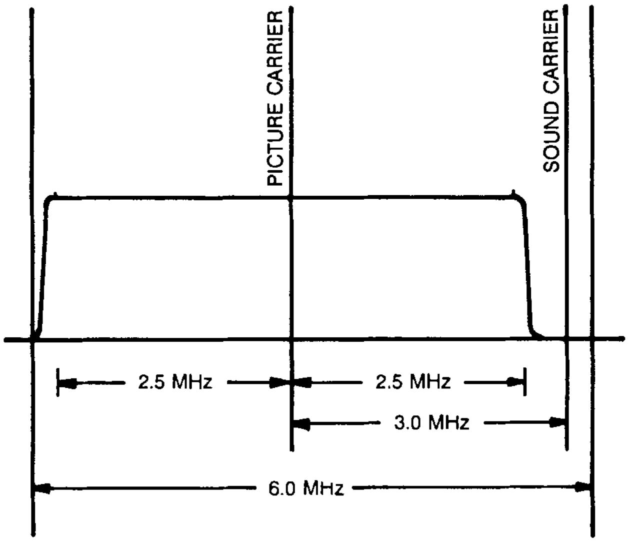


Figure 1

the number of scan lines was changed from 441 to 525, where it stands today.

In January, 1950, after the wartime freeze, the NTSC was reconvened to develop compatible color TV standards. By this time, it was politically impossible to expand the 6 MHz channel bandwidth. Therefore, the vestigial sideband, 525 line structure became literally immutable, and this standard was carried forward for NTSC color.

The Vestigial Sideband

What is the *vestigial sideband*? Simply stated, it is what is left after filtering out most of the lower sidebands generated in normal double sideband (DSB) amplitude modulation (see Figure 2).

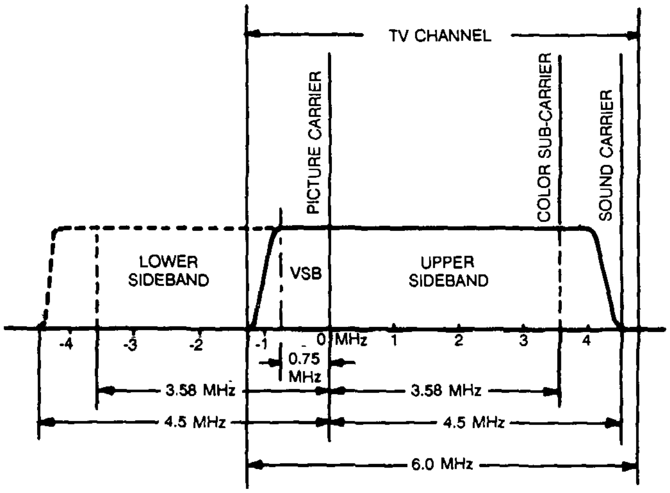


Figure 2

It is often useful to represent amplitude modulation as the sum of three vectors (see Figure 3). The large vector represents the visual carrier, and rotates at the rate of 54 to 550 million revolutions per second, the carrier frequency. The two shorter vectors represent the sidebands, rotating in opposite directions at a much slower rate, less than about 4 million revolutions per second, the video baseband frequency.

When both sidebands exist, with equal amplitudes and opposite phase, the resultant always coincides with the carrier vector. But when one of the sidebands is missing (shown as a dashed line in Figure 3) the resultant swings back and forth, depending on the relative position of the carrier and modulation vectors, causing quadrature distortion. The smaller the modulating amplitude, however, the smaller is the resultant swing back and forth.

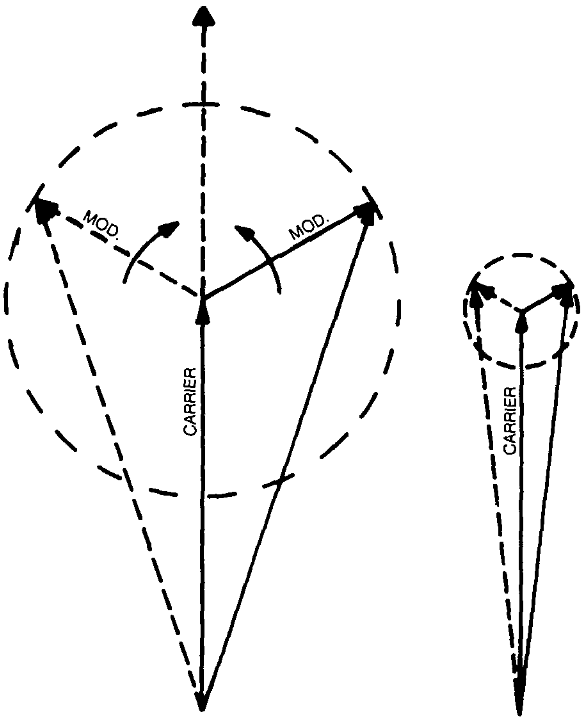


Figure 3

The RMA committee realized, correctly, that the sidebands at more than about 0.75 MHz from the visual carrier would normally be so small that most of the lower sidebands could safely be eliminated. It was a good tradeoff at that time. With VSB, the RMA committees were able to squeeze 4 MHz video bandwidth into the 6 MHz straitjacket.

The Nyquist Slope

Both sidebands do exist in VSB television, up to about 0.75 or 1.0 MHz. In this region, therefore, the resultant signal voltage is twice as great as it would be with only one sideband. An ideal detector would yield the response shown in Figure 4. To overcome this discrepancy, and to provide smooth transition from DSB to SSB, the receiver IF filter should have the shape shown in Figure 5. The so-called "Nyquist slope" at ± 0.75 MHz around the picture carrier, enables the combined amplitude of the upper and lower sidebands in the vestigial region to be the same as a single

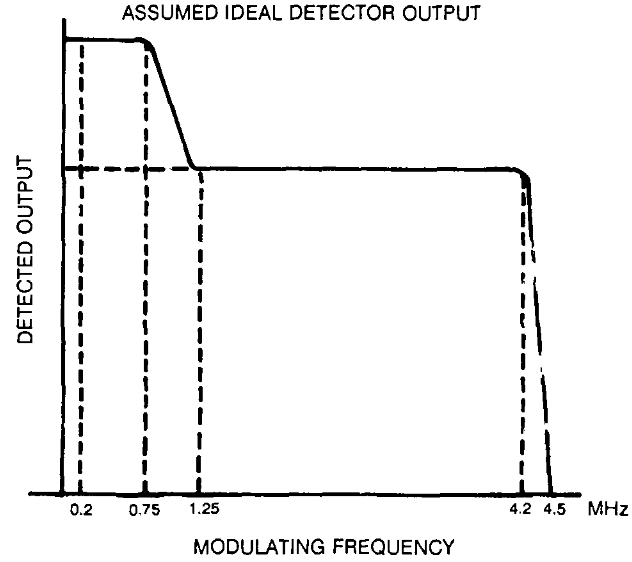


Figure 4

Group Delay

Now look at Figure 6 which shows what can happen because of phase errors in the residual lower sidebands at more than 0.75 MHz below the picture carrier. This represents the upper sideband in the single sideband region.[2] Ideally, the components of each sideband pair in the Nyquist region should have equal and opposite phase, like the DSB pair in Figure 3.

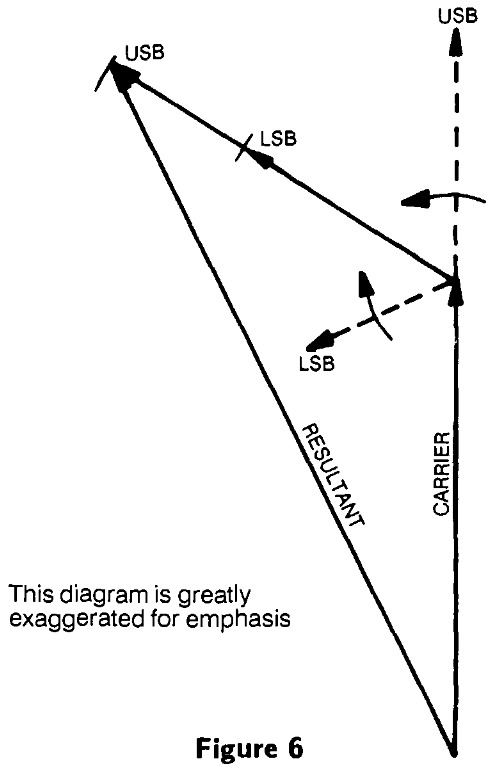


Figure 6

That is where the trouble arises. It is not easy to build a simple filter without phase shifts near the cut off frequency. Moreover, IF shaping filters designed to produce the Nyquist slope are likely to produce phase shifts above and below the picture carrier. The sharp corners at ± 0.75 MHz in Figure 5 do not exist. The real world looks more like the dashed lines.

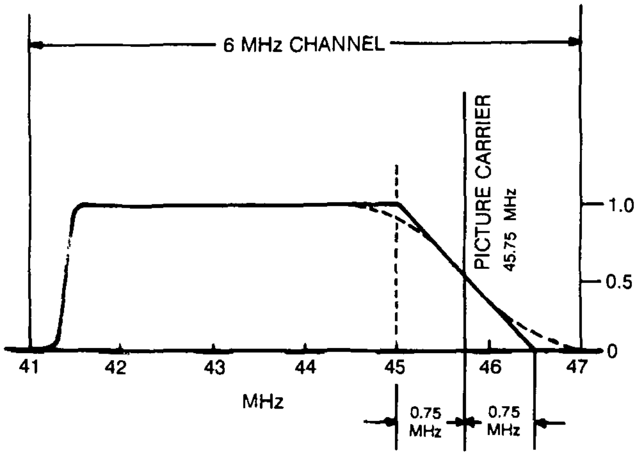
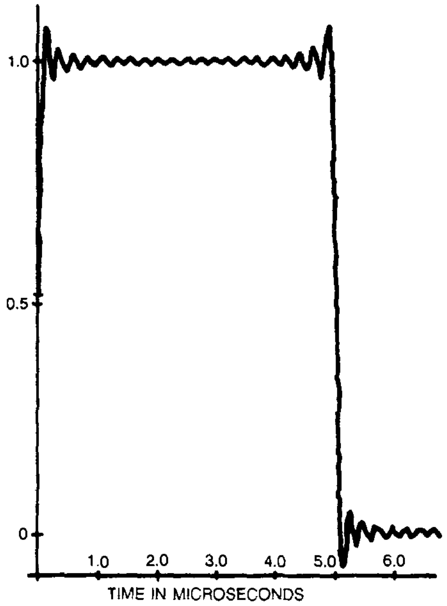


Figure 5

situation where the lower (vestigial) sideband is delayed substantially. At the instant when the upper sideband is in phase with the carrier, the lower sideband (dashed) has not yet arrived. A little later, the two sidebands will come in phase, as indicated by the solid arrows. However, the resultant envelope reaches its maximum substantially later than it should.

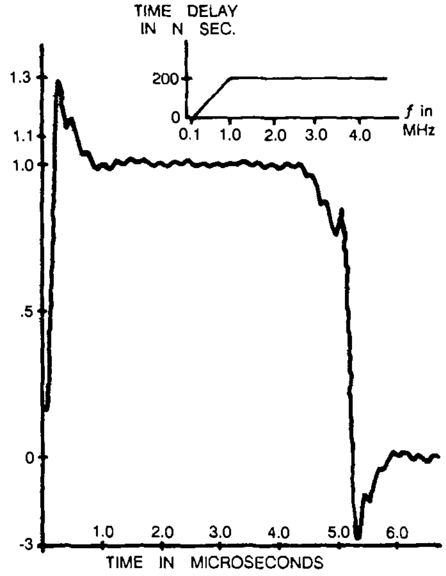
The lower sidebands, between roughly 0.5 and 1.0 MHz below the visual carrier, are susceptible to phase errors at both the VSB filter in the transmitter (or modulator) and at the IF shaping filter in the receiver (or demodulator). Upper sidebands between 0.5 and 1.0 MHz above the visual carrier also are generally susceptible to phase errors, but only at the receiver (or demodulator).

Figure 7 is a computer plot of the Fourier series for a 100 kHz square wave, with linear (i.e. correct) phase and 4.1



Computer plot. 100 kHz square wave.
Linear phase. 4.1 MHz bandwidth.
Source: Wilfred L. Hand 1970 (Ref. 3)

Figure 7



Computer plot. 100 kHz square wave.
Time delay as above. 4.1 MHz bandwidth.
Source: Wilfred L. Hand 1970 (Ref. 3)

Figure 8

MHz bandwidth The square wave, used for the calculation has zero risetime, with considerable energy remaining beyond the 4.1 MHz cutoff.[3] Had the sides of the square wave been 2T sine-squared, there would have been no ripple or ringing (this is why some character generators with steep risetimes, produce considerable ringing).

The time delay (related to the phase) of the Fourier terms below 1 MHz was then altered, as shown at the top of Figure 8, and the Fourier series recalculated. The result of the non-linear delay is a pre-shoot at the leading edge, and an overshoot at the trailing edge. Real world non-linear delays are more complex than was assumed for the computer plots. Nevertheless, Figure 8 shows how deviations in sideband delay cause the signal to come out of the second detector as a delayed low-level replica of the desired luminance pattern (picture).[4,5,6] That is a euphemism for a "ghost", and because the delay is relatively short, the effect is seen as a "close ghost" (not really "ringing", which is a different phenomenon).

