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A BROADBAND NETWORK STATUS MONITORING SYSTEM USING MULTIPLE PROCESSORS

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MANITOBA TELEPHONE SYSTEM

ABSTRACT

A hardware and software system capable of monitoring up to ten Cable TV networks is discussed. The use of multiple processors in combination with a real time multi-tasking operating system allows rapid detection and analysis of network faults. In addition to the reporting of catastrophic failures, amplifier alarm and analog data converted to digital are obtained and placed into a memory resident database during normal polling. Monitoring a Cable TV trunk presents a unique challenge due to the fact that the facility itself is used to carry monitoring communication. During partial network failures, reliable monitoring communication may not be possible. This system provides failsafe measures to minimize uncertainty during failure conditions. A communication problem is not allowed to affect all stations in the system because of the separate hardware ports and software tasks that accomodate each trunk.

INTRODUCTION

Manitoba Telephone System (MTS) has four Intercity Broadband Network (ICBN) trunks in place which facilitate the transmission of CATV, broadcast, and teleconference services between some of the major centres within Manitoba. Service areas are widely separated, both in terms of travelling distance and the number of active components. Status monitoring has therefore been essential in order to achieve acceptable availability.

The addressing capability of the original status monitoring system installed by Manitoba Telephone System was limited to 255 stations. The ICBN expanded and the small expansion capability was quickly lost. This was one of the limitations which prompted MTS to consider up-grading the central computer system while utilizing the existing transponders which were supplied with the Century III amplifier stations. Other limitations were that the system was single tasking, could only support one user terminal, and did not provide flexible alarm point usage.

Manitoba Telephone System issued a specification for a new status monitoring computer system and interface. The basic concept of the new system was to provide separate interfaces to each trunk (up to 10) and use these to communicate with a master computer. Quotations were received for two general design strategies. One was that the trunk interfaces would connect to a minicomputer via RS232C interfaces. The second design was that of a micro computer system that avoided the serial interface by including all interfaces in one custom system. This design was proposed by a Canadian computer supplier and accepted by MTS because of the inherent cost savings.

The system described in this paper is now operational with the exception of some software enhancements. The focus of this paper will be to identify and describe the key features of this system, especially with respect to large capacity operation, while avoiding a complete feature by feature description.

SYSTEM OVERVIEW

Maintainability of CATV trunks can be greatly enhanced by providing a central status monitor. A reasonable framework of requirements for a status monitor can be developed from the following functions:

1) Minimize length of time required to locate the cause of catastrophic failures.

2) Continuously monitor key performance indicators such as pilot levels.

3) Provide early warning of possible failures so that corrective action can be taken.

The ability of the system to locate the extent of catastrophic failures is vitally important, but ironically is usually the least frequently used feature of a status monitoring system. A key feature of the MTS broadband network status monitoring system is its ability to pre-process the alarm conditions that result when there is an outage. The desired output to the user specifies a synopsis in compressed form which will indicate possible failure causes whenever practical.

Communication to and from the amplifier stations is facilitated by data modulation of a forward trunk carrier and a keyed reverse trunk carrier. The data format for this system is a 300 bit/second Kansas City FSK standard which equates 1200 Hz to a binary 0 and 2400 Hz to a binary 1. The information sent from the computer to the transponders consists of an address byte, switch control information bits, and an 8 bit cyclic redundancy check byte. The format of this information is shown below in Figure 1.

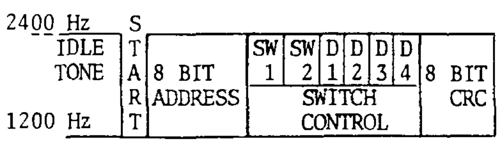

Figure 1. INTERROGATE WORD (23 BITS)

The transponder will reply to an interrogate if its own address matches that received, and the calculated CRC indicates that there were no transmission errors. The data returned consists of an address byte for confirmation, 4 byte values resulting from analog to digital conversion of 4 inputs, 4 binary bits indicating the status of internal or external alarms, 6 binary bits indicating switch settings, and a CRC byte. This is illustrated in Figure 2 below.

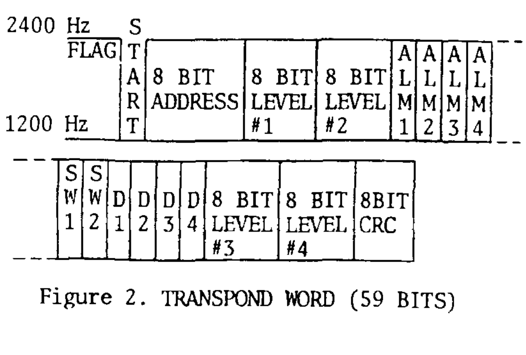

Figure 2. TRANSPOND WORD (59 BITS)

The diagram below provides an illustration of timing for the entire interrogation cycle.

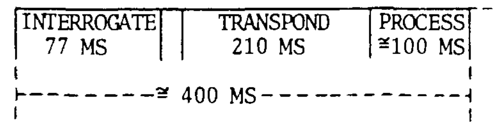

Figure 3. OVERALL INTERROGATION CYCLE

The user interface was specified to be as flexible as possible by the use of RS232C data ports. The ports are categorized as follows:

- Two dedicated work station terminals with associated alarm printers.
- Two dial-in work station ports for remote access to display screens.
- Two dial-out ports for access to remote signal level meters.
- One interface to another computer system responsible for overview graphics.

The status monitoring system is now equipped with 7 processor boards which run on an Intel Multibus. This allows the connection of 10 trunks to the system, each of which may contain up to 255 stations. A memory capacity of 1 Mb is provided. Non-volatile mass storage consists of a 35 Mb winchester drive and a cartridge tape which can store about 6 Mb. Both of these are used to store historical data from the system.

MULTIPLE TRUNK CONSIDERATIONS

There are two approaches that can be taken when multiple trunks must be monitored by a status monitor. The simplest and least expensive is to share one RF data modem with more than one trunk. This may not always be possible if the head-ends are separated, and also there is the inconvenience of level adjustments affecting the forward RF level on more than one trunk. Another method is to split and combine the transmit data and receive data respectively before modulation. This requires additional RF modems.

Both of the above methods were used by MTS before installation of the new monitoring system. As the number of total stations increases, the next logical addressing capability would be based on a 2 byte address. This would have required significant upgrades to existing transponders.

Even if one were to design or re-design transponders with an extended addressing capability, other pitfalls limit the practical size of the "one data I/O port" system. If the data speed is low, stations will be polled less frequently than desirable. The time to poll all stations for an arbitrary system of 1500 transponders at 400 ms per cycle would be 10 minutes. This assumes that all stations are scanned with equal frequency. It may be desirable to have certain stations such as end stations scanned more often. This will further lengthen the overall turn-around time.

Increasing the data rate normally means that the immunity to noise will decrease according to (1) assuming optimum design of modem characteristics for each case.

Immunity change = -10 log (new rate/Ref rate) (1)

A further limit exists when attempting to speed up the polling process. This is the processing time required after each poll. As more sophisticated alarm checking features are added, the processing time increases until at some point it becomes the dominant source of delay. The MTS status monitoring system requires approximately 100 ms for this overhead.

The above problems can be overcome by sharing the work load of normal polling among multiple I/O ports and processors. This solution maintained compatibility with existing transponders for the MTS system. A further advantage of splitting up the trunks for monitoring exists whenever a serious transmission impairment develops on a particular trunk. If this impairment prevents data transmission, only that trunk will be affected since the other trunks are physically separated.

OPERATING SYSTEM AND LANGUAGE

The status monitoring system includes both event driven functions and time driven functions. Event driven functions include the reporting of alarms as they occur and user access to informational screens. Time driven functions are required to handle storage of hourly and daily historical data and also to co-ordinate polling of remote signal level meters. The timing of the various functions is asynchronous in nature. This requires the use of a multi-tasking operating system. This system has 21 application tasks, excluding scanning tasks and operating system tasks. A useful feature is the ability to specify different priorities for different tasks. For example, the tasks that are responsible for generating alarm messages have a higher priority than those responsible for storing historical data to cartridge tape.

Flexible usage of memory is an important consideration, as many software tasks require extra memory only temporarily during certain functions. If all memory was allocated statically, additional hardware memory would be needed. Advantage can also be taken of the fact that not every trunk will contain the limit of 255 stations. The data-base for each trunk must reside in memory at all times. By locating each data-base dynamically, efficient use can be made of the pool of free memory.

The operating system used for the MTS status monitoring system is the Intel iRMX 86 object oriented operating system. The usual programming language for applications using this operating system is PL/M 86. A programming language for an application of this size must be geared toward high level modular style, for maintainability, and yet also allow some of the low level bit manipulation functions normally only present in assembly language. The ability to create large programs without overlays is also a desirable feature. One of the application modules in the system has in excess of 90K of object code.

SYSTEM ORGANIZATION

Processing responsibilities in the status monitoring system are divided between one master processor and six slave processors. Each of these processors (Intel 8088) interface with the multibus and have access to all of the main RAM memory. The master processor handles file accessing and the high level application tasks, while the slave processors provide I/O drivers for user ports and carry out the routine amplifier polling functions. A block diagram of the system is shown in Figure 4.

Each processor board contains EPROM memory of between 16K and 64K. The master processor uses its EPROM memory to automatically bootstrap load the monitoring system software. The slave processors use their EPROM code extensively even after system startup. The EPROM code and 4K of local RAM for each slave processor is not accessible by any other processor and does not require access to the multibus. This is an important advantage in that bus contention is minimized.

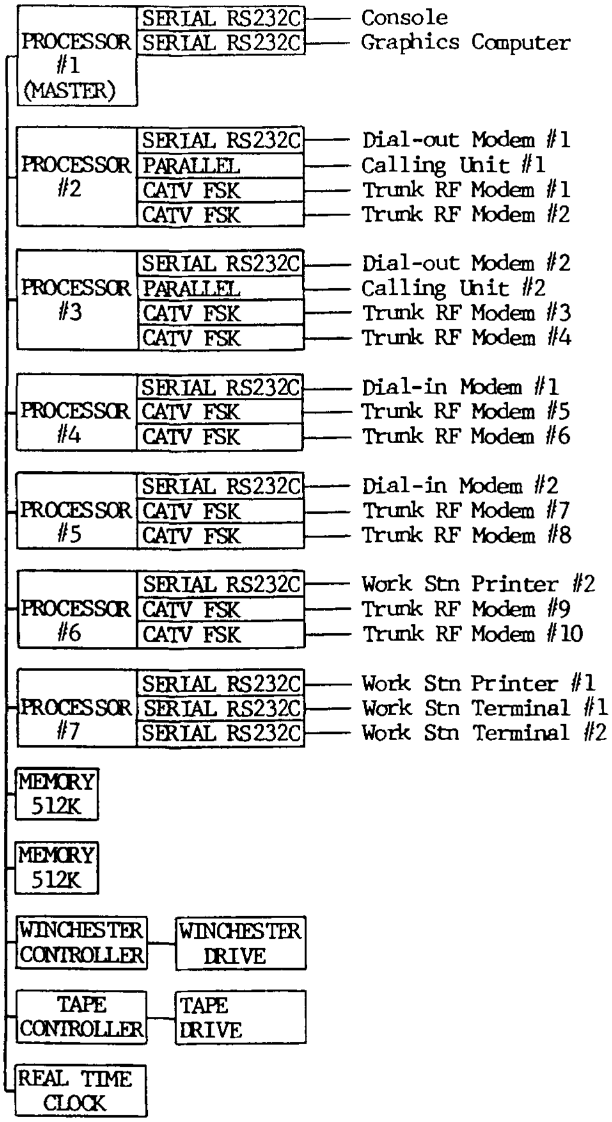

Fig. 4 - SYSTEM BLOCK DIAGRAM

Each processor runs its own local operating system, which except for one slave, includes multi-tasking features.

Tasks running on the master processor communicate with slave processor tasks via a custom operating system extension written by the supplier.

Scanning functions are facilitated by 5 of the slave processors. There are 2 intelligent scanning interfaces attached to each of these 5 slave processor boards. These are the interfaces that provide the Kansas City standard input and output data to the external RF modems. These interfaces each contain an 8 bit single chip micro-computer. Timing of the data for transmit and receive is accomplished by these interfaces. Each scanning board handles two interfaces and therefore two trunks by the use of separate tasks.

Scanning takes place with no intervention from the master computer other than instructions to start a particular scanning mode. The scanning firmware interacts with the memory resident data-base directly. The data-base is updated when valid data is received and new data is compared to alarm limits and alarm flags to determine if there is a change of alarm state. If a change of alarm state is detected, the scanning task will send an appropriate message to the master processor alarm task where it will be processed.

Each processor requires a certain amount of memory for its exclusive use. In this system the top 256K of memory is allocated for slave processor usage and interprocessor communication usage.

The master processor runs all the high level application tasks and requires a more complete compliment of operating system functional layers. The application software for the master computer can be broken down into four main modules:

1) Alarm generator
2) Work station
3) Background
4) Graphics computer interface.

The alarm generator processes messages sent to it from the scanning processors and issues alarms to the printers. Alarms are also stored in compressed format on a disk file. The alarm generator maintains counts of pending alarms for each section and station of the network.

User access via CRT terminals is provided by the workstation software. There are four user interfaces which have their own jobs and tasks. The work station screens provide overview alarm status during idle conditions and allow detailed viewing of CATV trunk measured parameters when requested.

Background tasks are responsible for storing historical data and for polling of signal level meters which are accessed by dial-up connections.

Each amplifier station has 128 bytes of data allocated in main memory. A compressed version (64 bytes) of each data-base entry is stored on disk files at the end of each hour, and then transferred to cartridge tape daily.

Polling of signal level meters is initiated every 20 minutes for the MTS status monitoring system. The software is designed to be compatible with Wavetek Sam IIID and Sam IV signal level meters. This software is currently being used to generate alarms when head-end television carrier levels exceed maintenance limits.

The graphics computer interface is a specific custom application used by MTS to integrate the Broadband Status Monitoring System with other alarm reporting systems. Its functions include sending change of alarm state messages and providing overall dumps of the status of a group of alarm points.

The above main modules are linked separately and are only bound together as an entire application by the operating system at run time. Approximately 256K memory is required for the entire operating system with application software. This does not include dynamic memory requirements such as task stacks and extra data segments. Dynamic memory of about 512K is available for these requirements as well as for the trunk data-bases.

SCANNING MODES

There are three types of scanning sequences used in the MTS status monitoring system.

1. Normal mode
2. Maintenance mode
3. Special purpose.

Any or all of these modes may be active at a particular time on a trunk. The scanning tasks are responsible for the sequencing of station polling in a manner that allows each mode shared access to the trunk.

Normal mode scanning is usually enabled continuously since this is the mode that checks the status of the network and generates alarms for out of limit conditions. The normal scanning sequence for this system consists of polling stations in two lists. The first list simply includes all stations of a trunk and the second is a subset of the first which consists of "priority" stations. Station polls alternate between these two lists resulting in two continuous scanning loops. Stations chosen as "priority" normally include the end stations of each trunk a well as stations that report critical alarms such as power supply alarms. This permits very rapid detection of outages and of selected critical alarms.

Maintenance mode scanning is invoked in response to an operator request to view the status of a single station. The same station is repeatedly polled and the data-base updated so that changes will be visible on the operators CRT terminal. Alarms are not generated by this mode.

Special purpose scanning includes functions such as amplifier balance checks and bridger switching. The Intercity Broadband Network in MTS uses feed-forward amplifiers. One of the useful features of feed-forward amplifiers, aside from their improved distortion performance, is their inherent redundancy. The main RF hybrid IC and the error RF hybrid IC must both fail before there is a loss of service. This feature is lost if an IC quietly fails and does not reveal any clues. Performance will only suffer noticeably when a significant number of stations have this problem.

The amplifier balance check modulates the power supply voltages of each of the RF hybrid IC's in a feed-forward station in a sequence. Balancing in a correctly functioning feed-forward stage minimizes the effect of this simulated impairment. Above normal modulation of a system carrier will be measurable, at the end of the trunk, during part of the sequence if one of the IC's is not functioning. This sequence can be performed manually using a spectrum analyzer at the end of the trunk or automatically if suitable detectors (performance monitors) are interfaced to system compatible transponder modules. The scanning firmware will update the data-base, and generate applicable alarms, if a "performance monitor" is used.

Bridger switching is one of the features that is yet to be implemented on this system. This also requires control information to be sent to the transponders. Its use is in locating the source of reverse trunk interference. This is accomplished by systematically switching off one reverse distribution leg at a time, under computer control, and noting when the interference changes at the head-end. Alternatively, the switches may be set up so that each leg is only attenuated (eg. 6 db) rather than completely cut off. Software or firmware could be designed to minimize operator input when a large number of switches are involved.

All of the scanning modes described perform integrity checks on the incoming data. If these checks conclude that errors may have occurred, then no action is taken other than to increment error counts for the station and trunks involved. The two checks are known as the cyclic redundancy check (CRC) and the station ID check.

The cyclic redundancy check used on the MTS system is an 8 bit CRC with a divisor polynomial of $X^8 + 1$. This check greatly minimizes the probability that random data will be interpreted as a correct transpond. This would normally occur about once in every 256 polls for completely random input data such as would be present with incoming noise without actual transponds. This is where the station ID check further reduces the probability of bad data being accepted. If the station address information received in the incoming transpond word does not match the station address that was requested in the interrogate, the data is rejected.

The above checking does have some limitations when data is received that is only partially corrupted. This occurs because the $X^8 + 1$ CRC polynomial has reduced performance when dealing with two errors in a transpond word. If two errors exist there is about 1 chance in 8 that the CRC will indicate correct data! The station ID will often still be intact in the case of only 2 errors within the entire transpond. Fortunately, this problem can be greatly reduced by choosing a more suitable 8 bit CRC polynomial. The use of a 16 bit CRC would render this problem insignificant, but might be too difficult to change on an existing system.

FAILURE REPORTING

Failures in this context refer to complete losses of service on part of a CATV trunk. The MTS Intercity Broadband Network imposed a challenge with respect to localizing this type of failure. The longest trunk monitored by the system is a straight line trunk consisting of 122 amplifier stations. The reverse trunk is regulated by AGC using a pilot originating at the end of the trunk. If a break occurs in the cable near the end of the trunk, the effect of all AGC stations back toward the head-end raises residual noise to high levels. For long trunks this build up is limited at the point where the AGC detectors determine that the noise level within the detector bandwidth is equal to the normal carrier level.

Normal interrogation cannot separate transponding stations from not transponding stations if CRC errors occur when polling stations before and after the discontinuity. In marginal cases extra interrogates could be attempted to provide statistically significant differences. This would slow down the fault locate process. The fault locating sequence on this system starts at the end of the trunk and works back toward the head-end until a transponding station is found. A more reliable method of determining transpond status was required to maximize speed and accuracy of this process.

A CRC error will usually be reported if there are any errors present in the incoming data. A more noise immune method of detecting the presence of the FSK data was developed specifically for fault locating purposes. This method uses the incoming 1200 Hz and 2400 Hz information directly rather than the 300 bps data. The coherent nature of this signal is utilized by digitally averaging the sliced FSK signal. The length of one cycle of the 1200 Hz tone is averaged 64 times. This cycle length or frame consists of 12 increments. The maximum value for each count is 64 and the minimum is 0. The maximum value is compared with the minimum value to determine if actual FSK tones are present. Examples of the results of this test are shown in Table 1. The absolute phase of the tones, at the beginning of the test, need not be zero as it is in the examples. Minimum drift and coherency, however, are essential requirements.

00	01	02	03	04	05	06	07	08	09	10	11	
64	64	64	64	64	64	64	0	0	0	0	0	1200 Hz only
64	64	64	0	0	0	64	64	64	0	0	0	2400 Hz only
64	64	64	32	32	32	32	32	32	0	0	0	1200/2400 Hz
56	53	57	29	34	31	32	30	33	13	10	15	1200/2400 Hz with noise

Table 1 - FSK DATA EXAMPLES

This test is performed in real time by the interface module firmware. It can be shown that if this test is performed 3 times during the transpond interval and suitable (max - min) thresholds are chosen for pass/fail, the following comparison can be made with the normal transpond method.

Probability of "noise only" being interpreted as data:

NOTE: $\text{Log}_{10}(p)$ is shown.

Normal method	-4.8 (ideal case/worst case -2.4)
FSK method	-5.5

Noise immunity improvement based on same probability of missing actual transponds for both cases.

Normal method	0 db (reference)
FSK	10 db (approx.)

Once a failure boundary has been found the status monitoring system issues a message specifying the range of stations affected. Other information is added when applicable. One example of this applies if the failure is on the edge of a powering boundary. Powering information is part of the data-base. Also, a re-check is done after every fault locate to determine if the failure was intermittent.

Conditions may exist on a trunk that cause the return data to be un-intelligible yet measurable by the "FSK" test. A warning message is issued when this condition is detected. This is necessary because some alarms may change state in the system without being detected by the status monitor until correct data is received.

CONCLUSION

A status monitoring system can improve service availability and decrease costs of maintenance on CATV systems. Limitations exist whenever one attempts to status monitor large networks with insufficient computer hardware at the head-end. Micro computers systems can be enhanced by sharing the processing load among multiple processors. This concept is now being used in applications that previously would have required the speed and sophistication of a mini computer. Software is a significant investment for the head-end computer, so expansion capability is an important consideration. Expansion capability refers to both the number of stations that can be accomodated and the ability to enhance software features in the future.

A Digital Audio System For CATV Applications

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ABSTRACT

With the recent interest in improving broadcast audio quality for the consumer, various systems are being proposed as solutions. After a review of current activities, a description of a digital audio system which offers quality equivalent to the Compact Disc is followed by a discussion of field trial plans.

INTRODUCTION

Audio quality as available to the consumer is improving from both the source and home reproduction perspectives. There are also several approaches being proposed for making similar improvements in the broadcast techniques used to deliver audio to the home, using either direct over the air, satellite, MDS or CATV systems.

The following table illustrates the relative performance of common consumer audio products:

System	Audio S/N dB
Compact Disc	90
HI-FI VCR	80
Cassette (Dolby C)	75
Turntable (LP)	70
Off Air FM Stereo	65
Cassette (Dolby B)	65
MTS (DBX NR)	65
Cassette	57
Cable FM Stereo(-15dB)	55
VCR	47

Many of the above systems suffer from performance which does not achieve the given specifications. Wherever alignment of the system is required, the operator or the consumer is unlikely to provide maintenance to preserve the maximum quality. Also, records and tapes suffer degradation from repeat usage. In general, a specification of 70 dB S/N is considered acceptable with 80 dB S/N considered excellent. As such, only the Compact Disc and HI-FI VCRs are currently considered to fall into the excellent category.

Program Source Improvements

Program source improvements are moving quickly on several fronts. In the recording studio, digital multi-track recorders (such as the Sony PCM 3324) are replacing the current analog based machines. The TV broadcast community is adopting the BTSC MTS stereo standard, CATV satellite delivered services are upgrading with digital and high quality analog transmission, and the Compact Disc is having a major impact on the studio operations of many quality conscious FM broadcasters.

In the home, the Compact Disc system is also taking off very quickly. At present, the acceptance rate is growing at least twice as fast as did VCRs. In addition, users of the system are buying double the average number of discs as they previously purchased as albums. this can be explained by the low cost of home players (under $300 units are available) and the initial need to stock a library with new discs. The net result is that the home listener is moving up in his expectation of audio performance.

Recording Improvements

Recording equipment improvements are also moving into the home at affordable prices. The Beta and VHS HI-FI cassette tape recorders are the main example of this trend. However, there are other aspects such as PCM adapters for older VCRs and Dolby C modes on standard audio cassette recorders. There are strong indications that a new home audio recording system will be unveiled next year by several Japanese manufacturers. This system would provide two hours of record time using a digital audio cassette format.

Transmission System Improvements

Transmission system improvements are following closely on the heels of the source and recording upgrades. Over the air broadcasters have adopted a new stereo standard for TV, the MTS (Multi Channel Sound) system which includes DBX noise reduction. FM broadcasters are mounting a campaign to take full advantage of the quality possible in their current system. Satellite delivered signals for CATV headend use are adopting both digital (Wegener ADM Dolby, M/A-COM VideoCipher II) and analog (Wegener Panda II, Studioline) techniques.

For delivery directly to the home several new alternatives are under development (see references 1,2,3 and 4). CATV equipment vendors are developing both in-band and out-of-band systems. An in-band system delivers audio within the video channel. Examples of this are the Oak Sigma series and M/A-COM VideoCipher II, which use digital technologies, replacing horizontal sync with digital audio. In an out-of-band system, the audio information is broadcast separately in another part of the spectrum. Both analog and digital designs are being suggested. For analog approaches, one alternative is carriage in the FM band in the standard format. A tracking adapter tunes to the proper FM channel when the video channel is changed. Examples of this product are being shown by Pioneer (reference 5) and Westinghouse/Sanyo. A "digital" quality analog system is being shown by Studioline, also of the tracking type. In the digital realm, products have been shown by Sony, Panasonic and Toshiba. Other vendors are known to have both types of CATV systems under development.

Other alternatives include DBS and MMDS (multi channel MDS) delivery systems. In the new DBS products there are digital audio channels being designed in. The MMDS market, which is now being launched, is expected to use the lure of digital audio as one of its selling points. An interesting option in MMDS is to devote a full video channel to audio only. This would provide at least 8 high quality stereo channels.

Why Consider Digital?

Why consider digital technology for the transmission of audio in CATV applications? Certainly, there is a trend towards digital recording and Compact Disc sales to the consumer. Therefore, it will be easy to convince CATV customers that they are getting the best sound when it is digitally broadcast into the home. But as engineers, picking systems which must be compatible with our cable plants, and which must make efficient use of the limited spectrum available, a closer examination of the alternatives is in order. Given these concerns, in-band solutions are attractive, however unless a complete changeout of equipment is possible this is not practical. Therefore, out-of-band solutions are likely to be chosen.

The next table shows the stereo channel efficiency for the major out-of-band contenders, all of which have high quality performance:

System	Channels/6 MHz
M/A-COM PCM digital	8
Sony PCM digital	8
Toshiba PCM digital*	8
Panasonic PCM digital*	12
Dolby ADM digital	16
Studioline analog	20

*These systems also have less efficient modes with S/N 90dB

The PCM (Pulse Code Modulation) systems use various forms of companding and QPSK modulation for greater efficiency. A Dolby ADM (Adaptive Delta Modulation) system designed with integrated circuits available this year from Signetics, is also likely to use QPSK modulation. Studioline, currently the sole analog system for consideration, is based on the Telefunken High-Com companding process and discrete L/R FM modulated channels.

Given the example of Studioline, it is shown that there is certainly not an advantage in terms of bandwidth considerations where digital is concerned. However, this is not to say that there is an inherent disadvantage with digital as improved systems such as the Dolby ADM are perfected. In fact, there may be definite advantages with respect to noise performance and security when digital is chosen.

Both analog and digital systems can operate at carrier levels which do not cause unusual loading of the cable plant, yet offer noise free reception against white noise sources (such as long amplifier cascades). But no system, no matter how rugged is its design, is totally free from the effects of impulse noise. One advantage of the PCM digital approach is the possibility to interleave (shuffle the order of the samples), so that an impulse noise burst is spread over a longer interval where the error correction coding can compensate without degradation. Also, with digital error detection coding it is possible to take further action if an error can't be corrected. A technique called analog concealment averages samples and substitutes a recent value if an uncorrectable error is detected. While the Dolby ADM digital system works in a different fashion, it also offers the same immunity from noise bursts. By transmitting only small positive or negative increments from the previous value, an error due to a noise burst has a much smaller impact on the signal.

An important aspect of any digital system is the ease of offering a very secure service with little overhead. System operators are increasingly concerned with theft of service, and in general are impressed with the security aspect of digitally based products. Addressability and all its features are easily incorporated into digital audio systems without additional data carriers. For future applications, additional data streams can be multiplexed into the system in a convenient fashion.

Given an uncertain outcome on the long term question of channel efficiency, the attractions of digital audio for consumer acceptance, impulse noise performance, security, addressability and future services provide ample reason to work with the technology today. The cost difference of full featured terminals is not a question since analog and digital products are already on a par. The typical price is in the range of $100-125 depending on quantity.

Service Opportunities

There are three service opportunities which are becoming of interest: 1)enhanced audio, 2) premium audio and 3) pay-per-record. Enhanced audio is the offering of superior audio quality over that which is available today as part of the TV program. This includes the standard network and local TV station feeds as they upgrade for MTS and cable services such as MTV, VH-1, HBO, Cinemax and others who are also upgrading for higher quality. Any of the broadcast systems which offer better performance than standard TV audio can be used for providing this service. Premium audio is interpreted as a pay service with multiple channels of commercial-free programming. Formats such as rock, contemporary, classical, jazz, news, sports, weather and business updates are all candidates for a premium audio service. Pay-per-record is a future possibility, particularly as new digital audio recording equipment is offered in the consumer marketplace. Possibilities to "publish" lesser popular works as well as special events make this an exciting opportunity for the future.

For premium audio and pay-per-record, high quality audio transmission is considered a must. The CATV operator is in a good position, if he selects a digital audio system, to set the standard and establish these businesses.

DIGITAL AUDIO DESCRIPTION

In June 1983, ATC R&D issued a RFP (Request for Proposal) for developing a digital audio product. After analyzing several responses, Toshiba was chosen for the task. Based on experience gained in the development of digital audio as used in DBS receiving equipment for the Japanese market, the DCAT (Digital Cable Audio Terminal) system was designed (reference 6). The following features indicate the capabilities of this system:

Feature	Specification
Tuning range	88-120 MHz
Input range	+5 to -24 dBmv
Required C/N	23 dB
Ultra Hi-fi	16 bit linear PCM
Frequency response	20-20 KHz
Dynamic range	86 dB
Total Harmonic Distortion	0.015%
Channel efficiency	4 channels/ 6 MHz
Super Hi-fi	14/10 bit NIC
Frequency response	20-15 KHz
Dynamic range	76 dB
Total Harmonic Distortion	0.1%
Channel efficiency	8 channels/ 6 MHz
Program number	99 values, 26 tier levels
Security	multi-keyed encryption
Error correction	BCH (63,56) SEC, DED
Headphone jack	front panel volume control, 600 ohm
RF Input	75 ohm, "F" connector
Line output	Phono jacks (L/R) with adjustable outputs (1-3 v RMS)
Power	105-132 AC (60 Hz), 15W
Size	13.5" (w) x 9.5" (d) x 2.25" (h)
Remote control	optional

As described above, the system has two modes of operation: 1) Ultra mode (16 bit PCM) and 2) Super mode (14/10 bit NIC). The Ultra mode provides the same performance as Compact Disc systems. By using 16 bit linear PCM and a sampling rate of 48 KHz no compromise of audio quality is allowed. The Super mode was designed for greater channel efficiency and yet also delivers high quality audio with a S/N of 76 dB. Samples are taken at a 32 KHz rate, with 14 bits reduced to 10 using NIC (Near Instantaneous Companding) techniques. In addition, pre-emphasis is used to further reduce any effects of quantizing noise. The subjective difference between the two modes varies from listener to listener, but tends to be interpreted as a reduction in "presence" or "fullness" of the material. It is very difficult for the average customer to know which mode is being used.

The data is packaged in one msec frames of 2048 bits each. These encrypted frames include sync information, audio information (one Ultra or two Super stereo pairs), addressing data and error correction codes. The resulting 2.048 Mbit data rate is QPSK encoded and occupies a 1.4 MHz RF channel.

Headend System

The headend system supports all encoding requirements for the digital audio system. It is comprised of the following functional elements: 1) A/D conversion, 2) Frame formatting, 3) QPSK modulator and 4) system controller.

The A/D conversion process is a critical function due to the high S/N capabilities of the system. Of particular importance is the input anti-ailiasing filters which must constrain the upper frequency to be either 20 KHz (Ultra) or 15 KHz (Super). To achieve proper rejection of frequencies above these limits and not sacrifice phase response requires careful design. Also included in this function is the pre-emphasis and NIC circuitry.

The frame formatting is a complex task because of all the elements that are put together on a real-time basis. These include audio sample data which must be interleaved, control information (both system wide and specific terminal dependent) which must be provided, then all data must be encrypted along with the error detection and correction coding.

The QPSK modulator and upconverter requires a mixture of digital and RF design. First, the incoming serial data stream at 2.048 Mbits must be formatted into dibits for the quadrature modulation process. After QPSK modulation and filtering at an IF frequency, an upconverter must be used to place the channel in the 88-120 MHz range.

For addressable system control, a system controller computer and software must interface to the frame formatting function in the headend. Also, as in any one-way CATV control system, appropriate interfaces must be made with local operators and the billing/management system.

Terminal Design

The terminal design has many similarities with existing equipment. As in a baseband video converter, there are tuning and demodulation functions. Similar to a Compact Disc player, there are decoding, reformatting and D/A functions. It is the marriage of these two families of requirements that is unique. Additionally, a desire to use existing components and low cost manufacturing techniques completes a picture of the constraints on the design.

The tuning system is standard, covering a range of 32 MHz (88-120 MHz in the initial product). It is microprocessor controlled with 100 KHz channel steps. For demodulation, a QPSK demodulator IC is used from the Japanese DBS system development.

The PCM decoding involves a reversing of the process that was performed at the headend. The de-encryption process must be performed and de-interleaving of the data is required. Any errors are corrected, or detected for analog concealment. The resulting L/R channel information must be D/A converted and carefully filtered to remove the quantization and pre-emphasis effects. Components were used from previous digital audio projects wherever possible. However, a new design of a security IC was required to handle the de-encryption process in a cost-effective manner.

The user interface is primarily through a set of front panel controls. In addition to a 14 position keypad and two digit LED readout, is a volume control and jack for the headphones. An optional remote control has the same features available on the keypad. Basic features include program selection and a memory function for advance selection of an upcoming program. A front panel volume control for the line outputs was not included for cost reasons. However, rear panel adjustment controls are provided separately for the L and R outputs.

FIELD TRIAL PLANS

The first field trial of the DCAT system is scheduled for May 1985 at ATC's Thornton, Colorado system. It will involve an 8 channel headend and up to 100 terminals. A variety of high quality program sources will be used and performance measurements will be made on the system. A market trial of enhanced and premium audio is then planned for fall 1985 as the next step in the development process.

Engineering Trial

In the engineering trial which is scheduled to commence in May several issues will be of major concern. Obviously, the audio performance of the system is the main feature to be studied. However, other concerns are also of a very practical nature: 1) wiring and compatibility issues at the CATV headend, 2) RF signal level measurement procedures and 3) customer premise interconnect configurations.

The audio performance will be measured at selected sites including the headend and locations throughout the cable plant. To help understand performance, a BER (Bit Error Rate) measurement will lead to an estimate of the RF headroom available for the QPSK modulated signal. Analysis of distortion and ingress effects will also be noted.

At the headend, care will be taken to preserve the signal quality available from a number of sources: 1) Compact Disc. player, 2) M/A-COM VideoCipher II audio from HBO and Cinemax, 3) Wegener Dolby audio from MTV and VH-1 and 4) local TV and FM broadcast sources. Any special precautions that are found to be necessary in the wiring layout will be reported.

New techniques must be derived for making practical field measurements of wideband QPSK modulated signals. An investigation of methods that allow usage of current measurement equipment (such as the Wavetek SAM series) will be necessary for field testing.

Perhaps the most uncertain path is the question of various home configuration possibilities. By noting various examples of real world situations, a better understanding of the cable operator's responsibilities will emerge.

As a conclusion to the trial, a summary report will be generated including information relative to the above concerns. Assuming functional success of the DCAT product, the next step is a market trial of high quality audio for the CATV customer.

Market Trial

At the present time, ATC NBD (New Business Development) is in the planning stages of a full scale market trial of enhanced and premium audio which would start in the fall of 1985. In covering the needs of both enhanced audio and premium services it is expected that 12-16 stereo channels will be carried in a high quality format, such as that provided by DCAT. Features which are important to the market trial are addressability, remote control and audio quality.

SUMMARY

Audio source, recording and reproduction equipment has made tremendous strides froward in the last few years. To complete the picture, improvements must also be made in audio broadcasting. Cable systems have an opportunity to set the standard of excellence through the adoption of high quality audio systems.

A digital audio system (DCAT) has been developed which offers the required level of performance and security from theft of service. An engineering field trial will start in May, with a market trial to follow later this year.

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A DISCUSSION OF A FIBER OPTIC OFF-PREMISES TWO-WAY ADDRESSABLE CONVERTER SYSTEM INSTALLATION: THE SUCCESSES AND LESSONS OF ALAMEDA

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ABSTRACT

United Cable Television Company's Alameda California cable system is an application of fiber-optic technology in a dual-cable, two-way franchise. The 24,000 homes passed in the star-switched Mini-Hub I system provided new lessons and solutions that previous French and Japanese developments attempted to solve with smaller subscriber bases.

Times Fiber Communications, Inc. (TFC) electronic developments incorporated commercial quality components into outdoor off-premises equipment. Micro-computer technology was incorporated into two-way, FSK, high traffic fiber-optic links between subscribers and the local hubs. Important lessons on trunk amplifier tuning and constructing the two-way coaxial link between the headend to the local hubs were also learned.

The world's most extensive aerial and burial fiber-optic distribution system contains patentable developments in fiber connections, junctions, and weatherproofing. Two new fiber optic connectors were introduced that reduced fiber connector costs by five times.

INTRODUCTION

The purpose of this report is to review the details of the design and installation of the fiber-optic subscriber distribution portion of the system, and put it in perspective with other phases of the Alameda construction. Each part of the link will be discussed with regard to the initial design and related theoretical decisions, lab test results, and an explanation of field experiences.

COAXIAL TRUNK PLANT

Star-switched systems greatly affect the design of the trunk and feeder portion of one- and two-way systems. The amplifiers in the Alameda system (Jerrold JN Series) were spaced 21 dB to satisfy a maximum cascade requirement of 14 amplifiers for the Cable A and Cable B downlinks. This short cascade is a benefit of star-switched designs. Long cascades used fused-disc to achieve the 14 amplifier design goal and 1.0 inch diameter and .750 inch diameter semiflex cables were used in the remainder of the lines.

Two-way addressing required rigorous enforcement of standard industry quality measures to ensure performance. Unterminated cable ends at future hub sites created severe noise ingress problems during activation of the two-way link to the first fully initialized hub sites. Trunk line connectors and splices required extensive reworking to reduce noise ingress during the hub-to-headend link activations.

COMPUTER CONTROL

User-friendly is a term most computer system engineers apply to software/operator interfaces; however, a star-switched system with computer diagnostics is very "user-friendly" to the radio-equipped service technician. When hub sites were activated or customer complaints were troubleshot, the field technician received confirmation within minutes that his actions had or had not resulted in success. As the system size expanded beyond previous system sizes (30 to 40 sites) during construction, new control requirements necessitated enhancements to the digital hardware in the hub.

THE SUBSCRIBER LINK

In Mini-Hub I the subscriber link (Figure 1) between the off-premises hub and the home contains two fibers--one for delivering video to the TV and the other to return the keypad encoded channel requests to the hub. The converter output originates from an LED to which one end of the optical fiber is directly connected. The subscriber end of the optical fiber is terminated in a receiver (RIU) which converts this optical signal to an electronic video signal. This video link of the fiber can carry channels 3, 6, and the FM band simultaneously. The return or uplink is similar, encoded FSK keypad commands are converted to optical pulses (9600 baud) at the RIU which then transmits them to the converter for channel selection.

LED AND FIBER

The Motorola LED (SFOE 101B) supplied in a TO-52 can was a design match to TFC's 200-250 micrometer step-index fiber; this resulted in the availability of 200 to 400 microwatts of launched optical power into each subscriber link. A performance minimum of 30 microwatts delivered to

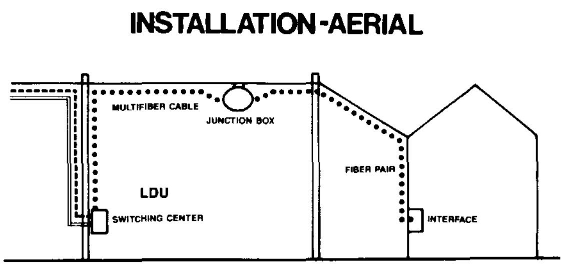


Figure 1

the subscribers' receivers required link losses no greater than 8 dB and an installation budget of 6 dB to allow for aging. Factory testing and selection of the LED resulted in very high converter light outputs that provided excellent reliability in the converter section. A field problem was keeping the optical ports of the transmitters and receivers clean enough to maintain high optical power transmission. This was accomplished with plastic caps.

The video receiver used was a Motorola SFOD133 and the FSK subscriber uplink which required much less performance than the video downlink utilized a Honeywell SE4342 with an SD4342-2 detector that had a 13 dB loss budget. Therefore, choices were available to the installer to utilize the lowest power loss link for the video downlink.

The 200 micrometer core fiber was made to a 250 micrometer ±3 micrometer outer diameter size with fiber attenuation of 7.0 dB per kilometer (or approximately .21 dB/100 ft). Connectors were fabricated with a 253 micrometer minimum bore. Most measuring instruments or wire gauges are made in increments of 2.5 micrometer (0.0001 inch) scale resolution; therefore, oversized fiber or undersized connectors can't be detected. To remedy these situations, the installers were provided with oversized connectors.

FIBER CONNECTORS

From the very beginning of the Mini-Hub I concept, the problem of fiber optic connector choices was a major issue. Optical fiber connector design, now as then, was based on low-cost epoxy fastened requiring high installation cost, or high-cost mechanical clamp technologies, both unsuitable for a CATV fiber star network. New development goals were needed. Three targets were chosen as connector design development goals.

1. The connector was to be manufactured for less than $1.00 per unit.
2. The connector was to be able to be field-installed in less than 5 minutes.
3. The connector had to possess an optical power loss of less than 1.0 dB.

The efforts took two directions--one, to develop a connector internally and two, to support a similar effort by an outside vendor. By the time Alameda construction was started, a third TFC-developed connector, the Three Pin Connector II or TPC II, had been developed. It could be installed in less than 2 minutes, had a mean loss of 0.9 dB, and cost slightly more than $1.00 per plug. Figure 2 shows a statistical compilation of loss measurements of five readings per connector-pairing for many connectors.

A second development contributed by AMP, Inc. was the crimpable Optimate SFR, which only required a one-step polish. The AMP Optimate could be installed in 2.5 minutes, had a mean loss of 0.8 dB, and a cost of $2.50 per plug. Figure 3 represents a statistical compilation of the results of five readings made on each connector.

The TPC II connector exhibited a better optical loss change over different temperatures and therefore it was preferred for outdoor use. It was estimated that over 150,000 connectors would be required for the Alameda system, so two production sources were needed to meet their needs.

The installation of connectors required the training of new people in a skill with which they were not familiar. Of particular importance is the cleaving operation on the TPC II connector. The use of simple crimping tools quickened the connector installation and one-step fiber polishing posed little problems.

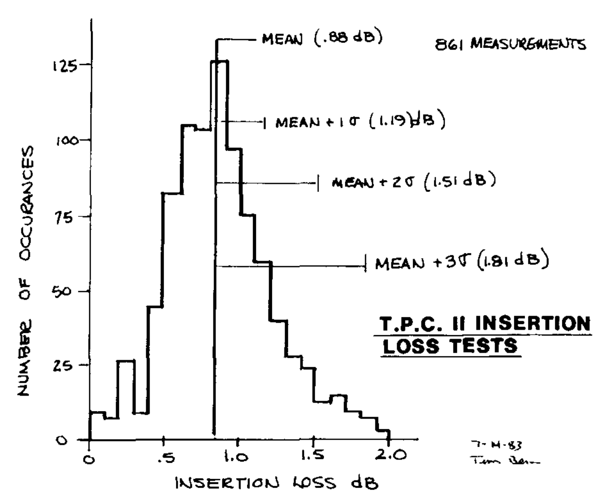


Figure 2

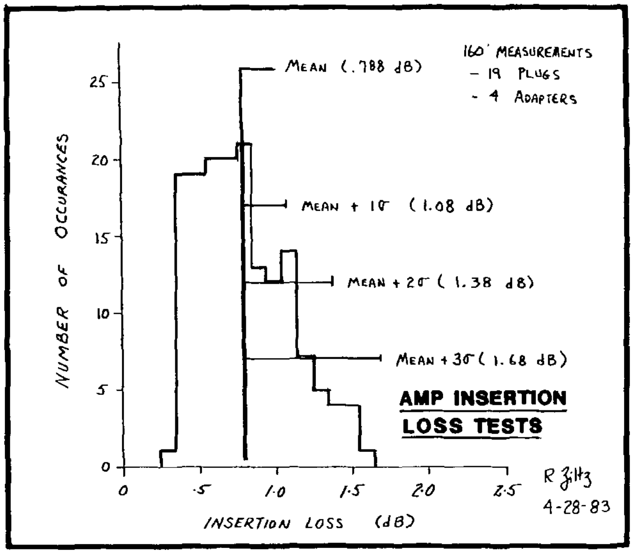


Figure 3

FIBER CABLES

Two different types of fiber cable were used in Alameda. The cable used in the preinstalled drop sections from the hub to a junction point near the subscriber's residence were of a loose tube multifiber construction. Two-, four-, six-, and eight-pairs of fibers were enclosed in a silicone grease-filled, steel-reinforced polyvinylchloride jacket (Figure 4). This type of cable was designed for pulling ease in both the aerial and underground plant situations. The cable's small diameters of 0.250 and 0.375 inches, resulted in clean, neatly lashed strands. Efficient scaling of junction box and tap sizes to the various neighborhood densities was permitted because several multifiber cable designs were used.

The second type of cable was a "zip cord" (Figure 5) duplex-fiber design. It was used for the "installed drop" from the junction box to the subscriber's home. This was a second generation cable developed by TFC which replaced an older oval duplex type of cable which required a fiber breakout assembly on both ends.

MULTIFIBER BREAKOUT

Mini-Hub I installations prior to Alameda had used a fiber cable jumper to connect a converter card to a junction box cable termination in the hub. An extra connector pair that had a higher link loss and cost more was the result. The duplex breakout idea was developed into the Multifiber Breakout (MFB) (Figure 6). The key to the success of the MFB was the novel idea of plowing the fiber into pre-slit tubing and then terminating the fiber in a connector. This allowed for a multifiber connection cable to be made to the converter output with an unbroken fiber. Tubing was color coded in pairs to match the fiber colors and to facilitate easy tracing of the fiber from the junction box to the hub.

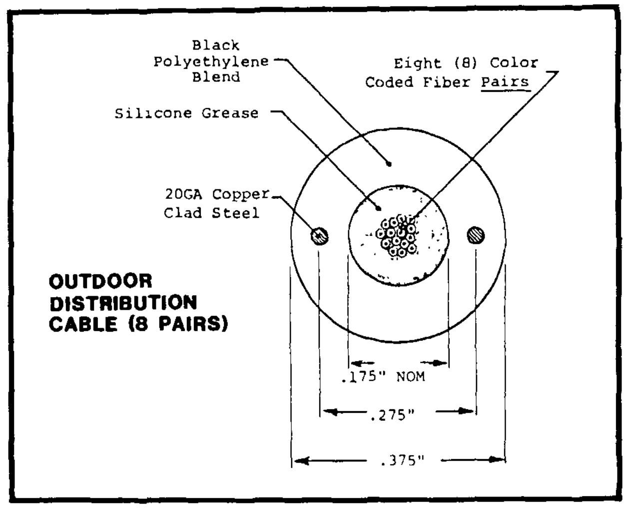
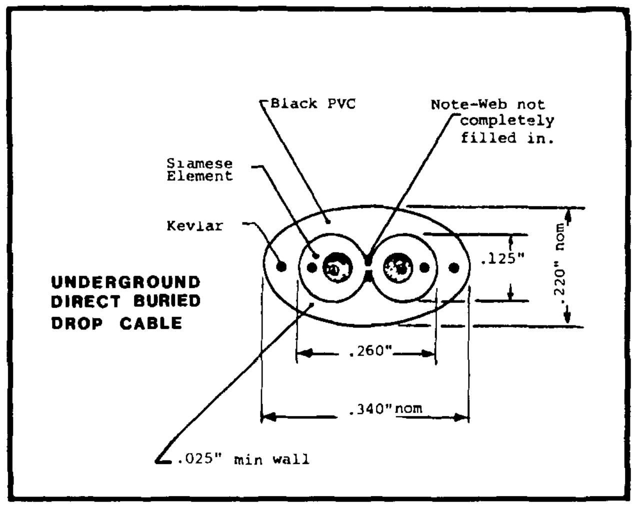


Figure 4



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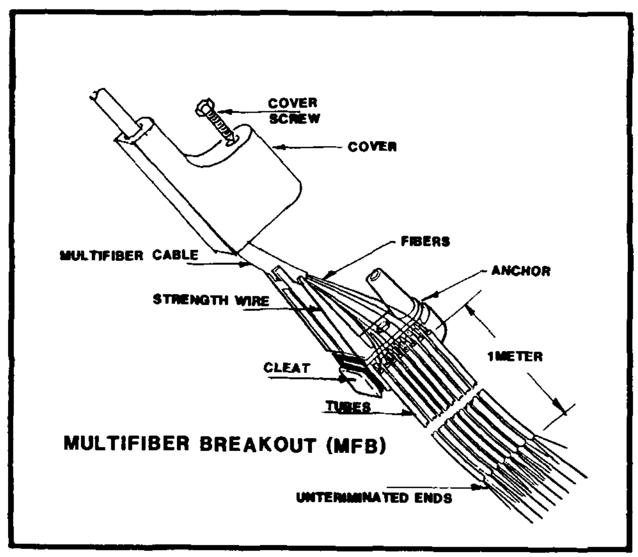

Figure 6

SUBSCRIBER JUNCTION BOXES

A new aerial subscriber junction box (SJB) (Figure 7) was designed to terminate multifiber cables in a subscriber tap configuration. Molded of UV resistant polypropylene in two compartments (one for weatherproof looping of the fiber and the second for weatherproofing the installed drop fiber connection), the SJB was made football-shaped to provide pulling a preterminated cable easy. In practice, 20 feet of cable was dropped from the strand to ground level where the junction box was assembled. This extra cable caused greater power loss and cost more.

The underground junction box (UJB) (Figure 8) differed from the aerial design only in that the top polypropylene shell was replaced with a cast polyester concrete air bell. Used in the underground plant in two- and four-pair versions, UJBs were placed in hand vaults that were subjected to water runoff from lawn sprinklers and rain. The underground duplex jacket of the fiber cable must be stripped away to remove an escape route for the air from the bell. Otherwise, air leakage caused by the soda straw action of the cable can force out all the air in the bell and cause water flooding. Also, the lack of stable mounting of a UJB in a vault would cause flooding.

TOOLING

Performance testing the preinstalled fiber drop links was accomplished by using a standardized light source that contained 16 output LEDs. The multiport light sources were enclosed in a portable case and battery powered. After each day's use, the light sources were charged overnight. Factory LED selection enabled all 16 LEDs to have the same dynamic tuning range, aging rate, and stay at a stablized tuned setting for each day's use.

The light sources were connected to the multifiber breakouts at the hub and power readings were made at the junction box connectors. A Wilcom model T319 meter was used to calibrate the light source and make the light measurements.

The performance readings taken provide an interesting statistical review of the installation quality, the connectors, the fiber, and the accepted links. Figure 9 shows a graph of 492 readings in which the bulk of the links has only a 2 to 3 dB loss that results in an average of 100 microwatts delivered to the RIU. The second peak at 3.0 dB corresponds to a predominance of 250 to 450 ft links in the plotted data.

SUMMARY

The lessons of the Alameda installation involve all phases of the project.

The review of insertion loss test results for the connector matings and installed subscriber links indicate that a theoretical approach of

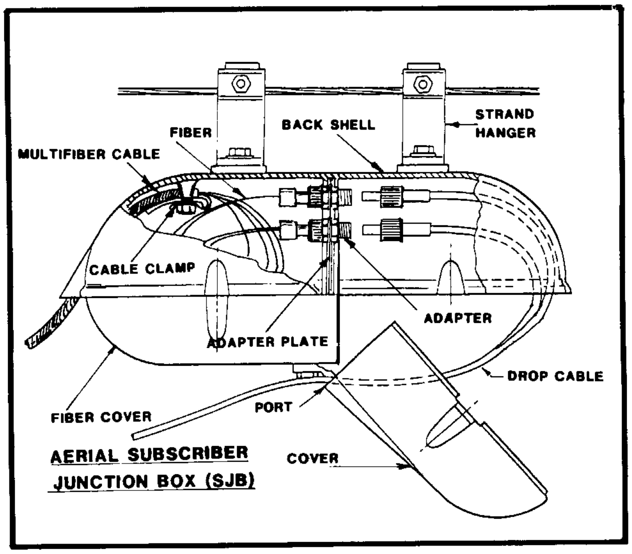

Figure 7

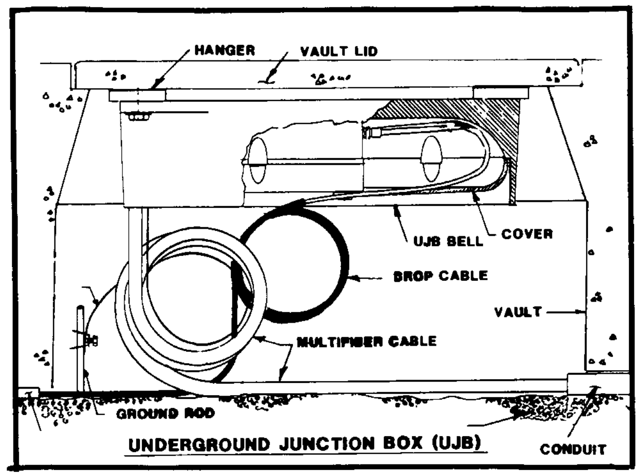

Figure 8

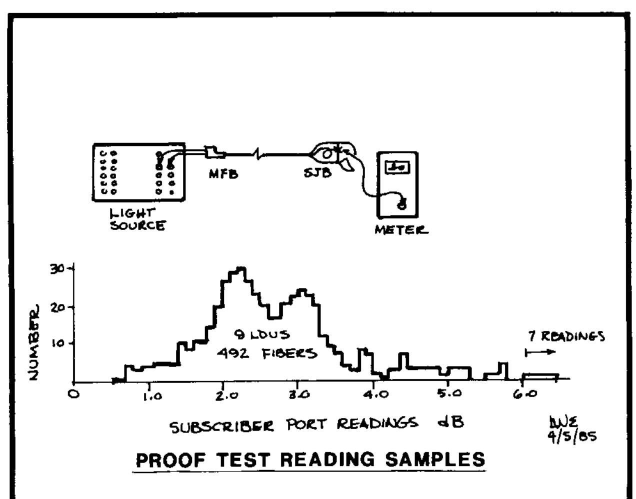

Figure 9

worst case design may not be necessary in the future. The statistical evidence indicates that designing to a less conservative statistical limit may be more in order.

The future generation design efforts will concentrate on improvements in the connector cleaver operation and the multifiber breakout. Desirable enhancements of the light source include improved diurnal stability and ease of recharge.

Another lesson of Alameda is that manuals, training materials and media presentations must reflect the detail "do's and don't's." Procedural steps and equipment positioning and orientation have to be explained in detail.

Last but not least, a recognition of one or two new crafts is necessary. The connector installation craft requires a training phase prior to and during the early on-site employment in order to quickly develop skills and weed out those not suited. Cross craft training between lineman, F.O. connector installers, and hub technicians is necessary to assure smooth working relations and to reduce reworking.

TFC has successfully installed the first large scale two-way addressable off-premises cable television converter system in the world and used fiber optic drops throughout. The project has definitely shown the technical efficacy of fiber optic subscriber distribution links in cable television systems. Newer second and third generation designs have brought the cost of fiber optics more in line with future needs.

A FIBER OPTIC PRIVATE NETWORK
FOR THE DALLAS MORNING NEWS

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James A. Keeley, Dallas Morning News

Acknowledgements: Arthur Simon, John J. Prisco, Julian Kelly
Warner Amex Cable Communications Inc.

ABSTRACT

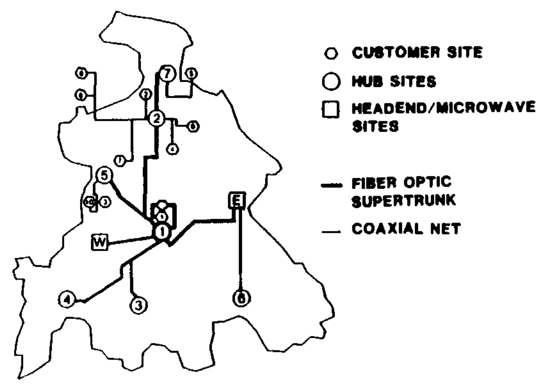
Classically, data communications for public and private institutions have been accommodated on a coaxial institutional network (shadow trunk) using RF data modems at the customer premise.

Warner Amex Cable Communications Inc. has installed an 80-km fiber optic backbone network in the City of Dallas to accommodate high quality, high capacity traffic including video and large private data users. The first major user of this network is the Dallas Morning News, for which a private link was established.

In the Dallas Morning News application, we are transmitting information from two laser-fax machines for platemaking between the plant in downtown Dallas and Plano--a distance of 36 km without repeaters at an optical transmission rate of 44.7 Mb/s. This paper will describe the system, its construction, and performance.

THE DALLAS NETWORK

The Dallas Morning News installation is a private system operating over a newly installed fiber backbone network which forms a part of the Warner Amex cable franchise in Dallas, Texas. Warner Amex won the cable franchise in 1981 and constructed the network using an arrangement of hubs (shown as circles in Figure 1) from which cable TV would be distributed to subscribers in Dallas. Cable TV programming is distributed to these hubs from the headend using AML microwave. As a requirement of the franchise, a shadow institutional network was constructed using coax, which is to serve public and private institutions with data and video communications services. This coaxial network roughly shadows all CATV trunk and, as such, provides a tree-type data network which emanates from the hubs. The hubs can, therefore, be used as cross-connect points or pseudo-central offices. Although coax provides an excellent means for interconnecting multiple low capacity data users, it is not well suited for longer distance trunking of high capacity users. Also, coax is not a preferred approach for hub interconnect for data or video over the distances imposed by the Dallas geography. The amplifier cascades reduce reliability and performance below that desired for either service. A suitable hub interconnect was required in order to establish a full data network and as a potential back-up for the video microwave feeds. Although the microwave has been performing exceptionally well for the subscriber video, and, therefore, requires no alternate back-up, the microwave has a limited return (two-way) capability. For data, another approach was needed.



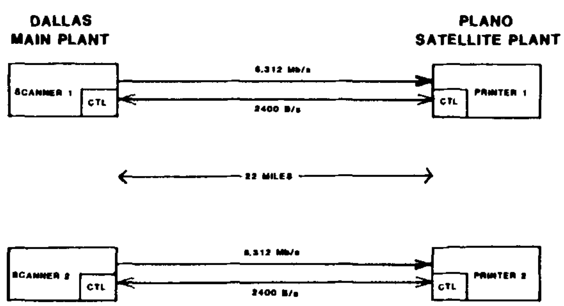
Interconnect Concept
Figure 1

Fiber optics is an exceptionally high capacity, low loss, and noiseless medium which has proven abilities for long distance transmission without repeaters (amplifiers). In 1983, Warner Amex established a program to evaluate fiber optics as a potential means for interhub supertrunks for video as well as data. The results of our video evaluations were reported at the 1983 and 1984 NCTA Conventions [1, 2]. Although it is still under evaluation for full-scale deployment, we were very successful in demonstrating that single mode fiber was indeed capable of competing with FM on coax for video supertrunks while providing performance of 8 to 12 channels per fiber with 60 dB weighted SNR. We were also quite aware of the widespread use of fiber for data and voice traffic, and its ability to provide high capacity trunks over distances well in excess of our hub spacings without any repeaters at all. Our cost studies [3] showed fiber to be the most cost effective means for data transport in the metropolitan area when circuit capacities exceeded three to four DS-1s (1.544 Mb/s circuits). Further implementation of the fiber as drops from the hubs would depend on user need and capacity. Small users, for instance, could access the coaxial network when fiber is not justified. If these users require interconnect with locations served by other hubs, then fiber would be used as the high volume interconnect. We further developed a means for fiber trunking of the signals directly from the coax without changing the format. Thus was created a hybrid fiber/coaxial network, shown conceptually in Figure 1, which takes optimum advantage of the capabilities of both technologies.

With this knowledge, fiber optics became the obvious choice for interhub trunking. A decision was made to implement these trunks as the higher volume business customers required service to certain areas or as customers began to cluster in a hub service area. Warner Amex was now in a position to serve the Dallas community with state-of-the-art fiber optic services.

THE REQUIREMENT

The Dallas Morning News (DMN) entered the picture in 1983 as a user of state-of-the-art printing and telecommunication mediums. DMN was searching for a highly reliable means of transmitting laser-fax information between their printing plant in the Dallas central business district (CBD) and their satellite plant in Plano, 22 miles away (see Figure 2).



The Dallas Morning News
Press-Fax Requirement
Figure 2

Because of the location of the new Plano north Dallas printing facility, communications capable of transmitting pages of text and graphics between the composing room in the downtown headquarters location and the north site was necessary. The alternative to a communications link was to physically transport page negatives by automobile to the north printing plant.

A decision was reached by the Dallas Morning News to buy digital laser facsimile equipment (state-of-the-art) to read page paste-ups and write page negatives from which offset plates could be made. This decision was based on a number of reasons. One was that normal copy flow from the newsroom precluded physical transport of page negatives to the north site. Another was to enhance the quality and speed of the operations of the Dallas Morning News.

The alternatives for a digital transmission link were to buy services from the existing local exchange carrier, buy and install and own a microwave system, or provide for a private terrestrial communications system (coaxial based or fiber optics based).

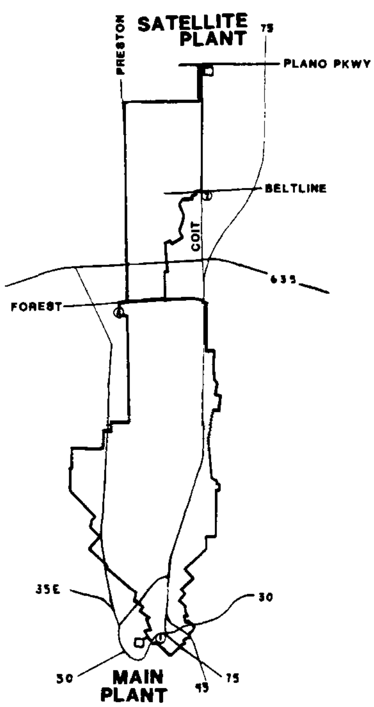
A very real concern in using a microwave system was the frequency slots available (congestion), the environmental impact of a 24-mile microwave link, and the dynamic real estate development in the Dallas area--a fear that new and interfering buildings would be built in the line of site and thus interrupt the communications capability of the locations. This led them to believe that microwave was not the best option.

The minimum bit rate needed for the systems was DS-2 or 6.312 Mb/s (T-2). The local exchange carrier was initially able to provide this service only by multiplexing T-1 circuits (1.544 Mb/s, DS-1), and thus a private terrestrial link was the most viable approach.

SYSTEMS IMPLEMENTATION

The interest expressed by the DMN for a communications link to Plano from the CBD prompted Warner Amex to consider building the fiber trunk between Hubs 1, 2, and 7, and to extend the trunk into Plano to serve the DMN satellite plant. The requirement for a high degree of availability (99.98%), however, underscored the need for some path diversity in the event that the cable was damaged. This is a concern of all commercial customers since it may take from 4 to 12 hours to restore a cable, depending on circumstances. Our AML microwave system was evaluated as a means of providing the diverse path. Although it was capable of handling the capacity requested by the DMN, the cost of interfacing a hybrid fiber/microwave link, the cost of microwave transmitters (one per channel at $15,000 each), and the limited per-channel capacity (6.3 Mb/s) eliminated this as a consideration. A coaxial trunk was also considered. Since this could be implemented by reconfiguring and activating the coaxial institutional network already in place, it would be inexpensive. Again, however, the cost and complexity of interfacing the frequency channelized carrier based coaxial system to the fiber system, which employs TDM transmission, was a negative factor. An additional negative factor was the length of the amplifier cascade from the Dallas CBD to Plano. A diverse fiber route, on the other hand, was not only fully compatible with the primary, but could be implemented with no added electronics. Since it could be overlashed on the existing coaxial cable plant, construction was inexpensive. Fiber became the obvious choice for the back-up link with all factors, including future expansion, being considered.

The route is illustrated in Figure 3. The direct line distance between facilities is approximately 22 miles. The cable route distance is 25 miles for the primary and 27 miles for the redundant path. The cable enters Hubs 1 and 2 and passes Hub 7, forming a double loop for redundant interconnect of Warner Amex hubs. These hubs can, therefore, be used for repeaters, routing nodes, maintenance points, or hybrid (coax/fiber) network interface points. Since the DMN requested a private network, interface at the hubs was not necessary. In fact, repeaterless operation was obtained for the full distance between the Plano plant and the CBD plant. The four fibers dedicated to the DMN were spliced through for the interconnect, and all electronics resides within the DMN facilities. Although all maintenance points are within the DMN, auto-dial fault alarms automatically alert Warner Amex maintenance dispatch over phone lines in the event of a major or minor alarm condition.



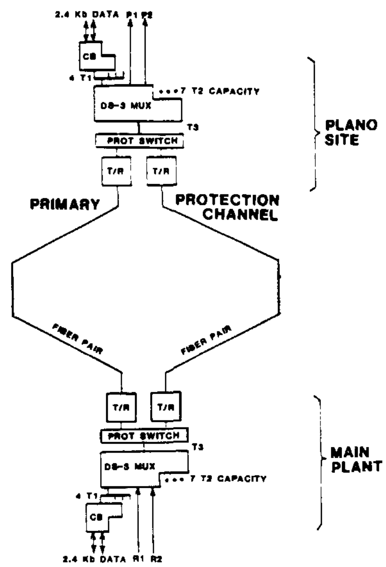
Routing
Figure 3

Approximately 90% of the plant was constructed aerial, with the remainder in underground conduit. Construction was accomplished with cable TV subcontractors using practices which are modifications of Warner Amex standard coaxial practices. Splicing was performed primarily by Warner Amex technicians after a period of on-the-job training by the cable supplier, Siecor. The project was constructed, installed, and activated on schedule. Construction, maintenance, and operation is managed by Warner Amex Dallas Commercial Services operations.

FIBER OPTIC SYSTEMS DESCRIPTION AND OPERATION

Figure 4 shows the schematic block diagram of the system. The main elements are:

a) Channel banks and data channel cards
b) Multiplexers
c) Fiber optic transmitters and receivers
d) Fiber pairs



System Block Diagram
Figure 4

The equipment used is the DML-45 single mode lightwave transmission terminals supplied by Rockwell International. The channel banks and data channel cards interface with the laser-fax control data lines and combine these digital lines (two 2.4 Kb/s channels) into a common data stream at a DS-1 rate (1.544 Mb/s). Channel cards are modular and can be mixed in each channel bank to accommodate various combinations of data rates. Standard RS232 interfaces are provided.

The DS-3 multiplexer contains data ports which can interface at a DS-1 rate (1.544 Mb/s) or a DS-2 rate (6.312 Mb/s). In this application, it is equipped with two DS-2 modules and one quad DS-1 module plus protection cards. The DS-3 multiplexer is expandable to accommodate seven DS-2 circuits or 28 DS-1 circuits. The multiplexer combines these circuits to form a single high speed DS-3 rate (44.7 Mb/s) line for transmission over the fiber optics.

The fiber optic transmitters receive the DS-3 rate signal, intensity modulate a laser, and transmit this optical signal over the fiber to a mating receiver at the repeater or opposite terminal. The receiver contains a photodetector which converts the optical signal to a binary electrical signal.

The terminal electronics at each site is capable of working without repeaters over the full length of the single mode cable. The optical transmitters and receivers are duplicated in order to provide redundant electronics over the redundant path in the event of failure or damage to equipment or cable.

Protection switching, internal to the multiplexer, automatically switches from primary to the hot standby protection channel in the event of a failure or signal degradation beyond a certain threshold. Redundancy is provided within the multiplexers at the DS-3, DS-2, and DS-1 levels. The protection electronics monitors the bit error rate (BER) on the primary channel, and if it falls below a certain threshold (10^{-7} nominal), switches automatically to the back-up hot standby channel.

In each of two diversely routed cables, there are two fibers for DMN operation. In one cable, the two fibers provide the primary channel; in the other cable, the two fibers provide the back-up protection channel. In each pair, one fiber is for downstream data and the other is for return. The fiber used is single mode operating at 1300 nm wavelength.

RESULTS

The system was designed for a spliced fiber loss of 0.6 dB/km. Actual plant loss averaged 0.45 dB/km spliced, providing an end-to-end loss of only 17 dB for the primary path and 19 dB for the back-up. The equipment had an allowable optical power margin of 31.5 dB between terminals (connectors included). An excess power margin of 12.5 dB, therefore, remained. Key performance parameters for the system were a received bit error rate (BER) of 10^{-9} and an availability of 99.98% (1.75 hours/year downtime maximum). BER was monitored full time for a period of two months. During that time, no bit errors were recorded. Since activation in December 1984, availability has been 100%. All newspapers printed in the Plano satellite plant since January 7, 1985, have used the fiber link for press-fax.

CONCLUSION

Fiber optics provides an excellent, cost effective, highly reliable, ultra-high quality means for data transmission in the metropolitan area. For newspaper operations requiring satellite plant printing or printing operations separated from composing, fiber optics is a very practical transmission medium for linking the operations. Fiber offers the wide bandwidth necessary to operate laser-facsimile equipment without the degradation in performance often suffered with other narrowband or more noise-susceptable means of transmission such as microwave or telephone lines. Cable TV networks offer a convenient and low cost facility for constructing such links, and due to the usually abundant aerial right-of-way, offer a low cost opportunity to provide fully diverse routing--the ultimate in systems reliability. Fiber optics is a mature technology and uncomplicated to build and maintain. It may be considered without reservation for private network applications.

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A REAL-WORLD SYSTEM COST MODEL FOR OFF-PREMISES SUBSCRIBER EQUIPMENT

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ABSTRACT

Off-premises subscriber equipment is either now available or under development by several manufacturers. This equipment includes outdoor addressable converters, taps, traps and jammers, applications for which are predicated on a growing need to minimize the electronic equipment inside the subscriber's home -- not only to increase signal security, but to reduce system maintenance and pay channel churn.

This paper presents a unified analysis of a fragmented and multi-faceted emerging technology. It proffers a simple and accurate method of estimating total system costs required in the use of off-premises subscriber equipment and presents a model that allows a direct relation between equipment costs and system costs applicable to all known off-premises devices.

There has been little or no means of providing a consistent comparison between the various manufacturers' products on a cost-per-subscriber basis. Presently, manufacturers can provide equipment pricing either for fully loaded (100 percent penetration), or partially loaded configurations, i.e., prices for a "common" housing, chassis, etc., and plug-in subscriber modules. However, these equipment costs cannot be related to the system cost without an actual model.

The model presented here is based on actual port usage, employing statistics from Jerrold's installed base, in order to arrive at a probability density function. It is applicable to any off-premises subscriber device and provides for an estimation of system costs and a comparison of competitive technology. The model has undergone extensive testing by application to actual systems presently under design.

SOME BROAD GENERALITIES

It is popular these days to consider technical approaches that would remove the set-top converter from the subscriber's home.

The two main reasons given for wanting to do this are to minimize the operator's investment within the home and to maximize signal security. Both of these perceived needs are of particular interest for application to the big cities; in particular, where lower economic scaled people are concentrated, thereby conjuring up visions of high churn, difficulty in maintenance, equipment theft and inability to audit installations.

The ideal is to provide all electronics off-premise within an "off-premise device" (OPD) in locations having unrestricted access by operators, with the only operator investment at the home being drop cable, ground block and an F-connector. This ideal can be rapidly compromised by consideration of the need for subscriber powering, channel selection and conversion for non-cable ready TVs. When features such as parental control, impulse-pay-per view, remote control and remote volume control are included, then the investment within the home can no longer be considered minimized, although it should still be less than a conventional scrambled addressable set-top based system. The cost per subscriber of the in-house electronics (IHE), however is a known entity, unlike, as is shown later, that of the OPD.

The signal security ideal can also be severely compromised with off-premise devices, especially if unscrambled premium signals are available on feeder lines up to the OPD. This is because high density housing provides plenty of opportunity for impossible-to-audit pressure taps and, not attempting to coin a new term, CPTTV, or Community Pressure Tap Television where enterprising pressure tappers can provide for locally operated distribution of the clear signals.

OPD TECHNIQUES

There are currently three generic techniques associated with off-premises devices. All of which are head-end addressable.

Off-Premise Converters

Here, the RF signal conversion electronics is placed within the OPD and the subscriber control unit within the IHE. One converter is needed for each TV or VCR. The drop cable is no longer broadband multichannel, but now only supports one channel per TV or VCR. Present technology provides for multiplexing of two channels (plus FM band) per drop, with no real technical reason for not increasing to three or more per drop. The drop lengths are dependent on powering, not bandwidth.

Addressable Traps - Filtering Method

This technique provides for addressable channel rejection filters (traps) for premium channels or tiers. The drop cable is broadband and all but the rejected channels are available to all subscriber TVs or VCRs. The IHE contains the subscriber control plus converter, the latter of which is normally plain but could also include a descrambler at higher IHE cost. The drop length can be limited by either subscriber powering or bandwidth.

Addressable Traps - Jamming Method

This technique uses an addressable jammer to jam premium channels or tiers. The drop cable is broadband and all signals are available to all subscriber TVs and VCRs. However, those that are jammed are useless. The IHE contains the subscriber control plus converter, plain or with descrambler.

OPD DESIGN

The OPD must contain head end addressable hardware, power supplies, microprocessor memory, signal splitting, etc., regardless of which of the three technologies is chosen. This "common electronics" portion together with the known requirements for surge protection, RFI seal, weather seal, feeder line through loss, etc., essentially dictates that the OPD equipment cost on a per port basis is minimized when the common electronics cost is distributed over the maximum number of subscriber ports. For this reason, equipment concepts of up to 32 ports have emerged with 8 and 16 ports being typical. Another typical feature is plug-in modularity, organized on a per port basis with the philosophy being to plug in subscriber modules on an as-installed basis, and assumedly, to pluck them out on an as-disconnected basis.

OPD SYSTEM COST MODEL

In other words, in order to implement an OPD-oriented system in the most economical way, a non-conventional system design configuration must be used. The design would be different for each of the three OPD technologies mentioned previously, but is, in general, characterized by more ports per housing, fewer housings and longer drop lengths than conventional tap (i.e., two, four or eight port) system approaches.

Since fewer housings are needed and each OPD contains RF gain, the through-line feeder insertion loss can be minimized so that fewer line extenders are needed. However, more power supplies or more power capability may be needed, even though fewer line extenders are used, to power all or part of the OPD electronics itself.

Of course, the problem with any non-conventional system design is that if for any reason things don't work out in the long run, the entire feeder system must then be rebuilt in order to revert to a set-top converter approach with conventional taps. Over the years, several manufacturers have standardized the various tap sizes and values so that multiple sources exist. Off-Premises Device technology, however, has not yet been standardized and the manufacturers currently involved have each come up with significantly different approaches that require different system designs. Each offerer has their own design rules, which apparently are chosen to minimize system cost for comparison purposes. However, in order to compare OPD technologies, at least a sample of each system has to be designed for all OPD approaches under consideration.

THE CONVENTIONAL MODEL FOR OPD DESIGN

For the reasons cited above, what is proposed in this paper is to apply all OPD approaches to a conventional (tap plus set-top) system model, for comparison purposes. This is totally real world (assuming clearances) for the upgrade market application and is not improper for the new build and rebuild applications, for those operators who do not want to accept the risk of forced rebuild in the event something goes wrong.

A reasonable approach would be to design the system using conventional two, four and eight-way taps. Then cost out the application of the OPD corresponding to those tap sizes.

From Jerrold historical records, the tap distribution in the United States is 36% two-way, 43% four-way and 21% eight-way. That's what is out there now based on one port per home passed.

Before we can crank out the numbers, however, there remains one burning question involving the OPD technology of off-premise converters: how many ports per home passed? Or how many TVs and VCRs are going to be in each home at any time during the next 20 years? If you pick a number too low and design to it, then higher penetration could mean system redesign or at least splicing in of more housings. Pick a number too high and the system's initial cost becomes prohibitive. And no number is right; one block may have homes wanting cable with three TVs and two VCRs each and the next block may not subscribe. There is no answer to this one, but some designers use three ports per home and hope for the best.

Since the intention is to replace conventional taps with addressable OPDs, it is important that the probability of port usage for each tap size be entered into the model. This would naturally depend upon penetration; for a perfectly designed system, all tap ports would be used at 100% penetration. At a typical 55% penetration, we can expect that about half of the available tap ports are in use for each tap size. Most two-way taps have one connection, most four-way have two and most eight-way have four or five, per the probability distribution breakdown shown in Table 1. The composite probability is the probability of having some number of connections in use for a tap of <u>any</u> size, for example, 5% of the total taps out there are two-ways with two active connections and 18% are four-ways with two active connections, for a composite of 23% of taps with exactly two connections.

TABLE 1

SYSTEM SUBSCRIBER TAP
PROBABILITY DENSITY FUNCTION

| PROBABILITY OF CONNECTED SUBSCRIBERS |

SUBS PER HOUSING	2 WAY	4 WAY	8 WAY	COMPOSITE	AVERAGE SUBS PER TAP
0	.12	.03	---	.15	---
1	.19	.08	---	.27	.27
2	.05	.18	---	.23	.46
3		.10	---	.10	.30
4		.04	.01	.10	.40
5			.094	.094	.47
6			.04	.04	.24
7			.01	.01	.07
8			.006	.006	.05
TOTALS	.36	.43	.21	1.00	2.26

NOTE:

AVERAGE SUBS PER TAP HOUSING LOCATION = 2.26

AVERAGE PORTS PER TAP HOUSING LOCATION = 4.12

CALCULATED AVERAGE SUBSCRIBER PENETRATION $= \frac{2.26}{4.12}$ 55%

EQUIPMENT COST

We can now apply the composite subs-per-tap factor to price out the system, under the rule of having to place the OPDs at the exact locations where two, four or eight-way taps would be placed in a conventional system. To do this, we need to price the OPD equipment out depending upon the ports used. Consider three cases:

Case 1: Equipment designed with minimum use of common electronics with almost all electronics dedicated to each subscriber drop module. The housing and common electronics is priced at $80, with $120 per subscriber module, assumed to be plugged in on an as-required basis.

Case 2: Equipment designed with maximum use of common electronics and relatively little dedicated to the subscriber drop module. The housing and common electronics is priced at $250, with $25 per subscriber module, assumed to be plugged in on an as-required basis.

Case 3: Same equipment as Case 2 except that the subscriber modules for the two, four and eight port OPDs are plugged in on initial system turn-on.

TAPS USED	CASE 1		CASE 2		CASE 3	
	TOTAL	PER SUB	TOTAL	PER SUB	TOTAL	PER SUB
0	$ 8	$ 0	$ 8	$ 0	$ 8	$ 0
1	200	200	275	275	300	300
2	320	160	300	150	300	150
3	440	147	325	108	350	116
4	560	140	350	88	350	88
5	680	136	375	75	450	90
6	800	133	400	67	450	75
7	920	131	425	61	450	64
8	1040	130	450	56	450	56

CASE 1 $80 Common plus $120 plug-in module per sub.