It is possible for phase errors to produce "negative delay"; that is to produce a leading effect rather than trailing. This is sometimes seen as a leading undershoot outlining the left edge of a dark image in white, or a light image in black.

What Can Be Done About It?

The cures for this problem seem to require too much spectrum, are considered too expensive, are not operationally feasible, or simply have not been considered to be important. Full double sideband would clear it up; but we cannot afford the extra bandwidth, at least not for over-the-air broadcasting. Receivers can be designed with negligible phase error; the Tektronix Model 1450 Demodulator is such a receiver but it costs $15,000. Many years ago, we considered time domain equalizers; but because the errors are likely to be different for different combinations of transmitter, modulator and receivers, such a cure is impractical, although it could be effective in individual cases. Figure 9 shows how widely the group delay varies from receiver to receiver in the VSB region below picture carrier.[3]

The situation appears to be improving. Television transmitters are available with low-level intermediate frequency exciters. SAW technology provides much improved phase control in the vestigial sideband region compared with the older type filters operating at high-power. To the extent that SAW technology is also utilized in recent receiver design, another major source of phase error may be brought under control.

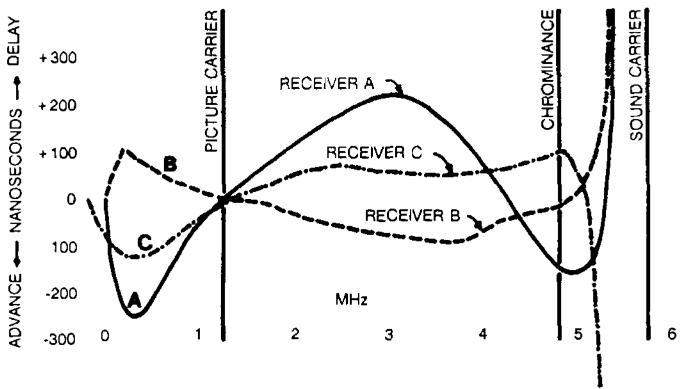


Figure 9

Lack of Awareness

The "close ghost" is still with us, directly off-the-air as well as on cable, although perhaps not quite as often as in the past. I am dismayed by the almost total lack of concern by television broadcast engineers, receiver engineers, and cable TV engineers for this type of picture defect. In 1969, I participated, along with others from NCTA, in the investigation of transmission (and reception) by a subcommittee of well known broadcast television engineers, sponsored by the JCIC (Joint Committee for Intersociety Coordination). We had a fairly elaborate receiving facility with waveform monitor and Polaroid camera set up in a motel room near Ottawa, Illinois. Full field test signals were transmitted after 1 a.m. from the Chicago network stations on channels 2, 5, and 7.

It was illuminating, and yet alarming, to realize that these experienced television broadcast engineers insisted on using a T-pulse instead of a 2T pulse for testing band-limited transmissions. It was discouraging to spend the time and effort (between 1 and 6 a.m.) only to read in the Final Report that the VSB problems we had hoped to quantify had been swept under a rug with "other multi-path effects".

But broadcasters are not the only technicians with tunnel vision on this point. I find that many cable TV personnel, both technical and otherwise, are not even aware of the "halo" effect until I point it out. Fortunately, it seems that the public is also unaware of this defect, and not bothered by it.

Advanced TV and the VSB

How likely is the public to become excited about 500 or 1000 line resolution when they are not even disturbed by the "close ghost"? How can we pump a Super VHS type picture through TV sets that put halos on the pictures? Remember that Super video cassettes can be played to Y and C monitor inputs without encountering the VSB problem. But in cable TV, we cannot get away from the IF shaping in the TV receiver, ahead of the second detector. We cannot correct the group delay ghost created in the subscriber's TV sets. However, we can and should make sure that our modulators and processors, provide as nearly flat group delay characteristics in the VSB region as is technologically and economically feasible. We need to make sure that any filters or traps or other frequency sensitive equipment do not distort the group delay in the sensitive vestigial sideband region.

But, how can we tell our customers that their TV sets are to blame for the edge effect, or halo, on our cable delivered pictures when they can see Super VHS (with Y/C input) on the same TV sets without such defects?

A Suggestion

We would be far better off if we were to transmit programs on coaxial cable (or optical fiber) with frequency modulation. We have the bandwidth to do it. The demodulated composite video signal could then be separated into Y and C components, just like Super VHS. Then the improved NTSC baseband techniques would really become effective. We would have totally by-passed the VSB problem.

What we need however, is a $25 frequency modulator, and a $35 FM demodulator. Don't laugh. For many years, a $5 AM modulator chip has been available for use with games, computers and VCRs. Why not FM?

Envelope Delay Pre-Correction

With the excellent hindsight afforded by 35 years of experience with NTSC, it seems clear (at least to me) that NTSC made a significant mistake in assuming that: "Past experience indicates that the envelope delays of color receivers will be sufficiently similar for the concept of the average receiver to be useful".[7] Based on this assumption, NTSC recommended the envelope delay pre-correction standard set forth in FCC RR 73.687(a)(3) (Figure 10).

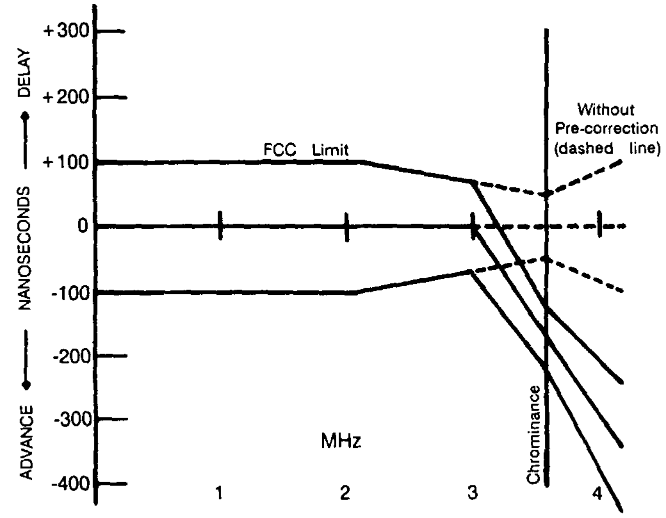


Figure 10

Unfortunately, there is no such "average receiver" group delay characteristic. Figure 9 shows the group delay measured on several 1970 vintage TV receivers (manufacturer not identified).[3] At that time, these receiver characteristics bore no resemblance to the FCC pre-correction curve. Today, SAW technology provides considerably tighter phase control, but even modern receivers probably do not conform with the 1954 NTSC idea of the "average receiver". Actually, pre-correction makes the large negative delay in receiver A even worse; and receivers B and C are reasonably close without any pre-correction.

Group delay errors at the chrominance sub-carrier frequency are most obviously the cause of color misregistration, sometimes called the "comic book effect". However, non-linear delays may also cause chroma crosstalk that cannot be corrected by such post-detection circuitry as comb-filters.

Further Suggestions

It is therefore, quite clear that group delay errors, in the vestigial sidebands and the chroma sidebands, will present serious obstacles to improving or enhancing NTSC video performance. I suggested above that the vestigial sideband problem could be by-passed by using frequency modulation for TV signals on our cables, providing someone finds out how to produce low enough cost FM modulators and demodulators to be included in the set-top interface at customer outlets. This would also greatly alleviate the chroma group delay problem.

There is no way broadcasting can shift its present terrestrial operation to FM. Therefore, in my opinion, it would be most desirable to delete the pre-correction requirement from the NTSC/FCC standards. With reasonably flat transmitted delay between 200 kHz and 4.0 MHz, receivers could be adjusted empirically to display pictures without serious chroma delay or crosstalk. As matters now stand, receiver designers really do not know what kind of signal consumers will receive. The receiver is often adjusted to match whatever signal is available, frequently improperly.

For improved NTSC, cable operators may have to devise sound notch phase equalizers, not only for processors and modulators, but for the bi-directional filters as well, so that we can maintain reasonably flat group delay, perhaps within 25, or at most 50 nanoseconds.

Conclusion

Extensive activity currently directed toward improving the NTSC color standard has been largely confined to the video baseband. These efforts will almost certainly be frustrated unless the NTSC radio frequency specifications are either more tightly controlled or appropriately modified, at both the transmitter and receiver. Otherwise, baseband improvements will surely be masked by:

(a) "close ghosts" and other luminance edge effects caused by group delay errors in the vestigial sideband region above and below the visual carrier; and

(b) chroma delay or cross-talk caused by improperly corrected group delay errors in the chrominance region. ■

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About The Author

Archer S. Taylor is a principal and co-founder of Malarkey-Taylor Associates, Inc. and its Senior Vice President, Engineering. He is a founder and pioneer in the field of cable television, having shared in building the first cable television system in the State of Montana in 1953. Mr. Taylor has maintained a professional practice as a consulting engineer for the broadcast and cable industries since 1944.

He was on the Board of Directors of The National Cable Television Association (NCTA) for six years. He served as National Vice Chairman, former Chairman NCTA Educational TV Policy Committee, and former Chairman of the NCTA Engineering Committee which developed many of the procedures adopted in the FCC rules and regulations.

He was Alternate Chairman of the Cable Television Advisory Committee (CTAC) which made engineering recommendations to the Federal Communications Commission concerning regulatory standards of good engineering practice. He was Chairman of the CTAC Panel on Picture Quality.

He is a Past President, Board of Governors of the Broadcast, Cable, and Consumer Electronics Society of the Institute of Electrical and Electronics Engineers (IEEE), a Fellow and Life Member of IEEE, Fellow Member, SCTE (UK), and Senior Member, SCTE (USA).

He also writes a monthly column entitled "My Turn" for CED magazine, on a variety of mostly technical issues.

TIME SELECTIVE SWEPT RETURN LOSS
A NEW LOOK AT COAXIAL CABLE

JOHN L. HUFF
STAFF ENGINEER

TIMES MIRROR CABLE TELEVISION

ABSTRACT

Swept radio frequency return loss using a spectrum analyzer and tracking generator with time selection will provide a new dimension in the measurment of cable quality and integrity.

The return loss bridge has been a standard of measurment for the Cable Television industry. The bridge's shortcomings are impedance balance, frequency bandwidth, connector adapters, and scan loss.

A spectrum analyzer, tracking generator, and a radio frequency counter with **Time Selective Swept Return Loss** will open up new avenues into coaxial cable testing and measurement. This technique could be particularly valuable in an HDTV environment. It is possible to analyze the effect of a single or a multiple of reflections from coaxial cable, connectors or other passive devices.

RETURN LOSS MEASUREMENTS

The detection of a swept radio frequency response from a bridge will indicate the quality of coaxial cable used in the Cable Television systems. The bridge makes impedance and reactance measurements possible. There are other devices that make the same impedance measurements.

Radio frequency bridges with port to port isolation of 60 Db from 10 kilohertz out to a gigahertz are available. Bridge effectiveness, however, is limited largely by the interface connector return loss.

Resolution of two reflections with a swept return loss display is possible. Resolution of three or more reflections is unsure.

The TDR with a stepped output measures the loop resistance and impedance characteristics of a coaxial cable. Broadband frequency response using a TDR is not easily determined. Making TDR measurements with Cable Television signals and power present on the cable system is not within the TDR's operational mode.

The **Time Selective Swept Return Loss** technique will change the way one thinks and uses the spectrum analyzer and tracking generator.

The block diagram of the test equipment and connections to the system's coaxial cable will appear bizarre. There will be differences in the setting of equipment's operating parameters. There is no set way the equipment should be connected to a test point. The connecting of cables should be as direct and short as possible, so that standing waves do not ocurr. standard procedures for blocking power to the test equipment should be observed. The procedures for connecting cables will be dictated by differences in equipment.

THEORY

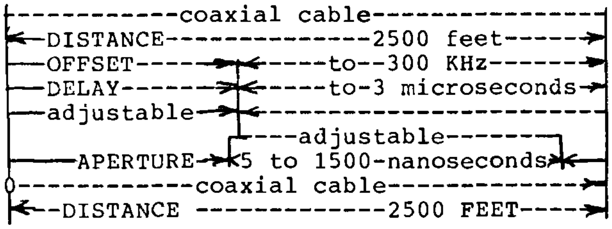
The reciprocal of frequency is time. With a known propagation velocity and a measured time the length of a coaxial cable may be determined. There are two discrete time references when using the **Time Selective Swept Return Loss** technique. The first reference is the time it takes the spectrum analyzer and tracking generator to scan a band of frequencies. The second reference is the time it takes a signal to travel the length of coaxial cable. Both times are used to calculate the frequency (delay) between the spectrum analyzer and tracking generator.

DELAY AND APERTURE DEFINED

The "tracking" adjustment is used to track the spectrum analyzer with the tracking generator. The tracking adjustment is also used to adjust the offset frequency. The offset frequency determines the time or delay, between the tracking generator and the spectrum analyzer, and determines the point of the segment of cable to be analyzed. The offset delay is adjustable from zero to over 3 microseconds or 2400 feet.

By adjusting the IF bandwidth scan time and frequency span, one can determine the aperture of the spectrum analyzer. By adjusting the aperture, one selects the time or length of coaxial cable to be analyzed. The **aperture** is variable in time from 5 to 1500 nanoseconds or 5 to 2500 feet in coaxial cable.

EQUIPMENT OPERATING PARAMETERS



AN RF SPAN OF 1000 MHz AND
THE RATES OF

SCAN AT	1.	.5	.2	.1	milliseconds
IF KHz					APERATURE IS
of 3	33	16	10	5	nanoseconds
of 10	100	50	20	10	nanoseconds
of 30	300	150	75	30	nanoseconds

THE OFFSET OF 100 KHz PROVIDES
500 nanoseconds OF DELAY

AN RF SPAN OF 200 MHz AND
THE RATE OF

SCAN AT	1.	.5	.2	.1	milliseconds
IF KHz					APERATURE IS
OF 3	165	80	50	25	nanoseconds
OF 10	500	250	100	50	nanoseconds
OF 30	1500	750	375	150	nanoseconds

THE OFFSET OF 100 KHz PROVIDES
2500 nanoseconds OF DELAY

The **aperture** table will not change with the types of equipment used. Calibration correction factors will change.

Standard CATV test equipment is not calibrated to operate **Time Selective Swept Return Loss** accurately.

The operating limit of the time scan depends on the spectrum analyzer local swept oscillator. The limit is on the local sweep oscillator's ability to track a linear time and sweep frequency.

With some tracking generator, spectrum analyzer combinations, tracking may not adjust with enough offset range. A second adjustable oscillator may be used to give the needed offset. The adjustable oscillator output is read directly with a frequency counter.

Scan and frequency amplitude response loss do not apply the same with **Time Selective Swept Return Loss.** The high sweep speed and narrow IF bandwidth will reduce the effect of other signals that are on the system and enhance the desired signals.

OPERATIONAL NOTES

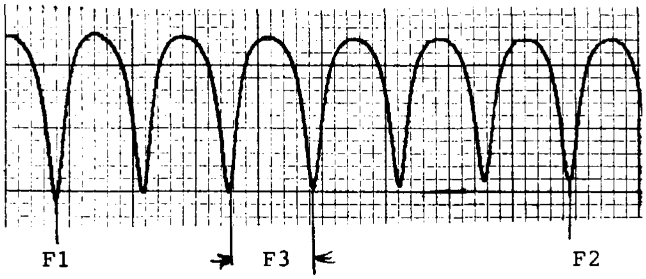
Five operating conditions exist with **Time Selective Swept Return Loss** which would not be normal for conventional swept radio frequency measurements:

1. A narrow IF bandwidth
2. A high rate of swept radio frequency
3. A wide band of frequencies swept
4. At least 50 nanosecond of propagation time delay
5. A very linear frequency and time sweep of the first local oscillator

It is not usual to sweep test with a narrow IF bandwidth. The IF bandwidth affect markers or other signal responses occupying critical swept frequencies.

CROSS CHECK

Standing waves of sweep frequency amplitude response is used to cross-check total length of a coaxial cable and to calculate delay time corretion.



(1/((F2-F1)/6)X.5=time in microseconds
microseconds X 984=free space distance
free space distance X 88%= coaxial feet

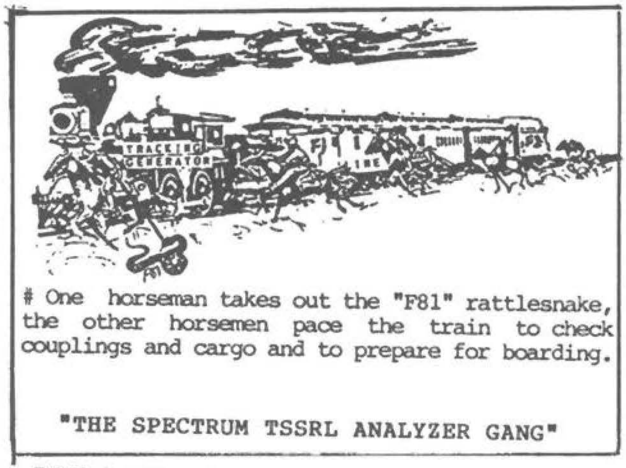
F2 = 79.581 MHz
-F1 = 63.947 MHz

15.634 / 6 = 2.6056 MHz = F3
1 / 2.6056 = .38378
.38378 X .5 = .19187 microseconds
.19187 X 984 = 188 feet free space
188 X .88% = 166 feet coaxial cable

OPERATION

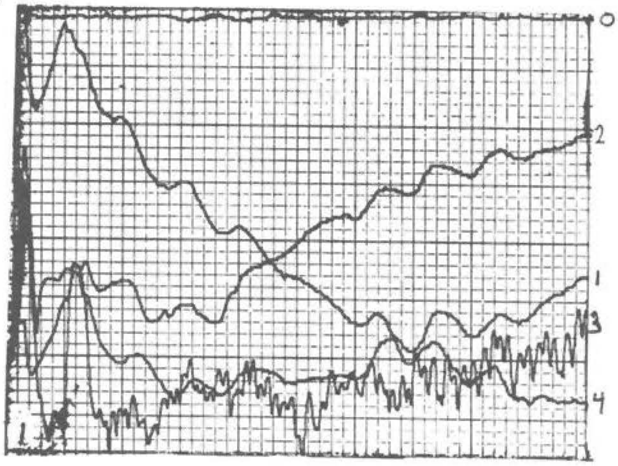
Connect a coaxial T to the tracking generator output. Connect one leg of the T to the spectrum analyzer input. The third leg is connected to a length of coaxial cable not less that 200 feet. The other end of the cable should not be terminated. Using the standing waves interference pattern, the cable length can be measured.

Compare **Time Selective Swept Return Loss** technique to and old western movie. Picture a fast moving train, the robbers are riding their horses alongside the train and can board any car.



One horseman takes out the "F81" rattlesnake, the other horsemen pace the train to check couplings and cargo and to prepare for boarding.

"THE SPECTRUM TSSRL ANALYZER GANG"



T.S.S.R.L. OF SAMPLE COAXIAL CABLE

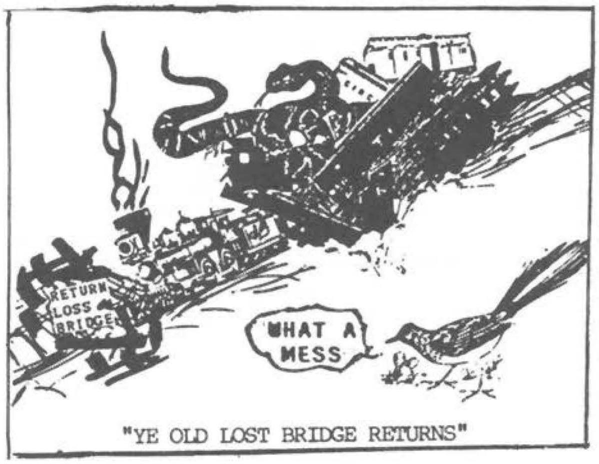
Zero reference span from -100 to +900 MHz. Zero reference offset frequency 499.7245MHz.

1. Bridge terminated with a standard termination 60 DB return loss at 600 MHz.
2. Cable connected through an F81 has a 34 return loss at 500 MHz.
3. Return loss of inter connecting cable is greater that 60 dB through 700 MHz. The offset frequency is 12 KHz.
4. Return loss from the 1.8 microsecond length of 500 coaxial cable is 54 dB.

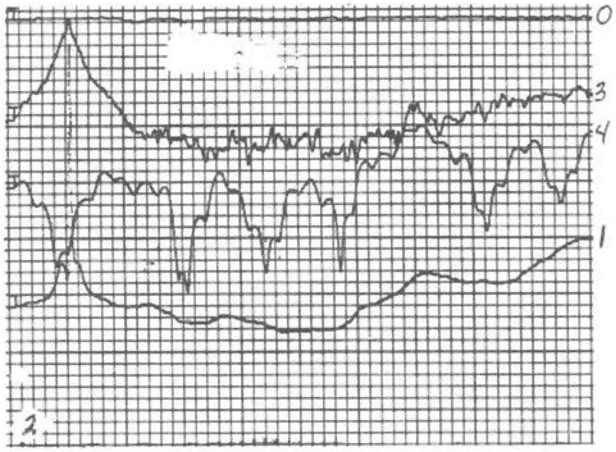
The offset frequency is 340 KHz.

The TDR traces to the right are a sample of .5 inch coaxial cable 1.8 microseconds long. The botton trace expands five time the first .5 micro-seconds of the top trace. The T.S.S.R.L. plots on the next page correspond to the discontinuities traced by the TDR. Five small vertical divisions are one ohm impedance. The T marks a coaxial cable connector, the causes of the other changes in impedance are not known.

The present bridge method for return loss measurements is like putting railroad ties on the track to stop the train. The result is a pile of train cars on the railroad tracks.

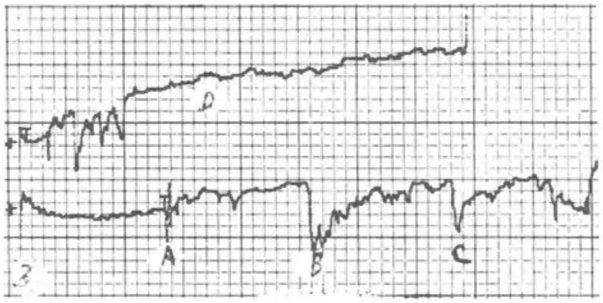


"YE OLD LOST BRIDGE RETURNS"

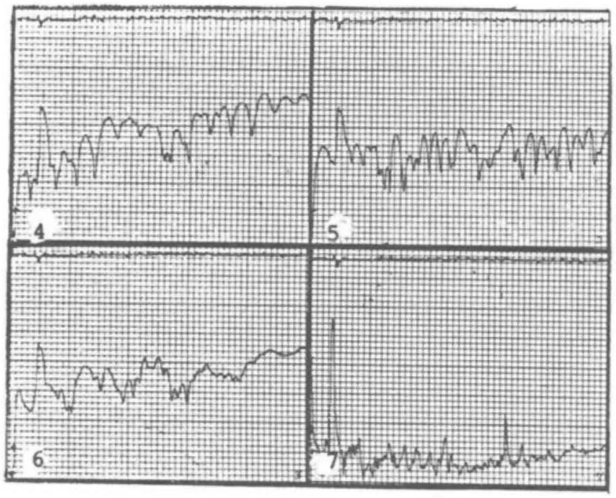


A series of plots made with a bridge with the standard method.

1. A zero dB reference trace with the bridge test port not terminated.
2. A quality termination on the bridge with 52 dB return loss at 500 MHz.
3. The return loss of the sample cable without the extreme end being terminated, a return loss of 21 dB at 300 MHz.
4. And expanded section of 10 MHZ span centered at 400 MHz showing the multiple responses from multiple reflections.



The TDR sample of coaxial cable was swept from a minus 100 MHz to a plus 900 MHz. Below are plots with various delays return losses as a continuation of plot 1. Each plot displays 80 dB vertical.



T.S.S.R.L WITH SELECTIVE DELAYS

PLOT	POINT	OFFSET	DELAY
#4	A	45.7 KHZ	118.0 ns
#5	B	68.0 KHz	228.5 ns
#6	C	84.9 KHz	340.0 ns
#7	D	124.4 KHz	625.0 ns

T.S.S.R.L. WITH SELECTIVE DELAYS
A a 500 splice connector.
B and C unknown underground faults.
D a repeated impedance changes 9;96 inches apart, a manufacture's characteristic.
The return loss is at 550 MHz as a spike.

Set the spectrum analyzer scan width to 500 megahertz. Set the sweep speed to 5 or 10 millisecond. Set the IF bandwidth from 3 to 30 KHz. Set the vertical calibration to log 10.

Adjust the tracking generator frequency offset to about 100 KHz. Set the vertical dynamic range to 70 or 80 Db. The vertical response above the noise floor is the return loss. Continue the offset through 300 KHz. The open end of the length of coaxial cable will be a swept R.F. amplitude response. The response will be twice the through loss of the coaxial cable. The coaxial T coupling provides an accurate output level reference.

OPTIONS

To use **Time Selective Swept Return Loss**, a frequency counter and a second, 2nd or 3rd local oscillator is not needed. To improve accuracy, reduce time and equipment operational confusion, a second offset oscillator is desirable. A frequency counter could be used with the offset oscillator in the tracking generator if there was a sample output of that oscillator.

There is an alternate method to offset frequency measurement. Stop the sweep of the spectrum analyzer in mid sweep, count the frequency of the tracking generator. A second frequency measurement is made after a tracking offset change has been made. The midsweep output frequency difference is the offset. The frequency offset of the tracking generator will determine the spectrum analyzer time delay.

TECHNIQUE

One has a 50/50 chance that the first offset frequency adjustment will be in the right direction. Only one direction has a response from on frequency tracking.

The offset frequency determines the delay time of the spectrum analyzer. A delay is an increase in frequency of a **tracking generator** offset oscillator. There is a decrease in frequency of the offset oscillator in a **spectrum analyzer.**

The bridge or directional coupler will extend the dynamic range of the spectrum analyzer. The bridge or directional coupler provides the isolation for observation of the reflections close to their test port. Isolation created by the directional coupler or the bridge must be included in return loss calculations.

Characteristics of a bridge are displayed as the balance is adjusted. The bridge balance adjustments are not effective as the spectrum analyzer delay time moves away from the response of the bridge.

Time Selective Swept Return Loss examines any section of a coaxial cable. All the passive equipment that is placed on the coaxial cable to the next active device can be examined for return loss.

The advantages of **Time Selective Swept Return Loss** will become apparent when you see the return loss of a coaxial cable being 70 Db or better. A connector at 500 feet may have a return loss of 40 Db at 50 megahertz and 20 DB at 400 megahertz.