CASE 2 $250 Common plus $25 plug-in module per sub.

TABLE 2

EQUIPMENT PRICING EXAMPLES

The prices given represent hypothetical situations and are not intended to represent any particular manufacturer or technology. Since there are no standards, it would not be surprising if the manufacturer of the Case B equipment would advertise a $56 per subscriber unit "less than half the price of his competitor", the Case 1 manufacturer. However, the systems are essentially equal in price.

The fact that Case 1 and Case 2 system cost is identical can be shown by applying the density function to the pricing examples to result in Table 3. In this model, both cases are about $139 per subscriber, in contrast to prices of $130 and $56 that are based on the fully loaded eight-way OPD (which occurs in 0.6% of the situations for conventional eight-way taps).

Case 3 further tells us that fully loading the OPD prior to subscriber connections only costs $9 per subscriber more than Case 2 equipment. The same exercise applied to Case 1 results in a $185 per subscriber price, however, about $45 higher for this mode of installation.

Both installation techniques and all three cases can be reduced to simple formulas, requiring as input only the cost data for the housing (common electronics) and subscriber module, as shown in Table 3.

			CASE 1			CASE 2			CASE 3		
TAPS USED	COMPOSITE DISTRIBUTION FACTOR	AVERAGE SUBS PER TAP	SELL PRICE	PRICE PER SUB	PRICE PER SUB XPDF	SELL PRICE	PRICE PER SUB	PRICE PER SUB XPDF	SELL PRICE	PRICE PER SUB	PRICE PER SUB XPDF
0	0.15	----	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
1	0.27	0.27	200	200	54.00	275	275	74.25	300	300	81.00
2	0.23	0.46	320	160	36.80	300	150	34.50	300	150	34.50
3	0.10	0.30	440	147	14.67	325	108	10.83	350	116	11.67
4	0.10	0.40	560	140	14.00	350	88	8.75	350	88	8.75
5	0.094	0.47	680	136	12.78	375	75	7.05	450	90	8.46
6	0.04	0.24	800	133	5.33	400	67	2.67	450	75	3.00
7	0.01	0.07	920	131	1.31	425	61	0.61	450	64	0.64
8	0.006	0.05	1040	130	.78	450	56	.34	450	56	.34
TOTAL	1.00	2.26			$139.67 PRICE			$139.00 PRICE			$148.36 PRICE
FORMULA			0.47H + 0.85M = PPS H = 80 M = 120			0.47H + 0.85M = PPS H = 250 M = 25			0.47H + 1.23M = PPS H = 250 M = 25		

TABLE 3

MODELED COST PER SUBSCRIBER

CONCLUSION

Operators contemplating off-premise subscriber equipment should be very careful when deciding system configuration and should consider using conventional system architecture to avoid the possibility of getting stuck with a special system for which rebuild is the only option. Accordingly, systems using off-premise equipment should be priced out using conventional system (tap and set-top converter) design rules. The examples given show that only a consistently and properly weighted per-subscriber equipment cost should be considered, which is generally significantly different than that of the improbable fully-loaded equipment.

ACCOMMODATION OF VCR'S AND STEREO TELEVISION IN THE DESIGN OF SUBSCRIBER DEVICES

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ABSTRACT

New devices and technologies in the home are creating new challenges for converter manufacturers. For example, one of the most popular applications of VCR's is time shifting of programs for later viewing. But subscribers wishing to use their VCRs' programmable features are finding their cable converter an obstacle. Another example: With the introduction of stereo television, NCTA-commissioned research has identified many technical problems associated with carriage of the broadcast stereo method on cable systems. Yet cable needs a practical stereo delivery method to keep its product competitive with broadcasters. An addressable converter system design approach is discussed by which these two consumer phenomena - the VCR and stereo TV - may be eliminated as problem areas for the cable operator.

CABLE AND THE VCR

As the penetration of VCR's into cable homes surges past the 35% penetration mark, the issue of compatibility and mutual friendliness between VCR and converter is moving into the forefront.

VCR owners look to cable's satellite-delivered basic and pay services as their prime source of program material for recording. To make such recording possible in the owner's absence, nearly all VCR's include a programmable 'timer' feature that allows the VCR to be pre-programmed to automatically tune to a specific channel at a later specific time. But most cable subscribers are finding that this convenience feature can't be used to pre-schedule recording of cable TV programs, because their cable service requires they have a converter/ descrambler between their cable input and VCR/TV. Since the converter's actual output is always a fixed channel (typically channel 2 or 3), regardless of the channel actually selected by the subscriber, the VCR's capability to tune to a specific channel at a particular pre-programmed time is rendered useless. The VCR's built-in timer might still be of value, except for the fact that:

(1) the converter power must already be "on", and
(2) the desired channel must already have been manually selected by the subscriber using the converter's tuning controls.

A straightforward solution to this converter/VCR incompatibility is to build into the converter a programmable timer of its own. A fringe benefit of such an approach is even additional converter functionality: using that same timer, the converter can be programmed for other applications, such as wake-up, snooze, or show reminder timing.

The timer feature is highly desirous in the converter. But price pressures in the converter marketplace demand the feature be added for an incremental cost which is at most minimal, and preferably nothing at all. Furthermore, subscriber simplicity is essential if the feature is included: the subscriber should not be expected to keep TWO complete electronic clocks (one in his VCR, one in his converter) synchronized and set for the correct time to make possible unattended time-shift VCR operation. For both these reasons - cost and simplicity - a "timer" approach other than just another clock is required. Fortunately, the latest generation of addressable converters already has inherent attributes which make such an alternate approach feasible.

With addressability, the cable operator has a data communications conduit established between one central cable office control location and thousands of converters in subscriber homes. The latest generation, which includes the "downloading" feature, makes possible easy operator setting and resetting of many system-related converter parameters (channel/frequency maps, channel format, etc.) by simple computer data entry from the operator's central vantage point. By application of this "downloading" capability to the converter's need for a VCR timer, it is possible to have one central computer clock at the operator's office keep track of the day, date and time, and simply keep all converters advised through "refresh" updates, "globally" broadcast to all converters. In data communication terms, the amount of information being distributed -day, date, time- is miniscule, so a refresh interval of every minute is not an obstacle. Thus no true "clock", per se, need be present in the converter...the operator's headend is really the one system master clock. Conventional RAM in the converter can receive and store the necessary refreshes. Even if the continuous flow of refresh updates should be interrupted by headend equipment failure, the same 10-year-life lithium battery backup in the converter used to backup other download functions can keep the converter aware of the last broadcast time refresh. A timing loop in the converter's firmware can then extrapolate actual day/date/time quite accurately for many minutes, even in the absence of additional updates from the operator headend.

The result is a quite simple and friendly VCR timer feature in the converter with almost no incremental cost.

One implementation with which the writer is familiar, the Pioneer BA-5000 series converters, offers two such programmable timers in the converter; i.e., at any time, two forthcoming unattended recording sessions can be in queue, as pre-programmed by the subscriber.

Through the use of prompting characters in the l.e.d. channel number display on these converters, a subscriber can easily program in cable channel number and start/stop day, hour and minute for each of the two "timers", as illustrated in Figure 1. The subscriber never need worry about his converter knowing the correct time...it always knows, thanks to one-way addressability with "downloading".

USER'S GUIDE - SETTING YOUR CONVERTER PROGRAM TIMERS

There are two independent program timers available. Once a timer is set, the converter will automatically turn the TV on/off at the designated time and will select the designated channel number. To set a timer, follow the procedure illustrated in the example below. If you make a mistake, press [TIM] [TIM] and restart the procedure.

In the following example, you will first set Timer #1 to automatically: * Turn on the TV and tune to channel number 5...,* Monday evening...,* Starting at 8:10 p.m....,* Ending at 11:15 p.m. Then you will have the Timer "read back" to you how it has been set, as a "double check".

SETTING THE TIMER

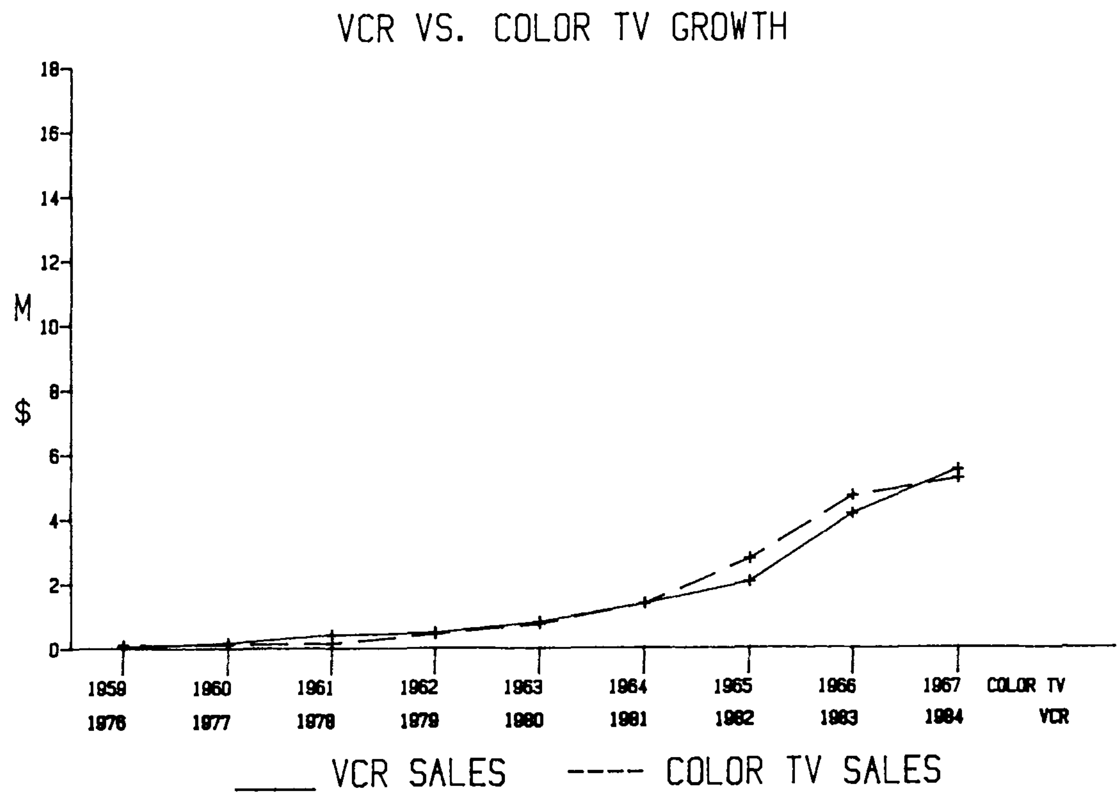
STEP	PRESS	SEE DISPLAYED
You tell the box to enter the "Set TIMer" mode.	[TIM]	
You tell the box to get ready to SToResettings for Timer #1 of the two available timers.	[1] [STR]	CH
The box asks for the CHannel number. You answer "channel 5".	[5] [STR]	dA
The box asks for the dAy number (Sun=1, Mon=2 etc.; 0=Everyday). You answer "Monday" (day number 2).	[2] [STR]	SH
The box asks for the Starting Hour. ("Military Time": PM = AM + 12 hours). You answer 20. (8:10 p.m.; 8 + 12 = 20)	[2] [0] [STR]	Sn
The box asks for the Starting Minute. You answer 10 (8:10 p.m.).	[1] [0] [STR]	EH
The box asks for the Ending Hour. You answer 23 (11:15 p.m.; 11 + 12 = 23).	[2] [3] [STR]	En
The box asks for the Ending Minute. You answer 15 (11:15 p.m.).	[1] [5] [STR]	P 1
The box tells you that you have successfully preset Program Timer #1.		
You tell the box to exit the "Set TIMer" mode.	[TIM]	

READING BACK THE TIMER'S CURRENT SETTINGS

STEP	PRESS	SEE DISPLAYED
1. You tell the box to "read back" (ReCaLl) Timer #1's settings.	[TIM] [1] [RCL]	
2. The box answers: channel 5, day 2 (Monday), starting 20:10 (8:10 p.m.) ending 23:15 (11:15 p.m.)		CH 5 dA 2 SH 20 Sn 10 EH [illegible] En 15

Figure 1.

Figure 2.



CABLE AND STEREO TV

The VCR, although only recently raised to prominence among cable's biggest issues of concern, has actually been brewing a long time. In fact, Figure 2 shows how VCR sales in recent years have quite neatly replicated the growth color TV enjoyed back in the 60's. Indeed, the VCR has been around "in quantity" a full decade, yet only now is reaching the point of major concern to cable operators. This point is cogent to keep in mind as one contemplates the much more recent phenomenon of stereo television, and its impact on cable.

Last year action by the FCC positioned the "BTSC" delivery stereo audio delivery method as a broadcast industry de facto standard. However, shortly thereafter, an NCTA-commissioned engineering study revealed that accomodating the new broadcast stereo cable signals would cost operators over $700 million in system upgrading costs, despite the fact that it will likely be many years before a large quantity of stereo TV sets capable of receiving BTSC stereo TV signals are in subscriber homes.

On the positive side for operators, however, the stereo TV issue has also brought to light a significant business opportunity for which the cable industry now finds itself ideally positioned...an opportunity for cable - not broadcast TV - to become the established place the consumer turns to to get stereo television reception and quality TV sound in general.

The TV networks and their broadcast TV affiliates are still largely in their infancy with stereo experience. On the contrary, cable operators currently have direct and easy access to a multitude of stereophonic satellite-delivered services. A March, 1985, survey among program suppliers revealed that 12 were already beaming a stereo audio signal to cable headends, along with their channel's video content. These suppliers include noteworthy advertiser-supported services like MTV, VH-1, Nashville Network, USA Network, Cable News Network, and pay services such as Bravo, Disney, Home Theater Network, and The Movie Channel.

For several years, some cable systems

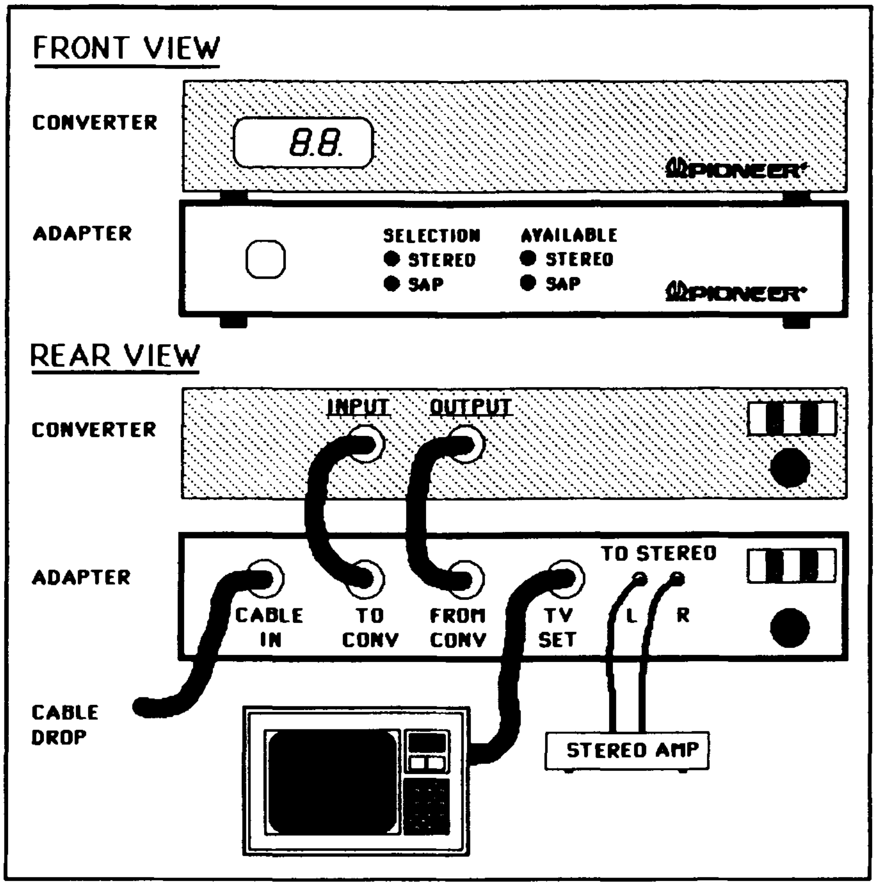


Figure 3. Stereo Adapter Installed Underneath a Converter.

have been offering their subscribers satellite-delivered TV channels with stereo sound by "simulcasting" the audio on additional FM stereo multiplex audio channels placed on the cable system. As a result, about 1.5 million 'FM outlet' subscribers (out of about 36 million total basic cable subscribers nationwide) can now enjoy the excellent sound quality of these FM stereo simulcasts with their TV viewing. But can they easily FIND the simulcast signal among all the other FM stations on the dial? And is it reasonable to expect them to institute another 'station search' every time they change TV channels? And what if a TV station they switch to is not even accompanied by an FM simulcast station on the cable at all? These shortcomings are a primary reason why FM simulcast TV stereo sound has not already gained a much broader acceptance among subscribers already offered the service. But the addition of a few pieces of headend equipment, and a subscriber-installable add-on near his converter, could easily eliminate these obstacles.

Let's call the in-home add-on "The Tracker". It is a device which can be added on to most existing models of converters. From the subscriber's standpoint, it is simply a 'Stereo Adapter' that allows him to connect his TV to his stereo system. Installation is so simple enough the subscriber can pick up a unit from his cable operator, take it home, and install it himself (Figure #3).

Electrically, it connects 'around' a subscriber's CATV converter, sampling rf on both the input and output sides of the converter (Figure 4). Standard audio cables then deliver left and right audio channels to the subscriber's stereo system.

At the cable headend, stereo channels - i.e., those channels for which the operator is also simulcasting an FM multiplex signal - are 'tagged' with a data signal by a relatively inexpensive additional piece of electronics. All other channels are processed as usual.

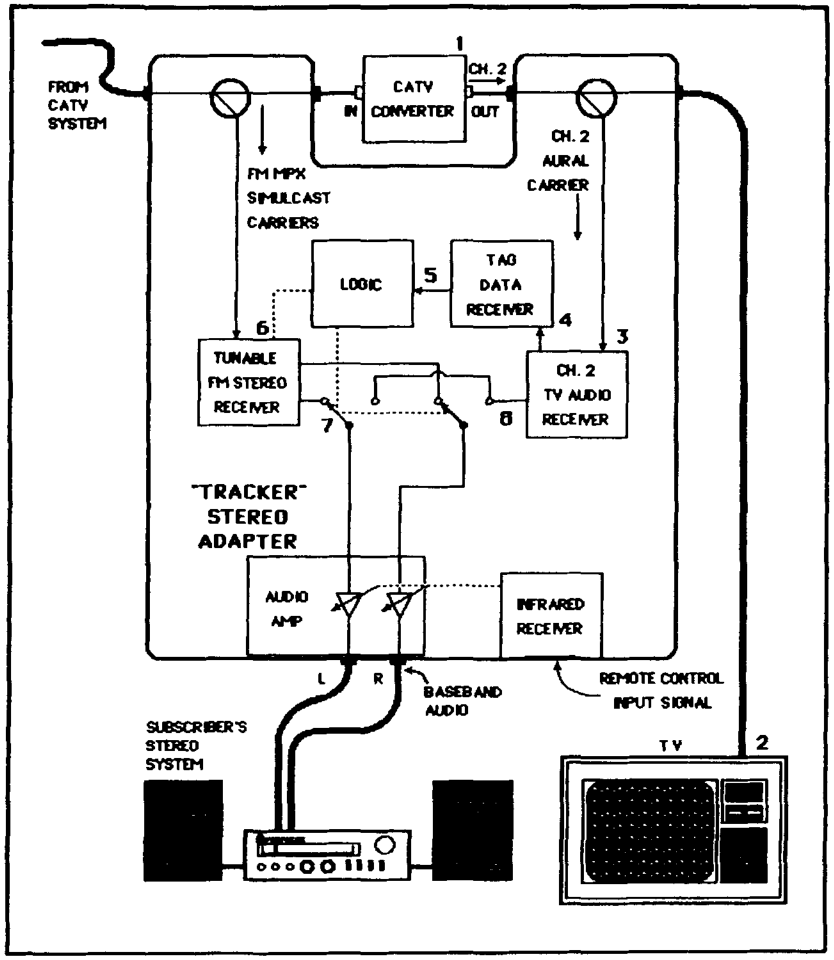


Figure 4. Stereo Adapter Functional Block Diagram.

No expensive BTSC processing equipment is involved anywhere. Troublesome BTSC signals are kept totally out of the cable system.

To understand how the Tracker works, refer to Figure #4. Suppose a subscriber selects for example, HBO. His converter outputs HBO on channel 2 (1), sending it on to the subscriber's TV for picture viewing (2). Meanwhile, a channel 2 audio receiver inside the Stereo Adapter also receives HBO's sound signal (3). This receiver in turn feeds a tag data receiver (4). HBO tag data is then passed on to a logic circuit (5). The logic circuit reads the tag data to determine at what frequency on the cable system the FM stereo multiplex simulcast for HBO can be found. It then tunes the FM multiplex receiver to the frequency where HBO stereo audio is being simulcast (6), and connects the FM stereo receiver output to the subscriber's stereo system (7).

Suppose instead a subscriber selects a TV station not broadcasting in stereo. In this case, the cable operator is not originating a stereo simulcast signal, nor generating any 'tag' data, for the channel. Again, the converter outputs the station on channel 2 (1), sending it on to the TV (2) and the channel 2 audio receiver inside the Stereo Adapter (3). This time, however, the Tag Data Receiver sees no tag at all (4). This tells the logic that no simulcast FM stereo channel exists for this station, so the logic circuit connects the channel 2 audio receiver output to the subscriber's stereo system (8).

Naturally, all the above takes place instantaneously, and transparent to the subscriber. All he knows is that, as he switches channels, he receives superb sound quality through his stereo system on all channels, and on some he also receives true stereo. He has obtained 'stereo television' without buying a new TV set. And sound quality on ALL channels is probably better than if he had purchased a new stereo TV, too, since his stereo audio system is likely alot better sounding than any of the new stereo TV sets.

There's another fringe benefit to the Stereo Adapter, too. A subscriber can have remote control of TV volume using an optional handheld keypad. Even subscribers who previously couldn't get volume control, due to limitations inherent in their r.f. converter design, now have remote capability via the Tracker.

Cable, as a "closed circuit" medium, is not required to use the broadcast BTSC stereo TV sound delivery method. Cable is free to offer any alternative delivery method it wishes. "The Tracker" is one such alternative having many practical advantages:

* Threatening BTSC signals are kept completely out of the CATV system.

* The customer service 'nightmare' sure to result otherwise, is avoided.

* A major expense is avoided in converter, headend processor, and possibly plant upgrades to accomodate BTSC signals.

* Headend equipment to stereo-ize a cable system is cheaper with 'tracking'.

* Many operators already FM simulcast satellite-delivered stereo channels, so only an inexpensive tag generator is required in those cases to "stereo-ize" a channel.

* Expensive BTSC signal originating equipment is not required!

* A new revenue source is created for the cable operator: The subscriber instantly gets 10 or more stereo TV stations through his cable operator, plus superb sound quality on all channels, WITHOUT spending $1200 or more on a new stereo TV set.

* The Tracker is subscriber-installable, no truck roll is required to retrofit converters for BTSC.

* The actual service delivered... 'supersound' on ALL channels...has a high perceived value to subscribers, yet zero incremental direct cost to the operator (the stereo comes along free to the operator with the TV channel).

* The greatest portion of marketing expense to sell subscribers on the service, that of educating them on 'stereo TV', is 'free' to the operator...thanks to set manufacturers', networks', and local broadcast stations' large marketing budgets promoting "stereo TV" to the public.

CONCLUSION

The VCR Timer feature and add-on Stereo Adapter alternative to BTSC stereo TV are specific examples of a new generation of technical innovations now emerging from converter manufacturers. They are solutions to the very practical problems involved with the more global issue of cable TV "interfacing" within the home.

For the very "long haul" - beyond 10 years - the author commends the work of groups like the joint EIA/NCTA Engineering Committee for its ongoing efforts toward practical standards for compatibility and interfacing between consumer devices hooked to cable systems. Meanwhile, for at least the next 10 years, innovative solutions like the VCR Timer and Stereo Adapter will hopefully make coping with "interface" not only more palatable, but also more profitable, for the cable operator.

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ADDRESSABLE CONVERTERS: WHY TAKE THEM OUT OF THE HOUSE?

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The design criteria for off-premises converters have been increased signal security and lower in-home costs. Products currently available in this market are clear channel systems selling at a premium price.

This paper questions the security of a clear channel system versus currently available scrambling techniques. It also presents an economic review of savings achieved by reducing in-home costs versus the premium price of off-premises converters. Finally, the ramifications of dedicated plant designs required by off-premises converter are discussed.

These issues must be addressed before making the decision to remove the subscriber's converter from the home and place it on the line.

Currently, six million subscribers have addressable terminals in their homes. These units convert and descramble the broadband spectrum for input to the subscriber's television set. Scrambling methods have evolved to a level of sophistication effective in preventing most theft of service. By scrambling the premium spectrum, security of signal is assured not only in the home, but also on the cable plant.

Addressable set-top units initially offered static modes of sync suppression. The industry offered either 6 dB square or sinc wave attenuation of the sync pulse of a channel. The latest offerings in RF converters provide either pseudo-random timing of sync suppression or variable levels of sync suppression with pseudo-random level change timing. These methods require the addition of encrypted data for descrambling the video signal. But the audio portion of the signal is not left alone. Attenuation of the audio and scrambled video is included in current RF converters for additional security. Baseband descramblers add video inversion and audio scrambling to the sophisticated RF scrambling techniques.

These scrambling methods were not only developed to prevent a subscriber from obtaining free service from his legal drop, but to impede the occurrence of illegal drops and taps.

Off-premises converters receive a clear channel via the cable system, convert that channel, if authorized, to a set 6MHz channel and pass it down the drop to the subscriber's home. Attenuation or off-channel tuning are utilized to prevent unauthorized premium channels from being carried on the drop. This method protects services delivered via the drop, but does not consider protection of the signal on the cable system and neighboring drops.

In addition, since the basic output of an off-premises converter is a single channel, limitations are placed on additional sets in the home. Most off-premises converter manufacturers offer a second non-adjacent channel output for second sets (2,4 or 3,5 are most popular channel allocations for dual sets). This requires either a second converter module or a single module containing dual converters. Also required is a second data path for independent communications. Currently, the second set market ranges between 10% and 50% with an average of 20%. The advent of the VCR marketplace will increase second and third set penetration levels.

An independent third set can't be supported on one drop with an off-premises converter. This requires a third, non-adjacent channel allocation and a third data frequency pair to support a third set on one drop. The third channel allocation would have to be in the high band. Also, some markets don't have three unused frequencies in the VHF range. Therefore, a third set requires an additional port in the off-premises converter backplane, which entails additional costs per subscriber, while making plant design more difficult. A second drop must be pulled to provide a third set.

Since a broadband spectrum is available on the drop, second and third sets are easily offered in an addressable set-top system. Individual authorizations can be stored for each terminal, allowing the subscriber to add additional televisions with unique premium packaging.

Off-premises converters do offer an inexpensive in-home unit that provides all subscriber features currently available with addressable on-premises converters. If theft of equipment is a substantial issue, this reduced investment in the home can provide a savings to the operator. But off-premises converters are premium priced when compared with set-top units. So it is necessary to define a break even point. At what level of equipment theft does off-premises technology really pay?

The chart in Figure 1 sets forth capital outlay required to start up an addressable converter system and to replace stolen equipment on an annual basis. The analysis assumes a $30 price for in-home unit for off-premises converters. The theft rate reflects a system-wide average. The data indicates that an investment in off-premises converters can't be justified in the first year, even under the most severe theft conditions, that is, 20% or one in five boxes stolen per year. Even over a five-year period only lower priced off-premises converters can be justified in a system with a 10% average theft rate. This translates into theft of 5,000 converters in a 10,000 converter

(Figure 1)

CAPITAL INVESTMENTS
FOR 10,000 SUBSCRIBER SYSTEM

	ANNUAL EQUIPMENT THEFT RATE			
	2 %	5 %	10 %	20 %
ON-PREMISES $100/Unit				
Initial Investment	$ 1000K	$ 1000K	$ 1000K	$ 1000K
Replacement Costs/yr.	20K	50K	100K	200K
Total Capital - 1 yr.	1020K	1050K	1100K	1200K
Total Capital - 5 yrs.	1120K	1250K	1500K	2000K
OFF-PREMISES $130/Unit				
Initial Investment	$ 1300K	$ 1300K	$ 1300K	$ 1300K
Replacement Costs/yr.	6K	15K	30K	60K
Total Capital - 1 yr.	1306K	1315K	1330K	1360K
Total Capital - 5 yrs.	1330K	1375K	1450K	1600K
OFF-PREMISES $150/Unit				
Initial Investment	$ 1500K	$ 1500K	$ 1500K	$ 1500K
Replacement Cost/yr.	6K	15K	30K	60K
Total Capital - 1 yr.	1506K	1515K	1530K	1560K
Total Capital - 5 yrs.	1530K	1575K	1650K	1800K

system over the course of five years. While pockets of high theft do exist in some systems, especially in apartment complexes, an overall rate of 10% in a system is rare.

Off-premises converters also require additional plant investment. Since dedicated ports are required for each home passed, some additional cost is required to hook-up the first subscriber in an eight subscriber housing. With the industry's basic penetration rate standing at approximately 50% of homes passed, an additional initial investment is required to allow room for expansion. Currently, the cost of the housing and backplane will be spread over only 50% of available ports, thus increasing this initial investment.

Intricate planning is involved in system design of an off-premises converter system. Not only must an operator plan for future penetration levels and new construction, he must also dedicate his plant to the architecture required by the technology. Once deciding to build the cable plant to support off-premises converters, there is no turning back to a conventional build.

Housings for off-premises converters are larger and are spaced differently than standard taps. While the typical housing replaces an eight-way tap, it's not economical to replace two and four-way taps with an eight port housing. Because of this new spacing of eight port housings, longer drops are required to reach locations normally served by two and four-way taps.

Because of the size of these eight-way housings, splicing is required in order to return to a standard eight-way tap. The smallest off-premises housing is 15 inches in length, and the largest standard tap is six inches, obviously leaving a cable gap of nine inches. Returning to standard system architecture, therefore, would necessarily impact the signal quality.

It is also necessary to take powering of the off-premises unit into consideration. If the converters or common electronics are backpowered from the subscriber's home drop cable, loop resistance and UL specifications must be considered in the design phase. To achieve some longer drop lengths, cable loop resistance must be decreased to meet the UL specification of 21.2 VDC maximum for outdoor environments. As the IR loss specification for drop cable decreases, its price increases.

If the cost of drop cable or local fire and electrical codes prohibit carrying power over the drop, then a local power source is required. Either a dedicated power supply or 60V square wave available on the cable plant can be utilized as a power source. This also means the cable operator assumes the expense of powering the converters, a cost not traditionally incurred with on-premises converters.

Conclusion

Current addressable terminal systems achieve signal security through scrambling. This method not only protects against illegal or unauthorized reception of premium services over a legal drop, but also illegal taps and drops. Off-premises converter systems prevent only the free use of premium service over the drop.

While off-premises converters do provide a significantly reduced investment in the home, the premium price of off-premises is only justifiable where there is an inordinately high amount of equipment theft throughout the system.

Finally, making the decision to go the off-premises route must be a final one, since a dedicated plant architecture is required to support this technology. It is possible to upgrade existing set-top addressable systems without making changes to the plant design.

There's an important question cable system operators should ask in all of this: Why move the converter out of the house?

###

AN FM/FDM/IM/WDM FIBER OPTIC SUPERTRUNK FOR REPEATERLESS TRANSMISSION OF 10 VIDEO CHANNELS UP TO 45 KM

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ABSTRACT

A repeaterless transmission system capable of transmitting ten video and two, 1.544 MBit/s, digital channels over one singlemode fiber up to distances of 45 km was developed. The system consists of ten wideband Frequency Modulation modems, two digital modems, two long wavelength laser diodes that are both in the 1300 nm range and approximately 50 nm apart, and a specially developed Wavelength Division Multiplexer pair with a total insertion loss of 2.5 dB. The received video signal quality meets or exceeds the Rs-250-B long haul standard and the uncorrected Bit Error Rate is less than 1.0x10E-9. The number of channels and wavelengths can be changed to meet specific link length and optical margin requirements. A description of the system as well as test results are presented.

INTRODUCTION

The application of fiber optic technology in cable television is rapidly advancing, especially since reliable fiber optic components are becoming commercially available. Fiber optics provides many technical advantages when compared to coaxial systems. Amoung the advantages are low attenuation, broad bandwidth, and no electromagnetic interference. Other advantages of using fiber optics are theft security, no need for FCC clearance, small physical size, and upgrade capabilities.

Philips Laboratories, a division of North American Philips Corporation, developed a high capacity, long distance, repeaterless fiber optic supertrunk with Magnavox CATV. Cost analyses have shown that the developed system becomes cost competitive with conventional coaxial systems for link lengths of approximately 10 km and longer.

MAGNAVOX CATV FIBER OPTIC SUPERTRUNK

10 CH/FIBER REPEATERLESS SINGLE MODE FIBER SYSTEM FM/FDM, WDM 1.3μm

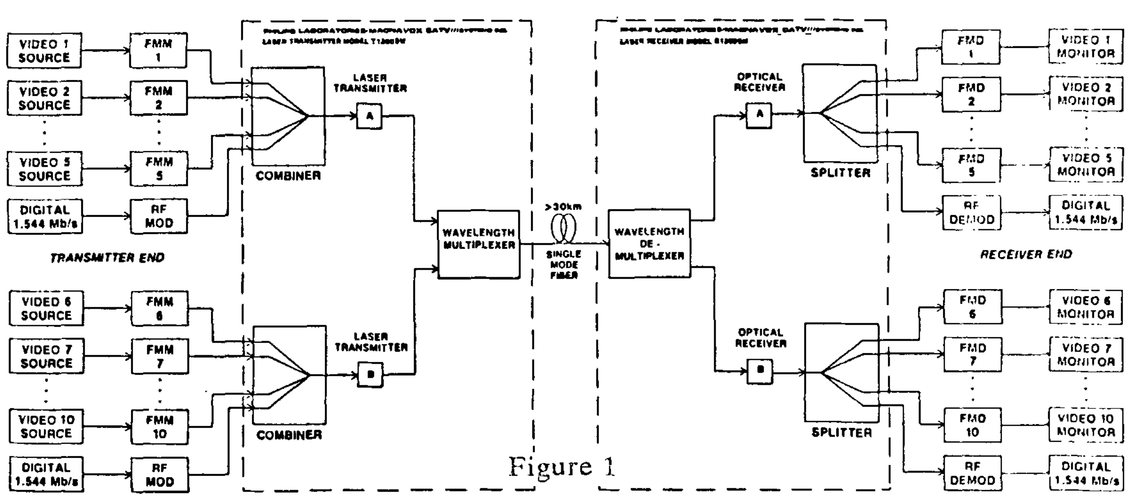

Figure 1

SYSTEM DESCRIPTION

The system configuration is shown in Figure 1. The system consists of 10 wideband Frequency Modulation (FM) modems, whose output signals are Frequency Division Multiplexed (FDM) in pairs of 5. These multiplexed signals Intensity Modulate (IM) two long wavelength laser diodes. The two light signals are Wavelength Division Multiplexed (WDM) into one singlemode fiber. For this purpose a special low loss, low crosstalk, and reliable WDM device was developed. By multiplexing two wavelengths that are both in the 1300 nm range, the low loss and maximum bandwidth window of the singlemode fiber is fully utilized. In addition to the ten video channels, it is possible to transmit two, 1.544 MBit/s, digital signals. The number of channels as well as the number of wavelengths can be changed to meet specific link length and optical margin requirements.

Nonlinearities and low dynamic range of wideband fiber optic links make it impossible to achieve high carrier-to-noise ratios. However, the detected video signal-to-noise ratios (SNR) have to be relatively high. It is therefore necessary to use a modulation method that requires low carrier-to-noise ratios. Two practical schemes are: i) converting the analog video into a digital video signal, or ii) FM modulation of the video signals. The least expensive and least complex of these systems today is the FM modulation of the video signals.

The FM modulators accept baseband video and audio signals at their inputs. The diplexed FM equipment first FM modulates the audio onto a 5.8 MHz carrier, using pre-emphasis, after which it is combined with the baseband video signal to form the composite signal. This composite signal is again FM modulated in the second stage of the FM modems after passing through a second pre-emphasis network. The frequency deviation of the wideband FM modems is equal to 8 MHz (sync-tip to reference white) and the FM enhancement factor is approximately 28 dB when compared with a Vestigial Sideband Modulated (VSB) video signal. The demodulated and de-emphasized video and audio signals are available at the outputs of the FM demodulators. By using wideband FM modulation and by transmitting only 5 channels per laser, the system is relatively insensitive to laser nonlinearities. This is especially important since laser nonlinearities tend to increase during the laser's lifetime.

Each of the digital modems accepts a TTL data stream with bit rates up to 1.544 Mbit/s. The modems use Frequency Shift Keying (FSK) and the output carrier of each modulator is frequency division multiplexed with 5 FM video signals. The measured uncorrected Bit Error Rate, after transmission, is less than 1.0x10E-9.

The optical transmitter is a wideband (450 MHz), analog laser transmitter with good linearity and low group delay distortion capable of carrying several wideband FM video channels. The major functions performed by these circuits are as follows: 1) laser diode temperature stabilization; 2) laser diode optical bias power stabilization; 3) laser diode optical modulation depth stabilization; 4) power combining and controllable attenuation of the individual frequency modulated carriers; 5) Automatic Gain Control (AGC) of the frequency division multiplex of carriers; 6) status monitoring of laser temperature, thermoelectric cooler current, and laser bias current; and finally 7) protection of the laser diode from power current surges.

The laser diodes are thermoelectrically cooled to an accurately controlled temperature. Since the operating wavelength of a laser is temperature dependent,it is possible to fine-tune the lasers. This useful feature makes it possible to relax the wavelength specifications to about a 10 nm range, which reduces the price and increases the availability of the lasers. The operating wavelengths are equal to 1275 nm (@ ~ 7°C) for the short wavelength laser and 1316 nm (@ ~ 20°C) for the long wavelength laser.

The receivers have a bandwidth of about 280 MHz. This allows some freedom in the allocation of the channel frequencies, which makes it possible to minimize the effects of laser nonlinearities (current or future). The optical power required at the input of the receiver, for a weighted video SNR of 54dB, is approximately -30 dBm.

Of the many types of optical fiber available, only multimode graded index and singlemode fiber need to be considered for long distance high bandwidth applications. While multimode has a limited bandwidth-distance product it allows a more efficient coupling of laser power than singlemode which has a much greater bandwidth-distance product. Furthermore, singlemode fiber systems do not suffer from modal noise; a noise source that can cause some serious limitations in multimode systems.

The demonstration fiber link consists of a 0.5 inch diameter fiber optic cable, which contains 24 singlemode fibers interconnected to form a continuous link of 31.2 km. With the above system configuration, this cable has a capacity of 240 channels.

WAVELENGTH MULTIPLEXING

Wavelength division multiplexing can be used to increase the capacity of the system. In wavelength division multiplexing the output of several laser diodes with different wavelengths are multiplexed into one fiber. The cost of the multiplexer is usually far outweighed by the savings in fiber.

Fiber attenuation and fiber dispersion are important considerations in wavelength division multiplexing. The dispersion has its minimum at approximately 1300 nm. At this wavelength the fiber has its maximum bandwidth. The fiber attenuation is also very low at this wavelength. Although the attenuation is even lower at 1500nm , the dispersion at this wavelength is quite large which results in a greatly reduced bandwidth. Other long wavelengths that are sometimes used are, 1100 nm, and 1200 nm. At these wavelengths, both the attenuation and dispersion are larger than at 1300 nm. Use of a wavelength other than 1300 nm will therefore result in a reduced number of channels or in a shorter link. Unfortunately there is only a very narrow window of low attenuation around 1300 nm. For typical fiber this window begins at approximately 1260 nm and ends at 1330 nm. This leaves about 70 nm in which one can assign its wavelengths. Due to this very narrow band, the optical filters have to be very sharp in order to guarantee low crosstalk.

Figure 2 shows a wavelength demultiplexer. It consists of two gradient index (GRIN) rod lenses and an interference filter. The input fiber, carrying two distinct wavelengths, is positioned slightly off axis on the face of a 1/4 pitch lens. The beam is projected and falls incident on a dichroic interference filter. The filter is designed to transmit one wavelength and reflect the other. The reflected beam is then focused and launched into an optical fiber. The transmitted beam is also focused onto another optical fiber. In singlemode applications, the demultiplexer's input fiber is singlemode and the output fibers are multimode. However for a multiplexer, singlemode fiber is used throughout. All the fibers in the multiplexer and demultiplexer must be singlemode for a two-way singlemode system.

Figure 3 shows the transmission curves of the interference filter selected for the device. Maximum transmission occurs at 1270 nm and 1315 nm. One can also see that the acceptable windows of transmission are from 1260 nm to 1275 nm and 1310 nm to 1330 nm. The slope of the short wave curve for wavelengths longer than 1275 nm is 8 dB/10 nm and for the long wave curve it is 10 dB/10 nm for wavelengths shorter than 1310 nm.

Figure 4 shows the measured insertion loss versus wavelength for both the multiplexer (dashed lines) and demultiplexer (solid lines). The optimum wavelengths are 1270 ± 5 nm and 1315 ± 5 nm. The wavelengths can be tuned over a short range in order to minimize the total loss of both fiber and WDM device. At these wavelengths the fiber attenuation is approximately 0.5 dB/km and the dispersion is approximately 4 ps/(nm-km). At 1275 nm and 1316 nm, the total insertion loss of both the multiplexer and demultiplexer is approximately 2.5 dB. Optical crosstalk in the 1275 nm channel is approximately -29 dB (equivalent to -58 dB electrical) and -27 dB in the 1316 nm channel (equivalent to -54 dB electrical). With wideband FM modulation, this results in crosstalk levels that are more than 30 dB below noise level.

LINK BUDGET CALCULATIONS

The demonstrated total fiber length is 31.2 km and consists of 18 fibers of 1.73 km each. Additional fiber attenuation was simulated with an optical attenuator. Table 1 lists the optical link budget. The lasers have a maximum coupled output power of 1 mW. The bias point of the laser is set at 500 µW or -3.0 dBm. The insertion loss of the multiplexer is approximately -1.5 dB. The two connectors had a total loss of -1.0 dB maximum. The fiber attenuation was equal to 0.45 dB/km. Average splice loss equaled -0.12 dB. There are 19 splices in the link and therefore the total link loss equaled 31.2 x 0.45 + 19 x 0.12 = 14.0 + 2.3 - 16.3 dB or 0.52 dB/km. The insertion loss of the demultiplexer is -1.0 dB. In the actual setup, the number of splices was somewhat higher due to the fact that the multiplexers and laser were pigtailed before the connectors were attached. However, even if (for some reason) this would be necessary, the link loss would not increase significantly. In fact, due to rapid improvements in splicing equipment it is very likely that in future links, the total link loss can be reduced to an even lower value.

The receiver sensitivity is -30.0 dBm for a video signal to noise ratio of 54 dB and one digital and 5 video channels per laser. The actual received optical power (without optical attenuator) is -22.8 dBm. This gives an optical margin of 7.2 dB. This was verified with the optical attenuator.

Inserting an additional 8 fiber lengths of 1.73 km each plus 8 additional splices will give an additional loss of 8 x 0.52 = 7.2 dB. This is equal to the optical margin. Insertion of an equivalent additional length will give a total link length of 31.2 + 8 x 1.73 = 45.0 km, with no optical margin. In a real installation one always wants some margin to compensate for future degradations. However, a 7.2 dB margin is probably too conservative. Inserting 4 instead of 8 fiber lengths would have given an additional loss of 4 x 1.73 x 0.52 = 3.6 dB. So the total link length in this case would be 31.2 + 4 x1.73 = 38.1 km with an optical margin of 7.2 - 3.6 = 3.6 dB. The latter case is probably more suitable for an actual installation since it would allow some 30 additional splices or some significant drop in laser output power over the system's lifetime.

TABLE 1

coupled laser power (bias)		-3.0 dBm
multiplexer loss		-1.5 dB
total connector loss (2)		-1.0 dB
fiber attenuation	-0.45 dB/km	
link length	31.2 km	
total fiber loss		-14.0 dB
splice loss	-0.12 dB	
number of splices	19	
total splice loss		-2.3 dB
demultiplexer loss		-1.0 dB
received power		-22.8 dBm
receiver sensitivity	-30.0 dBm	
optical margin	7.2 dB	

(number of channels = 12 : 10 video + 2 digital)

SYSTEM PERFORMANCE

The received video signal quality meets or exceeds the RS-250_B [1] long haul standard. The received video signal to noise ratio is equal to 54 dB [2]. The use of singlemode fiber makes it possible to use a bandwidth of 280 MHz that was only limited by the receiver. This gives some freedom in frequency assignments which, together with the use of wideband FM modems, makes the system relatively insensitive to nonlinearity distortions. Any future increase in laser nonlinearity distortion (due to aging or other effects) will therefore not affect the system to the degree it would in a system that uses narrowband FM modems. Furthermore, the system is also less sensitive to instabilities in the FM equipment, since the separation between the various channels is quite large. Optical crosstalk is far below the required value and does not degrade the signals.

The uncorrected bit error rate is equal to 1.0x10E-9. The digital channels are not affected by the video signals and nonlinearity distortions. Insertion of the digital signals does not reduce the video signal quality, nor does it reduce the optical margin.

Preliminary investigations show that two-way transmission will be possible with the current WDM device if the multimode pigtails out of the demultiplexer are replaced with singlemode pigtails.

It is possible to reconfigure the system. For longer link lengths the WDM device can be left out. This will increase the received optical power by approximately 2.5 dB and transmissions up to 50 km should be possible. The number of channels would then be reduced to 6 (5 video and one digital). It is also possible to increase the number of channels if the link length is reduced or if the WDM device is taken out. Finally, link length and/or the number of channels can be traded off against the amount of optical margin.

CONCLUSIONS

A fiber optic supertrunk for repeaterless transmission of ten high quality video and two 1.544 Mbit/s digital channels, up to a distance of 45 km over a single fiber was developed. Tests with the system have shown that even substantial increases in nonlinearities will not degrade the signals significantly. The developed WDM device makes it possible to increase the number of channels per fiber and allows both wavelengths to be in the optimum 1300 nm region.

The number of channels, the long transmission distance, and the many advantages of fiber optic technology, will make these types of systems an attractive alternative for many conventional systems.

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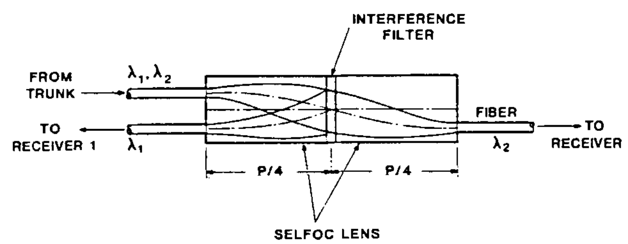


Figure 2

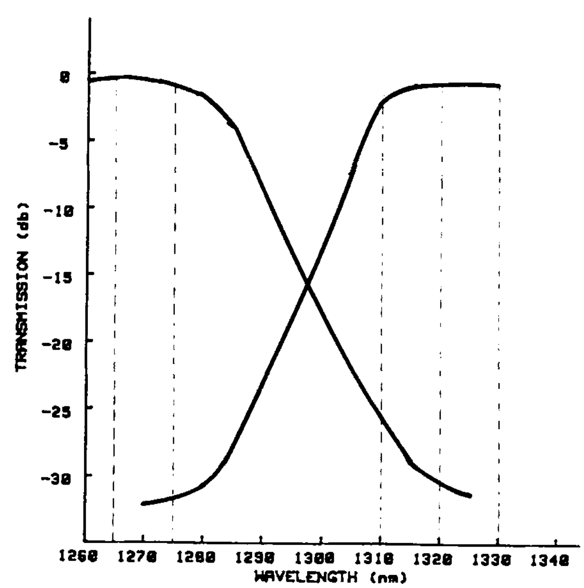
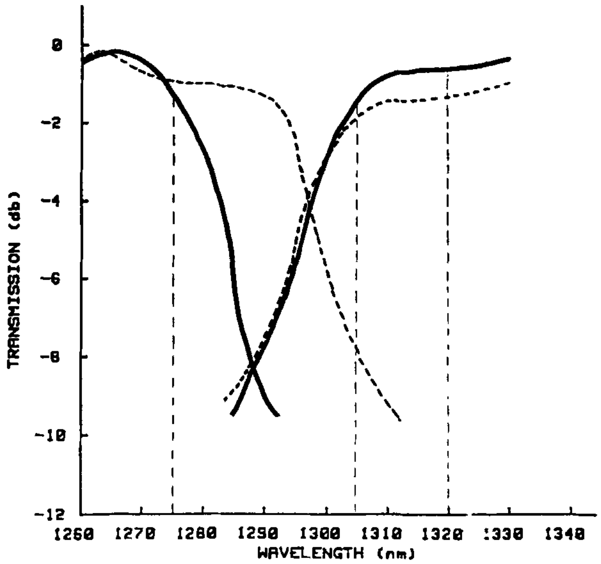


Figure 3


TRANSMISSION (db)
0
-2
-4
-6
-8
-10
-12
1260 1270 1280 1290 1300 1310 1320 1330 1340
WAVELENGTH (nm)
Figure 4

AUDIO PROGRAM DISTRIBUTION IN CABLE TELEVISION SYSTEMS

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NATIONAL CABLE TELEVISION ASSOCIATION - LAS VEGAS, NEVADA - 1985

ABSTRACT

Conventional stereo-FM audio transmission on cable is analyzed as "mediocre". Digital transmission to a new generation of digital audio receivers is recommended. Additional bandwidth is required but is judged worthwhile.

AUDIO PROGRAM SERVICES ON CABLE

Present audio program services on cable systems consist mainly of:

- FM radio stations (stereo) received off-air and redistributed in the cable system in the 88 - 108 MHz band, and

- FM radio stereo services (88 - 108 MHz band) which are generated at the head-end as "simulcasts" of the audio program of certain TV program services. These "simulcasts" might be intended as substitutes for the BTS stereo audio originally provided with the television program or might be "high fi stereo" augmentation of television programs that otherwise have "mono audio" only.

- New "pay cable audio" services which are generated at the head-end as a "premium" audio service offering commercial-free music on a subscription basis. These "pay cable audio" services should for the time being be considered "experimental" since their commercial success is not yet established nor is there any concensus yet on the transmission technology.

Most of these services use the conventional FM-stereo signal format so as to be receivable by subscribers on ubiquitous FM-stereo radio receivers. "Pay cable audio" services use a variety of transmission techniques. Some use conventional FM-stereo format but transmit in a band other than the usual 88 108 MHz band. This system counts on the use of "non-standard" spectrum as a "service security" technique. Some "pay cable audio" systems use other analog transmission technologies such as use of discrete L and R carriers.

PROBLEMS OF CONVENTIONAL FM-STEREO TRANSMISSION IN CABLE SYSTEMS

Cable audio services which use conventional FM-stereo transmission, as presently distributed on cable systems, provide mediocre service as measured by "professional" or "audiophile" standards, principally because of,

- inadequate carrier levels in the cable distribution system, and

- inadequate head-end processing and modulation equipment.

The low carrier levels make it impossible to provide adequate demodulated audio S/N (stereo) from cable stereo-FM transmissions. Inadequate head-end equipment compromises stereo separation and audio distortion characteristics.

FM-STEREO CARRIER LEVELS IN CABLE SYSTEMS

Conventional FM-stereo transmission provides stereo by means of an L-R subcarrier. Since the L-R subcarrier gets only a small proportion of the available FM deviation it effectively has only a small proportion of the available "signal power". In marginal C/N situations the stereo L-R subcarrier suffers significant quality degradation. The demodulated L-R baseband has poor S/N. When "matrixed" with the main channel L+R baseband to produce separate L and R basebands the noisy L-R baseband introduces excessive noise. This is a well known effect in FM-stereo radio broadcasting. The effective reach of an FM radio broadcast station is substantially reduced when it broadcasts in stereo, compared to "mono". Stereo transmission suffers a penalty of approximately 20 dB compared to "mono" FM radio transmission. Cable transmission of FM-stereo suffers from exactly the same effects.

EFFECT OF CABLE SYSTEM NOISE ON FM-STEREO TRANSMISSION (1,2,)

The carrier to noise ratio for FM signals in a CATV system can be calculated as follows:

$$C/N_{(FM)} = C/N_{(TV)} + 10 \log \frac{BW\ (TV)}{BW\ (FM)} - [L_{(TV)} - L_{(FM)}]$$

BW (TV) = noise bandwidth of TV signal
BW (FM) = noise bandwidth of FM signal
C/N (FM) = carrier to noise ratio for FM signals in cable system
C/N (TV) = carrier to noise ratio for TV signals in cable system
L (TV) = carrier level (dBmV) of TV visual carrier
L (FM) = carrier level (dBmV) of FM carrier
S/N (FM) = signal to noise ratio at output of FM receiver

A cable system operating to minimum FCC specification could have a visual carrier to noise ratio as low as 36 dB in a 4 MHz bandwidth. It is the usual American cable system practice to transmit FM-stereo services 15 dB below TV visual carrier levels. If we consider an FM radio receiver to have a 180 KHz bandwidth the C/N for the FM-stereo signal would be

$$C/N_{(FM)} = 36 + 10 \log 4000/180 - 15 = 34.5 \text{ dB}$$

Is this an adequate C/N for satisfactory FM-stereo transmission? No! Generally accepted relation- ships (for 180 KHz noise bandwidth) between FM C/N and demodulated baseband S/N

$$S/N_{(FM)} = C/N_{(FM)} + 15 \text{ dB}$$

indicate that this 34.5 dB C/N would provide only 49.5 dB baseband audio S/N. 67 dB S/N would be a desirable objective for "imperceptible" noise. A more typical cable system would have 5 - 7 dB better noise situation, but more typical "hi-fi" FM receivers would have a wider IF and noise bandwidth. Typical FM receiver operation on cable might also be degraded by 1 or 2 dB because of relatively low input signal levels. The calculation for a "43 dB C/N" cable system and a 240 KHz noise bandwidth receiver would be

$$C/N_{(FM)} = 43 + 12.2 - 15 = 40.2 \text{ dB}.$$

This would produce a baseband S/N of only 55 dB, still 12 dB short of "imperceptible" noise and 3 dB short of "just perceptible" noise.

The IEC standards, prevalent in Europe, call for $C/N_{(FM)}$ of 51 dB (in 200 KHz bandwidth) for FM-stereo services in cable. Cable systems in Europe do operate with high (compared to U.S. practice) FM-stereo carrier levels, typically -3 dB to -6 dB relative to TV visual carrier. They can do so because they carry relatively few FM-stereo and TV channels and they have designed their systems for this FM-stereo performance objective from the very beginning.

HEAD-END SIGNAL PROCESSORS AND STEREO MODULATORS

Most cable systems process off-air FM-stereo services by heterodyne techniques. Virtually all American systems use the popular CATEL FM radio heterodyne signal processor. This is virtually the only FM radio signal processor available in the American market and has been sold unchanged for more than ten years. Cable systems cannot complain about the price but fussy users might make some adverse comments on specification and performance. The CATEL unit provides good (but not superlative) signal processing at a very reasonable price. It does not, however, meet "professional" standards for "heterodyne repeaters". The various European national broadcast authorities are large scale users of heterodyne FM radio signal processors in FM radio rebroadcast facilities (FM radio "translators"). Their specifications for "FM translators" are much more rigorous than the spec' met by the low cost CATEL processor, particularly in the area of IF group delay distortion and AM/PM conversion. IF group delay distortion affects stereo separation. The CATEL IF is not as good as that found in current "top of the line" FM-stereo radio receivers. I do not blame CATEL. They respond to the market and the American cable system market has not demanded or expressed a willingness to pay more for higher quality FM-stereo signal processors.

The rest of the audio signal processing equipment (subcarrier demodulators, stereo generators, etc.) found in the typical cable system head-end has similar characteristics - "good" but not "superlative" specification at low cost, in response to the manufacturers' peception of the current head-end equipment market. This equipment would not be used by fussy "professional" buyers of FM-stereo broadcast equipment.

The attitude of cable system operators is perhaps understandable. FM-stereo broadcasters who's entire revenue is bound up in the transmission of a single service will lavish much care and attention on the selection and maintenance of their origination equipment. A cable system operator who operates perhaps forty such services, and who can perceive very little direct revenue coming from them, will spend the minimum amount which provides acceptable service.

REMEDIES

INCREASED CARRIER LEVELS

If low C/N is the problem in cable system transmission of FM-stereo services, why not raise the carrier levels? Cable systems in Europe usually carry FM-stereo services at 3 dB below TV visual carrier levels to provide first class service.

American systems cannot raise FM-stereo carrier levels because the high carrier levels required would overload the system. The total power of forty FM-stereo carriers at identical levels is

$$10 \text{ Log } 40 = 16 \text{ dB}$$

greater than the power of a single carrier. Put another way, at -3 dB relative to TV visual carrier it requires only two FM-stereo carriers to equal the peak power of a single TV visual carrier. Forty such carriers would be equivalent to twenty TV carriers. Raising the FM-stereo carrier level, in a system carrying forty such FM-stereo services, to -3dB relative to TV visual, would be equivalent to adding twenty TV channels to the system loading! Our present system designs just won't stand that much additional loading. Alternately, if the system is to be designed to accept that much additional loading, system operators would prefer that the loading be TV channels from which significant revenues can be more clearly and certainly expected.

Increased FM-stereo carrier level is not a practical solution in American cable systems.

CHANGES IN MODULATION TECHNIQUE

INCREASED DEVIATION

The FM deviation could be increased from the present 75 KHz standard. This would trade occupied bandwidth for noise performance. The increased deviation could be provided at the headend by a multiplication and heterodyning process, but additional spectrum would have to be found and new FM-stereo receivers for the new IF and deviation developed and provided to subscribers.

COMPANDED L-R BASEBAND

"If we knew then what we know now" we would have used companding of the L-R baseband in conventional FM-stereo radio broadcasting, as used in the new BTS stereo audio standard for television audio broadcasting. Introducing it now would mean new FM-stereo receivers for subscribers and complex demodulation and remodulation equipment requirements for cable system headends.

DISCRETE L/R TRANSMISSION USING FM

Handling of L and R basebands as discrete channels would improve transmission and stereo separation but would also require new receivers for subscribers as well as increased bandwidth in the cable system.

DISCRETE L/R BASEBAND TRANSMISSION USING AM

We can calculate the performance of an AM transmission technique using a 15 KHz noise bandwidth in a cable system with a 36 dB $CN_{(FM)}$. The 15 KHz noise bandwidth has

$$10 \log 4000/15 = 24.3 \text{ dB}$$

less noise than the TV visual carrier. At -15 dB relative to TV visual the audio service AM carrier would have a

$$C/N = 36 + 24.3 - 15 = 45.3 \text{ dB}.$$

We would save a lot of bandwidth since a stereo channel would require only about 60 KHz but we would need very high carrier levels to achieve 70 dB C/N. Loading effects would be intolerable unless suppressed carrier transmission was used. Special receivers would be required.

DIGITAL MODULATION

If the cable system has to change modulation technique, allocate additional bandwidth and use special receivers in order to provide superlative audio services why not go "all the way" - to digital! It is true that "superlative" service can be achieved by analog transmission. Several such techniques have been proposed and demonstrated for the new "pay cable audio" services. Superlative service is also achievable by digital transmission. The advantages of digital audio techniques have been demonstrated by the nearly universal acceptance of digital audio for master recording in professional sound studios and the rapid growth of digital "compact discs" (CD's) in the consumer market. Why fool around with analog when digital is:

> Unquestioned performance specifications - digital audio systems meet the highest professional standards for audio system performance.
>
> Low cost - the prices quoted by these companies for head-end equipment and for subscriber receivers are very reasonable for the facility provided - highest quality digital audio performance,

comprehensive "addressability", secure encyphering. Prices would be even lower if a technical standard was agreed on before introduction of the service.

The only disadvantage that I would acknowledge is the increased bandwidth requirement. A typical "ultra-high-fidelity" stereo digital service (Panasonic) uses a 1 MHz transmission channel. This compares with a 400 MHz transmission channel (typical spacing) for conventional FM-stereo transmission in cable. The effective "occupied bandwidth" for the highest quality digital transmission mode is about twice that of conventional analog FM-stereo transmission. This is not a bad trade-off, particularly since digital transmission could occupy spectrum that is otherwise problematical for TV transmission (e.g. the entire 88 - 136 MHz band, 48 MHz in total). This spectrum should be available in most cable systems. Digital audio carrier levels would be low - below the threshold of FCC rule 76.610. Digital audio service should be a very acceptable replacement for the conventional FM-stereo service presently offered by cable systems in the 88 - 108 MHz band - and would not cause system loading problems. Small cable systems with a large number of FM-stereo subscribers might not wish to make the change if their subscribers are happy with the present quality of service. My experience in large urban systems is that subscribers are generally not very happy with the quality of service presently provided.

The Japanese companies who are proposing digital audio technologies for cable system use are gradually providing some of the technical details. They typically provide both a "super high fidelity" mode using 16 bit linear encoding and a "high fidelity" mode using 8 bit "digitally companded" encoding. Discrete L and R transmission is provided. I would personally prefer a standard which is directly compatible with the digital chips in the CD players presently being marketed. Ideally the cable digital audio receiver should be integrated with the CD player to provide a "radio receiver" complement to the CD player. The digital cable audio receiver could share the D/A converter(s) and filters in the CD player.

I see no reason why cable digital audio receivers should not be owned by the subscriber. The encyphering and addressing techniques should be sufficiently secure to allow subscriber ownership. An agreement on standards among interested manufacturers would keep equipment costs down and create a competitive market which would benefit cable subscribers. Cable systems would also benefit by being relieved of the burden of buying and maintaining this particular piece of subscriber terminal equipment.

AN OPERATING SCENARIO FOR DIGITAL AUDIO SERVICES

Initially cable systems would have to provide high quality receiving and demodulation equipment at the head-end to derive quality L and R baseband for remodulation to digital format. Eventually audio service providers will see the wisdom of transmitting in digital format from the program provider's main studios. FM-stereo radio broadcasters will continue to broadcast in conventional analog format, but there is no reason why there should not eventually be a digital radio broadcast service as an improvement over FM in the same way that FM radio broadcasting was introduced as an improvement over AM. Digital transcoding equipment will no doubt be available for directly translating digital audio received at the head-end from the received digital format to the digital format used by the cable system for distribution to subscribers. Again, an industry-wide agreement on standards for transmission would be very desirable.

(1) CABLE TELEVISION SYSTEM CAPABILITY FOR TRANSMISSION OF FM BROADCASTING SIGNALS - Paul K. Wong - Cable TV Standards & Practices - Department of Communications, Government of Canada - 1978.

(2) CAFM ADAPTABILITY OF FM RECEIVERS - Tsuneo Takezaki, Michio Okamoto, Junji Suzuki - Wireless Research Laboratory - 1975 - translated from Japanese by Cable TV Standards & Practices - Department of Communications, Government of Canada.

AUTOMATIC TESTING OF CABLE TELEVISION DECODERS

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ABSTRACT

Many types of test equipment are available which use the GPIB Bus (also known as IEEE 488 and HPIB Bus) for control and access. By using a personal computer and this test equipment, it is possible to fully automate the testing of a cable television decoder with a minimum of custom made parts. By using BASIC as the control language, anyone with experience in programming a personal computer can develop their own test programs.

We have developed programs for many tests including the following: headend calibration RF, video, and audio measurements; decoder box RF, video, and audio measurements; decoder beat measurements; and tuner gain and noise figure measurements.

WHY AUTOMATIC TESTING?

A manufacturer or purchaser of cable televison decoders must test a portion of the units to insure they meet design requirements. For any measurements, test equipment must be purchased and employees trained to measure units and document results. The steadily declining cost of computers coupled with the widespread availability of GPIB Bus-compatible equipment and an increasing number of people with BASIC language programming skills, makes it now feasible to develop automatic measuring systems at a reasonable cost. There are many advantages in doing this, including: rapid testing time, improved accuracy and repeatability, lower skilled personnel required for day-to-day testing, automatic graphics generation for clear reports, and automatic report generation. The disadvantages are higher equipment cost (offset by time and labor savings as well as better accuracy) and programming required. With the use of a personal computer, it is possible to write programs in BASIC which will do testing and write reports in a minimum of time. With a minimal amount of experience, it is possible to quickly convert a manual test procedure to an automatic test procedure. A logically structured sequential test program written in BASIC is also self documenting. This makes it a permanent record of the way a test was done, allowing another person, familiar with BASIC, to analyze the test procedure used. Once the program is debugged, the testing can be done by unskilled personnel, allowing engineers and technicians time for analysis of the data. Because of the speed and ease of automatic testing, many more units are tested and more parameters are measured, making statistical analysis more meaningful and allowing for tracking of trends.

There are two types of automatic testing, one for rapid production testing and the other for detailed engineering measurements used for checking engineering design and for calibration of production testing. The system described here is primarily designed for engineering type testing. This means using general purpose test equipment as much as possible for the following reasons: guaranteed performance specifications, elimination of design and cost of custom designs, and flexibility in adding or changing tests. This last feature is very important as all types of products, modules, and prototypes can be tested on one station.

HARDWARE CONFIGURATION

The block diagram in Figure 1 shows the computer interface of equipment used for decoder measurements.

Whenever possible, we have selected equipment which can be operated and read using GPIB Bus (GPIB is a handshaking parallel bus which is defined as IEEE-488 and also known as HPIB). This is a fast, easy-to-use (from a high level programming point of view, however, the hardware is fairly complex) method to control and read data from various test instruments. The instruments and primary uses are as follows:

1. Digital Multimeter - Used primarily to measure internal decoder parameters for drift or the effect of different input parameters. With a switcher, a number of measurements can be made by multiplexing the input.

2. Audio Analyzer - Generates signals and monitors results for frequency response, distortion, volume adjust range, output audio level, audio carrier deviation, and signal-to-noise ratio. With the use of a switcher, analog, digital, and digital stereo audio parameters can be measured.

3. Spectrum Analyzer - This is the most expensive instrument listed but also the most useful. It can be used for measuring RF and audio levels and frequencies. All controls can be set

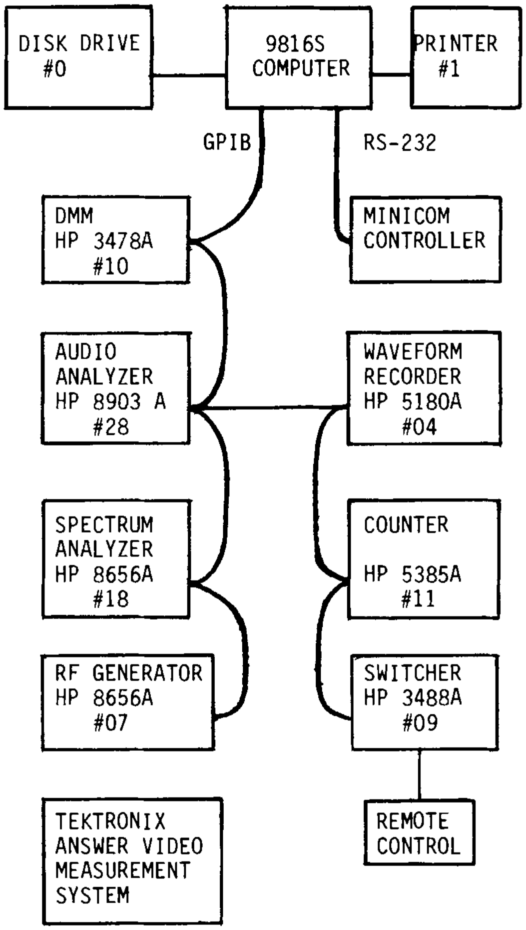

Figure 1. Computer Interface and Major Test Equipment

and the output display printed for accurate measurement and complete documentation. With a switcher, both input and output signals can be measured. It is used to measure beats, carrier levels, carrier frequencies, distortion, and bandpass response.

4. RF Generator - Generates carriers for beat test measurements on all channels. Also used with mixer and modulator output to generate any channel for special tests such as AFC range.

5. Waveform Recorder - Digitizes the video signal at a 20-MHz rate with 10 bits (one in 1024) of resolution. Hewlett-Packard is developing software to allow measurement of all video parameters with this instrument. We are currently using it for depth of modulation, Oak Sigma scrambling signal measurement, sine wave scrambling measurement, and documentation of various waveforms (abnormal audio or video responses). Anritsu Electric Co., Ltd. also makes a waveform recorder which is supplied with software and hardware for video measurements.

6. Counter - Used for measuring intercarrier frequency and for digital audio bit error rates (measured using input signal with poor video signal-to-noise ratio).

7. Switcher - This instrument is the key to maximum automation and utilization of equipment. It controls a modified IR transmitter to control the decoder being tested. It insures that input signals are correct before measuring output performance, and allows multiplexing of test equipment so only one of each type is required.

The computer, using an RS232 port, controls the Oak MiniCon Encoder/Decoder Controller. This permits changing scrambling modes as well as authorizing/deauthorizing the decoders. The Tektronix Answer automatic video measurement system is currently used to measure and document video parameters.

SYSTEM CONNECTIONS AND EQUIPMENT

The simplified block diagram in Figure 2 shows the basic signal paths of the decoder test system. The headend generates the test signals desired to check decoder parameters. The video signal, provided by the video generator, is usually a five-step staircase for adjustment and test of Sigma

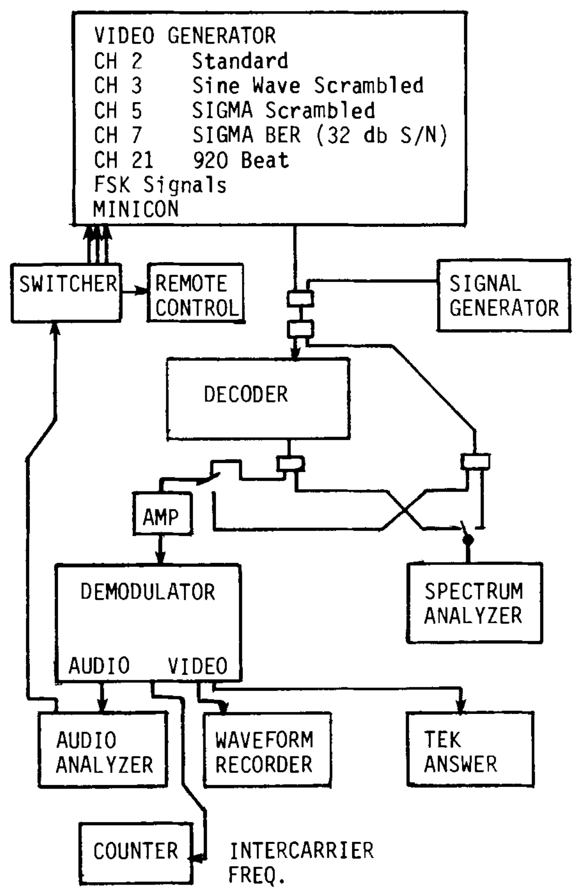

Figure 2. Test Station

scrambling, and includes VITS signals which are used by the Tektronix Answer system for video measurements. The channel 2 modulator supplies a nonscrambled signal for video and analog audio testing. Channel 3 is a sine wave scrambled signal with the switcher controlling single or double line-rate scrambling. Channel 5 is used for Sigma scrambling, with the encoder status controlled by the computer through a MiniCon controller. Channel 7 is also Sigma scrambled with a separate encoder. Noise is added in the IF signal to produce a 32-dB video SNR to test bit error rate of the digitized audio. Channel 21 has only a color signal for video and is used to measure 920-kHz beat and locate any decoder IF beats. The signal generator is used to generate upper adjacent video with 15-kHz modulation for adjacent video rejection tests with sine wave scrambling and also lower adjacent audio rejection. At this time, the input attenuator is manually adjusted for tests at +15 dBmv and -6 dBmv. Future plans are to control this with the computer.

A switch (controlled by the computer through a switcher) allows the unit under test to be bypassed for testing input signals prior to test to insure they are correct. The Tektronix demodulator supplies video to the Hewlett-Packard waveform analyzer and Tektronix Answer system. The intercarrier out frequency is supplied to the counter and the audio is sent to the audio analyzer. The automatic remote control unit, run by the switcher, tunes the decoder to the correct channel and sets volume level for audio measurements.

Figure 3 shows the physical arrangement of the decoder test station. The left-most rack contains all the signal generating equipment including video generators, encoders, and modulators. The next rack contains much of the automatic and manual test equipment. The bench has the computer, spectrum analyzer, and signal generator.

Figure 3. Decoder Test Station

SOFTWARE

BASIC was chosen as the programming language for several reasons. These include wide availability in personal computers, the large number of technicians and engineers who know the language, and availability of extended BASIC's which allow structured programming. The use of the BASIC which allows merging of named subroutines saves considerable time in writing programs. The HP 9816 supports this, as does as the Commodore computer with their Simon's BASIC cartridge. With this advanced BASIC, it is possible to write and debug a program for each test before adding it to the main program. A simplified block diagram of our main decoder test program is shown in Figure 4.

This type of main program structure allows for easy addition of new tests or modification of existing tests. Each major subroutine is a complete package, i.e., it can stand alone to complete a test and print out data. Each major test subroutine may have its own subroutines to perform any repetitive tasks. By using descriptive names for subroutines, it is easy to read a listing and quickly locate a part which may need revision. The primary goal in our program structure is to have easy-to-follow procedures with no module interdependence. This may make the programs longer, but it is a very small price to pay for easy debugging and revision.

With a little practice, this method of program writing is extremely powerful. Once a library of tests is created, a very quick method of producing custom programs becomes available. To write a test subroutine, the following procedure is used. First the hardware is connected and the test is done manually to produce a test method and to insure the results are as expected. This also generates test result numbers which can be used to verify the program is working properly. In a complex test, it is important to document in detail each part of the test. Usually, the manual test procedure is used instead of a formal flow chart to write the program. If the test is a modification or extension to an existing test, the old test routine can be loaded and edited to produce the new test. If there are any special parts of the test or printout which are difficult, a small test program should be written and debugged. This is much quicker than repeatedly running a long program to improve or debug one small part. The working module can then be merged into the longer program.

Program troubleshooting techniques include adding multiple print statements to locate when bad data is collected, using single step to observe program flow and insure instruments are properly set. All modules must reinitialize test instruments to insure that all settings are at a known state before being set to the desired state.

As an illustration of an actual program, the following is a portion of the subroutine for RF measurements with comments:

```
3000 OUTPUT 718; "IP I1 CF65MZ RL20DM
     SP20MZ RM100KZ AT0DM KSB"
```

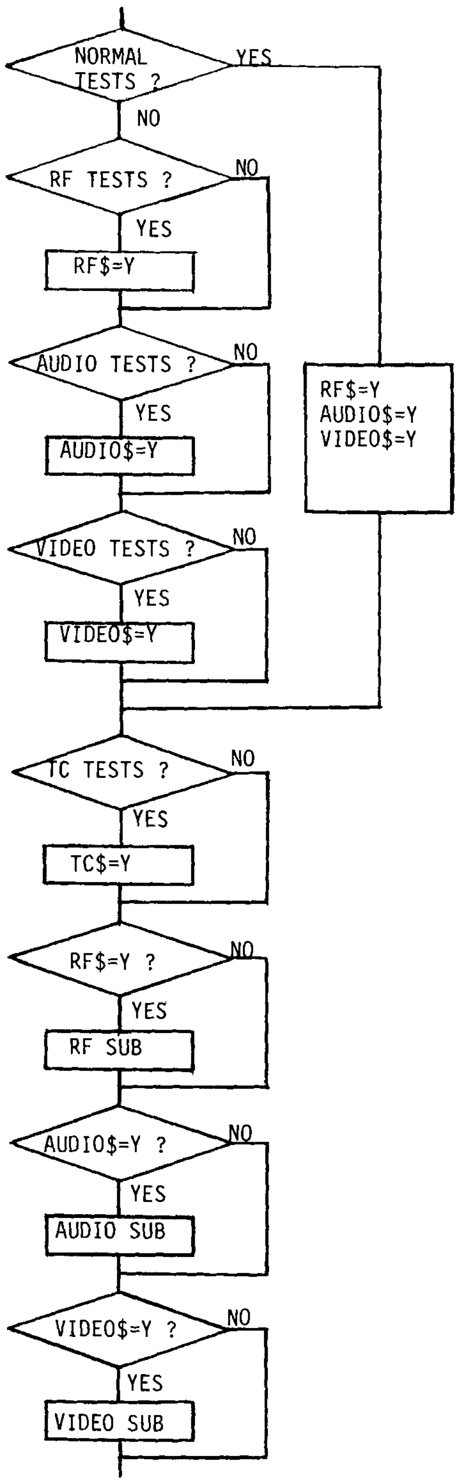

Figure 4. Overall Program Flow

Output 718 specified the spectrum analyzer. IP is instrument preset which places all controls into a known condition. I1 specifies input 1 which is the 75-ohm input. CF65MZ sets center frequency at 65 MHz. RL20DM sets reference level at 20 dB. SP20MZ sets the frequency span to 20 MHz. RM100KZ sets the resolution bandwidth to 100 kHz. AT0DM sets the input attenuator to 0 dB. KSB is equivalent to pressing shift to dBmv. As can be seen, most instruments use some mnemonics which suggest what function is selected. The command output 718; "O3TA", tells the spectrum analyzer that the controller plans to sequentially read the complete trace. This is done using a FOR/NEXT loop to input 718; D(N) 1000 times. This data can be displayed on CRT, stored to disk, plotted, printed, or analyzed by the computer.