Coaxial cable loss must be subtracted from the return loss measured. All intervening coaxial cable loss and the resulting return loss from that section of coaxial cable is added. The swept radio frequency through loss is in one direction of a length of the coaxial cable. The through loss is half of the return loss of the signal reflected from a coaxial cable that is not terminated.

The relative location of two close spaced reflections or the interference pattern of multiple reflection can be resolved with ease. The coaxial characteristics will be displayed in a variety of new responses. Other electronic passive devices on the cable will also reveal their particular characteristic influence.

Try **Time Selective Swept Return Loss** on TV receiving antennas and coaxial cable. The true return loss of the coaxial cable or the TV receiving antenna can be determined.

SUMMARY

Time Selective Swept Return Loss is not a **solve all** or a **cure all.** The technique will solve many problems dealing with television signal loss and distortion on a coaxial cable.

It is not possible here, to cover all the aspects, uses, and possibilities of **Time Selective Swept Return Loss.**

A new user may accept the technique as being a more normal function of the spectrum analyzer and tracking generator.

Test equipment calibrated and control panel marked to perform the required functions of this technique, operations would be easier.

TV AUDIO DEVIATION:

How To Measure It, Set It Right, And Keep It That Way

FRANK F. McCLATCHIE

F M SYSTEMS, INC.

ABSTRACT

Measurement and Control of TV audio volume has always been with us, but other concerns have usually taken precedence. Loudness contrast between channels is accentuated by program source switching and local ad insertion, not to mention audio volume changes with each new program on any given channel. This paper explains why two programs of equal peak deviation can have very different loudness, how to measure "loudness", how to adjust TV audio modulators to equal loudness on each channel, and how to keep loudness constant even though the source program volume changes. First some theory, then the practical art "equalizing" audio levels.

FIRST A LITTLE THEORY

Peak Factor

The peak factor of an audio signal is herein defined as the ratio between the peak voltage and the RMS voltage in the particular waveform being observed. This is usually expressed in dB. Thus a square wave has a 0dB peak factor, since the peak and RMS voltages are equal. A sine wave has a 3dB peak factor since the peak voltage exceeds the RMS voltage by 1.414 and 20 log 1.414 = 3.01dB. Natural voice or music waveforms can have peak factors ranging from 13 to 17 dB. "Single talkers" tend to have the highest peak factors, with certain languages and talkers ranging up to the 17dB level. Multiple musical instruments and combined voices (such as singing) tends to reduce the peak factor to about 13dB.

Well, if most natural audio has a 13dB peak factor, why does the audio industry refer to a standard 10dB peak factor? Because almost all testing is done with sine waves that have a 3dB peak factor! Thus we are referring to the difference between the 3dB sine wave and the 13dB music peak factors.

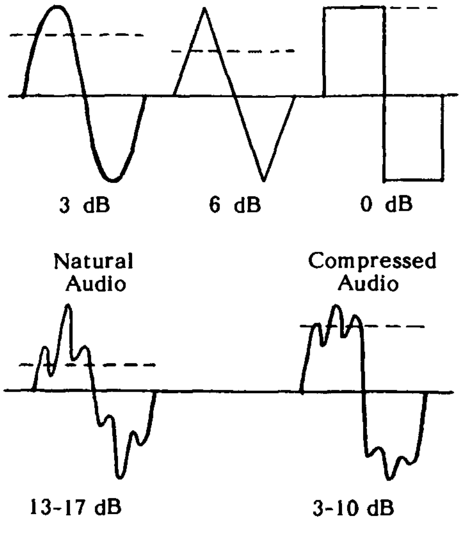
Compression

All of the foregoing discussion refers to natural voice or music. In practice these numbers will vary according to the degree of peak clipping and/or compression applied to the natural audio prior to transmission. Note that the FCC defines Frequency Modulation (FM) in terms of a deviation limit, which is directly proportional to the peak voltage of the modulating waveform. However the human ear perceives loudness as a power-derived factor, which relates to the RMS value of the modulation waveform. Since the Broadcaster has a natural interest in producing the loudest audio possible without exceeding the FCC deviation limits, the industry has expended considerable effort and ingenuity to compress the peak factor ever more while still not increasing distortion excessively.

Of course, it could be said that any change in the waveform constitutes technical distortion, but what is important to the Broadcaster is perceived distortion. Thus it comes to pass that some broadcasters (and recording studios) are far more aggressive in peak factor reduction than others. As a result, any two program sources that exhibit equal peak deviation can be very different in perceived loudness.

A good practical example of differing peak factor compression resulting in loudness differences can be found on your FM dial. Tune in a "classical" station, then a "rock" station. They are both modulating ±75 KHz, but the "classical" station will sound much weaker, even during a loud passage of music.

Peak Factor



PRACTICAL IMPLEMENTATION

Facing Reality

While all of the foregoing leaves us with program of varying loudness, the sub still will complain if the volume changes more that he or she perceives as acceptable. No standard fits all subscribers in how much is acceptable. The only thing that will reduce complaints to a minimum is to reduce volume differences below the level of audible perception. One deciBel is ordinarily conceeded to be just perceptible level change, so if we can hold average level differences between channels and between successive programs to the order of ±1dB or so, we can hope to reduce this source of subscriber complaint to a minimum.

Which Channels to Control

Off-air channels usually have their audio carefully controlled and so should not require further control at the headend. This is fortunate since most off-air signals are I.F. converted and cannot be controlled without going to baseband conversion. In fact, since these channels tend to have constant volume and can't be controlled in most systems anyway, these are usually the "reference channels" to which the volume of other channels are adjusted.

Ad Insertion channels are prime candidates for program audio level control. The same ad video-tape will play back at differing loudness on different VCR's and obviously tapes recorded at different times and locations also vary in volume and all of these combinations tend to be different from the preceeding program material. All channels carrying local advertising should be equipped with audio ALC systems between the ad-insert equipment and the TV modulator (not just within the ad-insert equipment).

Program Switching between different sources very often results in severe volume changes. An audio ALC system should be placed between the program switches and the TV modulator.

Local Origination audio is very difficult to control and usually requires an operator, but he or she is busy enough with the video, so often the audio volume changes more than it should. An automatic audio ALC system would exert this control and thus keep this channel under control.

In addition to the preceeding group of channels that are on the "must control" list, you may find that some other program sources should be added to the "controlled" list.

The Conundrum

Now, if we are to placate the subscriber, we must either re-process all incoming audio to the same peak factor and so have equal loudness, and equal audio deviation, or we can accept audio as we find it, but set the audio volume to be constant between channels and let the deviation fall where it may (within reasonable limits). Since the cable operator is not constrained by the FCC in the same way that a Broadcaster is, the cable operator can adjust his deviation over ±25 KHz for under-processed audio and under ±25 KHz for aggressively processed audio.

How to Set Equal Loudness

The "old-fashioned way" is to let your ear decide by switching between channels. Very time consuming and pretty frustrating because the ear has very poor loudnes memory. The ear is pretty good for comparing on an A/B basis, but since the two programs are not necessarily at 100% modulation at the same time, much time is lost waiting for volume peaks on both in quick succession.

As we have already seen, neither peak deviation (as measured on a storage spectrum analyzer), or peak voltage measurement (as measured by "peak flashers" or peak reading voltmeters) will measure comparative loudness between audio waveforms of differing peak factors. The only measurement that comes close to the human ear perception of volume is the RMS measurement. An ordinary RMS reading voltmeter will do this, but it still requires considerable interpretive skill to read, since the operator must establish just what "peaks" to read. If it is an analog meter, this difficulty is compounded by the mechanical time constants and dynamics of the meter. It is digital, reading the flickering numbers is literally impossible. The RMS reading meter must record and store the highest RMS reading over the testing interval to be practical, for it is the highest (or 100% modulation level) that should be recorded, not some lower intermediate level that may be on part of the time.

It does little good to measure the audio going into the TV audio modulator even with the digital RMS storage meter that was just postulated. To compare one channel with another, the digital RMS storage meter should be connected to the audio output of a TV tuner. Such a meter is available today①. It is called the ADM-1.

How to Keep Loudness Constant

Now that we know how to equalize the volume on the channels that we can control, how can we keep them from changing during ad inserts, program source switching, and other sources of volume changes? The answer is automatic audio level control applied between the audio source (such as the satellite receiver) and the TV audio modulator. This requirement is especially accute on the new BTSC stereo modulators, some of which have an audio control system built-in. A number of audio automatic level control systems (ALC) are available today②. Some are elemental in operation, while some are quite sophisticated. Just what can a sophisticated ALC do that it's more elemental brothers cannot do? Why buy the fancy model?

Characteristics of Audio ALC Systems

Audio ALC systems range from simple automatic variable gain devices to complex systems that control the gain in such a way that the listener is not aware that control is being exerted.

Simple ALC Systems

The simple ALC control system will maintain a constant audio output, but with certain rather obvious "control artifacts" such as:

1. "Noise Pumping". This is heard as a rushing hissing noise gradually increasing and decreasing in amplitude as the program volume changes. This hiss can be really objectionable during long pauses between normal program levels.
2. "Ducking". The sudden reduction of ordinary background sound following a sudden loud sound such as a gun shot.
3. "Program Pumping". This is caused when intermittant high level low frequencies such as bass drums or other low frequency pulsing sounds modulates the volume of mid and high frequency sounds. This can be particularly noticeable and objectionable on certain program content.

Sophisticated ALC Systems

These more complex ALC systems deal with these control artifacts with varying degrees of success. The best of them give no audible clue to their operation. Except that the audio level stays substantially constant over a wide range of input levels. Characteristics to look for when searching for a very good audio ALC:

1. "Gating". A good gating system will prevent "Noise Pumping". The gate locks the gain setting upon a sudden reduction of audio level, like a pause in speech. A good gate will not permit the gain to change until program audio returns. Since the gain is prevented from increasing during pauses, noise cannot be pumped up.
2. "Program-Dependent Gain Control". This feature, when properly implemented will prevent "Ducking". Sudden very loud noises will not change system gain, while longer term loud passages will exert gain reduction to maintain a constant output level.
3. "Dual-Band Control". By splitting the audio band into two parts, the low frequencies can be separately controlled from the high band, therefore intermittant high level low frequencies cannot modulate the volume of the higher audio frequencies, thus preventing "Program Pumping".

Artful implementation of these three aspects of the automatic level control system can control audio level to very close tolerances even with input level variations of 30dB, and do so with no perception on the part of the subscriber that any control is being exerted. In effect a very good ALC system acts just like a tireless professional audio operator on the job.

SUMMATION

Over the years, TV audio has almost been a "necessary evil": Necessary for obvious reasons, and evil because really good control systems were absent and there were many other more pressing problems to solve. Cable has grown and with that, subscriber expectation of professional grade video and audio. New equipment is now available that enable entirely new levels of audio professionalism. Better control of audio levels as well as stereo TV audio transmission in cable systems will go a long way toward increased subscribers satisfaction.

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   ALM672 Audio Level Master; FM Systems Inc.
   Compellor Model 300, 301; Aphex Systems Ltd.
   Orban 464A; Orban
   Scientific Atlanta Part #106044

WIRELESS OR WIRED CABLE: COMPARABLE TECHNOLOGIES?

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ABSTRACT

A comparison between the performance of a 10 watt multichannel multipoint microwave distribution system (MMDS) and a simple cable system is provided. Comparisons are made of received signal level, carrier-to noise ratio and nonlinear distortion performance. MMDS system limitations and operational features are briefly discussed.

INTRODUCTION

As the cost of building a cable system continues to increase, operators continue to search for alternative technologies to deliver equivalent or better performance at lower costs. One alternative operators now have is to supply programming over a microwave multichannel multipoint distribution service (MMDS) and reduce the amount of cable plant. New FCC regulations have allotted sufficient frequency spectrum in the 2.5 to 2.7 GHz range to give operators the ability to offer an attractive number of channels.

Eliminating the need for a cable plant certainly proves MMDS to be less costly, but can the performance of an MMDS system meet or exceed cable system performance? The answer is yes. MMDS performance can meet and even exceed cable in fundamental performance areas like received signal level, carrier-to-noise ratio and nonlinear distortion products. Also, current equipment available to MMDS systems can provide many of the technical advances found in cable such as addressability, scrambling and stereo broadcasts. Combining comparable features and improved performance can make MMDS a successful complement to an existing cable system or a very competitive alternative.

PERFORMANCE

MMDS Received Signal Level

To begin, let us define a typical MMDS and cable system as shown in Figure 1. The MMDS system will utilize an omnidirectional transmitting antenna mounted 500 feet above ground level. For simplicity we will assume a constant receiving antenna height of 20 feet and a flat earth, realizing the farthest practical receive site distance will be limited to approximately 40 miles by the radio horizon. The detailed characteristics of the transmit and receive site equipment are listed in Table 1.

The received signal level can be calculated from the formula

$$P_R = P_T - L + G_T - L_P + G_R + G_B \qquad (1)$$

where

P_R = Received signal power at downconverter output (dbm)
P_T = Transmitter power (dbm)
L = Transmit site losses due to channel combining and waveguide losses (db)
G_T = Transmit antenna gain (dbi)
L_P = Free space path attenuation (db)
G_R = Receive antenna gain (dbi)
G_B = Block downconverter gain (db).

Typically, transmitter output powers will range between 10 and 100 watts. For this comparison, the transmitter output power will be 10 watts (40 dbm).

Losses between the transmitter and transmitting antenna depend upon the length and type of waveguide being used, whether adjacent channels are being transmitted and the number of transmitting antennas available. Non adjacent channels can be combined with passive waveguide combiners and incur

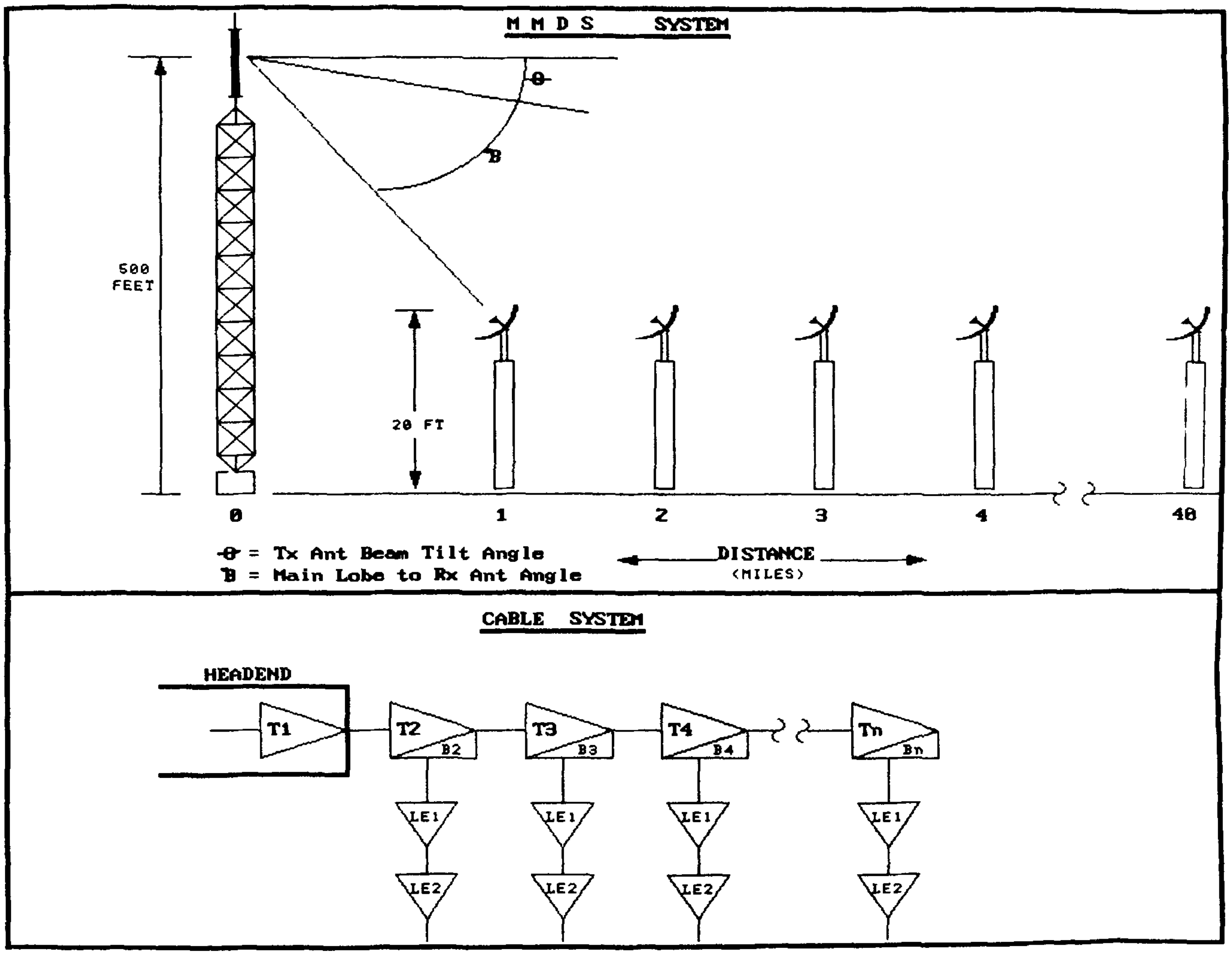

Figure 1. MMDS and cable system architectures.

only 1-2 db of loss plus the waveguide run losses. However, if adjacent channels are being transmitted and only one transmitting antenna is available, a minimum loss of 3 db plus the loss of the waveguide run must be incurred in order to combine the microwave channels. Utilizing more than one transmitting antenna to transmit adjacent channels will eliminate the hybrid combining problem. For this comparison, waveguide and combining losses will be assumed to be 3 db.

A variety of transmitting antenna patterns and gains are available. Standard omnidirectional antennas either horizontally or vertically polarized, can be obtained with gains from 10 to 17 dbi. Various cardioid patterns can be obtained with gains as high as 24 dbi. For this comparison, a typical omnidirectional antenna with 13 dbi gain was chosen.

Free space path loss can be calculated from the equation

$$L_P = 96.6 + 20 \log f + 20 \log d \qquad (2)$$

where f is in gigahertz (GHz) and d is in miles. The frequencies available for multipoint systems are 2.150 - 2.162 GHz and 2.5 - 2.686 GHz. For this comparison a median frequency of 2.6 GHz will be used.

The receive site consists of a receive antenna and a block downconverter to convert the microwave channels into the cable midband or

Freq (GHz) =	2.6		
Tx Pwr (watts) =	10		
Combining Losses (db) =	3	BDC Noise Factor	3.16
Tx Ant Gain (dbi) =	13	BDC Noise Temp	670.16
Rx Ant Gain (dbi) =	21	System Noise Temp	820.16
BDC Gain (db) =	20		
Rx Ant TE (Kelvin) =	150	Noise Power BDC Output	-8.34E+01
BDC NF (db) =	5.00		
Tx Ant Height (ft) =	500		
Tx Ant Tilt (degrees) =	0.5		
Typ Rx Ant Height (ft) =	20		

Distance (miles)	Path Loss (db)	Rx Level (dbm)	C/N (db)	Tx/Rx Ant Angle (degrees)	Elevation Pattern Attn (db)
0.5	98.88	-28.88	54.56	-9.80484	-21
0.75	102.40	-26.90	56.54	-6.41122	-15.5
1	104.90	-30.40	53.04	-4.69442	-16.5
1.5	108.42	-21.22	62.22	-2.96822	-3.8
2	110.92	-21.42	62.02	-2.10256	-1.5
3	114.44	-23.94	59.50	-1.23570	-0.5
4	116.94	-26.19	57.25	-0.80195	-0.25
5	118.88	-28.13	55.31	-0.54162	-0.25
6	120.46	-29.46	53.98	-0.36805	0
7	121.80	-30.80	52.64	-0.24405	0
8	122.96	-31.96	51.48	-0.15106	0
9	123.98	-32.98	50.46	-0.07872	0
10	124.90	-33.90	49.54	-0.02085	0
15	128.42	-37.42	46.02	0.152757	0
20	130.92	-39.92	43.52	0.239566	0
25	132.86	-41.86	41.58	0.291652	0
30	134.44	-43.44	40.00	0.326376	0
35	135.78	-44.78	38.66	0.351180	0
40	136.94	-45.94	37.50	0.369782	0
45	137.96	-46.96	36.48	0.384251	0
50	138.88	-47.88	35.56	0.395825	0

Table 1. MMDS system characteristics used in analysis.

superband frequency range. The receive antennas typically have gains in the range of 18 to 30 dbi. A variety of block downconverters exist with gains ranging from 20 to 40 db and noise figures from 2 to 5 db. For this comparison, a receive antenna gain of 21 dbi, a block downconverter gain of 20 db and a downconverter noise figure of 5 db will be used.

The calculated received signal levels are shown in Table 1 for distances of .5 to 50 miles from the transmit site. The perturbations in level from .5 to 1.5 miles out are caused by the elevational pattern characteristics of the transmitting antenna as shown in Figure 2.

MMDS Noise Performance

The carrier-to-noise ratio (C/N) at a given receive site can be obtained by comparing the received carrier level calculated in Table 1 to the noise level present at each receive site. The noise level at each site will remain fixed assuming the same receiving antenna and block downconverter are used. Therefore, the noise level at each receive site can be calculated from

$$N_R = kBT_EG_P \qquad (3)$$

where

N_R = Noise power at downconverter output (dbm)

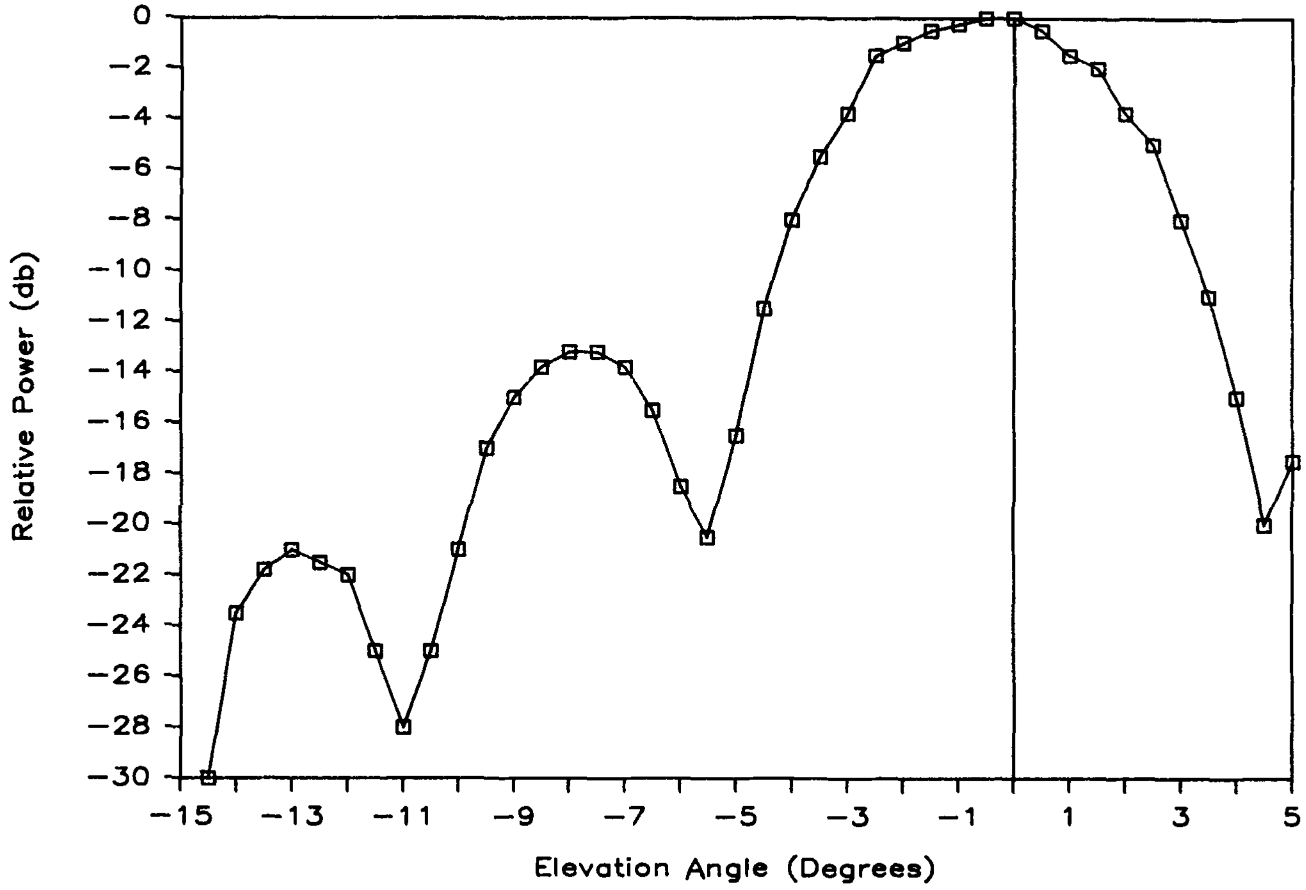

Figure 2. Transmitting antenna elevational characteristics.

k = Boltzmann's constant (1.38 x 10^-23 J/K)
B = Bandwidth (4 x 10^6 Hz)
T_E = Effective noise temperature of receiving system
G_P = Block downconverter gain (power ratio).

With the receiving antenna and block downconverter characteristics shown in Table 1, the effective noise temperature of the receiving system is approximately 780K and the noise level at the output of the block downconverter from equation (3) is -83.7 dbm. Table 1 shows the resulting C/N for the various receive sites in the MMDS system.

Cable System Noise Performance

The cable system design consists of a series of feedforward trunk amplifiers with a generous 2600' of separation. Each trunk amp breaks off into feeder legs consisting of a bridger amplifier and two line extenders. The performance levels at the output of this second line extender will be compared with the MMDS performance levels at the block downconverter output. The amplifier characteristics are listed in Table 2.