As an example of analysis of spectrum analyzer display, the flow chart in Figure 5 shows the method used to check a decoder for internally generated beats. With a -6 dBmv input, the decoder is cycled through all channels, with carrier generated

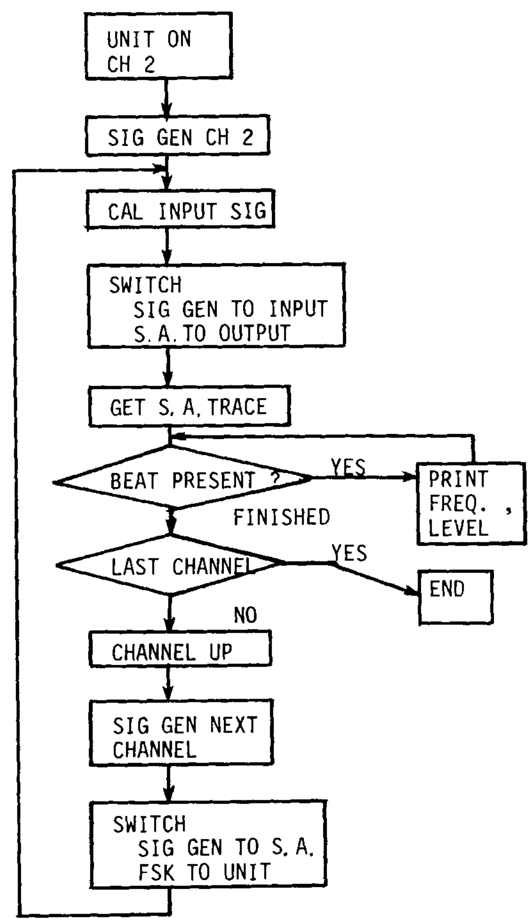

Figure 5. Beat Test Flow Chart

by signal generator. The spectrum analyzer display is loaded into an array of 1,000 points giving dB level. A portion of the program listing is shown below:

```
475  OUTPUT 718; "03 TA"
480  WAIT 1
485  FOR N = 1 TO 1001
490  ENTER 718'; A(N)
495  NEXT N
500  OUTPUT 718; "MZ E1 03 MA"
     Rem Marker Peak Search
505  ENTER 718; Cl
     Rem Marker Amplitude Level
510  OUTPUT 71; "MF"
     Rem Marker Frequency
515  ENTER 718; Mf
     Rem Carrier Frequency
520  OUTPUT 718; "01 MF"
525  ENTER 718; Mpos
     Rem Display Marker Position
530  K = 1
535  FOR I = 1 to 899
540  IF A(I) > Cl -60.1 THEN GO TO 555
545  IF I <898 THEN GO TO 630
550  GO TO 640
555  FOR T = -3 to 3
560  IF A (I + T)> A(I) THEN GO TO 590
565  NEXT T
570  J(K) = A(I)
575  POS(K) = I
580  K = K + 1
585  I = I + 3
590  NEXT I
```

This section of the program loads the array A(N) with data points from the spectrum analyzer display. After using the peak search feature of the spectrum analyzer to locate the output carrier frequency and display position, it then looks for beats greater than -60.1 dBC. Lines 555 to 565 are a peak search routine to locate each peak less than 60.1 dB below the carrier. A print routine following this section prints channel number, beat level, and beat frequency for each beat found.

<u>TUNER TESTING</u>

In addition to decoder testing, we have also automated the noise figure and gain measurements for tuner testing. Figure 6 is a block diagram of the setup used. The interpod IEEE-488 interface allows the Commodore computer to control GPIB Bus instruments using Print # and Input # commands. One bit of the parallel port is used to control channel up on a modified remote control. After measuring the tuner, the results are plotted giving an easy-to-read report as shown in Figure 7.

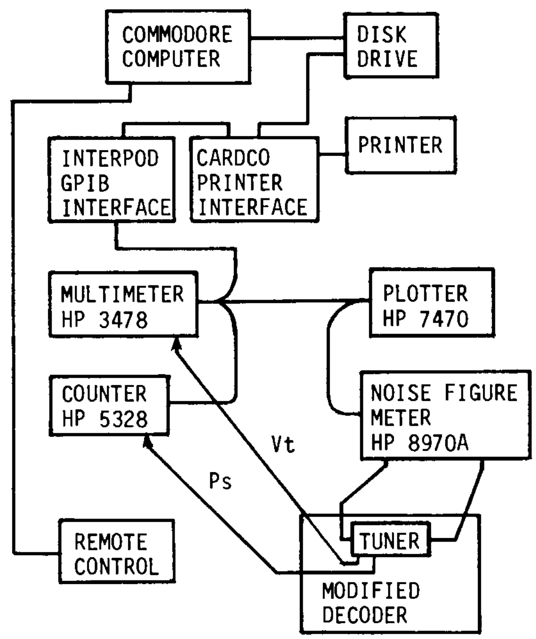

Figure 6. Tuner Noise Figure Test

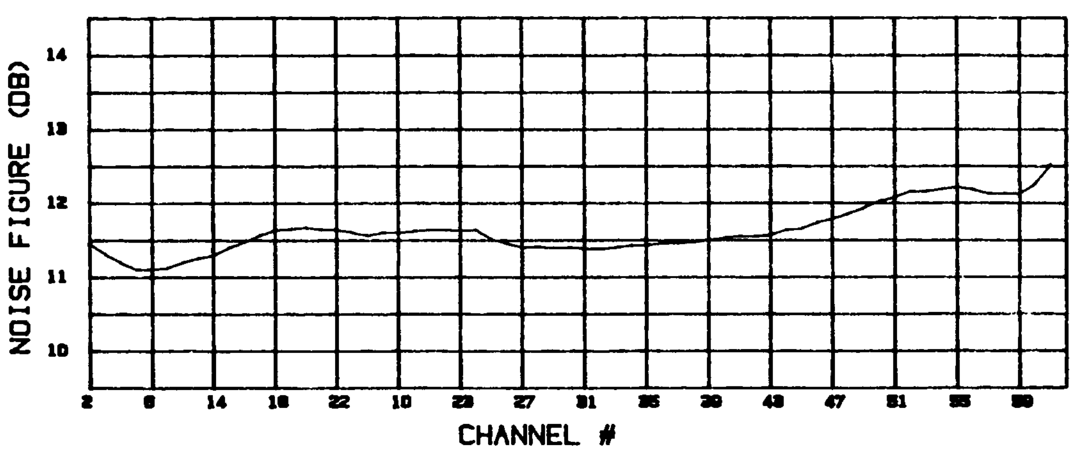

Figure 7. Sample Test Plot

FUTURE PLANS

Now that we have developed automatic methods for all the major tests, we are working on the following automation projects:

1. Automatic testing of life test units. Using A/B switches and a demultiplexer, we can isolate the output of each decoder to do tests. Eventually we expect to do testing of life test units automatically at night.

2. Use of Commodore computer and HP 853 spectrum analyzer display to measure intermodulation performance of tuners and decoders.

We have found this project very useful as not only a labor and time savings, but also an accuracy improvement due to precise setup and checking of test signals.

BROADBAND PACKET-SWITCHING

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INTRODUCTION

In 1983, Viacom successfully implemented a value-added data communications service for the City of Mt. View, CA Police Department. Asychronous terminals were remotely linked to a host CPU for interactive file inquiries and updating. Sytek packet-switching broadband modems linked the terminals to the host over a subsplit institutional cable.

The subsequent success of the application proved that a subsplit system could be used for a value-added CATV communications service. In order to be economically viable, however, the service must cover a wider geographical area than the small subsplit institutional cable system in Mt. View. Since the service should potentially cover a wide metropolitan area, then it must be interfaceable to entertainment and institutional cable systems, two-way microwave links, and private broadband local area networks.

Viacom's Nashville CATV system is a subsplit, 1800-mile entertainment cable with AML microwave linking 6 hubs and 200 to 300 miles of plant to a master Headend. The service area has large geopolitical boundaries (an entire city and county), and therefore enough potential users to justify implementation of a two-way enhanced service.

This paper describes the implementation of this packetized broadband data communications service over a hybrid microwave and CATV system covering a large metropolitan area.

CURRENT BROADBAND PACKET TECHNOLOGY

Viacom chose the Sytek LocalNet 20 (TM) family of broadband modems and multiplexers because of the positive experience in Mt. View and the fact that the modems (called PCU's or Packet Communications Units by Sytek) could still function with a propagation delay equivalent to 35 miles of Coax. Each PCU is frequency agile, and can operate on any of 20, 300-KHz sub-channels within a 6 MHz pair. An upstream and downstream is necessary for two-way communications created by an RF frequency translator at the main broadband Headend.

Many modems can share the same 300 KHz subchannel since access to bandwidth is based on the Carrier Sense Multiple Access with Collision Detection method (CSMA/CD). Modem logic monitors (senses) the sub-channel for carrier presence, and transmits data packets via FSK modulated carriers. During transmission the modem checks its own received data packets for damage occuring when two modems transmit simultaneously, as happens when contending for channel access. When collisions occur, each PCU detects the damaged packet and waits for a predetermined backoff period before again requesting channel access. The random wait period varies with each modem according to an algorithm within PCU firmware logic.

The modems detect errors in packet transmission by a polynomial-based cyclic redundancy check (called CRC-16) which causes the receiving modem to not acknowledge (a nack) an improperly delivered packet. When the network is not inoperable due to ingress or outage conditions, this should ensure bit error rates of 1 in 10 to the tenth power or greater. Modem data transfers (sessions) cease or abort whenever an RF path interruption occurs. These sessions must be reestablished as soon as the CATV system restores service.

Input to the modems is via 2 to 32 EIA RS-232 ports operating at data rates selectable from 75 bits per second to 19.2 Kbps for asychronous devices and 1200 to 9600 bps for bisynchronous equipment. Multiple port host communications are supported by multiplexing the individually addressable input ports onto a 128-Kilobit RF output F connection to the 300 MHz wide broadband subchannel. Many more terminal ports may be on a subchannel than host ports since busy ports can be detected, and the calling modem can be passed or rotored to a non-busy host port. Port and bandwidth contention also allow very economical network cost per port figures.

The PCU converts the serial input into packets containing destination and sending addresses, data, sequence and control information, and CRC error detection check bytes. This seven-layered Open System Interconnect packetizing process defined by the I.S.O. allows end-to-end speed and flow control conversion between communicating devices. This value-added process differentiates CATV broadband packet communications from reqular analog twisted-pair tariffed services.

INTERFACING THE PACKET NETWORK TO THE CATV SYSTEM

Since Viacom had a franchise requirement of return video from each subheadend site, frequency modulating microwave transmitters were chosen to complete the two-way link. The FML transmitters and receivers were multiplexed with the Hughes AML downstream microwave so that the same antenna could be used for both links. The lower 4.5 MHz of the return microwave spectrum would be for video with the balance to be filled with packet channel subcarriers.

Experience with a successful two-way security service in its Dayton, OH franchise had prepared Viacom for the problems of end-to-end dynamic level ranges. Realistic CATV system dynamics with varying operating levels would potentially allow modems with higher carriers to dominate the network. Furthermore, excessive carrier levels fed from the coax network to a sub-headend return microwave path could cause transmitter overdeviation of the CARS carrier in excess of FCC standards.

Other problems with the 1800-mile CATV system include the noise floor contribution of over 4500 amplifiers funneling into the master Headend from remote hub sites. Ingress and distortion from any point in the system would interfere with the network sub-channel for all return packet carriers since the two-way bus is shared.

To minimize system dynamics and prevent microwave transmitter overdeviation, Viacom's engineering staff modified a Catel FM processor/limiter (See Figure 1) to convert the upstream data carrier to a microwave compatible subcarrier. Since the PCU's use FSK modulation, limiting maximum carrier levels would not damage data packets. The limiting also prevented overdeviation and widely varying carrier levels throughout the system.

Viacom's engineering staff also added a very important squelch circuit which prevented any output, including return noise and ingress, to the microwave transmitter when a sub-channel data carrier was not present. This meant only the return hub with modems transmitting packets would contribute to Headend return noise and ingress funneling degradation problems at the master Headend translator. The modified processors later proved to be fast enough and stable enough not to cause packet carrier errors.

Using subsplit frequencies but not CATV channel standards, the PCU transmits in the very upper portion of T-7 and lower 2/3rds of T-8. The translation chain converts the upstream transmit frequencies to the downstream receive frequencies with a 216.25 MHz offset. This places receive sub-channels in the upper portion of Channel K and lower 2/3rds of Channel L.

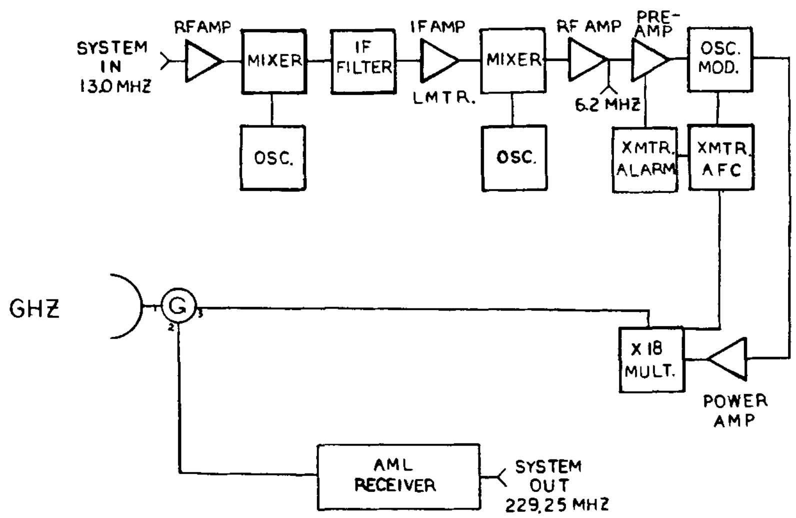
Not wanting to waste valuable CATV channels, the 10 sub-channels available for the T-8/Channel L combination with adequate guardband allocation were used to implement initial circuit testing. Using 13.0 MHz as the first transmit frequency, the upstream carrier is limited (See Figure 1) and then down-converted to a 6.2 MHz microwave subcarrier.

At the master Headend (See Figure 2) the FM microwave receiver feeds the 6.2 MHz subcarrier to a 6.2 to 13 MHz upconverter/limiter. A very stable translator then does the 216.25 MHz offset conversion with output turned downstream via AML links. Frequency stability tests have proven this translation chain to be within the modem specifications for frequency deviation tolerances.

SERVICE TESTING AND IMPLEMENTATION

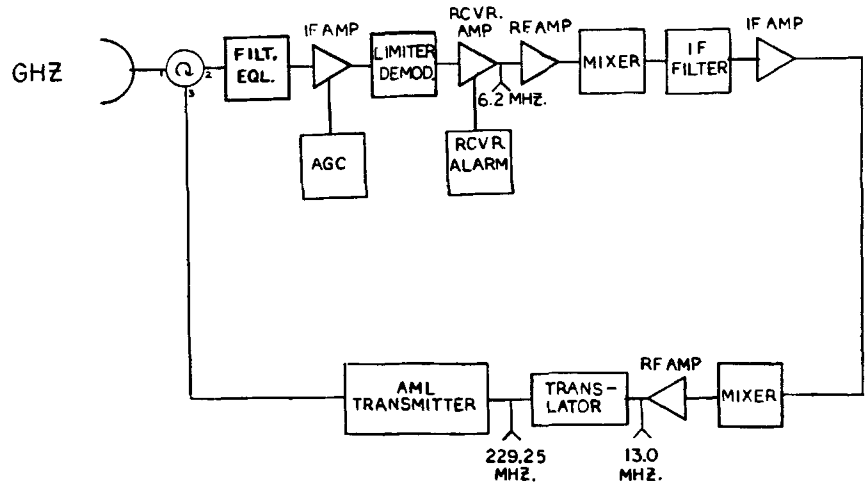
When Viacom's New Business Development staff began testing the packet network and translation chain, too many aborted and bad packets were detected by a network statistical monitor. The initial culprit was assumed to be a carrier-to-noise or carrier-to-ingress problem

Field and lab tests soon revealed the surprising source of the packet errors --- the PCU receiver. The receiver works very well even with C/N ratios as low as 15 dB. But if the absolute noise floor was greater than -36 dBmv (weighted into 300 KHz), then the receiver over-sensitivity caused noise to interfere with packet carrier detection. Since the modems could operate properly down to -23 dBmv, a standard -13 dBmv +- 3 dBmv receive level at a data C/N of 30 dB or better was chosen.



SUB-HEADEND DETAIL

FIGURE 1



3 MASTER HEADEND DETAIL

FIGURE 2

The PCU's do not allow separate transmit and receive level adjustments, therefore Viacom constructed a diplex filter black box with separate pads in the upstream and downstream paths. This device allowed independent adjustment of modem transmit and receive levels where noise levels presented problems.

Field testing soon revealed positive results and minimum errors now occurred. Load tests on channel capacity also were positive and concluded that over 1000 simultaneous sessions transmitting at 9600 baud and a 10 percent duty cycle could share the 10 subchannels. Practically, many more interactive users could share the frequencies since lower baud rates and lower channel needs would be sufficient for many users.

HOOKING UP TEST CUSTOMERS

Since 1981, Viacom in Nashville has provided fixed-frequency synchronous RF links to the City of Nashville for 9600 baud data transfer between an IBM host and terminal servers. These circuits were point-to-point and point-to-multipoint bisynchronous links.

Recently, the fixed-frequency modems were replaced with the packet modems with good results thus far. The most difficult portion of the switchover was modem internal setup required by the PCU to be compatible with the character-oriented bisynchronous protocol between the host front-end communications processor and the remote terminal server.

Neither the host vendor nor the user were sure of such esoteric parameters as the hexidecimal value of the synchronization characters or the maximum block size. However, a Comit model 1500 circuit analyzer from Phoenix Microsystems captured a block of data and provided all the information necessary for modem parameter table set-up.

APPLICATIONS AND THE MARKET PLACE

That 128-kilobit packet communication services can be readily provided by Viacom is undeniable but currently risky due to State Regulatory unknowns. Despite the current National deregulatiory environment, State officials have varied reactions to data communications over CATV systems. However, even when return on investment requirements are commiserate with this risk, packet data communications over cable is potentially a cost-effective alternative to cross-subsidized data communications over a voice network.

Viacom has opted for a deliberate approach to packet communications until regulatory and de facto communications standards emerge more clearly. Meanwhile, the knowledge and experience gleaned from current testing has been marketed with less risk to the private network market place. Private networks include local area networks, campus area networks, and private cable systems. These users have well defined needs that often will involve multiplexing of many services onto the network including; entertainment and commercial video programming, T-1 links, security, energy management, teleconferencing, high-speed imaging, CAD/CAM and more.

One factor that could give many cable systems an edge in this private market is the fact that it is currently being served by unqualified retail outlets or small, poorly financed broadband contractors. Furthermore, their designs or installations are generally substandard compared to most CATV systems with two-way experience. Add the options to lease and provide on-going maintenance, then a very marketable broadband product and service can be provided by the CATV industry.

If Viacom can serve this market niche for private systems very well and slowly develop the backbone network, then a telecommunications maxim may ring true: 80 percent of communications are internal and 20 percent are external. The high-speed internal systems cannot be externalized by the analog, low-speed bottlenecks currently overpriced for bandwidth offered. A 128-kilobit to a 5-megabit external bus should be as affordable as a business telephone, especially when competition and production quantities bring down broadband modem prices.

Time, technology, and the marketplace will soon more clearly determine the future for data communications and the CATV industry.

BROADBAND SWEEPING: A NEW APPROACH

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ABSTRACT

An active CATV system frequency response is typically measured by using either a high-level or a low-level sweep--but both of these methods have inherent limitations. Gillcable's on-going gated mid-level sweep project is developing a new method which can improve resolution and readability, while simultaneously minimizing system interference.

High-level sweeps provide good signal to noise ratios and are easy to detect, but they significantly interfere with existing cable signals. Because of this interference, the sweep repetition rate is usually low, thus impairing readability. While low-level sweep is relatively non-interfering, its low level reduces the signal to noise ratio thus impairing resolution. Furthermore, any higher level cable signal will mask the sweep and also impair readability.

Gillcable's gated mid-level sweep project is based on selective spectrum sampling; it is not an analog sweep, but a series of samples at arbitrary frequencies. The sample points can be set to avoid any critical cable frequencies. But beyond just that, to avoid interfering with television pictures, the signal source will only generate signals on an occupied channel during video blanking intervals.

Since the gated signals only minimally interfere with existing signals, sweep level can be set high enough to deliver good signal to noise ratios for a high-resolution display.

METHODS FOR MEASURING FREQUENCY RESPONSE

Frequency response, gain variation at different frequencies, is a critical CATV distribution system parameter. Several methods exist for measuring this response. Some, like noise insertion or standard broadband sweeping, require the cable signals be removed; others, like slow sweeping, require technicians in constant communication at both the head-end and in the field; while others, like simultaneous high-level sweep or low-level sweep can be continuously and automatically combined with regular cable signals.

The two former cases are not applicable in large active cable systems. The first method would require removing 24 hour premium services for extended periods, an act certain to provoke customer complaints, while the second method would require far too much time to sweep an 1800 mile plant like Gillcable. The latter method avoids those deficiencies. The sweeps run concurrently with cable programming, so no program interruptions are required. Furthermore, since they are continually available, many sweep receivers can be in use simultaneously, so a large plant can be swept in reasonable time.

The high-level sweep is typically run 15 to 20 dB above video carrier level. This relatively high level delivers a clear display because of its high signal to noise ratio. Also, its level makes it easy to recover, so sweep receivers are relatively uncomplicated and hence inexpensive. High-level sweep, however, does have a significant drawback--it interferes with the existing cable signals. As the sweep passes through an occupied TV channel, it can

- create visible distortions in the picture,
- prematurely trigger the vertical sync circuits in the TV causing the picture to roll,
- cause VCR servos to lose lock while recording, or
- fool AFC'd set-top decoders into "following" the sweep up and then locking onto the next channel.

The exact symptoms depend on subscriber terminal equipment, sweep level, and sweep speed. High-level sweeps also affect in-band and out-of-band telemetry and system pilots. The sweep can be trapped at these critical frequencies, but in a loaded system the sweep display soon begins to have as many holes in it as a golf course. One other distortion that can occur is loss of accuracy caused by too high a sweep level driving amplifiers into compression. Basically, as long as the amplifiers are operating in their linear regions high-level sweep provides a clear accurate display, but the interference is significant.

The interference can be minimized by reducing the time the sweep is actually present on the system. The repetition rate for high-level sweep is typically one sweep every 5 to 20 seconds. This low "rep" rate can be accommodated by using storage oscilloscopes or patient technicians. Incidentally, to further minimize the effects of the high-level sweep used at Gill, we have installed timers that prevent sweep from occuring during prime-time hours and have installed radio-controlled switches that enable sweep for 10 minutes at a time. That is enough time for a technician to adjust a station, then the sweep automatically turns off while he is in route to the next station.

Low-level sweep systems typically run 20 to 40 dB below video carriers. This prevents it from being as interfering as high-level sweep. Low-level sweep can be set far enough below video carriers so as to be virtually non-interfering. This reduction in level, however, makes the sweep signal more difficult to recover, so the receivers are correspondingly more complex and expensive. They are narrow-band spectrum analyzers that track the transmitter by locking to a pilot carrier. The reduction in level has also had an effect on display resolution. Since the sweep signal is below the level of cable signals, the sweep is masked by the cable signals and some of their side-bands. In a fully loaded cable system, much of the sweep is simply not visible. Also, the corresponding signal to noise ratio of the recovered sweep signal suffers from the reduced sweep level; the display is often an ambiguous 2 dB wide trace. This effect is accentuated by amplifier cascade length, but then so are system frequency response problems. So in long cascades where the most careful adjustments are needed, low-level sweep provides the least resolution.

In short, both high- and low-level sweep methods leave room for improvements.

MID-LEVEL SWEEP PROJECT

The purpose of this paper is to describe an on-going research and development project at Gillcable. We had as our goal, an improved CATV sweep system. We wanted a sweep system that was non-interfering, yet was continually present, and of course, required no technicians at the head-end. The sweep level was to reflect the typical video carrier levels on the cable: low enough to avoid non-linearities from the amplifiers, yet high enough to provide a clear, unambiguous sweep display. The receivers had to be easy-to-use, accurate, reliable, and inexpensive. Since they were field equipment, they also had to be compact, lightweight, rugged, and battery operated.

With these goals in mind, we proposed a sweep system uniquely suited to our CATV environment. We refer to it as the "Mid-level Sweep System." Mid-level refers to the RF carrier level, which is set at video carrier level. This puts it midway between high- and low-level sweep; 15 to 20 dB below high-level and 20 to 40 dB above low-level. This RF level will provide a clear display even in long cascades while avoiding any non-linear amplifier distortions from using too high a level. The term "sweep", however, is a misnomer. Instead of using an analog sweep that would pass through all possible frequencies, this proposed system would instead, use a switched carrier at discrete frequencies. The frequencies could be selected somewhat arbitrarily as long as they were sufficiently closely spaced to provide enough resolution to assure response anomalies were not missed. But more importantly, critical frequencies, like system pilots and telemetry carriers could be bypassed entirely. Interference at those critical frequencies, then, would not be a problem.

Obviously, we couldn't bypass all occupied TV channels, and interference caused by inserting an additional carrier into an occupied video channel is a major problem. There is simply no way to do it without creating some beat in the picture. However, during the horizontal and vertical blanking intervals in an NTSC television signal, the TV receiver is blanked; the picture tube is cut off, and the screen is black. We proposed to use these blanked intervals to hide any interfering beats our additional carrier created. Additionally, video side-band energy should be minimal during those intervals, so we would have a relatively clean spectrum in which to insert our signals.

The transmitter and receivers would be synchronized by an auxiliary data channel. Both timing and frequency data would insure the receivers could find these very short pulses as they are moved through the cable spectrum.

TRANSMITTER DESIGN CONSIDERATIONS

The transmitter control section needs to be intelligent enough to decide when a channel is occupied, even when the video is scrambled. It also needs some form of memory wherein to store the critical frequencies to be skipped. For these reasons, a microprocessor will be used to implement the programmable control section. Figure 1 shows a simplified block diagram of the transmitter.

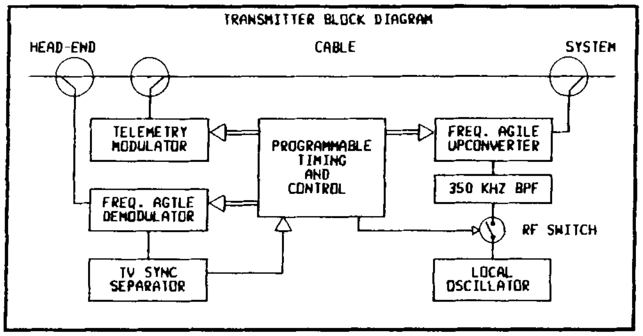

Figure 1. Simplified block diagram of transmitter.

One of the unique parts of the transmitter is the "look-ahead" frequency agile video demodulator. This demod is steered to the channel to be sampled next. The video is detected and the sync information stripped off. The sync is used for timing of the inserted carriers; no energy will be added to an occupied channel until either horizontal or vertical blanking is occuring.

The carriers are created by steering a synthesized upconverter to the proper location, then at the proper time, adding the local oscillator to its input. Pulse rise- and fall-times are restricted to one microsecond by the 350 KHz band-pass filters. This is derived from the approximation:

Bandwidth = 0.35 / rise-time.

Without the filter, the effective bandwidth caused by switching the carrier on and off at microsecond rates, would extend beyond the channel being tested.

Synchronizing signals are continually sent downstream on the auxiliary data channel. This data stream contains the necessary frequency and timing information for the receivers. The carrier frequency of the FSK telemetry modulator is considered one of the critical frequencies.

RECEIVER DESIGN CONSIDERATIONS

The receiver uses a microprocessor for coordinating received telemetry with synthesizer control, as well as for interpreting and preparing the received RF data information for the display. A simplified block diagram of the receiver is shown in figure 2.

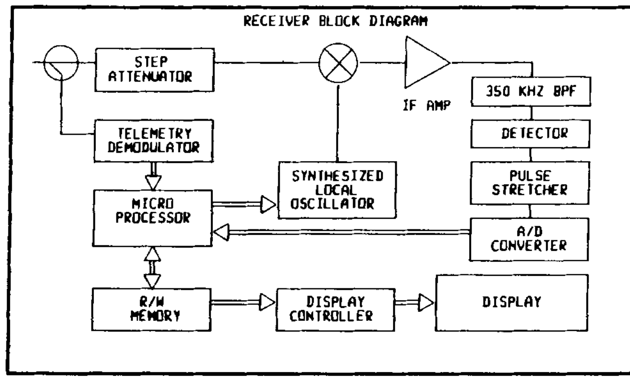

Figure 2. Simplified block diagram of receiver.

The auxiliary data channel is demodulated and the frequency and timing information made available to the microprocessor. Using this information, the local oscillator is steered to the proper frequency, then at the proper time, the pulse is detected. Its level is captured and converted to a digital value. These digital values are then decoded and used to generate the display.

The digitization of the RF signal provides the means to great flexibility in receiver design. Individual receiver flatness can be compensated for digitally. By connecting the receiver directly to the transmitter, any frequency response anomalies can be recorded and stored in non-volatile RAM. Then by compensating the readings by those factors, the displayed response will reflect only cable system response, not receiver response. Other techniques like digital averaging can be used to help readability in long cascades.

Incidentally, bypassing critical frequencies with this system will not cause the display to have holes in it. The points in between the sampled points will be approximated by using a quadratic approximation generated by the nearest three sampled points.

INITIAL TESTING PHASE

Our early days were spent trying to discover how much we could abuse an NTSC video signal and not cause perceptible interference. We wanted to use the horizontal sync pulses for timing because they were contained in the horizontal blanking interval, see figure 3[1], and their high frequency, if completely utilized, would allow the entire spectrum to be scanned in a very short time. If we were to sample a 50 to 300 MHz cable spectrum every megahertz it would take 251 samples. The horizontal line rate for NTSC is about 15750 Hz. If we could manage to use every line for one sample then we could scan the entire band in less than a sixtieth of a second. We could then have a display refresh rate of better than 60 Hz as indicated by table 1.

HORIZONTAL RATE

BAND	SAMPLE FREQ.	TOTAL SAMPLES	SAMPLE RATE	DISPLAY REFRESH RATE
50-300 MHZ	1 MHZ	251	15750 HZ	62.8 HZ
50-300 MHZ	2 MHZ	126	15750 HZ	125.0 HZ

VERTICAL RATE

BAND	SAMPLE FREQ.	TOTAL SAMPLES	SAMPLE RATE	DISPLAY REFRESH RATE
50-300 MHZ	1 MHZ	251	60 HZ	4.2 SECS.
50-300 MHZ	2 MHZ	126	60 HZ	2.1 SECS.

Table 1. Minimum screen refresh rates for typical frequency intervals during either vertical or horizontal blanking.

Actual display refresh rates would be higher, as there is spectrum where there are no video signals to wait for, some critical frequencies would be bypassed, and adjacent video channels' horizontal sync phase relationships would tend to reduce the effective horizontal rate when moving from channel to channel.

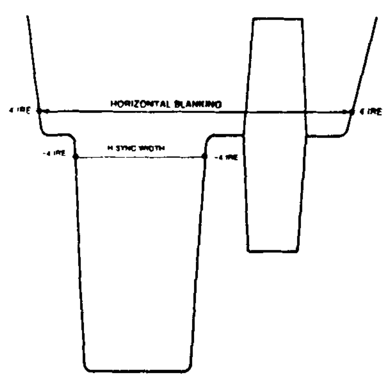

Figure 3. Diagram showing horizontal blanking and sync relationship.

Keeping up with these rates was going to be difficult. Synthesizers had to be able to slew to a new frequency and lock within one horizontal line, about 63 microseconds, and the auxiliary data channel had to have a very-high data rate. This turned out to be impractical, not because of equipment limitations, but because of television receiver complications.

TV receivers suffered from three types of visible interference, even though the beats were invisible. The exact symptoms varied from model to model depending on what type of video AGC was used; what type of horizontal AFC was used; and what type of detector was used. Video AGC's were of two varieties:

- Sync peak detectors with low-pass filters, and
- Sync gated circuits.

By adding extra energy during the horizontal sync period, that sync pulse had a higher amplitude than adjacent sync pulses. This extra amplitude had no visible affect on the AGC circuits that used sync peak detectors and low-pass filtering. But the gated AGC circuits behaved differently. These gated circuits derived AGC voltage on a line by line basis, so the AGC voltage applied to the following line of video was almost entirely determined by the preceeding sync pulse's amplitude. By artifically increasing one sync pulse's amplitude, the gain was reduced for the entire following line of video. This reduced the contrast for that line and, depending on program video content, the effect varied from nearly imperceptible to very obvious.

Horizontal AFC circuits were also affected by the timing of these pulses. When inserting these pulses in the horizontal sync period, we had some discretion in pulse position relative to sync. Some types of set AFC's ignored the extra energy when the pulse was started coincident with the start of sync, while others ignored it when it was exactly centered in the horizontal sync. The visible effect of not being properly timed was a slight pulling of the horizontal oscillator which was visible as a discontinuity in vertical lines, followed by a curved line as the oscillator regained its original phase. No matter where we chose to start the pulse, we were guaranteed to visibly affect some of the TV sets.

TV sets with product detectors also exhibited one other sensitivity to these additional carriers that diode detector sets did not. When the additional carrier was removed, the detector started oscillating. The duration of these oscillations were both frequency and level sensitive. At our chosen levels, the oscillation lasted through color burst, back-porch, and into active video, about 8 to 10 microseconds. This was visible as disturbance in one line at the left margin of the picture.

Short of reducing the RF level to 20 dB below video carriers or less, there was no way to insert these pulses into the horizontal blanking interval undetected. Since we had set out to have a higher level than that for improved resolution, we then focused our attention on the vertical interval (see figure 4[1]).

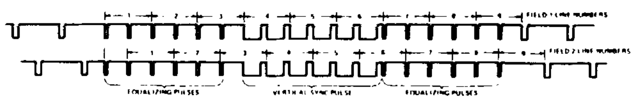

Figure 4. Vertical sync intervals for fields 1 and 2.

By using the vertical interval, we effectively hid all of the above mentioned video artifacts. Single line AGC affects in gated sync circuits occured during the time the entire line was blanked, hence the effect was invisible. By restricting ourselves to lines 4 through 9, any affect we had on the horizontal oscillator has until line 21, where active video starts, to recover. This was long enough for all the sets tested. Lastly, since the screen is blanked the detector oscillations are not visible as video disturbances. This is not to say that any of these problems quit occuring, I only indicate that their effects cannot be viewed on a normal TV set when they occur in the vertical interval. We have in fact inserted additional carriers into the vertical interval at RF levels 20 dB higher than the video carrier with no visible interference.

The relatively slow 60 Hz rate of the vertical interval had concommitant simplifications. Synthesizer design was much simpler; we no longer had to slew and lock in less than 63 microseconds. Also, the auxiliary data channel could now carry much more data between samples at a lower data rate for better synchronization. The lower throughput also permitted the use of common, inexpensive microprocessors to reduce cost. But as Table 1 indicated, the display refresh rate had fallen to one sweep every four seconds. The display requirements had become slightly more complicated, screen refresh had to be independent of incoming data.

CONCLUSION

Tests are still in progress to determine if there are any unforseen and as yet undiscovered complications that would prevent this from being a viable method. All the evidence so far indicates that signals carefully inserted into the vertical interval are ignored by normally operating television receivers and VCR's. Nevertheless, we are trying to find if any combinations of timing, level or frequency can cause a VCR to break servo lock or cause interference to a TV receiver.

Further tests are needed to clarify just how close the samples need to be in order to assure we will not skip typical cable frequency response problems. Certainly, one megahertz is close enough as experience indicates that response anomalies seldom affect less than six megahertz. But six megahertz is probably not close enough for the occasional problem that affects only a small portion of the cable spectrum. Sampling at two megahertz intervals now seems to be the optimum compromise between speed, synthesizer design, and resolution.

Still to be decided is the final form of the receiver display. Among the options are flat panel displays, especially the electro-luminescent types. But the lowest cost display is still an X-Y display using portable oscilloscopes like the Tektronix 323's or Leader LBO-308'S.

As a work-in-progress report, I can say that the initial concepts and designs have been worked out and patents applied for. Continuing work will certainly bring the new sweep system out of the lab and into the field by the end of the fiscal year. Initial results are encouraging and indicate that we will be able to have a non-interfering, high-resolution CATV sweep system in use at Gillcable then.

ACKNOWLEDGEMENTS

I would like to acknowledge those at Gillcable who have helped this project along. In particular, David Large was responsible for the initial concepts, and Rich Wayman was responsible for much of the data gathering and transmitter design. There was also the sweep crew who continually reminded us of what real cable problems were like outside of the lab.

REFERENCE

1. Figures 3 and 4 were adapted from "TELEVISION OPERATIONAL MEASUREMENTS, Video and RF for NTSC Systems", Tektronix, 1984, p. 9, 11, 12.

CABLE INTERFACE AND DECODER INTERFACE WORKING GROUP PROGRESS REPORT

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INTRODUCTION

Standards committee progress is often painfully slow. To a newcomer, especially someone accustomed to the "fast lane," this activity can be quite frustrating. There are several points to be made about this. Firstly, if cable interface and decoder interface standards were easy to achieve, they'd have been agreed to a long time ago. Secondly, the issues being settled are delicate points involving trade-offs which impact the economics and performance of two industries. These two industries have a history short on cooperation and long on animosity. Fortunately, the trend toward cooperation is on the up swing.

At first blush, it would seem difficult to find two industries with more reason to cooperate than the Cable Television Industry and the Consumer Electronics Industry. Better pictures should enhance satisfaction in cable service and better choice should increase the desire for quality images. I believe that most of the difficulties are due to a lack of information and misunderstanding. Open, honest, and frank contacts should be helpful to all. That is the purpose of this discussion.

STRUCTURE

In 1982, the NCTA and the Electronic Industries Association, EIA, formed a Joint Engineering Committee to discuss technical issues which impact both industries. The first order of business of that committee was to create a channelization standard for frequency assignment. After considerable debate, the committee recommended the plan which became an EIA Interim Standard for one year. It has recently emerged from this probationary phase to become an official recommended standard.

It is important to note that these standards are voluntary standards. Neither the NCTA nor the EIA have enforcement powers. Adherence to the standard depends on the good faith of the companies involved.

After the channelization standard, two Working Groups were formed to consider a cable interface standard and a decoder interface standard. Shortly after formation of the Decoder Interface Working Group, it was discovered that the EIA R-4 Group had its own decoder interface group. Seeing little point in duplication of effort, the Joint Committee Working Group disbanded.

ATTITUDES

An important reason for the successes of the Joint Committee has been a change of attitude on the part of the participants. In the past, cable/consumer electronics relations were marked with finger pointing and name calling. Very important technical trade-offs were the focus of arguments which had significant economic impact. Now a realization has been achieved of the importance of customer satisfaction. The customer/subscriber must be satisfied if the two industries are to prosper. It is pointless to try to shift blame. The customer/subscriber demands satisfaction from both industries.

A significant step in the right direction has been the relaxation of what has been called the 70dB syndrome. In the past, the cable industry has tended to demand that any potentially harmful phenomenon be suppressed by 70dB. The consumer electronics industry has become offended by this approach since this degree of suppression is difficult to measure for most parameters and impossible to achieve in practice. The result has been near zero progress.

The 70dB syndrome has been replaced with a much more reasoned discussion of actual problems. A phased approach has been recommended which sets achievable targets, timed to cover frequencies ranges as they are implemented in the cable practice over time.

The defensive guards are down and technical people are listening to one another in open dialog. People are trying to understand each others problems and accommodate.

Occasionally, a new member joins the committee and makes moves in the old ways. The committee brings the newcomer in line and progress resumes.

THE CABLE READY TV

A subject of intense discussion in the cable industry today is the "cable ready" or "cable compatible" television set. Much of this debate applies to other consumer products such as VCR's. But first a couple of comments. It is a fact of life that nothing is every really ready. If, by chance, it comes close to being ready, something will change to make it less ready. A second fact of life is that "compatible" is a rubber word which is stretched to meet the needs of the moment. In the strict sense, compatible means that two things, like a TV set and a cable system, work perfectly together without any loss of functionality of either. In the loose sense, compatible means that they both run on electricity. "Compatible" is used in the loose sense more often than in the strict sense.

Cable ready TV is a receiver with a premium tuner, the correct 75 ohm connector and, usually, remote control. The customer's benefits in selecting such a model include convenience features and substantially increased reliability due to the electronic (versus mechanical) tuner. Under certain circumstances, the customer may also enjoy the ability to connect directly to cable.

Let's investigate the requirements for full cable compatibility. There are only two: 1) The channels the subscriber is interested in receiving must be available without the need of having a tuner ahead of the television receiver. 2) TV signals must not be directly picked up off-air by the television's internal circuits. This potential problem is called DPU for direct pick-up. The first requirement can be satisfied in several ways: a) The cable system uses traps for signal security. b) The subscriber is not interested in the channels which are scrambled and is satisfied with those which are in the clear. However, the trend will be towards more scrambling for purposes of tiering. c) A decoder and a television receiver which interfaces to the decoder are used. At the present time, the only example of this are recent Zenith receivers and a version of the Zenith cable descrambler. The second requirement is satisfied if: a) The subscriber is fortunate to not live near broadcast antennas, or b) The receiver's internal shielding is adequate to protect against DPU.

When the above requirements are not satisfied, a cable operator supplied converter must be placed ahead of the TV receiver. It should be emphasized that this represents a capital investment and the placing of property at risk of loss. The cable operator would much prefer to avoid these negatives. The cable business is a service business selling programming. The cable operator is better off using his limited capital to build more miles of plant so he can hook-up more subscribers, than in putting that capital in the homes of existing subscribers. The investment and maintenance of hardware, particularly in-home hardware, is a necessary evil.

Several problems arise when a cable ready receiver is connected to a set top converter. The most severe is that the channel changing feature of the receiver's remote control is lost. Most set top converters include a switched convenience power receptacle. Unfortunately, nearly all modern remote control receivers behave in an incompatible manner when plugged into these switched power outlets. When power is removed from the line cord of these modern receivers, they go off but will not come back on when power is applied. Thus, the subscriber must separately turn the receiver on.

Additionally, the receivers usually revert to channel 2 and forget their previous volume setting. Since the output of most set top units is on channel 3, 4, or occasionally 5, the subscriber must retune the set.

The cable operator's objection to the sale of cable ready TV is the frustration his subscriber feels when the promise of cable ready is not realized. Often the subscriber feels that the cable operator should somehow share in the responsibility for this disappointment. In the extreme, the subscription is cancelled. This is a life and death matter for the cable operator, and he has no logical choice but to do all he can to overcome these problems.

In those cable systems where cable ready TV receivers function satisfactorily, multiple TV receivers can be connected without the need for cable converters. There are several potential hazards centered around unauthorized connection of these receivers. The most obvious potential problem is splitting the signal too many times, resulting in snowy pictures. Both the cable company and the TV dealer will likely receive complaints. But this is not the only problem. There is a more serious reason for controlling multi-set hook-ups. When the do-it-yourselfer makes these hook-ups, cable signal quality usually suffers. Often he will use TV twin wire or even lamp cord. Even when the proper cable is used, the connections are usually not tight. Signals are picked up and injected into the cable affecting the reception of other cable subscribers. A more severe consequence is that these improper connections will radiate signals which may interfere with other services. Of particular concern is radiation in aircraft navigation and communication frequencies. The cable operator has a responsibility to control illegal connections which violate Federal Communication Commission rules.

THE CABLE INTERFACE WORKING GROUP

The Cable Interface Working Group's major concern is the Cable Compatible Consumer Product, such as the Cable Ready TV. The committee very quickly got over the issues of converter type, impedance, and signal levels. A more serious problem has been DPU.

The committee has taken voluntarily committed receivers and measured them in a T.E.M. (Transverse ElectraMagnetic) cell. The tests were funded by the EIA, and each manufacturer received data on his products. However, a non-identified table of data was supplied for committee use. Sets ranged in performance from satisfactory behavior in fields of a couple of volts per meter, to sets with considerably lower levels of tolerance. Manufacturers have been carefully considering the art of radiation immunity as it applies to their products. Progress has been made.

A next step is the measurement of cable converter product in T.E.M. cells. The goals will be to understand techniques for implementing converter's seemingly better performance.

Measurement procedures and acceptable parameters are currently under investigation.

A reoccurring problem is the separation of performance standards from interference standards. It is felt that the regulation of performance is best left to the market place. However, the control of interference is a standards matter. Three kinds of interference have been considered in order of increasing severity: 1) Interference with the product's own performance 2) Interference with other products in the same home 3) Interference with other subscribers' reception.

THE LONG TERM FUTURE

The logical conclusion for the trends in CATV home terminals is for subscriber ownership. This is the best outcome for nearly all concerned. The subscriber has his favorite hardware relationship, ownership. Unlike his European cousin, the US TV receiver user has always preferred ownership to rental. The same should apply to the decoder hardware. This will especially be the case if he can own the tuner, remote control, and other convenience features as part of the bargain. These later goals are achieved by having the descrambler come after the TV receiver's tuner. There are two ways of accomplishing this. One way has a "decoder interface plug" on the back of the TV receiver (or VCR, etc.) into which the subscriber owned (or leased) descrambler fits. The second method is to build the decoder directly into the receiver by the receiver manufacturer. The latter will happen if there is a de facto or actual decoder standard which would permit free movement from cable system to cable system. If this is not achieved for what ever reason, then plug-in, re-sell, or swap devices will be required.

The principal entity which is disturbed by this approach is the manufacturer of home terminals who doesn't also make TV receivers. He sees more than half of his "value added" eliminated. But from the bigger picture, the waste and inefficiency of having a tuner, remote control circuits, and related components in the home terminal, only to have them duplicated in the TV receiver, is undesirable.

From the cable operators' point of view, the program protection method must insure that subscribers cannot defeat the system and receive the programming for free. Another interested party in all this is the programming producers. If they believe their product can be stolen, they will not make it available to the cable operator. The cable operator realizes that the would-be pirate has nearly unlimited time and resources at his disposal. Engineers will use their employers equipment and facilities to try to meet the intellectual challenge. Some would try to convert this mental exercise into a financial advantage. The system which meets this test will be robust indeed. It can be predicted that the US National Bureau of Standards Data Encyrption Standard, DES, will be required to yield adequate confidence. Once this assurance is obtained, the cable operator will gladly give up the capital requirements caused by the need to supply the descramblers. The money would be better invested in more programming, service-enhancing facilities, or home terminals that provide new services to subscribers.

THE DECODER INTERFACE WORKING GROUP

The Decoder Interface Working Group is not a Joint Committee effort, rather it is entirely an EIA activity. In spite of this, there has been significant friendly dialog between the two industries. Specifically, there have been cable industry contributions to the design and testing of the interface plug.

The Interface Plug is also called the Cenelec 20 pin plug. Even with twenty pins, the committee wished it had more! Red, Green, and Blue, RGB, as well as composite video in and out are provided. A data line pair to communicate logical instructions such as EIA Homebus signals, has been provided. At some day in the future, it will be possible to connect consumer electronics products to a master home system. Fast blank for text insertion and decoder restored sync input pins are provided. Devices with the interface plug are intended to be "daisy chained." That is, devices may be designed in such a matter as to be connected in series, allowing interaction between devices and an extension of product into an easy to use, consumer friendly system.

The most serious and controversial issue regarding the interface plus is automatic gain control, AGC, design philosophy. AGC has two modes of operation with strongly conflicting demands, acquisition and stable operation. The circuit time constants must be different for these two modes. Additionally, the AGC time constants of the cable converter and television receiver must be significantly different so one is dominated by the other. If the two time constants are close together in value, oscillations may result. The problem is that some receiver manufacturers are using long time constants while others have decided upon short time constants. An important difficulty to appreciate is the fact that in scrambled mode, most systems suppress horizontal sync pulses. For decades, television AGC design philosophy has depended on finding and accurately measuring sync pulse parameters. The two processes are fundamental conflict. Without sync pulses, there is a tendency for the amplifiers to increase gain and saturate. This crushes the signal and insures that sync pulses will never be found. This "lock-out" condition is a disaster which must be avoided. It is most complicated in systems which suppress sync pulses in the vertical interval as well. This phenomenon is extremely non-linear and not well understood. Some engineers insist that there is no theoretical basis for these systems to ever work! They claim that each time the system achieves synchronization and decoding, it is simply a fortunate electrical accident!

One serious complication is the fact that AGC expertise in television receivers is a scarce commodity. There are probably less than twenty experts in the entire world. The subject is very complex with almost no published technical literature. Engineers become experts in this field through years of apprenticeship to an existing expert. A second complication is that competitive performance between manufacturers' products is largely determined by AGC characteristics. To someone who appreciates this, the committee interactions take on a whole new dimension. There is the careful guarding of secrets, the pained release of just enough information to make the interface plug system work, but the anxiety that too much may have been revealed to a competitor.

The committee has a life cycle of its own. At first there is a small group of attendees trying to make it happen. Slowly the group expands until so many attend that it's difficult to get anything done. After several months, those low on patience cease to attend. Decision-making picks up. Then some dramatic event such as a field trial takes place. Once again, attendance soars. A new danger to progress takes place. New members attend for the first time. They start questioning the fundamental philosophy. Old ground is revisited. The skillful chairman must maintain progress, yet not turn off the new attendees. The new attendees will have their say in the final standards approval process. They must not be alienated. As the committee reaches the end of its work, two forces come to conflict. Those who have put in years of work want to bring it to a close. Others who have been alerted to the committees work by the expected issue of a new standard become alarmed. They see all kinds of threats to their interests and, of course, better ways to do the job, usually using advanced technology which wasn't available when the committee started its work. The committee chairman must manage these forces or total grid lock will result.

Another committee practical difficulty is the fact that the most likely contributors are industry experts and industry decision-makers. By definition, these individuals are very busy and in demand by their company's engineering departments and by other committees. Getting the right people involved is critical to success. Occasionally, a company's management's view of committee work is too parochial. Important contributors are denied permission to attend, or are not supported in this activity.

The Decoder Interface Working Group had a field test in ATC's Mile-High cable system in Denver. Several TV receiver manufacturers and several decoder manufacturers participated with varying results. The level of success exceeded expectations and re-energized the committee. At least one receiver manufacturer's engineers formed a strong alliance with a decoder manufacturer's engineers. Extensive cooperation and mutual sharing of information has resulted in a raising of the potential for success of these two companies. At least one other manufacturer took a very unfriendly, parochial approach which offended the other participants. This manufacturer has gained an unfortunate reputation as a bad citizen in the community. This has caused embarrassment to others at that company who have worked long and hard at trying to establish a record of cooperation and leadership.

The best indication of the success of the field test is the lively interchange that took place afterwards, resulting in significant improvements in the proposed standard. The most interesting improvement at the time of this writing is the proposal of an AGC time constant control pin which would yield control of the time constant to the decoder. A second field test is currently scheduled for mid-June in Denver.

CONCLUSION

Progress is being made on two fronts, the cable interface and the decoder interface. Progress is slow and painful but essential if the customer/subscriber is to be provided with the maximum utility potential of the technology. These are long term solutions. But they will never arrive without heavy investment of energy and time in current committee work.

CABLE-READY HOME ELECTRONICS INTERFACE DEVICES AND THE CULTURE AND PHILOSOPHY THAT SURROUNDS THEM

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A combined total of fifty million cable ready TV sets and VCRs are in use today. Cable systems are still not ready to serve cable-ready equipment. Some of the problems are described and a few solutions are offered.

There are twenty-six million cable-ready TV sets in use at this time and it is anticipated that at least ten million more will be provided in 1985. There are roughly twenty-five million VCRs existing today, most of them cable-ready and eleven million more will be added this year. Most cable-ready TV sets are bought by people who have cable service, with the thought, hope and belief that this new set will provide more convenience. VCR owners, using the unit as a time-delay for watching programs more conveniently, expect to be able to interface directly with cable. Unfortunately, only the equipment is ready, the cable is not ready.

Cable-ready equipment came into being when digitally controlled synthesized tuners began to appear on TV sets with remote control. Adding these new channels, and additional channels imposed a very small price penalty. So small, that most top-of-the-line sets are offered with 101 channels, 181 channels, or any other variety which makes market sense. Market acceptance was quick! Advertising proceeded to praise the great convenience and flexibility of these new devices. Quite properly, the consumer expected that the marriage between cable and something cable-ready would be without serious complications.

For a long time, a number of cable systems ignored the VCR, cable-ready or not, and refused to make a hook-up. Other cable systems did hook up VCR's as a second outlet and provided a second converter. The second converter then required an A-B switch to allow the subscriber to watch a recorded program and also, required the subscriber to forego the fourteen-day, eight event, unattended recording features of his VCR.

We have now come full circle. Cable systems are now much more aware of the importance of subscriber satisfaction and are moving forcefully to insure subscriber retention in their systems. They recognize that the problems caused by VCR's and cable-ready TV sets are irritating their subscribers and they are trying to do something about it.

In a classic cable-ready, cable-TV subscriber home, we find a remote control TV set being fed by a remote control converter descrambler and interconnected with a remote control cable-ready VCR. The subscriber can now plan to watch TV, using the left hand remote control to turn on the TV set, selecting the channels with the right hand remote control, turning the sound up or down with the left hand, and then deciding to watch a prerecorded program. If the subscriber is lucky, this operation will take place at a control box with an A-B switch feeding the VCR directly to the TV set input. Now control of the VCR is with the right hand remote control, with the left hand remote control used to operate the sound control on the TV receiver. What are the solutions? What can be done? Will things get any better or worse?

The first thing to recognize is that this type of equipment will undoubtedly persist in the marketplace for at least one or two decades. Zenith, Sony, and Quasar indicate that approximately 95% of their color TV set production is now cable-ready. With the average replacement of TV sets being on a seven to ten year cycle, it can be expected that the majority of TV sets connected to cable television systems will be cable-ready by 1990. Even today, there are many cable systems reporting thirty to forty percent of their connections are to cable-ready TV sets.

VCR's are not only being sold at a high rate, with prices dropping, but are being offered by cable systems. Obviously, the cable system offering to provide the VCR also will provide a convenient method of connecting the VCR. It behooves all cable systems to look toward simplicity and convenience in providing these connections to serve the subscriber.

Many MSOs are studying this problem and a number have initiated advertising campaigns and provided guidance to their subscribers showing them how to hook up a cable-ready TV set, a cable-ready VCR and how to perform the various functions that these devices offer. Group W Cable, for example, offers its subscribers a collection of simple cartoon diagrams with step-by-step instructions for a do-it-yourself activity. They also offer to make the connections for the subscriber at a "small fee." Other systems have been exploring modifications in the converter to allow remote control selection so the TV set can be fed with either the VCR or the cable system.

It appears that the industry has a good handle on the method of providing A-B switches or remote controlled diode switches which will allow connection between VCR and TV set. The industry is also beginning to educate the subscriber by helpfully offering assistance in connecting all of these devices. A problem still exists, however, in providing for the pre-programmed, unattended recording activities which make the VCR attractive to so many people.

An approach has been made and devices are available which will interface with the remote control of the converter descrambler to switch channels at prearranged times, over fourteen days, and eight separate events. In effect, these units duplicate the equipment built into the VCR for week, day, time, and channel selection, and also duplicate the infra-red remote control transmitter that is used to operate the converter. The ads for these devices talk about "lost VCR programability" and offer these one hundred dollar units as a solution. They are one solution. At this time, there have been suggestions from converter manufacturers that they may build just such a capability into the IR control package being offered for their individual converters. This may provide for a lower cost, more integrated and simpler to operate package.

Is there any other solution? Well, everything seems to be simple if there is no scrambling and if all authorized channels are on the cable feed at the subscriber's location. In a trapped system, cable-ready TV sets and cable-ready VCR's would work simply and conveniently with the addition of an A-B switch to allow the VCR output to feed the TV set. In a system where off-premise control is involved, an addressable tap, using trap or using jamming osullators, will allow the same convenience.

An off-premise converter does not change anything as far as cable-ready or VCR programability is concerned. The same solution that is used for an on-premise descrambler converter will work with an off-premise system.

A trade-off analysis is required to determine how far the operator can go with technology to offer cable service and to satisfy subscribers. The use of off-premise control provides a very high degree of security and simplifies maintenance operations. An off-premise converter has more flexibility in the number of channels that can be controlled than any off-premise tap offered to date. The off-premise converter also has a higher degree of security when used in locations where subscribers might elect to "feed their neighbors." Both devices have different costs for equipment, for installation and for multiple set operations. The costs, the convenience, the flexibility, and the security must be compared first. Decisions can then be made as to the best way to serve the subscriber and the cable-ready equipment with the least hassle.

CENTRALIZED CABLE LEAKAGE DETECTION, LOCATION AND MEASUREMENT

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ABSTRACT

Continuous leakage monitoring is a firm requirement under the FCC rules. Meeting this requirement may well become a very expensive and time consuming routine. Centralizing and automating the necessary procedures would be a welcomed relief for the cable industry. This goal will be achieved only after numerous technical problems are solved. This paper discusses several possible mechanisms which might be employed to reach it.

INTRODUCTION

CATV signal leakage needs no introduction, in fact, it is the focus of intense interest in the CATV technical community. CATV leakage has always been with us. Starting from an annoyance as a source of "off-the air cable signals" it has become a national concern, first to aeronautical communication and navigation circuits in the mid '70's, and later to ground-based radiocommmunication systems (early 1980's). The die appears to be cast in the FCC's Second Report and Order on Docket 21006 with rigorous monitoring, measurement and record-keeping requirements. Now the monitoring problem is not, "Must we do it"?, but, "How can we do it efficiently and economically"?

Traditional monitoring techniques are based largely upon the use of leakage detection equipment in vehicles. Once leaks are located measurements must be made and indices calculated according to Part 76, Subpart K of the FCC rules and regulations. In considering this matter the first thing that becomes apparent is that these requirements could be "forever". Under the FCC rules monitoring must go on day after week, after month after year; and indeed it should to protect other services from cable leakage as well as cable systems from ingress by over-the-air services.

Some feel that the costs of this on-going monitoring program will be excessive and most believe that it will become a part of life better done without. Streamlining of implementation of these requirements would relieve the system operator of manpower, and equipment expenditures allowing him to do things which, from a business point of view, are more important. It certainly would be nice to have a "black box" in the headend that would automatically detect leaks, alarm their presence, pin-point the locations, and calculate intensities without need for constant human attention. It is to this end that this paper is addressed. It is probably better to state it is to this "beginning" that this paper is addressed, since ultimate development of such a system, although inevitable, may be a long and complex task. At this time we can only discuss "some possibilities" for centralized automatic leakage monitoring.

BASIC PRINCIPLES

With a problem like this the first cut at a solution usually suggests some kind of automation of the basic tasks, which now are manually performed. This conjures up pictures of robot vans without drivers; antennas which automatically rise from the top of the vehicle, and seek-out leakage plus data systems that automatically record or transfer data to computers at a centralized location. These do make good science fiction stories, however, in the main, do not apply.

There are some basic considerations which do apply. For instance reciprocal effects. Wherever there is leakage out of the cable system there is a potential for leakage in. In such reciprocal situations measurement of the inverse effect may often be translated to a measurement of the primary effect. In leakage monitoring and measurement, working with ingress, maybe a good way of quantifying egress.

One factor that bears on remote monitoring possibilities in a cable network is the fact that leakage signals from the CATV spectrum are present on the outside of the cable, not only at the exact point of egress, but for some distance from this point due to the transmission line (or antenna) effects of the suspended cable. These signals vary in amplitude due to the local impedance of the cable structure, the distance from the leak, and the contribution of other leaks. Coping with these variations presents certain problems.

A cable system is a distributed communications medium. Even in a basic one-way downstream system effects such ingress, usually leave their tell-tail sign as a signal which propagates from the point of origin to the end of the cable plant. Therefore, in many cases, monitoring can be done effectively at a few points which encompass a substantial portion of the network. With two-way plant upstream ingress in the entire network can usually be sensed from the headend due to the collection of upstream signals by the tree- and branch structure.

All radio frequencies, however, do not propagate in all portions of the cable plant, so that direct ingress measurements are not always possible. For instance, ingress in the downstream path cannot be turned around and sent to the headend. However, localized monitoring and translating devices can communicate over the network to strategic monitoring locations. Bridger and feeder switches are already used by some to isolate the location of the ingress sources.

The goal then is to juggle these various factors and converge upon one or more possible remote monitoring configurations.

DISTRIBUTED RECEIVERS

The first and most straight-forward approach is the concept of receivers distributed about the cable system and arranged to detect leakage of a specific carrier frequency(s) from within the cable. Such a receiver could use a dipole or other type of receiving antenna to intercept the radiation. However, it might be simpler and mechanically more acceptable to measure the current flow on the outside of the cable, converting or calibrating this to indicate the radiation field.

There are a number of inherent problems with these external measurements. First, the frequencies chosen must be "clear channels" in the local over-the-air frequency allocations. The standing wave pattern on the cable will provide different indications, depending upon the configurations of cables, grounds, etc., and the distance from the leak. In addition, it must be determined what the rate of fall-off of the current intensity is at distances far removed from the leak, so that the spacing between adjacent detection devices can be established to provide the required detection and measurement tolerances. Due to wavelength effects, greater spacings can probably be tolerated when using lower monitoring frequencies.

Let's consider the mechanism for coupling energy from inside the cable through a flaw to the outside of the cable. First of all, the amount of energy coupled will be determined by the impedance match between the source (the flaw allowing the leakage to occur) and the impedance of the outer conductor structure as modified by turns and branches of the cable plant, the powerline neutral to which the plant is bonded, system grounds, etc. As in any source/sink situation, maximum power will be transferred when there is a conjugate match between source and load and less power is transferred when a mismatch is encountered. In addition, since the antenna formed by the coax shield and associated conductors radiates and the impedance will seldom be totally resistive, standing waves will exist along the cable.

In the presence of standing waves, a probe to measure either voltage or current will give different results when moved fractional wavelengths along the cable. This would dictate that in order to be sure of detecting any leak, at least two detectors would be necessary, spaced to assure that no situation could exist where simultaneous nulls could cause the leak to go unnoticed. Moreover, the spacing plus amplitude readings (assuming the impedence is known) should allow computation of the maximum value of the standing wave. It can be seem that some interesting and difficult problems are encountered in this detection and measurement procedure. Manually, one moves his detection dipole to find the maximum area and then the peak within that area. To accomplish this automatically some innovative approaches towards smart but economical equipment are required.

MULTIPLE FREQUENCIES

Very little work has been done to correlate leakage intensities produced by a given system flaw, over a range of frequencies. It can be hypothesized that two largely different frequencies applied to a given leak will produce very different standing wave patterns and radiation efficiencies and therefore resultant field strengths, etc. If this is indeed true, it would behoove the monitoring system to employ two or more frequencies. In addition, monitoring frequency relationships should be established that would tend to complement one another so that leaks that might produce nulls at one frequency would be accentuated at another. Frequency agility of the detection receivers could also provide a means for checking leakage at a specific frequency where an interference problem exists.

INGRESS DETECTION

Being the reciprocal of egress, ingress detection holds some promise. This is a sophistication of using a mobile CB transmitter to find a leak by noting where it interferes with cable TV reception. There are two types of sources to be considered for ingress detection. These could be categorized as global and local sources. A global source would be one having an r.f. field that engulfs all or a large portion of the cable network, such as that developed by a local radio broadcast station.

Local sources might be signal generators installed along the cable system (on the outside), which would produce small currents at specific points, thereby offering the ability to locally check for signals leaking in. This approach has some promise since the local sources could be controlled by a data stream and switched "ON" one at a time. Measurements of ingress could be correlated with which unit was switched "ON" and give a good indication of the areas where leaks were present. In addition, the levels of these sources could be remotely controlled to more effectively calibrate the magnitude of the leak.

A basic drawback is that a local source radiates when in use. It would therefore, be manditory, that such sources be limited in maximum amplitude to remain below the specified radiation criteria for the particular band of operation. One might dream of the FCC allocating standard frequencies that could be used nationwide. In such cases, many advantages would be derived such as standarized equipment, standardized listening frequencies, interference immunity from frequencies used in conventional monitoring; plus the ability to do experimentation with larger signals allowing even better margins, easier to detect thresholds and the like.

One also could use the global field approach. Unfortunately, there are very few, if any signal sources that are available every place and at all times. In a given system one might use an FM transmitter nearby, however this frequency, power-level, etc., would be unique to that system precluding broad standardization. In addition, the power densities over the CATV system could be expected to vary greatly, requiring individual thresholds and a good deal of calibration complication between locations.

There are certain very low frequency signals that have large areas of uniform field and might be of use throughout the country, however, they are operating at frequencies which are not usually propagated by the cable system. Therefore, detection of these signals would not only require distributed receivers but conversion of the received signal information to amplitude data to be collected. The approach would work but the complexity would be greater. One advantage associated with these low frequency groundwave signals, is that the fields throughout a local CATV would be relatively uniform at any instant. A single receiver and external antenna tuned to the selected frequency could be used to provide instantaneous amplitude calibration.

CALIBRATION

It can be seen from the above that these suggested approaches are relatively complex in that there are many variables which are difficult to calibrate, and some which seem to be so elusive as to threaten the viability of the approach. Suffice it to say that a good deal of development is required to perfect any of the above. On the other hand, it must be realized that many of these same pitfalls are inherent in the present methods as encompassed by Part 76. For instance, measurements of leakage are now required to be at a single frequency within an aeronautical band. Carrying through on the previous discussion, it is reasonable to assume that grossly different frequencies probably have grossly different leakage and radiation characteristics from a given fault. Therefore, there is the possibility of experiencing not only nulls, but significantly higher levels of leakage at other frequencies which may be of public concern. Even a crude system configured to measure multiple frequencies will contribute a great deal of imperical understanding to the overall CATV leakage phenomena.

"Calibration" may be the wrong heading for this paragraph, since the first work to be done is more like "investigation", such as determining the fall-off rates of signals, relative to the distance from the leak. Should this fall-off be too rapid, it would require the deployment of too many remotely located receivers, switches, and/or generators, and make the system too complex and expensive. For this reason, investigation of lower frequencies should be undertaken since the fall-off should be less rapid with distance, due to the longer wavelengths.

Assume that it was determined that some frequency below the minimum propagated by the cable network was required to obtain reasonable spacing of the remote units. At this point, some correlation must be made between the performance of the leakage fault at standard monitoring frequencies, and at the new lower frequency. A measurement program could easily be instituted to at least determine the qualitative relationships between vastly different frequency ranges in generalized cable system configurations.

Ultimate calibration must be performed by simply setting up conditions that produce threshold leakage levels as recognized by Part 76 and relating these to the particular ingress or egress detection and measurement scheme. The FCC will require this type of information presented with a thorough engineering statement before allowing use of any alternate method.

SUMMARY

In summary, "there is more than one-way to skin a cat"! That is, there are many tools available to us to approach an automatic leak detection, and possibly measurement system. A system that simply alarmed the presence of a new leak and located it to within one-thousand feet would be a major step forward.

A lot of work in the industry will be necessary to reach the goal of centralized automated leakage detection, location and measurement. As a matter of fact, one of the most important phases in this development is going on at this very moment. The routine, and hopefully, continuous monitoring that you are doing at your system can be the source of a good deal of important data which could materially add to the early arrival of semi-automated monitoring systems. Are you carefully collecting and recording your data? Have you considered using two or more frequencies? Perhaps you have a little spare time in which to run some simple tests of the various techniques described above. This industry need, like others in the past, will be met by a few who will rise to the task and reach the goal.

COMPARATIVE STUDY OF HYBRID-IPPV IMPLEMENTATIONS

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INTRODUCTION

The cable business has reached a stagnant stage with dwindling revenues and needs a new marketing approach to generate additional revenue and increased subscriber penetration. The success of Impulse-Pay-Per-View would seem now to be limited to the small percentage of cable systems with two-way capabilities. Some other less radical technology for collecting user requests on an impulse basis will be necessary to bring the potential benefits of IPPV to the vast majority of cable operators.

The public telephone network can readily be used to collect user requests while the cable system is providing the video programming. Economically and technically this is the only basis for a solution at present. Hybrid Impulse-Pay-Per-View, as it is called, has been implemented or considered in several forms: this paper describes and compares them. It then proposes a new approach utilizing both the present telephone system technology and real-time computer capabilities. The proposed scheme also offloads the central office switch and allows a large number of calls to be processed at higher capacity than standard call switching. The high volume of requests that are passed to the cable headend must be translated and validated by the headend computer to allow for timely authorization of addressable decoders. This approach overcomes most of the problems associated with other forms of hybrid Impulse-Pay-Per-View implementations.

HYBRID-PPV

Hybrid-PPV is a system for distributing PPV programming in an addressable one-way cable system where the orders can not be received through the cable plant itself. In a Hybrid-PPV system, the broadband coaxial cable is used to deliver video programming while user requests are gathered through the conventional telephone switching system, replacing the upstream return cable path with the telephone network. Moreover, 'impulse' buying becomes possible if the central office switch and trunks can be offloaded by frontend call processing.

Methods discussed in this paper are: manual call-in, auto-dialing, credit downloading, touch-tone ordering and ANI (Automatic Number Identification) ordering.

MANUAL CALL-IN

This is the current 'solution' used by most cable operators. Customers call in and tell an operator what program they want to buy. This information is then entered into the billing computer which, in turn, instructs the system controller to authorize the decoder.

This solution makes heavy use of phone lines, tying down a physical circuit for a relatively long period of time, approximately three minutes per transaction. In addition, it has a very limited capacity, results in blockage of orders, discourages ordering of 'R' or 'X' rated materials and has high transaction costs. Because of the delays and limited capacity it cannot be considered an 'impulse' PPV system.

Part of the reason for the delay is that customers must identify themselves orally. This oral identification must be confirmed and translated into a decoder address for the order to be processed. This system is relatively sensitive to human error at both ends, and the cable operator has no control over how long a transaction may actually take.

AUTO-DIALING

An auto-dialing system alleviates some of the problems of manual call-in by establishing the connection automatically, transmitting the information to the headend and then immediately terminating the connection, all in response to the customer pushing a button (or some other simple action). The customer interface is simpler, and identification of the customer is fast and error free. The duration of the call is shorter, averaging ten to fifteen seconds, and its processing is not labor intensive.

However, the auto-dialer is an additional (possibly expensive) piece of hardware that must be bought, installed, maintained and tracked. It is also subject to certain limitations inherent in any call-in system, most significant of which is a relatively low limit on the number of late calls. It is, therefore, not really an 'impulse' but rather an advance-buy system.

CREDIT DOWNLOADING

One solution to the mass call-in problem is to allow the decoder to authorize itself, and then call in or be polled at a low background rate. Some sort of ordering limit is downloaded from the controller. This solution does allow a very high rate of last minute purchases and has low variable costs per transaction.

However, this is still an add-on unit (or a replacement, more expensive than a simple decoder), which must be bought, installed, maintained and tracked. It may even require an additional telephone jack. It is vulnerable to abuse and malfunction. If the decoder can self-authorize then there are likely to be numerous ways that cheaters can prevent it from reporting the purchase. It solves the 'impulse' problem at the expense of reliability, security and economy.

TOUCH-TONE ORDERING

A touch tone ordering system allows the customer to call up and 'talk' to an automatic order-taking device by pressing a sequence of digits on the touch tone phone after the connection has been established. It requires no additional hardware in the home, and no manual processing of the orders. However, touch tone is not universal (approximately fifty percent of customer premises equipment cannot handle touch tone dialing) and it still requires a large volume of incoming calls each with a moderately long connection time (an average of sixty to ninety seconds). The subscriber or user has to enter a relatively long stream of digits, which increases the probability of error.

INHERENT LIMITATIONS ON TELEPHONE HYBRID PPV SYSTEMS

No automatic system can provide high volume phone hybrid PPV service if it requires a completed phone call - even if it could somehow process the request instantly.

The first inherent problem is that the ordering customer must be identified. Customer entry is error prone and slow. Auto-dialing units are additional hardware and cost.

Most importantly a physical phone connection (circuit switching) must be made. Phone systems are not designed to connect the cable operator to all of the subscribers who might want to order in the last 30 minutes, let alone the last five.

The telephone switching system is designed for long point-to-point sessions averaging three minutes. Hybrid-PPV needs to pass one simple request and perhaps receive an acknowledgment. The phone system is designed around random independent usage, with 6-12% of all potential connections active at maximum. See the illustration "Physically-Connected Hybrid Pay-Per-View", which shows that a normal call between two local switches ties up the scarcest resource in a telephone system, the trunks. PPV traffic is bursty in nature. A Hybrid-PPV system wants to take as many orders as possible as late as possible. The timing of orders is decidedly non-random.

A telephone circuit is a powerful resource, designed to carry the information in a full duplex audio conversation. The connection time represents a significant portion of the total operating cost of a circuit switching telephone system. PPV ordering horribly underutilizes it. It is also the most scarce and critical resource in a phone system. The cable operator cannot afford to buy, nor can the telephone switching system afford to provide the number of last minute physical connections that would be needed to support Hybrid-PPV. The surge of requests for telephone circuits would overload the switching system.

THE ANI SOLUTION

The acronym ANI (Automatic Number Identification)will be used to designate a class of hardware/software systems developed by various telephone companies to accommodate alternate long distance carriers and large PBX's. This class includes the "Bulk Calling Line ID" system. The following discussion will concentrate on common features of these systems.

The four main requirements for a complete ANI solution for Hybrid IPPV are as follows:

determine caller/selection without making a connection for each order.

reliably relay this data in real time to the cable operator for automatic processing.

perform required processing including addressing and authorizing the decoder.

post transactions into billing system.

GETTING THE ORDERS

ANI alleviates the overload problem by intercepting the ordering 'call' before it becomes a physical connection. It extracts the information required (caller telephone # and caller-entered digits pertaining to ordering information), and passes it out in serial data output form. Because physical connections are not set up the switch is not overloaded. See the illustration "The ANI Solution for Impulse Pay-Per-View" for a graphic depiction of the (pardon the expression) "bypass" of the local switches and trunks made possible by the ANI system.

The caller is also reliably identified because the calling phone # is supplied automatically by the switching system itself, so that no customer entry is required.

To place an order the caller takes the phone off the hook, waits for a dial tone, and then enters information (some of which will be fixed format routing information, some used for specifying the order). Consequently, the call is acknowledged with a tone or voice response.

GETTING THE DATA TO THE CABLE OPERATOR

The telephone switching system will provide serial output at 1200 Baud from each Central Office. There are several problems which must be overcome with this data format:

It is at the wrong place. It must be relayed to the cable operator's premises for processing. There is simply no feasible way for the cable operator to maintain a decision-making processor and its required data at the central telephone office.

It is probably at several wrong places. Unless the cable franchise is very small it will probably be served by multiple central offices.

It comes at its own pace, because there is no pacing protocol. The receiving device is presumed to be available and working at all times.

It assumes the data is correct. There is no error detection capability, let alone the ability to request retransmission of a garbled message.

Most of the problems can be worked around with reliable high speed modems which accept the data and forward it to the cable operator office. These modems must have their own buffering, error detection and retransmission capabilities.

At first glance it might seem strange to intercept phone calls and then forward the data over a phone line. However, the requests have been multiplexed at the central office so that only a single line is required.

At the receiving end the data from the various central offices must be multiplexed and buffered for input into the main processing computer. Even at 1200 baud, a computer dealing with multiple input streams along with complex processing and output requirements, cannot reliably accept unpaced input. It can try, it might even look like it's working, but in the field some messages may be lost, and every lost message represents what would have been a satisfied PPV customer and a sale.

PROCESSING THE DATA

Data must be dealt with in real-time. For example, if there exist four central offices sending three transactions per second, then twelve transactions per second should be multiplexed on a single connection to the cable headend. For larger systems there may be more central offices. Later ANI software/hardware from the telephone companies will probably have even higher capacities.

Customer pictures must unscramble within seconds of making the phone call. Otherwise there is no feedback on the success of an order. If they supplied an incorrect event #, or if their phone # is not correctly entered into the database, there will be no error indication until they fail to see the program they wanted. By then it is too late.

What must be done at these rates of 20 per second (or more) is: first identify the decoder based on the originating phone # and possibly some of the input data (to allow for more than one box per house), then identify the event being ordered. This information must then be passed to a decoder controller system.

Depending on the rules for addressing the decoder, and how much data is required, processing each transaction will require going through one or two indexes. This will require a real-time computer, not a general purpose billing computer. Billing computers are designed to handle large amounts of data and history about customers and decoders , not to shovel data in and out this quickly.

This real-time processor can control the addressable decoders in one of three ways:

it can include controller software within itself and thereby talk to them itself.

it can communicate with a controller using a special optimized protocol designed for the application.

it can pretend to be a billing computer and instruct existing controllers. This is not likely to be feasible in many situations. Since billing computers are not designed to process high data volumes in real time few controllers will expect or be prepared to take 16 or more unsorted 'turn on' commands per second from their billing computer interface.

POSTINGS

Transaction records must be written to disc as quickly as possible, then uploaded to the billing computer. Some billing computers have developed an uploading capability to support two-way IPPV ordering. ANI IPPV postings should be similarly uploadable and processable.

OTHER DEMANDS ON THE MAIN PROCESSOR

The main ANI processor has to be more than just a dumb pass-through machine with posting. There are a number of other activities which it either must or should manage as well, making it a complete IPPV management system.

It either acts as or connects to the addressable decoder control system. Since only a deranged controller would be prepared to deal with two management computers, it must totally manage the addressable decoder functions for the billing computer. This can be done by providing a complete higher level definition of the whole problem, and using the actual addressable system controller to implement parts of it. More realistically, some degree of 'pass-through' command must also be provided.

Orders will have to be taken in advance, often farther in advance than the system controller can handle. Since the ordering numbers will have to be published, many customers will advance order in case their phone is tied up later. The channel or tag that must be authorized for the event may not be available yet, due to conflicting earlier usage, thus requiring the "buffering" of authorizations.

Unless the cable operator wants to have extra staff present for the start and finish of each PPV program there must be an automatic schedule which controls when ANI orders will be taken and required decoder controller scheduling tasks as well. Taking part of the task of scheduling, particularly that of program tag allocation, is not feasible. Once one bite is taken, the whole task must be assumed.

BRIDGE TO TWO-WAY IMPULSE PPV

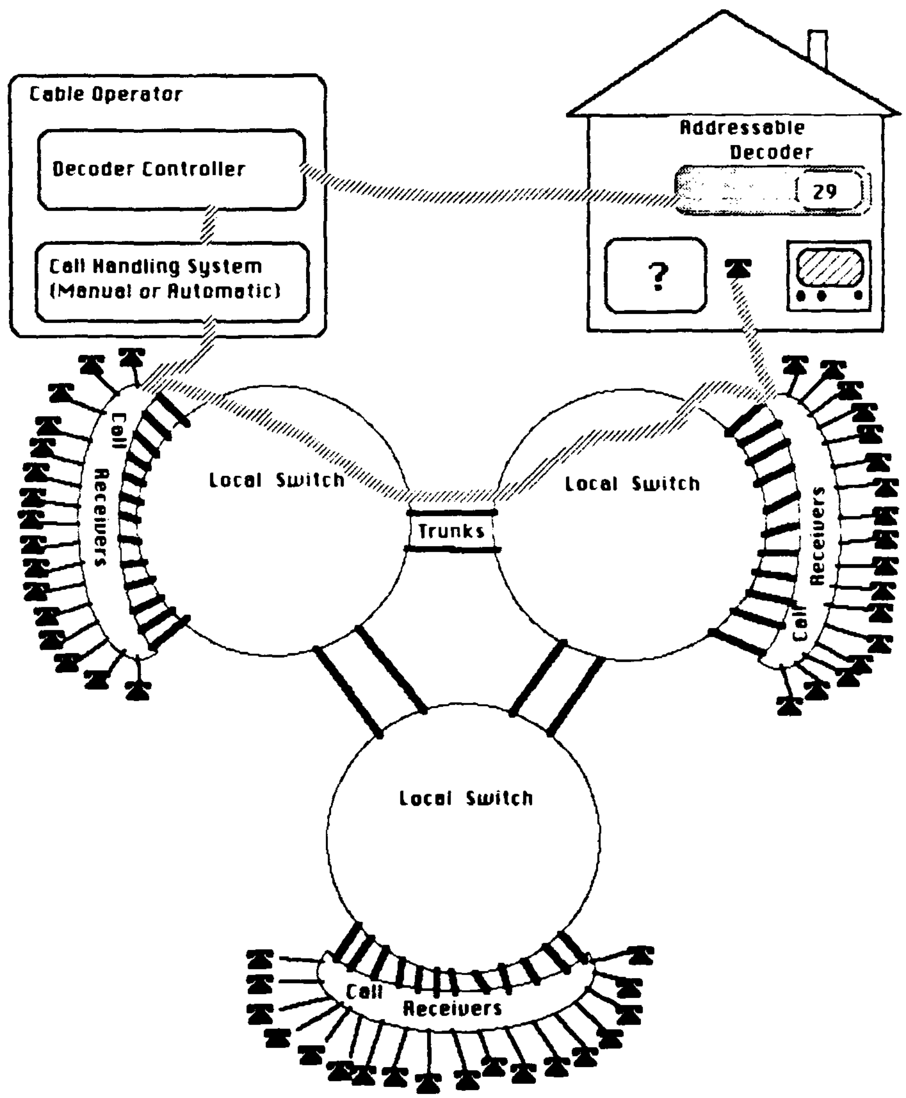
The main advantage of ANI as a hybrid PPV system over a real two-way plant Impulse PPV solution is low startup cost and risk. However once a successful IPPV market has been established it would make sense to phase over to an interactive two-way IPPV solution with its lower transaction costs and higher speeds. A good IPPV management system should facilitate this transition by providing a single source of control for all PPV scheduling and a single source for PPV postings.