The C/N ratio can be calculated for the trunk, bridger and line extender systems independently using

$$C/N = P_R - G_A - NF - 10 \log N + N_O \qquad (4)$$

where

P_R = Received signal level (dbm)
G_A = Amplifier gain (db)
NF = Amplifier noise figure (db)
N = Number of amplifiers
N_O = System thermal noise level, -59.1 dbm for a 4 MHz bandwidth

and then combined using

Trunk Amp #	Distance (miles)	C/N @ Trunk Amp Output	C/N @ Line Ext Output
1	0.49	59.10	54.49
2	0.98	56.09	53.20
3	1.48	54.33	52.20
4	1.97	53.08	51.40
5	2.46	52.11	50.72
6	2.95	51.32	50.13
7	3.45	50.65	49.61
8	3.94	50.07	49.15
9	4.43	49.56	48.73
10	4.92	49.10	48.35
15	7.39	47.34	46.82
20	9.85	46.09	45.70
25	12.31	45.12	44.80
30	14.77	44.33	44.06
35	17.23	43.66	43.43
40	19.70	43.08	42.88
50	24.62	42.11	41.95
60	29.55	41.32	41.18
70	34.47	40.65	40.53
80	39.39	40.07	39.97

Trunk Amp :
Gain = 26.00
NF = 10.00
C/N = 59.1

Bridger Amp :
Gain = 31.00
NF = 9.50
C/N = 59.60

Line Ext :
Gain = 30.00
NF = 8.00
C/N = 62.1

Table 2. Cable system characteristics used in analysis.

$$C/N = -10 \log \{10^{(.1\ C/N_T)} + 10^{(.1\ C/N_B)} + 10^{(.1\ C/N_E)}\} \qquad (5)$$

where

C/N_T = C/N for the trunk cascade (db)
C/N_B = C/N for the bridger amp (db)
C/N_E = C/N for the line extender cascade (db).

The C/N was calculated for distances out to 40 miles (80 trunk amplifiers) and the results are shown in Table 2.

Figure 3 is a comparison of the C/N performance of the cable and MMDS systems. The results show that even at 10 watts of output power, MMDS performance can rival cable performance out to distances of at least 23 miles (47 trunk amplifiers).

Now, the results shown in Figure 3 describe the ideal situation where the C/N is only limited by the signal level received at each receive site. For systems of 2 to 16 channels in size this level of performance is quite practical. However, when the number of channels increases to beyond 16, the downconverter dynamic range will typically limit the maximum allowable received signal level and thus will be the controlling factor for C/N. The received signal level must be chosen to balance between C/N and nonlinear distortion performance. This is especially true for clear line-of-site receive sites out to distances of 20 to 25 miles.

Nonlinear Distortion

As previously mentioned, the downconverter dynamic range will typically be the controlling factor for the system nonlinear distortion performance. The architecture of the MMDS transmitting system is optimized for minimum distortion generation. An individual transmitter is used for each channel and channels are combined through the use of passive waveguide combiners. Cross modulation and intermodulation numbers of -60 db are very typical at the output of the transmitting antenna(s). Therefore, the downconverter is the only active element in the system handling the combined power of all channels. Because of this, the downconverter input level must be kept within the manufacturer's specified dynamic range to insure intermodulation and cross modulation performance on the order of -55 to -60 db as delivered to the subscriber. Obviously, this adjustment of received signal level will ultimately affect the C/N ratio.

Cable systems have a much more severe problem with nonlinear distortion because of the number of active devices

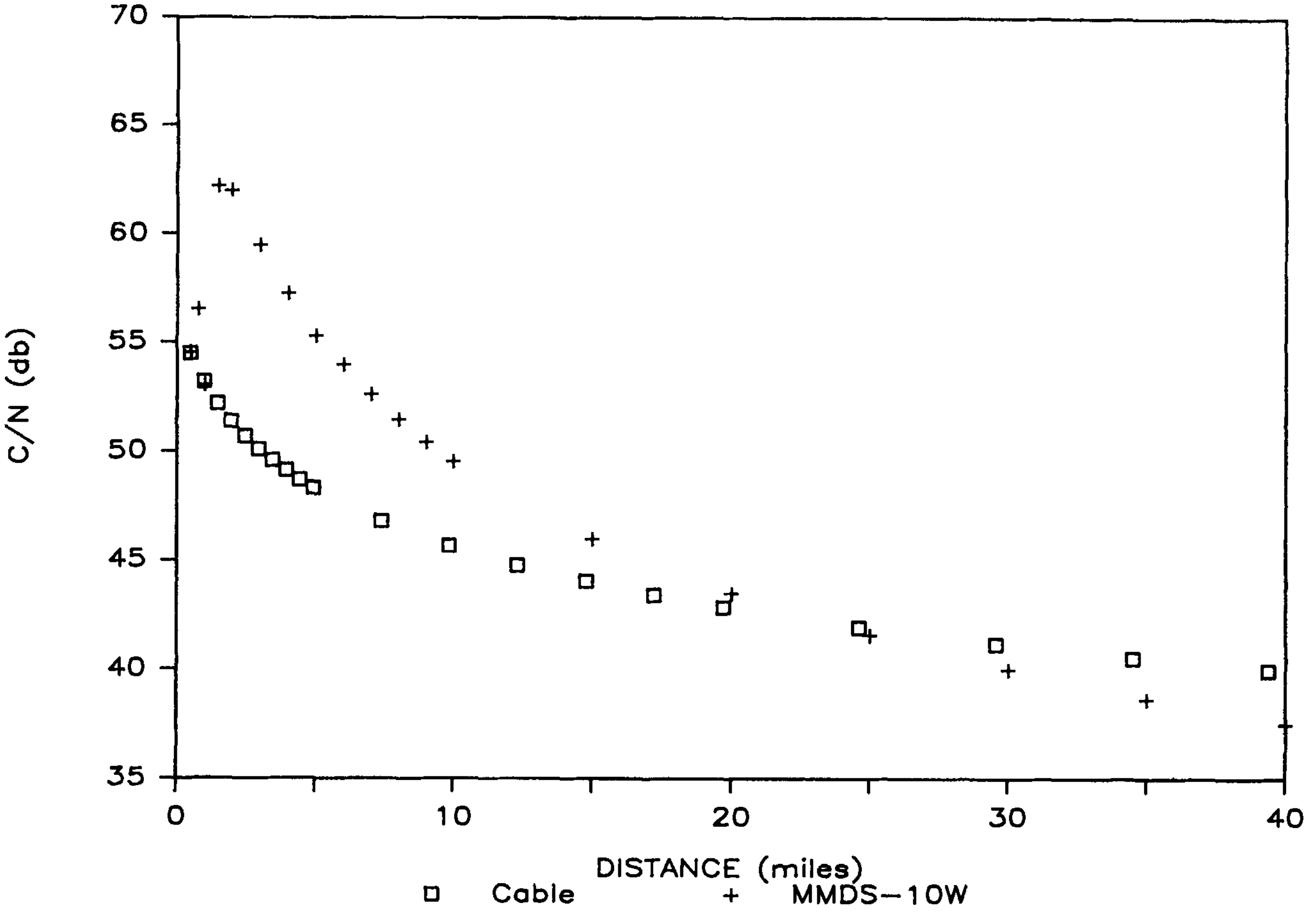

Figure 3. 10 watt MMDS versus cable carrier-to-noise performance.

handling all of the video channels. Cross modulation, intermodulation and composite triple beat worsen through every amplifier. The major contributor to nonlinear distortion products in a cable system are the feeder lines containing the bridger amplifiers and line extenders. These amplifiers typically have 20 to 30 db worse distortion figures than the trunk amplifiers. Because the cable system model used in this comparison contains only two line extenders and one bridger amplifier per trunk amp, the cross modulation calculations result in excellent performance. However, unlike MMDS, distortion products increase as the cable system grows.

MMDS Limitations

As described above,. MMDS can have significant performance advantages over cable. However, there are limitations placed on MMDS because it is an over-the-air technology. Because of the transmission frequencies (2.1 to 2.7 GHz), MMDS is essentially a line-of-site technology. Receive sites with totally or partially obstructed views of the transmitting antenna may have tremendous variations in received signal strength. Receive sites surrounded by foliage may experience large signal level fluctuations as the seasons change. It is essential to insure clear line-of-site between transmit and receive sites in order to obtain consistent performance at all times.

However, these problems with terrain and obstructions can be managed. There are signal strength contour studies available which will predict the amount of loss an MMDS operator can expect from terrain. By combining these studies with intuitive reasoning regarding other structures in the propagation area and foliage, an MMDS operator can predict his coverage area very accurately.

OTHER MMDS ADVANTAGES

Not only can MMDS offer performance advantages over cable, but also increased system reliability. Since there is no closed distribution system and no large cable plant to maintain, the only equipment reliability concerns exist at the transmit site and the subscriber's home. Also, the current design trend for MMDS transmitting equipment is away from tube technology and towards solid state devices. Solid state technology is more reliable and less power consuming.

The receive site antenna and downconverter are designed to reside on the subscriber's roof and provide excellent reliability in a variety of weather conditions. However, the potential weak link in the receive site installation can be the interconnections from the downconverter to the antenna and into the subscriber's home. Care must be taken to insure all connections are sealed and weather tight. The ingress of moisture into these interconnections can have considerable impact on received signal quality.

Other significant MMDS advantages include the speed at which a system can be built. Once transmit site construction begins, it is not unusual to be ready to install subscribers in a 1 to 3 month time frame anywhere in the potential coverage area. This is significantly better than the typical cable start-up times. Also, there is significantly less up-front cash needed to start a system as the major cost comes from subscriber equipment, not transmission equipment or plant.

BELLS AND WHISTLES

Transmission and reception equipment currently available to MMDS operators offers many of the cable system operational features and more. Signal security, addressability, stereo compatibility and spectrum space for ancillary data services are all available in MMDS.

From a security standpoint, both audio and video scrambling techniques are available. Current techniques consist of video inversion, sync suppression, bandwidth compression and combinations of these.

Addressability is performed through the use of in-band data transmission. Current techniques involve transmission in either the video or audio paths. Along with addressability come features like pay-per-view capability, flexible tiering and combining of programming, channel mapping and increased deterrents to pirating of signals and converters.

Since most MMDS equipment is designed to handle the additional audio bandwidth for BTSC stereo, the system is stereo transparent from the beginning. With the addition of stereo encoders at the transmitter site and decoders in the home, subscribers can enjoy excellent quality stereo sound.

CONCLUSIONS

A well designed and well managed MMDS system can exceed cable system performance in the fundamental areas which significantly impact subscriber satisfaction. Through careful and detailed system design, MMDS can achieve an excellent reputation as a high quality and high performance broadcast service. Also, since MMDS operators do not have an expensive distribution system to maintain, more attention can be paid to customer service and satisfaction. However, it is important for an MMDS operator to understand the technical capabilities and limitations of his system. With this understanding, an MMDS operator can build a successful and profitable business.

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2. John C. Cunningham, "Cable Television", Second Edition, Howard W. Sams & Co., Inc., 1980.

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WIRELESS TV VIEWER RESPONSE

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ABSTRACT

For over 20 years, the cable television industry has sought a cost effective way to retrieve real-time information from the home. Recent laboratory and field tests have demonstrated the suitability of over-the-air radio transmission as an alternative way to received pay-per-view and other data from subscribers' homes. The new system uses bandwidth efficient pulsing to achieve high speed viewer polling, (upwards from 784,000 per minute; nominally 945,000 per minute), without two-way cable or telephone connections. The TV Answer System is currently being tested at Media General Cable in Fairfax, Virginia. In addition, the Federal Communications Commission is considering the allocation of one-half MHZ in the 216 to 222 MHZ band for the use of this new viewer response service. Field tests are now underway to support a petition for formal rulemaking.

THE TV ANSWER SYSTEM

The TV Answer System utilizes a radio transmitter, "the TV Answer Box," in each subscriber's home. The household transmitter is polled via data inserted in the forward video signal, just off screen in the over-scanned television receiver. The first 5 microseconds of each horizontal line are used to transmit one bit. The initial 24 lines identify the polled group and transport other useful information from headend to home unit. The polling bits, plus the horizontal synchronizing pulses, tell the units when to transmit their locally stored data. In each home one bit is transmitted each polling cycle. At one bit per horizontal line, capacity exceeds 900,000 bits per minute. In the present implementation of TV Answer, the vertical interval is avoided, and, allowing for some over-the-air transmission time, 784,000 bits-per-minute capacity is achieved. For simple Yes/No questions like, "Do you wish to watch this movie?" 784,000 homes per minute can be polled. Future generations of the box may allow for multiple pulses per horizontal line. This will allow over 1,000,000 responses per minute.

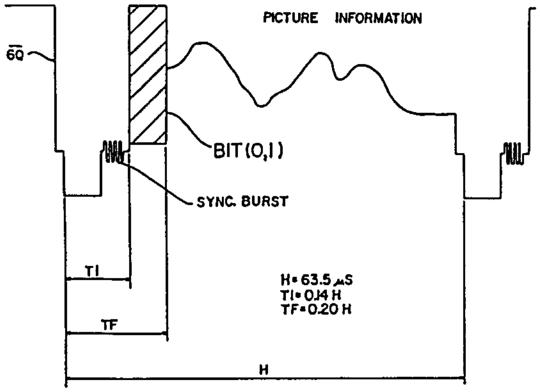


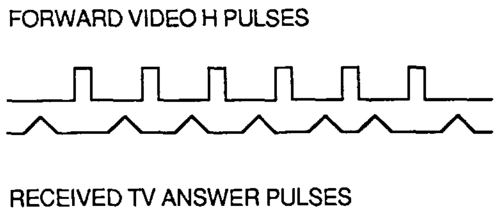
Figure 1 - Location of Forward Addressing Bits

Figure 1, reprinted from Figure 6 of US Patent 4,591,906, shows the location of the forward addressing pulses. The pulses are off-screen on the television receiver. If a receiver were intentionally underscanned, they would appear as a black and white vertical strip on the left side of the screen. Since the data are actually "in the video" (albeit off-screen), the vertical interval is left available for other uses. One disadvantage of this method, presently unstudied, is that horizontal timing information must be available to address the home unit. This means that, at the present at least, the TV Answer addressing channel cannot be scrambled. In the Media General test situation, an unscrambled "ordering channel" is used. In home shopping and direct response situations, as well as opinion polls, games or educational uses, this poses no problem. If an ordering channel is not available because channel space is tight, an ordering interval, with unscrambled video might be used. To address the TV Answer Box, a 5 to 15 minute unscrambled period might be necessary, for example, before a movie or event. This problem will be studied further as the product is developed.