CONCLUSION

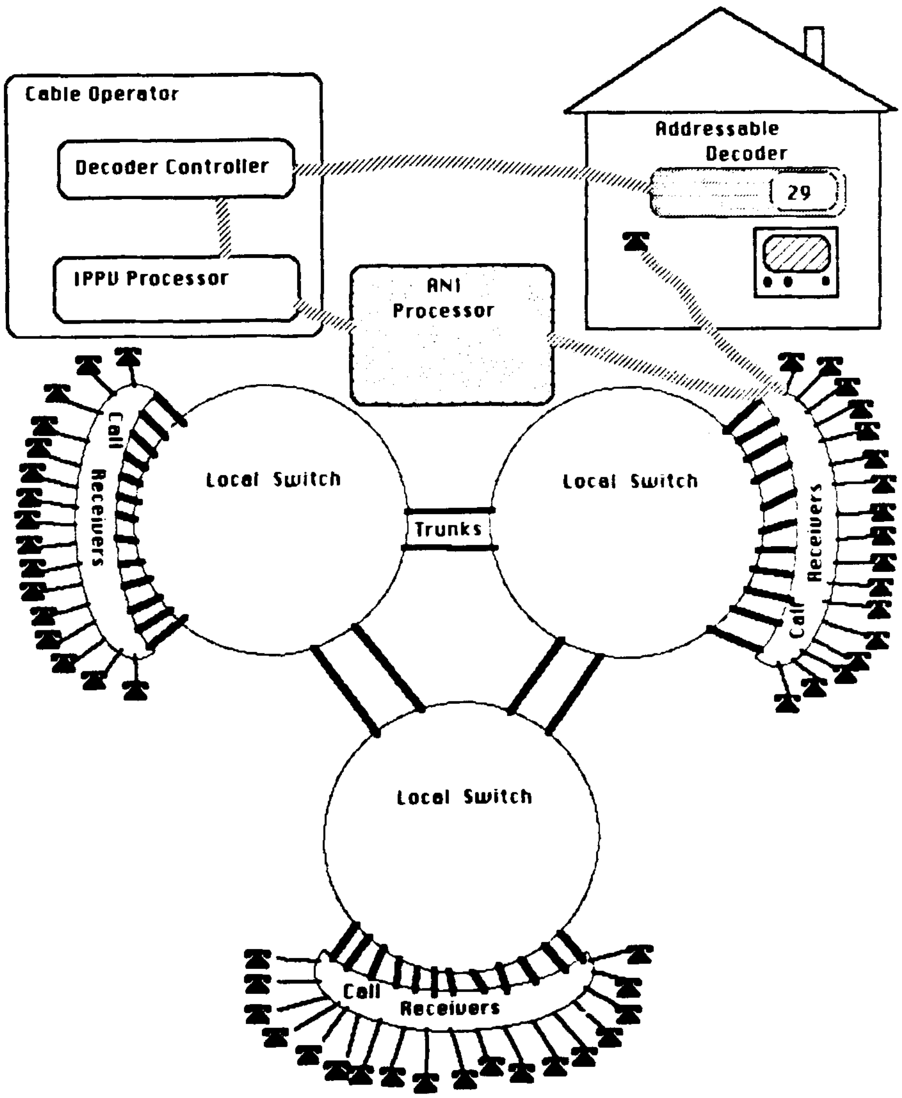
If Pay-Per-View will provide the revenues cable operators need to become profitable; if the ability to buy on an impulse is a significant key to that profitability; if building a new two-way plant or upgrading an existing one is an unreasonably risky expense for a prudent operator, then the ideal solution is a hybrid system involving the public telephone companies.

Given the serious problems with traditional approaches to hybrid PPV, only the ANI-based system with a real-time IPPV processor on the cable operator's premises can provide the necessary functionality.

PHYSICALLY-CONNECTED HYBRID PAY-PER-VIEW



THE ANI SOLUTION FOR IMPULSE PAY-PER-VIEW



COMPOSITE SECOND ORDER DISTORTION
AND
DISTRIBUTION SYSTEM PERFORMANCE

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ABSTRACT

Consistent throughout the evolutionary development of the electronic equipment, which is used in cable television distribution systems, has been the villan referred to as "The System Limiting Distortion". As system bandwidth has increased, the distortion form that has limited system performance has changed. Cross modulation controlled performance in the early years; composite triple beat ruled until recently; now that distribution system bandwidth has continued to expand composite second order distortion threatens to limit system design flexibility.

Therefore, the objectives of this paper are to provide an introduction and a comprehensive analysis of composite second order distortion. An in depth analysis as well as empirical measurement data are offered.

INTRODUCTION

As the number of channels carried by cable TV distribution systems has increased, it has been necessary to specify and control more of the distortion products generated by the CATV amplifier. Composite second order is the distortion product of most recent concern[1].

Second order beats are generated at sum and difference frequencies of the video carriers.

Except for channels 5 and 6, the video carriers for a standard IRC (incrementally related carriers) frequency assignment are given by:

$f = 6m + 1.25$ MHz
where m is the appropriate integer for a particular channel.

Therefore, the sum beat of two channels is given by:

$$f_1 = 6m + 1.25$$
$$f_2 = 6n + 1.25$$
$$f_1 + f_2 = 6(m + n) + 2.50$$

The sum beat falls 1.25 MHz above the victim video carrier, which is a sensitive area of visible interference (Reference Figure 1). The difference beat falls 1.25 MHz below the video carrier at a frequency of negligible sensitivity.

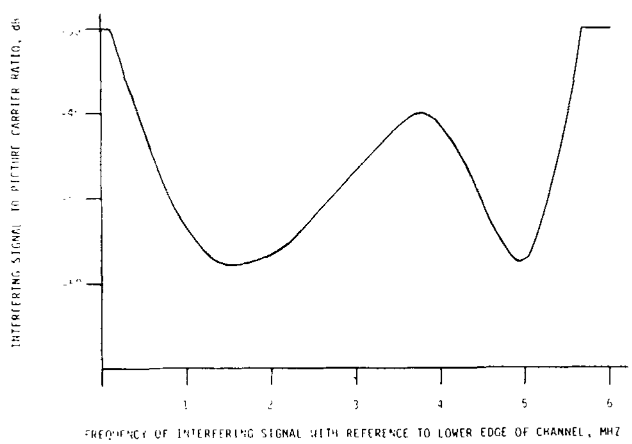

FIGURE 1. PERMISSIBLE LIMITS FOR INTERMODULATION AND OTHER UNDESIRED SINGLE-FREQUENCY SIGNALS

The largest number of sum beats falls on the highest channel and the number of sum beats on the highest channel increases rapidly as the number of channels increases. For a 52-channel, 400-MHz system the number of sum beats falling on the highest channel of 397.25 MHz is 16. For a 77-channel, 550-MHz system, the number of sum beats on the highest channel of 547.25 MHz increases to 29.

SUBJECTIVE PERCEPTION OF COMPOSITE SECOND ORDER

In order to gain insight into the amount of composite second order (CSO) that can be subjectively tolerated, the test set-up diagrammed in Figure 2 was used. The camera was focused on the scene shown in Figure 3. Figures 4 and 5 show a close-up of this scene without CSO and with CSO, which was generated using a hybrid IC driven by a 77-channel Matrix using CW carriers. Channel M39 (547.25 MHz) was extracted using a bandpass filter and converted to Channel 3, the same as the output channel of the camera/VCR. A step attenuator provided relative adjustment of the CSO level. The notch filter eliminates the Channel 3 video carrier from the converter while passing the CSO beat. A Hewlett-Packard Model 8568B Spectrum Analyzer was used to measure the peak video carrier level and the CSO amplitude. A resolution bandwidth of 30 KHz and a video bandwidth of 10 Hz were used to measure the CSO amplitude, the same as recommended by the NCTA for measuring composite triple beat[2],

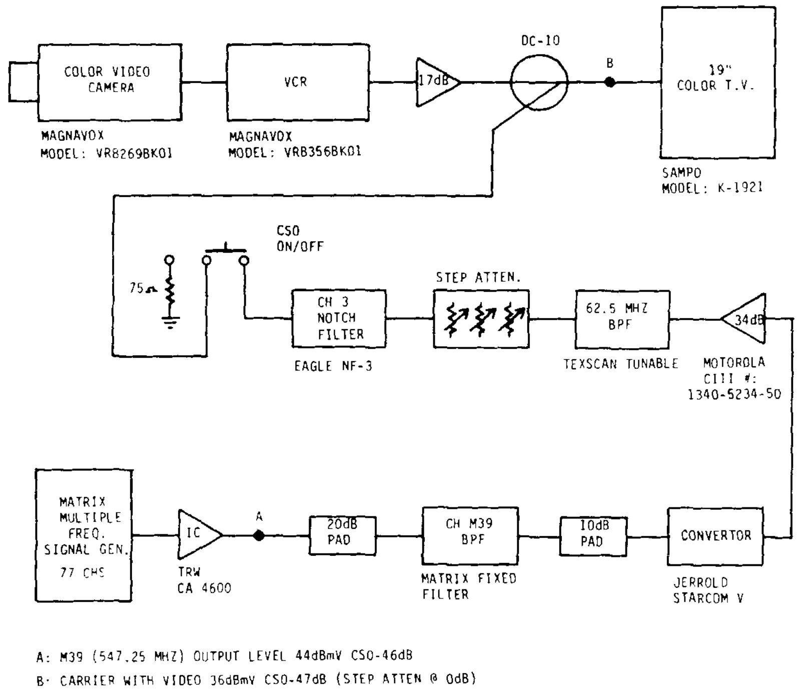

FIGURE 2. CSO INTERFERENCE TEST SETUP BLOCK DIAGRAM

The results of the test are given in Table 1. The level of barely perceptible CSO ranged from -52 dB to -63 dB, with an average value of -59 dB. Because CW carriers were used to generate the CSO, the results represent an unrealistic worst case condition, i.e. video modulation on only one channel and standby carriers on all other channels.

An IRC headend was not available for evaluating CSO generated from carriers modulated with video from multiple sources. However, an estimate can be made of the improvement using modulated carriers. The average rf level of a modulated carrier is about 6 dB below the sync peak level. With CW carriers, each 6 dB lower than normal (except for the victim channel level, which remains unchanged), the CSO relative to the victim channel would be reduced by 12 dB[3]. As it is probably unrealistically optimistic with actual video to expect a 12-dB reduction in CSO, the author has chosen one-half, or 6 dB, as a reasonable reduction in CSO that could be expected using modulated carriers as compared to CW carriers.

Therefore, for the average viewer of Table 1, the CSO could be -53 dB (-59 + 6) when measured using CW carriers. This number is the same as that recommended by the NCTA for composite triple beat. (2) It may be somewhat on the conservative side as one would expect less visual sensitivity to a beat 1.25 MHz above the video carrier as compared to a beat falling on the video carrier. (Refer to Figure 1).

OBSERVER	BARELY PERCEPTIBLE CSO (dB)
#1	-57
#2	-58
#3	-60
#4	-52
#5	-54
#6	-59
#7	-59
#8	-63
#9	-62
#10	-62
#11	-63
#12	-61

AVERAGE: -59.2dB

TABLE 1. CSO SUBJECTIVE TEST RESULTS

CASCADE TEST RESULTS

Composite second order has been measured on a cascades of 16 550-MHz trunk amplifiers, using the Model XFTA-26/550 Trunk Amplifier. The XFTA-26/550 uses a conventional pre-amp driving a TRW FF224 post-amp. Operational gain is 26 dB.

The overall trunk amplifier CSO is determined predominantly by the pre-amp performance. A PHI 5517-21 is used as the pre-amp with CSO specified as -60 dB maximum for 77 channels at a 44 dBmV flat output. Cascade results are as follows:

Amplifier Model	No. in Cascade	Output Level (dBmV)	`Tilt (dB)	Worst Case CSO (dB) @-25°F	@70°F	@134°F
XFTA-26/550	16	39	6	-64.5	-64	-64

FIGURE 3. PICTURE ON WHICH CAMERA WAS FOCUSED

FIGURE 4. CLOSE-UP OF SPACE SHUTTLE PICTURE

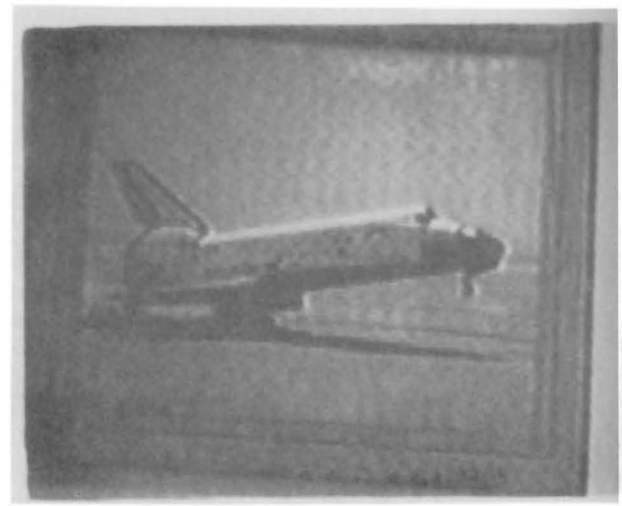

FIGURE 5. SAME AS ABOVE, EXCEPT WITH -47 DB OF CSO

The worst case reading of -64 dB occurred on the highest channel. This worst case reading is well below the -53 dB barely perceptible limit, allowing for further derating from cascade extension, bridger, and line extenders. CSO derating appeared to follow a 10 log N curve.

CONCLUSIONS

Composite second order distortion can indeed be a factor that can limit cascade performance on 550-MHz, 77-channel systems. However, by specifying hybrid IC CSO performance, this distortion product can be contained at a comfortable level.

ACKNOWLEDGEMENTS

The author wishes to exprfess his thanks to:

(1) Harry Reichert, former Manager of Systems Evaluation, Jerrold, who originated the idea for this paper.
(2) Ron Solomon, for his helpful comments and suggestions.
(3) Steven Do, for setting up and conducting the subjective tests.

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COMPUTER AIDED DESIGN IN A TAPPED TRUNK ENVIRONMENT

Bob Romerein and Dan Kolis

LINDSAY SPECIALTY PRODUCTS LIMITED

ABSTRACT

Rural areas are becoming the focus of increased attention as the cable industry searches for new areas of growth. In many cases, urban franchisers are being pressured to serve fringe areas and are looking to manufacturers to make the necessary technology available and affordable. While the high tech solutions to expansion continue, there is another avenue of simplicity and tighter economy emerging in system design known as TAPPED TRUNK, which we will explore further.

This presentation documents our experience in gaining an understanding of rural design problems, and addresses methods in which computers can aid in the design process. Software development is discussed in detail with an emphasis on overcoming the constraints imposed by the desire to create a useful software package which will run effectively on a personal computer.

INTRODUCTION

The increasing diversity of CATV plant presents opportunity as well as liability for the system designer. As he explores the frontier for new sources of revenue, he is challenged by a departure from the familiar demographics of the large urban areas where the population density is fairly homogenious. He is faced with lower densities and increasing costs with less revenus potential. There is usually less technical expertise available to cope with system maintenance, but there is certainly no lack of desire for access to the media.

Tapped trunk designs, which unify the previously segrated functions of trunk and distribution, are frequently the best method of serving these needs. However, there are a few special problems involved in extracting the economy and performance potential. The added design complexity of the tapped trunk cascade, together with the iterative nature of the system design process, strongly implies computer analysis so long as there is a high degree of certainty in the methodology of prediction.

THE TAPPED TRUNK ENVIRONMENT

No doubt everyone is familiar with the view from an airplane window. The countryside bears a resemblence to a microscopic view of cellular material with scattered nodes of activity connected by a network of arteries. The density patterns are irregular. Many of the arteries have smaller nodes randomly distributed along their length. This visualization is helpful in establishing a sensitivity to the lack of generality in the design. Rural systems are a string of special cases.

The Rural Electrification Administration has studied rural demographics carefully in an effort to asses the technical and economic considerations of these marginal applications. The basic design philosophy which they have found to be economically appropriate in delivering acceptable quality signals in these areas is to combine the conventional concepts of trunk and feeder plant. Noise and distortion are distributed equally throughout the system by adopting one transmission level which is typically half way between conservative trunk levels and high powered feeder levels. Subscriber taps are also allowed to exist on the primary signal path.

The system design concept which has evolved from studies of this nature has come to be known as TAPPED TRUNK. The benefits of this approach are, first of all, a substantial reduction in the amount of cable necessary, since backfeed situations are virtually eliminated. While backfeed is often a very useful tactic in dense urban areas, it becomes a burden in cable costs when the distance between subscribers increases. Other savings are realized in the inevitable reduction in amplifiers as well. There is less cable loss to overcome, and the amplifier spacing is increased due to the higher transmission levels. For example, in a conservative tapped trunk redesign of a trunk and feeder system built outside of Orillia, Ontario, we uncovered a saving of 16% in cable material costs. We also discovered a cost saving of over 30% in amplifiers, however this effect seems to be a measure of the economy of distributed simplicity as opposed to concentrated complexity in amplifier design rather than simply a reduction in amplifier numbers. It is true too, that maintenance becomes easier with identical amplifiers set at identical levels. Even the cable can be made uniform in the smaller systems. Uniformity is intrinsically cheaper, and can be especially attractive when the access to skilled technical personnel is scarce.

The TAPPED TRUNK concept is not essentially new. Back in the early days of cable technology, when the notions of hardware methodology were similar to plumbing, there was a nasty device called a PRESSURE TAP. Basically, this was a type F connector which actually penetrated the main coax. A simple resistive attenuator inside the connector tapped off a portion of the signal for each subscriber. However, it ignored the perameters of isolation and return loss so the problems encountered with reflections, not to mention the damage to the cable, were discouraging. In retrospect, it seems likely that the tapped trunk concept was abandoned along with the pressure tap, and the two have remained linked in the minds of many of those who have, by now, ascended to positions of authority in the cable industry. Resistance to the belief that tapped trunk is even worth considering seems to be couched in a blanket distrust of the integrity of subscriber taps in general.

MODERN DIRECTIONAL TAPS

The state-of-the-art multitap is produced in high volume and is marketed much like a commodity. Its function is virtually taken for granted. Performance specifications tend to be used as marketing tools rather than design criteria. Yet, there seems to be a cloud of uncertainty about their presence in the primary signal path. Since we at Lindsay have had experience in designing and manufacturing taps, we have access to the basic information which may help to dispell some of these doubts.

The design process involved in manufacturing a series of taps is a mixture of science and black art. There are seven perameters to optimize simultaneously and, even though most of them have a common link with the characteristic impedance, the outcome is a matter of destiny. The insertion loss is the most significant consideration with respect to its effect in cascade. It is still referred to as FLAT LOSS which is quite reasonable in a 220 Mhz world. But this assumption is no longer valid as bandwidths increase. While there are slight variations in the signature with each tap value, the overall effect is a build-up in level in the mid band followed by a gradually increasing rolloff in the hyper band. Any effort to design out this effect to preserve the simplifying assumption that the insertion loss should still be flat will inevitably have to sacrifice some other peramener. However, it is unlikely that TAPPED TRUNK systems will be loaded beyond 300 MHz anyway. (The basic premise of the design philosophy is economy in marginal applications, and there are escalating headed and maintenance costs as the channel loading increases.) So, within this perspective, the deviation from the flat loss assumption will be easily manageable with simple mop-up techniques. Idiosyncratic variations from tap to tap will tend to randomly cancel, and cable loss between taps will limit the build-up of reflections.

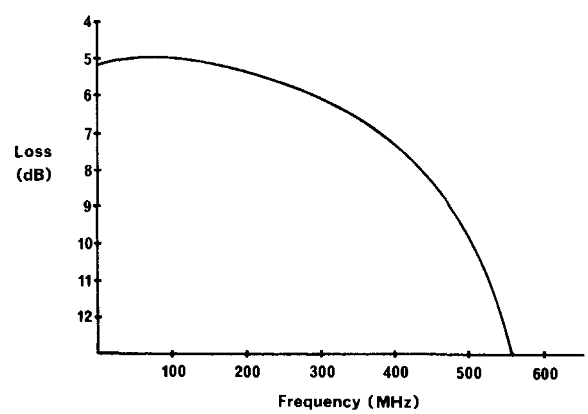

FIG.1

Figure 1. is a wide bandwidth view of a cascade of five multitaps typical of the values found in a tapped trunk cascade. The deviation from ideal flat loss is apparent by drawing a straight line through any two points representing the upper and lower frequencies of a given bandwidth. It is also apparent

that as the bandwidth becomes wider the deviation becomes greater.

Changes in the thermal environment have an impact on everything including taps. The concept of flat loss is further erroded by the findings of a study of insertion loss vs. temperature during a recent multitap design program at Lindsay. It was found that the variation in the insertion loss of a cascade of taps is frequency dependent. Unlike cable, the variation is not a given percentage of the loss. Each tap, regardless of its insertion loss has roughly the same variation which is a function of temperature and frequency only. The effect over wide bandwidths is to accentuate the deviation from the ideal flat loss mentioned earlier. The thermal equation predicting the thermal response of a span of cable containing a given number of taps should be modified to include the equivalent cable contribution due to tap behavior. The contribution appears to be significant enough to be considered in system design calculations especially where open loop thermal compensation methods are being proposed.

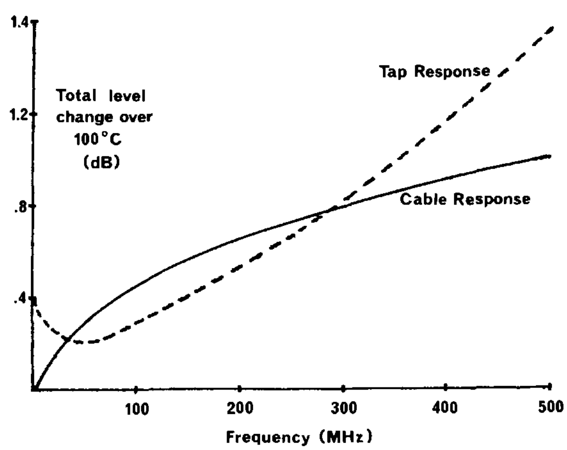

FIG. 2

Figure 2. shows the thermal behaviour of a cascade of five taps compared to the thermal behavior of a length of cable. The length of cable is chosen such that the thermal change over 100 desgrees celsius at 300 Mhz is equal to the thermal change of the taps at 300 Mhz. The length of the cable is actually 4 dB. This means that each tap, regardless of its value, contributes 0.8 dB to the thermal response of the system under these conditions.

Another concern to those uninitiated to the tapped trunk environment seems to be the intrinsic reliability of the tap in the system. There are undoubtedly vast quantities of data available in the maintenance records of cable systems around the world. We examined the maintenance log of Lindsay Cable in Lindsay Ontario to get some idea of the maintenance liability of introducing taps into the main line. Lindsay Cable serves about 5600 subsribers through 64 miles of cable. The evidence we uncovered in the Lindsay Cable log indicated that, over the last five years, 7 of the 1150 taps failed. This represents a 0.12% failure rate per year. Failures in connectors were also of interest since the tapped trunk architecture imposes a greater liability on the main signal line with a greater number of connectors. This accounted for 8 failures out of a total of about 3300 connectors or 0.04% per year. Interviews with service personnel indicated a belief that the reliability of each connection rested heavily on the workmanship involved in the installation. This then seems to be a local variable to be assessed on an individual basis.

REALITY CHECK

The REA has been good enough to provide excellent documentation on the performance of an actual TAPPED TRUNK system showing how well the calculated system perameters correlate with actual measured results. Its studies have identified several of the frontiers of experience with the TAPPED TRUNK concept, and have demonstrated that performance and cost estimates in this domain can be made with a reasonable level of confidence. For example, cascades of 40 amplifiers supporting 150 passives in series are conceivable for bandwidths up to 300 Mhz. The distortions arising from reflections in a system this size are expected to be visually undetectable based on extensive video tests conducted at the tapped trunk system in Edinburg, Virginia. Group delay in a one way system of this size will be on the order of 200 nanoseconds negative on channel 2 and about 120 nanoseconds negative on channel 13.

Unfortunately, the program of rural cable television development at the REA was truncated by a federal policy decision shortly after the Edinburg study so the continuity of development in this field has been somewhat fragmented. Undoubtedly, the frontiers will be pushed back further as greater risks are taken to exploit the potential cost savings of TAPPED TRUNK designs. William O. Grant, who headed the REA development program, estimates savings on the order of 20% over the conventional trunk and feeder approach.

PROSPECTS OF COMPUTER MODELING

When given the opportunity to make several small system design proposals, we were immediatly struck by the diversity of the population density. TAPPED TRUNK design seemed to be appropriate for part of each project, however there were areas of higher density where the technique was clumsy and placed an unnecessary burden on the integrity of the trunk. We felt compelled to develop a computer aided design tool which would be driven not by simplifying assumptions, but by a sensitivity to the demographics, the hardware and the costs.

AN IMPLEMENTATION

The program we designed supports many capibilities meaningful in exploring tapped trunk cable plant. Some of these tasks include:

1) Capture strand and demographic information into an accurate, maintainable DataBase,

2) Allow speculation as to modes of service to that region.

3) Examine this speculation from a number of facets such as costs, RF degradations, temperature, etc.

4) Generate Bills of Material and other documents meaningful to technical and financial professionals.

5) Model sub-optimum device performance to study how this effects cable systems.

The program was authored on an Apple and was written in Basic under the CP/M operating system and MicroSoft Basic. This choice was not optimum but did not function as a constraint.

The eventual bounds of a programs capability are determined by initial premises which later become limitations. In exploring other computer aided methods in use in the cable industry we became aware of approaches which are intrinsically suboptimum. The most common (and painful) tactic we found was a preoccupation with the visual representation of the cable plant. Conspicuous by its absence in the foregoing list of objectives is rendering of the final design as a drawing. A bent to automating the drafting side of the design process is a problem which may have begun as an ill-directed cost control measure. Casual analysis of the costs-to-design a plant may show drafting as a significant, if not outstanding cost. This is true only if the instantainious costs are evaluated. Costs occuring "downstream" in unnecessary cable, line extenders and labour during construction as well as the long term burden of unneccessary actives must be fully comprehended. In order to insure that our software effort would not encounter a limitation before it reached its goals was difficult. We utilized a combination of techniques to maintain generality in the core of the program early in the authoring process. It is sometimes said "Every complex system that works began as a simple system that works", this is certainly true in software development in general and this program in particular.

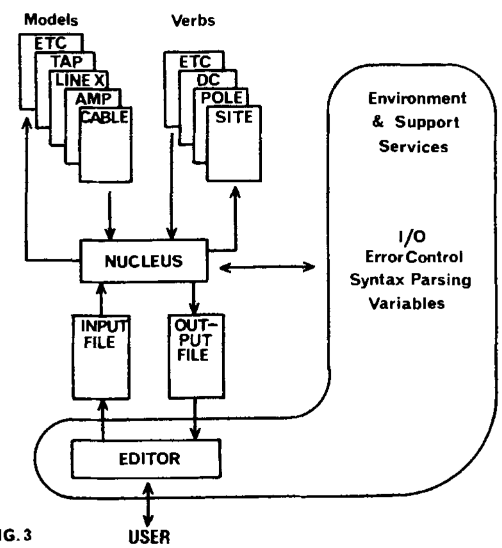

FIG.3

Figure 3. will help the reader visualize how this program is constructed. The program is composed of a small nucleus of code which refers to a library of models of the devices under study. The emphasis here is on "small" and "devices under study"; we were careful to leave these pieces of the program totally free of non-essential complexity. The support services, such as text control and syntax parsing (turning the program into a custom programming language of sorts) are very large in comparision. This partioning of the program to isolate the model is very important. It allows the researcher to consider a particular model in isolation, change it, and see how this effects the cable design.

Another important black box inside the program is the verb dictionary; in the context of computer languages this precise kind of dictionary is called a lexicon. The function of the lexicon is to specify what must be done upon encountering each word in the directions. What "must be done" is specified as a series of transformations which are specified as models. The "things they are done to" are the elements of the environment, which are any entities that have both names and values. Of course, what knits these black boxes together, is the nucleus. The nucleus is simple, but calls up black boxes of significant complexity. The overriding concern of the nucleus is as simple as its structure; from its perspective the conclusions are byproducts of reading through the directions looking for the special verb called "END".

The content of the lexicon and transformations in the models characterize precisely what the output file will contain. No other portion of the program will effect the environmental values. Thus improvements in input/output, editing or other subsystems will not affect the calculations and/or results.

The first pass of the program had a repetoire of seven verbs. This was barely adequate to perform a tapped trunk design requested for a small site in Hawaii. By the time we were ready to attempt a system of non-trivial size, the lexicon contained more than twenty verbs. Table 1 contains the verbs and how they are evoked in the current implemention. Many of the additions do not direct the cable plant design, but produce condensed reports of one kind or another. Examples of this are the pseudo-family of "REPORT" commands, which show how loss was accumulated,(useful in deciding on the relative merit of AGC vs thermals), and "BUMPS" from non flat loss devices. Procedurally it appears that the commands and/or verbs do fall into catagories, such as "REPORTS", "RESETS", "ASSIGNMENTS", "DEVICES", etc. This adds a linguistic uniformity useful as a memory aid for the researcher but has no impact on the machines implementation. All VERBS point to the LEXICON which directs the MODELS to change the ENVIRONMENT. There are no exceptions and the VERBS do not directly modify or reference each other in any way.

CABLE? = N	: ft. of special cable
CABLE5 = N	: ft. of .500 cable
CABLE7 = N	: ft. of .750 cable
TAP	: calc. tap value
DC? = N	: specify coupler
AMP = N	: specify amplifier
NOTE = T	: remark
GAINON	: normal amp placement
GAINOFF	: no amp placement
FL = N	: specify flat loss
REPORTLOSS	: loss summation
REPORTBUMPS	: bumps summation
RESETLOSS	: loss reference pt.
RESETBUMPS	: bumps reference pt.
A.T = N	: assignment
SETCABLE? = N	: specify cable

TABLE 1. N is a Number - T is Text

INADEQUACIES AND EXTENSIONS

A significant flaw in our first implementation was its inability to elegantly handle how branches of the system interrelate. This was the primary drawback of authoring this program in a non-recursive language such as Basic. The only approach to elegantly handle this important aspect is to model the system as a large linked list which should be memory resident. This implies an implementation in PASCAL, LISP, C, SNOBOL, or even ADA. It implies a fairly large memory as well.

It is probably possible to do such wholistic analysis on the most powerful of personal computers with the addition of lots of extra memory. Another inadequacy of our implementation, also stemming from the language, was how slowly the most complete version ran. Waiting for end to end analysis for the Orillia plant was an ordeal. However the exhaustive nature of the analysis generates a pleasant certainty that the design is valid.

As is always the case with technology, our effort supplied us with a few answers and generated a multitude of questions; most importantly, what would the general shape be for an optimum program? We have pondered this thought and would like to present the reader with some further directions. In some ways it is similar to what we have written but is substantially more open-ended. Figure 4 may be helpful in visualizing these principle points:

1) The central nucleus should be highly interactive. Primarily this means clarity and speed are of the highest priority.

2) The source files should be amenable by software entities just as if these changes were done by the researcher/ designer. The concept of In and Out should be softened to meld both into one entity with two "flavors". When decisions on what to do are made, the entity which made them should "initial" the entry. The concept here is that input files transform into conclusions in a stepwise fashion.

3) The environment variables should be more contained and multiple values for a given variable should be allowed to exist depending on context. An example of how to utilize this function is that a branch, when explored would seem a self-supporting system independant of the whole. Also, variations of the entire design could exist for comparative purposes.

4) Entities called advisors could inspect in real time any value or event occuring. These entities could be activated or deactivated with ease. Expansion of the programs power would be done by adding advisors. Some might be large. Examples of potential advisors specialties are represented by their names; Tap-placer, Amp-placer, Drop-placer, Constructor, Maintainer, De-bumper, Reliability-watcher, Reverse-watcher, etc.

5) Considering all the variations of reports which may be required is a mind numbing task. What all "pure" reports have in common is that they are passive. That is, they look at but do not change the design. An advisor could be charged with interfacing with external spread-sheet programs. An example of an appropriate use for such a function would be to move bills of materials and labour estimates directly from the program into accounting tuned spreadsheets such as LOTUS 1-2-3. This would allow economic planning vs time estimates to transpire without reprocessing this information. Also summaries of all different systems could be merged into regional type reports for comparative analysis and/or presentation. Using intermediary languages such as DBase 11 for this would allow merging with addresses, pay TV records, outage history make ready directives and a mass of other knowledge useful in other aspects of the cable operation.

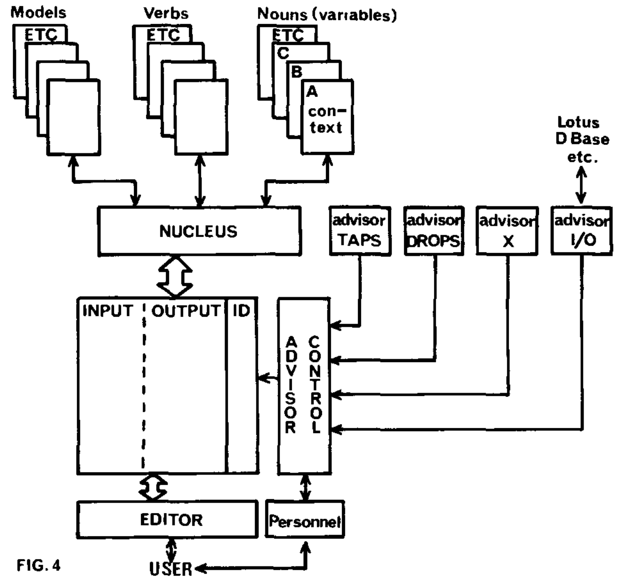

FIG. 4

6) An intrinsic method of marking boundaries into the source file should exist. In text for example, paragraphs, sentences and punctuations put words into context. The analogues in a cable system are street names and regional demarcations such as "North Ward". These should be elegantly supported.

There is no doubt that the above agenda is extensive. It is fortunate that writing the initial portions, such as the nucleus, is not significantly constrained by future inclusion of more complex functions. Any effort to write code of this sort is a major project and the architecture of the program should be documented and understood in significant detail before any work begins.

The existence of a truly superb cable design program for general use would benefit the cable operators to a significant degree. It would be of particular value in tapped trunk, where the interconnectivity of the plant is a particular opportunity for clever methods and careful clear logic to yield savings. How likely is such a program to exist in the near future? This is a difficult question that we cannot answer. However, there are some encouraging trends. First there is an increasing awareness that designs in circulation can and should be improved; this is clear from our external communication with our customers as well as recent articles about suboptimum designs. Second the general trend of literacy is benefiting the cable industry. A recent program which may be available commercially has been written based on a linked list model. It is written in Pascal. It is fast and clear. Hopefully those responsible for design in the cable industry can encourage more programs of this calibre to be authored and made available. Those interested in this particular effort should speak with Mr. Frank Himsl of CableNet in Oakville, Ontario.

CONCLUSIONS

Both Tapped Trunk and extended accuracy of computer modeling in cable environments are at an embryonic level of development. This leaves the system operator/designer in a difficult position; in order to achieve savings some exposure to risk must be tolerated. We had hoped to define where and when Tapped Trunk was appropriate and be able to state this with relative certainty.

We believe our effort yielded results between certain success and total failure. On one hand we can state with certainty that the reliability of taps and connectors has reached a satisfactory level to consider tapped trunk systems and that effects of temperature and signature in concert generate tolerable distortions of the passbands at frequencies up to 300 Mhz. The commonly held belief that the normal distribution of tap values have signatures which do not generate summed massive distortions is borne to be true using computer, manual, and experimental analysis. We can also state that in the isolated cases of two particular cities Tapped Trunk resulted in a 20% saving in material costs alone.

The existence of a successful system built by the REA proves a system with 18 amplifiers and 74 passives in line can work. Extrapolating the REA experience and combining that with our studies it would not be difficult to support the claim that a system of twice that size is viable. No intrinsic barrier to construction of the 400 tap system (Orillia) seems apparent, especially considering the slight branchedness imparted there to be conservative. The actual length of this tapped trunk cascade was only 17 amplifiers deep. The REA projected the upper limit of tapped trunk technology to be about 40 amplifiers with between 100 and 200 passives.

It is our hope that the contours between pure Tapped Trunk, moderation of Trunk and Feeder with Tapped Trunk and classical design will become clearer as systems in the safe regions of design philosophy are constructed. Experimental knowledge of this type can then be used to tune the computer model(s), which, in turn decrease the likelyhood of experimental systems becoming liabilities.

We are indeed fortunate have an opportunity to work with an informed and well managed system operator and may soon embark on such a multi-faceted, multi-site project. It is encouraging to be part of an exploration linking the efforts of the design, manufacturing, operations and finance phases of the cable industry into a cooperative unit. Perhaps the experiment in corporate communication is as meaningful to the cable industry as the technological and economic advances under study!

ACKNOWLEDGEMENTS

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COMPUTER-AIDED DESIGN (CAD) OF TVRO EARTH STATIONS

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SCIENTIFIC-ATLANTA, INC.

ABSTRACT

Not long ago the process of designing a TVRO earth station was relatively uncomplicated. Consider that there were a few manufacturers offering a few products to a few prospective customers. Economy was secondary to performance since all earth stations were very expensive and since very strong signals were necessary because of equipment limitations and projected use. Of course the situation at present is much different. The amount of equipment on the market has increased spectacularly. The costs have fallen as competition has increased and as the equipment is manufactured in larger numbers to accommodate a much larger market. Satellites have proliferated, become more powerful and more closely spaced. In a word the design of a modern TVRO earth station is now "complicated".

Faced with these increasing pressures on our engineers and mindful of the expanding market opportunities the decision was made to enter the modern age when it comes to earth station design. We committed ourselves to Computer-Aided Design. In this way we would form a powerful design team by combining best aspects of our talented engineers with the speed and agility of our mainframe computers.

The importance of this CAD package to the CATV operator or engineer is twofold: 1) confidence that earth stations resulting from the use of this CAD package are highly appropriate and cost-effective and 2) the reports resulting from this CAD package are available to the industry.

This report summarizes the decisions made while developing our earth station CAD package. A sample design session illustrates the effectiveness, flexibility and speed of the CAD process. The enhancement of designer creativity is pointed out. Many of the details concerning the performance calculations and the assumptions upon which the calculations rest are outlined. Finally, a few thoughts are given on the future usefulness of this CAD package in the 2-degree spacing environment.

THE NEED

Our design engineers' offices used to contain bookshelves crammed with thick notebooks containing satellite information, volume after volume of manufacturer's specification sheets and folders of various technical reports detailing the computations necessary to design and predict the performance of a TVRO earth station. The design process was cumbersome, error-prone and slow. There was no easy way to ensure that the data used by each of the engineers was up-to-date or even the same. A quick performance estimate could only be produced by the 'old-hands' who could rely heavily on intuition based on their past experience. Armed with their unique (and often cryptic) notes, these experienced engineers could pretty quickly converge on a reasonable design and, even more importantly, could usually spot a probable error in one of the calculations soon enough to avoid wasting valuable time.

But, what was sorely needed was a way to capitalize on this design intuition, a way to allow our designers to see the performance estimates of several systems at the same time for easy comparison and a way to encourage design creativity by relieving the engineers of the laborious calculations and endless searching for data. The need was for a means by which an optimum earth station system to be quickly converged upon by an engineer new to the business. Simply stated, we saw a need for a Computer-Aided Design (CAD) package which would allow our engineers to use our mainframe computers as a design tool. Since we could not find the necessary help from commercial software vendors, the decision was made to produce our own programs. Our philosophy was that these programs would be menu-driven (that is, would present a list of operator choices when appropriate) and user-friendly (that is, the users would not need to know anything about computers or programming to use these CAD programs). Our goal of a man-machine design partnership for the TVRO earth station design process is shown in figure 1.

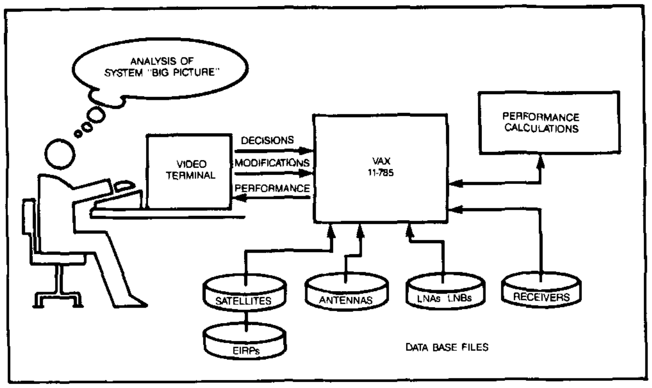

Figure 1. CAD Man-Machine Partnership

As with all CAD routines, success would hinge on the ease of use and the ability to capitalize on the inherent strengths of the human designer and the computer. The engineer would provide the raw data about the site and an understanding special factors important to the customer and would make the necessary design decisions. The computer would be the custodian of the miriad data on equipment, satellites and standards, which must be available. These data would be stored in database files representing digitized versions of the packed bookshelves formerly used. Each of our engineers would thus have immediate access to the most up-to-date and reliable information. A database management program would be used to maintain this database, allowing the manager to add, delete or modify any record at any time. The computer would perform all necessary calculations since it is very fast and highly precise. The computer could now instantly provide the engineer with reliable information and projected signal qualitites.

The engineer would capitalize on the machines's strengths of speed and data-storage. But for the man-machine partnership to function at its best, the superior analytical abilities of the engineer must be brought to bear on the design of the system. The Computer-Aided Design programs must be highly interactive, providing considerable flexibility to the design engineer so as to promote and not hinder his creativity. The engineer is called upon to evaluate the performance of the system under design. Until the performance is satisfactory, the engineer must be afforded complete latitude in deciding on what system changes should be made. After these modifications have been made the computer will instantly reevaluate the system performance and allow the engineer to analyze the effects of the modifications. This man-machine interaction continues until the engineer is satisfied with the resulting performance.

The step-by-step decisions are always left to the engineer since he can understand and interpret many subtle and seemingly unrelated interactions which that computer cannot. For example, the engineer can more easily weight such factors as cost, unique site situations, interfacing with equipment already in place, customer idiosyncracies and the like. The human mind is much better at being able to see how each detail fits into the "big picture". A successful CAD program is a powerful tool for the engineer to use, it cannot replace him.

AN OVERVIEW

A clearer understanding of the CAD partnership can be obtained by following along with an example design session which is presented here. The next part of this paper will summarize the details of the assumptions and algorithms used in the programs. The components which the CAD system recognizes as comprising a TVRO earth station are shown in figure 2. As can be seen, this system includes the satellite source of the downlink microwave signals and produces the baseband output which can then be further processed by the headend equipment and distributed.

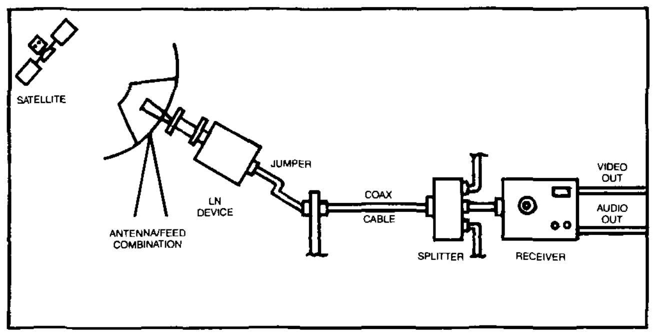

Figure 2. Earth Station System Components

The customer provides the information necessary to begin the CAD process; that is, the site's latitude and longitude, the name of the satellite(s) which may be accessed, and the intended use of the signals that will result from the receiver. The latter information gives the engineer a feeling for the levels required to

Applications Engineering
EARTH STATION CAD Version 1.0
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1. Customer: *NCTA TEST*
2. Location: *ATLANTA, GEORGIA*

latitude [D,M,S]: *34,10,15*
(N) or S: *N*
longitude [D,M,S]: *84,20,5*
(W) or E:

Figure 3. First CAD Screen
(NOTE: The *ITALICS* represent input to CAD)

produce acceptable results. As soon as the engineer calls for the Earth-Station CAD program, a screen similar to figure 3 appears on his video terminal. The engineer enters the customer's name, site location and latitude-longitude coordinates in the appropriate locations according to the prompts.

When first started, the CAD program has the engineer assemble a preliminary earth station system. These first-system components are chosen in an order roughly opposite to the signal flow; that is, working from the receiver "backwards" to the satellite. Therefore, the engineer first chooses one receiver for the system. The engineer's choices reflect the goal of total design freedom. He can decide to choose any S-A receiver by simply entering the model number. If this is done, all of the necessary data for later calculations are read by the computer from an internal database file which is, in a sense, a digitized version of our specification sheets. However, the engineer can also choose to enter the necessary receiver data, guided by prompts on his terminal, effectively defining any receiver whatsoever. By this means, the product of another vendor can be tested, or the designer can experiment with any "what if" scenario. Either way the receiver data necessary for performance calculations are now stored in the computer's memory. Figure 4a approximates the screen seen by the designer choosing an S-A product and 4b shows the prompts used if the designer chooses to define a receiver.

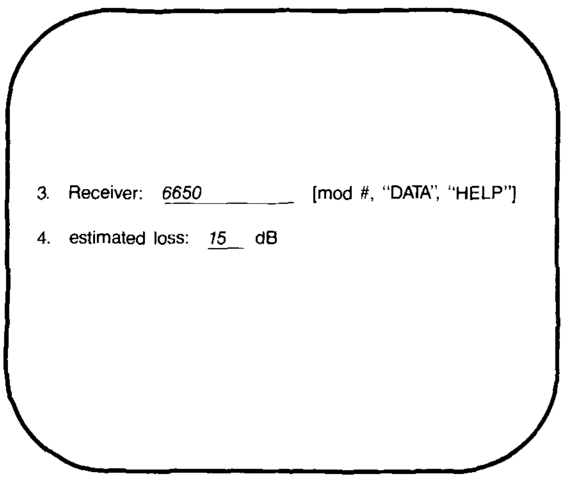

Figure 4a. Receiver Choice by Model Number

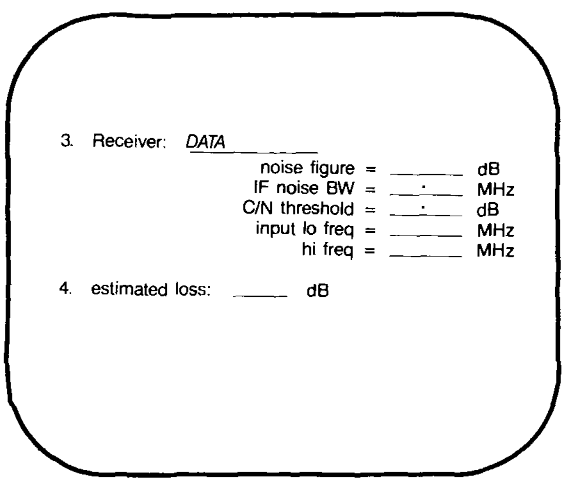

Figure 4b. Receiver is User Defined

Next, the engineer is prompted to provide an estimate of the total dissipative and dividing loss, in dB, between the LNA (or LNB) and the receiver (see either of the figures 4). This parameter would include the coax cable runs, the jumpers and splitters that may be necessary. On the first run, a typical value is often used. Later, after the system component choices have been narrowed by successive design runs, the effect of more or fewer splitters or of more or less expensive cable can be carefully analyzed by the engineer.

Working backwards, the next system component that must be chosen is the Low Noise (amplifying) Device. The computer program can use either an LNA with a block-downconverter at the receiver or an LNB delivering an amplified and downconverted frequency band to the receiver. Flexibility of design is provided by allowing the engineer to use the S-A LN Devices which would interface with the receiver already chosen or by allowing him to define the parameters of any LN Devices. These choices can be be seen in the menu shown in figure 5a. If S-A LNDs are to be used the computer will obtain the device parameters by searching its LND files. On the other hand, if the designer chooses to define his own LNDs the computer uses the prompts shown in figure 5b to obtain the required data. In either case the program stores the specifications for up to six LNDs thereby allowing for easy comparison of LNDs differing in gain and/or in noise temperature.

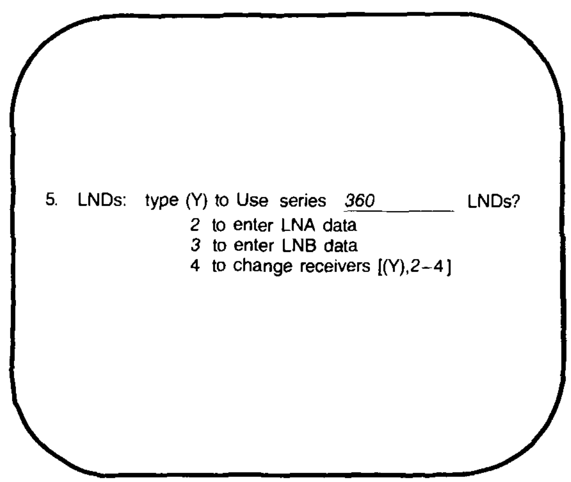

Figure 5a. LND Data Menu

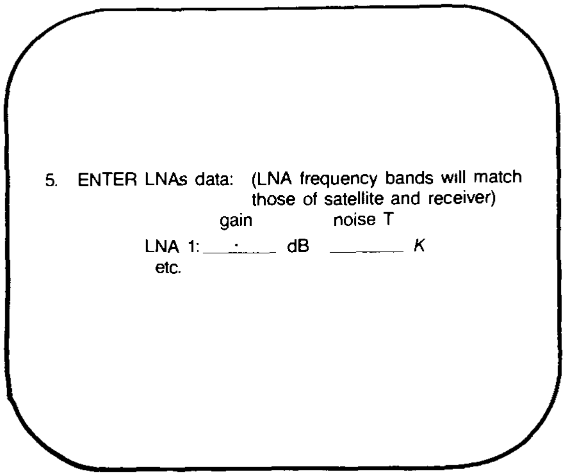

Figure 5b. Example Screen for Entering LND data

The name of the satellite for which the system performance will first be predicted is now entered as seen in figure 6a. The program will determine the performance of the earth station for signals originating at one satellite at a time. This is not a limitation however, as the satellite can be changed as many times as desired thus simulating the moving of the antenna from one satellite to another. Computer records on every satellite worldwide capable of C or Ku band video programming have been included in the database. However, as in the past entries, the operator is free to define his own satellite, prompted as shown in figure 6b, and can therefore explore any "what-if" problem that comes to mind. The elevation angle of the satellite is immediately determined for the site. Additionally, for the eight most popular satellites visible from CONUS, we have digitized the typical footprints from which the computer can obtain a very good estimate of the EIRP of the satellite viewed from the site's location. Otherwise, the engineer must (or may at any time) provide an estimate of the satellite's EIRP.

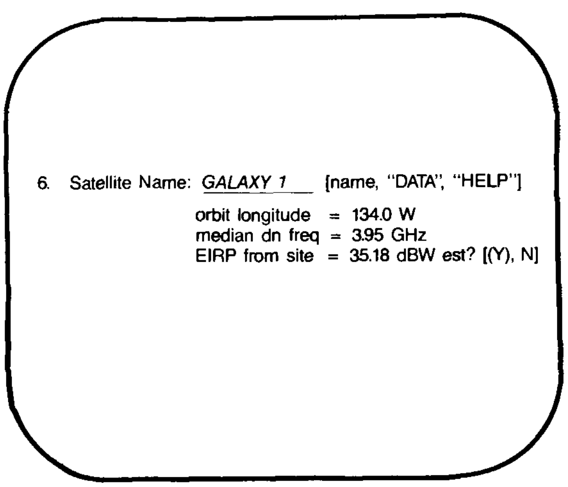

Figure 6a. Satellite Chosen by Name

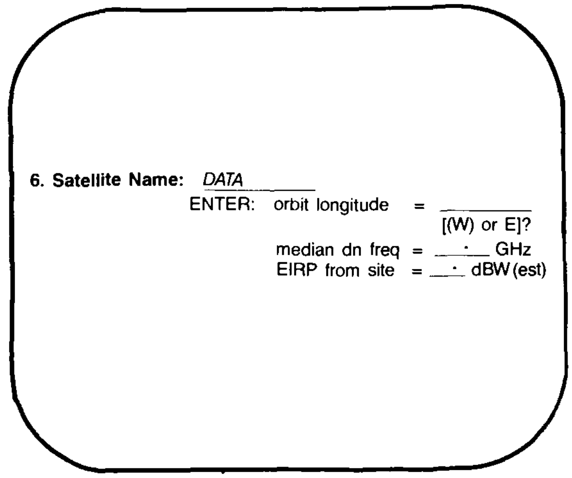

Figure 6b. Satellite Data Entered

The last system components chosen by the engineer are the antenna/feed combinations. The program treats the feed as a part of the antenna, and therefore, the antenna data are always referenced to the feed port. There is virtually no limit to the number of antennas that can be entered for any computation run. To maintain the concept of complete design freedom, the choice alternatives are presented as a menu as seen in figure 6a. It is common for our engineers to have the computer include every S-A antenna on record for the first run in order to get a quick idea of a reasonable antenna size. Choosing menu items "A" or "S" (see figure 7a) sends the computer to its antenna files to obtain the necessary data. Again notice that menu option "D" allows for total design flexibility. An engineer choosing "D" is prompted to enter the necessary antenna data as shown in figure 7b. Antenna noise temperatures are either interpolated from the S-A records for the proper elevation angle or must be entered by the engineer. Noise temperatures are redefined whenever the satellite (and therefore the elevation angle) is changed.

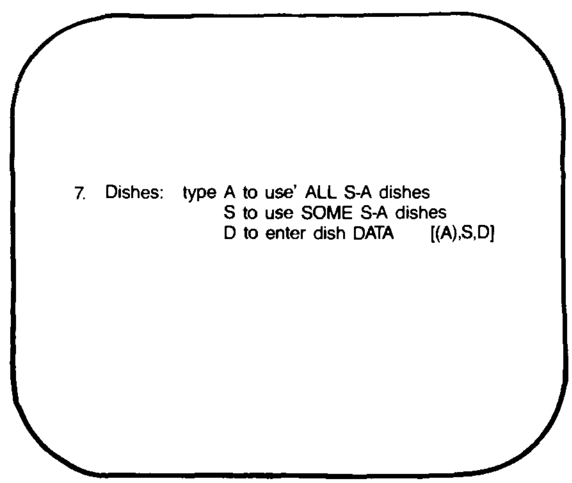

Figure 7a. Antenna Choice Menu

```
ENTER data for C band dishes:
        size  gain ,   24 deg elevation
         (m)           (dBi)   noise temp. (K)
DISH  1:   __.__     __.__     _____.
 etc.
```

Figure 7b. Screen Allowing Antenna Data Entry

Finally, the engineer is presented with a menu of possible choices for video format to be decoded by the receiver (figure 8). The formats are named using by the color encoding that is usually associated with each. Here for example, "NTSC" denotes video signals using: 525-line, CCIR standard M, 60 Hz, 4.2 MHz bandwidth and with NTSC color modulation. Therefore, menu choices #1 to #4 cover the vast majority of video transmissions in use. The programs provide the video format parameters required in the calculations. Menu options #0 and #5 enhance flexibility by allowing video S/N calculations to be omitted or by allowing user definition of any other video format. Thus, other formats such as B-MAC or half-transponder conference video are effectively handled.

```
8. Video S/N option:  0 NO  VIDEO S/N calculations
                      1 NTSC      525, 4.2 MHz
                      2 PAL I     625, 5.0 MHz
                      3 PAL B/G   625, 5.5 MHz
                      4 SECAM     625, 6.0 MHz
                      5 USER DEFINED video format
                        [(0)-5]
```

Figure 8. Menu for Video Format to be Used in S/N Calculations

At this point the computer takes over and does all of the necessary calculations to predict the performance for every possible combination of receiver-LND-antenna which can be assembled using the equipment that the engineer has entered. The details of these calculations are presented in the next part of this paper. The results of the calculations are stored in memory and are available to the engineer at his convenience. Normally a preliminary summary of the system performance predictions is requested by the engineer and scrutinized on his terminal.

Now the real man-machine teamwork begins. The engineer is now presented with a menu that allows any modification to be made on the system under review (see figure 9). Different receivers can be tried, different antennas, LNDs, cable loss, video format, satellite. After each change (or whenever he likes) the designer can tell the computer to recalculate the system performance predictions and can immediately see the effect of the change(s). This iteration of modification and recalculation can continue for as long as necessary; however, we find that even inexperienced designers quickly converge on an optimized system.

```
9. CHANGES?  0  No changes - EXIT CAD
             1  another customer
             2  another site, this customer
             3  change receiver
             4  change loss estimate
             5  change LNDs
             6  change Satellite
             7  change dish(es)
             8  change video format
             9  to see a performance report [0-9]
```

Figure 9. Change Menu Allowing Any Series of Alternations Until Performance is Satisfactory

It is interesting to note that even the satellite can be changed. Normally, this is done after a system-optimization has been done on the satellite of primary interest. This feature allows the designer to "point" the system at any satellite visible from the site and obtain a prediction of the system performance instantly. Also, many internal checks are built into the program to prohibit invalid combinations in the earth station system. All system components are constantly checked to ensure frequency compatibility. Systems resulting in C/Ns below the receiver threshold are flagged so to be immediately apparent to the operator.

So the key to this and all successful CAD systems is the concept of a man-computer partnership that capitalizes on the strengths of each. The human partner brings a clear view the the overall plan, and with experience has an intuitive feel for the system that cannot be programmed. The man has the fantastic flexibility of the mental processes that allows for unusual or unique circumstances to be easily dealt with. It is also easy for the human to compare the performance predictions of many systems at a glance, to quickly discern meaningful trends and cull "blind alleys".

On the other hand, the computer is a faithful and tireless keeper of the miriad data that must be be available to the designer. The computer can perform the tedious and complex calculations instantly and unerringly and can store these results for access at the engineer's convenience. But the success of the design still rests on the decisions made by the engineer; however now those decisions can be made based on much more data. You can see that the CAD program has not replaced the design engineer, but has instead freed him of the tedium and allowed for more creativity and effiency.

DETAILS OF THE CALCULATIONS

1. Satellite Trignometry:

The computer makes the following calculations immediately after the satellite data has been stored. These formulas are based on the assumptions of a perfectly spherical smooth earth of radius 3957 miles, satellites in perfectly circular geosynchronous orbits at an altitude 22245 miles above the earth's surface. Northern latitudes and eastern longitudes are positive, southern latitudes and westernly longitudes are negative.

The great-circle angular distance, θ, from the site to the satellite sub-point is first determined using the following formula. If $\theta > 81.3$ then the operator is informed that the satellite is below the local horizon and another satellite must be chosen.

$$\theta = \cos^{-1} (\cos \emptyset \quad \cos a) \qquad (1)$$

where $\emptyset$ = site-satellite longitudes
a = site latitude

Local terrain variations or unusually low elevations need to be carefully considered by the designer.

The program for visible satellites proceeds by calculating the azimuth angle (A), and elevation angle (E), and the distance in miles (S), for a line-of-sight path from the site to the satellite. The following algorithms are used:

$$A = \tan^{-1} \left[\frac{\tan \emptyset}{\sin a}\right] + \left[180^{\circ} \text{ if in northern hemisphere}\right] \qquad (2)$$

$$S = \sqrt{R^2 + (R+h)^2 - 2R\,(R+h) \cos \theta} \qquad (3)$$

(4)

$$E = \cos^{-1} \left[\frac{S_2 + R^2 - (R+h)^2}{2RS}\right] - 90^{\circ} \qquad (4)$$

Where $\emptyset$, a, θ see (1) above
R = 3957 miles
h = 22245 miles
S = line-of-sight distance, miles

2. Satellite Eirp

The program searches through the files of digitized footprint tables attempting to find a record for the requested satellite. EIRP estimates for recorded satellites are found by using a standard bivariate interpolation on the table. The accuracy of the interpolation is better than the footprint data themselves thus introducing no additional uncertainty.

The digitized footprints were determined from the EIRP contour maps released by the satellite operators. There is only one record per satellite, so the digitized EIRPs are assumed to represent typical values for a saturated transponder. For this reason, the performance estimates obtained are typical for the satellite. For atypical situations the engineer can override the computer estimate of the EIRP and assign a different value.

3. System Noise Temperature and System G/T

The first series of performance calculations determines the system noise temperature and then uses that result to determine the figure-of-merit (G/T). Recall that these calculations are performed successively on every possible combination of antenna, LND and receiver entered by the engineer. The formulas used are:

$$t_s = t_{ANT} + t_{LND} + \frac{t_{CABLE}}{g_{LNC}} + \frac{t_{RCVR}}{g_{LNC}\, g_{CABLE}} \qquad (5)$$

where t_s = system noise temperature at feed flange, K

t_{ANT} = antenna noise temperature K

t_{LND} = LN device noise temperature, K

$$t_{CABLE} = \left[10^{LOSS/10} - 1\right] (290), \text{ K}$$

$$t_{RCVR} = \left[10^{N.\ FIG/10} - 1\right] (290), \text{ K}$$

g_{LND} = LND gain ratio

g_{CABLE} = cable loss ratio

$$G/T = G_{ANT} - 10 \log t_s \qquad (6)$$

where G_{ANT} - antenna gain (dBi)

Several points should be emphasized at this point. First, the system noise temperature is referenced to the input flange on the LN device. Second, the antenna and feed horn are treated as a unit; thus the antenna's gain (dBi) and noise temperature are referenced to the feed output port. The noise temperatures for the antennas and the LNDs and the noise figures for the receiver have been stored in memory after being read from internal files or input by the engineer. All cable, splitters, etc. are considered to be at a temperature 290 K. The calculations also suppose that the VSWR is better that 1.3:1 and its effect can be neglected. Lastly, the antenna gains used in this calculation are specified at mid-band (3.95 GHz for C-band and 11.95 GHz for Ku-band). For some of the other Ku-band frequency schemes (Telecom 1 for example), the gain of the antennas are revised according to the formula:

$$G = G_{nom} - 20 \log \left[\frac{f}{f_{nom}} \right] \qquad (7)$$

where the antenna efficency is assumed not to vary appreciably. No changes are made to the antenna noise temperatures since it was felt that the difference due to the frequency shift was less that the variation of noise temperature among different samples of the same antenna.

4. IF C/No and C/N

The next receiver IF carrier-to-noise power-density (C/No) and the C/N are found as outlined below. Note that no performance margin was included in the downlink calculations. Degradation allowances are always left up to the engineer since he has a better picture of what may be appropriate for each site. Again, recall that the necessary variables have been previously determined have been stored in memory.

$$L_p = 96.6 + 20 \log f + 20 \log S \qquad (8)$$

$$C/N_o = EIRP - L_p + G/T + 186.6 \qquad (9)$$

$$C/N = C/N_o - 10 \log B_{IF} \qquad (10)$$

where L_p = free space path loss (dB)
f = satellite median downlink frequency (GHz)
S = (see formula 3)
EIRP = satellite transponder EIRP
186.6 = Boltzman's comst
G/T = (see formula 6)
B_{IF} = effective IF noise bandwidth (MHz) of receiver

5. Baseband Video S/N

The last of the system performance parameters to be determined is the (optional) baseband video signal-to-noise ratio, S/N. The algorithm used is:

$$S/N = C/N_o + 20 \log \left[12 \quad F \right] - 30 \log B_n \qquad (11)$$

where C/N_o = (see formula 9)
F = half the peak-to-peak deviation produced by the luminance signal
B_n = noise bandwidth of the weighted baseband filter function

The computer is programmed with the basic data for the four most common video format standards. These data are based primarily on CCIR Rec. 421 and assume a weighted baseband filter-function, however the user is free to define any format he wishes.

THE FUTURE

It is important to realize that the CAD programs described so far have been found extremely valuable and are used on a daily basis by our engineers; however, we do not consider the program development at an end. The actual programs themselves are written in a modular form so that enhancements and updates can be easily made. Many minor and major modifications have been made based on the suggestions of our users. As our engineers gain familiarity with the computer as a design tool they are encouraged to suggest new uses.

As of this writing, the decision is that our next major effort will be to expand the capabilities of the performance calculations to include a detailed analysis of the carrier-to-interference levels due to the neighboring satellites. Some groundwork has already been done towards that end. We expect to be able to use the computer and our already extensive satellite database files to compute very good predictions of the C/I levels unique to each site and orbital position. No longer will we have to make rule-of-thumb estimates of the C/I. The thrust for this next addition is, of course, the 2-degree spacing rule passed by the FCC. As the 2-degree rule is implemented we expect that this part of the CAD package will become very important.

ACKNOWLEDGEMENTS & REFERENCES

The author wishes to acknowledge the contributions of the following people without whose help this CAD package and this paper would not have been possible: Bob Mauney for suggesting the need for CAD in the first place. Jerry Henning for his many constructive ideas as the project developed. Alex Best for his helpful comments as this paper was written.

Considerable additional information regarding the calculations outlined above can be found in the following sources:

formula (1) - (4): F.M.Fonda; "Earth Station Geometry"; Communications Symposium '83; 11/83.

formula (5): J. S. Hollis; "Noise Temperature and G/T of Satellite Receiving Systems"; Communications Symposium '83; 11/83.

formula (6): J. Cook; "Earth Station G/T"; memo to J. Levergood; 10/15/75.

formula (7): R. Barker and J. Friesz; "Earth Station Antennas, RF Considerations"; Communications Symposium '83; 11/83.

formula (8) - (10): "Satellite Link Analysis"; Communications Symposium '83; 11/83.

formula (8) - (10): J. Hart; "Satellite Receiver System Presentation"; Earth Station Technology Conference; 7/76.

formula (11): T.M. Straus; "The Relationship between NCTA, EIA and CCIR Definitions of S/N"; IEEE Transactions on Broadcasting, Vol: BC-20, No. 3; 9/74.

formula (11): L. Clayton; "FM Television S/N"; IEEE Transactions CATV, Vol: CATV-1, No. 1; 10/76.

general: S. Havey; "Update of CATV Data Book"; memo to Bob Mauney; 2/28/84.

Considerations in The Operation of CATV Headends Carrying BTSC Stereo Signals

BY

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Important parameters in the proper operation of a cable television headend carrying BTSC stereo audio signals are discussed, and the reason for their importance is presented. The reason for not adjusting aural carrier modulation levels with a program BTSC stereo signal is presented. Methods of adjusting a headend for BTSC stereo transmission are presented, as well as some basic considerations in generating a BTSC stereo signal.

INTRODUCTION

The use of the BTSC stereo transmission method in cable television systems has generated much controversy. The BTSC format, however, has been universally accepted by television receiver manufacturers as the stereo sound transmission standard to be used in the United States. If a cable system operator decides that he will carry signals in the BTSC format, it is important that he understands the requirements for operating such a system. In addition to hardware changes, the manner in which the cable system is operated will have to be changed. This article addresses some of the more important issues in operating a system which carries a BTSC stereo signal. It will be assumed that the cable television system operator has studied the technical issues involved in selecting a stereo transmission method (i.e., set top converter compatibility, scrambling, etc.) and has determined that the BTSC format is suitable for his system.

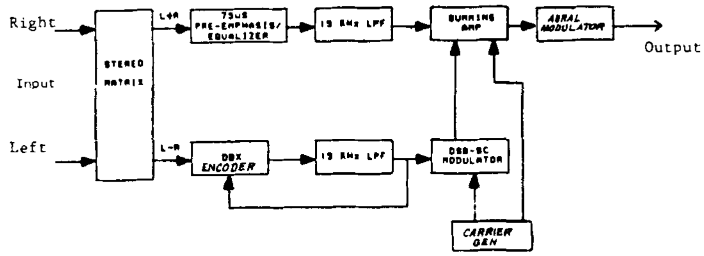
BASIC BTSC THEORY

In order to help understand the problems associated with the BTSC signal, a cursory review of the system is in order. The system is conceptually similar to commercial broadcast FM stereo. As with commercial FM stereo, the BTSC stereo signal consists of a baseband signal which is the sum of the right and left audio channels and a double sideband suppressed carrier (DSB-SC) subcarrier which is modulated by a signal which is the difference between the left and right audio channels. The carrier frequency of the DSB-SC signal is twice the horizontal scan frequency of the video signal. A pilot carrier that is used to demodulate the DSB-SC subcarrier and to indicate the presence of a stereo signal, is transmitted at a frequency equal to the horizontal scan frequency. Figure 1 shows a basic block diagram of the system and an illustration of the baseband spectrum of the encoded signal. Note that an additional subcarrier is shown. This is the Second Audio Program (SAP) subcarrier which is used for bilingual broadcasts. This subcarrier is FM modulated. The maximum deviation of the main carrier by each component is indicated in the figure. Because of the wider baseband bandwidth (100KHz) and the higher peak deviation (±73KHz) of the aural carrier, the stereo compatible CATV headend must have wider baseband and RF aural carrier bandwidths than those required for monaural operation.

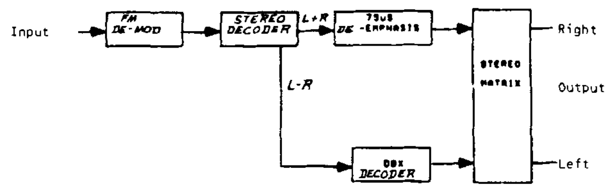
In order to achieve a good signal to noise ratio in areas of poor signal quality, it was determined that some noise reduction method was required for the difference subcarrier and the SAP subcarrier. The noise reduction system chosen was the DBX companding system, which consists of wideband compression and variable pre-emphasis in the encoding process, and a complementary wide band expansion and variable de-emphasis in the receiver.

It is important to note that for good stereo separation the gain in the sum signal path must be the same as the gain of the difference signal path. Note that ideally the DBX encoder at the modulator (transmitter or headend) and the DBX decoder in the television receiver are totally complementary and have no overall effect on the difference signal level and frequency response.

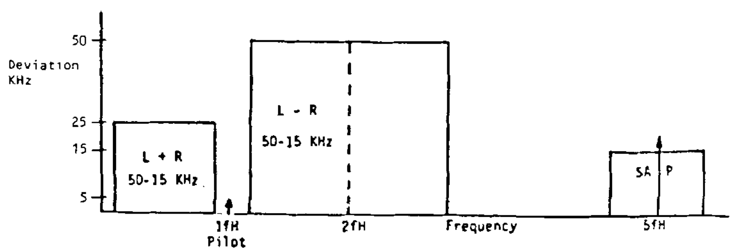
In order for the DBX decoder in the television receiver to properly track the DBX encoder at the transmitter (or CATV headend), the deviation of the aural carrier must be accurately set to the levels specified for the BTSC System. If the proper deviation levels are not maintained, the stereo separation of the system will be reduced. If the deviation is being set, there must be some reference signal from the BTSC encoder which corresponds to a specific deviation. Since there is no reference signal when the input to the encoder is a program audio signal, there is no way to correctly adjust the aural modulator deviation when the modulator input is program audio in the BTSC stereo format.



BTSC ENCODER/AURAL EXCITER



BTSC RECEIVER



BTSC BASEBAND SPECTRUM

FIGURE 1

SIGNAL PROCESSORS

As television stations start to broadcast BTSC signals, CATV signal processors will be required to process the BTSC signal. Signal processors fall into one of the following categories: heterodyne processors, strip amplifiers, and demodulator/modulator combinations. Of these, strip amplifiers and heterodyne processors are the simplest to use with a stereo signal. As determined by the NCTA studies and subsequent studies, these types of signal processors typically have few deleterious effects on the stereo signal. Since the audio signal is never demodulated, they require little attention in operation. This is not to say that these types of processors will not require modification or realignment to operate with BTSC stereo signals (although, many units will have sufficient bandwidth and passband amplitude flatness to operate satisfactorily with a BTSC signal). However, once these changes have been made, processing a BTSC stereo signal requires no more attention than processing a monaural signal.

If processing is performed with a demodulator/modulator combination, then the manner in which the aural signal is connected between the two units is critical. If the BTSC stereo signal is demodulated to a broadband baseband signal, it must be remodulated in the modulator to the modulation levels of the original signal. Any errors in this modulation level will be detrimental to the stereo separation. In an attempt to determine how critical the modulation level is to system performance, a computer program was written to simulate the BTSC encoder, the FM modulator, and the television receiver. The results from this program are shown in figure 2. As can be seen from the figure, in order to

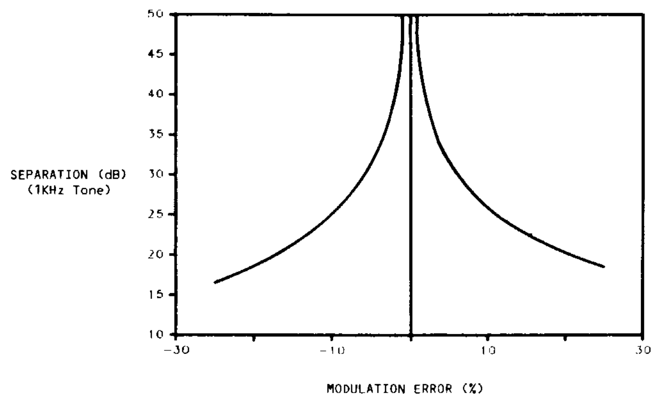


Figure 2

maintain a stereo separation of at least 30dB in an otherwise perfect system, it is necessary to maintain the modulation level to within ±5% of the correct level.

For these reasons it is preferable to interconnect the demodulator and the modulator audio path with a 4.5MHz link. This eliminates the problems associated with adjusting the modulation level since the signal is never demodulated. It is important to note that Scientific-Atlanta and other manufacturers' demodulators and modulators can be connected in this manner and provide satisfactory results with BTSC signals provided that the 4.5MHz path has sufficient bandwidth. There is much standard monaural equipment connected in this manner that when properly aligned, works well with a BTSC stereo signal.

If for some reason it is essential to demodulate a BTSC signal to broadband baseband, it is recommended that the demodulator/modulator combination be aligned in the following manner. Apply a FM carrier, which is modulated by a tone, to the RF input of the demodulator. Using a Spectrum Analyzer, adjust the tone to the correct frequency and level to produce a Bessel carrier null (i.e., a 10KHz tone modulating the carrier to ±25KHz deviation). Set the demodulator audio output to a convenient level or to the level recommended by the manufacturer. The modulator aural modulation level should then be adjusted until the same carrier null is present in the spectrum of the RF output of the modulator. This process will require that the demodulator/modulator be taken out of service while the adjustment is being made. Once the modulation has been set in this manner, it should not be necessary to adjust the demodulator output level or the modulator deviation.

It has been proposed that one way of setting modulation levels in a demodulator/modulator signal processing scheme would be to design a more complex modulation indicator which would have a narrow bandpass filter centered at the pilot carrier frequency. Since the pilot carrier always deviates the main carrier 5KHz, it is conceivable that some modulation indicator, either a peak deviation indicator light or meter, could then be used to measure the deviation due to the pilot. To set the overall modulation to the correct level, the pilot deviation would be set to 5KHz. Although this idea has some merit (and it is the only method which allows the modulation to be adjusted with an active signal), the standards for the BTSC stereo signal as they now exist allow for an error of ±500Hz in the pilot deviation. If the pilot were used to adjust the modulation level there could be as much as a 10% error in the modulation level. As can be seen from figure 2, this would give marginal stereo separation performance.

MODULATORS

Undoubtedly, as the popularity of stereo television grows, many cable system operators will desire to produce a BTSC stereo signal for their pay channels. It will be assumed that left and right audio signals' are available from a satellite earth station or other suitable source. Figure 3 illustrates how such a system might be configured. As can be seen, some form of BTSC encoder will be required. It will be necessary to decide whether the audio modulator portion of the video modulator will be replaced with a stereo-compatible unit or if the encoder will be purchased with an audio modulator. If the encoder is purchased with an audio modulator, then adjusting the system should be relatively simple because the modulation level will have been preset at the factory. It is only necessary to apply the proper left and right input levels to the encoder (these levels are not that critical). It might be pointed out that the level adjustments on the encoder audio inputs serve essentially the same function that the modulation control performed on the monaural system.

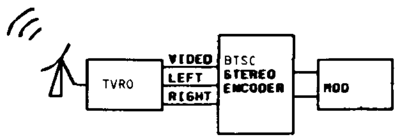


FIGURE 3

If the encoder which is purchased does not contain an audio modulator then it will be necessary to have an aural modulator which is compatible with the BTSC stereo signal. Once this is obtained it will be necessary to set the modulation level of the modulator. This presents a problem similar to that of setting the modulation level in the demodulator/modulator combination. One solution to the problem of adjusting the modulation level is for the BTSC encoder to provide a test tone to the modulator which produces a specified deviation. (In the case of the Scientific-Atlanta 6380 BTSC encoder, the tone should produce 25KHz deviation of the main carrier.) When the test tone is switched on, the aural modulator modulation level is adjusted until the overdeviation indicator on the aural modulator is just flickering on. It has been found that with a properly designed overdeviation light, this method gives excellent results in setting deviation levels. This method also allows the encoder to be aligned with the modulator with no test equipment.

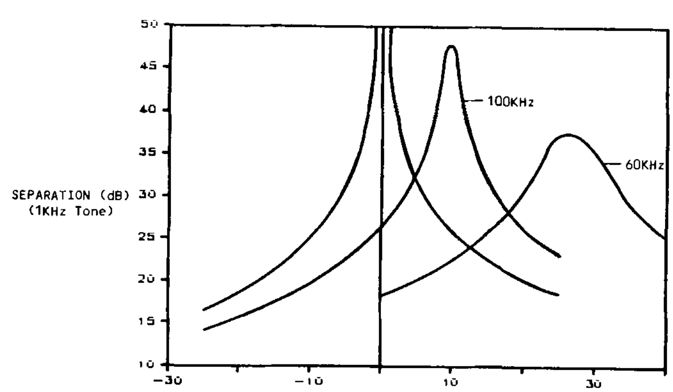
DEMODULATORS

This leaves only the demodulator to be considered. If it is desired to demodulate a BTSC signal to left and right audio (perhaps for simulcast into the FM band), it is important to choose a BTSC decoder which can demodulate the 4.5MHz output of the demodulator instead of decoding the broadband audio output of the demodulator. This will eliminate the problem of having to adjust the baseband level into the decoder. There are several consumer decoders which are designed to use baseband inputs. Although these could theoretically be used on the output of the demodulator, there is no way to properly set the signal level going into the decoder. This would present a problem similar to the problem of adjusting the modulation level of the modulator. (An error in the baseband level going into the decoder would have the same effect as an error in the modulator modulation level). For this reason it is recommended to use a decoder that will accept a 4.5MHz input.

As can be seen from the information presented here, the accurate adjustment of modulation at the headend is important in order to achieve the maximum amount of separation. This might suggest to some that the best way to adjust the modulation of a BTSC signal is to maximize the separation by driving one audio input to the BTSC encoder and adjusting the modulation level for a null in the undriven channel when the signal is monitored with a stereo television. Although this can be done to produce the maximum amount of separation, it is not a recommended method to adjust the modulation level. It was found (as shown in figure 4), that it is possible to correct for imperfections in the television or in the aural modulator (such as inadequate bandwidth of the television receiver) by allowing errors in the modulation level. This indicates that it is possible to maximize the stereo separation of the system by overmodulating the system! This is undesirable, and indicates that stereo separation is not the criteria which should be used to adjust modulation levels in a headend.

CONCLUSION

This article has pointed out some of the major headend operating problems that operators will face if they decide to carry BTSC stereo in their cable system. The most important point made is that the modulation level of a BTSC signal cannot be adjusted accurately with a program audio signal. For each combination of headend equipment there is an accurate method for adjusting the modulation level. All of these require the use of a test tone or external source. Although these procedures may seem overly complicated, they are required to obtain optimum performance from the headend when processing a BTSC stereo signal.



Separation of system with different baseband bandwidths.

Figure 4

CONTROL OF REMOTE HUBS IN ADDRESSABLE CATV SYSTEMS

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The application of CATV systems in an urban environment encompassing large geographical areas, large numbers of subscribers and varying clusters of ethnic/demographic groups requires the distribution of signals from local hubs. Operation of these hubs can be controlled from an addressable computer at a remote location using digital communications techniques (protocols).

This paper discusses the control of remote hubs in addressable CATV systems. It examines both continuous and discontinuous communications, emphasizing a distributed intelligence approach.

Both one-way and two-way communications and the use of non-CATV cable signal paths are discussed. Also explored are the interface requirements for the converters, scramblers and data modulators being controlled. In addition, frequency agility techniques are described.

INTRODUCTION

Control systems have been used in many industries for years not only to improve overall operations, but to allow for remote controllability in a more accurate and rapid fashion. Such control systems have helped produce both lower costs and a higher quality product for many companies.

The CATV industry, having the same business requirements and goals in mind, introduced the first CATV Addressable Control systems in 1979. These systems allow cable operators to control subscriber services from a remote computer.

Many extra benefits were realized from the introduction of addressable control systems. Addressable converter/descramblers, unlike programmable converters, can be turned on and off from the computer, contain system specific "site-codes" and receive authorization and operating instructions from the headend computer-controller, making them inoperable in other systems, and helping to reduce converter theft. Technological improvements in converter and signal security and direct links from the addressable controller to computer billing systems have all been implemented with good results and improved efficiency in cable systems.

One area in which addressable control systems are helping to make their greatest technical contributions is pay-per-view. It is no surprise that one of the reasons many pay-per-view events have not been successful financially is their technical inefficiency. Marketing, personnel, order taking and billing costs taken together can make pay-per-view offerings marginally profitable undertakings for many operators, at best. Most systems are ill-equipped to handle peak loads, last-minute program orders and billing problems. And it is the last fifteen minutes before an event that seem to count, a critical time period where, according to some studies, at least two-thirds of a cable operator's revenues can be earned.

In order to overcome the peak load and last-minute ordering problems with pay-per-view, Jerrold has developed practical technical solutions for both one-way and two-way cable systems. This "impulse pay-per-view" technology (IPPV) makes implementation and use of PPV easier and less expensive for cable operators. The IPPV technique allows subscribers to purchase an event and receive immediate authorization to view this programming without communication by the converter to or from the addressable control computer.

The technique uses "distributed intelligence", where each node, or device in the network is capable of making a limited range of decisions based on operating parameters and data loaded into the device from the remotely located computer. Up to this time, this intelligence and memory has been concentrated in the control computer and the subcriber terminals.

Scrambler/Encoder Control

Distributed intelligence technology now impacts the headend components required for addressable systems operation. This equipment includes scrambler/encoders (S/E) and data modulators/demodulators. Engineering and marketing personnel planning to implement PPV will value the system's ability to transmit new operating parameters to scrambler/encoders. A continuous pay-per-view operation might require service code changes every 1-1/2 to 2 hours, in which case the program's service code must also be changed as frequently to permit purchase of distinct events. (Generally, specific channels are reserved for PPV programming and the service code or "tag" transmitted digitally within each pay channel works to distinguish between sequentially offered services on the same channel.) At the same time, the scramble mode can be changed, too. This permits broadcast of previews in the clear, followed by scrambled programming while the same tag is transmitted.

Scrambler/encoders located anywhere in the addressable system -- no matter how far from the hub -- can be controlled from the addressable control computer. Wherever an addressable data stream is transmitted to subscriber terminals, whether to unmanned headends on mountain-tops, or wide-spread distribution hubs, scrambler/encoder information will also be present. This is possible because headend components are addressed over a communications channel that uses the distribution cable. Headend components are assigned their own group of addresses in the system and the computer transmits to them using the same data transmission technique used for converters.

If two-way RF communications is available, headend components can send status information to the computer to assure proper operation. The commands, operating parameters and data transmitted between the control computer and the scrambler are different from the information transmitted between the control computer and converters, since converters receive primarily pay service authorization information.

Scrambler/encoders information received includes:

- Service code
- Sync suppression scramble mode
- Baseband scramble mode
- Dynamic switching time
- Encrypting key
- Price of the service
- Purchasability
- Morality rating
- Barker channel
- Date and time to begin this mode

The intelligent scrambler/encoder is capable of storing the above information in an internal memory. It can invoke these parameters at any specified date and time. In fact, the intelligent S/E can store 63 entries such as this list in a queue, and switch from one entry to the next as time elapses. If the data path or the control computer fails at a critical time, the S/E already has the information to function properly.

There are two methods of loading the queue entry into the S/E from the computer. Direct entry is accomplished by entering the information on a computer screen, and then designating the queue position number (0 to 63). If "0" is selected, the parameters are transmitted to the S/E and take effect immediately. Queue positions 1 through 63 are stored in non-volatile memory until the date and time specified.

The second means of programming the S/E is through Channel Scheduling. This is a computer software feature that permits scheduling all known future channel usage. For each new entry into the channel schedule, the computer operator specifies the new operating parameters for the scrambler/encoder that controls each channel. The computer then keeps the 63 queue positions loaded automatically.

Control of the S/E is possible using a standard (EIA-RS232C, ASCII) CRT terminal to load queue entries . A front panel equipped with controls and indicators provides for operation by a headend attendant.

Data Modulator/Demodulator Control

Data modulator/demodulator units can be used to relay data between remote hubs in the addressable system. If the system is implementing IPPV using an RF return path, it is desirable that these devices be under the control of the computer. Early in the development of two-way RF systems, a failure mode was recognized in which one malfunctioning subscriber terminal could block the return path by continuous uncontrolled transmission. Frequency agility -- the ability to move to another frequency -- was designed to identify and isolate converters that transmit when they shouldn't. This technology overcomes the problem of "babbling" converters, by using remote-controlled data demodulators, subscriber terminals, and sophisticated computer software. Software algorithms control the converter's upstream transmission frequency and the headend data demodulator receiving frequency by moving the malfunctioning terminal to an unused frequency, or by moving all terminals except the offending one.

The intelligent data modulator/demodulator is equipped with a control interface that permits control of the operational parameters of the device. Each control interface has a system address, like the subscriber identification number of the converter/descrambler. All communication between the control computer and the interface makes use of that address. The control interface commands the data modulators and demodulators to

- Initialize
- Change frequency
- RF output on/off (modulator)
- Data output on/off (demod)
- Display frequency of operation, lock and data present
- Send module status (2 bytes of status data)

Frequency selection is by digital phase-lock loop frequency synthesis, with default settings on decade switches on the modulator and demodulator boards. Communication between the computer and the control interface is via the standard data stream used for subscriber terminals. A block of addresses is reserved for data modulator/demodulator units. The control computer stores the configuration of all the data paths in the system. For each mod/demod unit, the computer must store information such as the system address, the types of modules, frequency assignments, and cable connections to other system devices. Also stored are the allowable alternative frequencies.

Any hardware reconfiguration must be reflected in the control computer database. In case of loss of communications the device will retain its operating parameters, and local control can be done with a CRT terminal as well. Default conditions are established with decade switches and hard-wired cables.

Data Transmission Protocol

Data from the control computer is bi-phase Manchester-encoded, with special voltage levels (logical 0: 0.00 volts, logical 1: 1.8 volts) that permit driving several thousand feet of standard 75 ohm cable. The data rate is nominally 14K baud, but in actuality is a 3.58 MHz colorburst crystal frequency divided by 256, yielding 13,982.598 Hz.

Data is transmitted in packets containing byte count and checksum. All bytes in the packet conform to the standard EIA word format, but have non-standard ASCII interpretation. Byte translation and packet construction are proprietary, however, it may be said that a packet contains the device address, a command code and data.

RF Data Transmission Protocol

The above 14 KHz data is FM modulated on a selected carrier frequency, with ± 75 KHz deviation, resulting in occupied bandwith of ± 200 KHz about the carrier. For compatibility with existing cable systems, 106.5 MHz in the FM band is used for the downstream data path. Transmitter output level is nominally -10 dB below channel 6 video level. Other downstream frequencies may be used in the spectrum reserved for FM audio. Selection is based on spectrum availability (avoidance of frequencies in current use) and the requirement to maintain 400 KHz separation between carriers. Upstream data transmission from standard IPPV terminals is on one of eight 300 KHz spaced channels with carriers between 8.3 and 10.4 MHz. This range occupies part of the T7 channel allocation, thus the remainder of T7 is available for other sub-band transmissions.

Multi-Hub Systems

Data communications for the purpose of addressable system control is required when

- control computer is not co-located with distribution hub,

- multiple distribution hubs are required, or
- isolation is required between trunks returning to a single hub.

In all cases, the computer stores the network topology representation of the interconnected devices making up each link, including interface frequencies, default frequencies and allowable alternate frequencies. As data passes through a hub, data translation may be required, in order to use bandwidth efficiently in different links or to regain losses in S/N ratio. The data translation function uses a retimer module to re-synchronize data to clock timing integrity. A translator consists of

- data demodulator
- data retimer
- data modulator
- interconnecting cables

Figure 1 is a simple block diagram of a typical system with multiple hubs, connected with two-way trunk cable, assumed to be sub-split frequency convention. The control computer is shown at the business office, which is on a two-way trunk and feeder from Hub #1. Alternatively it could be located at a hub on the RF headend. In this initial example, scrambler/encoders are located only at the main headend.

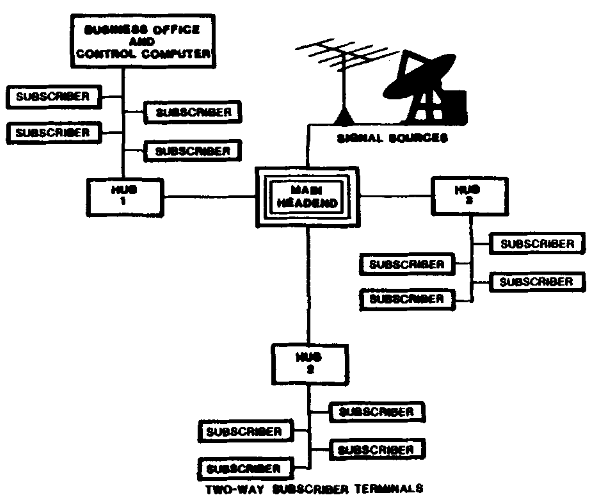

FIGURE 1 TYPICAL MULTIPLE HUB SYSTEM

Figure 2 shows the system configuration with lines between office, hubs and headend representing particular data paths. These channels must be implemented by selecting frequencies on the subsplit cables to/from the hubs. The control computer output data is modulated on a sub-frequency, typically in channel T7, and is sent upstream to Hub #1 where it is translated, and sent on to the main headend. There a demod/remod is used to modulate the downstream data on 106.5 MHz that addressable subscriber terminals are tuned to receive the authorization data stream.

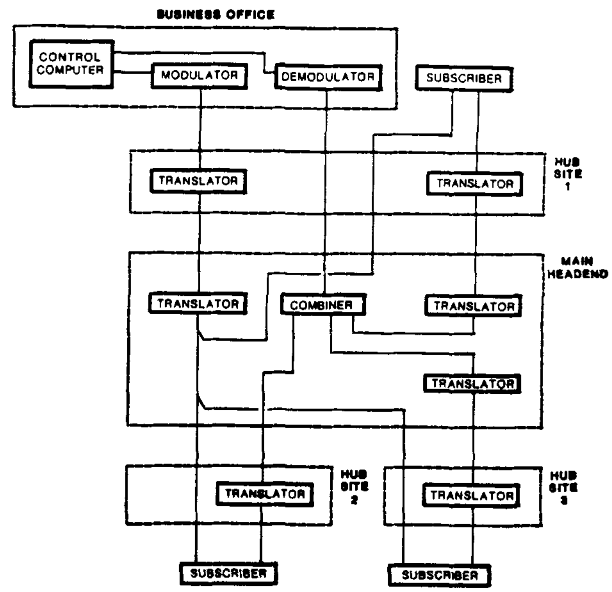

FIGURE 2 SYSTEM CONFIGURATION

This is illustrated going out from the Headend to each of the three hubs, and then to subscriber terminals. Purchase data requested from IPPV terminals is received at 8.3 to 10.4 MHz by each hub and translated as needed to conserve trunk bandwidth, to avoid jammed frequency channels and to insure clock sync. These signals are combined in a Data Combiner prior to modulating the return data carrier, which is then demodulated at the control computer. Upstream, or return data is not continuous. It is intermittently transmitted by one subscriber terminal after another in a time-controlled sequence under the direction of the control computer. Only one terminal may transmit at a time. The data combiner has been designed to operate with up to 16 input lines with discontinuous (or transient) data. Data combiners and data splitters may be cascaded to accomodate the necessary number of devices.

Figure 3 shows a detailed representation of the main headend site. The addressable data stream enters the headend from Hub #1 at the low side of the diplex filter, to a demod/retimer through a data splitter to become the control input signals for a number of scrambler/encoders and control interfaces. Also supplied with data is the system's 106.5 MHz modulator. Data return paths from low side of all three RF trunks uses demod/retimers to generate baseband data signals, which are combined with feedback signals from S/E's and control interfaces, re-modulated on a downstream frequency and communicated to Hub #1 and then to the demodulator at the control computer.

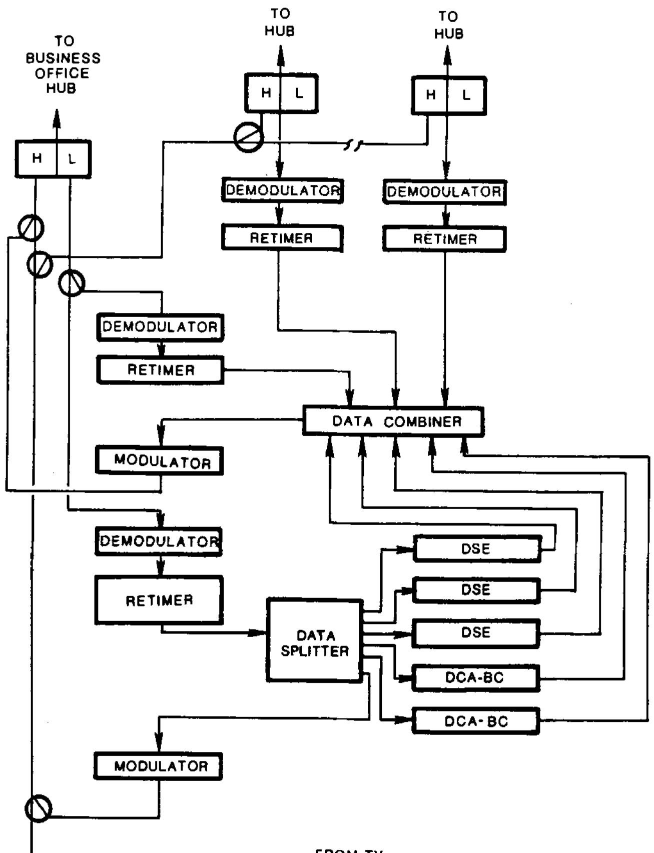

FIGURE 3 MAIN HEADEND SITE CONFIGURATION

Figure 4 represents Hub #1, showing two upstream data paths, one for the computer data stream to the entire system, the other for return data coming from all IPPV terminals on this hub. Note that demodulated data is used as input to the control interface at this hub site.

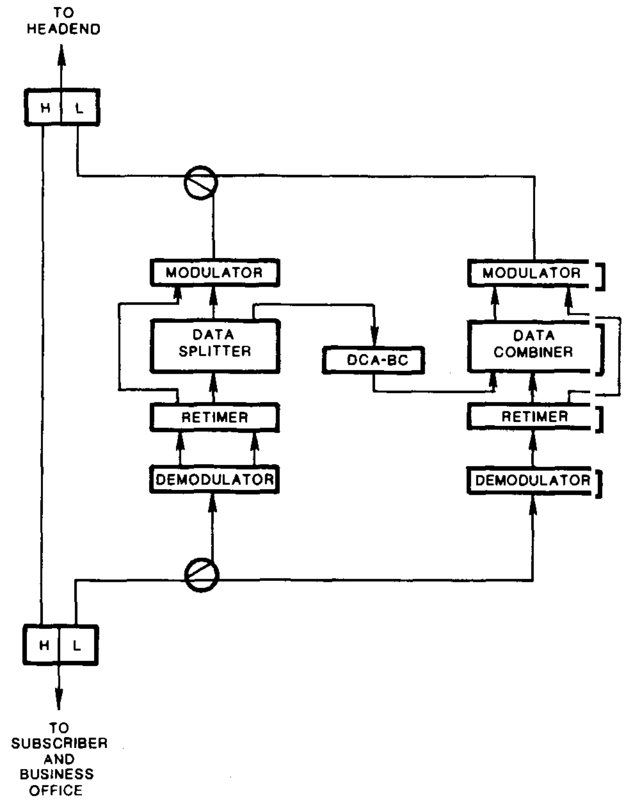

FIGURE 4 HUB SITE 1 CONFIGURATION

Figure 5 shows a typical hub site that does not need to relay control computer data signals.

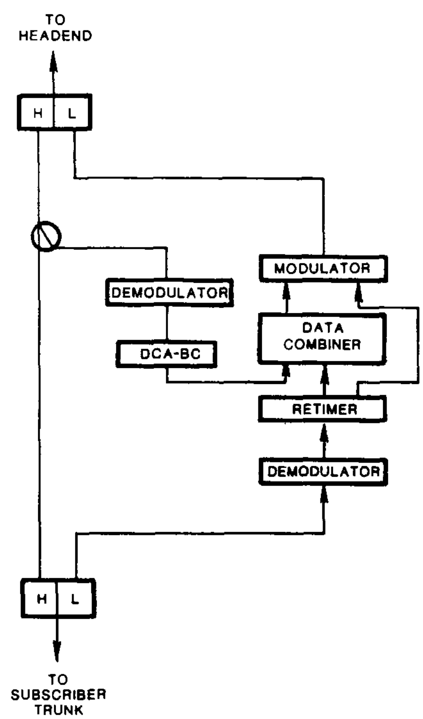

FIGURE 5 HUB SITE 2 OR 3 CONFIGURATION

Figure 6 shows a similar hub that has its own complement of scrambler/encoders which are controlled from the computer. This configuration can be controlled to switch operating parameters at the same time as S/E's at any or all other headends and hubs. This simultaneous switching minimizes personnel cost and enables system-wide IPPV offerings.

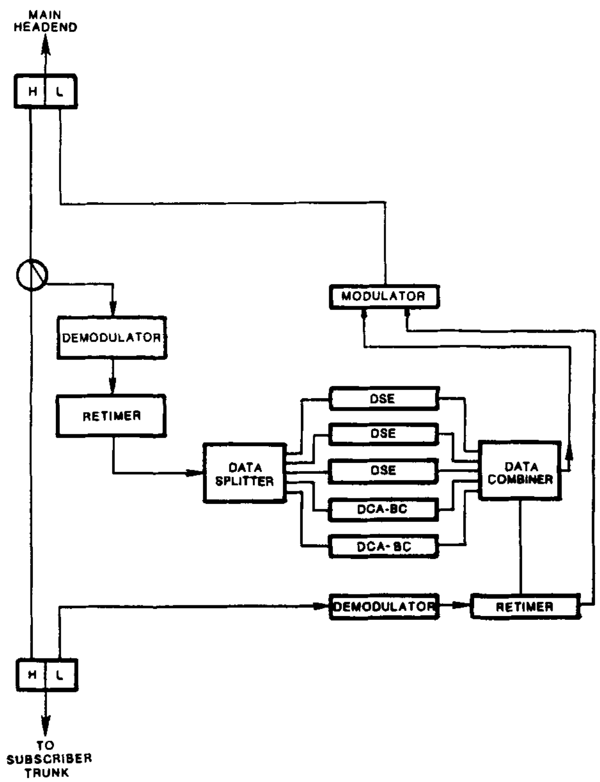

FIGURE 6 HUB SITE WITH REMOTE CONTROL SCRAMBLER/ENCODER

There are systems that must transmit the addressable control data stream by telephone line. Equipment required includes a pair of telephone modems, and a pair of data adapters to convert the synchronous data stream to the asynchronous EIA-RS232C convention (we have packaged the data adapters with 14.4K baud modems), permitting transmission on a leased telephone line.

The delay experienced by telephone link mod/demod processing is not detectable in downstream data, but upstream response data arrives later than its RF-linked equivalent. To insure that data returning over telephone line does not collide with data returning over an RF path, we require all non-telco return paths be delayed equally, using a Transmission Link Equalizer (TLE). This unit will handle up to four data paths that require added delay. Figures 7A and 7B show the control computer site and an independent hub with leased telephone line data path.

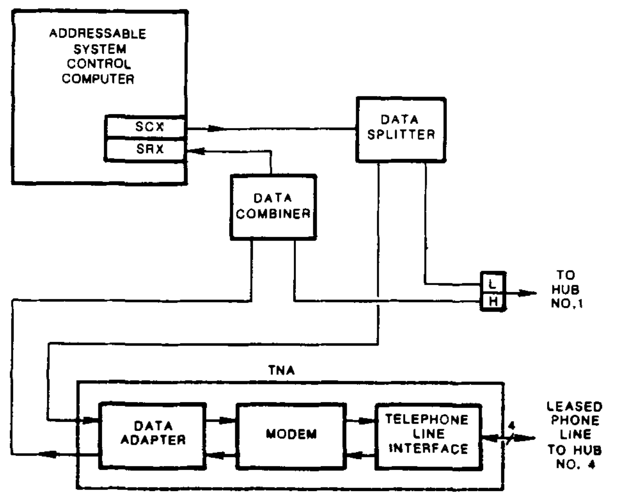

FIGURE 7A NEW CONTROL COMPUTER SITE CONFIGURATION WITH TELEPHONE LINE DATA PATH

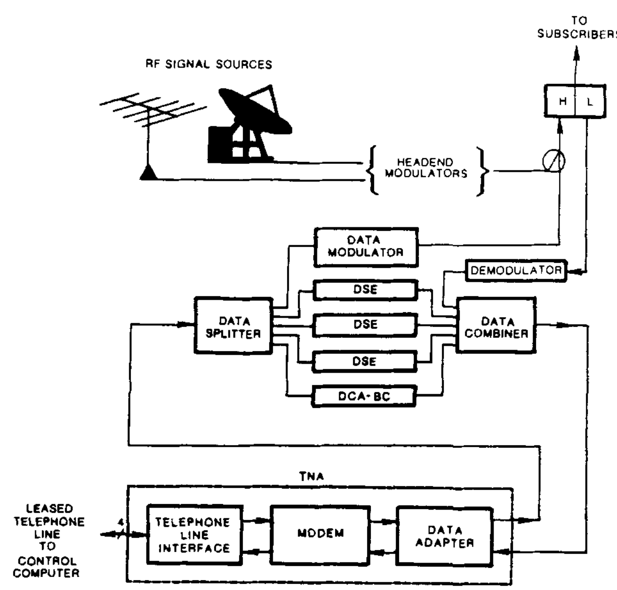

FIGURE 7B INDEPENDENT HUB WITH LEASED TELEPHONE LINE DATA PATH

An alternative implementation of IPPV with one way plant utilizes return data transmission over telephone lines from subscriber terminals. The advantages over two-way RF distribution plant are the time and cost required to install it. If there are remote S/E's, they may be controlled in one-way mode, however, there is no certainty that commands are being executed at the device without feedback.

Conclusion

The systems described here demonstrate the new ability for the remote control of scrambler/encoders and data modulator/demodulators from a central addressable system control computer. This promotes cost effective and timely implementation of pay-per-view, and impulse pay-per-view in systems with multiple hubs and remote headends.

REFERENCES

1. "System Design Criteria of Addressable Terminals Optimized for the CATV Operator", T. E. O'Brien, Jr., NCTA Technical Proceedings, 1980.

DIGITAL AUDIO APPLICATIONS IN COST-EFFECTIVE CABLE TV SYSTEMS

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ABSTRACT

Cable television performance must periodically be upgraded to meet new requirements. The application of digital devices and techniques to provide improved security, multichannel audio and other features is described. Basic cable equipment functions, reasons for selecting digital techniques, audio and video multiplexing, constraints encountered, functional blocks developed, encryption, synchronization and overall performance obtained are reviewed. The outcome is a system which provides audio with stereo or bilingual capability. Furthermore, the digitized and encrypted audio is transmitted on the same carrier as the video signal.

INTRODUCTION

New technical developments continue to generate products with improved performance at moderate cost. Today we have many high performance products including audio, television and computer equipment, which were not previously affordable, due largely to these developments.

Existing industries, including the cable-TV industry, are also affected by technical advancements. For example, multichannel sound capability has been recently introduced and impacts directly on the performance requirements for cable television. Fortunately, techniques and devices are available for processing and transmitting audio signals, which ease the incorporation of multichannel sound and other features into cable TV equipment. These techniques and devices provide cost-effective means for upgrading the equipment to include these capabilities.

A brief review of a typical cable television system is followed by a comprehensive summary of the design goals and efforts leading to a complete operating system which is now in use and utilizes state-of-the-art digital audio techniques. Reasons for specific selections are illustrated along with some basic computations to support the choices made.

BASIC SYSTEM DESCRIPTION, ENCODER--DECODERS

Figure 1 illustrates a basic cable television system utilizing encoders and decoders for processing video and audio signals. Typically, an encoder is used at the headend of the system for every channel which will be subject to scrambling. For the Sigma system described herein, the encoders provide both audio and video scrambling and transmission of both signals on the same RF (radio frequency) carrier.

After distribution through the cable system, decoders are used to receive the RF carriers, demodulate the selected carrier and unscramble both the video and audio signals. Finally, both signals are used to modulate carriers on a preset, standard channel and delivered to a TV receiver.

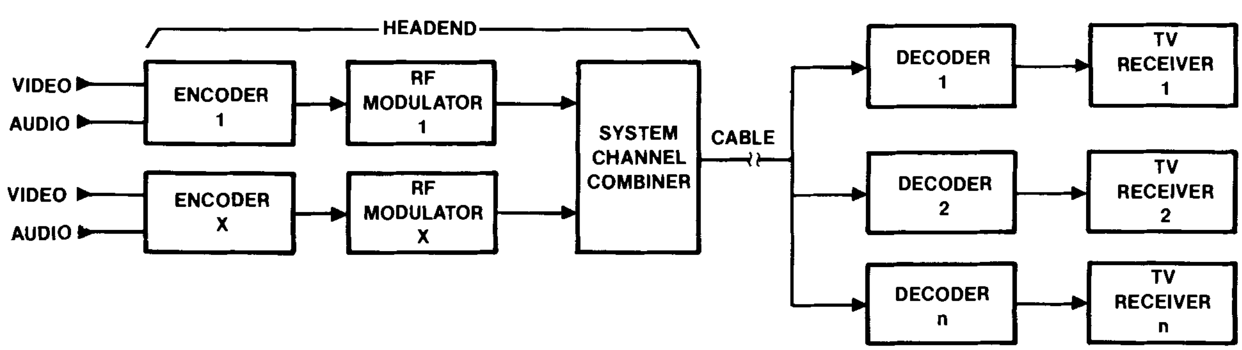


Figure 1. Basic Cable Television System

TECHNICAL DISCUSSION

Selection of Digital Approach

During the preliminary design of the cable TV equipment described in this paper, a digital approach was selected for handling the audio functions. The main reasons for this selection included:

1. Availability of techniques for digital encryption.

2. Feasibility of using a common RF carrier for both video and audio transmission.

3. Readily available techniques and devices for stereo, bilingual and other multichannel audio processing functions.

4. Improved dynamic range, noise immunity, fidelity and other audio quality features readily attainable with digital approach.

Multiplexing of Audio With Video Signals

A conventional video signal generated in conformance with NTSC (National Television Standards Committee) standards includes a sequence of sync and blanking signals for synchronization of receiving equipment. However, the method of scrambling selected for the video system resulted in the complete deletion of blanking and sync pulses. This left all of the time, normally used for horizontal sync, available for transmitting other data. In the system described, this time is used to transmit groups of pulses, which carry the digitized and encrypted audio signals.

Figure 2 is a simplified diagram illustrating the use of a switch to alternately select either the scrambled video or the digitized audio signals for delivery to the output. The technique of combining signals in this manner is called time division multiplexing. The resulting combination of signals can be readily transmitted on a single RF carrier. At the decoder a reverse switching function separates the audio and video signals.

Bit and Sampling Rate Constraints

The maximum bit rate for transmitting audio data is determined by the maximum bandwidth of the existing video channels which is typically 4.18 MHz. On this basis, as well as providing a multiple (x 260) of the TV line rate (15,734.26 Hz), the bit rate selected for the system was 4.09 MHz. With an NRZ (non return to zero) digital format the maximum fundamental frequency for this bit rate is 2.045 MHz. However, special low-pass filtering can be used to limit the rise time and otherwise restrict the bandwidth of the digital signals, within channel limits, while still maintaining good recoverable pulse shapes (approximately raised cosine). This enabled a conservative time-bandwidth product, approaching unity, to be realized for comfortable communications link margins under a variety of channel impairments.

Examination of Figure 3a illustrates the maximum time available for transmission of audio data, 6.75 μs for each line of video data. This includes the time during which the normal NTSC video signal provides the front porch, sync and part of the back porch, up to the beginning of the color burst.

For this system the actual time assigned for transmission of audio data was selected at 6.6 μs as shown on Figure 3b. This is a multiple (x 27) of the bit period selected (0.244 μs) and allows some time for smooth transitions between video and digital audio signals.

A total of 15,734.26 lines per second are generated for NTSC video transmissions. This number, multiplied by 6.6 μs, is 0.103844 second, the total time available for transmission of audio data during each second.

With a bit rate of 4.09 MHz each bit period is 0.244 μs. The quotient of 0.103844 s/0.244 μs = 424,818, which is the maximum number of bits that can be transmitted during each second of video transmission.

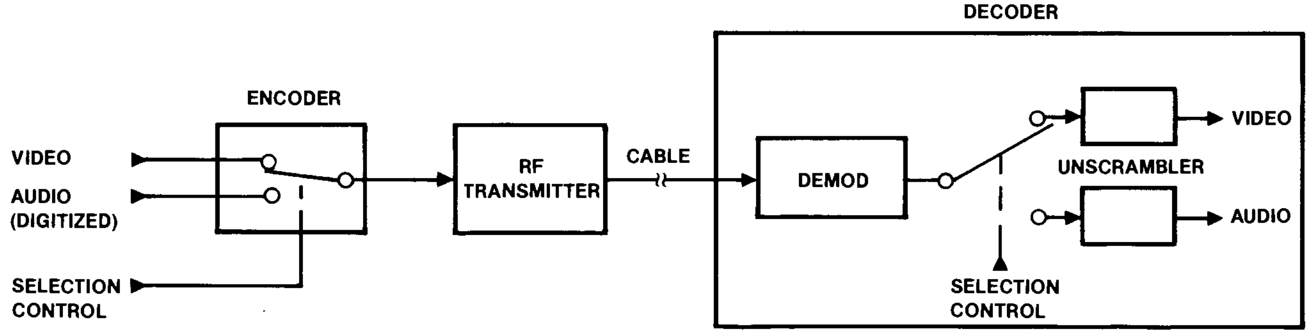
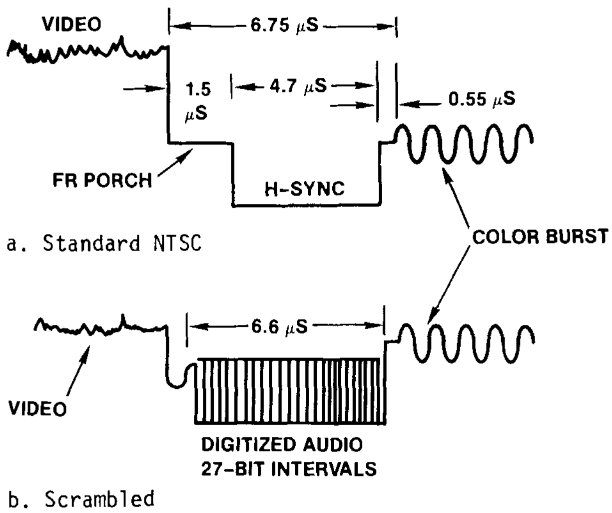


Figure 2. Time Division Multiplexing



a. Standard NTSC

b. Scrambled

Figure 3. Horizontal Blanking Time Interval

The current design transmits a total of 27 bits of data for each television line transmitted, as shown on Figure 3b. This includes a start bit, a squelch bit, 24 bits (3 samples) of audio data and a parity bit. Thus the actual system transmits a total of 15,734.26 x 3 = 47,202.78 samples per second. For two audio channels, the sampling rate for each channel is 23,601 samples per second.

Audio Performance Optimization

In order to provide optimum audio performance within the bit rate and sampling constraints described above, the following elements were included in the design:

Companding. Companding techniques are used in the A to D (analog to digital) conversion circuits which provide finer resolution for the least and coarser resolution for the most significant bits, compared to linear conversion. This results in amplitude resolution and dynamic range performance, with 8 bits, which approaches that of 12-bit plus sign, linear conversion circuits. The devices are used to accomplish this companding function in accordance with the Bell System-developed u-255 Law, defining the resolution of conversion at different levels.

High Performance Filters. In order to provide the maximum audio frequency response within the sampling constraints, high-performance low-pass filters were designed for use in both the encoding and decoding ends of the system. These filters, utilizing elliptic configurations, achieve a 70-dB attenuation slope within 800 Hz. This assures performance approaching the theoretical maximum response (per Nyquist criteria) of one-half the sampling rate without incurring distortion due to aliasing errors.

Encoding Functions

Figure 4 is a simplified block diagram illustrating the main elements involved in the encoding functions of the system, especially the audio processing. This includes input audio amplification, A to D conversion, encryption, time buffering and insertion into the video signal channel.

Through remote control, typically from a control computer or terminal, the selection matrix determines whether the system is to operate in a monaural mode from either the A or B input, generate A + B and A - B signals for stereo, or select both A and B inputs for bilingual operation.

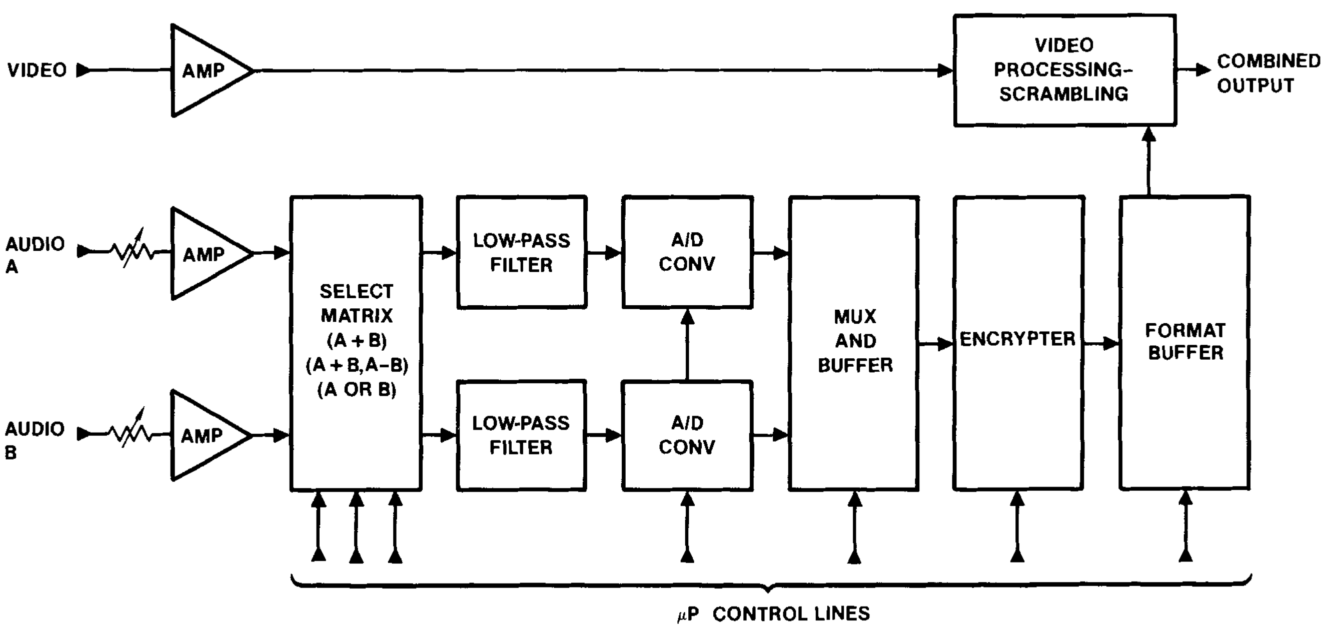


Figure 4. Encoding Functions

The main reason for the time buffering is the requirement for sending the digitized audio data in bursts, during the time normally assigned for horizontal sync, yet sampling the audio signals at a continuous unbroken repetition rate. This technique is known as "sound in sync." Buffers are also required to handle other digital data which is inserted into the video channel during the vertical sync time interval.

Decoding Functions

Figure 5 is a simplified block diagram illustrating the main elements involved in the decoding functions of the system, again with emphasis on the audio processing.

The tuner is used to select one of the many channels typically available from the cable TV system. The IF (intermediate frequency) and demodulator stages recover the baseband video-audio signals. After separation, the video signal is unscrambled and the audio is decrypted.

Recovering the audio signals involves reversal of the encryption process, time buffering, D/A conversion, filtering and other audio processing. The time buffering takes the data arriving in bursts and delivers it to the D/A converters at a constant rate. The output filter smooths out the steps on the recovered analog audio signals from the D/A converters. This filter removes spectral image signals which are generated at multiples of the sampling frequency by the digital processing.

Figure 5 also indicates elements of the decoder which have been incorporated into specially designed LSI (large scale integration) devices. This design was undertaken to reduce the cost of these functions in decoder units since they are manufactured in large quantities.

Encryption

Encryption of digital data is becoming commonplace wherever privacy and security are desired while sending this data through public or other readily-accessible transmission media.

Figure 6 is a block diagram illustrating the basic functions of devices at the sending and receiving ends of a cryptographic system, serving to provide security through the use of encryption techniques.

At the sending end, the input digital information, called "plain text," is applied to an encryption device. The device utilizes a group of bits K (for key), in processing an algorithm which performs a nonlinear mathematical function on the plain text input. The mathematical function involves a complex series of permutations and substitutions to the plain text, resulting in an encrypted output called "cipher text." The operation performed is a one-way mathematical function since it is easy to perform, yet the inverse function is exceedingly difficult to perform, even if the key and output encrypted data are available.

At the receiving end, the decryption device uses the cipher text and K data as inputs and performs the same algorithm as the sending device. The output of this device is the recovered original plain text.

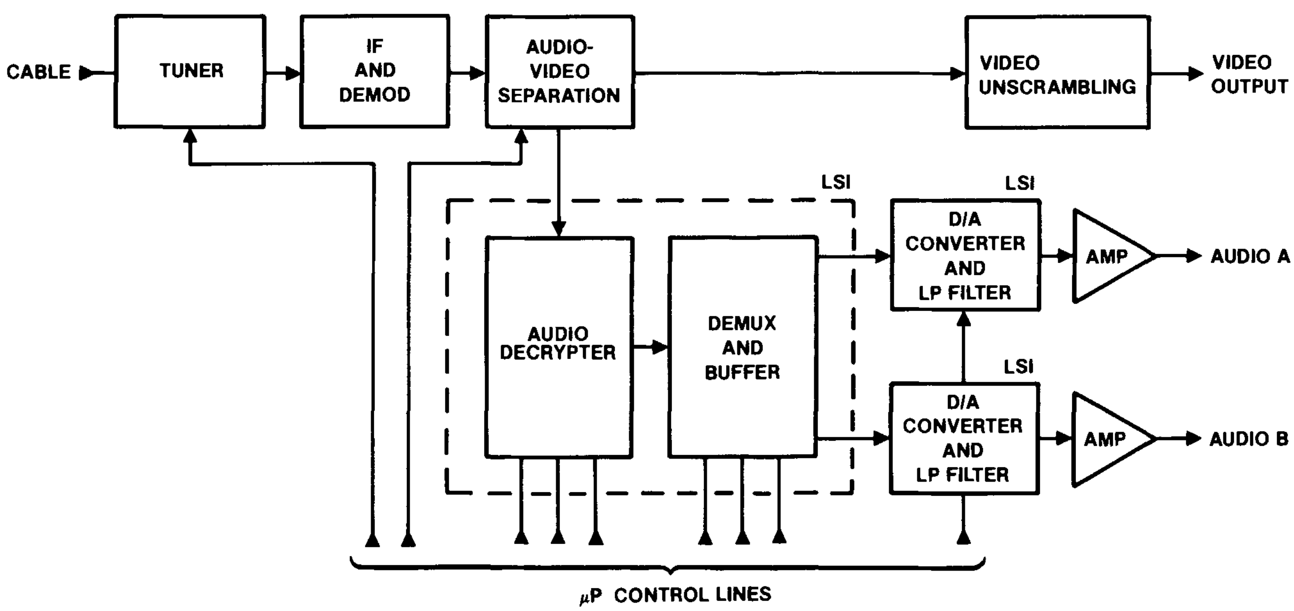


Figure 5. Decoding Functions

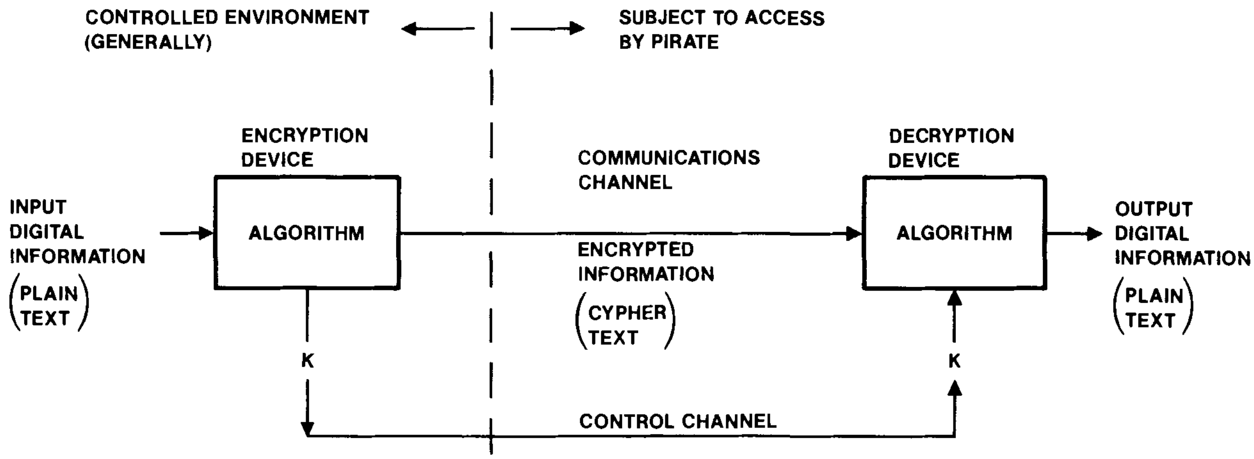


Figure 6. Classical Cryptographic System

Figure 7 illustrates an enhancement of the basic decryption system described above and used on the decoders. The enhancement is realized through multilevel key distribution. Input information together with a stored unique box key generate a second key (variable) using one decryption algorithm. This second key together with other channel information and a second device generate a third key (also variable). Finally a third device, using the third key, decrypts the service data input to produce the service data output. This output includes the clear digital audio and data for unscrambling the video signals.

To further frustrate the efforts of even a skilled cryptologist attempting to unscramble the incoming data, the keys can be changed periodically, as often as once per second.

Synchronization Functions

In systems transmitting digital signals between two or more stations, successful recovery of the digital data at the receivers is dependent on accurate synchronization between the stations. This is typically achieved by generating internal, accurate synchronized clock signals.

As shown on Figures 8 and 9, in the Sigma system both the encoders and decoders utilize PLL (phase-lock-loop) techniques, to lock-in a VCXO (voltage controlled crystal oscillator). In both cases the VCXO serves as a clock generator and is locked to a specific reference input signal.

In the case of the encoder the input reference is the composite TV sync signal derived from the

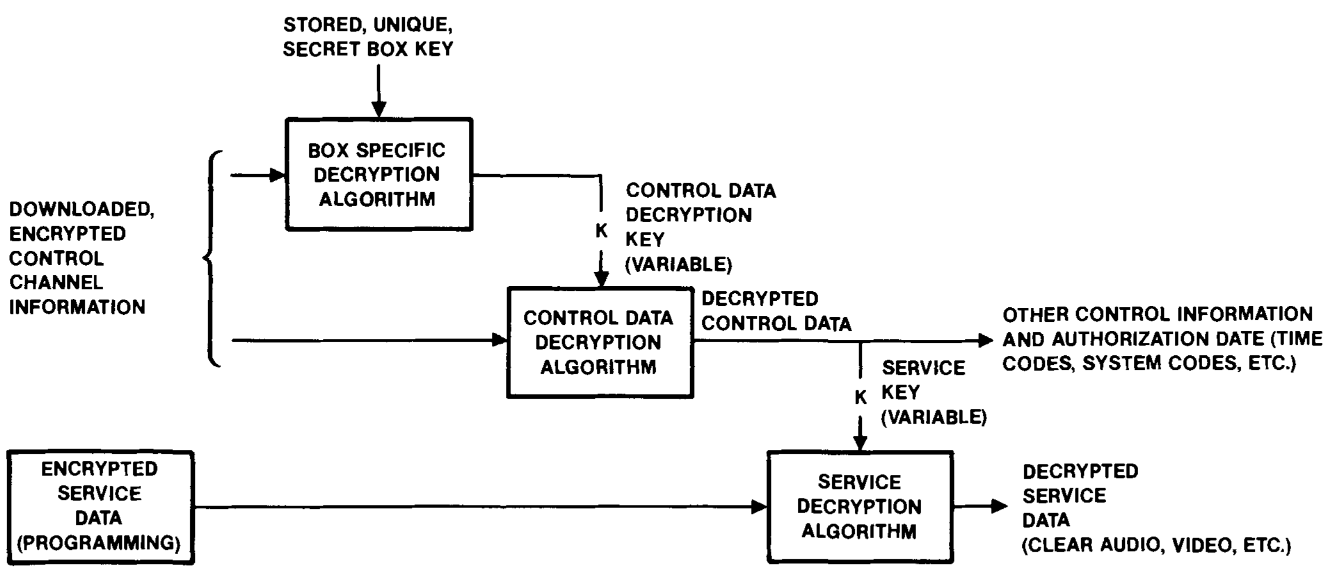


Figure 7. Multilevel Key Distribution

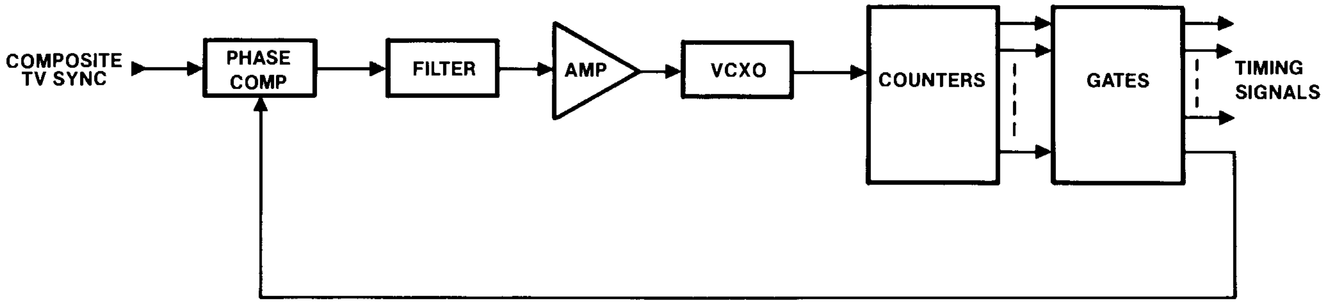


Figure 8. Encoder PLL

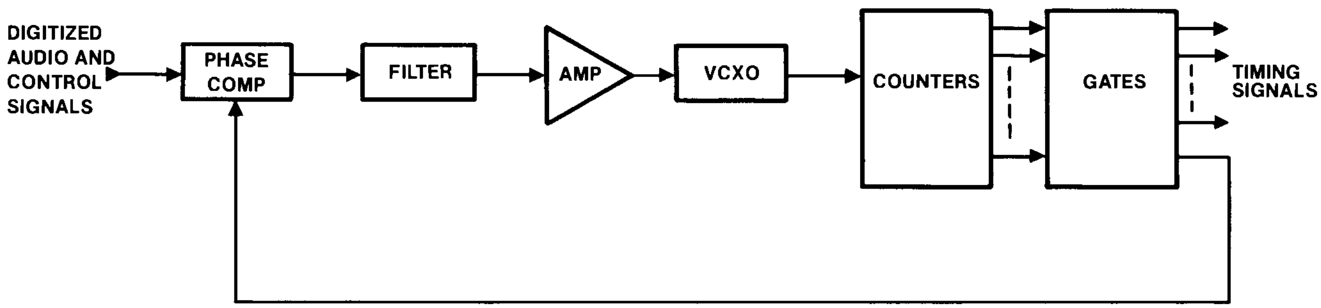


Figure 9. Decoder PLL

incoming video signal. This assures that the digital signals generated in the encoder are synchronized to the video signal, thus allowing time division multiplexing and other synchronous functions essential to the system's successful operation.

For the decoder the input reference to the PLL constitutes the digitized audio and control signals. This synchronization enables the successful separation of the digital data from the TV signals and the unscrambling functions of the decoder described earlier.

Performance Considerations

From extensive laboratory and field tests conducted on the Sigma system, with data collected from operation in actual cable TV facilities, considerable performance data has been obtained. The usual minor circuit problems were uncovered and corrected, but overall performance has been outstanding. The overall system from end-to-end has displayed more than adequate margin against channel impairment (fading, multipath interference, etc.) and intra-network processing such as AML/FML links.

An area of concern during the development of the system was the amount of audio performance degradation which would occur with decreasing video signal (multiplexed with digitized audio) to noise ratio. Many of the tests involved measuring BER (bit error rate) versus video carrier-to-noise ratio. The results demonstrated that non-degraded audio performance is achieved down to a 32-dB carrier-to-noise ratio, a level where the picture quality displayed is marginal (grade 2 picture).

Physical Configurations

Figure 10 shows the Sigma Encoder, an assembly designed for installation in a standard electronic equipment rack. The assembly features a modularized configuration using plug-in circuit boards and power supply, all replaceable from the front. The circuit board dimensions and connectors conform to the Eurocard standards, highly favored in Europe and increasingly popular in the United States.

The Sigma Decoder assembly is enclosed in a thermoplastic housing with a sheet metal base (see Figure 11). A keypad facilitates local control and channel selection. An infrared receiver in the assembly enables remote control from a compact hand-held controller. Other decoder features include:

1. Selection of up to 128 channels.

2. Favorite channel memory to recall channels in a prearranged order.

3. Parental control to lock out selected unwanted channels.

4. Remote volume control with mute capability.

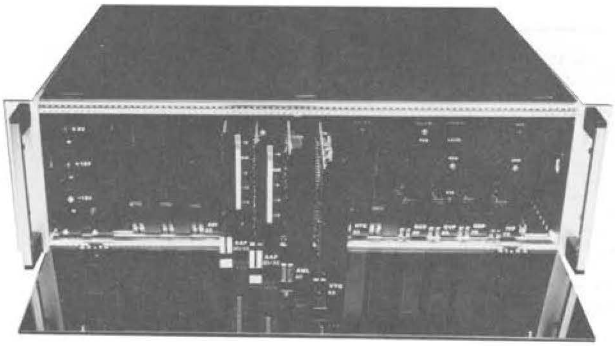


Figure 10. Sigma Encoder

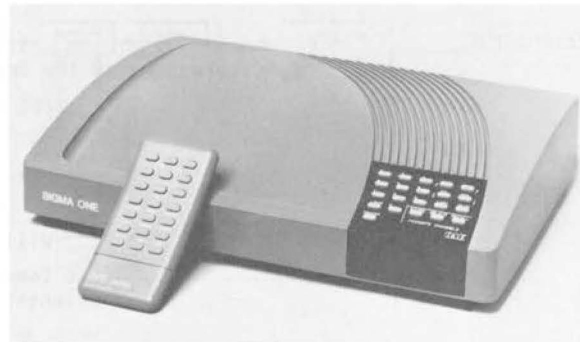


Figure 11. Sigma Decoder

SUMMARY AND CONCLUSIONS

A summary of many of the design decisions and the rationale behind them has been presented. Also some computations which led to the selection of specific modes of operation, such as bit and sample rates, have been reviewed. Generally, the design used state-of-the-art technology and therefore no unexpected surprises were encountered.

All of the features designed into the system are operating successfully. These include:

1. Monaural, stereo and bilingual modes of operation.
2. Digital transmission of audio signals.
3. Encryption of audio signals.
4. Use of common carrier for video and audio transmission.
5. Cost of decoders competitive with other addressable units on the market, even considering the advanced level of technology implemented.

REFERENCES

For additional related information refer to the following publications:

1. M. Davidov and V. Bhaskaran, "Digital Audio in Cable Systems," Oak Communications Inc., December 1983.

2. "Multichannel TV Sound: Basis for selection of a single standard," published by EIA Consumer Electronics Group, August 6, 1982.

3. B. A. Blesser, "Digitization of Audio," Journal of the Audio Engineering Society, Vol. 26, No. 10, October 1978, pp 739-771.

DIGITAL TECHNIQUES CURE LINE SEGMENTATION SCRAMBLING PROBLEMS

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ABSTRACT

Digital domain techniques are used to correct artifacts encountered in line segmentation video scrambling schemes. In particular, baseband frequency bandlimiting and line tilt distortion corrections are discussed.

INTRODUCTION

Video security is a topic well known by the cable television industry. With proposed future services, it is becoming more and more likely that highly secure image transmission systems will have to be used. These systems will have to provide security commensurate with the value of the visual information being communicated.

It has been ATC's interest to play a role in the selection and development of secure video scrambling systems for the future. With this in mind, this paper discusses the advances made at ATC in the area of line segmentation scrambling.

LINE SEGMENTATION VIDEO SCRAMBLING

Several options are available in the selection of a secure video transmission scheme (reference [1] overviews various video scrambling methods). In typical sync-suppression techniques, the visual portion of the signal often remains relatively uncorrupted with only the sync intervals being modified. This characteristic allows simple reconstruction of the original signal at the subscriber site. However, the interested pirate with a bit of television electronics background can "break" such a system with a minimum of effort.

Digital encryption techniques, on the other hand, offer the ultimate security with the strength of the National Bureau of Standards' Data Encryption Standard (DES) behind them. In this technique, each video frame is digitized into discrete samples, with each sample encrypted using the DES standard. Unfortunately, these systems require the digital transmission of video data, a high-bandwidth mode for which cable systems lack the capacity.

A happy middleground appears to be a scrambling technique that mixes both low video signal corruption and digital control of the descrambling; such a technique is line segmentation. In the line segmentation scheme, the bulk of the visual signal is left unchanged. One or more cuts are made in each video line with the various segments interchanged within the line. The cut points are controlled by pseudo-random number patterns.

The pseudo-random cut patterns are generated at the headend scrambler and subscriber descrambler in synchronism. Pseudo-random pattern "seed" values are passed to authorized subscribers allowing their units to track the patterns of the headend scrambler. An unauthorized subscriber is given bogus "seeds". With the "seed" values digitally encrypted using the DES standard, a high level of security is maintained for their passage.

At ATC, a line segmentation scrambling approach was chosen for study because of its hybrid characteristics between predominately unmodified video and secure encryption techniques. Both parameters pair to provide secure transmission as well as relatively simple reconstruction. Furthermore, by not corrupting the horizontal and vertical sync intervals, NTSC signal compatibility of the scrambled video is maintained.

The system to be discussed herein uses a single cut per video line made at a pseudo-random point within the line. Illicit reconstruction of the video signal without benefit of subscriber authorization codes proves to be exceptionally difficult. One such scenario requires the use of high-speed digital correlators that attempt to match a given line with its previous neighbor. Aside from being rather costly, even this technique tends to fall apart with significant line-to-line video differences.

DISTORTION PROBLEMS

Line segmentation video scramblers suffer from a few self-induced distortion mechanisms. In particular, when a line segmented signal is subjected to baseband frequency limiting and line tilt, serious reconstruction distortions are produced. Where these distortions may normally be imperceivable to the viewer when applied to clear video, the line segmentation reconstruction process introduces resulting visual artifacts that are unacceptable (reference [2] overviews these distortions and their effect on the line segmentation process).

First, baseband frequency limiting, caused by poor high-frequency response baseband processors and mistuned vestigial sideband receivers, adds step response degradation to the video signal. This distortion will typically cause a signal to experience roll off or ringing of its sharp transients. This is a problem at two sharp discontinuous portions of the line segmented signal, particularly at the start of the line between the back porch-to-visual line transition and the end of the line between the visual line-to-front porch transition. These two points must be mated without perturbation in the reconstruction process. Signal roll off or ringing at these points causes an undershoot or overshoot response in the patched reconstructed signal. The visual effect is dark or light sparklets at the reconstruction patch-points.

Second, line tilt is seen as a DC droop across a video line between black-level clamping periods. Even high amounts of this slow luminance variation across the line is typically undetectable by the viewer. However, following line segmentation reconstruction, relatively low amounts of this seemingly minor distortion provide for a chaotic hashing of luminance stridations overlaying the viewed video image. This distortion comes up because the imposed DC droop is cut, along with the visual portion of the line, in the reconstruction process. Once the video line is reconstructed to its original form, the line tilt component appears as a sawtooth luminance variation with the entire magnitude of the tilt making a transition at a single location.

In order to make line segmentation scrambling a viable mode of security in real-world video transmission systems, it is essential that the effects of these two "induced" distortion mechanisms be removed. Where Charge-Coupled-Devices (CCDs) have been classically used for reconstruction of line segmented video signals, analog corrections for line tilt induced distortions, in particular, are extremely difficult to implement. By digitizing the video upon receipt at the subscriber site, simple methods may be used for the corrections of both baseband frequency limiting and line tilt.

CORRECTING THE PROBLEMS DIGITALLY

Digitizing the Video Signal

The line segmentation system constructed at ATC is digitally based. Both the headend scrambler and the subscriber descrambler units work with digitized video for their processing.

Each unit accepts baseband NTSC video as input. Following a standard input buffer and black-level clamp is a high-speed Analog-to-Digital converter. Working on a line-by-line basis, the digitized video is written into a Random Access Memory (RAM) for storage.

The horizontal blanking interval is read out of the RAM unmodified. The visual portion of the line is read out from a pseudo-random point within the line with the end of the visual line butted up with the start of the visual line. In this way the line segmentation process is effected.

The digitized video data is read from the RAM directly into a high-speed Digital-to-Analog converter for conversion back to the analog domain. An output post-aliasing filter serves to reconstruct the converted video signal back to its NTSC form.

All digitizing is carried out at a sample rate of four times the color subcarrier frequency, or 14.318 MHz. Eight-bit digital conversion is used to span the entire video amplitude. A 12.5% amplitude overrange is provided to allow for the capture of a video signal with a line tilt of + or - 6.25% without clipping.

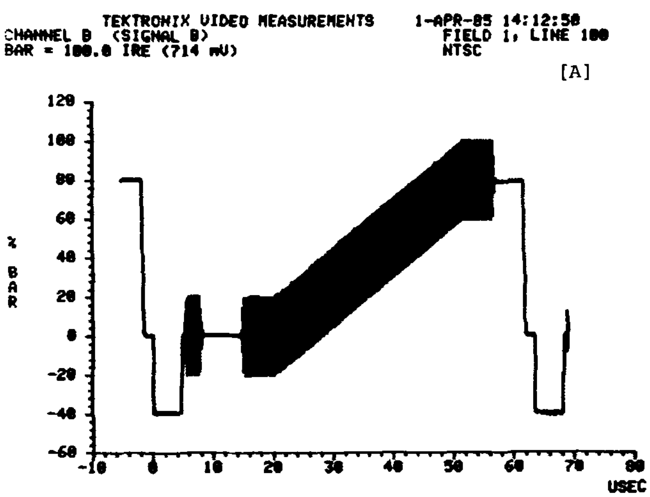
The digital range of the video spans 256 levels. 32 levels (12.5%) are given to overrange leaving 224 levels for the video. This means that the video amplitude has a digital resolution of 1/224, or 0.45% of full-scale resolution.

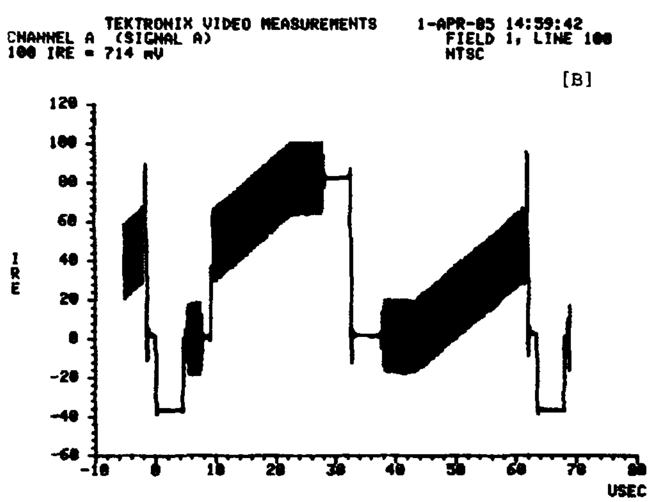
Correction of Frequency Limiting

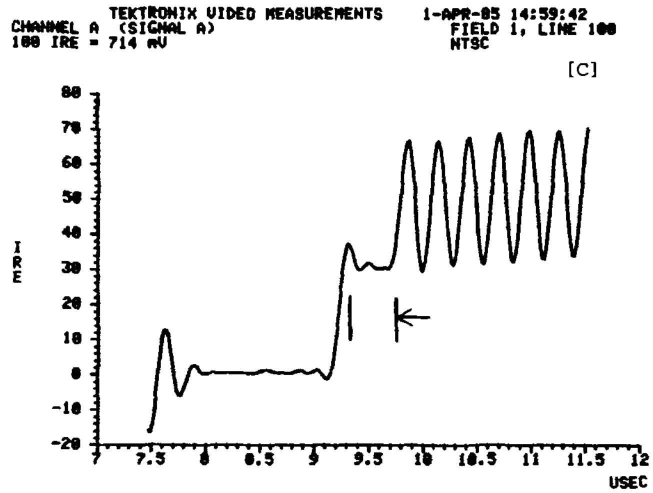
With frequency limiting causing the video signal to roll off or ring at its sharp transitions, it is necessary to ensure that the start and end of the visual line be at the same amplitude level when patched together in the reconstruction process. This may be handled through the addition of amplitude hold levels applied to the beginning and ending of the visual line in the scrambling process (see Figure 1).

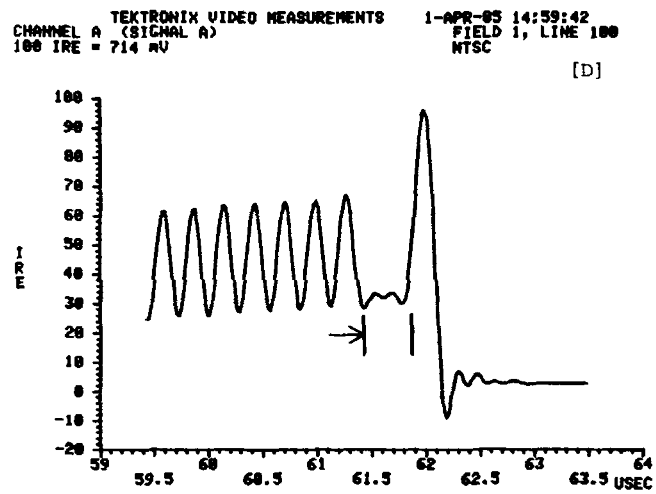
The hold levels serve to allow roll off and ringing to dampen out to their correct video levels prior to the sample points where the two segments must be patched.

Hold level durations of 500 nS are used. The price paid for this compensation is that the active visual line is reduced by two times 500 nS, or 1 uS. This represents a loss of 1 uS/52.7 uS, or 2% of the visual line. Since television receivers have a line overscan of about 5%, the 2% loss is not visible to the viewer.









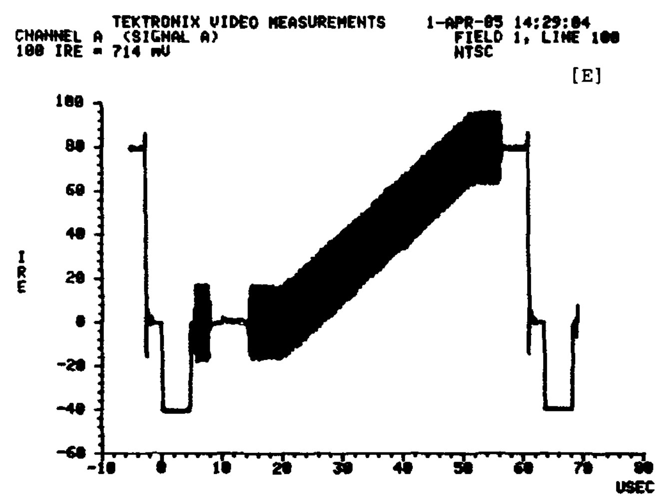


Figure 1- a) Original input video line waveform (80 IRE Modulated Ramp), b)signal following line segmentation (no line tilt), c) hold level applied at start of visual line, d) hold level applied at end of visual line, e) reconstructed video line.

Hold levels are added to the visual portion of the scrambled signal by modified addressing techniques. When the digitized video is read out of the RAM memory in the scrambler system, the address of the first and last samples are held for the 500 nS duration. The visual portion is truncated by 1 uS prior to this operation such that the final visual portion, with holds, is of the original duration as prescribed by the NTSC format.

Correction of Line Tilt

With the presence of line tilt in the scrambled video signal, it is necessary to correct for its disastrous effects caused when descrambled.

In dealing with line tilt distortion, two distinct operations must take place. First, the amount of line tilt incurred by the signal during the transmission process must be measured, and second, the line tilt must either be removed prior to descrambling or its reconstruction sawtooth error must be corrected following descrambling. The method to be discussed in this paper treats the removal of the line tilt prior to the descrambling process.

In order to measure the amount of line tilt in the video signal during its transmission and processing, it is necessary to add some measurable information to the signal. This is accomplished by adding reference levels to each line. A known amplitude is added at the start and end of the visual portion of each line. Both levels are equal. In fact, these levels are one in the same with the baseband frequency limiting hold levels described above.

When the signal is received, these levels are read following the digitizing process. Their difference represents the amount of line tilt imposed upon the signal over the visual portion of the line. By employing averaging techniques across time to the measured amplitude difference, the amount of line tilt may be accurately measured in noisy environments.

Knowing the amount of line tilt in the signal, it is then removed prior to the line segmentation reconstruction process. A temporal look-up table is used to digitally sum in an inverse line tilt component to the incoming video signal. This look-up table has a data value associated with each sample in the line. When loaded with a ramp waveform, inverse to the amount of line tilt in the signal, each sample is compensated in its amplitude to remove the line tilt component (see Figure 2). The same look-up table ramp function is applied to all lines.

As mentioned before, 224 digital amplitude levels are used to represent the digital video signal. Therefore, summation of the inverse ramp to the incoming video may be made with an accuracy of one part in 224, or 0.45%. Also, it was stated that an input signal with + or - 6.25% line tilt could be digitized without clipping. These two digitizing parameters indicate that an input signal with a line tilt of up to + or - 6.25% may be corrected to within 0.45% of the peak-to-peak video amplitude.

A microprocessor is used to measure the amount of line tilt in the signal, calculate the inverse ramp waveform and load the data into the look-up table. In a typical subscriber terminal, the system microprocessor could be used for this function.

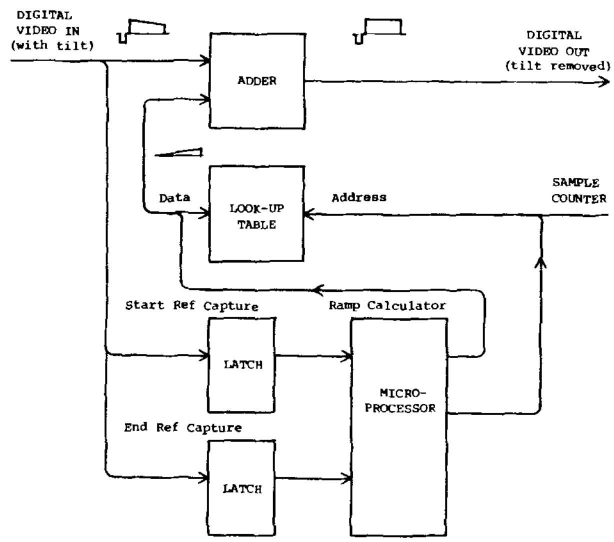


Figure 2- Block diagram of line tilt corrector.

RESULTS OF THE CORRECTION PROCESSES

Baseband frequency limiting corrections through the use of added amplitude hold levels of 500 nS to the visual portion of the signal have proved to mask the effects of simple bandlimiting. Visual patching of line segments where roll off and ringing do not exceed 500 nS is perturbation free.

Although 500 nS hold levels durations are currently used, this could be increased based on further studies of the requirements of typical transmission environments.

The correction of line tilt is being carried out by an 8748 single-chip microprocessor in the laboratory prototype descrambler. The measurement of line tilt, calculation of the inverse ramp data and loading of the look-up table require a fraction of a second to execute. The look-up table loading process is done during the vertical interval providing hidden operation to the viewer. Long-term correction tracking of the video signal over time and through subscriber channel selection has indicated no disturbance to the displayed video signal.

Correction of line tilt to within 0.45% has shown to be satisfactory in subjective tests. All line tilt induced hashing is removed from the displayed video (see Figure 3). Although the need is not clear, it would be possible to tighten the correction tolerance by restricting digitization of the signal to just the visual range. In this case, the sync intervals would have to be re-created in the subscriber terminal.

Figure 4 shows displayed video with both corrections implemented.

CONCLUSIONS

Line segmentation video scrambling offers an excellent compromise between digital encryption techniques and classical sync-suppression scramblers. High security is maintained through the use of DES encrypted descrambling codes while authorized reconstruction of the video signal is left relatively simple.

With the application of digital techniques such as those described in this paper, line segmentation video scrambling systems may overcome the persistent problems of baseband frequency limiting and line tilt induced reconstruction distortions.

Although still somewhat costly to the high-volume user, Analog-to-Digital and Digital-to-Analog converter technologies are advancing to the point where their entrance to the high-volume marketplace is expected within the next few years. At this point, implementation of line segmentation video scrambling schemes will present viable high-security alternatives to the video distribution industries.

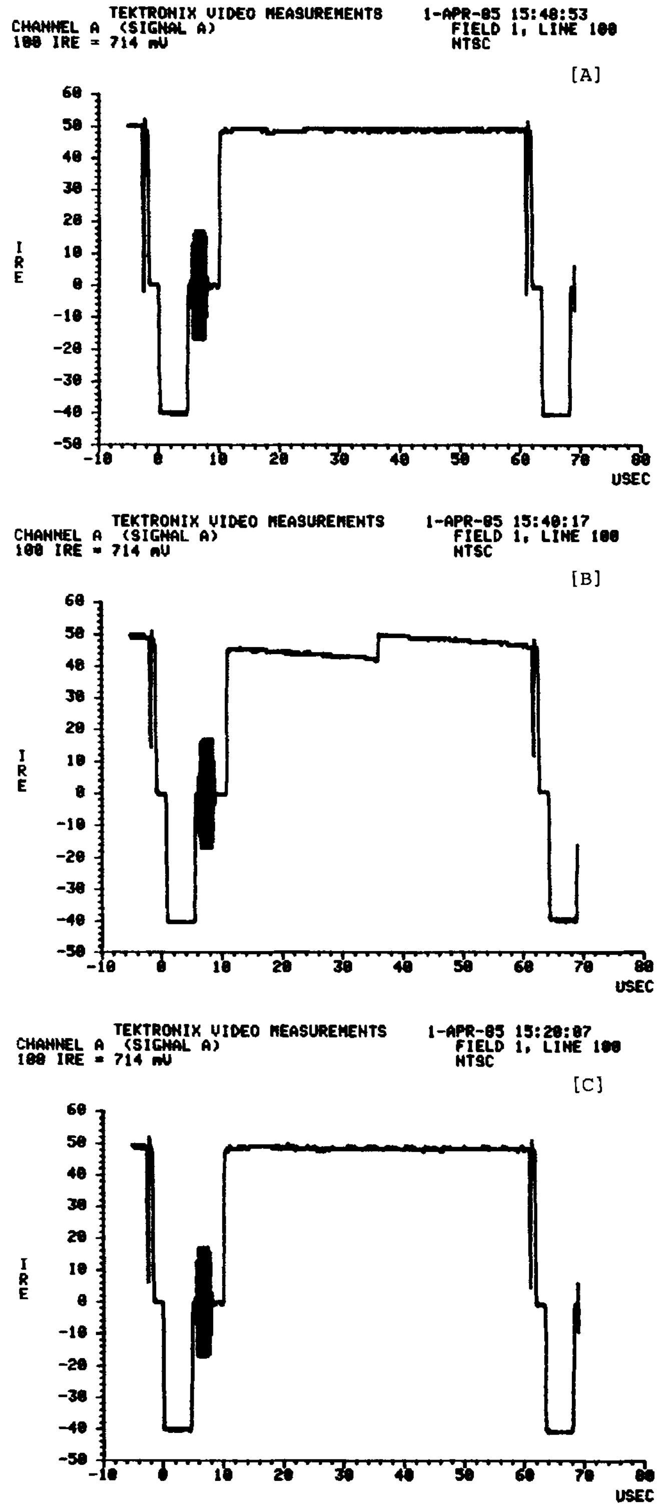


Figure 3- a) Original input video line waveform (50 IRE Pedestal), b) signal following line segmentation with 6% line tilt, c) reconstructed video line with line tilt correction.

[A]

[B]

[C]

[D]

[E]

Figure 4- a) Original input video frame, b) scrambled video, c) descrambled video without frequency limiting compensation, d) descrambled video without line tilt correction, e) descrambled video with frequency limiting and line tilt correction.

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[2] J. D. Lowry, "B-MAC: An Optimum Format for Satellite Television Transmission," SMPTE Journal, pp. 1034-1043, November 1984.

DOING SOMETHING ABOUT SERVICE CALLS!

Fritz Baker

VIACOM CABLEVISION

ABSTRACT

Unnecessary service calls waste money and contribute to customer dissatisfaction. Subscribers call our offices between one to three times per year feeling they need a service man. A third to three quarters of them still receive a service call. Computers can now identify the reasons why our subscriber call for service and will indicate for us the individual employee whom last had contact with that customer. Knowing what the employee did or said that may have caused a service call allows us to work with that person to improve their work skills. Tracking of service calls and making each employee accountable for their work is improving productivity. There are now fewer phone calls for service and we are making fewer trips to the home because we are learning to do it right - the first time.

INTRODUCTION

Today, good customer service must extend beyond answering our subscribers' inquiries over the phone and responding quickly to their service difficulties in the field. We must work at understanding the specific reasons why our subscribers phone our offices for a service call. Then armed with this information, we must do all we can to satisfy that subscriber on his initial install, phone call, or service call. The key is first obtaining this knowledge and effectively putting it to use. Figure 1 shows the relationship between our subscribers calling for service and those actually receiving a service call.

A subscriber normally will call for service because they have a problem with their reception or are in need of information. Typically when the technician responds to this type of call he finds a TV that is broken or is in need of fine tuning, a problem with the converter, the drop, or the distribution system. Too often he finds no one at home, no adult present, no problem at all, or the call was canceled or rescheduled. Unfortunately, by the time the technician responds to a service call we have lost on two previous occasions opportunities to resolve the subscriber's problem.

UTILIZING CABLE DATA

Cable Data is used in many of Viacom's systems. We are currently using reports obtained from Cable Data to assist us in reducing the number of service calls we do each year. The interpretation of this data is helping the efficiency of all of our service departments. The customer service representative is now sending fewer non-productive service calls into the field especially for fine tuning, subscriber education and the not home call. The technician is now having fewer call-backs because he has learned to correct the problem the first time. In order for the installer to do his job properly he must have a converter that works on installation, be taught to do an install that lasts for years instead of weeks, and shown how to encourage the subscriber to operate any of his cable related equipment on his first visit. By providing our subscriber, on his first contact (install, phone call, or service call), all that he needs to enjoy and operate his cable, we eliminate the need for his calling our offices a second or third time.

Most systems keep track of service calls in general: how many and of what type. Cable Data provides a new twist to tracking these calls by identifying the individual employee (service representative, technician, or installer) associated with each call. Various reports will list what they did while working with the subscriber and compare what the subscriber thought against what we found. This can be accomplished within 95 different

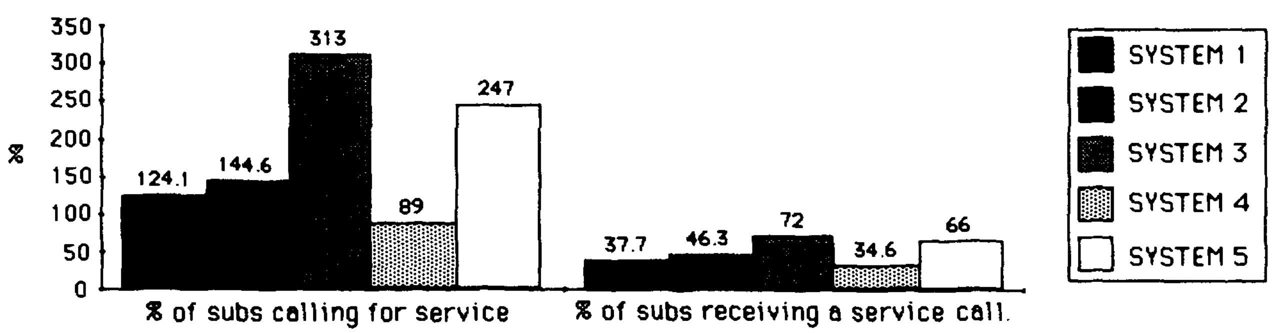

FIGURE 1

categories of our choosing. Cable Data reports are assisting our customer service representatives, technicians and installers to be our best front line force in reducing the need for our subscribers to call for service. The following paragraphs show ways that we have used these reports to become more efficient at our jobs.