The return pulses are timed to reach the central computer located at the headend or studio in a continuous stream. Boxes more distant from the receive antenna anticipate the delay and launch their pulses early. A numerical value proportional to the delay is stored in each box during a "calibration cycle". This cycle corrects for the delays of the forward transmission system as well as the return pulse transmission time.

Figure 2 shows the normal transmission system as seen at the central receiving point: a continuous stream of pulses, synchronized by the forward video horizontal "sync."

FIGURE 2 - RECEIVED PULSE SYNCHRONIZATION

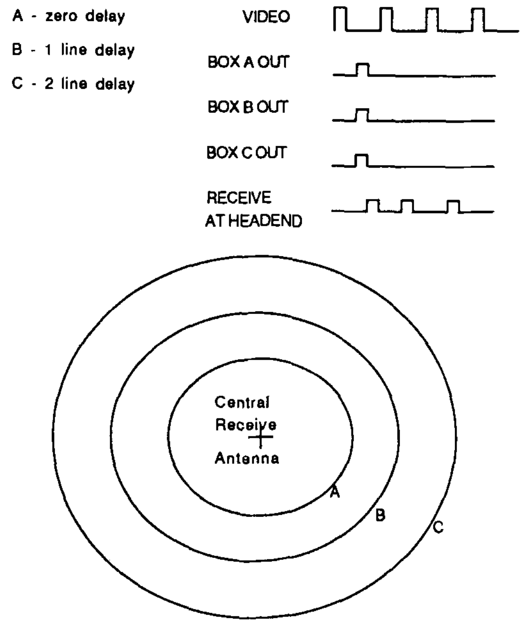


During the calibration mode, 5 horizontal lines are left unused after each request for a poll. Each unit, then, has 5 times 63 microseconds, i.e. 315 microseconds, in which to respond. When the pulse is received, the value of the delay is sent to the home unit for local storage. Thus, if a distant location takes 300 microseconds to respond, the TV Answer Box will transmit 300 microseconds early in order to arrive at the central antenna at the proper time. A close-in box would transmit with nearly zero delay. Figure 3, illustrates this point. If one unit in each zone transmits at the same instant, pulses would arrive as a continuous stream at the central antenna. The calibration cycle takes 5 times as long as a normal cycle. Figure 4 shows the calibration cycle. Figure 5 shows the normal cycle. Note the 5 blank lines before the first box response is received. This allows that unit to be at the farthest extreme in the transmission area. The calibration cycle can be run as often as necessary when questions are not being asked.

The home units are grouped 200 at a time. The addressing can reach all 200 boxes at once with one address. Each unit then begins counting horizontal synchronizing pulses to know when to transmit. In the present configuration, 4 bits are stored locally. Thus, a question, could have 4 multiple choice answers, and four cycles would be needed to get all the information. The forward bits also tell when a question is being asked, and communicate when to clear memory. The home unit will only transmit when a question is asked from the headend.

Multiple channels can share the same return frequency by coordinating the timing of the retrieval of pulses. Since the forward polling is through the video, only the boxes watching the channel that is asking questions will respond. Computer software is being developed to coordinate the forward pulse insertion, and data retrieval process.

FIGURE 3 - DELAY FROM HOME TRANSMITTERS



PROPAGATION ISSUES

The forward signalling system over a cable system or over-the-air is relatively controlled and predictable. The return signal is severely attenuated in the return journey as a result of man-made structures and natural terrain. The receive antenna must be able to distinguish the pulse from man-made and natural noise. While the propagation concerns seem to require the largest transmitter possible, interference issues require a suitable frequency which will not interfere with existing services, yet allow an economically efficient transmitter.

Efforts so far have concentrated on 216.25, 218.25, and 220.25 MHz. These frequencies were chosen because they are presently underutilized due to potential interference to Channel 13. They also allow construction of a reasonably priced in-home transmitter.

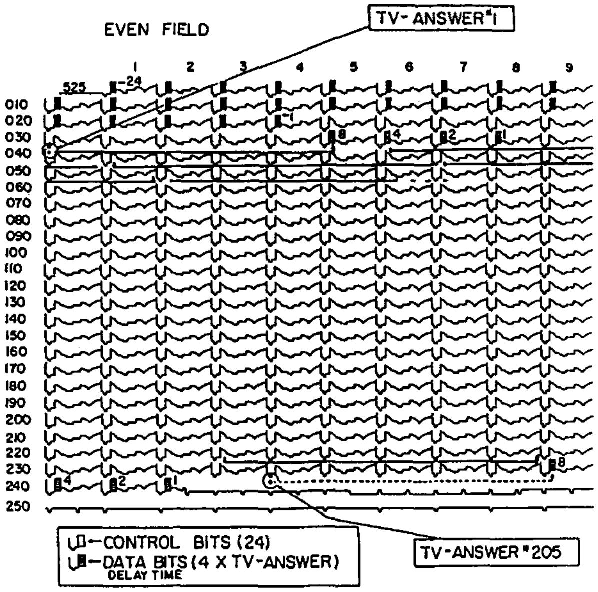


FIGURE 4 - CALIBRATION CYCLE

Pulses received within 5 line window at headend depending on transmission time.

TECHNICAL TESTS

The shaping and random nature of TV Answer's pulses lend themselves to a statistical analysis of interference. Present testing is intended to measure the effects of these pulses in television receivers, and model the potential problems. Two of the major tests presently underway are:

1. An analysis of the susceptibility of television receivers to interference at 216.25, 218.25 and 220.25 MHz., and,

2. Measurements of the time average power delivered by actual units in subscriber's homes spread across a geographic area.

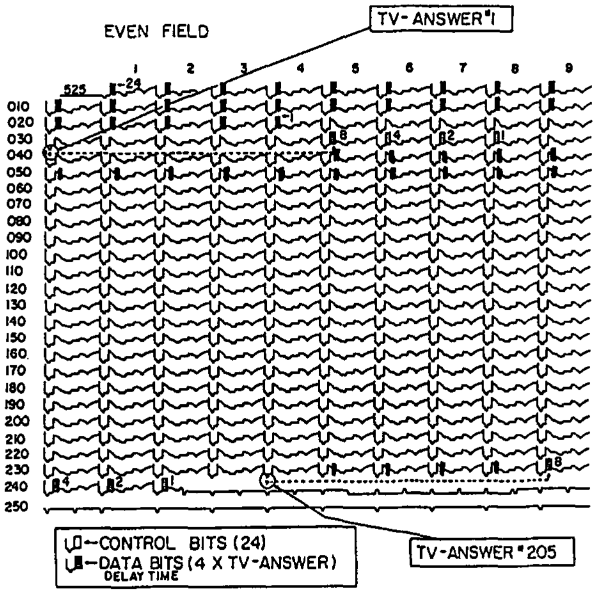


FIGURE 5 - QUESTION CYCLE

Pulses received every video line at headend

BACKGROUND

The 216-220 MHz. band is presently underutilized due to potential interference to Channel 13. The rules for creating a band for "Viewer Response Television" require an engineering determination of the potential for interference.

Figure 6 shows the parts of a transmission model for exploring the potential for interference.

Measurements of the susceptibility to interference to television receivers were performed in 1975, (see Reference #4). TV Answer has repeated these tests on 30 modern receivers for both CW and the actual TV Answer pulses using the equipment shown in Figure 7. A second test involves placing TV Answer Boxes in homes and measuring the accumulated power from a cluster of homes over time. Each unit transmits in its own time slot, only one pulse at a time is launched. However, pulses are launched to reach the headend one horizontal

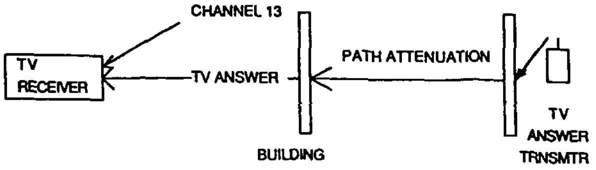
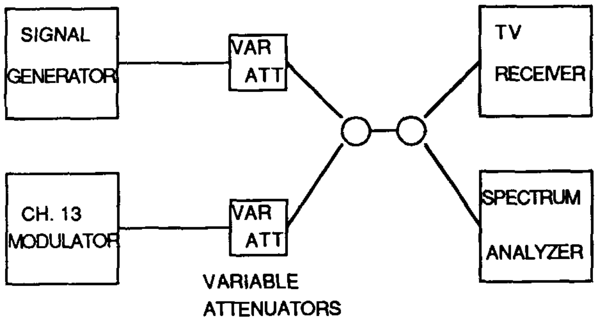


FIGURE 6 - INTERFERENCE TRANSMISSION

line apart. The more distant pulses are transmitted to overcome the delay in getting back to the headend. The transmit antenna is omni-directional and signals radiate outward in concentric circles. At any point in the system pulses may converge in or out of phase in a random pattern. Not all of the units transmit on every cycle. Interference then must be statistically modeled.

TV Interference was measured at three frequencies: 216.25, 218.25 and 220.25 MHz. The visually displayed pattern varied from TV receiver to receiver. TV receivers were generally more affected by 216.25 than 218.25 or 220.25, as expected. Additionally, the effects of 220.25 MHz (2 times 4.5 MHz above Channel 13's picture carrier.) on sound and AFC were observed in TV receivers using 4.5 MHz. internally. For these functions, the receivers was often confused by the 4.5 MHz beat between the interfering signal and sound.

FIGURE 7 - TV SUSCEPTIBILITY MEASUREMENTS



CENTRAL RECEIVING ANTENNA

The centralized receiving point must be able to receive levels down to about -90 dBm, based on preliminary path calculations and actual measurements. The economics favor improvements at the one receiver rather than the many transmitters.

This type of reception array problem should not be new to any cable television engineer. We need to find a low level pulse above man-made and natural noise near Channel 13. The present receive configuration consists of a +10 dB gain , 215-225 Mhz. whip antenna, 300' of cable, a 30 dB pre-amplifier, a 1 MHz wide cavity filter, and a communications receiver with a 200 KHz IF bandwidth. The overall configuration will detect signals down to a signal-to-noise of +10 dB above the receive equipment noise floor of -116 dBm .

FCC PROCEEDURES

In 1987, TV Answer Inc. began field testing under controlled conditions, to develop a feasible transmit/receive configuration using a temporary license granted by the Federal Communications Commission. In December 1987, we petitioned the FCC to begin a formal rulemaking on the permanent allocation of one-half Mhz, nation wide, to support "viewer response" television. As of the publication of this paper, the FCC is still deciding whether to begin that formal rulemaking.

One-half Mhz. seems a small amount of spectrum to allocate in order to achieve something that has been talked about for over 20 years, but never before accomplished. In various forms, two-way cable and telephone interconnection have produced disappointing attempts to give the public an ability to interact with television programming. Wireless transmission offers a solution to the problems other technologies have been unable to overcome.

TV Answer continues to test and develop its product, and work with industry and government to document the utility of the "Viewer Response" electromagnetic band.

Mr. Dattner is President of DAI, a Telecommunications Engineering Firm, and a Senior Engineering Consultant to TV Answer Inc. of McLean, Virginia. He has 17 years experience in cable television including Media General Cable of Fairfax, Virginia and a major cable television manufacturer. He has a Masters degree in System Engineering and is working on a Masters degree in Business Administration.

Note: Due to publishing deadlines, this paper does not contain the results of field tests presently (March, April 1988) being conducted. For more information contact the author or TV Answer, Inc., 8201 Greensboro Drive, McLean Virginia, 22102, (703) 356-7800.

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2. Federal Communications Commission, Third Notice of Further Proposed Rulemaking, "Television Broadcast Services," Federal Register, Vol. 16, No. 68, Page 3072, U.S. Government Printing Office, Washington, D.C., April 7, 1951.

3. Goldberg, Henry and Jeffrey H. Olson. "Petition for Rulemaking". In the Matter of TV Answer inc., before the Federal Communications Commission:", Washington, D.C. December 2, 1987.

4. L. Middlekamp, H. Davis, "Interference to TV Channels 11 and 13 from Transmitters Operating at 216-225 MHz., FCC Lab Division Report, Project No. 2229-71, Oct. 1975.

5. United States Patent 4,591,906, issued May 27, 1986.

APPENDIX

(This section is based on "Guidance for Evaluating the Potential Interference to T V From Stations of Inland Waterways Communications Systems," by R. Eckert, OST Technical Memorandum, FCC/OST TM82-5, July 1982.)