THE PHONE SERVICE REPRESENTATIVE

One Cable Data program produces a report for our service phone representatives that tracks every service call assigned to a technician. A second report lists those calls that could have been handled over the phone but were sent into the field i.e., fine tuning, subscriber education, etc. We were surprised that some representatives were scheduling calls for fine tuning at twice the rate of others on the same shift. Rather than re-train the whole group the art of fine tuning a television over the phone (this was done several times in the past), we were now able to target individuals for that training. When we discovered that one representative sent so many calls into the field in comparison to the others on that shift, we replaced that representative with a service technician for one week. The technician manned the phones while the representative rode with a technician. During that period the technician was so effective at reducing unnecessary calls from being scheduled that his lack of presence in the field was not missed. In fact, he eliminated enough calls from going into the field that a second technician had nothing to do. The program worked so well that all the service representatives were given this week long, one-on-one training. The results have been 10% fewer service calls scheduled.

Figure 2 is a sample of a report given to the phone service supervisor. This report lists the occurrences of calls scheduled by the service representative #305, where a technician fixed the problem by fine tuning the customer's TV set. The end of the month report summarizes the department's phone activities and lists the number of service calls by type that was sent into the field by each representative.

THE SERVICE TECHNICIAN

The service technicians now receive a report that lists the number of call-backs each technician has had in a 30 day period. Again the group as a whole was good, but a few technicians had far more call-backs by a particular category than other technicians. As an example, a report indicated that certain technicians swapped out converters more often than others; the call-back report showed that other technicians would finally solve the subscriber's problem by fixing the drop. Our supervisors armed with this information can now work with each technician on specific problem areas. We also print on the technician's service work order: the date, fix code, and the name of the last technician that was at that home. We then give back to the technician any job that he had previously been to in the past 30 days. When we started to track the performance by individual service technicians, call-backs ran 20% per month; they now run 5%.

Figure 3 is a sample of a report given to the service repair supervisor. In this instance Mr. Kessler received a service call on the 26th of March. Technician #806 fixed a bad fitting. Mr. Kessler called back that same day complaining of flashing. We sent technician #806 back to the house where the final solution to the problem was to fine tune the TV set. Had he noted the condition of the TV on the first visit the call-back may have been avoided. The month end report summarizes the service technicians' activities. The supervisor noted that technician #806 had nearly three times the number of repeat visits for fine tuning than the other technicians.

THE INSTALLER

The installation report shocked us! The report indicated that out of every 100 installs completed, 30 of them required a service call within 30 days; most in 48 hours. Again the group was good, however a few installers had more than their share of problems in various areas such as fittings and low drops. Some installers had a habit of leaving little or no information with the subscriber on how to use the converter or fine

FIGURE 2
THE CUSTOMER SERVICE REPRESENTATIVE

ADDRESS	CUSTOMER NAME : PHONE	ACCT #	ORDER -TIME : COMPLETE	PHONE REP	PROBLEMS	FIX CODE
321	MIRIAM LOAGUE	33344-8	3/28/85 :9		NO PICTURE	FINE TUNED
LAKE	375-8888		3/29/85 :9	305		TV
321	KATHRYN ROSE	13245-9	3/30/85 :14		FLASHING	FINE TUNED
LAKE	291-4006		3/31/85 :10	305		TV

//

FIGURE 3
TRACKING A TECHNICIAN

ADDRESS	CUSTOMER NAME : PHONE	ACCT #	ORDER -TIME : COMPLETE	TECH	PROBLEMS	FIX CODE
1876	ROBERT KESSLER	611117-9	3/26/85 :08		NO PICTURE	BAD FITTING
MEADOW	229-0000		3/27/85 :12	806		
1876	ROBERT KESSLER	611117-9	3/27/85 :13		FLASHING	FINE TUNED
MEADOW	229-0000		3/28/85 :09	806		TV

tune their TV. It was a relief not to bore the entire group with how to put a fitting on again and work with those installers that really needed help. The installers also appreciated the fact that in addition to rewarding them for the number of installs they did every month, we now could reward those of them that had the fewest number of call-backs.

Figure 4 shows Mr. Baker called for an install on March 21, and was installed on the 25th at 4 p.m. by installer #705. The following day he called at 9 a.m. and complained that his converter was slow to change channels. On the 27th technician #806 found a poorly installed fitting inside the home that corrected the problem. At the end of the month Cable Data summarizes these occurrences in a report that is provided to the installation supervisor.

TRACKING CONVERTERS

An additional program within Cable Data now being implemented is one that tracks converter problems. The program, as highlighted in Figure 5, will provide the converter repair technician with information as to why a service technician had removed a converter from a home for each of the past six service calls. Also listed is what was done each time to repair that converter. The program has already identified for us a few converters that check out as "Ok" on the repair bench, but had been removed from the field six times for problems that we had been overlooking in converter repair. We are still looking for ways to include the converter technician's name with the converter history to provide them with accountability for their work. This program should decrease the time it takes to repair a converter, reduce paper work of our current manual methods of tracking converters, and improve the chances of getting a converter in the home that works right - the first time.

CONCLUSION

The detailed tracking of phone calls, service calls, and converter problems is helping to make our employees accountable for their work. With such tracking we are able to reward our employees for the quantity of work performed but also praise them for the quality of their work. Because we now know why the subscriber is calling for service and know the employee associated with those calls, we are able to effectively train and motivate every employee to eliminate service call-backs. The fruits of service call tracking are: a house is installed properly - the first time; a converter's problem is identified and repaired - the first time; a subscriber gets all of his questions answered - on the first call; a technician fixes a problem - on the first visit. Fewer service calls mean contented subscribers. What would happen to your subscriber growth if every subscriber kept his cable service just two months longer because of better service - the first time?

ACKNOWLEDGEMENTS

The author is appreciative of Fred Blake, MIS Coordinator in our Cleveland System, for his time and assistance in helping me to track service calls with Cable Data.

FIGURE 4
TRACKING AN INSTALLATION CALL-BACK

ADDRESS	CUSTOMER NAME PHONE	ACCT #	ORDER - TIME COMPLETED	TECH	PROBLEMS	FIX CODE
14363 WATT	STAN BAKER 338-7531	503946-2	3/21/85 :10 3/25/85 :16	 705		
14363 WATT	STAN BAKER 338-7531	503946-2	3/26/85 : 9 3/27/85 :14	 806	5-10 SECONDS TO DECODE	BAD FITTING INSIDE

FIGURE 5
REPAIR HISTORY OF A CONVERTER

BOX # STATUS	IN SERVICE	DATE RETURNED RETURNED BY	PROBLEM FIX	DATE RETURNED RETURNED By	PROBLEM FIX	PROB FIX	PROB FIX	# OF REPAIRS
43966 HOUSE	10/6/84	11/9/84 806	DEAD CORD					1
44187 REPAIR	9/5/84	3/21/85 812	SOUND COSMETICS	2/30/85 805	SOUND COSMETICS	SOUND COSM.	SOUND COSM.	6

Dr. STRANGELEAK

Or

How I Quit Leaking and Learned to Love the Bomb

Ted Hartson

Capital Cities Cable

ABSTRACT

This presentation is a compilation of several papers and presentations directed toward the issue of Signal containment for Cable TV. This presentation will be subdivided into three categories:

1. What Can Leak, How Big Can They Get?
2. We Are Not Alone
3. The Residual RF Smog

Buried among these words will be some fact, presumption, hope and maybe a little humor. While our dedication to the issue of Signal Leakage, containment should be resolute, we should occasionally take a look at the big picture associated with the ever present issue of "Radiation".

INTRODUCTION

The potential of aeronautical interference by cable television has consumed vast amounts of ink, newspapers, magazines, legal briefs and the Federal Register have all reduced the issue to writing in the form of studies, objective analysis, sensationalism and regulations. Being against aeronautical safety is the implicit burden ascribed to anyone who is less than four square behind absolute containment of cable TV signals.

At the outset it is important to understand that all cable systems could generate (project) fields of about the same intensity from a catastrophic failure. Failures of this type are no more or less likely to occur from an old or new system or one that leaks a little or not at all.

What is not being said is the number of other devices and services capable of projecting fields in the aeronautical bands. This paper will identify some of these devices and compare their amounts of potential radiation to that of cable television. It is not the intent of this article to belittle the potential for calamity in the case of catastrophic failure of shielding integrity from cable systems. It is however intended to offer a fresh perspective on that degree of perceived safety lost by relaxing existing CATV leakage standards.

WHAT CAN LEAK AND HOW BIG CAN THEY GET?

What could leak in a system? One mile of system probably has:

5280'	of Distribution Cable
1600'	of Trunk Cable
6600'	of Activated Drop Cable
1	Trunk Amp
4	Line Extenders
3	Passives
40	Taps
72	Drops (.9x80) 44 Active
100	Trunk/Dist. Connectors
44	Elevated F Connectors (if trapped system x 2 or more)
132	Low Level F Connectors (2 at G/B one at conv.)

What then are the number of high level radiation opportunities versus those at low level?

High Level
Exposed to trunk or distribution levels

- 6880' of cable
- 5 amp housings
- 3 passive housings
- 40 tap housings
- 100 connectors

Low Level
Exposed to drop levels

- 6600' of activated drop cable
- 176 connectors

It is interesting to note that in our model system the high level system is about the same as the low level in feet of activated cable as well as connector interfaces.

In a typical 150 mile aerial system, 453 system leaks and 1086 drop leaks were found.

When a drops level is around 10 dbmv on average and the levels in trunk distribution are around 30 dbmv the difference in levels is 20 db. Twenty db represents a voltage ratio of 10, consequently the equivalent microvolt per meter contour would project 10 times further theoretically from the source of leakage driven at +30 dbmv than the same contour from the source driven at +10 dbmv. Likewise the area within the given microvolt per meter contour will increase by 10^2 or 100. The impact of 453 system leaks illuminating areas 100 times greater results in 453 system leaks being 42 times more significant than the 1086 drop leaks.

(453 x 100/1086 = 41.7)

It becomes obvious that the greatest impact on system leakage will come from maintenance of the distribution plant and not the system drops.

HOW BIG CAN IT GET?

Consider a distribution line operation at +42 dbmv. The power at this point may be calculated:

$$+42 \text{ dBmv} = \text{Log}_{10}\left(\frac{42}{20}\right) / 1000 = .125 \text{ Volts}$$

$$P = \frac{E^2}{R} = \frac{.125^2}{75} = .0002 \text{ Watts}$$

Assume that one half of this power is radiated istropically from a leakage source resulting in a source power of 100 microwatts.

$$P = \frac{P_t}{4\pi(R)^2} = \frac{100 \times 10^{-6}}{12.56 \times (3)^2} = 884 \times 10^{-9} \text{ Watts}$$

$$E = \sqrt{WR} = \sqrt{884 \times 10^{-9} \times 377} = 18{,}000 \text{ uV/m}$$

Under these proposed conditions a leakage field of 18,000 uv/m would be present at 3 meters. That ain't hay!

While cable television may leak and conceivably leak a lot, cable retains control over the frequencies of its emission. Under the present and proposed standards these frequencies remain offset from channels of aeronautical usage.

It is elementary radio science that a higher level of leakage is necessary for an offset frequency to cause air space interference than for a non-offset frequency. From this, one might logically conclude frequency avoidance can provide all the caution necessary to safeguard aeronautical operations.

The second point of concern is when the leakage from a cable system interferes with services having exclusive and valid use of the airwaves on frequencies used within the "closed" cable spectrum. The distinction is, cable leakage rules in this regard do not stop with objective limits imposed by standards, such as this many microvolts per meter at this distance, but impose an additional and logical burden on CATV systems to take whatever steps are necessary to limit actual interference. This fact should not be overlooked when terrestrial users speak out against "relaxed" leakage standards.

WE ARE NOT ALONE

Many other devices and services are capable of projecting incidental radio fields.

In the following tables the permitted fields from the various devices are graphically compared to the allowable emission of cable television in the same portion of the spectrum.

The Federal Communications Commission maintains an ongoing record of complaints alleging interference to various services. These records are anaylzed by the development of a matrix showing the number of complaints reported from a particular service into another. Tables (1&2) show the record of such reports for the period of 1982 thru part of 1984. The various services are represented by numbers that generally correspond to the portion of the Federal Regulations that control the service.

The following guide should be used in reading tables (1&2):

Part	Description of Service
15	Radio Frequency Devices
18	Industrial, Scientific, Medical
21	Domestic Public Fixed Services
69	Home Electronics (TV,Radios,Etc.)
73	Broadcast Services
76	Cable Television Service
81	Maritime
83	Shipboard
87	Aviation
89	Safety Land Mobile
91	Industrial Land Mobile
93	Land Transportation
94	Private Operational Fixed
95	Personal Radio Service
97	Amateur Radio Service
G	Governmental
Other	Not Defined

Table 1

FEDERAL COMMUNICATIONS COMMISSION
FIELD OPERATIONS BUREAU

FIR002

REPORT OF INTERFERENCE COMPLAINTS RECEIVED
** NATIONAL SUMMARY **
CUMULATIVE - FY1982

FROM \ TO	15***	18***	21***	69***	73***	76***	81***	83***	87***	89***	91***	93***	94***	95***	97***	G****	OTHER	TOTAL
15*	28	1	4	5432	10	15	10	0	2	45	20	2	0	47	86	4	20	5726
18*	1	0	0	278	3	2	0	0	0	5	4	0	0	26	4	3	1	327
21*	1	1	75	143	1	4	1	1	1	23	26	7	1	7	15	6	8	321
69*	18	0	2	26	3	1	0	0	0	4	3	1	0	9	3	0	2	72
73*	8	0	2	1691	205	18	3	3	24	19	59	2	0	4	29	23	59	2149
76*	4	0	0	1156	4	34	1	1	2	9	5	0	0	1	86	4	21	1328
81*	2	0	0	15	0	0	67	34	0	6	7	4	0	0	1	16	5	157
83*	0	0	1	8	0	0	54	260	3	10	9	0	0	0	3	100	2	450
87*	1	0	0	37	2	0	1	1	129	2	1	0	0	0	2	18	0	194
89*	4	0	7	85	2	3	5	3	1	637	28	4	0	6	9	13	5	812
91*	10	0	27	268	3	3	4	3	2	166	2919	29	0	10	19	25	14	3503
93*	1	0	3	26	3	0	1	2	1	9	45	260	0	1	5	7	3	367
94*	0	0	0	2	1	1	0	0	0	0	0	0	4	0	0	0	0	8
95*	68	3	3	42263	14	96	3	0	2	25	39	10	0	4537	51	9	160	47283
97*	13	0	6	2489	2	10	2	0	3	20	16	3	0	11	1323	34	16	3948
G**	1	0	0	26	3	0	18	11	7	3	2	3	0	4	18	50	10	156
OTHER	55	4	28	6870	65	92	124	51	84	241	308	54	1	90	358	249	176	8850
TOTAL	215	9	158	60815	321	279	294	370	261	1224	3491	379	6	4753	2012	562	502	75651

FEDERAL COMMUNICATIONS COMMISSION
FIELD OPERATIONS BUREAU

FIR002

REPORT OF INTERFERENCE COMPLAINTS RECEIVED
** NATIONAL SUMMARY **
CUMULATIVE - FY1983

FROM \ TO	15***	18***	21***	69***	73***	76***	81***	83***	87***	89***	91***	93***	94***	95***	97***	G****	OTHER	TOTAL
15*	90	0	8	4307	3	33	0	0	1	40	33	4	0	12	116	6	15	4668
18*	1	1	0	35	0	2	0	0	1	0	7	1	0	11	9	3	1	72
21*	3	0	48	127	1	0	5	4	1	27	32	12	0	10	7	17	3	297
69*	4	0	0	24	2	0	0	0	0	2	2	0	0	24	6	0	2	66
73*	19	0	2	1719	188	14	6	2	14	14	35	0	0	1	27	45	32	2118
76*	1	0	1	1133	1	49	2	0	0	12	2	1	0	1	105	2	4	1314
81*	0	0	0	7	0	0	56	24	0	5	0	3	0	0	3	16	0	114
83*	0	0	8	15	1	0	42	205	5	27	4	2	0	0	22	91	2	424
87*	0	0	0	41	2	0	1	1	128	0	0	0	0	1	0	21	2	197
89*	0	0	6	81	0	2	2	5	1	503	26	2	0	1	10	8	6	653
91*	5	0	10	215	4	2	0	1	2	113	2683	25	0	0	13	27	11	3111
93*	3	0	0	34	0	0	1	1	0	6	32	222	0	0	7	4	1	311
94*	1	0	0	7	0	0	0	0	0	0	0	0	3	0	0	0	1	12
95*	78	0	12	36517	17	130	2	0	3	27	25	1	0	4075	46	9	79	41021
97*	27	0	2	2679	2	34	2	0	5	7	13	1	0	4	1273	18	26	4093
G**	0	1	0	27	0	0	19	15	7	4	3	2	0	1	24	58	10	171
OTHER	61	2	41	5518	42	108	90	50	127	223	315	41	4	79	410	1904	222	9237
TOTAL	293	4	138	52486	263	374	228	308	295	1010	3212	317	7	4220	2078	2229	417	67879

Table 2

FEDERAL COMMUNICATIONS COMMISSION
FIELD OPERATIONS BUREAU

FIR002

REPORT OF INTERFERENCE COMPLAINTS RECEIVED
** NATIONAL SUMMARY **
FIRST QUARTER - FY1984

FROM \ TO	15***	18***	21***	69***	73***	76***	81***	83***	87***	89***	91***	93***	94***	95***	97***	G****	OTHER	TOTAL
15*	17	0	0	873	4	6	1	0	0	4	4	0	0	6	18	2	0	935
18*	0	0	1	13	0	1	0	0	0	0	0	0	0	3	1	0	0	19
21*	2	0	6	35	0	0	0	0	0	4	5	3	0	0	0	4	2	61
69*	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	1	8
73*	5	0	1	332	42	5	2	0	2	4	8	0	0	3	8	5	9	426
76*	0	0	0	254	1	10	0	0	1	1	1	0	0	1	39	0	1	309
81*	0	0	0	0	0	1	23	3	0	0	0	0	0	0	1	0	0	28
83*	0	0	0	4	0	0	13	44	1	2	3	0	0	0	3	31	0	101
67*	0	0	0	6	1	0	1	0	23	0	0	0	0	0	0	6	0	37
69*	2	0	1	13	0	0	0	0	1	124	2	0	0	1	1	0	2	147
91*	0	0	4	57	1	0	0	1	0	30	623	7	0	1	6	2	4	736
93*	0	0	0	14	0	2	1	0	0	2	2	54	0	0	3	1	0	79
94*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
95*	36	0	2	10103	5	22	0	0	0	3	5	0	1	877	7	0	7	11068
97*	13	0	0	689	1	5	1	0	0	3	6	0	0	1	316	4	1	1040
G**	1	0	0	8	1	1	3	5	0	1	2	0	0	0	8	18	2	50
OTHER	13	2	4	1242	13	11	27	8	69	49	76	7	1	10	89	544	181	2346
TOTAL	89	2	19	13650	69	64	72	61	97	227	737	71	3	903	500	617	210	17391

FEDERAL COMMUNICATIONS COMMISSION
FIELD OPERATIONS BUREAU

FIR002

REPORT OF INTERFERENCE COMPLAINTS RECEIVED
** NATIONAL SUMMARY **
SECOND QUARTER - FY1984

FROM \ TO	15***	18***	21***	69***	73***	76***	81***	83***	87***	89***	91***	93***	94***	95***	97***	G****	OTHER	TOTAL
15*	22	1	1	1539	1	1	0	0	0	7	0	0	0	3	21	0	1	1597
18*	0	0	0	18	1	0	0	0	0	0	0	1	0	4	0	0	0	24
21*	1	0	7	41	0	2	1	0	0	12	13	3	1	3	3	3	0	90
69*	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	4
73*	6	1	1	518	59	1	2	0	6	6	8	2	0	1	7	8	1	627
76*	0	0	0	366	1	6	1	1	0	3	0	0	0	5	33	2	0	418
81*	0	0	0	1	0	0	8	2	0	1	0	0	0	0	0	1	0	13
83*	0	0	0	1	0	0	10	49	0	4	1	0	0	0	9	20	0	94
87*	0	0	0	8	0	0	0	0	10	0	0	0	0	0	0	5	1	24
89*	0	0	1	21	0	1	2	0	0	88	8	1	0	0	4	0	0	126
91*	1	0	0	173	2	2	0	0	1	17	673	0	0	4	4	4	1	882
93*	0	0	0	17	0	0	1	0	0	0	7	49	0	1	3	0	0	78
94*	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	3
95*	14	1	0	9725	7	13	0	0	1	4	35	0	0	1155	6	2	0	10963
97*	12	0	0	739	1	9	0	0	0	4	2	0	0	3	384	5	4	1163
G**	1	0	0	8	0	0	3	6	0	2	7	1	0	0	7	18	2	55
OTHER	26	3	4	1570	5	6	21	16	63	43	65	10	1	9	81	793	42	2758
TOTAL	84	6	14	14748	77	41	49	74	81	191	819	67	3	1189	562	861	53	18919

It is not intended to be implied that each of the various devices actually project fields of the indicated amounts but to identify the limit imposed on these services by the Commission. Conversely under some circumstances the fields of these devices may actually exceed the standards. This can occur thru enhancement brought about by the introduction of gain providing elements not found under the conditions specified in the Commission testing routine. An example of enhancement might be the Local Oscillator of an FM receiver being introduced to the gain of a directional antenna. Excision of the standard can also occur thru defect, many of the items shown are consumer devices which may be subject to negligent repair, misapplication or gradual deterioration resulting in emissions greater than the standard. No one routinely looks after the emission from these devices until an incident and investigation brings to bear technical scrutiny, these things keep humming along for years. The following tables are divided into two categories:

Category I (Table 3)

Transmitting facilities whose permitted incidental emissions are specified relative to the main carrier. In these cases the power of the evaluated device is shown and the permitted power in watts represents the power level of the permitted incidental output.

Category II (Table 4)

Incidental emitters such as radios whose intended purpose is not to transmit or if transmitting services those whose incidental fields are specified as intensity at a prescribed distance.

Because Cable Television leakage standards are given in field intensity it has been necessary to relate these values back to power for comparison to the category one devices. This was accomplished by traditional techniques. Also the assumption is made the source power will radiate isotropically.

Some of the Category 2 devices have been modified by Linear Conversion to reflect the anticipated level at 10 feet from the source. This is necessary to relate them to the Cable field intensity from 54 to 116 MHz which is also given at 10 feet. Further cable intensity below 54 and above 216 MHz is represented at 10' thru correcting by linear conversion the standard which is given at 100'.

In a close call one could question the assumptions and conversion practices shown herein but these are not close.

The first line of Table 3 shows a category I FM station. Where the permitted power in watts is <u>252 Billion</u> times that of Cable TV.

These tables graphically illustrate the fact that cable has been given standards that do not "fit" with the other potentially hazardous sources and further demonstrates a lack of overall Federal policy in the area of incidental emissions.

The assumptions and calculations necessary to develop these tables are too numerous to include here. For a more comprehensive understanding of the processes used in the preparation of this report, the reader is invited to contact the author

THE RESIDUAL RF SMOG

A further source of signal leakage is present from a cable system. A certain cloud of signal leakage remains in many cable systems which is beyond the control or apparent liability of the cable operator. This "background count" is a function of the radiation of cable system frequencies by subscriber devices attached to the system. These devices may be subdivided into two classes:

a. Purposeful system operation

b. Signal misappropriation

When a cable system uses a converter as a channel selection device before a subscriber's receiver, a secondary benefit is obtained. The converter serves as the termination of the subscribers drop. This termination is under the operator· control and always achieved in shielded coaxial cable. The opportunity for leakage is no more than any other coaxial junction. When any class or tier of service is relayed directly to the television receiver the termination becomes the input of the TV tuner which generally is highly reactive (a bad match). This coupled with propensity to use open feed lines within the television from the antenna terminals to the actual tuner input, all set up an opportunity for signal leakage. Additionally a television, while already a bad match will be an even worse match on signals to which it is not tuned. This likewise is true of FM receivers which are notorious for signal radiation. The leakage of cable signal components from these points can represent a substantial portion of the "background noise" from an operating system. Strictly on point with careful scrutiny of the FCC Rule 76.617 one could decide this leakage is not the responsibility of the cable operator.

Category I

Table 3

Type of Service or Device	Detail	Rule Cite	Permitted Emission*1 (watts)	Converted Cable Emission*2 (watts)	Differential*3
FM Broadcast	100kw @ 107.9MHz	73.317 (13)	3×10^{1}	$1.19X10^{-10}$	252 Billion
FM Broadcast	100kw 88-107.5MHz	73.317(14)	1×10^{-3}	$1.19x10^{-10}$	8.4 Million
VHF Television	Low Band 100kw	73.687	$1x10^{-1}$	$1.19x10^{-10}$	840 Million
VHF Television	High Band 316kw	73.687	$3x10^{-1}$	$1.19x10^{-10}$	2.52 Billion
Low Power TV	1 Watt VHF	74.736	$1x10^{-3}$	$1.19x10^{-10}$	84 Million
Low Power TV	90 Watt VHF	74.736	$5x10^{-4}$	$1.19x10^{-10}$	4.2 Million
Low Power TV	100 Watt VHF	74.736	$1x10^{-4}$	$1.19x10^{-10}$	840 Thousand
Amateur Radio	1000 Watts	97.73	$1x10^{-3}$	$1.19x10^{-10}$	8.4 Million
Amateur Radio	25 Watts	97.73	$2.5x10^{-3}$	$1.19x10^{-10}$	21 Million
Private Radio	350 Watts	90.209	$5x10^{-4}$	$1.19x10^{-10}$	4.2 Million
Aeronautical (ground station)	100 Watts	87.71	$1x10^{-4}$	$1.19x10^{-10}$	840 Thousand
Aircraft Transmitters	10 Watts	87.71	$5x10^{-4}$	$1.19x10^{-10}$	4.2 Million

*1 By application of the requirement to the operational level shown in the detail column.
*2 By conversion of Rule 76.605 a(12) to power in the Band 54-216MHz
*3 Ratio of power difference

Category II

Table 4

Type of Service or Device	Detail	Rule Cite	Permitted*1 Field at 3 Meters	Cable Field at 3 Meters	Differential*2
Radio Receivers (Radio,TV,Etc.)	Tuning 30 to 890 MHz	15.63	1500 uv/m	20 uv/m	75
Cordless Phones	49 MHz	15.118	500 uv/m	20 uv/m	25
Wireless Mikes (Etc.)	above 70 MHz	15.120	1500 uv/M	20 uv/m	75
Transmitter	72-76 MHz	15.359	1500 uv/m	20 uv/m	75
VCR/Video Games	88-216 MHz	15.610	150 uv/m	20 uv/m	7.5
Class A Computers	Systems	15.810	500 uv/m	20 uv/m	25
Class B Computers	Home Units	15.830	150 uv/m	20 uv/m	7.5

*1 Worst case 54 to 216 MHz converted to 3 meters as necessary

*2 Ratio of field intensity difference

Practically the cable system will be held accountable for these sources.

The second phase of the RF Smog problem comes from signal misappropriation. This class included:

* Bootleg second sets using marginal hardware and/or bad installation practices.

* Activation of twin lead internal wiring systems.

* Siphoning of FM signals with bad hardware.

* Internal antennas inadvertently reattached.

If systems deliver signals without converters and the levels are kept close to the minimum (around 0dbmv) the radiation will be also at minimum. There will be a direct relationship between the signal input and the radiated field. A rough approximation of the magnitude of signal radiation by television receivers can be made by surveying a system using converters for leakage on the converters output frequency. For this method to be effective the output channel must be free from over the air reception and the survey device must cover a sufficiently wide spectrum to include the accumulated error of the individual channels being received and the heterodyne accuracy of the individual set top. The cable channel which corresponds to the convertor channel output must either be accurately identified and discounted or suspended during the actual survey period. Present Commission standards prescribe convertor delivery accuracy at plus or minus 250 KHz of the nominal visual frequency. This technique will not pick up radiation from devices connected directly to the cable without the convertor.

CONCLUSION

More heat than light has been brought to the issue of Signal Leakage. Until the rules related to Signal Leakage are borne of study and not reaction, Dr Strangeleak will keep hanging around. We as an industry are on the right track but we must continue our efforts along the lines of seeking equitable regulation, applying peer pressure to those who lag behind in leakage maintenance and ever important, keeping our system clean and tight.

EFFECTIVE FLEET MANAGEMENT

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ABSTRACT

With an average of one unit per 1200 subscribers, the Motor Vehicle Fleet has a significant impact on all cable operators' P and L. Acquisition and maintenance costs are on a continually escalating curve. Fuel costs, though currently at a low point, will be volatile through the foreseeable future. Vehicle down time will continue to idle expensive manpower. Are these controllable costs or is the operator held hostage by vehicle dealers, repair shops and OPEC?

The objective of this paper is to identify the factors which, when properly controlled, will help to minimize operation costs whle maximizing the effective use of each vehicle. Analyses will be accomplished in the primary areas of Maintenance, Fuel Usage, Acquisition and Record Keeping. Procedures which have proven successful will be discussed along with suggested implementation plans. The understanding and techniques of effective fleet management will be beneficial to all cable operators regardless of size.

As has been stated, there are four primary areas to be addressed in a cost effective fleet management program. These are acquisition, maintenance, fuel and record keeping.

1.0 RECORD KEEPING

From the outset it must be understood that accurate record keeping is mandatory. Without up to date and correct records, fleet decisions will be, at best, gut level guesses. Detailed records will reveal whether the vehicle, which, is the most expensive general tool being used, is doing the job for which it was purchased.

1.1 Miles

The number of miles put on the vehicle for the measuring period are recorded. This is the fundamental information from which more finite performance measurements are to be made. If technician performance reports are already being generated, it is recommended that these mileage reports be for the same period. If not, a calendar month basis will suffice. Maintaining the same measuring periods for these different reports will allow monitoring of such informantion as regularity of miles traveled per install or service call, whether that average is higher or lower than others in the same department, whether any inexplicable aberrations appear and whether routing is being accomplished in the most effective manner. Current odometer readings, year to date miles traveled and vehicle to date miles traveled should also be kept.

VEH NO./DRIVER		JAN	FEB	MAR	YTD	VTD
#79 JOYCE	MILES	2002	1557	1832	5391	91167
81 FORD PU	GALS	165.0	136.0	138.5	439.5	7293.1
	MAINT $	$37.05	$ .00	$115.48	$152.53	$3648.68
	MPG	12.1	11.4	13.2	12.3	12.5
	MAINT$/MI	$ .02	$ .00	$ .06	$ .03	$ .04
#88 SPELLMAN	MILES	1427	1677	1636	4740	42585
82 S-10 PU	GALS	123.9	122.3	118.8	365.0	3043.1
	MAINT $	$165.95	$25.29	$47.38	$238.62	$1272.55
	MPG	11.5	13.7	13.8	13.0	14.0
	MAINT$/MI	$ .12	$ .02	$ .03	$ .05	.03

Figure 1 - Vehicle Performance Report

1.2 Fuel Usage

The number of gallons of fuel used for each measuring period is also to be recorded. When combined with miles traveled, the resulting MPG data will show the effeciencies or lack thereof by specific vehicle types, possible maintenance problems, driver effectiveness, and, if fuel unit costs are maintained, more accurate job costing. It also can reveal areas of potential employee theft of fuel.

1.3 Maintenance Costs

Measuring period maintenance costs are to be recorded. These costs can be total maintenance costs or can be broken out into preventative maintenance, repair and body damage categories. If company vehicle performance is of importance to the Fleet Manager, then preventative maintenance and repair figures should be kept separate from body damage. This allows a more accurate comparison between equipment types and/or brands. Whether the operator is self insured or uses a regular insurance carrier will make a difference also. In most cases it will be best to split the costs by source (i.e. maintenance/repair, body damage, etc.) and then combine at a later date when overall costs are needed.

While measuring period maintenance costs per mile can provide insight into specific problems, the vehicle-to-date information is generally the most useful. It can be used to compare vehicle types/brands and drivers over a longer period of time thereby allowing for the implementation of more precise corrective measures in the areas of operator training and vehicle acquisition.

1.4 Regular Maintenance

There are specific maintenance routines that need to be monitored. These are Lubrication, Tune Ups, Brake Work, Exhaust System Repair, Rustproofing and Cooling System Maintenance and Level. Keeping the dates of last service performed and/or levels in the use of coolant generates "ticklers" for needed maintenance. As a point of information, there are companies such as Quaker State who for a price will provide a computerized vehicle PM status report to the fleet operator if so needed.

1.5 Files

In addition to a fleet summary reflecting the above information, each vehicle should have a file contining all pertinent data on that vehicle. This file will contain the vehicle title, a copy of the current registration, a copy of the proof of insurance, copies of any warranties on that vehicle and any special equipment that is part of the vehicle, general maintenance records and copies of all repair invoices. This information is invaluable when analyzing vehicular or service shop performance and whenever warranty questions arise. Accurate and detailed record keeping is not important. It is essential.

2.0 ACQUISITION

The acquisition of vehicles for the modern CATV operator must be as carefully and meticulously approached as acquiring any other major components in the system. Before actually purchasing a vehicle, the following are to be considered:

2.1 Establishing Specifications

A cost effective vehile must be equipped to perform a specific function. Too big or too little will not do.

The first step in establishing specifications for a vehicle is to clearly define its usage. Observe how other vehicles operating in the specific task area for which the new one is intended are used. Obtain accurate dimensions and weight of the entire intended payload including the driver. Have the drivers profile their specific needs from the vehicle. Check any special equipment requirements. Identify the types of terrain over which the vehicle must operate. Determine towing requirements. Verify applicable OSHA, State and Local regulations. Talk with other operators regarding their experiences meeting similar needs. Refer to your individual vehicle records and reports to determine the sufficiency, performance and operating costs of the variously equipped vehicles currently in your fleet. Compile a list of all the above data.

C/K PICKUP

POWER TEAMS

ALL STATES EXCEPT CALIFORNIA

C-K10/1500 SERIES

POWER TEAMS (MUST ORDER ENGINE, TRANSMISSION AND REAR AXLE)

(Consult GVWR Selector and Tire Chart to insure tire capacity and availability)

ENGINE	TRANSMISSION 3-SP	4-SP	AUTO	AXLES 2.73	3.08	3.42	3.73	GVWR
W/NA5 STANDARD EMISSION EQUIPMENT								
–C10703-C10903								
LB1 V6 4.3 Liter (262-4BBL)	MM3	MM4	MX1	GQ1	*GU4	—	—	49/5200
		MM7	MXO	—	GQ1	*GU6	—	49/5200
	MM3	MM4	MXO	—	GQ1	GU6	—	5600
		MM7		—	—	GQ1	%GT4	5600
			MX1	GQ1	GU4	—	—	58/6100
		MM7		—	—	—	%GQ1	6100
		MM4		—	GQ1	—	—	6100
	MM3			—	—	GQ1	—	6100
			MXO	—	GQ1	GU6	—	6100
LE9 V8 5.0 Liter (305-4BBL)	MM3	MM7		—	GQ1	GU6	—	N/A 6100
		MM4	MXO/1	GQ1	GU4	—	—	N/A 6100
	MM3	MM7		—	—	GQ1	—	6100
		MM4		—	GQ1	—	—	6100
			MXO	GQ1	GU4	GU6	—	6100-
			MX1	GQ1	GU4	—	—	6100
LH6 Diesel 6.2 Liter V8 (379 Cu In)(Reqs B3J)		MM7		—	GQ1	GU6	—	52/5800
		MM4	MXO	GQ1	GU4	—	—	52/5800
		MM7		—	—	GQ1	—	6100
		MM4	MXO	—	GQ1	GU6	—	6100
–K10703-K10903								
LB1 V6 4.3 Liter (262-4BBL)		MM4	MXO	—	—	GQ1	%GT4	6100
		MM7		—	—	—	%GQ1	6100
LE9 V8 5.0 Liter (305-4BBL)		MM7		—	—	GQ1	GT4	6100
		MM4		GQ1	GU4	—	—	6100
			MXO	—	GQ1	GU6	GT4	6100
LH6 Diesel 6.2 Liter V8 (379 Cu In)(Reqs B3J)		MM4	MXO	—	GQ1	GU6	—	6100
		MM7		—	—	GQ1	—	6100
W/NA6 HIGH ALTITUDE EMISSION EQUIPMENT								
–C10703-C10903								
LB1 V6 4.3 Liter (262-4BBL)	MM3	MM4/7	MXO/1	—	—	GQ1	%GT4	N/A 6100
	MM3	MM4	MXO/1	—	—	GQ1	%GT4	6100
		MM7		—	—	—	%GQ1	6100
LE9 V8 5.0 Liter (305-4BBL)	MM3	MM4/7	MXO	—	GQ1	—	GT4	N/A 6100
	MM3	MM7		—	—	—	GQ1	6100
		MM4	MXO MX1	— —	GQ1 GQ1	— —	GT4 —	6100 ALL
LH6 Diesel 6.2 Liter V8 (379 Cu In)(Reqs B3J)		MM4/7	MXO	—	GQ1	—	GT4	52/5800
		MM4	MXO	—	GQ1	GU6	GT4	6100
		MM7		—	—	GQ1	GT4	6100
–K10703-K10903								
LB1 V6 4.3 Liter (262-4BBL)		MM4	MXO	—	—	GQ1	%GT4	6100
		MM7		—	—	—	%GQ1	6100
LE9 V8 5.0 Liter (305-4BBL)		MM7		—	—	GQ1	GT4	6100
		MM4		—	GQ1	—	GT4	6100
			MXO	—	GQ1	GU6	GT4	6100
LH6 Diesel 6.2 Liter V8 (379 Cu In)(Reqs B3J)		MM4/7	MXO	—	—	GQ1	GT4	6100

*N/A P195/75R15 or P205/75R15 Tires

%Reqs KC4 Eng. Oil Cooler

C/K Pickup—Page 18 General Motors Corporation January,

Figure 2 - Vehicle Facts Sheet

Secondly, obtain a specification book from the various manufacturers. If you have national fleet account status with the manufacturers, they normally will provide the spec books to you at no cost. If you are not yet qualified for this status, your local dealers will generally allow you to use their facts books.

Thirdly, match your compiled list of needs with the manufacturer's fact book. This will quickly begin to identify specific types and manufacturer parameters within which you will operate. It is critical that, once this process has begun, you resist the temptation to compromise these minimum specs. Under equipping a vehicle will result in an inability to perform the required tasks. Over equipping wastes expensive capital.

Special equipment needs (i.e. utility bodies, lift units, etc.) must be approached in essentially the same manner. The specs furnished to the special equipment manufacturer or OEM should include the physical dimensions and capabilities of the generic vehicle type on which the equipment will be installed.

2.2 Fleet Account Numbers

All U.S. manufacturers currently have fleet incentives and discounts available to fleet operators who have applied and qualified for their specific programs. Qualifying requires basically the following:

2.2.1 AMERICAN MOTORS

The fleet must be ten vehicles or more. The fleet operator should send a letter requesting fleet status, with proof of ownership of ten or more vehicles, to the local AMC dealer. AMC offers option package incentives and/or discounts on vehicle purchases. These discounts are in addition to the best deal you can make with the dealer.

2.2.2 CHRYSLER CORPORATION

The fleet must be ten vehicles or more. The application procedure is the same as AMC. Incentives and discount structures are also similar.

2.2.3 FORD MOTOR COMPANY

Fleet must purchase ten or more vehicles annually. The fleet operator should request a national fleet account application form from a local Ford dealer which the dealer will obtain from his district office. The form will be completed by the fleet operator and submitted with proofs of purchase of ten or more vehicles within the past twelve months to the local dealer. The dealer verifies the information and submits the application to the district office which approves and issues the account number. This account entitles the fleet operator to incentives and/or fleet discounts on certain vehicles ranging normally from $100 - $500.00. Periodic bonus incentives are offered in addition to the standard discounts. As with AMC, these discounts are in addition to the best deal that can be made with the local dealer.

2.2.4 GENERAL MOTORS CORPORATION

GM has several fleet programs. The basic plan requires the purchase of ten or more vehicles annually and has incentive and discount structures similar to Ford. Application procedures are similar to Chrysler with the exception that application must be made to each division (i.e. Chevrolet, GMC, Buick, etc.). The Mega-Fleet program requires the purchase of five hundred or more vehicles annually and offers improved terms resulting in $100 - $300.00 improvement over the standard program.

Most dealers will generally grant additional labor and parts discounts to fleet operators having the appropriate national fleet account numbers. It is also important to understand that these numbers are not based on each local fleet but can apply to the national operation as long as the name on the registration is fundamentally the same. (i.e. UA Cablesystems of Michigan, UACC Midwest, UACI, etc.)

2.3 Requesting Quotes

FULL SIZE PICKUP

MINIMUM 6100# GVWR
LONG WHEELBASE
TRANSMISSION - AUTOMATIC (SPECIFY IF LOCKING TORQUE CONVERTER)
TRANSMISSION COOLER
ENGINE - MINIMUM 6.0 L DIESEL
AXLE - TRACTION LOK REAR 3.73 GEAR RATIO
TIRES - P235/75R 15 BSW STEEL BELTED ALL SEASON TIRES (5) OR EQUIVALENT
BATTERY - H.D. (SPECIFY RATING) MINIMUM 515 CCA
BRAKES - POWER
STEERING - POWER
COOLING - H.D.
GUAGES - FULL INCLUDING TACHOMETER
ALTERNATOR - H.D. (SPECIFY RATING) MINIMUM 64 AMP
GLASS - TINTED WINDSHIELD ONLY
RADIO - AM
PAINT - DARK BLUE METALLIC
INTERIOR - VINYL - BLUE OR DARK GRAY
MIRRORS - LO MOUNT SWING LOK PAINTED
BUMPER REAR - STEP PAINTED

QUANTITY - 1

DELIVERY - 7/1/85

TERMS - NET 30 DAYS FOLLOWING DELIVERY

Figure 3 - Quote Request Specs

Format a generic list of the specifications. The list must be specific while simultaneously sufficiently generic to prevent precluding a manufacturer whose product could meet the need. Request that the dealer quote the vehicle as requested specifying in detail any variances from the specifications listed. Be sure and note any fleet account numbers which apply. Note on the list quanity, desired delivery dates and locations, and terms. Most dealers prefer to work on a cash or a maximum of Net 15 days basis. If, however, other terms are specified on the request for quote, the dealer can often use the request in procuring an extension on his money from his floor planner (i.e. GMAC, FoMoCo Credit, etc.).

A specific cover letter to each dealer should indicate the fleet operator's request for quotes on the attached specified vehicles. The letter should give a specific date and time by which the quotes are due and should provide the name and telephone number of a contact person who can answer any questions the dealer may have.

When the quotes are returned, the Fleet Manager must establish a method of comparing "apples and apples". Use a side by side, item by item comparison chart. This will quickly indicate which dealers have omitted certain requirements. A telephone call to these dealers will determine whether the omissions can be corrected or whether the vehicle simply cannot qualify. The bottom line price comparison will help to select the winner from the remaining qualifying quotes.

FULL SIZE PICKUP	GOOD GMC	KELLER FORD	COURTESY DODGE	BERGER CHEV
≥6100# GVWR	✓ 6100	✓ 6300	5900	✓ 6100
TRANS	✓ Auto 4spd.	✓ Auto 4spd.	✓ Auto 3spd.	✓ Auto 3spd.
ENG ≥ 6.0 L DIESEL	✓ 6.2 L	✓ 6.9 L	N/A	✓ 6.2
AXLE LOK 3.73:1	✓ 3:73	✓ 4:10	✓ 4:10	✓ 3:73
TIRES	✓ P235 75R	✓ P235 75R	✓ P235 75R	✓ P235 75R
BATTERY	✓ 515	✓ 515	✓ 500	✓ 515
BRAKES POWER	✓	✓	✓	✓
STEERING POWER	✓	✓	✓	✓
COOLING H.D.	✓	✓	✓	✓
GLASS TINTED	✓	✓	✓	✓
RADIO AM	✓	✓	✓	✓
MIRRORS	✓ Lo Lok	✓ Lo Lok	✓ Lo Lok	✓ Lo Lok
BUMPER	✓ Step	✓ Step	✓ Step	✓ Step
PRICE	10,497.61	11,477.00	N/A	10,194.41

Figure 4 - Quote Comparison

The lowest price should not always be the final qualifying factor. Before making the decision, verify service capabilities and past performance. Political considerations are also very important especially in this industry. It is often wiser to purchase from a dealer within the franchise area. Evidence of returning money to the community from which it came is always positive during rate increase hearings and franchise renewals.

3.0 MAINTENANCE

Maintenance is an area of fleet management which is second in importance only to accurate record keeping. While intensive preparation in vehicle selection and purchase is vital, it will all be for naught if proper preventative and repair maintenance procedures are not adhered to consistently.

3.1 Preventative Maintenance

3.1.1 Lube

Lubrication schedules are some of the most critical and frequent of all preventative maintenance procedures. Oil and oil filter replacements for the vehicle's engine, transmission, generator and other on board equipment must take place regularly and be monitored closely. Differential grease, brake and power steering pump fluids also require systematic level and condition checks. Steering and suspension components are in need of periodic lubrication.

The frequency of maintenance on each of these is determined by several factors:

3.1.1.1 Manufacturer's Recommendations

Most manufacturers will recommend maximum lubrication intervals. In order to maintain the warranty, these intervals are not to be exceeded.

3.1.1.2 Environmental Considerations

While the manufacturer establishes generous intervals, the environment will help to set more realistic maximums. Dust, sand and heat from the Southwest, salt sprays and humidity from the Eastern Seaboard and chloride from the icy roads of the Northlands all affect the vehicle's lubricants and, as a result, profoundly shorten their effective life. All of these substances, when not cleaned from metal surfaces, cause excessive wear and, eventually, breakdown.

3.1.1.3 Equipment Usage/Condition

A well tuned vehicle operated at a constant 55 MPH under cool and dry conditions for distances of more than twenty miles per trip will operate with less frequent lubrication intervals than the vehicle with an engine miss pulling a 5,000 pound load through the mud. Other factors such as idle time add lubricant wear and tear not reflected on the odomoter.

When establishing lubrication intervals, all of the above factors must be analyzed. The result should be general intervals, related to specific vehicle categories, that have both time and mileage "ticklers". For example, a light pickup averaging 12,000 miles per year should have a 2,500 miles or a 3 months interval, while a bucket truck, which spends a great deal of time idling, would more appropriately be scheduled for 2,000 miles or 200 hours.

The implementation of regularly scheduled lubrication intervals not only gives the confidence that comes from knowing that dirt is being cleaned out but also gives the operation greater availability of additional diagnostic information. Fluid leaks can be spotted. The coloration and smell of fluids being replaced provides insight into potential problems. Wear on mechanical components is readily detectable. In most cases, the repair or quick lube shop is more than willing to check all these points, while doing the full service lube and to give the operator a report on what is found.

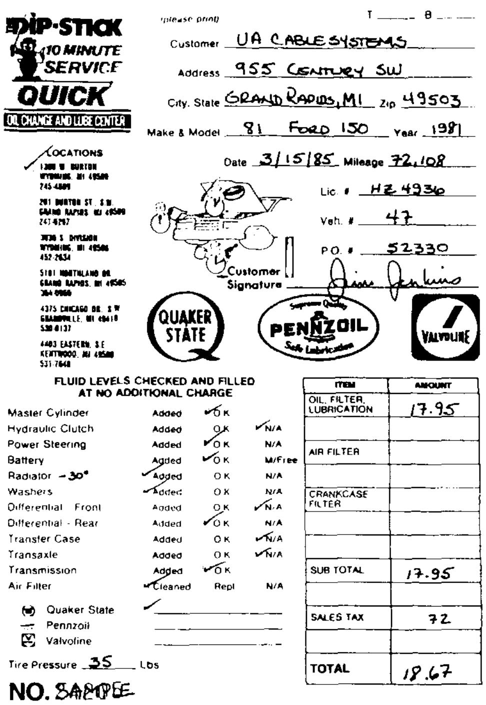

Figure 5 - Oil Change Inspection Report

Many subscribe to an oil/fluid analysis service which can give a more in depth picture of what wear is taking place inside the engine or transmission and will advise if that wear is within normal limits.

PPM BY WEIGHT — Spectrochemical Analysis

	IRON	LEAD	COPPER	CHROMIUM	ALUMINUM	NICKEL	SILVER	TIN	SILICON	BORON	SODIUM	PHOS.	ZINC	CALCIUM	BARIUM	MAGNESIUM
9802	062.	010.	003.	002.	000.	000.	00.0	000.	007.	000.	036.	1300	14 00	1530	0000	0270
7148	082.	010.	003.	002.	008.	000.	00.0	000.	008.	000.	030.	1310	14 10	1550	0000	0260
7955	150.	018.	005.	015.	038.	001.	00.0	010.	035.	000.	030.	1320	14 00	1510	0000	0270
	Wear Elements								Abrasives	Coolant Additives		Oil Additives				

Figure 6 - Oil Analysis Report

This information has not been shown to be consistent enough to be considered "Gospel" but rather a trend indicator.

The utilization of conservative lubrication intervals allows the Fleet Manager to extend the useful life of the vehicle by minimizing wear, to correct many problems before a costly breakdown occurs and, to operate a safer more cost effective fleet.

3.1.2 Tune Up

With today's modern engines, tune ups though less frequent, are still critical and substantially more expensive than in the past. Unleaded fuels, computerized ignition systems and electronically controlled fuel injection all combine to extend spark plug life and have actually eliminated components such as contact points and condensors. Tune up maintenance will generally be to improve driveability or correct running problems rather than strictly as preventative maintenance. The increased test equipment and mechanical skill levels required to maintain these technologically advanced systems, however, have increased the overall cost. Diagnostic time is such a factor that the mechanic has to have a solid working knowledge of both theory and application.

Tune up frequency will be based on several factors:

3.1.2.1 Manufacturer's Recommendations

Manufacturers have suggested maintenance intervals for various components in the ignition/fuel systems. While some of these may have an actually longer life than that recommended, warranty maintenance mandates compliance. Additionally, the recommended checks may reveal problems that are correctible at a lower cost than if left to breakdown.

3.1.2.2 Vehicle/Equipment Type

Whether a vehicle is normally aspirated or turbo charged, fuel injected or carbureted, has an electronic ignition system or plugs and points will also affect the maintenance frequency. The vehicle with a carburetor and standard ignition system will probably require, under normal usage, tune up maintenance every 10,000 - 14,000 miles. A multiport fuel injected vehicle with a computerized electronic ignition system will go 15,000 - 21,000 fairly easily.

3.1.2.3 Vehicle Usage/Conditions

Idling, frequent starts and stops and environmental conditions will also impact tune up maintenance schedules. As with lubrication scheduling, time rather than mileage, may often be the "tickler".

While all of the above must be considered in establishing an appropriate tune up maintenance schedule, the two primary ticklers will be driveability and fuel consumption. The individual operators are responsible for informing either the Fleet Manager or their Supervisor when their vehicle is not running right. The aforementioned proper record keeping will enable accurate monitoring of fuel consumption.

3.1.3 Tires

Proper tire maintenance is contingent on operator awareness. The operator is the individual who should be the first to be aware of the two primary causes of shortened tire life - improper inflation and front end alignment/tire balance:

3.1.3.1 Inflation

Tire pressures should be maintained within the manufacturers prescribed limits for loading, operating and environmental conditions. Under or over inflating causes excessive tread wear and can weaken sidewalls resulting in adversely affected handling and the danger of a blowout.

3.1.3.2 Alignment/Tire Balance

Improper alignment and/or tire balance will result in irregular wear patterns shortening tire life. Handling characteristics such as pulling, drifting, darting and wheel vibration will generally be manifest causing unpredictable and unsafe operation. Each vehicle operator is to visually note tire inflation and wear daily. Precise air pressure guage checks should be made at least weekly. Inflation and front end maintenance will result in safer and more dependable operation along with extended tire wear.

3.1.4 Cooling System

The vehicle's cooling system is as equally important as the lubrication system. This fluid keeps an engine from over heating while also preventing ice from forming and causing permanent component damage. Overheating is one of the primary causes of premature bearing and ring failure in engines. Freeze ups can cause severe cylinder head and engine block damage. Levels should be monitored and maintained at factory settings. Antifreeze effectiveness should be checked at every oil change and be kept between -25 to -40 F. The vehicle's entire cooling system should be backflushed at least every two years. The radiator should be cleaned periodically to keep it free from buildups of debris that restrict air flow thereby reducing effectiveness. Hoses should be visually checked at every oil change. The thermostat and pressure cap should be checked for proper operation at least yearly. An improperly operating thermostat can cause over heating or can prevent an engine from reaching proper operating temperatures. Use a good brand of antifreeze. All vehicles should be equipped with temperature guages so that the operator can monitor minor temperature increases or decreases that can affect performance.

3.1.5 Body Maintenance

There are two main sources of generation of body repair. One is corrosion and the other is accidental damage. Both can be addressed to a certain degree by preventative procedures.

3.1.5.1 Corrosion

Rust is a problem in most geographic areas and is a result of improperly treated or unprotected metal. Fleet operators need to take several steps to prevent this rust from starting, for once begun, it is difficult if not impossible to totally eradicate.

First, a vehicle should be thoroughly rustproofed by a reputable company before being put into service. Firms such as Rusty Jones, Ziebart, Tuff Kote Dinol and others will do a comprehensive job and offer rust through warranties.

Keep in mind that just rustproofing a vehicle when it is new is not sufficient. Most warranties require annual cleanings and inspections. While these inspections and any touchups usually are without charge, the cleaning necessary to do the inspection is not. This cost can be minimized by regular cleanings of both the outer and under bodies. In addition to keeping inspection cost down, this procedure will help in preventing rust.

The vehicle should be checked

periodically for stone chips and other sources of surface rust. Use rubbing compound to clean the surface and then touch up with the manufacturers recommended touch-up paint. This few minutes weekly will help to add to the usable life of the vehicle and to good customer perception of the operation.

3.1.5.2 Accidental Damage

The most prevalent type of body damage is the small ding and dent variety. Prevention of this type of repair is, as in most moving vehicle accidents, 90% the responsibility of the operator.

There are a number of procedures that can be used in bringing driver generated damage under control:

When a person is considered for a position, initiate a driving record check with the State Department of Motor Vehicles. Visually check each operators driving permit annually. Make the ability to safely operate a vehicle part of the criteria for getting and keeping a job.

When an employee is being trained to perform their specific job function, include, as intregal part of the training, how to safely, by regulatory and company standards, operate their vehicle. The driver must perceive the vehicle as an expensive tool requiring proper operation and maintenance.

Provide long term safe driving recognition and awards on a frequent basis. Do not assume that pride in one's vehicle and driving record comes naturally.

Set up disciplinary procedures for incidents of preventable accidents. These actions should range from time off without pay up to and including termination. Accident damage is not only expensive to repair but also endangers health and the community's perception of the company.

The Fleet Manager or department supervisor should physically check each vehicle for damage and safety problems (i.e. broken mirrors, poor housekeeping, etc.) at least monthly.

3.2 Repair Maintenance

Repair is expensive. The cheapest approach to repair is always a comprehensive preventative maintenance program. Even the best PM programs cannot prevent all component failure and when that happens, the Fleet Operator must be prepared to respond in the most effective manner. A decision must be made regarding who will repair the vehicle. Will it be a specialty shop, a dealership, general repair garage or maybe the company's own in-house mechanic? For most fleets, however, the latter cannot be cost justified and will not be considered at this time.

Generally, a hybrid approach must be taken with several factors being considered.

First is quality of work. No matter how quickly or inexpensively the work is completed, if it's not right it's not quick enough and too expensive. Check past information in the vehicle files for an insight into repair shops performance. Also spot check each shop's equipment, mechanical expertise and work in progress.

Secondly is down time. The time a technician spends waiting for a vehicle to be repaired is money lost. A shop that can provide repairs during off hours or one that will give your fleet higher priority should be given higher consideration.

Thirdly is cost. Cost can be controlled in several ways. The fleet operator should request fleet quotes on different types of repairs, negotiate discounted rate structures, obtain work quality guarantees and use flat rate manuals to verify that services performed are not being overcharged. These manuals can be purchased through a local distributor. Some dealers however, will even provide this to their fleet accounts as a method of assuring dealer intent and retaining the account. The best manuals to use are Chiltons, Motor or Mitchell.

As was stated, a hybrid approach will generally be the most effective. Send all warranty work to the selling dealer if geographically possible. Use specialty shops for brake, exhaust, transmission and tire repair. These are specialists, usually guaranteeing their work and probably giving the fastest turn around. Establish a relationship with a good general repair shop that can take on miscellaneous and long term repair. Monitor the work performed and the stability of costs. Annually request quotes and re-evaluate the shops being used

Utilizing these procedures and a good PM program will maximize the fleet operator's control of cost and the operating life of the vehicles.

4.0 FUEL

The fleet operator is faced with essentially three fuel alternatives in powering his fleet - gasoline, diesel and propane. He can buy this fuel at a local pump or can fill up at a company owned and operated pump. Which fuel type and source is the best?

4.1 Fuel Type

4.1.1 Gasoline

Unleaded gasoline is the predominant vehicle fuel sold. It is readily available, relatively inexpensive and most vehicles can be specified to run on it.

Gasoline fuel systems are more complex and expensive to maintain than diesel but also more familiar to most service shops than diesel or propane.

4.1.2 Diesel

Diesel powered light duty vehicles are more common now than twenty years ago. Diesels will exhibit better fuel consumption rates than similar gasoline fired vehicles. Diesel fuel is almost as readily available as unleaded gasoline and more so than propane though it is somewhat more expensive than either. High usage rate diesel powered vehicles generally are cheaper to operate than their gasoline powered counterparts. Light duty U.S. diesels are being phased out by GM and are available in quantity only from Ford. There are fewer shops that will do repair and and maintenance on diesels and diesel engines cost more.

4.1.3 Propane

While fairly popular ten years ago, propane is not being used as much as was originally projected. Propane can provide both lower unit cost and better consumption rates than gasoline or diesel. It requires special fuel tank and fuel system modifications and is not as readily available as the other fuels.

For most fleets, gasoline powered passenger cars and light duty trucks are preferrable to diesel or propane. The general unavailability of diesel powerplants in all light duty equipment but Ford makes the diesel's future in this class uncertain. Fuel system technology is advancing rapidly enough to make manufacturers compliance with CAFE standards using gasoline powered engines almost a certainty thereby assuring continued availability and MPG improvement.

Medium, heavy and 4 x 4 trucks are another matter. Diesels such as the International 6.9L, the Detroit 8.2L and others of the same type are readily available and well proven. Fuel consumption rates average approximately fifty percent higher than similar gasoline powered units. Ignition systems in the newer generation of diesels are sufficiently improved that winter starts no longer need be a problem. When specifying a diesel, however, great care must be exercised in gearing. To obtain the maximum efficiency from the more expensive diesel engine, it must be operated within its designed range. A knowledgeable truck rep can be invaluable in properly equipping these vehicles.

Propane powered vehicles are not usually recommended for fleet usage. The cost of installation of the propane system is rarely returned through improved performance and the limited availability of fuel sources is inconvenient.

4.2 Fuel Sources

Whether to purchase gas from a local gas station, a company owned pump or from a combination of the two is a decision that requires due diligence. Each has its positive and negative aspects and must be considered in the light of several factors.

How much of what types of fuel are pumped monthly? Is there a service station operator that will carry a running tab and invoice monthly? Will all drivers have to carry major oil company credit cards? Is there the physical space to install a fuel tank and pump? Is the area zoned for a pump?

If there is physical space, the area is zoned properly, and the fleet uses three thousand gallons or more of a particular type of fuel monthly, there is probably sufficient justification for a company owned pump. The comany owned pump allows access twenty four hours a day, seven days a week which can be very beneficial during late night or Sunday long term outages. It will save a net cost of about three cents per gallon if monthly purchases are under ten thousand gallons and about five cents if over that amount. It is more easily controllable than credit cards which are subject to misuse. If used as the only source of fuel, it is inconvenient for trucks deep in system which need to fill up.

The best approach for those fleets that can justify a pump will be to use the pump as the primary source of fuel and issue a limited number of credit cards to the specific field personnel who need them. A sign out log or computerized issue system should be incorporated with the company pump. Individual vehicle gas logs should be maintained. Monthly, all credit card slips and the company pump log should be reconciled aganst the vehicle logs and the tank stick measurements. This will allow the maximum in cost savings while not sacrificing convenience or control.

5.0 CONCLUSION

When analyzing fleet management, one must bear in the mind that the fleet of vehicles exists primarily for the conveyance of workers and equipment to and from the job site. All efforts must be directed at meeting that need as efficiently and consistently as possible. Implementing the above suggestions will assist in accomplishing that objective while concurrently controlling costs. The results of effective fleet management will be reduced costs with improved integrity.

GASOLINE LOG

DRIVER: Verne Reed VEH #: 214 VR 6-90

DATE (JULIAN)	ODOMETER (LAST FILL-UP)	ODOMETER (THIS FILL-UP)	GALLONS/ LITERS	LOCATION CODE	COMMENTS
8-6		35 690	18.0		* Last Entry from July
8-8	35 690	35 771	13.6	1	
8-10	35 771	35 901	17.7	1	
8-13	35 901	36 028	16.4	1	
8-15	36 028	36 138	18.9	16	
8-16	36 138	36 258	18.2	1	
8-21	36 258	36 369	19.5	1	
8-23	36 369	36 480	17.0	1	
8-27	36 480	36 598	16.98	1	
8-28	36 598	36 718	17.8	1	
8-29	36 718	36 817	16.9	1	
8-30	36 817	36 908	17.3	1	
8-30	36 908	36 982	16.8	5	
8-31	36 982	37 114	18.2	1	
9-2	37 114	37 244	17.9	1	
		MILES: 1 554	GALS: 243.2		M.P.G.: 6.4

CODE #	GAS STATION LOCATION	CODE #	GAS STATION LOCATION
1	G.R. OFFICE	13	COOPER'S, 7535 MAIN, JENISON
2	N E. HUB	14	EASTERN, 5225 EASTERN S.E.
3	BENTON'S, 5 - 28TH S.W.	15	GEORGE'S, 3287 ALPINE
4	BRETON, 2363 - 28TH S.E.	16	LANGS, 3960 28TH SW
5	BUCHANAN'S, 4417 KALAMAZOO	17	PAGANELLI'S, 608 - 28TH S.W.
6	DAN'S, 2600 E. BELTLINE	18	PAUL'S, 1201 MICHIGAN N.E.
7	DAN'S, 3603 BYRON CENTER	19	SHELL, 415 S. DIVISION
8	MARINER'S, 808 - 44TH S.W.	20	WONDERLAND, 4133 W. RIVER DR.
9	MARINER'S, 5381 S DIVISION	21	
10	JAY'S, 3960 - 28TH S E.	22	
11	MASON & NOVITSKY'S, 2050 LEONARD N.W	23	
12	CASCADE HILLS, 4019 CASCADE	24	OTHER

Figure 7 - Monthly Gas Log

6.0 ACKNOWLEDGMENTS

I would like to thank Frank Baxter, Vice-President of Engineering of UACC Midwest, Inc., for his encouragement in the preparation of this paper. Thanks also to Bill Kimmel, Don Peterson and especially to Paul Brooks for his friendship and editorial support.

EFFECTS OF CHANNEL LOADING ON COMPOSITE TRIPLE BEAT AND CROSS MODULATION

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Lee Thompson

Scientific-Atlanta, Inc.

Distortion in CATV amplifiers is due to the non-linearity of the hybrids and is influenced by channel loading and signal level. Composite triple beat and cross modulation, which are both forms of third order distortion, increase 2 dB for every 1 dB increase in signal level assuming that the hybrid is not in compression. An attempt will be made to develop an expression that accurately reflects the change in CTB and cross modulation with respect to channel loading.

The data used to generate the empirical equations for CTB and cross modulation is the result of several thousands of individual distortion measurements performed at Motorola on a total of 60 CATV hybrids using 6 different types of hybrids. The objectives of the test were to characterize the effects of distortion as a function of channel loading for sub-split, mid-split, and high-split systems.

The results of the tests show that CTB and cross modulation depend not only on the number of channels, but also on the frequency where the beat product falls. The change in CTB and the change in cross modulation due to increased channel loading cannot generally be determined by simply considering the number of new channels alone.

CASE #1 Changes in distortion caused by changes in channel loading at the high end of the band.

The equation, F (N1, N2), chosen to fit the data is an extension of the form K*log (N1/N2) that is presently used to describe changes in CTB and cross modulation as a function of new channel loading, N1, and old channel loading, N2. A correction term, G (N1, N2), is added to provide a second degree of freedom so that the least-squares error between the analytical equation and the empirical data can be further minimized.

The equation

$$F(N1,N2)=K1*\log(N1/N2)+G(N1,N2) \quad (1)$$

must satisfy the following conditions:

1. As N1 approaches N2, F (N1,N2) approaches 0
2. F (N1,N2) + F (N2,N3) = F (N1,N3)
3. F (N1,N2) = -F (N2,N1)
4. F (N1,N2) must continuously increase as the number of channels increases

CTB distortion is influenced not only by the number of beats falling on the channel under test but also by the frequency of the test channel. A 234-450 MHz high-split system with 37 channels has worse distortion at 450 MHz than a 54-330 MHz sub-split system with 41 carriers does at 330 MHz. In a cable system, if the number of channels at the high end of the band were to be increased in a linear rate, the CTB would increase in a greater than linear rate. One reason for this is that the number of triple beats at any channel is proportional to the square of the number of channels; in particular, for a system with equally spaced channels, the number of triple beats at the highest channel is $[(N-1)/2]^2$. Conditions #4 above is satisfied by this relationship.

A simple equation that meets these four conditions is:

$$\Delta CTB=K1*\log(N1/N2)+K2*(N1^2-N2^2)/2000, \quad (2)$$

and

$$\Delta \text{Cross modulation} =K3*\log(N1/N2)+K4*(N1^2-N2^2)/2000 \quad (3)$$

Where ΔCTB and ΔCross modulation are the changes in distortion in going from old channel loading, N2, to new channel loading, N1.

The data used to curve fit equations (2) and (3) is the result of thousands of distortion measurements

TABLE 1

CHANNEL LOADINGS USED FOR HYBRID TESTS

SUB-SPLIT	MID-SPLIT	HIGH-SPLIT
61 channels 55.25-451.25MHz	47 channels 175.25-451.25MHz	37 channels 235.25-451.25MHz
52 channels 55.25-397.25MHz	38 channels 175.25-397.25MHz	28 channels 235.25-397.25MHz
41 channels 55.25-331.25MHz	27 channels 175.25-331.25MHz	17 channels 235-25-331.25MHz

taken on individual hybrid amplifiers. CTB and cross modulation were measured at the low end and the high end of the band for the 6MHz channel loadings listed in Table 1.

Distortion measurements were taken at 46dBmV hybrid output level with 0dB tilt. These measurements were repeated for 3dB and for 6dB of cable equivalent tilts for sub-split loading. Mid-split and high-split channel loadings were obtained by simply turning off the lower channels without readjusting the tilt as it was set up for the sub-split case. The test results showed that CTB is generally worse at the higher frequencies and cross modulation is worse at the lower frequencies. Also CTB and cross modulation did not get substantially better in going from 450MHz sub-split to 450MHz high-split loading, although they were progressively worse by comparison in going from 330MHz sub-split to 450MHz high-split channel loading.

The test data was used to solve for the coefficients K1,K2,K3, and K4 in equations (2) and (3) using a least squares solution to an overdetermined system of linear equations. These coefficients are listed in Table 2.

The mean-square error in these tables is given by

$$\sqrt{\sum_{i=1}^{N} \frac{r_i^2}{N}}$$

where r_i is the residue of the ith linear simultaneous equation used to solve for the coefficients K1, K2, K3, and K4.

The data taken at 0dB tilt, 3dB tilt, and 6dB tilt can be combined to provide a single approximating equation for these three cases without increasing the mean-square error. These coefficients are listed in Table 3.

Further reduction is possible because the coefficients K1, K2, K3, and K4 can be closely described by an exponential function. The resulting equations are:

$$\Delta CTB = 22.378*\log(N1/N2)+4.92 *e^{0.0029FL} *(N1^2-N2^2)/2000 \quad (4)$$

$$\Delta \text{Cross Modulation} = 43.526*e^{0.001965FL}*\log(N1/N2) - 2.055*e^{0.004189FL} *(N1^2-N2^2)/2000 \quad (5)$$

Equations (4) and (5) can be used to predict the change in CTB and the change in cross modulation as channels are added (or subtracted from) the high end of the band with the low end fixed at some predetermined frequency, FL, between 54MHz and 234MHz. The computed change in distortion as a function of channel loading is listed in Table 4.

CASE #2 Changes in distortion caused by changes in channel loading at the low end of the band.

If channel loading is changed by adding (or removing) channels from the low end of the spectrum, with the high end constant, then a new set of equations must be developed to describe the change in CTB and the change in cross modulation. Applying least squares solution to an overdetermined set of linear simultaneous equations yields the coefficients listed in Table 5.

TABLE 2

ΔCTB

SUB-SPLIT	K1	K2	MEAN-SQUARE ERROR
0dB tilt	36.7895	3.16712	0.5309
3dB tilt	17.9795	6.8319	0.4994
6dB tilt	12.6939	7.67	0.6253
MID-SPLIT			
0dB tilt	27.6869	6.1294	0.5625
3dB tilt	23.6957	7.0402	0.6484
6dB tilt	14.7859	9.7131	0.8102
HIGH-SPLIT			
0dB tilt	25.9	8.6362	.7773
3dB tilt	22.396	10.222	.9463
6dB tilt	19.474	11.6365	.8086

ΔCROSS MODULATION

SUB-SPLIT	K3	K4	MEAN-SQUARE ERROR
0dB tilt	34.2969	-1.9995	0.6495
3dB tilt	37.8658	-2.3286	0.6046
6dB tilt	43.3751	-3.4727	0.5979
0dB tilt	31.8567	-3.7134	0.7525
3dB tilt	32.0924	-3.7179	0.7327
6dB tilt	33.4841	-4.9949	0.7396
0dB tilt	28.8249	-6.1806	0.8077
3dB tilt	26.6492	-5.6224	0.7234
6dB tilt	24.325	-4.9346	0.8726

The coefficients are listed for tilts of 0dB, 3dB, and 6dB. It is not possible to continue toward a single equation that applies for any value of tilt (as was done in case #1) without seriously degrading the mean-square-error. In order to apply the information in Table 5 to a system with, for example, 4dB of tilt it is necessary to compute ΔCTB and Δcross modulation assuming 3dB of tilt and 6dB of tilt and interpolate. As stated earlier, tilt is cable equivalent tilt referenced from 54MHz to the high channel (331.25MHz, 397.25MHz or 451.25 MHz) for sub-split, mid-spit and high-split systems.

CASE #3 Changes in distortion caused by a change in channel loading at the low end and at the high end, simultaneously.

Calculating changes in distortion caused by changes in channel loading at the low end and at the high end of the band is simply an application of case #1 and case #2. A small difference in the computed result will occur depending on whether the change in distortion is computed by first considering the change in channel loading at the high-end (case #1) and then be adjusting for changes in channel loading at the low-end (case #2), or vice-versa. The change in distortion should be computed both ways and the result averaged.

CASE #4 Distortion in a system spaced other than 6MHz.

Distortion in a non-6MHz system can be calculated relative to a comparable 6MHz spaced system by

$$10*\log(N1/N2) \qquad (6)$$

where N1 is the number of triple beats at frequency, F, in a 6MHz system and N2 is the number of triple beats at the same frequency, F, in a system spaced other than 6MHz. The use of the same equipment for both systems and the same high and low-end frequencies is implied. The number of triple beats and the computer program to calculate the number

TABLE 3

Δ CTB

K1	K2		MEAN-SQUARE ERROR
22.4876	5.8897	Sub-Split	0.5882
22.056	7.6275	Mid-Split	0.7096
22.59	10.165	High-Split	0.8702

Cross Modulation

K3	K4		MEAN-SQUARE ERROR
38.51	-2.6003	Sub-Split	0.6238
32.477	-4.142	Mid-Split	0.7544
26.5999	-5.579	High-Split	0.8298

Δ TABLE 4

Sub-Split (54MHz to 330/400/450MHz)

	Bandwidth Change
Δ CTB = 4.33dB	330MHz to 400MHz
Δ CTB = 4.55dB	400MHz to 450MHz
Δ XMOD = 2.64dB	330MHz to 400MHz
Δ XMOD = 1.35dB	400MHz to 450MHz

Mid-Split (174MHz to 330/400/450MHz)

	Bandwidth Change
Δ CTB = 6.00dB	330MHz to 400MHz
Δ CTB = 4.95dB	400MHz to 450MHz
Δ XMOD = 3.34dB	330MHz to 400MHz
Δ XMOD = 1.41dB	400MHz to 450MHz

High-Split (234MHZ to 330/400/450MHz)

	Bandwidth Change
Δ CTB = 7.41dB	330MHZ to 400MHz
Δ CTB = 5.71dB	400MHz to 450MHz
Δ XMOD = 4.38dB	330MHz to 400MHz
Δ XMOD = 1.58dB	400MHz to 450MHz

of triple beats occurring at any frequency for a 6MHz spaced system is given in Table 6. The computer program calculates, for each channel, all possible triple beats, FB, produced by F1, F2 and F3 such that

FB = F1 + F2 - F3
FB = F1 - F2 + F3
FB = -F1 + F2 + F3
FB = 2F1 - F2, and
FB = F2 - 2F1.

The situation where the triple beat falls on the same frequency as a carrier producing that triple beat, is not allowed.

TABLE 5

Δ CTB

Upper Frequency 450MHz	K1	K2	Mean-Square Error
0dB tilt	21.2408	-0.8260	0.1732
3dB tilt	21.6743	-1.7904	0.08844
6dB tilt	12.4627	-0.94018	0.10
400MHz			
0dB tilt	21.1186	-0.8089	0.4007
3dB tilt	19.498	-1.6228	0.2436
6dB tilt	17.6072	-2.3779	0.21505
330MHz			
0dB tilt	21.7981	-1.2693	0.3385
3dB tilt	19.6684	-2.7336	0.3498
6dB tilt	20.2212	-4.9050	0.3029

Δ Cross Modulation

Upper Frequency 450MHz	K3	K4	Mean-Square Error
0dB tilt	27.3634	-0.1026	0.38814
3dB tilt	29.2604	-1.0479	0.3388
6dB tilt	20.69899	-0.21577	0.52345
400MHz			
0dB tilt	22.686	-0.3277	0.5559
3dB tilt	23.0488	-1.332	0.5736
6dB tilt	21.74025	-1.816	0.59137
330MHz			
0dB tilt	21.1496	-0.1468	0.4165
3dB tilt	18.5581	-0.7348	0.3918
6dB tilt	17.828	-1.9623	0.4138

TABLE 6

6MHz SPACING

NUMBER OF TRIPLE BEATS PER CHANNEL

FREQ	1	2	3	4	5	6	7	8	9	10	11
55.25		640		615		435			240		
61.25		664	608	639		455			254		
67.25		687	632	661		473			267		
77.25		57	56	56		48			37		
83.25		57	56	56		48			37		
121.25		895	849	865		641			385		
127.25		921	875	890		662			401		
133.25		944	898	913		681			414		
139.25		965	920	933		697			425		
145.25		985	941	953		713			435		
151.25		1004	961	971		727			444		
157.25		1022	980	989		741			452		
163.25		1039	998	1005		753			459		
169.25		1055	1015	1021		765			465		
175.25	529	1071	1032	1036		776	342		471	169	
181.25	550	1086	1048	1051		787	359		476	180	
187.25	571	1101	1063	1065		797	375		481	191	
193.25	590	1114	1077	1078		806	390		484	200	
199.25	609	1127	1090	1090		814	404		489	209	
205.25	626	1138	1102	1101		821	417		491	216	
211.25	643	1149	1113	1111		827	429		492	224	
217.25	658	1158	1123	1120		832	440		491	228	
223.25	673	1167	1132	1128		836	450		490	233	
229.25	686	1174	1140	1135		840	459		488	236	
235.25	699	1181	1147	1141	324	844	467	182	487	239	64
241.25	710	1186	1153	1146	340	845	474	194	484	240	70
247.25	721	1191	1158	1150	356	845	480	205	481	241	76
253.25	730	1194	1162	1154	370	844	485	215	476	240	80
259.25	739	1199	1166	1158	384	842	489	224	471	241	84
265.25	746	1201	1169	1159	396	841	492	232	464	240	86
271.25	753	1202	1170	1159	408	839	494	239	457	239	88
277.25	758	1201	1170	1158	418	836	495	245	449	236	88
283.25	763	1200	1169	1156	428	832	495	250	442	233	88
289.25	766	1198	1168	1155	436	827	495	254	434	228	88
295.25	769	1197	1167	1153	444	821	495	257	426	223	88
301.25	770	1194	1165	1150	450	814	494	259	416	216	86
307.25	771	1191	1162	1146	456	806	492	260	406	209	84
313.25	770	1186	1158	1141	460	797	489	260	394	200	80
319.25	771	1181	1153	1135	464	787	485	260	382	191	76
325.25	770	1174	1147	1128	466	776	480	260	367	180	70
331.25	769	1167	1140	1120	468	764	474	259	350	169	64
337.25	766	1158	1132	1111	468	751	467	257			
343.25	763	1149	1123	1101	468	738	459	254			
349.25	758	1138	1113	1090	468	725	450	250			
355.25	753	1127	1102	1078	468	712	440	245			
361.25	746	1114	1090	1065	466	698	429	239			
367.25	739	1101	1077	1051	464	683	417	232			
373.25	730	1086	1063	1036	460	667	404	224			
379.25	721	1071	1048	1020	456	650	309	215			
385.25	710	1054	1032	1003	450	632	375	205			
391.25	699	1037	1015	986	444	612	359	194			
397.25	686	1019	997	969	436	589	342	182			
403.25	673	1002	979	952	428						
409.25	658	984	961	934	418						
415.25	643	956	942	915	408						
421.25	626	946	922	895	396						
427.25	609	926	901	874	384						
433.25	590	904	879	852	370						
439.25	571	882	856	828	356						
445.25	550	857	832	801	340						
451.25	529	830	805		324						

8MHz SPACING

FREQ	NUMBER OF TRIPLE BEATS
153.25	342
161.25	359
619.25	375
177.25	390
185.25	404
193.25	417
201.25	429
209.25	440
217.25	450
225.25	459
233.25	467
241.25	474
249.25	480
257.25	485
265.25	489
273.25	492
281.25	494
289.25	495
297.25	495
305.25	495
313.25	495
321.25	494
329.25	492
337.25	489
345.25	485
353.25	480
361.25	474
369.25	467
377.25	459
385.25	450
393.25	440
401.25	429
409.25	417
417.25	404
425.25	390
433.25	375
441.25	359
449.25	342

COLUMN DESCRIPTION

1 Number of triple beats on any channel for a 47 channel,6MHz spaced mid-split system.

2 Number of triple beats on any channel for a 60 channel,6MHz spaced sub-split system.

3 Number of triple beats on any channel for a 59 channel, 6MHz spaced sub-split system.

4 Number of triple beats on any channel for a 59 channel, 6MHz spaced sub-split system.

5 Number of triple beats on any channel for a 37 channel,6MHz spaced high-split system.

6 Number of triple beats on any channel for a 52 channel, 6MHz spaced sub-split system.

7 Number of triple beats on any channel for a 38 channel, 6MHz spaced mid-split system.

8 Number of triple beats on any channel for a 28 channel, 6MHz spaced high-split system.

9 Number of triple beats on any channel for a 41 channel, 6MHz spaced sub-split system.

10 Number of triple beats on any channel for a 27 channel, 6MHz spaced mid-split system.

11 Number of triple beats on any channel for a 17 channel, 6MHz spaced high-split system.

12 Number of triple beats on any channel for a 38 channel, 8MHz spaced system.

NOTE: For an HRC system, the triple beat caused by F1+F2+F3 must also be included in the program. This can be done at line 205 with 205 count(INT(A(I)+A(J)+A(J)+A(K))=count(INT(A(I)+A(J)+A(K))+1.

```
10 DIM A(78),COUNT(1100)
20A(1)=55.25
30A(2)=61.25
40A(3)=67.25
50A(4)=77.25
60A(5)=83.25
70FORI=1TO73
80A(I+5)=121.25+(I-1)*6
90NEXT
100 INPUT "LOW FREQ CHANNEL NUMBER", LF
110 INPUT "HIGH FREQ CHANNEL NUMBER", HF
120 FOR I=LF TO HF-2
130 FOR J=I + 1 TO HF-1
1 FOR K=J+1 TO HF
1A=ABS (A(I)+A(J)-A(K))
160  IF  A=A(K)  THEN  COUNT  (INT(A))=
COUNT(INT9A))+1
170  A=ABS(A(I)-A(J)+A(K))
180   IF A=A(J) THEN COUNT (INT(A))=
COUNT(INT(A))+1
190  A=ABS (-A(I)+A(J)+A(K))
200   IF A=A(I) THEN COUNT (INT(A))=
COUNT (INT(A))+1
210  NEXT
220  NEXT
230  NEXT
240  FOR I=LF to HF-1
250  FOR J=I + 1 TO HF
260  A=ABS (2*A(I)-A(J))
270  COUNT (INT(A))=COUNT (INT(A))+1
280  A=ABS (2*A(J)-A(I))
290  COUNT (INT(A))=COUNT (INT(A))+1
300  NEXT
310  NEXT
320  FOR I=LF TO HF
330  LPRINT A(I), COUNT (INT(A(I))
340  NEXT
350  STOP
360  END
```

For a system operated at 0dB tilt, it is easy to relate the triple beat at a particular frequency to the composite triple beat (CTB) at that frequency. To show this, six hybrids were measured at 0dB tilt and 46dBmV output level for an average CTB of -59.4dB at 445.25MHz with 54MHz - 450MHz sub-split loading. The average measured triple beat was -89.75dB at 445.25MHz (adjusted for level). With 801 triple beats present at 445.25MHz, the expected CTB, based on a triple beat measurement of -89.75dB, is -60.72, compared with an actual measured CTB of -59.4dB (see Table 7).

The purpose of this test was two-fold. It shows that the magnitude of the triple beat at any particular channel is independent of the choice of frequencies, F1, F2, and F3 that produce that beat, and that the composite triple beat can be accurately related to a single triple beat measurement by equation (6). However, the magnitude of the triple beat is dependent on the frequency on which the triple beat falls, with the higher frequencies giving worst results.

NOTE: Each triple beat measurement is an average of seven individual triple beat measurements involving different combinations of frequencies, F1, F2, and F3 such that F1 + F2 - F3 = 445.25MHz. The choice of channels for F1, F2, and F3 made no difference in the magnitude of the triple beat at 445.25MHz.

The accuracy of equation (6) for predicting ΔCTB at the highest channel as a function of the change in the number of triple beats can also be compared against the data in Table 5 using a 0dB tilted system and the data in Table 7. Here Table 5 is used to predict the change in CTB at the highest channel in the band as channels are removed from the low end of the band. The data in Table 7 used with equation (6) represents a theoretical approach and gives "close" results.

As a final illustration, the CTB of a 150MHz to 450MHz system with 8MHz channel spacing and a 3dB hybrid output tilt can be determined by application of the data in Table 5 and equation (6). A starting point is required and might, for example, be the CTB of a 54MHz to 450MHz, 6MHz spaced system operating at

TABLE 7

CTB and Triple Beat Measurements on Individual Hybrid

Hybrid	**CTB at 445.25MHz**	**Triple Beat at 445.25MHz**
1	-60.5	-91.9
2	-59.9	-88.5
3	-60.8	-92.1
4	-59.4	-90.4
5	-59.3	-89.4
6	-56.6	-86.2
AVERAGE	-59.4	-89.75

NOTE: Each triple beat measurement is an average of seven individual triple beat measurements involving different combinations of frequencies, Fl, F2, and F3 such that Fl + F2 - F3 = 445.25MHz. The choice of channels for Fl, F2, and F3 made no difference in the magnitude of the triple beat at 445.25MHz.

TABLE 8

Test Channel	**Change in loading**	**ΔCTB predicted by Table ΔCTB**	**ΔCTB predicted by 10*log(Nl/N2)**		
445.25MHz	SS to HS	3.64dB	4.1dB,	Nl = 830,	N2 = 324
397.25MHz	SS to HS	4.90dB	5.1dB,	Nl = 589,	N2 = 182
331.25MHz	SS to HS	7.45dB	7.4dB,	Nl = 350,	N2 = 64

a 3dB hybrid output tilt with a known CTB distortion. A 1 CTB of 1.19dB is calculated from Table 5 based on Nl = 52 and N2 = 61 for a 150MHz to 450MHz bandwidth, 6MHz spacing, and a 2 CTB of 2.62 dB is calcusing 10*log (Nl/N2) where Nl = 625 for a 6MHz spaced system and N2 = 342 for an 8MHz spaced system. The total CTB is therefore 3.81dB better than the performance of the same equipment operating with a 6MHz channel spacing from 54MHz to 450MHz.

SUMMARY

The results presented here are optimal in the least-squares sense for CATV cable systems employing sub-split (54MHz), mid-split (174MHz), or high-split (234MHz) bandwidths with a high end frequency between 330MHz and 450MHz. The accuracy of the approximating equations, if used outside this range, should deteriorate significantly. More data is required on a wider variety of hybrids in the 54MHz to 550MHz region in order to develop a method of predicting changes in distortion versus changes in channel loading and channel spacing throughout the entire CATV band. The author would like to thank the Motorola RF & Optoelectronic Products Division in Phoenix, Arizona, for the use of their automatic test facility that made this article possible.

ENCRYPTION FUNDAMENTALS - A NON-TECHNICAL OVERVIEW

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ABSTRACT

A popular buzzword today, "encryption" and its various spinoff terminology (cryptography, cryptanalysis, cypher...) are frequently used to bombard the observer attempting to understand an application into submission. Submission that the subject is just too esoteric for the average technocrat to understand; such that one just has to accept the "bombardier's" obfuscation.

This paper will explain in layman terminology the basics of encryption, as it's being applied in today's TV industry:

1. What is it?
2. Why do it?
3. What's special about it?
4. What are encryption algorithms, encryption keys?
5. Can it be misused, abused?
6. What questions should be asked about its application?
7. Why is it different from scrambling?
8. Why now?

The concepts of encryption and its proper application can be explained at a nontheoretical level. The paper will discuss the significance of digital versus analog coding for encryption applications, the many methods of using the encryption algorithm and why the algorithm (such as DES) does not represent the "strength" of an encryption system. The use of controlled access key variables as the most important problem to solve in any encryption application will be explained, and why, through solving that problem, encryption avoids the necessity for secrecy of circuits or physical security.

FIBER OPTIC TECHNOLOGY FOR CATV SUPERTRUNK APPLICATIONS

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ABSTRACT

A review of the optical fiber technology currently available for long-haul, multi-channel CATV interconnections, intended to provide groundwork for CATV system engineers exploring fiber optic options for their applications. Video FM coaxial transmission techniques are reviewed and compared with both analog and digital video fiber optic transmission. Performance and cost comparisons are made. The conclusion is drawn that while video FM coaxial transmission continues to have advantages, both analog and digital video fiber transmission are already attractive alternatives in some applications, and will become more so in the future.

INTRODUCTION

This presentation is not intended to be a definitive study of fiber optics, but to provide pertinent background information to CATV system engineers wishing to evaluate the fiber alternative to traditional supertrunking. It represents a collection of information from technical literature, fiber optic cable and equipment vendors who have targeted the CATV market, and CATV engineers with fiber optic experience. It was gathered while researching fiber for a specific application This information is intended as a starting point rather than an answer.

Applications for fiber in CATV may include system hub interconnects, earth station links, and advertising interconnections between systems. Much of the information presented is also applicable to systems which will be used to carry data and other kinds of information.

Optical fiber transmission of video can be cost competitive with RF transmission, depending on distance, number of channels, performance requirements, and system configuration, and is inherently more reliable. There are a growing number of systems in use, and their experience indicates that great strides have been made in the last few years in this technology.

The three alternatives that will be compared are FM video carried over traditional coaxial cables, analog video carried via fiber, and digital video via fiber.

VIDEO FM VIA COAXIAL CABLE

This technology has been in use for at least a decade and is fairly familiar in the CATV industry. A block diagram of a typical system is shown in figure 1. Video channels (with their associated audio information) are frequency modulated at different frequencies and the resulting RF carriers are combined onto one or more coaxial cables, depending on trunk bandwidth and the number of channels required. These systems typically require 12 to 16Mhz of bandwidth per video channel. Cable-powered broadband amplifiers are located every 2,000 to 3,000 feet to compensate for cable losses. The coaxial network can undergo almost unlimited branching using conventional CATV techniques. The video signals are recovered at the destination point or points through demodulation.

The performance of these systems is largely determined by the noise and distortion introduced by the cascade of trunk amplifiers. Reliability is also determined by the number of active devices in use, primarily trunk amplifiers, and by their dependence on the local power utility. Preventing ingress and egress of RF signals is of significant concern in both construction and operation.

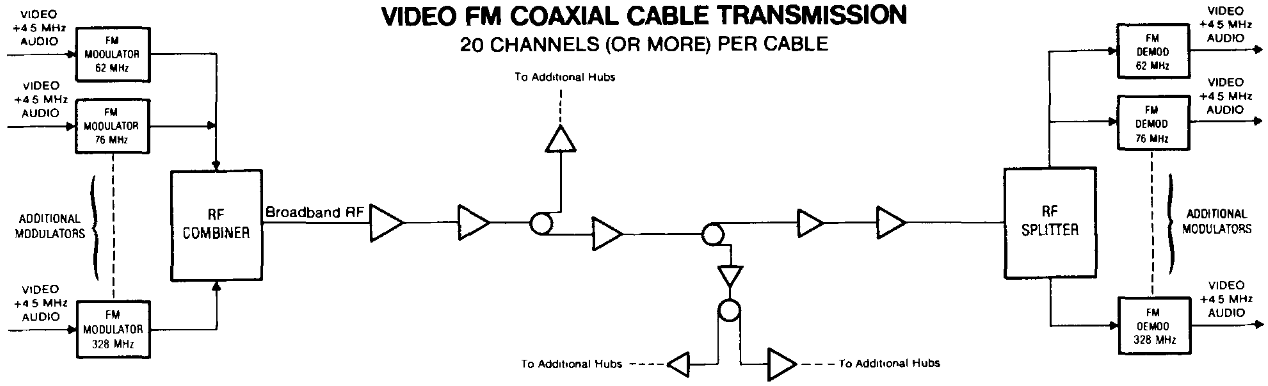
The costs of these systems, in addition to labor and supporting structures, include the cable or cables, trunk amplifiers, and power supplies, as well as the FM modulators and demodulators. There are also significant ongoing costs for trunk powering, and preventive and corrective maintenance of the amplifiers. These costs must be included in a meaningful comparison of this system with others.

An opportunity exists to optimize costs through the use of extended bandwidth amplifiers for high capacity trunks to avoid the use of a second cable, and by spacing high gain amplifiers farther apart than normal CATV practice because of the noise improvement inherent in frequency modulation. Reliability can be improved through the use of redundant amplifiers, status monitoring, and

[Figure 1]

VIDEO FM COAXIAL CABLE TRANSMISSION

20 CHANNELS (OR MORE) PER CABLE



standby power supplies.

The costs of the conventional broadband plant required are typical of CATV plant. Video FM terminal equipment typically costs about $5,000 per video circuit.

FIBER OPTIC TECHNOLOGY FOR CATV

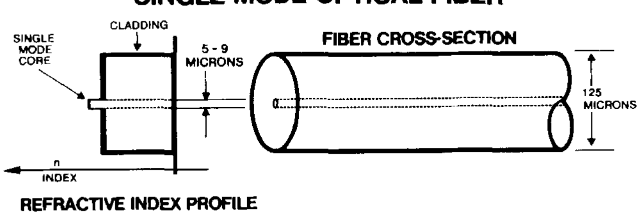
The use of optical fiber has become widespread in recent years in interconnecting telephone switching centers, among other applications. This has provided a fair amount of experience in the manufacture and installation of fiber.

Optical Fiber

An increasing amount of the fiber being installed is of the single-mode variety, with its low loss and high bandwidth. This fiber suggests itself for most CATV trunking applications.

[Figure 2]

SINGLE MODE OPTICAL FIBER



Single-mode optical fiber consists of highly refined glass which has been doped in such a way that its inner and outer cores have a different refractive index. Figure 2 shows single-mode fiber construction. While the fiber is mechanically homogeneous throughout its diameter, its refractive index undergoes a transition to define a very small light waveguide within the fiber. The waveguide diameter (5 to 9 microns) is close to the wavelength of the light being transmitted (1300 nanometers or 1.3 microns). The fiber is termed "single-mode" because the waveguide diameter has been selected to avoid multipath reflections, which create signal dispersion (time domain distortions) characteristic of large diameter "multimode" fibers. Dispersion effects are magnified with distance.

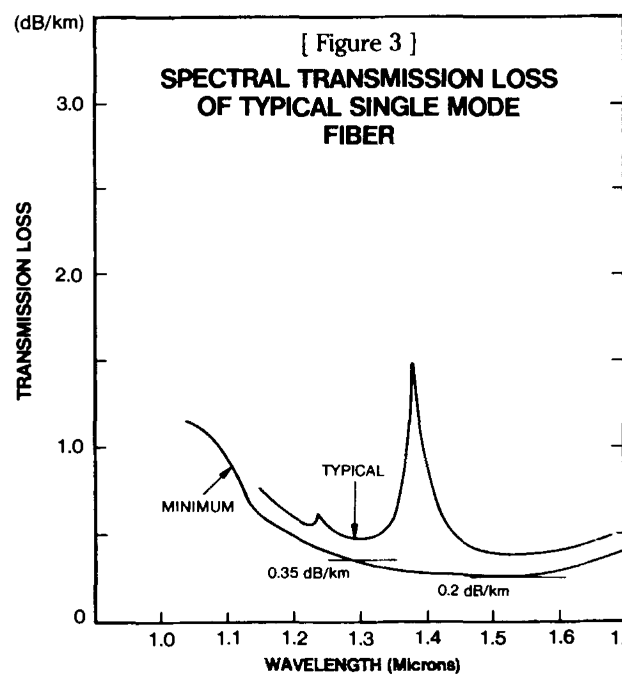
Figure 3 shows loss versus wavelength in single-mode fiber. The peaks are a function of the atomic spectral absorbtion characteristics of the glass used. The shape of the curve yields 2 "windows" of potential use centered at 1300nm and 1550nm. The 1300nm window includes the area of minimum dispersion, and the 1550nm window includes the wavelengths of lowest fiber loss.

Fiber is available today with a nomimal loss of 0.5dB per kilometer at 1300nm and less than 0.4dB per kilometer at 1550nm. Somewhat lower loss fiber may be specified at additional cost.

Research indicates that the potential exists to construct fiber with losses as low as 0.16dB per kilometer at 1550nm, allowing very long fiber runs. The current record for fiber transmission in experimental systems involved transmitting data at 2 gigabits per second over 130 kilometers of fiber without repeaters.

[Figure 3]

SPECTRAL TRANSMISSION LOSS OF TYPICAL SINGLE MODE FIBER



Single-mode fiber used at both 1300 and 1550 nanometers is clearly of potential use in CATV systems, since the low loss allows long distance interconnection without repeaters, even with a certain amount of power splitting.

Fiber Cables

Fiber cables are available packaged in a variety of ways appropriate for CATV. In addition to containing different numbers of fibers, they may be ordered with different kinds of strength members, jacketing, and armoring. Cabled fiber is available in reels of 2 kilometers and more, and cabled lengths may be specified in ordering.

While the cost of single-mode optical fiber cable has come down substantially in recent years, there is still a great incentive to carry as many video signals on each fiber as possible. Costs for cable configurations appropriate for CATV applications, containing 2 to 8 fibers, range from 55 to 80 cents per fiber meter. A typical 4 fiber cable might cost approximately $0.75/ft.

Plant Construction

Cabled fiber is relatively tough, and its handling characteristics are, in most ways, as good as or better than CATV cable. Because cable lengths are large (2KM), and splices must be kept to a minimum, the penalty for error may be greater than CATV crews are accustomed to, and pulling tension and bending radius should be closely monitored. This is not to indicate that CATV engineers should be reluctant to undertake fiber projects where appropriate, but rather that the differences in technique in working with a new medium be recognized.

For the most part, normal CATV practices can be used for both overhead and underground construction. It is probably advisable to obtain experienced help from cable vendors, telephone construction personnel, or other sources when embarking on a first project.

Splicing

Single-mode splices done in a laboratory can have extremely low losses. Because of the very small diameter of the core, however, splice loss involves some element of chance.

Fibers may be spliced either with very expensive fusion devices which align and melt the fibers together, or with mechanical splices which clamp the fibers in proper alignment. While fusion splices have been favored in original construction, mechanical splices have been developed with average losses nearly as good as fusion splices. The sensible approach today may be to do initial system splicing with fusion, and to use mechanical splices for changes or repair.

Studies of many field splices indicate a mean splice loss of about 0.2dB. Once a fiber trunk has been constructed, it can be examined with an optical time-domain reflectometer (OTDR) and the relative loss of each splice can be approximately measured. Especially lossy splices can be redone until they are optimized. The time devoted to splice optimization depends on the length of the trunk and the size of the system power margin. The combined loss of fiber and splices can be measured with an optical field strength meter.

Optical Transmitters

Transmitters for fiber systems contain solid state, temperature controlled lasers. They may be modulated with either analog or digital information of a fairly wide bandwidth or high data rate. They are limited in terms of linearity, and intermodulation products are of concern, particularly in analog systems. Present transmitters are highly reliable, but laser linearity does change somewhat with aging. Because lasers are expensive, it is advantageous to share as many video signals on each laser transmitter as possible. Typical outputs coupled into the fiber are in the -3 to -5dBm range.

Optical Receivers

Optical receivers use two basic types of detectors: PIN-FET's, (field effect phototransistors) and avalanche photodiodes. While the photodiodes are potentially more sensitive, PIN-FET's are currently more widely used at 1300nm and beyond. Detector operating levels are in the -15 to -40dBm range, depending upon the type of modulation used. Because it is necessary to operate these devices close to threshold to maximize the power budget, the type of modulation selected is critical. For analog systems, wide deviation frequency modulation, similar to that used in satellite video systems, is most often used (for similar reasons). Digital systems may be operated at lower input levels because of their superior noise performance.

Detector operating levels in available systems range from -15 to -20dBm for narrow deviation FM analog systems, -25 to -30dBm for wide deviation analog systems, and -34 to -40dBM for digital systems. In digital systems, operating levels are best at lower speeds, and decrease at higher data rates.

Experimental developments in detector technology and fiber system modulation techniques promise substantial improvement in detector operating levels in the next few years. These improvements may be as great as 10 to 20dB.

System Design and Power Budgets

The assumptions behind any optical power budget depend on the type and configuration of the terminal equipment and the fiber and construction techniques to be used. Unless there are wide power margins, fiber systems must be designed with a fair amount of attention to the number of splices. This, combined with the physical constraints of cable routing, often requires that specific splice locations be designed, and that fiber cable lengths be ordered to fit the spans between those splices. Since cabled fiber is available on reels of 2 kilometers or more, the opportunity exists to greatly minimize the number of splices when power budgets require.

[Figure 4]

FIBER TRANSMISSION POWER BUDGET

(DIGITAL SINGLE-MODE SYSTEM)

Transmitter Output	-4 dBm
Detector Sensitivity	-36 dBm
TOTAL SYSTEM LOSS	32 dB
WDM Losses	3 dB
Connector Losses	1 dB
System Margin	4 dB
AVAILABLE FOR SYSTEM LOSS	24 dB

Distance @ 0.6 dB/km Path Loss: **40 km ≈ 25 mi**
(fiber & splicing)

[Figure 5]

FIBER TRANSMISSION POWER BUDGET

(ANALOG SINGLE-MODE SYSTEM)

Transmitter Output	-4 dBm
Detector Sensitivity	-28 dBm
TOTAL SYSTEM LOSS	24 dB
WDM Losses	3 dB
Connector Losses	1 dB
System Margin	4 dB
AVAILABLE FOR SYSTEM LOSS	16 dB

Distance @ 0.6 dB/km Path Loss: **27 km ≈ 16.5 mi**
(fiber & splicing)

Figure 4 shows a power budget for a digital system using moderate data rates and combining lasers onto a single fiber through wavelength division multiplexing. The 0.6dB per kilometer path loss assumes one splice every 2 kilometers, with a mean splice loss of 0.2dB. Although a system margin of 4dB has been used, careful design and construction techniques would be necessary to keep splices to a minimum and to ensure that both cable and splice losses were within specification, if such a system were used near its maximum distance.

Figure 5 shows the same power budget for a wide deviation FM analog fiber system. The only difference is in detector operating level, which illustrates the advantage of digital over analog systems. This becomes significant in links long enough to require an analog repeater, with its additional costs and its additive intermodulation and noise contribution.

Obviously, the generation of a power budget is a key step in examining fiber for a given application, and in reviewing both equipment specifications and construction plans for such a system.

Expected Developments

A number of developments will continue to make fiber more attractive for CATV supertrunking applications. Both cost and loss will improve somewhat for fiber cables. More economical circuitry will be developed capable of processing and multiplexing digital information at higher data rates. Laser costs will decrease and coupled power output will increase, allowing larger power budgets. Detector sensitivity will increase as avalanche diodes are economically produced which work reliably at longer wavelengths. New and more refined analog approaches will also be developed which may be very attractive both economically and from a performance standpoint.

A properly designed and built fiber trunk using today's dual window single-mode fibers can be expected to have a higher channel capacity in the future as new terminal equipment is developed, and as more exotic existing equipment becomes less expensive.

ANALOG VIDEO VIA FIBER

The block diagram in Figure 6 represents a practical analog video fiber optic transmission system. To maximize the number of video frequencies on a fiber, both frequency division multiplexing (FDM) (the combination of different RF frequencies) and Wavelength Division Multiplexing (WDM) are shown.

In the diagram shown, video signals are frequency modulated and combined. The center frequencies are selected to minimize intermodulation effects caused by laser non-linearities. The combined broadband signal is then used to modulate a laser, and the output of two lasers at different optical wavelengths are combined to feed a single fiber. Wavelength division multiplexers can be related to the RF diplex filters which are common in CATV. These multiplexers and de-multiplexers have some insertion loss, which can range from a few tenths to about 2dB.

At the destination, a de-multiplexer is used to separate the different optical frequencies, and two optical detectors are used. The broadband RF outputs of the detectors are split and demodulated. The FM modulators and demodulators in these systems are often identical to those which are used in video FM coaxial systems, except that they usually have wider deviations (often substantially wider) to improve detector performance.

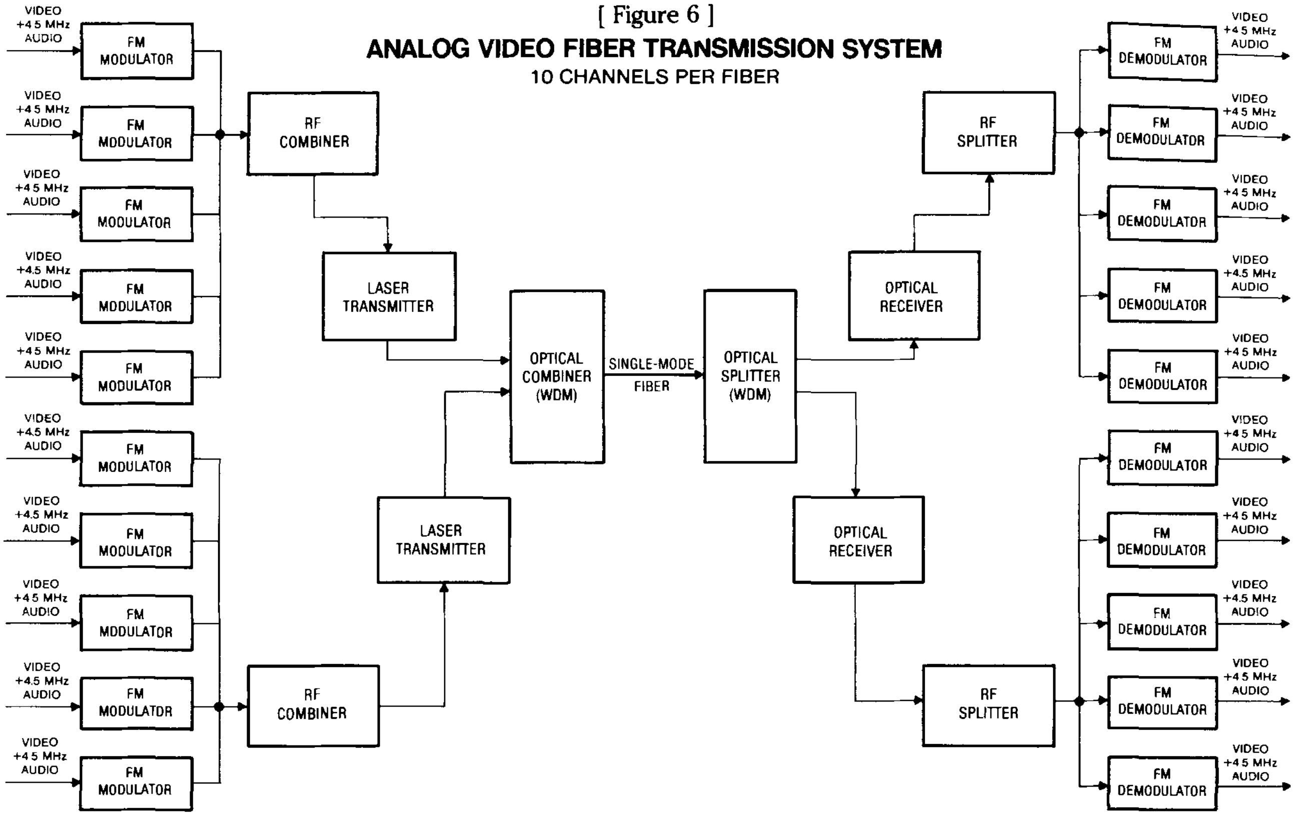
A repeater, if required, is relatively straightforward, and its effective cost depends on the number of channels being carried per fiber in the system. In the event wavelength division multiplexing is being used, de-multiplexing (and multiple detectors and laser transmitters) as well as re-multiplexing, would be required. The addition of repeaters to an analog system raises performance concerns, both in terms of video signal-to-noise ratios, and additional intermodulation products.

One technique used to achieve economies in analog optical fiber systems for earth station links is

[Figure 6]

ANALOG VIDEO FIBER TRANSMISSION SYSTEM

10 CHANNELS PER FIBER



taking the 70 Mhz IF outputs of the satellite receivers (which carry wide deviation FM video information), and frequency converting each to avoid the cost of FM modulators.

The primary performance limitations for analog video fiber systems are intermodulation products caused by laser nonlinearity, the signal-to-noise performance of the detectors, and the resulting lower power budget of these systems compared to digital systems.

Obviously, intermodulation degradation increases with the number of FM frequencies applied to each laser. Typically, between 3 and 6 frequencies are used per laser, although some systems carry more. Because laser nonlinearities change with aging, expected changes must be taken into account in examining long term intermodulation performance and effective laser life.

The cost of analog systems is currently in a state of flux. The key factors are the number of video channels per laser and the number of lasers which are combined onto a single fiber. Terminal costs for multi-channel systems are presently in the range of $7,000.00 per video circuit.

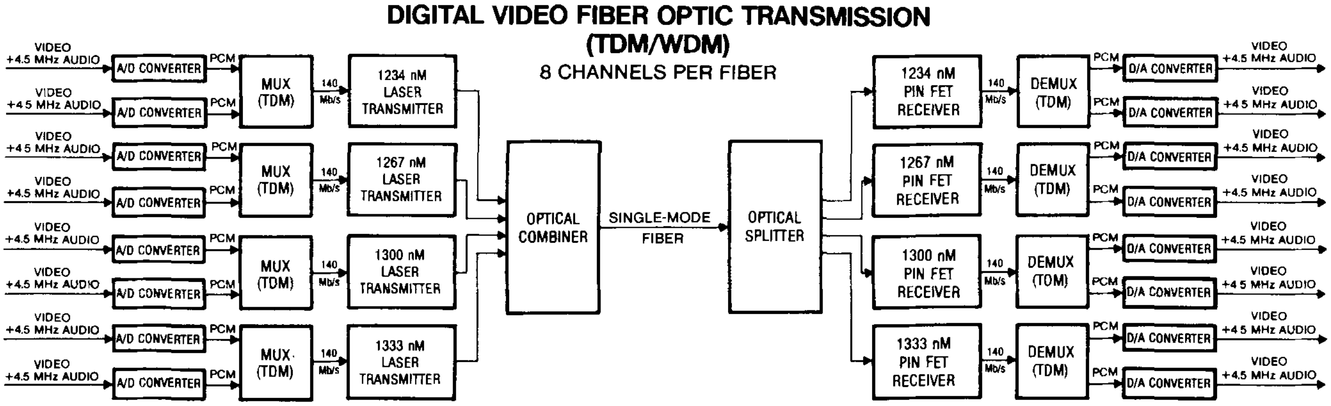
DIGITAL VIDEO VIA FIBER

Figure 7 shows a block diagram of one approach to digital video fiber transmission. Video signals are converted from analog to digital form. De-

[Figure 7]

DIGITAL VIDEO FIBER OPTIC TRANSMISSION (TDM/WDM)

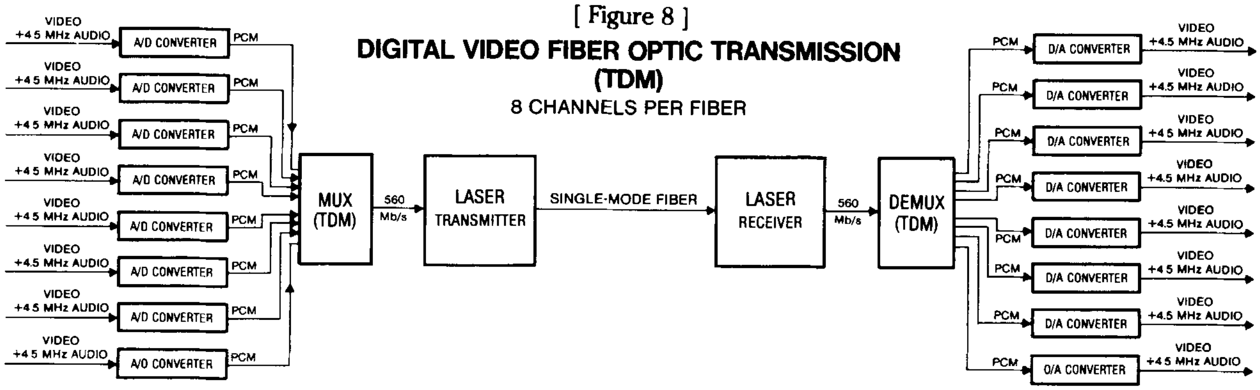
8 CHANNELS PER FIBER



[Figure 8]

DIGITAL VIDEO FIBER OPTIC TRANSMISSION (TDM)

8 CHANNELS PER FIBER



vices for this application are reliable and have been refined for video use through applications in the broadcast industry. This conversion process almost solely determines the video quality of the entire transmission link. Eight-bit encoding, which is favored by broadcasters, yields signal-to-noise ratios of approximately 63db. Seven-bit encoding (resulting in the sensing of 128 instead of 256 discrete levels) yields signal-to-noise ratios in the vicinity of 57db. In the context of most CATV transmission, this is considered sufficient. The use of seven-bit encoding allows multiplexing of a larger number of video channels in a given bandwidth at a lower cost.

Beyond the analog-to-digital conversion point, the system is processing digital pulses, and unless bit error rates become significantly higher than 10 as detector thresholds are approached, essentially all the information will be recovered with no loss in quality.

The output of two or more D/A converters can be combined into a higher rate data stream. This process is termed Time Domain Multiplexing (TDM). The multiplexed digital information is applied to a laser transmitter, and the output of two or more lasers may be combined through Wavelength Division Multiplexing (WDM) to increase the number of video channels carried per fiber.

Figure 8 shows an eight channel per fiber digital scheme which involves multiplexing together all eight videos into a high speed data stream. Systems have been built combining up to 16 8-bit encoded video channels into a 1.2 gigabit/second data stream, but are not within economic reach at present. Data rates as high as 560 megabits per second may be multiplexed through commercially available equipment.

In very long systems, where repeaters are required, digital systems are especially advantageous, since data can be received, regenerated, and transmitted transparently essentially any number of times.

At the destination, the digital data stream is recovered from the optical detector, and the individual video data streams are de-multiplexed. The analog video signal is generated through digital to analog (D/A) conversion.

The advantages of digital video fiber transmission are its relative transparency, indifference to laser nonlinearities, and improved detector sensitivity over analog methods, as well as a high degree of reliability and stability of terminal equipment, which compliments fiber's high reliability. The advantages also include the body of experience which has been gathered in telecommunications applications.

In terms of cost, digital optical systems are also in a state of flux. Systems are currently being planned which have 8 video signals per fiber, with a terminal cost of approximately $9,000 to $10,000 per video channel.

SYSTEM COST COMPARISONS

With an understanding of the trade-offs involved in the above three transmission schemes with regard to reliability, performance, branching ability, and other non-economic factors, the primary remaining factor to examine is their comparative costs.

The cost comparison graphs include the assumptions listed below. These assumptions are general, and demonstrate the dynamics of the comparison, but must be tested and changed for specific applications. In addition, changing technology and the entrance of new vendors into the market will date these assumptions rapidly. It is also assumed that physical support plant (strand, duct, hardware, etc.) labor, make-ready and construction costs are comparable for installing a fiber cable containing any number of fibers, as well as any number of coaxial cables.

Video FM/Coax

Cable, amplifiers & power supplies:	$0.66/ft.
Present value, assuming 10 yr. life and a 12% discount rate, of power (assuming average power consumption and rates) and one technician per 200 miles of plant:	$0.33/ft.

Terminal equipment costs, assuming a point-to-point system with no branching: $5000/ch.

Channel capacity per cable, assuming 14Mhz channels on a 330Mhz trunk with standard trunk amplifiers: 20 ch./cable

Analog Video On Optical Fiber

Single-mode fiber cable costs for the following configurations:	
Single fiber:	$0.30/ft.
Two fiber:	$0.45/ft.
Three fiber:	$0.60/ft.
Four fiber:	$0.75/ft.
Five fiber:	$0.90/ft.
Terminal equipment costs:	$7200/ch.
Channel capacity:	10 ch/fiber
Number of miles before repeater is required:	16 miles
Repeater cost:	$2600/ch.

Digital Video On Optical Fiber

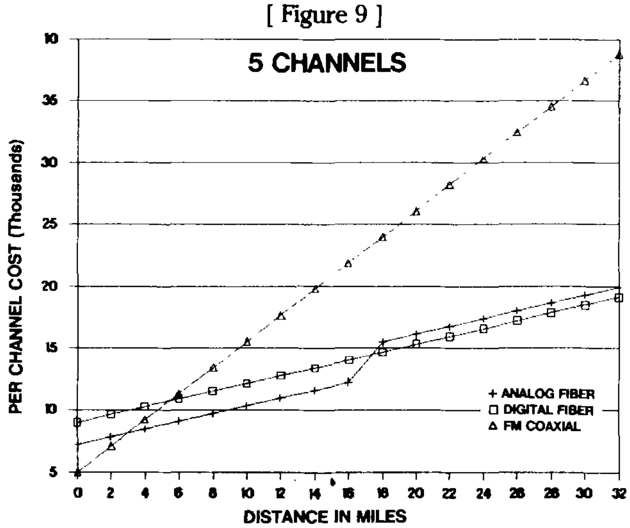
Cost of fiber cable:	Same as above
Video terminal equipment cost:	$9000/ch.
Channel capacity:	8 ch./fiber

Figures 9 through 18 are comparisons of per-channel costs for the three supertrunking approaches being discussed under various conditions. Figures 9 through 12 represent cost as a function of mileage for fixed channel loading. Figures 13 through 18 represent cost as a function of channel loading for fixed mileages.

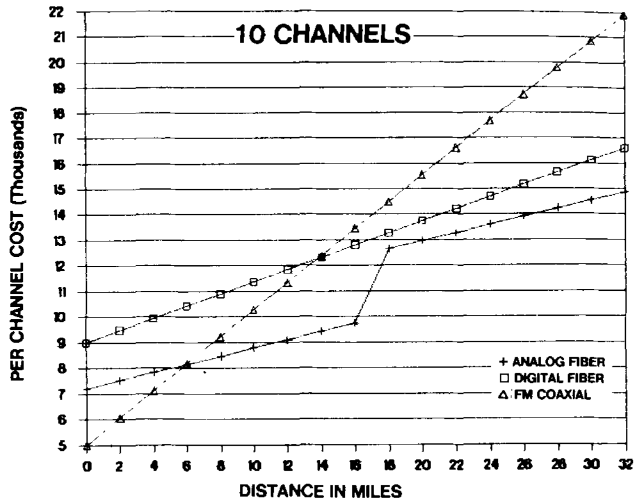
Observations

In the cost versus channel comparisons, breakpoints occur where repeaters are added to analog fiber systems. Because the per-mile cost of building and operating coaxial systems is greater than that of fiber systems, longer systems approach and exceed the per-channel cost of fiber systems.

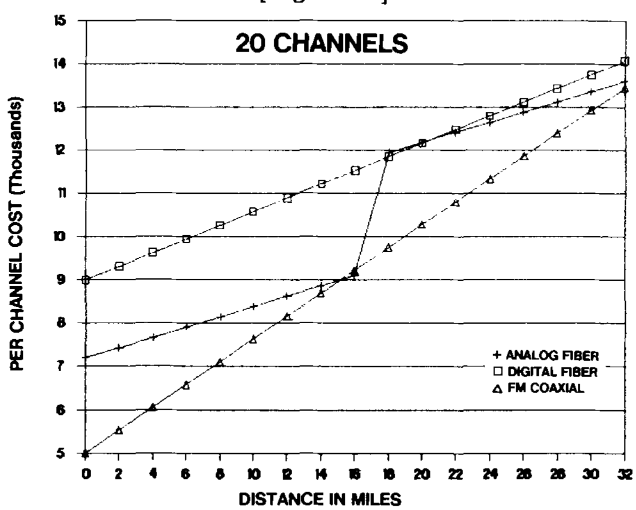
[Figure 9]



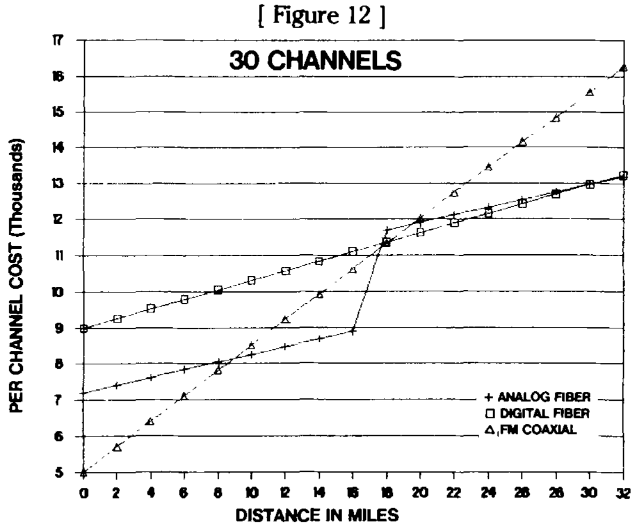
[Figure 10]



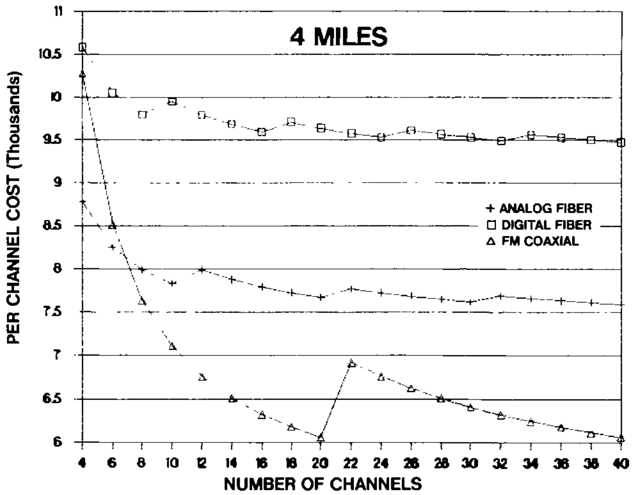
[Figure 11]



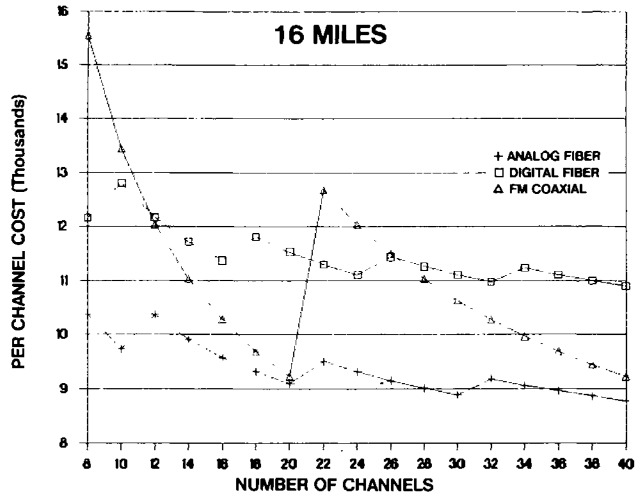
[Figure 12]



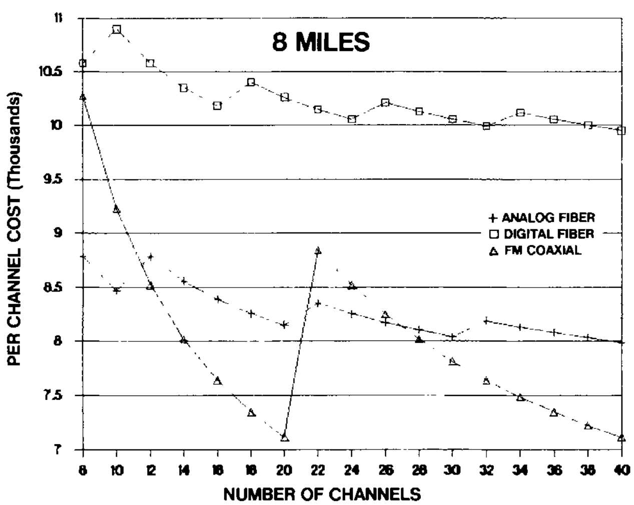
[Figure 13]



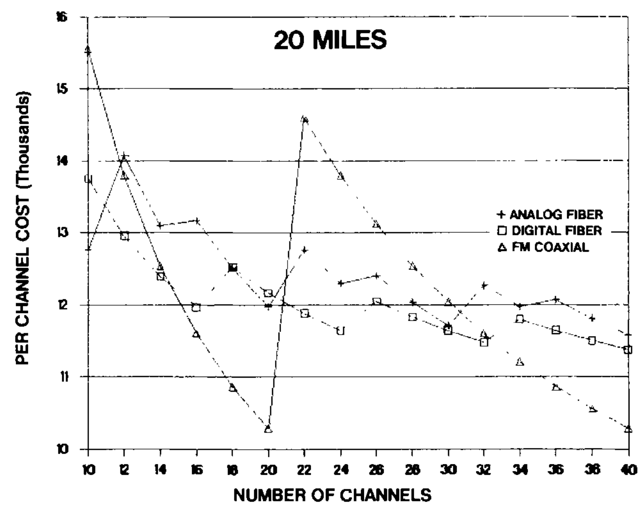
[Figure 16]



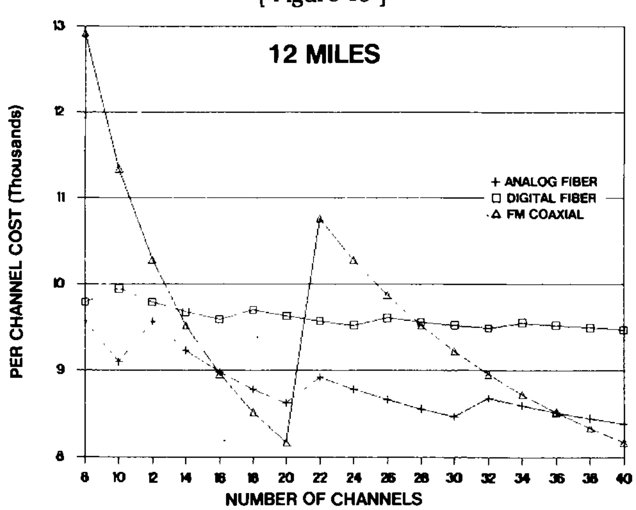
[Figure 14]



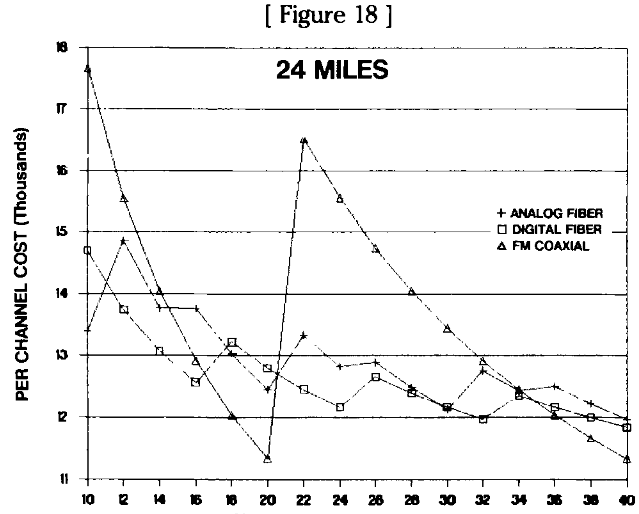
[Figure 17]



[Figure 15]



[Figure 18]



than that of fiber systems, longer systems approach and exceed the per-channel cost of fiber systems.

In the comparison of per-channel cost versus the number of channels to be transported, breakpoints occur for fiber systems where additional fibers are required. In coaxial systems, a major breakpoint occurs where it is necessary to add a second cable to carry additional channels. Video FM on coaxial cable is at its most attractive when it is heavily loaded with channels, illustrating the premium to be gained by expanding cable bandwidth before adding a second cable. Fiber systems are especially competitive for longer and more lightly loaded links.

The results shown are colored by the assumptions made, but the dynamics of the cost comparisons should be clear in demonstrating the strengths of each approach.

A Practical Example

Much of the information presented here was gathered in examining a practical application for a CATV system on the island of Oahu in Hawaii. The acquisition of a neighboring system led to a need for a high capacity interconnection between hubs on both sides on a major mountain range. Because of site access and availability problems, microwave was ruled out as an option. While video FM coaxial trunking was a possibility, the available 16 mile route passes through a rain forest and a major highway tunnel. Long power interruptions are common at the points where power would be supplied to a coaxial system. Access to trunk amplifiers was also a concern in the highway tunnel and its approaches. The length of the interconnection and the channel capacity required, as well as the reliability factor, argued strongly in favor of a fiber approach on both a cost and on a performance basis.

It is expected that a fiber link will be implemented in mid-1985. The first increment of channels will be delivered using digital transmission, and analog techniques will be tested to explore possible cost savings on additional channels, while maintaining acceptable performance.

CONCLUSION

The information presented here was gathered in evaluating a specific potential application for fiber optics. Each individual vendor has a story to tell, and it is important to develop a broad perspective if fiber is to be examined in a balanced manner. If a fiber project is being considered, it is suggested that this information be updated and supplemented with information from current vendors. It is also suggested that conversations with CATV engineers who have constructed and operated fiber systems will prove invaluable.

It is strongly recommended that a CATV engineer considering the use of fiber technology review the technical papers contained in Fiber Optic Communications, edited by Henry F. Taylor (Artech House, Dedham, MA., 1983). This excellent collection brings together a wealth of information, much of which is applicable to CATV systems.

For some combinations of distance and channel capacity fiber optic systems are the correct choice with today's technology. This may be further influenced by the relative weights given to performance, cost, and in particular, reliability. It is only fair to assume that the number of applications for fiber optics will increase with future technological developments in the field.

FIBER OPTICS: CATV'S FRIEND OR FOE

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ABSTRACT

Serving the business consumer's voice, data, and video telecommunications needs through fiber optics represents a significant revenue opportunity for cable companies. The AT&T divestiture, rising local loop phone costs, and general deregulatory philosophy of the Reagan administration have fueled the growth of competition for the telecommunications dollar. Cable operators together with the phone companies, find themselves having to decide between ambitiously pursuing the high speed communications markets or passively standing by to watch one of the new fiber competitors steal the opportunity away and perhaps even threaten their existing business.

This paper begins to examine the cable companies' telecommunications opportunity and the market advantages and threats fiber optic technology represents.

THE OPPORTUNITY

U.S. consumers will spend $50 billion on long distance communications this year and additional billions for local service. Some experts estimate well over half this figure will go for local loop distribution currently provided by the phone company. In a recent study AT&T, the largest long distance carrier, discovered that in excess of 80% of its intrastate toll revenues went to the local phone companies for last mile distribution and connections. While total long distance revenues will grow about 6% a year, the local access revenue portion will grow at a much faster rate. One consultant predicts a 60 to 80% increase over just the next year or two. While local costs climb, accelerating competition will restrain revenue growth somewhat. By 1995, total long distance traffic will exceed $87 billion with intra state calling accounting for better than 40% of the total as referenced in

Figure 1

FORECAST OF TOLLS

RESIDENTIAL, BUSINESS, AND GOVERNMENT

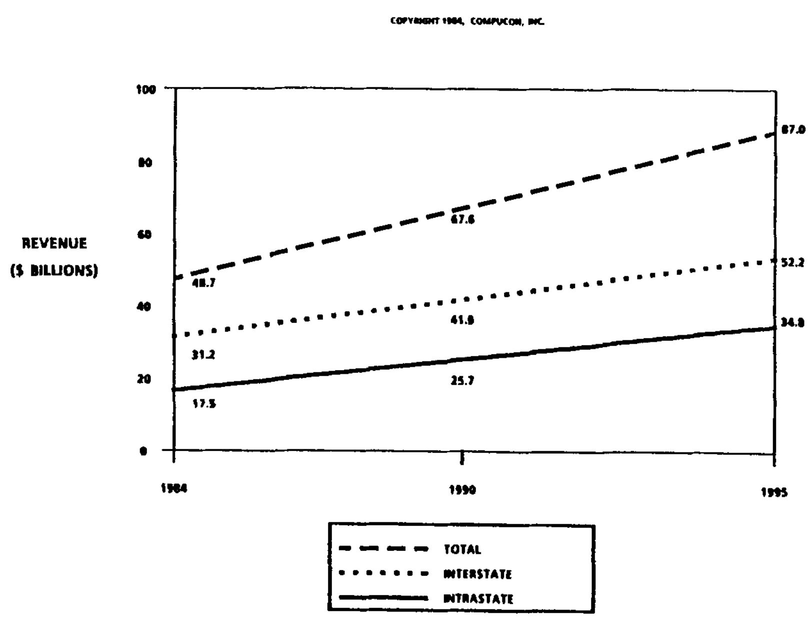


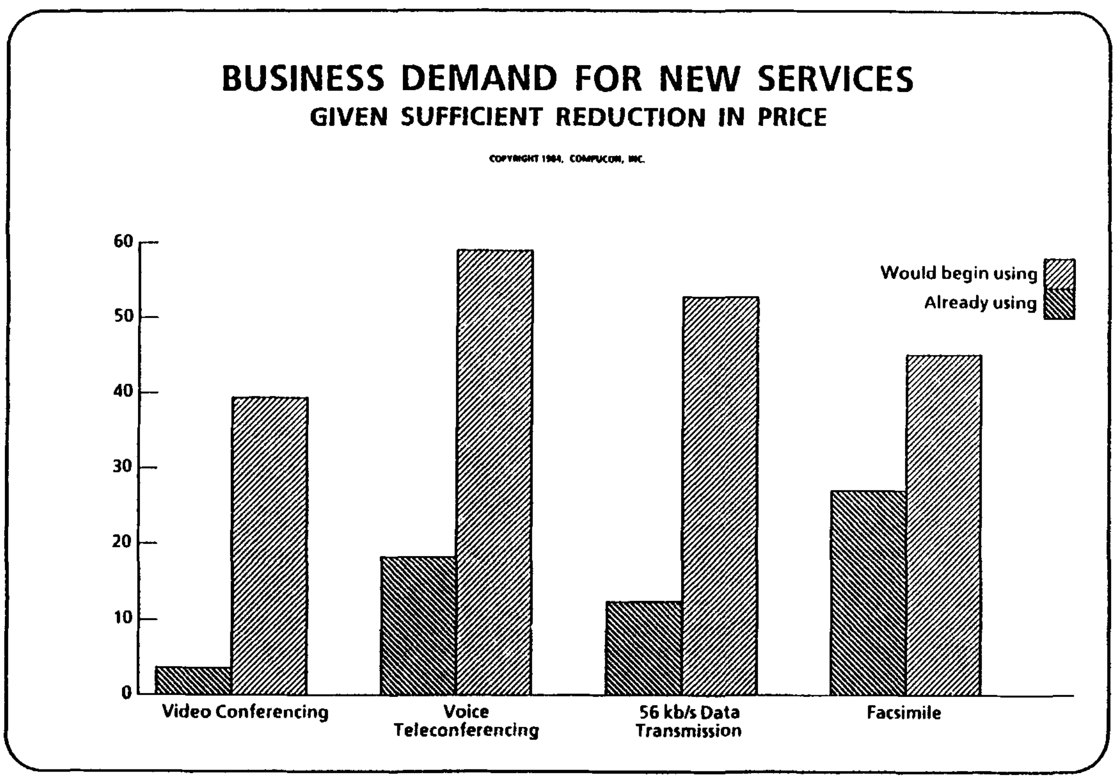
Figure 1. A study done by Ameritech, one of the seven Regional Bell Operating Companies, indicates that in the Midwest competitors could successfully service up to 60% of this revenue.

A recent report examines the distribution of both toll revenue potential and growth for different regions throughout the country. California and Nevada account for better then 15% of the total long distance market with an explosive revenue growth of 60% from 1979 through 1983. Other regions of the country with high toll growth rates include the District of Columbia, Virginia, the Mountain states (i.e., AZ, CO, ID, MT, NM, UT, and WY) and Connecticut, all of which experienced growth in excess of 55% during this four year period. Collectively, they account for about 11% of the long distance market. Indiana and Illinois fall out at the bottom of this list with a four year growth of less than 25%, substantially below the U.S. average of 44.5%. But their significant business base still makes them attractive long distance markets, generating almost 5% of the country's total revenue. In fact, after reviewing this distribution and growth profile nationwide, most states and regions offer viable telecommunications opportunities.

Of course, cable systems can provide not only last mile connections for long distance service, but a variety of other local communications services as well. Businesses spent millions last year connecting local facilities and branch offices together with their own communications links. Links that the cable operator could have provided. Local area networks, now numbering in the tens of thousands, continue looking for ways to expand beyond the confines of building walls or office park boundaries, to increase network utility and value through connecting with other locations a few blocks or miles away.

Whether the communications needed involve long distance or strictly local services, voice dominates telecommunications today with a better than 85% revenue share. Various forecasts show voice growing at 5-7% per year with little growth acceleration expected, even if telephone rates drop substantially. Video and, more importantly, data offer a much higher growth profile with annual rates in excess of 15%. The wide bandwidth and high transmission speeds required often exceed existing phone company plant capacities, so customers often find themselves forced to look outside of the phone company for this service.

Figure 2



These higher transmission rates are needed by some 4,000 plus computer installations throughout the country that could use 45 mbps links between remote and central facilities. They are also needed by the growing number of firms installing full motion, full color, videoconferencing facilities. In a recent Compucon survey, over 40% of the businesses interviewed indicated they would start using videoconferencing if costs came down (as referenced in Figure 2).

Whether it be voice, data, or video, last mile connections for long distance service as well as strictly local point to point communications represent a real opportunity for cable companies. Business customers need links for tying together their decentralized facilities, for directly connecting with their long distance carriers, and for obtaining the higher speed circuits currently unavailable or uneconomical. While this market represents a business versus residential consumer for the cable operator, the operator's local area knowledge, facilities, and trained personnel all coupled with the advantages of fiber optic technology, give him an edge over most competitors in pursuing this opportunity.

THE MARKET SEGMENTS

The three key market segments cable operators should consider targeting include: end users, long distance companies, and other communications system operators.

The end user segment consists primarily of businesses with large communications requirements resulting from their numerous branch offices or remote facilities, from their heavy data processing orientation, or from simply the nature of their industry. Companies in the service, financial, insurance, and real estate industries generally have higher than average communications needs. Larger companies, regardless of industry, typically spend more on communications than smaller ones, and some cable operators have discovered that servicing a few key accounts captures a large portion of the telecommunications dollar. According to Bill Woods of AT&T, four percent of the businesses in California pay approximately 83% of the total local access fees, or almost one billion dollars. In Ohio and Georgia, half a percent of the businesses generate 45 to 50% of the long distance revenues, and similar relationships exist elsewhere in the country. Many of these larger firms spend hundreds of thousands of dollars each month on communications transmission. Even numerous medium size companies expend tens of thousands of dollars monthly on transmission costs.

The residential end user represents a future market for fiber communications as well. With the PC explosion, increasing popularity of electronic mail and home security/banking/shopping, and slowly growing interest in videotext, automated meter reading, and remote medical diagnosis, homes will need fiber optic communications someday. The justification does not exist yet, but some futurist now predict the day that a single company will carry power, TV, phone, and various other services into the home all over a single cable. The rapidly improving fiber electronics, repeater requirements, drop and insert techniques, and overall maintenance characteristics make the economics for consolidating services on one cable quite attractive.

Another customer type, the long distance carrier, offers a potentially attractive revenue source since it currently relies upon the local phone company for connection between its point of presence (POP) and end customer locations. These carriers don't have the capital or right-of-ways required to tie directly into their customers' facilities and find themselves saddled with some extremely high local distribution charges. One carrier estimates that out of an average 30 cents per minute revenue it receives from its customer, better than 20 cents of that goes for local distribution costs. Most of these carriers such as MCI and Sprint have expressed real interest in circumventing these excessive charges and trying alternatives offered by the local cable company and others.

Private microwave operators, teleports, local area network providers, and cellular system companies all fall into the third customer class.

Private microwave operators currently maintain their own communications systems and find the newer technologies obsoleting their existing networks. Their ten year old analog radios don't offer the needed capacity or speed to handle new data requirements or the increased voice traffic. Furthermore, the FCC may have recently imposed stricter technical standards on their microwave equipment, and they may no longer be able to buy radios compatible with their existing network.

Teleport developers offer tenants of their office buildings shared communications facilities often including satellite gateways, state-of-the-art PBXs, and "wired" walls and floors. They have discovered that many companies near their real estate development don't want to move into it, but would like access to their satellite gateway. The local cable company's fiber optic system may provide an attractive means for connecting prospective customers to the teleport.

Local area network providers need right-of-ways or alternatives for connecting their LAN nodes together and cellular system companies need to tie their cell sites back into the central switch. Leased phone lines represent a considerable expense and radio frequency congestion often prohibits the use of microwave for interconnection. Fiber optics offers one of the few viable alternatives.

One exciting characteristic about all these customer types: many companies in each category will want to secure enough capacity for their peak communications load. This will obviously free cable companies from having to meter customers' communications and generate a usage-based bill. Fees can simply be based on the number of dedicated, leased circuits.

MAJOR COMPETITORS

The local phone company may represent the most troublesome competitor. They understand the business, have the right-of-ways and have probably installed some fiber already. Most importantly, they operate under the protective regulatory umbrella. This protection may force cable companies currently operating in an unregulated environment to file as regulated common carriers before offering phone company like services. Manhattan Cable's data transmission services battle with the New York Commission looks like it will result in their ultimate regulation. The State of New Mexico recently passed legislation requiring cable operators to file for common carrier status if they want to offer communications services. And the outcome regarding Cox Cable's ongoing fight in Omaha remains uncertain. Clearly, regulation could eliminate many of cable's competitive advantages as well as greatly restrict the types of services to be offered.

Fortunately, this regulatory environment also creates the phone companies' biggest competititve weaknesses. It restricts them to only providing service within their exchange boundaries and to providing service to all customers under a regulated rate structure. It also saddles them with a lot of antiquated, yet not fully depreciated equipment, that they must continue to use. Some of this equipment, like the twisted pair wire and analog switches, can not provide the new services and higher speeds demanded by their customers. The regulated rate structure has forced the phone companies to average costs over all customers. For example, in California, some businesses leasing WATS lines end up paying seven times the actual cost for local access while some remote residential customers only pay a fraction of their true cost. Recently, phone companies have started a campaign to de-average prices for selective business customers, in an effort to combat growing competition from bypassers and retain their key accounts. It is unclear at this point that regulators will allow de-averaging given the resulting increases it would force on smaller customers.

Many of cables other competitors such as the long distance companies, fiber optic carriers, large businesses with their own private systems, and local area network providers, are also potential customers. While these companies may compete with the cable company for the same end user, they probably don't have the pole attachments, right-of-way, or local cable crews necessary to connect with each customer location. So they would probably prefer to negotiate a joint arrangement with the cable company rather than try to build their own local distribution network.

Regardless of the competition, cable operators will have to brave the regulatory battles and aggressively pursue telecommunications customers to take advantage of the existing market turmoil. Competitors canvassing the marketplace frequently sign up large potential voice and data users to long term contracts. Within a year or two, they will have gobbled up most of the really lucrative local distribution telecommunications opportunities.

Cable companies also need to protect their existing CATV business from competitors leveraging their larger size and fiber optics superiority over coaxial cable. Phone companies continue to eye the attractive home entertainment cable market, and talk about the day their fiber will supplant cable. Dick Snelling of Southern Bell recently discussed how the two companies will have consolidated together in many markets by 1990. And one consultant predicts that the cable operator and phone company will both be relegated to fairly minor roles as the power company provides power, phone, and TV into the home over a single cable.

THE TECHNOLOGY

The basic transmission media today include twisted pair wire, coaxial cable, satellite, analog and digital microwave, and fiber optics. Fiber optics offers a number of advantages over some or all of the other alternatives. A single fiber offers the same capacity theoretically as many coaxial cables. The size and weight of fiber makes it easier to install through crowded conduits than coax. Since it doesn't radiate or absorb energy, it avoids:

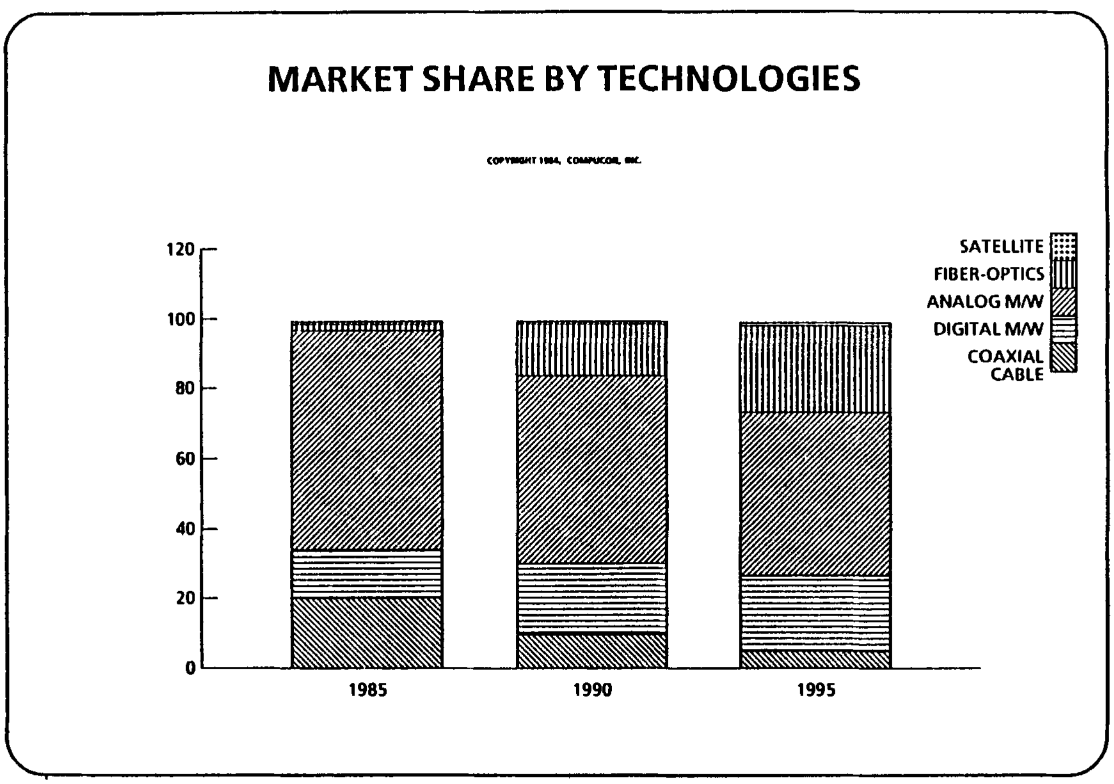
- electromagnetic and radio frequency interference;
- attracting lightning;
- degradation from co-location with high voltage lines;
- crosstalk from laying fibers side by side.

Fiber is insensitive to temperature and humidity when compared to coaxial and is insensitive to heavy rain and other adverse weather when compared to microwave or satellite. Also, since transmitting through fiber results in less signal distortion and attenuation than cable, repeaters/equalizers are spaced farther apart and fewer are therefore required.

Fiber provides basically error free, high capacity, relatively secure communications. Its maintenance costs seem lower than other terrestrial technologies and its capacity can be greatly increased through simply changing out the electronics and perhaps adding a few more repeaters. Some feel this extra capacity will become particularly important as HDTV and stereo audio gain popularity in the entertainment market, while videoconferencing and data transmission gain popularity from the business side.

Fiber offers digital communications, or cleaner, higher quality communications than that provided through analog transmissions. Transmitting digitally allows for easier and more economical integration and switching of voice, data, and video signals. While other technologies also offer digital transmission, they have other problems. Complaints about satellite communications include annoying delays and echos, frequency congestion, weather, and transmit/receive earth station costs. Terrestrial microwave offers a viable, low capacity transmission medium, if frequency congestion and weather don't pose problems.

Figure 3



Fiber has its shortcomings too. The three most noticeable include obtaining right-of-way, optically switching voice and data traffic and loading the fiber to break-even capacity. Right-of-way costs currently range from a few hundred dollars per year per mile to over $10,000/year per mile. True optical switching still seems a few years away, although progress continues in the area. And several recent analyses show loading fiber to a 50% fill level with moderate capacity electronics results in satisfactory rates of return. Thus, in spite of these shortcomings, experts predict fiber will carry almost one-fourth of the long-haul traffic by 1995 (as highlighted in Figure 3).

MARKET ENTRY STRATEGIES

The divestiture has tarnished the phone companies' reputations. Service problems, confusion regarding responsibilities and policies, and long delays with new circuit orders have created discontent in the marketplace. While customers do use MCI, Sprint and other alternative carriers for long distance service, these companies have their share of problems with poor circuit quality, disconnects during the middle of a conversation, and billing errors. Given this discontent, prospective customers would consider using a cable system's service. Some of the features they would look for include:

- 15 to 25% discount off their current communications rates;
- turn-key phone service providing end-to-end connectivity;
- guaranteed maintenance and response times, error rates, grade of service, electronics redundancy, and in some cases, route diversity.

To effectively offer these features, cable operators will either need to form a consortium with neighboring cable systems, or participate in some type of joint venture with a long distance carrier, local area network provider, cellular system operator, or other communications company.

If the cable company prefers to avoid entering the end-user phone business, another alternative appears viable. The company could offer service as a carrier's carrier, simply hauling other carrier's traffic throughout the market, but not pursuing any end user business directly. This arrangement could take the form of a simple lease, where the carrier leases the needed capacity from the cable company, a condominium style agreement where the carrier owns the fiber but the cable operator maintains it, or a joint venture where ownership and maintenance responsibilities are shared.

PUTTING IT ALL INTO PERSPECTIVE

Competition for the television viewer continues to intensify with increased aggressiveness from LPTV, ITFS, MCTV, SMATV, VCR's, as well as traditional UHF and VHF broadcasters. Cable penetration still stagnates in many markets at 50% to 60% of the homes passed. Pay-per-view growth remains disappointing as does consumer interactive two-way services. Cable operators constantly seek additional revenue sources which utilize their pole attachment agreements, ubiquitous local market presence, experience in cable installation and maintenance, and other strengths.

Long distance and local telecommunications represent a sizable opportunity for the cable operators while leveraging their competitive strengths. Cable companies can install and maintain fiber less expensively than most telecommunications companies. Fiber offers significant technological and capacity advantages over coaxial and other transmission mediums. Furthermore, it is just beginning to enter the learning curve of rapidly decreasing component costs, whereas most competing technologies have already passed through the curve. Costs for terminal equipment, splicing gear, and many other components will continue to drop making fiber more economical than coax in the future for all but the lowest capacity applications.

The regulatory environment poses the biggest obstacle between cable companies and telecommunications profits. Warner Amex and Manhattan Cable have successfully pursued voice and data communications, but Cox and others have found state commissions stifling their progress. The long term trend clearly points to deregulation, but savvy attorneys predict a fairly rocky road over the next couple of years.

While competition also presents an obstacle, the wide gap existing between current "retail" communications rates and anticipated fiber optic costs, will allow plenty of room for mark-up while still staying competitive. Cable companies offer an alternative to the fastest growing communications cost component, local last mile distribution. Most of the fiber installed or announced to be installed is along major backbone routes or between phone company central offices, leaving the local distribution network largely "unfibered". Rapid growth characterizes the data portion of this market, which is the portion existing phone systems have the toughest time servicing, but that fiber is ideally suited for. Potential key customers are interested in considering alternatives to their existing suppliers and find fiber offered as an end-to-end service an attractive alternative. Lastly, the size of this market in most urban areas climbs well into the multi-million's of dollars. Securing even a small share of this market still represents a sizable business opportunity.

HOW AN INSTALLER SAVED MY CABLE SYSTEM

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ABSTRACT

Installs, upgrades, downgrades and service calls: these are basics of cable life. Done well, they pay the bills. Done poorly, they eventually do in any cable system.

These four tasks are the ideal starting point in every maintenance and preventive maintenance program. What follows below are proven suggestions on using these basic activities to keep systems running well.

INTRODUCTION

Across the country today, cable TV trucks will roll down the roads. Many new droplines will be installed, many pay units added (a few disconnected), and many service calls will be solved.

AND many causes and signs of future service calls will go unheeded or unnoticed.

Why? Sometimes it is a lack of training. If an installer does not know what he is looking for, he certainly will not find it. Often it is a lack of concern. "Job security for the technicians," or "Let somebody else do it" are heard many times. Sometimes it is simply time pressure. "I know something should be done, but I'm already 45 minutes late for my next install."

All the reasons add up to one thing: money. It costs plenty to send a truck back to the same address several times. It costs more if some of these are overtime trips after hours by the on-call technician. It costs when downgrades or total disconnects result from poor or frequently interrupted service.

Obviously then, getting the job done right originally, maintenance and preventive maintenance are not things to be taken lightly. They always have had and always will have an impact on the bottom line. Here are some suggestions to help ensure this impact is positive by taking full advantage of installs, upgrades, downgrades, and service calls.

NEW INSTALLS

One of the most crucial times in the life of a cable system has to be when a new install is performed. The distance between tap and television, whether 50 or 250 feet, and the manner in which the dropwire traverses it, have a direct bearing on future troubles and maintenance.

The old adage, "Why not do it right the first time," should be every installer's motto (and every other cable employee's motto for that matter). Taking the easy way out does not pay off in most businesses and it certainly does not in cable TV.

Foresight is a key word in installs. Encourage installers to consider how well their work will be holding up (as far as physical appearances go) and performing technically five, ten or more years from now. Many installs would have been done differently if only the installers had realized they might be technicians someday and have to maintain and service their old work. Many installs would have been done differently if only the managers and chief technicians knew how much trouble and expense would be involved in maintaining and servicing them.

Foresight should apply to so many aspects of installs. Here are a couple areas that come to mind.

1. Trees--How many droplines are thoughtlessly run through trees only to be torn down during windstorms. Granted, some houses set in the middle of a forest and it is impossible to get a clear shot. In those cases the drop is hung and you cross your fingers when the wind blows. (Then again, these drops could be buried.)

But houses like that are the exception. Usually there is only one tree to contend with. What then? Mid-span around it! Sure, the installer may spend an extra 15 minutes doing it that way and use an extra 30 or 40 feet of cable. But it is more than worth that to avoid a future service call to replace broken cable.

One last thought on trees. Those cute, little sapplings are in the yard when a house is originally wired for cable usually grow to become giant cable-eaters. The smart installer keeps this in mind as he routes the drop.

2. Street and alley clearance---- There are huge creatures that lurk in the dark (and even the daytime) that seemingly exist only to tear down drop cables. Garbage trucks, moving vans, cement trucks, dump trucks, etc. will play havoc with low-hanging droplines. Often it appears like an installer will run wire to the lowest point on the house so he can work everything from a step ladder.

Once again a little extra time spent on the install pays off. It takes more wire, stapling, and time to attach at the peak of the house (or at least someplace higher than the lowest point), but it keeps the phones from ringing every time the garbage trucks hit the streets.

Clearance may seem like such an elementary and simple thing. Yet, I know of systems where the technicians complain that certain drops are torn down every two or three months. Do they ever raise them? Heck no! They just put them back up. That is not only lack of foresight, but also lack of common sense.

Common sense and clear thinking play a big role in installs. Installers should be asking themselves questions like, "What's the best splitter location?" Many times the wiring will come together in a crawl space and the splitter lays on the dirt floor. That is fine as long as the crawl space is constantly dry. But how many are? Countless splitters are laying in puddles, pretending to be sponges, and soaking up water. Presto! Service calls! If the splitters had only been stapled up to floor joists, the outcome would have been different.

"Should this drop be RG59 or RG6?" If all drops were 75 feet long, this would be a moot question. But, for those drops 125 feet long or longer, RG6 can make a difference. Murphy's law says that the houses with the longest drops will have the most outlets on cable. Many installers run RG59 for miles and then complain to the technicians about "the taps running low."

A final word on new installs. Give the installers time to do the job right. Overbooking only leads to frustrated workers and poorly done, sloppy installs. Quality work takes time.

WIRE-IN INSTALLS, SERVICE LEVEL CHANGES, AND SERVICE CALLS

These three activities lie at the heart of a good maintenance and preventive maintenance program. Why? They put cable employees in contact with a lot of miles of existing drop cable. (I use the term drop meaning the wire from the tap to where it attaches at the back of the television. If just that part of the drop from tap to ground block is well cared for, then that part from ground block to TV will be a system's downfall.)

Too many systems equate maintenance only with caring for the trunklines and feederlines. Often systems even over emphasize trunklines to the detriment of feederlines. A proper maintenance program, however, must put the right focus and attention on all three types of lines: trunk, feeder, and drop. It makes no difference what wonderful shape two of the three are in if the other one is allowed to degrade into unsatisfactory condition.

How to use these activities wisely

Make sure your employees are not wearing blinders. I wonder how often a scene like the following is repeated daily: The cable employee gets out of the truck, walks to the house (as he does this his eyes are busy scanning the work order), and is met at the door by the subscriber. The installer goes directly to the TV, wires up the converter quickly, and heads out to the pole. Once there he locates the drop he wants, hooks it up or changes traps, etc., and hurries back to the house to see if everything is working okay. Then he is off to the next job.

On the surface this sounds okay. The job was completed and all was well. Or was it? The employee never really paid attention to anything other than the limited things he was there for. He had on "blinders."

An employee need not be like the Greek's mythical creature Argus and have a head with 100 eyes. Two eyes are all it takes if they are used wisely. What should employees be looking for and what kinds of questions should they be asking themselves?

Was the install done right the first time? Do not prolong the agony of a poorly done install. If time permits, redo it. If it does not, at least get a time scheduled so someone can get the install done properly.

Does the drop look like it has been well maintained? Have past service calls been done correctly? There are countless drops that are simply spliced to death. I have seen drops of 100 to 125 feet that have over 10 splices in them. Sure, somebody had come to these houses in the past and "fixed" the cable, but he sure did not do it right!

Someone has said that putting a splice in a drop is like scheduling your next service call for that address. There is a lot of truth in that. Many times the most cost-effective (in the long run) and technically sound choice is to change out the drop instead of splicing it. Make sure that service calls are not really a disservice to the cable.

More questions. Are there limbs hanging heavily on the cable? Are the staples or siding clips loose causing the cable to hang low and look ugly? Is the P-hook fastened to the house securely? Do the ground block and wire look okay? These sound like a lot of time-consuming questions, but actually just walking out the drop on the outside of the house (which should only take two or three minutes) will answer them quickly.

Now, some questions for inside the house. If the cable comes into a basement, does the wire look okay? Stapling holding up? Is the wire routed too closely to furnace ducts or hot water pipes? Here is a big question: Has the subscriber cut into the cable to hook up illegal outlets. Time and time again a close check of the inside wiring will turn up all sorts (and kinds!) of extra connections radiating signal in all directions and costing the cable company money in lost revenues.

How about the transformer on the back of the set? Is it on the right terminals? Is it a new, modern kind? If not, change it. For approximately 50¢ or less, you will get better balance ratios, better isolation, etc.

By far one of the most important questions should be: How do the fittings look? Many systems are filled with the old, two-piece varieties. These were great in their time, but the hex-crimp, one-piece fittings do a superior job. Good advice would be to change out all old fittings: at the tap, at the ground block, behind the set, on the converter jumper, etc. I am convinced this alone will save countless service calls and cut down significantly on signal leakage.

In short, when a cable employee is at a residence doing upgrades, downgrades, service calls or whatever, he should be looking for anything that could affect the future performance of that install.

SIGNAL METERS

Signal meters have to be one of the best maintenance and preventive maintenance tools in the industry. Unfortunately, many meters seldom leave the comfort of their trucks. If the pictures look good after an install or upgrade, that is satisfactory for a lot of installers. "If the picture's good, that means the signal's good, right?"