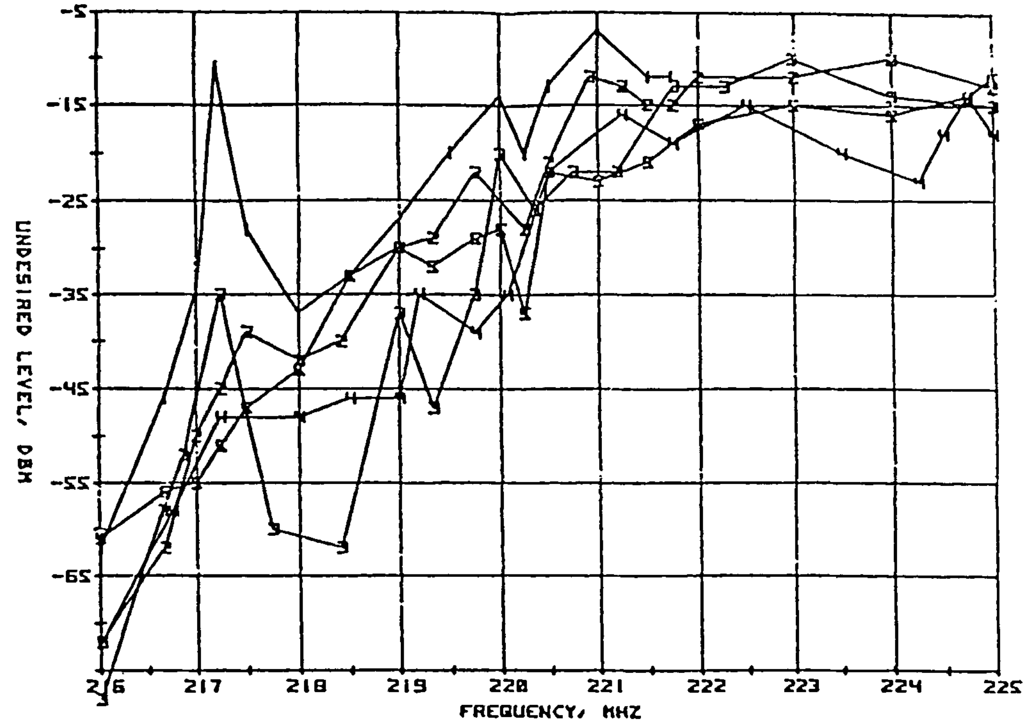


Figure 8 - CW Interference Susceptibility
(See Reference 4)

One important factor in the decision by the Federal Communications Commission to create a "viewer response" radio band, or not, will be the susceptibility of television receivers to interference at 216.25, 218.25, or 220.25 MHz.

A review of the FCC's bench test (see the data in Reference #4, reproduced here) produces the following minimum ratios for an input level of -65 dBm:

Protection Ratios (dB) for Just Perceptible Interference

Frequency	Desired to Undesired Signal Ratio
216.25 MHz.	+ 5 dB
218.25 MHz.	-15 dB
220.25 MHz.	-25 dB

These ratios are for CW signals on a small sample of receivers (5). The ratio chosen is for the most susceptible receiver. TV Answer is presently compiling data on receivers and the effects of the TV Answer shaped pulses.

To identify possible interference, it is necessary to statistically account for the time variation of the desired Channel13 signal and the undesired pulses. A log-normal distribution is assumed to account for terrain variations. In the analysis below, the objective is to determine the percentage of locations, L, at which there will be interference free reception T % of the time.

The desired condition of no interference occurs when the ratio of wanted to unwanted signals is better than the barely perceptible ratio in the chart above. Figure 19 of the FCC Report predicts the signal level for 50 % of the Television Receivers, 50 % of the time, F (50,50), based on antenna heights and distance. Figure 20 of the same report gives analogous data for 50 % of the Television Receivers, 10 % of the time, F (50,10). A fading ratio can be calculated from subtracting the two curves. These three curves are reproduced in Reference #1, and on the next three pages. Variability of the signal is accounted for by using a log-normal distribution with a standard deviation of 8.6 dB. This means that there is a 90% chance that signal variations will be as large as 11 dB.

To combine the fading factors of the desired and undesired signals, the square root of the sum of the squares is used, based on the assumption of uncorrelated distributions.

The percentage of homes, L, at which there will be no perceptible interference can be determined from the following equation:

$$R(L,G) = A + P_u - P_d + F_u(50,50) - F_d(50,50) + \sqrt{R_d^2(T) + R_u^2(T)}$$

where,

A = Minimum acceptable desired to undesired ratio in dB between the fields.

$R_d(T) = F_d(50,T) - F_d(50,50)$, depth of fading in dB

$R_u(T) = F_u(50,T) - F_u(50,50)$, depth of fading in dB

$\sqrt{R_d^2(T) + R_u^2(T)}$ -- Variation with time combination in dB

P_u = Undesired, pulse - effective radiated power in dB above 1 kilowatt radiated from a half-wave dipole,

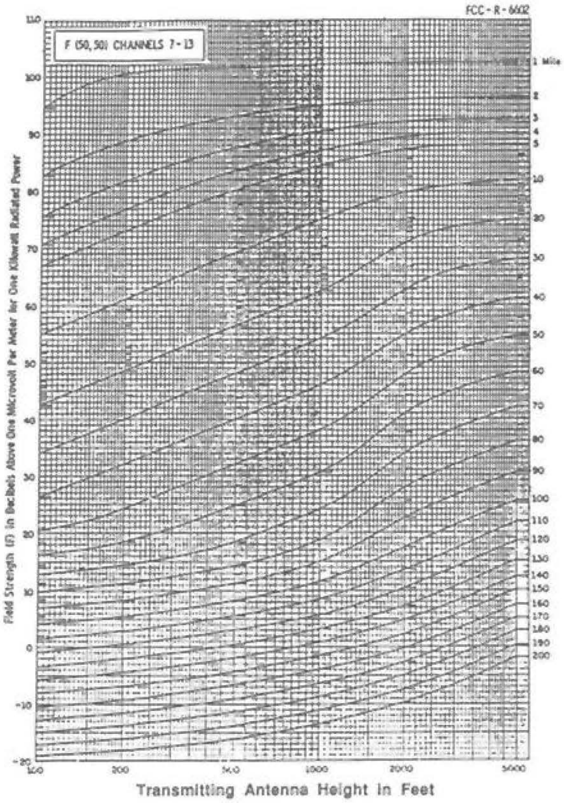
P_d = Desired (Channel 13) signal, effective radiated power in dB above 1 kilowatt radiated from a half-wave dipole,

$F(50,T)$ is in units of dB(uV/m),

$G = F_d(50,T) - F_s$,

where F_s = the minimum TV Field strength for service.

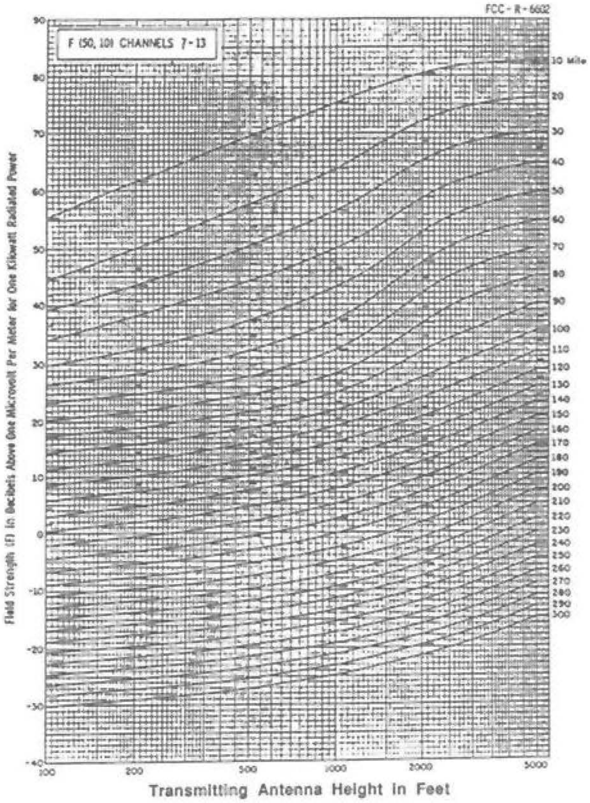
By applying the distributions of F_d and F_u, it is possible to create a graph of potential interference based on distance and antenna heights. Figure C-1 from Reference #1 is reproduced here to give an example of potential interference area calculations. The TV Answer task is complicated by the inclusion of losses created by man-made objects as well.



Television Channels 7 - 13
Estimated Field Strength Exceeded at 50 Percent
of the Potential Reciver Locations for at Least 50 Percent
of the Time at a Receiving Antenna Height of 30 Feet

April 12, 1966

Figure 19



Television Channels 7 - 13
Estimated Field Strength Exceeded at 50 Percent
of the Potential Receiver Locations for at Least 10 Percent
of the Time at a Receiving Antenna Height of 30 Feet

April 12, 1966

Figure 20

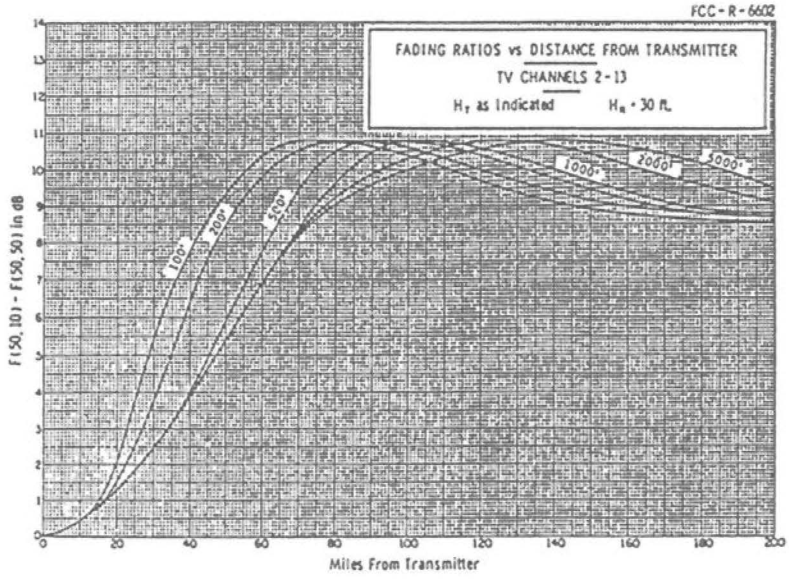
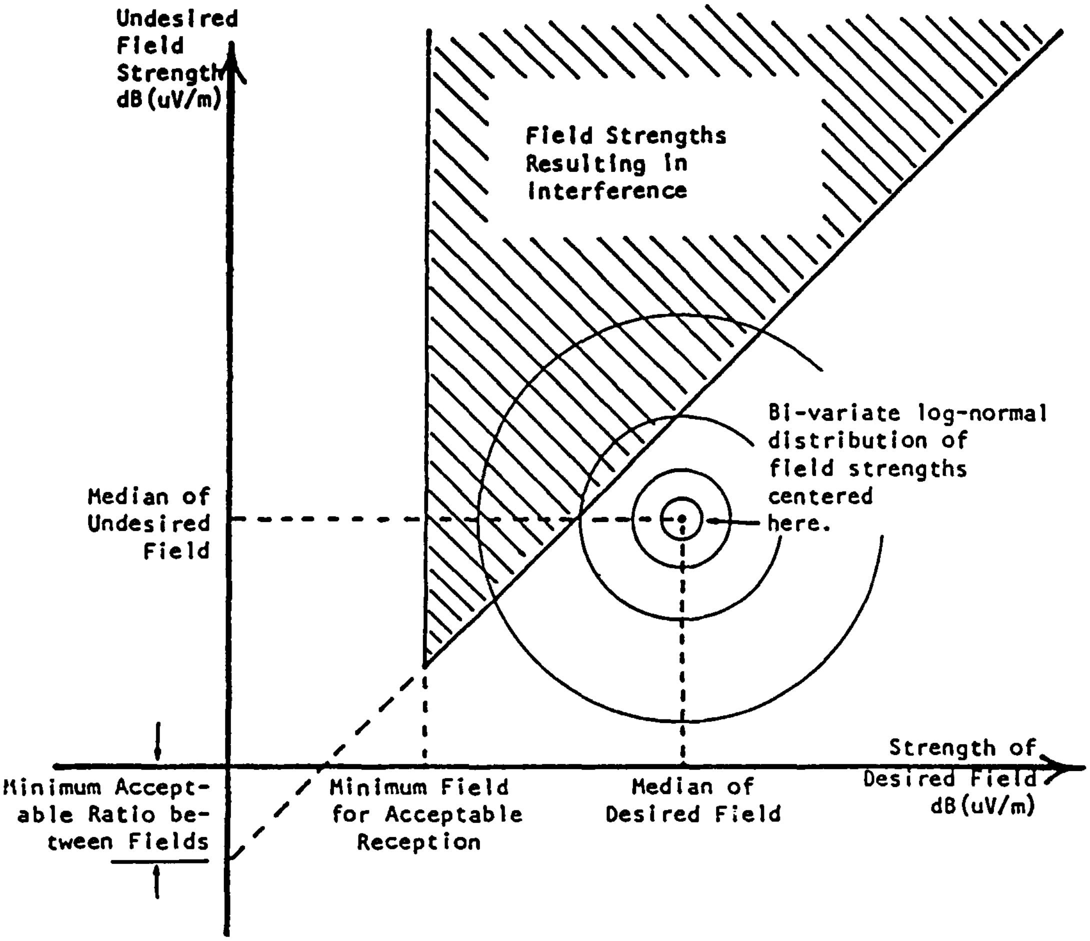


FIGURE 10



GRAPHICAL ANALYSIS OF RECEPTION AND INTERFERENCE CONDITIONS

FIGURE C-1

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