Wrong!!! Good pictures can still hide many things. Here again an employee should be asking questions <u>and</u> using his meter. Are the signals flat across the band? Or are there suckouts? Peaks? Are signals excessively tilted? Are they too low? Just borderline? Too high? These could be indications of amplifiers at the wrong levels, damaged cables, tap values wrong, etc.

Signal readings should be written down if at all possible for every work order and attention called to them if anything abnormal appears. Often signal readings will catch developing feederline or trunkline problems before they become catastrophic. Problems are just like tooth cavities. The best time to find them is while they are small, if you cannot prevent them altogether.

PICTURE QUALITY

Even if an employee is at a residence to install only a pay service, he should still look through all other channels. Installers and technicians are literally the eyes and the ears of a cable system. If they are trained to know what to look for, they often will spot troubles long before the subscribers do.

What should they be looking or listening for? Beats, distortion, electrical noise, fundamental pick-up, hum bars, buzzing in the sound, etc.

Once again, anything abnormal or degrading to picture quality should be reported at once. What look to be minor problems can suddenly blossom into major problems. Nip them in the bud!

CONCLUSION

Installs, upgrades, downgrades, and service calls will always consume the major portion of cable employees' time. However, if employees will but stop, look, and listen while going about these tasks, cable systems will benefit greatly. And on-call technicians will sleep at night.

IMPLICATIONS OF THE DEVELOPING OPERATING ENVIRONMENT ON CATV TERMINAL EQUIPMENT

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ABSTRACT

Terminal equipment options are analyzed with respect to marketing and operating environment factors. Based on this analysis, a business model is proposed and developed in two scenarios for further terminal equipment development.

INTRODUCTION

Over the past two years, we have seen a major refocusing of effort in our industry. As franchising has wound down, we have seen the emphasis change from high technology blue-sky services to basic operating principles. This is best seen in the evolution of this convention over the past five years. Today, the watchword is: How do we run our day-to-day business smarter and more efficiently. During this same period, our industry has been overwhelmed by spiraling technological development. We have gone from 270 Mhz one-way plant to 550 Mhz two-way plant. With all of this excitment concerning our new technological abilities, it has been easy to lose sight of our reason for being in business. You have perhaps seen signs of it in your own company. In discussions with cable television engineers around the industry, I have been informed that we must build fiber optic switched star networks because the telephone company is doing so. Or that 1,000 Mhz is feasible and just around the corner in order to provide us additional channels. Between our historical infatuation with technology and the current emphasis on efficiency, it is critical that we keep focused on our business - the delivery of entertainment and information to consumers.

In answer to the question "what product does a cable system sell," one of two perspectives can be taken. Historically, we have been in the business of selling clear pictures and different program viewing opportunities to our customers. More recently, an alternative answer based on the broadcasting model might be appropriate: we are in the business of selling our viewers' time and attention to advertisers. Nowhere does it say we are selling technology. The technology is simply a means to an end. It can certainly enhance the viewing experience for our customer by providing full-color stereo-sound entertainment. Or it can increase our customers' convenience by providing full function remote control or time shifting through a video cassette recorder. But this technology is not an end to itself.

In the following sections, I will outline several environmental considerations which impact our business today, the technical tools we have to address these concerns and the effectiveness of our current approaches. Based on this analysis, I will suggest a business model to guide our future strategy. Two terminal equipment configurations are analyzed with respect to the model. This exercise is based on the belief that our industry has reached a level of maturity which now requires us to take a long range view of our ultimate destination. Our current practice of discarding our plant and completely rebuilding every 15 years cannot continue.

ENVIRONMENTAL FACTORS

There are three forces in our environment which must be considered in building a foundation for future developments. These are: the operating business parameters of a cable system, our customers, and the entertainment marketplace in which we and our customers meet.

Historically, the cable television business has been a capital intensive one. Despite dramatic decreases in the general cost of electronics, our capital investment per subscriber has increased due to two reasons: our desire to provide more services yielding greater revenue and the franchising authority's desire to get the ultimate, state-of-the-art communications system built. While the total demand for capital is decreasing as our new build period concludes, there is a continuing requirement as we rebuild our older, more mature systems. A portion of this expenditure is justified as we add the capacity necessary to introduce profitable services, but a portion is driven by the desire of each community to have at least the bells and whistles of its neighbors. Within the "utility" business, we are probably unique in this regard. When was the last time your local telephone company rebuilt its plant and increased services in order to get its franchise renewed?

As we have gone from delivering a few off-air signals to importing distant signals to providing unique satellite-delivered services and premium movie services, we have continually increased the value of our product. Today, the entertainment value we provide to our customer is so great that we have created a parallel shadow industry in the selling of "black boxes." Obviously, this has a negative effect on our ability to achieve a fair return on our capital investment. While we have demonstrated that smart management and legal protection can contain theft of services to manageable levels, the need for a more secure delivery technology continues. Our practice of changing converters periodically to increase our signal security just aggravates our capital requirements.

While the industry has been evolving, so has the consumer. Today, convenience is foremost in the mind of the consumer, what some have called the "7-11 mentality." Their battle cry is: "I want what I want when I want it." This attitude has been mirrored by the growth of the service sector. The consumer electronic industry has been one of the most successful respondents to this attitude. Success in the consumer electronics marketplace is no longer based upon functionality. Rather, it is based upon responding to diverse individual requirements by providing a wide selection of features and benefits. For example, one manufacturer of audio cassette decks has 14 current models in its lineup ranging in price from $87 to over $500. The increase in quality from the bottom of the line to the top of the line, i.e., frequency response of the recorded signal, is marginal. The variety of features and packaging options is great: one transport or two to allow high speed dubbing, with or without automatic reverse, with a mechanical or electronic revolution counter, with rotary or linear volume controls, etc. Similarly, a few years back Sony had a hit product in the Walkman. Today, there are at least eight different models from that one manufacturer for what is a very simple product. These models range in price from $40 to $400, and again the difference is not function or quality but rather features. Probably the ultimate example is the compact disk (CD) player which has been such a success this year. By employing digital recording techniques, these devices produce no measurable difference in the audio quality from the bottom of the line to the top of the line. Yet, there is a sufficient range in features to warrant a price range from $250 to $1,500. Again, this price difference is justified on the basis of ancillary features, e.g., sequential playback or random access, remote control, portability, etc.

In reviewing spending patterns for consumer electronic products, it is difficult to say whether this diversity is cause or effect. The fact is that over the last five years, consumers have spent an increasing percentage of their disposable income on consumer electronics, increasing from $66.60 per capita in 1980 to an estimated $103.80 in 1985, adjusted for inflation. (See Table 1) The message here is that our marketplace can be expanded by responding to the consumers' desire for diversity and convenience.

At the same time our industry and consumers have been changing, we have entered into a new and different marketplace as well. Historically, cable television was a product introduced in the surburban and fringe area except for New York City and San Francisco. Today, we have moved into the middle of the urban marketplace. What we have found there is that the demographics are much more diverse, varying from the stability of home owners to the transience of renters. We are also operating in an environment where there is increased competition for the entertainment dollar. The options available to the urban consumer range from live theater to video cassette rental with many more in between. While the overall demand for entertainment continues to increase somewhat, the consumer has a much greater opportunity to become increasingly selective. She will pick those options which are found to be most desirable to that individual. Satisfying this consumer requires a range of solutions.

CURRENT TERMINAL EQUIPMENT OPTIONS

As the value of our product has increased and the consumer electronics industry has adapted to the cable environment through cable-ready television sets, an important function of our consumer interface has become that of protecting our product. The two principle devices for performing this are converter/decoders and traps. The converter/decoder has provided a reasonable solution to extending the tuning range of the customer's receiving equipment while at the same time providing for signal security through the selective descrambling of the signal. However, there are specific shortcomings.

- Capital intensity: Use of converters currently requires placement of up to $200 of our equipment in the customer's home. In this environment, our investment is subject to theft, tampering and damage, an added cost of doing business.

- Customer convenience and selection: With converters, we are still in the era of the "black dial telephone." The only option we typically offer the customer is a remote control, generally not full function and at an extra charge, even if the customer already has the remote control feature on his television set. We don't even offer an option as simple as color coordinating the converter with the

Table 1
Consumer Electronic Expenditures
(all amounts in 1985 dollars)

YEAR	PER CAPITA EXPENDITURE	% OF DISPOSABLE INCOME
1980	$ 66.60	.6%
1981	$ 65.20	.59%
1982	$ 80.40	.74%
1983	$ 96.10	.88%
1984 (est)	$100.00	.89%
1985 (est)	$103.80	.89%

Source: Link Resources

customer's furnishings. And as becomes more apparent daily, our devices are incompatible or awkward in the developing consumer entertainment environment. The confusion and misunderstanding generated by cable-ready television sets and VCRs has just begun.

- Enhanced services: Our equipment currently depends upon the signal format being delivered, leaving us vulnerable to changes in television technology. Thus, the development of Multichannel Television Sound or High Definition TV can have serious capital investment implications for an operator. Our systems do not provide transparent pipelines. Thus, the introduction of enhanced services will generally require either incremental investment, aggravating our capital intensity or the denial of the services to the customer and the revenue to us.

- On-premise vs. off-premise equipment: With the diversity of demographics present in the urban market, it is to our advantage to have a range of solutions which include both on-premise equipment for the up-scale market where flexibility is important and off-premise equipment for the transient market where asset protection is important. However, general product incompatibility limits our ability to tailor the solution to our needs.

The principle alternative to converter/decoders for signal security is trapping. With the development of the multi-pay service environment, traps have become impractical. Their lack of flexibility, imperfect security, number of combinations to be stocked and degradation due to stacking have limited their applicability, especially in the modern urban system. On the other hand, because traps are passive rather than active devices, they provide the greatest degree of compatibility with the developing home entertainment environment by allowing us to let the customer select and invest in the consumer viewing equipment desired. Thus the home entertainment environment can be directly tailored to the customer's desires and means.

More generally, our technology has developed as a series of small incremental steps in response to short-term goals. We have developed from no interface equipment using the existing television tuner for delivery of off-air channels to an extended tuning range using the mid-band and providing a converter for those signals. Security was achieved because television sets could not tune the mid-band. Further developments extended the tuning range, introduced scrambling, two-way communications and impulse pay per view. However, with all this development, or perhaps because of it, there is little compatibility from one system to another. It is evident that our technology has developed without a long-term rationale to guide short-term decisions.

As a result, we have developed a closed network. Each small step has removed a degree of freedom. We have confused our customer with the variety and complexity of interconnections of our interface equipment. We have introduced incompatibilities between our systems, locking us into single-source purchasing and creating inefficiencies in our inventories. At the same time, our manufacturers have limited their markets. In short, we have let our technology get in the way of our customer's enjoyment and our success. My basic premise is that this situation arises, in large part, from one mistake: **the wrong person is making the purchase decisions.** The motivation of a cable system chief engineer is radically different from that of his customer. The engineer is motivated to minimize capital expenditures and maximize the life of each converter/decoder or trap. The consumer, on the other hand, is motivated to buy those products which appeal to his fancy. The power of this distinction is illustrated by the difference in converter and television set sales, shown in Table 2.

Table 2
Television Set versus Converter Sales
(all units in millions)

YEAR	INCREASE IN TV HOUSEHOLDS	TV SET UNIT SALES	INCREASE IN BASIC CABLE SUBSCRIBERS	CONVERTER SALE
83	.8	19.8	4.3	8.3
84 (est)	.8	21.2	4.6	8.4
85 (est)	.8	20.9	4.8	7.1

Source: U.S. Bureau of the Census, EIA, Paul Kagan

In other words, while television set sales have outpaced marketplace growth by 25 to 1, converter sales are less than double marketplace growth.

BUSINESS MODEL

This analysis demonstrates two points that are critical to the continued success of our industry. First, responding to the consumers' desire for diversity and convenience expands but also fragments the marketplace. Second, although it seems contradictory, this expansion can take place only where there are stable, well understood, **standard interfaces.** For all the diversity in audio cassette decks, there is one standard for tape size and speed, input signal levels, etc. Diversity of features could not have developed in the absence of these basic functional standards. Even in video cassette decks where there are currently two competing standards, each standard is stable and has spawned a family of functionally compatible but feature-diverse products.

These factors are easily accommodated by a model which divides our business into two complementary sectors: a utility sector and a consumer sector. The business of the utility sector is to provide a high-quality, simple, transparent transport service. The utility sector is capital intensive, based on our investment, with operating efficiency as the key success factor. Important aspects include:

- protecting capital investment by limiting customer premise equipment owned by the operator,
- controlling bad debt through approaches such as addressability,
- limiting service calls through status monitoring, addressability and better training.

The logical terminating point for the utility sector's responsibility is at the ground block.

In contrast the business of the consumer sector is providing the customer with the product desired delivered with the options and benefits desired. The product is video entertainment and information software packaged to provide the desired content in a manner which balances cost with perceived value. The convenience, features and benefits come from the viewing equipment chosen. The key success factors are selection and price/value. This sector fits directly into the consumer electronics marketplace - provide a wide range of features and let the consumer choose, and pay for, those desired. Match what is received with its perceived value. Thus, the consumer has options which range from black and white normal definition television to full-color high-definition television. Likewise, the options for audio might range from a three-inch low fidelity speaker to full stereo compact disk quality digital sound. The choice of how the signal is viewed and the incremental investment necessary to receive these options are the customer's. Under this model, the operator's investment is in the utility plant, i.e., the stable, transparent, protected transport medium. The consumer sector which is more volatile is not capital intense - the consumer has made the investment. The operator can now make a rational business decision whether to participate in the sale and rental of the home equipment.

The viability of this model is based on observation of 30 years of development in the telephone industry. Thirty years ago, the telephone company was in the business of selling dial tone. They provided a black dial telephone, and the concept of consumer choice didn't enter into their business. The local network was closed - the telephone company owned everything from one end of the network to the other. Development was stagnant, and there were limited opportunities for additional services.

A combination of regulatory and competitive pressures have forced the development of this over the past 30 years into a dynamic industry in which everyone will ultimately benefit. Today, we see the regulated companies operating in the utility mode. They sell dial tone, the provision of a transparent transport medium. In parallel, we have seen the blossoming of a new consumer electronics business in which there has been a proliferation of manufacturers, of equipment options available and of new services offered to the consumer. The magnitude of this developing marketplace and the benefit of allowing the end user to make the purchasing decision can be seen in Table 3.

Table 3
Telephone Sales

YEAR	SALES (Thousand Units)	AVERAGE PRICING ($)
1982	5,700	70
1983	19,700	47
1984 (est)	30,300	41
1985 (est)	34,200	40

Source: EIA

Despite the rhetoric, this appears to be a win-win situation. The consumer today has a range of choices not just in the color of instrument but in the features which it provides and ultimately in the carrier providing the service. While we are seeing some temporary price dislocation as subsidies lapse and prices become cost based, ultimately competition will drive the unit costs of communications down.

At the same time, the manufacturers have benefitted. There are many new manufacturers in business, and the range of products offered today has generated an increased demand on the part of the consumers. The regulated companies have also benefitted because per capita usage has increased. If you make the service easier to use by providing features which speak to the consumer's individual needs and desires, they will pay you back by increasing their usage. And, despite all the dire predictions to the contrary, the telephone network has not fallen apart.

FUTURE TECHNICAL DIRECTIONS

There are two requirements which must be met in order to implement this model. The first of these is stability, the assurance that our long-term ability to receive a fair return on our capital investment depends on the wisdom of our business decisions and not on political whimsy. The recently enacted cable communications bill provides us the stability necessary to operate a utility-type business by providing the presumption of franchise renewal.

The second requirement is the standardization of the interface between our network and consumer reception equipment. This is the more difficult one to meet for several reasons. First, it runs counter to the entrepreneurial heritage of our industry. In this business, everyone is an inventor, most in exactly the area which requires standardization, the interface to the customer. Second, there is the fear of legal restriction. In an industry where the largest operator controls less than 10% of the marketplace, there is no de facto standard setter as there was in the telephone industry. The necessary cooperation to achieve such standards would require an interaction between operators and manufacturers that might be subject to scrutiny under antitrust laws. Third, any standardization would require the active cooperation of our manufacturers and they have a valid concern with an increase of foreign competition made possible by standardization. Would the development of an interface standard and corresponding open network have the same impact on the manufacturers of cable television equipment that it has had on the manufacturers of consumer electronic equipment? Fourth, and foremost, there is no short-term pressure to achieve such standardization. The benefits which standardization provides are all long-term.

It is interesting to note that, even in the "black dial telephone" days, there was a high degree of standardization in the telephone industry. This is due in large part to the dominance of a single operator but also was due to the need to interconnect telephone systems as a natural extension of the services provided.

Two potential scenarios for future systems development meeting the conditions of the business model suggest themselves. These are only two out of many potential scenarios and are not necessarily the most likely. While it is important to evaluate many such scenarios, the ultimate implementation would depend upon general agreement on **one standard.**

Scenario 1. Security the consumer can own. A natural extension of the current trend in set top converters would be a form of signal scrambling sufficiently secure that operators would feel comfortable with the consumer owning the descrambler. Minimum requirements for such advice would include:

- o Addressability with a nationwide addressing scheme to provide for free movement from system to system,
- o Mechanical and electrical security sufficient to prevent successful tampering with the device,
- o A parameterized scrambling algorithm with many potential variants,
- o Use of a key required for descrambling,
- o Use of standard techniques for secure encrypted delivery of these keys.

Several products are now coming on the market which have some or all of these characteristics. Typically, they provide for soft video scrambling with hard (digitally encrypted) audio scrambling. This combination is adequate to discourage the manufacture of pirate boxes, assuming that the encryption methodology is secure.

Customer-owned, secure converters fit the requirements outlined above by placing the purchasing decision where it belongs, with the consumer. With the standardization of such a scrambling methodology, it would be feasible to include the descramblers and addressable receivers in all appropriate consumer electronic devices. Thus, the issue of consumer convenience is adequately addressed. The implementation of such an approach requires overcoming the standardization hurdles mentioned above. Specifically, in addition to standardizing on NTSC signals and F fittings, it would be necessary to standardize the scrambling algorithm, key distribution method and the addressable data transmission protocol. It would also be necessary to establish distribution channels for these products. The logistics of introduction must also be examined but are no more difficult than the situation today when we change converter types in a system.

The benefits to all industry participants are evident:

- o Increased consumer satisfaction through increased selection, convenience and lack of duplication,
- o Reduced capital investment on the part of cable operators,
- o Reduced risk for cable operators in the event of the introduction of new signal types since the interface equipment would be purchased by the consumer. Note that the security can depend upon the signal format since, in the event of a new signal format being developed requiring new security, the consumer has to purchase new viewing equipment anyway. The operator's investment is protected.
- o Increased demand for manufacturer's product by expanding from an engineering-driven to a consumer-driven marketplace.

Scenario 2. Cost effective, non interferring security. An alternative approach is the separation of security from the consumer interface equipment. Minimum requirements for such a device would be:

- o An addressable tap or trap,
- o The method of obtaining security would not be dependent upon the signal format thus providing compatibility with future signal types,
- o Independent control of each 6 Mhz section of spectrum, finer resolution would be desirable,

- o A capital cost of approximately $20 per port.

While this attacks the problem from a different angle, it also fits the characteristics outlined above. The capital investment of $20 per port is manageable, and the transparency provides for consumer convenience. In this case, there is no customer interface decision to be made in the home. Rather, current cable-ready television receivers and other consumer electronic products would work. Further, the ability to control bandwidth without being sensitive to signal format provides a transparency necessary for the introduction of future ancillary services.

Again, the benefit to industry participants is evident:

- o Transparency to the consumer and therefore convenience of not having to worry about yet another set of control devices,

- o Limited risk of obsolescence to the operator because of the ability to control bandwidth in a signal transparent fashion,

- o A new market for manufacturers in providing such a device.

In this scenario, the burden of standardization is less severe, basically F fittings, signal levels, frequency assignments and channel numbering plans. However, the technical hurdles to overcome are much greater.

CONCLUSION

As our industry matures, reaching the end of its new build phase, we have achieved a significant level of penetration and offer a consumer electronic marketplace to be reckoned with. However, we still suffer from considerable technological fragmentation. I have suggested a long-term view which separates the utility and consumer sectors of our business. I believe that all participants benefit from an evolution from our current closed network to an open network in which we as operators provide a transparent pipeline for the delivery of entertainment signals. This pipeline, because of its transparency, provides the long-term stability needed to achieve a reasonable return on our capital investment. The consumer participates by investing in the appropriate interface equipment, thus allowing for the diversity and feature orientation that should rightfully be an individual choice for each person. By putting the purchase decision where the value is perceived, we increase consumer satisfaction at the same time that we reduce our capital commitment.

IMPROVED AM MICROWAVE PERFORMANCE WITH PREDISTORTION

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ABSTRACT

Predistortion provides an effective means of improving the linearity of an AM microwave transmitter. Unlike power doubling and feed-forward, predistortion can be implemented with a relatively simple VHF circuit that partly compensates for the nonlinearity of the microwave klystron amplifier utilized in the output of the high power Hughes AML® STX-141 transmitter. The resultant improved overall linearity could permit additional channel loading of an FM band transmitter, the running of either FM or TV channel audio at a higher level than the normally specified -17 dB relative to video without compromising the transmitter C/IM performance, or a 3 dB increase in TV channel transmitter output while maintaining intermodulation distortion and differential gain and phase within specified limits.

INTRODUCTION

In AM systems the amount of intermodulation distortion depends on the signal level and on the linearity of the input/output transfer characteristic. Ideally, the amplitude transfer is perfectly linear right up to saturation and the phase is unaffected by the level at which the signal operates. Real amplifiers, such as the klystron utilized in the AML transmitter, will differ significantly from this ideal. However, by placing a predistortion module in series with the amplifier, the overall transfer characteristic can be made to be more linear. This results in less distortion at a given output level, or alternatively, in a greater output capability at a specified level of distortion.

An alternative view of predistortion which is most useful in the band-limited small signal regime is to consider the predistortion module as a generator of third order distortion products. These intermodulation products are controlled in amplitude and phase so as to just cancel out the intermodulation products created in the output power amplifier. The paper decribes the implementation of such a predistortion circuit operating at VHF. Performance improvement of a typical high power AML transmitter incorporating this form of predistortion is also detailed.

LINEARITY IMPROVEMENT ALTERNATIVES

The problem of non-linearity in CATV systems is a familiar one. Together with noise, it is the mechanism which limits system performance and the ability of the cable to reach out to a greater distance and service a wider geographical area from a single headend. Nonlinearity also limits the performance of AM microwave transmitters and usually requires substantial backoff from the saturated output power capability. Since the power is thus reduced, the range, although generally much greater than what can be obtained with cable alone for equivalent distortion performance, is again limited by considerations of noise in the microwave receiver and signal distortion in the microwave transmitter.

Both power doubling and feed forward are extensively used in modern CATV amplifiers. These techniques of linearity improvement are however not limited to the VHF regime. Power doubling is widely applied to obtain increased output capability in microwave GaAs FET amplifiers. For instance, Figure 1 shows a block diagram of

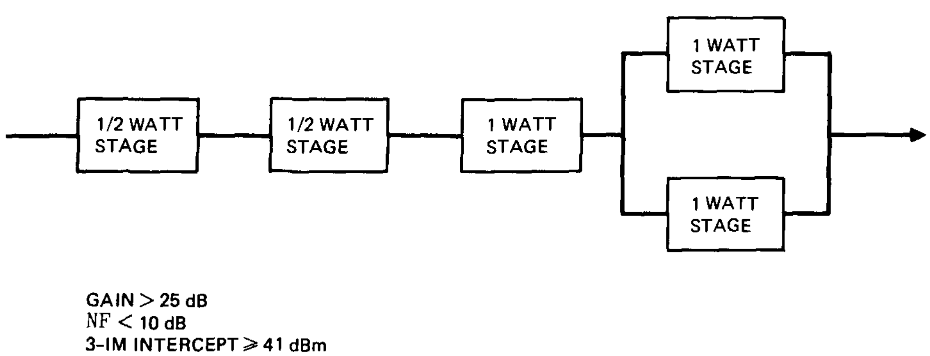

Figure 1 2-watt GaAs FET amplifier with power doubling.

the 2-watt amplifier utilized in the Hughes AML OLE-111 transmitter[1]. In such amplifiers the phase shifts of the paired output stages are well matched to obtain the full benefit of the power doubling technique. Feedforward has also been utilized at microwave frequencies since the classic paper by Seidel[2]. However, just as in VHF application, the feedforward technique requires a substantially greater level of complexity resulting in higher cost and reduced reliability due to increased component count.

A far simpler technique, which has been used for many years to improve the efficiency of TV broadcast equipment, is predistortion. This technique has also been applied at microwave in various forms to optimize traveling wave tube amplifier performance[3]. The principle underlying this form of predistortion is illustrated in Figure 2. Both the amplitude and phase input/output transfer functions are linearized by preceding the TWTA with a predistortion circuit which compensates for the amplifier nonlinearity. As a goal, the overall amplitude transfer would provide a 1 dB output change for 1 dB input change while the phase transfer characteristic would remain constant up to the point where the amplifier reaches saturated output.

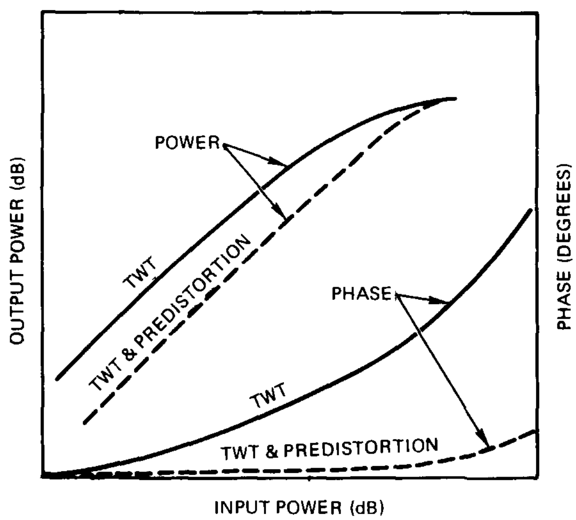

Figure 2 Typical TWT transfer characteristics with predistortion.

Another way of understanding predistortion is to consider the predistortion unit as a generator of intermodulation products which are 180° out of phase with the intermodulation products generated within the output amplifier. By further adjusting these IM products to be of equal relative amplitude, complete cancellation of the principle IM products is ideally possible. This concept is illustrated in Figure 3. The viewpoint is particularly useful when the output amplifier backoff must still be substantial due to the large C/IM requirements of typical SSB-AM systems.

The predistortion circuit may be implemented at VHF frequency even if the transmitter output stage is at microwave[4,5]. The only requirement is that the phase of the IM product generated at VHF is 180° out of phase with the distortion produced in the microwave output stage so that the overall IM is cancelled. This necessitates that the intervening circuits be sufficiently broadband so as not to introduce group delay or amplitude distortion as a function of frequency lest only some of the IM products are properly cancelled.

PREDISTORTION IMPLEMENTATION

Figure 4 shows a block diagram of an STX-141 transmitter modified to include VHF predistortion. Two new parts were added to the standard transmitter: the predistorter module which includes a +12 volt power supply, and a GaAs FET microwave amplifier. The FET amplifier is included so as to be able to broadband tune the klystron without requiring additional signal level output and consequent intermodulation products from the upconverter. The klystron must be sufficiently wideband in order to prevent phase shift in its input sections from interfering with the IM cancellation near the FM band edge. Predistorter IM phase and amplitude adjustments are made available at the rear panel to facilitate correct alignment during initial installation and in the event klystron replacement is required. Touch up adjustment may also be required to reoptimize long term performance as the klystron amplifier ages.

The predistortion module block diagram is shown in Figure 5. The input VHF signal is split into two arms - a distortion arm and a linear arm. The main signal goes through the linear arm which includes a delay line to match the delay in the distortion arm. This helps the circuit to maintain relatively constant phase relationships between desired carriers and IM products over a wide percentage bandwidth. The intermodulation (IM) product

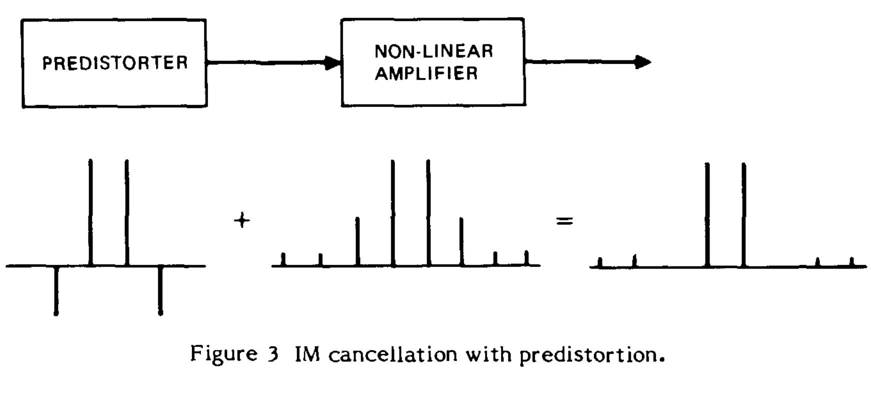

Figure 3 IM cancellation with predistortion.

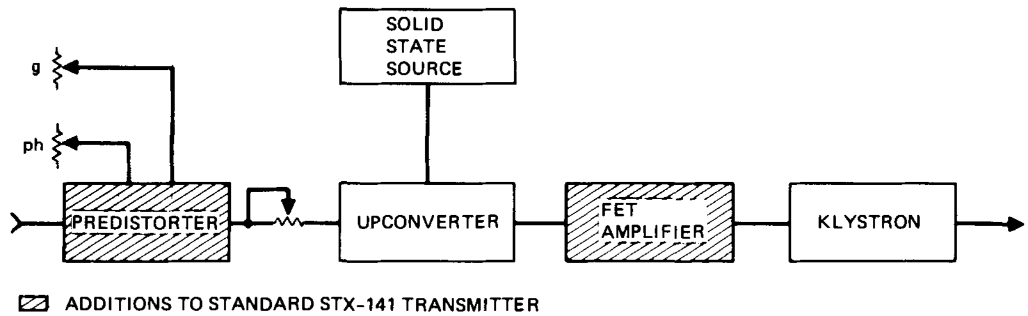

Figure 4 FM-band STX-141 including predistortion modification kit.

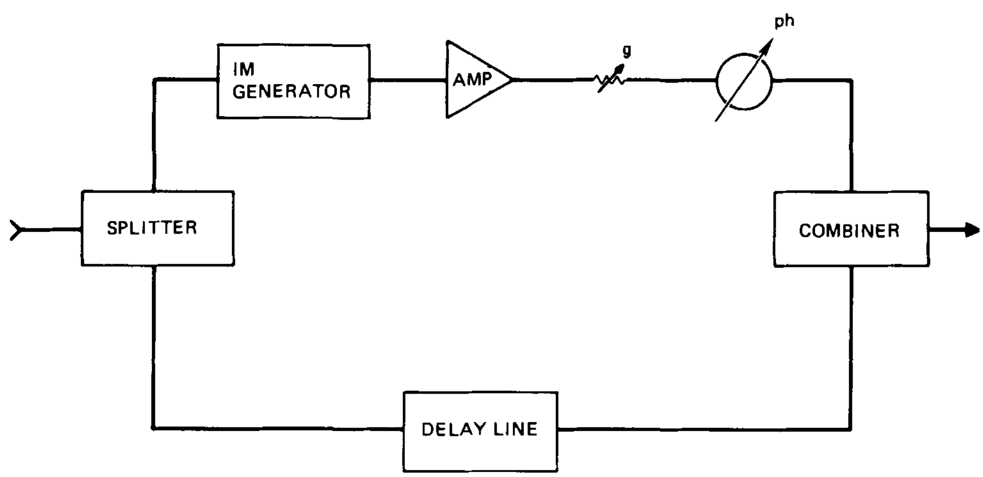

Figure 5 Predistorter block diagram.

generator also acts to suppress the input carriers in the distortion arm. An internal adjustment maximizes carrier suppression so that only IM products pass through the amplifier, attenuator, and phase shifter. In this way the IM amplitude and phase are precisely controlled relative to the output VHF carriers after recombination in the output combiner. Figure 6 summarizes the theoretical amplitude and phase error limits for various levels of IM improvement. Phase error limits are particularly stringent. For instance, to maintain 20 dB improvement over the 88-108 MHz FM band requires less than 2 ns of group delay. This cannot be achieved without broadbanding the upconverter output filter and klystron employed in the Standard AML STX-141 transmitter.

Figure 7 shows the internal construction of the predistortion module. The coaxial delay line is evident in the photograph. Figure 8 shows the same module with cover and attached power supply. The wires lead to the rear panel mountable gain and phase adjust potentiometers. The unit is designed so that a field retrofit kit implementation is possible.

EFFECT OF PREDISTORTION ON AML TRANSMITTER PERFORMANCE

The standard 6 MHz wide STX-141 transmitter is tested at the factory with three cw tones, representing the video, color, and audio carriers respectively at 0/-20/-17 dB from the reference output of +33 dBm. The $f_V \pm (f_C - f_A)$ beat that results is specified to be at least 58 dB below the reference level. One can describe this linearity performance with a single parameter, the 3-IM intercept, which in this case is 46.5 dBm. By contrast, the broader bandwidth 88-108 MHz FM channel STX-141 transmitter performance may be as much as 2.5 dB less, i.e. 3-IM intercept of +44 dBm. Efforts to improve this performance are particularly important in European applications where the FM deviation is considerably less than in the U.S. For this reason, the predistortion technique previously described by Figure 4 has initially been applied to the 87.5-104 MHz European FM band. Results to date have been very encouraging. 3-IM intercept points as high as 54 dBm have been obtained. The circuit is stable as a function of time but, at this writing, requires retuning for wide temperature excursions.

A word of caution is required when applying the 3-IM intercept point concept to circuits involving predistortion. For normal "well-behaved" circuits, third order distortion products increase at the rate of 3 dB for each 1 dB increase in output level. However, when predistortion is applied this is often not the case and thus the circuit must be tested for stability as a function of drift in input level. Table 1 describes a specific measurement with the predistortion adjusted for operation at the 0 dB reference level. It is seen that the IM increases faster than 3 for 1 at output levels exceeding

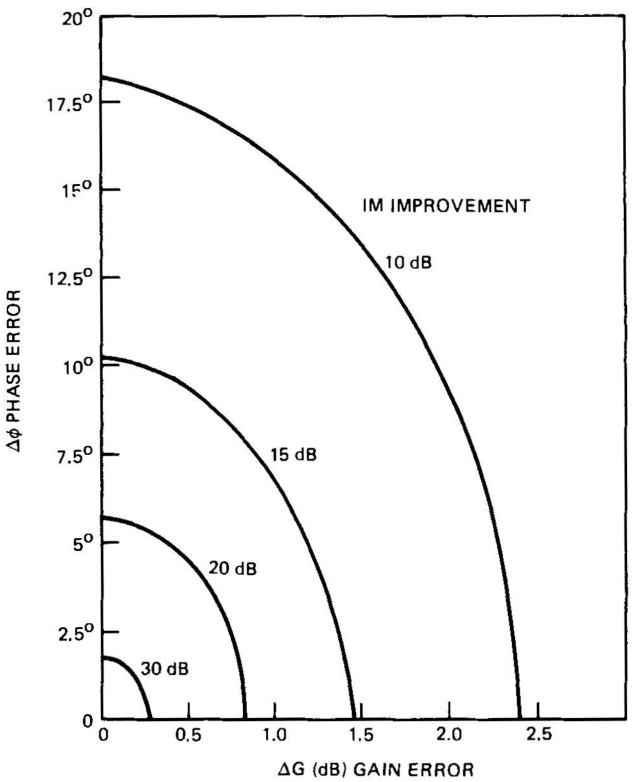

Figure 6 Allowable gain and phase error versus IM reduction.

the reference level by 2 dB and acts irregularly, i.e. "better" than normal, at 1 dB above the reference. At power levels below the reference level the IM exhibited a monotonic decrease ensuring that the specification would be met at any level up to the reference level.

The LNA (FET driver amplifier) serves two functions in the predistortion scheme reported here. First, it permits the klystron to operate at reduced gain corresponding to maximum broadband tuning. This reduces the

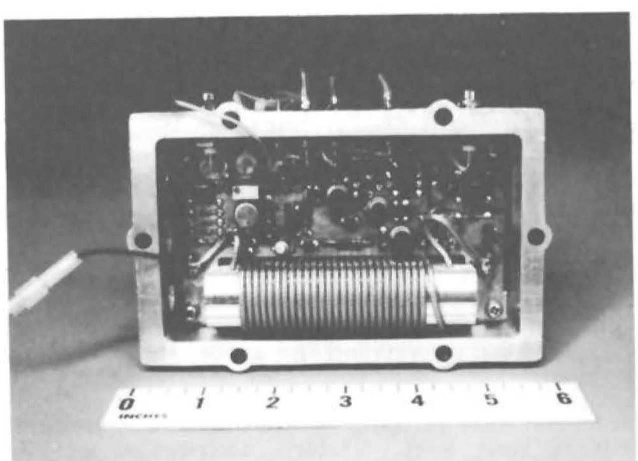

Figure 7 Predistorter internal construction.

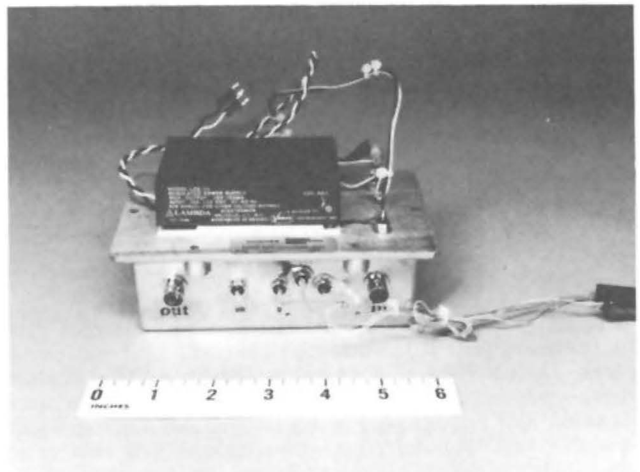

Figure 8 Predistortion module with power supply.

gain and group delay variation with frequency to a minimum and permits better IM cancellation as was shown in Figure 6. Secondarily, the reduction in klystron gain is more than compensated by the LNA gain so that the signal level at the upconverter can be reduced. In this way the upconverters contribution to the IM becomes entirely negligible. The 3-IM intercept point of the LNA is also sufficiently high to ensure that its IM generation can be neglected.

With the LNA removed from the transmitter, overall performance was still significantly better than with no predistortion. For the 87.5-104 MHz FM channel a 3-IM intercept point of +49 dBm was obtained. These results are summarized in Table 2.

The table also shows comparisons for video signal applications. Three key differences must be noted. First, the signal bandwidth is only 6 MHz so that broadband tuning of the STX-141 klystron is much less important. However, note that the $2f_V$-f_A intermodulation product would be 14 dB greater than the in-band 3-tone IM were it not for the fact that the single side band filter provides the necessary attenuation. Unfortunately, group delay is unavoidably associated with this attenuation characteristic. Thus it is not possible for the predistorter to simultaneously and completely cancel both the in and out-of-band IM generated by the klystron. A possible solution to this dilemma would be to replace the upconverter output filter with a broader band unit to reduce group delay, and then again back off upconverter drive level by using an LNA. It is doubtful that such an extensive modification to the standard STX-141 would be justified by the possible supplementary linearity benefits which in any case would be limited by the third key difference.

TABLE 1

VARIATION OF C/IM WITH OUTPUT LEVEL

Output (dB_{ref})	0	+1	+2	+3	+4
C/IM	70	70	66	60.5	56

TABLE 2

TRANSMITTER LINEARITY SUMMARY

Type Trans-mitter	Signal	Pre-distortion	LNA	3-IM Intercept (dBm)
STX-141	87.5-104 MHz	Yes	Yes	+54
STX-141	87.5-104 MHz	Yes	No	49
STX-141	88-108 MHz	No	No	44
STX-141	Video	Yes	No	49.5
STX-141	Video	No	No	46.5
MTX-132	Video	Yes	No	36.5
MTX-132	Video	No	No	35.5

This third difference is tied to the fact that unlike the FM signals, TV signals vary in amplitude. Thus IM cancellation is not the only criterion by which to judge the non-linear performance. Differential phase and gain must also be taken into account. The klystron transfer characteristic must be more precisely matched over a wider range of amplitude level variation with the compensation provided by the relatively simple predistortion circuit described by Figure 5. The optimum tuning condition is a compromise between the various parameters and cannot be adequately described by just the 3-IM intercept point. Table 3 provides the additional detail comparing the STX-141 performance with and without the predistortion module. The LNA was not used in these experiments. Tuning was optimized for operation at 4 watts output and shows that the AML transmitter can provide good linearity performance at an output 3 dB higher than normal.

TABLE 3

EFFECT OF PREDISTORTION ON STX-141 VIDEO PERFORMANCE

	2 Watts Output		4 Watts Output	
	Std.	With Pre-distortion	Std.	With Pre-distortion
Differential gain (%)	3	3	7	4
Differential phase (°)	2	1	3	1
In-band C/IM, (dB)	61	65	55	62
Adjacent channel C/IM, (dB)	58	66	49	64

The final two entries in Table 2 refer to the Hughes AML MTX-132 transmitter in which a high level parametric upconverter is the distortion limiting element rather than a klystron. The situation is considerably simplified in that there is no high Q microwave filter introducing group delay between the predistorter module and the transmitter distortion limiting circuit. Nevertheless, the results were disappointing although not entirely unexpected. Figure 9 shows that the amplitude transfer characteristic of the parametric upconverter is nearly ideal to begin with. The +22 dBm operating point is typically within 6 dB of hard saturation. Comparing this to the 13 dB klystron output backoff it is readily apparent that linearity improvement of the MTX-132 transmitter cannot be expected to be as large as that obtained with the STX-141 transmitter.

SUMMARY

Improved linearity performance of AM microwave transmitters may be obtained through the technique of predistortion. In particular, it has been found that a relatively simple VHF predistortion circuit can be tuned to partially compensate for the klystron amplifier distortion in the AML STX-141 transmitter. With a FET driver amplifier additionally inserted between the upconverter and the output klystron, up to 10 dB increase in transmitter 3-IM intercept performance has been obtained over the European 87.5-104 MHz FM band. Between 5 and 7 dB improvement is anticipated over the wider 88-108 FM band used in the U.S. Preliminary experiments with the same type VHF predistortion module, and without the FET driver amplifier, indicate that the STX-141 transmitter power output can be increased by 3 dB to 4 watts while maintaining the TV channel intermodulation specification at 58 dB. When the same technique is applied to the MTX-132 transmitter, only 1 dB improvement was obtained. This is attributed to the already excellent linearity performance of the MTX-132 high level upconverter up to within a few dB of saturation.

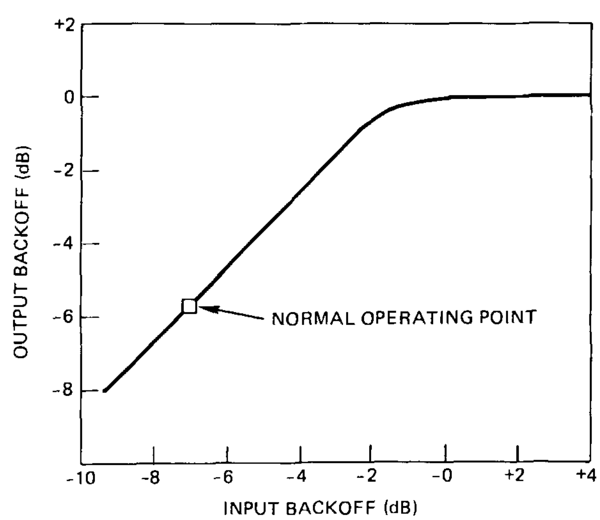

Figure 9 MTX-132 up-converter amplitude transfer characteristics.

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INGRESS - SOURCES and SOLUTIONS

by John W. Ward Jr.

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Signal ingress is a problem which has always plagued cable systems. While there has always been potential for problems from VHF television stations, with the modern cable system encountering the UHF television band, the susceptibility of cable systems to ingress interference is increasing. Immunity from ingress problems can only be achieved by maintaining system integrity at levels better than those required by specification.

Interfering signals leak into a cable system not only thru flaws in the cable system but also by way of consumer equipment, cable ready televisions and VCRs. The increase in the number of these devices as well as other factors lead to a need to be able to efficiently diagnose and cure signal ingress problems.

WHAT IS INGRESS

Ingress, as far as the CATV community is concerned, is the entrance into a cable system of any undesired external radio source. Ingress will occasionally be in the form of static or electrical noise, but it is normally considered to be interference from a radio frequency signal. Ingress of such signals will result in interference to cable pictures. Modern cable systems have sufficient isolation from ingress, or shielding, to prevent ingress of carriers in even the noisiest of radio environments. But, an awareness of ingress related problems is required by the cable system operator to enable repair of inevitable, natural, flaws in the system.

Ingress is the opposite of egress, or system radiation. The principle by which both phenomena operate is the same, related by the principle of antenna reciprocity, which is that antennas transmit and receive equally well. That cable systems do radiate energy is an established fact, that cable systems are susceptible to ingress therefore follows. As system egress levels are reduced to within regulation, effects of ingress are reduced toward acceptable levels. Still, in order to completely overcome the effects of ingress in areas where external radio signals are especially high, even defects that are otherwise insignificant must be found and corrected.

Interference due to ingress can be classified into two basic forms, either co-channel or discrete carrier. When there are one or more local VHF TV stations located near a cable system which uses a channel occupied by one of these VHF stations, there will without doubt, sooner or later, be need to correct co-channel interference between the two. Discrete carriers from communications transmitters will cause problems on mid-band and super-band cable channels. As communications transmitters include everything from car phones and personal pagers to amateurs and the National Weather Service, discrete carrier ingress can occur anywhere and often at random times.

Cable systems near the VHF TV transmitters of a large city are the systems that will likely suffer from co-channel ingress related problems. At two to five miles from a full power TV transmitter it is not uncommon to have a field strength of 35 to 40 dBmv or more, very often 25 dB more than than what is inside the cable. Levels from TV transmitters as far away as 30 miles may exceed the average levels of a CATV plant. Beyond that range the effects of ingress related co-channel interference become less noticeable.

Co-channel type ingress interference in its most basic form will appear on a TV picture as a strong beating pattern , when the cable channel is not phaselocked with the interfering station. If the cable programing is phaselocked to but not sync locked to the unwanted carrier, a wiping of the interfering stations' sync bar through the background of the desired picture is the first effect noticed. If cable programing is both phase and sync locked to the local station, as it is when operation is "on channel", the first effect will be faint ghosts in the picture, either of text characters with their high energy edges, or of the horizontal sync bar, stablized, but in the middle of the screen. The difference in the time it takes the signal to arrive at the set both through the cable and through the air allows the channel to interfere with itself. If the two signals arrived at the same time they would mesh perfectly, all the interference would be hidden.

When operating "on channel", or with alternate programing phase-locked and sync locked to a local VHF transmitter, the cable signal must be at least 50 dB or more above any ingress from the airwave signal in order to suppress sync bar ghosting of the picture. Without sync lock, a separation of 55 dB is a minimum to prevent an annoying wiping pattern in the background. If the cable channel operates with alternate programing not phaselocked to the local TV station sharing the same channel, the cable video carrier should be 60 dB higher than any interference. In extreme cases of co-channel ingress interference, where an off air signal is only 40 or 45 dB down from the cable signal, strong ghosts or other distortions may be expected, regardless of the operating mode. Customers will surely call for service when the interference is this bad.

The effect of ingress due to discrete carrier interference is similar to second order beat problems in that both will appear on the customers set as a herringbone pattern or wavy series of vertical lines. If several unwanted carriers are present, as is often the case with channels shared by the communications bands, the effect may be a soft distortion similar in symptoms to third order product accumulation. A discrete carrier located near the color sub-carrier of a cable channel may cause a beating pattern in picture tint or, if sufficiently strong, may even drive the picture into black and white.

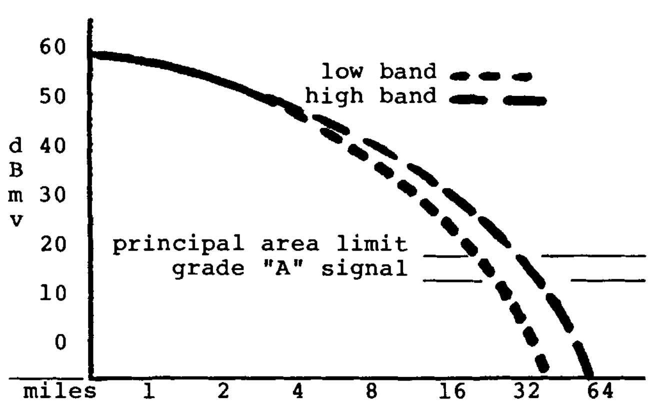
Picture distortions due to discrete beats vary depending upon the level of the beat as well as the position of the beat in the band of the cable channel. For example, an interfering carrier 30 dB down and 10 khz. from the cable video carrier will probably not cause any noticeable picture distortions. Interference located 1/2 mhz above the video carrier with a level as low as 40 dB down from it, will cause strong beats in the picture. When the interference is from a carrier located in the middle of the cable channel, 1-1/2 mhz away from the video, a rejection of up to 55 to 60 dB is necessary to prevent a "busy background" effect. The amount of immunity required by the cable system from ingress beats is the same as and can be compared to FCC specifications regarding carrier to second order beat ratios.

HOW DOES INGRESS GET IN

Ingress gets into the cable system by way of poor shielding and faulty connections. The cable acts as an antenna and will have currents from external radio fields induced onto it's shield. Electron flow, or currents, of radio frequency energy, happens only on the surface of a conductor. Under normal conditions, the cable signal energy flows on the inside surface of the shield and broadcast radio signals flow on the outer surface of the shield. A "hole" in the shield will join the two surfaces, allowing undesired currents to flow both out and in. Unbalanced current flow between the shield and center conductor of the cable will cause the undesired signal to be added to the cable signal.

Experience has shown the most common point of ingress to be a slightly loose connector. The connection is normally tight enough not to noticeably effect the cable signals, if not for the ingress problem. The connection may be just loose enough to permit air molecules to permeate between the threads and, given time, form a layer of corrosion. The improperly made connector will also permit gasses to corrode the aluminum of the shield itself, forming aluminum oxide, a poor electrical conductor. Corrosion will create a point of resistive and/or capacitive nature in the shield of the cable. This breakdown of the outside conductor is the unwanted hole in the shield.

Theory and experiment show that a mismatch on the inner conductor will not permit signals to enter the cable, only the signals inside the cable already will be affected. This can be demonstrated by cutting the center conductor short at a splice in the middle of a section of drop. The isolation is as good as the shield in this experiment. It can also be demonstrated that a single crack or hole in the shield,



FIELD STRENGTH OF TV TRANSMITTERS [3]

not completely around the cable, is in itself not a significant source of ingress. However, when the small cracks are spaced at regular distances, an effective amount of energy is transferred into the cable (as well as out).

Improper handling or installation of drop cable can cause periodic cracks in several ways. One common way a flaw may arise is when a staple gun, faulty itself or improperly used, causes a severe sharp dent in a drop wire as the staple is fired. Even though the outer shield is not actually pierced by the impact, a small crack might be created. A series of a dozen or so of these, regularly spaced 18 to 20 inches apart, can reduce the shielding of a drop, down from a nominal 90 dB, to only 50 or 60 dB of isolation at mid band frequencies. Periodic bumps and cracks in drop cable can also be caused by rough pulling the wire from boxes and reels, or flexing the cable sharply around corners, although the observed occurrence of this type of failure is rare.

One way the largest amount of unwanted signals can be transferred into the cable is by a total discontinuity of the shield due to radial cracks. Faulty connections are similar to these radial cracks. A radial crack all the way around the cable shield will typically reduce the cable signals by about 10 to 12 dB, implying, in the worst case, as low as 3dB isolation between the the outside and inside of the cable. On the other hand, a typical "bad" connector might reduce the isolation to 40 dB, with less than 1/10 of a dB reduction in cable signals.

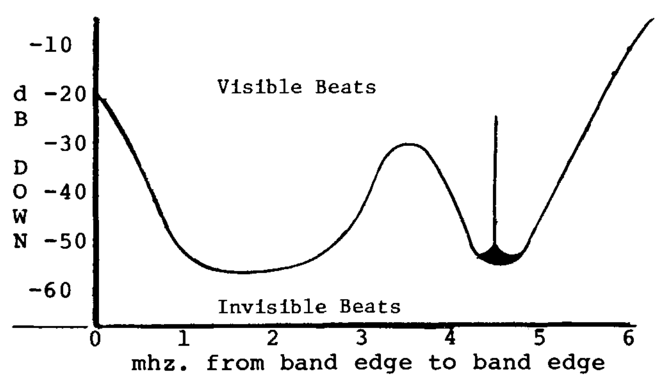
Compared to defects created by bad connections, the amount of shield provided by the wire itself is of minor importance as far as ingress is concerned. With trunk and feeder lines, the shielding is complete as possible, with more than 110 dB of isolation often the case. Flexible drop wires with foil shields under a wire braid, the type used by the cable industry, typically are rated with 85 to 100 dB shield isolation.[1] The ability of the cable shielding to physically withstand handling and to survive the elements is of more importance when selecting drop cable of this quality then the shield factor itself.

The shielding factor of the drop cable becomes significant when non standard wire is used, such as a situation in which a house has been wired by a customer using his own wire. The shield for this wire can be as low as 50 dB for wire with a heavy braid, 35 dB or so with typical 40% braid shield wire. Also, aside from the poor shield, it is almost impossible to make a proper connection to these wires as the dimensions vary greatly from type to type and it is next to impossible to find a proper fitting. The fitting must not only pass signals but must properly seal the shield from ingress as well as survive through time.

Other parts of the cable system responsible for ingress are loose amplifier covers and tap plates. Although experience is that an amplifier housing must be open and the amp's module cover almost off in order to get a significant amount of ingress into the cable itself, amplifier covers must not be ruled out.

Tap plates, however, especially when drops are connected to them, are crucial points of shielding breakdown in the feeder system . The rf shield around the edge of a tap plate can only work well when making a good pressure connection to the housing plate. Loose tap plates, with contaminants between the plate and the housing will cause a discontinuity to occur between the drop shield and the shield of the feeder cable, allowing ingress into the drop and to a lesser extent, into the feeder itself. Even when the tap plate is tight, corrosion due to moisture is frequently a problem as the rf gasket is located at the point of maximum water accumulation as a tap hangs on the feeder line. A very thin layer of waterproofing grease will aid in preventing this problem. A word of caution needed here, over zealous tightening of tap plate screws will lead to striped housing threads, clutch type torque drivers are recommended.

Studies have indicated that an unterminated tap port will provide greater RF isolation than a terminated tap port.[2] The terminator itself is a connector and hence subject to the inevitable natural corrosion of the connector threads. As the outer shell loses its ground connection, the terminator becomes a stub antenna and hence a point of ingress into the cable system. The port to port isolation of a two way splitter is normally about 25 dB and a



CARRIER/INTERFERENCE RATIO [4]

stub antenna about an inch and a half long will pick up as much as 0 dBmv of signal near a high band VHF TV station. A strong to moderate interference is observed on drops connected to adjacent tap ports.

Port to port transference is also responsible for mysterious interference problems when temporary disconnections of a neighbors drops are made. In one case, when a neighbor disconnected the cable drop from his VCR, the center conductor of the drop would contact the metallic case. The field strength of the local TV stations were about +35 dBmv in the area. This resulted in +10 dBmv of interference being back-fed into the other customers' otherwise perfect drop. And, due to the directional coupler characteristics of the tap itself, the rest of the system was uneffected. This happened every night for a few hours at a time, greatly reducing the mental stability of the service personal. The solution was simple when the reason was discovered. The customer with the VCR was given an A/B switch so he could switch inputs and still maintain system integrity.

SUBSCRIBER CAUSED INGRESS

Perhaps the most perplexing cause of ingress problems is subscriber owned equipment. It is the one part of the system over which the cable operator generally has the least control. As the consumer becomes more and more 'video active', the occurrence of ingress problems due to consumer related equipment is sure to increase. The fact that subscribers will loosen drops by simply moving converters as well as by connecting their own equipment will be a sure ingress problem from now on in any metropolitan area. In a typical case an otherwise perfectly good VCR and TV set will be connected with factory included wiring with easy to use push on fittings. The customer installs the source and will suffer the effects of ingress. Installation of quality wiring with proper connections will correct the problem. While the solution is easy, it is a service call never the less.

Another common occurrence with customer installed equipment leading to an ingress problem is the video game or computer switch normally supplied with such equipment . When installed before a cable ready TV or VCR , or indeed installed anywhere but after a converter, they will without doubt permit ingress. When video games or computers must be connected to cable ready TV sets it is necessary to install a well shielded, self terminating CATV grade A/B switch in place of the customers switch. Using these and standard adaptors available at local electronic dealers, a connection can be made that will provide a proper amount of isolation. In some extreme cases it might be necessary to replace game switches located after the converter if a local transmitter is operating in a channel adjacent to the converter output channel. The lower sideband of a broadcast station extends well into the lower channel. Suppressed properly, it nevertheless has enough strength to overcome the poor shielding of these inexpensive, manufacturer supplied switches.

Of all the ailments created by subscriber equipment, problems due to the poor shielding of some cable ready TV sets are the only truly incurable ones. The amount of ingress which is introduced by cable ready televisions varies greatly from model to model and no brand can be said to be best. There are many models of cable ready televisions that exhibit excellent shielding while other models of the same brand don't. It is also found that problems with cable ready sets depend upon the location of the set in the room , as well as the strength of the interfering local transmitter. Cable ready sets are subject to the same conditions as the rest of the cable plant and if there is a potential for ingress, it will enter the system through the poorly shielded television just as easy as it would any other part of the distribution system. It will sometimes be necessary to tell a customer there is nothing that can be done, that the set itself is the problem.

Cable converters have the critical portions of the signal path inside a tight metallic box, which constitutes a good shield. A typical television will have the shielding open on one side, or have a circuit card pass through it, with the shield only spot soldered to the circuit card, leaving gaps enough to allow more ingress than several loose fittings, plenty enough to cause problems. The set will otherwise work perfectly, on channels other than the ones occupied by any communications band or local television station. The best option the cable operator has in order to correct a ingress problem directly inside the television set, is to place a converter before the cable ready set, allowing the set to operate on a clear channel. This sometimes upsets the customer who has paid extra for the cable readiness, and often complicates the instructions of using various remotes in order to gain satisfactory operation.

Aside from placing a converter before a cable ready set, the only other practical solution to this problem is to raise the signal levels into the set to a point where the level of the interference becomes insignificant. If the cable ready TV set has a shielding factor of 40 dB for example, about the average for the a problem causing set, and the field strength of a local transmitter is 0 dBmv, an input level of

+10 dBmv to the set will a provide brute force solution. Even this solution proves impractical if the set is located only several miles from local TV transmitters, the input levels needed to mask the interference will be more than the highest level the cable system is allowed to operate at by law.

The degree of the isolation provided by cable ready sets can easily be determined by reading the strength of the known source of interference directly out of the back of a TV set and comparing this to dipole readings at the same location. If one positions the antenna for maximum receive levels , and does the same with a television receiver, with the TV set off to prevent reading RF generated by the set itself , a direct estimate of the shielding factor of the set may be made.

Cable ready VCRs present another potential source of ingress, fortunately though they do not generally appear to be as great of a problem as cable ready TVs. Although poor VCR shielding has ocasionally been the source of ingress, the cables used and other problems with connections are much more bothersome than the VCRs themselves.

A poorly shielded cable ready set can also present a problem to other sets if the field strength of a local tv transmitter is moderately strong. It is quite possible for a set with 30 dB or less shielding factor, about the worst encountered, located in a typical urban environment, to pass ingress at -10 dBmv up a drop to a splitter. There it will back-feed down the other drop leg at a level of -35 dBmv of interference versus 5 dBmv of signal, more than enough to be noticeable.

FM hook-ups create two types of ingress related problems. The first is with interference to FM services provided by the cable system, and the second with addressable converters when connected along with a FM hookup. The typical FM tuner will work perfectly well with little or no antenna connected to it in an urban environment. While the shielding of the tuner is generally very poor, it is possible to deliver quality FM signals thru a cable system. If the signal from a local FM station is delivered unshifted in frequency, FM tuners will generally be unable to distinguish between the two carriers, in the cable and off the air. If the cable operator is careful to avoid using FM channels within 400 khz of local FM transmitters for other, imported or operator generated signals, problems may generally be avoided.

The possibility of ingress into the cable system of signals which could interfere with data carriers used by addressable converters and home security systems is greatly magnified by FM tuner hook-ups. With FM transmitters often as powerful as TV stations, combined with a tuner's characteristically poor shielding, backfeed of unwanted signals into the cable can create serious problems. As the data carrier is already well below the operating level of a cable video carrier, the sidebands of a local FM station can easily distort a data carrier. Data transmissions, when distorted by interference, may contain errors resulting in random characters being received between transmissions, or worse yet, in severe cases, the corruption of a desired transmission. To avoid problems with data communications in the FM band, you may use a directional coupler between FM tap-off device and the effected equipment to prevent backfeed. The use of regular splitters in place of FM taps should be avoided.

TROUBLESHOOTING THE INGRESS PROBLEM

As the number of urban homes wired for cable increases and as older drops aproach life expectancy, the amount of service calls related to ingress is bound to increase also. The problem is compounded by the wider bandwidths of modern cable systems as they encounter more communications bands and even UHF television. Increases in the number of communications transmitters in the spectrum and the huge impact of consumer equipment will lead to the need for quick and sure means of detecting and correcting ingress problems. Even today it is often the case that a cable system in a urban area will find 10 to 15, and sometimes as much as 30, percent of its service manpower spent finding and correcting ingress related problems. Routine procedures must be taught to service employees so that they can handle the problems efficiently.

It is often difficult to distinguish between faint interference and the symptoms of amplifier distortion. However, if the interference is strong enough to cause a heavy beat, it may generally be assumed that if a amplifier was emittimg a spurious product strong enough to be clearly visible it would probability have other by-products on adjacent channels. If you have a problem with beats on one channel only, it will most probability be ingress related, a quick check of other channels will provide an answer. Also, high signal levels at a customers set will likely indicate amplifier distortions as a cause of beats, for as the levels go up, the probability of distortion increases and problems from ingress decrease.

In an area where it is expected that there will be a sufficient number of ingress calls to warrant it (an area where there are many local TV stations and etc.), it may prove very practical to leave the channel of the station most likely to leak into the system empty. The empty channel will provide a convenient way to determine the degree of system integrity. Measurements of a local station leaking into the cable on a channel not occupied by any cable channel, when compared to the levels of an adjacent cable channel, will provide a good indication of the signal to interference ratio between other local TV stations and cable signals. If the television set or converter is tuned to the channel of the local station not on the cable and a noisy but steady picture is present, a faint ghost or beat on another channel will almost certainly be caused by ingress.

The point at which the ingress first enters a feeder system can also be measured quickly by making signal/interference readings at taps, via the unused channel method. Customers will still have service while troubleshooting is being performed and this method will physically disturb the system as little as possible. This is desirable as a small movement of a slightly loose connector may be enough to correct the problem for the present, but it will likely soon start misbehaving again. Also any disturbance to perfectly good portions of the plant will often lead to them becoming less tight, resulting in more problems.

If it is necessary to maintain a signal to interference ratio of 50 dB or more between a local transmitter and a channel used in a cable system, then the levels on the unoccupied cable channel of the local TV transmitter should be -40 to -45 dBmv at the input to the set or converter. This is near or below the lower limit a normal field strength meter can read, so any deflection of the meter scale with attenuation fully down is undesirable. If the video buzz can not be heard at all, or if system generated beats at the extreme range of the meters sensitivity are heard instead, then the service technician can be assured the ingress problem is not coming from the upstream portion of the drop or feeder. The test becomes more valid as cable signal levels increase, and, as an aside, provide rough measurements of system noise.

Another practical troubleshooting practice is to disconnect the section of a suspected bad drop or feeder leg and measure the levels of the local transmitters directly out of the downstream leg. This permits a direct comparison of the signal to interference ratio to be made at any frequency desired when the levels of the cable signals at that point are known. By disconnecting different sections of a drop at a splitter and measuring ingress levels from each, a fast and sure troubleshooting decision can be made. Readings from a disconnected section of drop, terminated at the other end, will indicate if a drop is good or if it must be serviced or possibly replaced. A drop cable in service should typically be capable of 70 dB or more isolation , so any detectable levels inside the drop would indicate the necessity for service.

As the drop is connected to the field strength meter, first insert only the center conductor of the drop in the meter, then tune to the source of off air interference and read the level (often close to or more than what is read with a dipole at the same location). If you then tighten the drop on the meter and turn the attenuator all the way down a good indication of drop integrity can be made. If an amplifier with a gain of 20 dB is placed between a good, terminated long length of drop and a meter, in an area where the field strength is 40 dB or more from off air transmitters, it is just barely possible to detect the local transmitter above the noise floor , indicating a 90 dB shield or better for the drop (and the test equipment too).

The only other practical way to detect the source of ingress is to make use of the various sensitive radiation detectors currently available from several manufacturers. Just as ingress gets in cable, signals leak out and can be detected. With this equipment, and little or no training beforehand, a technician will almost be able to walk right up to a defect causing ingress. Sensitive equipment capable of detecting radiation levels 15 to 20 dB below the FCC radiation threshold of 34 dBmv is required. A shield factor of 60 dB or more should be maintained in drops when both the field strength of the local transmitter and the signal level in the drop are 5dBmv.

Standard dipoles and meters are difficult to handle as troubleshooting aids, and very often unable to detect faint radiation from points which are, nevertheless permiting noticeable ingress interference. In areas of strong radio interference, even the more sensitive equipment is sometimes incapable of finding faint radiation from leaks permitting severe ingress , for example in drops when cable signals close to 0 dBmv and the local transmitters are above 20 dBmv at that point.

Using equipment accepted as being many times more sensitive than what is required to detect the FCC egress threshold, and capable of being calibrated so, will also permit the technician to determine if a leak legally needs to be reported or not. Typically leaks radiate -40 dBmv or less in about 75 to 80 % of the service problems, while leaks above -25 dBmv are found less than 10% of the time. This severe a leak will normally affect customers severely, and therefore will also be corrected very quickly. It is often the case, though, that the strongest points of egress are points where the level in the feeder is the greatest, hence the points where the greatest immunity from ingress can be expected. So by no means does a lack of ingress mean that a system is tight and totally within it's requirements.

The repair actions taken to correct ingress problems due to cable faults are straightfoward and direct, tighten it, splice it, or replace it. Detection of ingress problems will require training of personnel as to the way to quickly distinguish between ingress related beats and those of amplifier distortion. Service personnel should be able to determine if customer equipment is at fault and how to bypass these problems. Additional training is required as to how to use signal level meters as a means of locating a point of ingress. Specialized equipment will make the technician more efficient and help assure FCC compliance. The routine soon will establish itself if the system is susceptible to ingress problems.

NEW BUILDS IN HEAVY INGRESS AREAS

Before any new build is first turned on, the cable operator should determine the levels of all local off air transmitters at various locations throughout the build. It will then be possible to assign character generators and other similar programing to channels likely to have interference from ingress. Phase locking and sync locking and 45 dB of system immunity is good enough for a character generator only, all that can be expected if cable ready TV sets are to be connected. The same channel will be more usable under the same conditions in total converter build.

It might also be desirable to require measurements of the ingress level present in each feeder leg as it is turned on. With the input to a section terminated, a reading should be made at the end of each leg. Accept no ingress whatsoever and require checks to be made with a spectrum anaylizer, photo's included.

Plan to put a significant amount of energy into ingress related maintenance in an urban build until you have time to correct all construction and new drop defects. Even the best of construction methods and workmanship will show some minor flaws, and a flaw can be very minor and still be a significant point of ingress. But with a properly equipped staff of technicians, the ingress problem can be overcome in a routine fashion, with luck.

ACKNOWLEDGEMENTS:

1: Belden Corp,CATV Coaxial Cable Catalog #EL10-79, Oct. 1979, pp 15-18.

2: Reg James, Comcast Corp.Staff Engineer From a report July, 1982

3: Based on FCC Rules and Regulations,Vol III, part 73, pp189-191, 1972
From "Reference Data for Radio Engineers"; Howard W. Sams & Co., 1979, p 30-12

4: Based on Jerold "CATV Reference Guide" #RD-14, April 1983, p36

Special thanks to all the service technicians who helped gather the data and who came up with some good fixes, too.

MAPPING AND MAP MAINTENANCE
SIMPLE METHODS THAT WORK

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ABSTRACT

An introduction to maps and map maintenance for the technical and non-technical C.A.T.V. professional is presented based on experiences gained in the development of methods currently in use in a medium size cable system.

User groupings are presented and catagories of maps are described. The production of one catagory, general purpose design maps, is expanded upon. Reproduction and distribution of these maps is discussed.

Map maintenance is an important and often overlooked aspect of a mapping system. A method is presented for ongoing information gathering and reporting, with techniques for maintaining the accuracy and currency of the maps. One follows a map through the stages from the need for a change in physical plant to the point at which an updated copy is distributed. Revision procedures are discussed, and an easy to use filing system is described.

PURPOSES OF MAPS

Why do we need maps? Who uses them? What for? C.A.T.V. maps can be grouped into five basic user catagories. Accurate maps are a requirement of field technicians for use in troubleshooting, preventative maintenance, and quality control. Customer service operations and installation departments need maps to answer questions of serviceability and provision of adequate signal to subscribers. Engineering uses maps for plant design and costing, analysis of performance, and examination of system upgrade options. Construction uses maps for permit applications, initial plant build, continuing maintenance, and for efficient locating and marking of underground facilities in response to staking requests. Maps aid management in determination of property taxes, pole ownership and attachment fees, and general record keeping.

TYPES OF MAPS

Several types of maps are necessary to satisfy the above requirements. Here is a list of commonly used types:

Trunk block diagrams: field & office sizes.
Key maps: maps used to find other maps.
System powering maps.
Property line maps: for permit applications.
Intertie & interceptor (supertrunk) maps.
Project maps: to show detail in dense areas such as apartments and mobile home parks.
Trunk and distribution maps.

The trunk and distribution maps are used every day in the field and office. These general purpose design maps will be the main topic of this discussion.

CHARACTERISTICS OF GOOD MAPS

General purpose design maps must satisfy the needs of the five user catagories previously mentioned. The information shown must be reliable and up to date. The maps must be easy to use, convienient, and readable. They should be cost effective in the long term. Map sets need to be accessible to all users. These desirable characteristics can be provided by use of durable originals in conjunction with an inexpensive duplication process. The trunk and distribution mapping method presented here has these qualities, and fulfills the needs of all user groups.

MATERIALS AND TECHNIQUES

The basis of a good mapping system is a set of durable originals. These are produced on heavy (five mil) drafting film, single or dual matte finish. Pre-cut sheets are used rather than roll stock, to facilitate easy reproduction and storage. Permanent notes and line work are drafted in ink, using "rapidograph" pens and the appropriate templates. Lettering must be clearly readable and carefully placed. Hand lettering will suffice, provided the necessary care is taken if reduction is planned.

The sheets, if connected, would form a grid. A four digit numbering system is used, with sheet number 5050 near the geographic center of the service area. The rectangular sheets are long in the east - west direction. The first two digits indicate row, and the second two column. When the maps are in order, two consecutive pages in the book share the longer of the two match lines.

PRODUCTION OF FIRST ORIGINALS

A. Preparation

The first step in producing a map set is to obtain the source maps for background work. The best source maps are "tax atlas" maps, of which copies can usually be purchased or leased. If these are not availiable, bluelines can sometimes be obtained from local utility companies, governments, or civil engineering firms. These may not be to scale, or may have a scale larger than 100 feet to the inch, requiring reduction to that scale before production of the first originals. Previous C.A.T.V. system maps can be used if they were drawn to scale, and if background information (streets,etc.) is still valid. Aerial photographs can also be used, but scaling inaccuracies and lack of property line information make them less desireable. The source maps will determine the working scale. It can be 100 feet to the inch with later reduction, or at the final scale of 200 feet to the inch.

Before background drafting begins, a master sheet of film is produced. On this sheet are drafted the border line, match lines, north arrow, and legend with places for map number and revision dates. Copies of this master are printed on sheets of drafting film to form the blanks of the first originals.

B. Background

To begin background work, start with sheet 5050. Letter in the sheet number and matching sheet numbers on the film blank. Place the film over the source map(s). Partial or multiple source maps are used to cover the approximate 1800' X 3000' area of each sheet. Trace the right-of-way (R.O.W.) lines, or scale them in using centerlines. Here are some typical street widths:

Residential streets	60' or 66'
4 or 5 lane feeder streets	80' to 120'
Divided highways	120' to 200'
Expressways	200' and up

The scale can be stretched or compressed slightly so that plant information does not have to be drawn directly on top of match lines. Street names are then drafted in bold ink far enough away from R.O.W. lines to allow for strand and underground routing and footages.

Franchise boundaries need to be shown precisely. Both sides of the boundary are labeled. R.O.W. lines and franchise boundaries overlap match lines only to border lines -- not into margins or duplication allowance. Show lakes, rivers, and other natural features. Show locations and names of schools, apartments, etc.

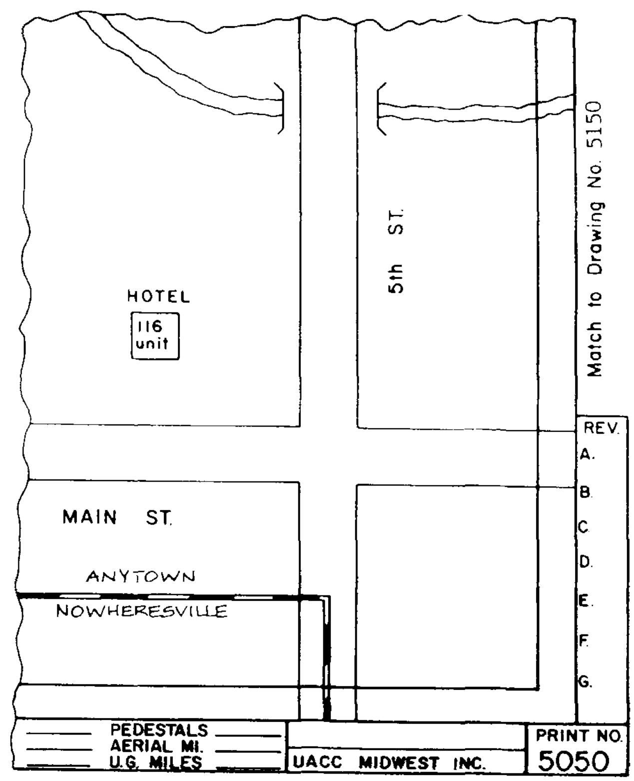


Figure 1. - Background

This drafting process is repeated for each sheet until the entire area is covered, corresponding to the grid. Bluelines can now be run so that field work can be accomplished, and/or information from old maps can be transferred.

C. Strand

The following process assumes all needed field information has been gathered. Draw in poles, pedestals, manholes, etc. on the background originals in their approximate scale locations. These items must be shown outside of the R.O.W. lines. The scale is stretched or compressed slightly to accomodate curves and intersections. Be careful not to draw on top of match lines -- choose one side. Complete all strand information beyond match lines to border lines. Connect poles with solid lines for strand, and use dashed lines for underground routes. Draw in anchors, span guys, and street and driveway bores. Letter in footages large enough for clear duplication and reduction, but small enough to avoid clutter. Show footages on the "field" side of strand or routing. Again, do not letter on top of match lines -- choose one side. Note riser pole locations. Do not include up and down in footage measurements.

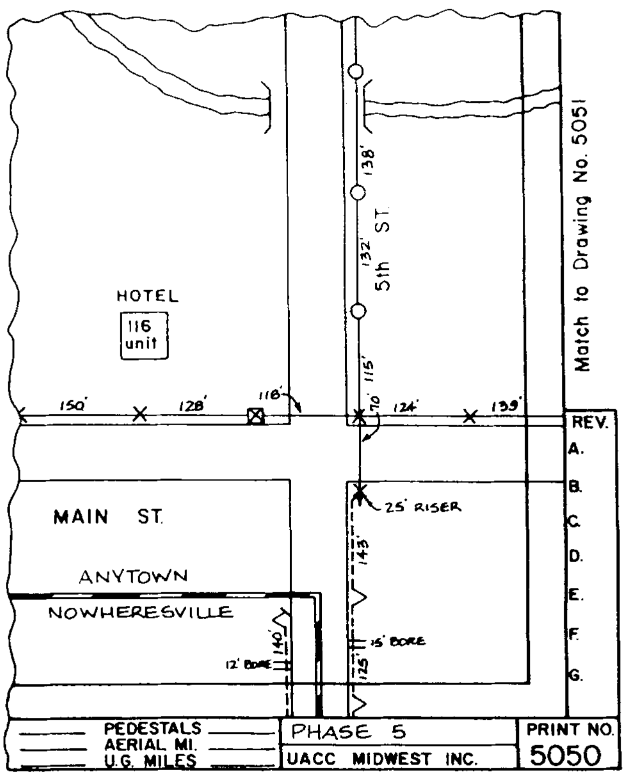


Figure 2. - Strand

D. Subscribers / Notes

Draft the number of potential subscribers next to each possible tap location. Draft a zero if there are no potentials. Letter in notes for feed points to apartments, schools, future developments, etc. Indicate name and file reference number if a separate project map is needed. Letter or use symbols for non-standard signal requirements such as "long drop" or "6 sets" etc. Some or all of the strand map items can be counted and added to the legends of each sheet if desired.

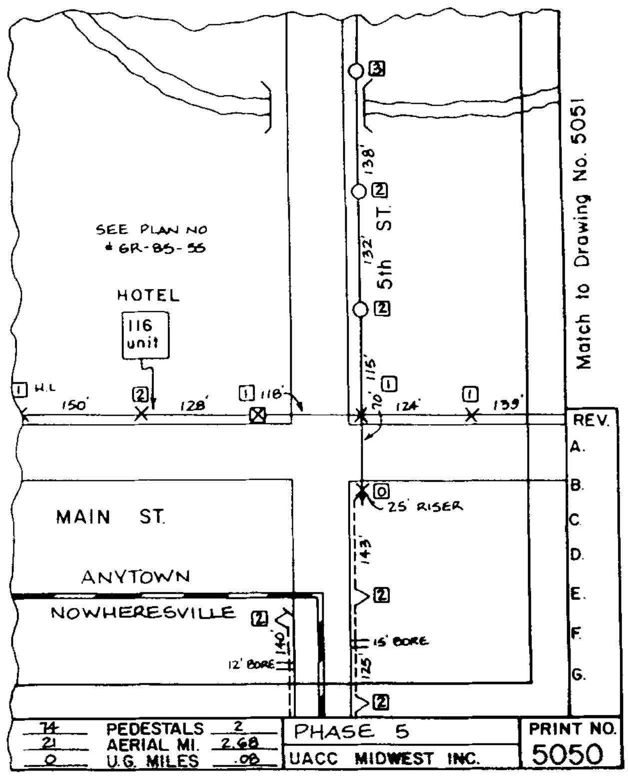


Figure 3. - Subscribers / Notes

The entire process of producing strand originals can be accomplished by a contract mapping company. Many contract mappers will customize their product to the needs of individual operators.

PRODUCTION OF FINAL ORIGINALS

A. Duplication / Reduction

After the strand originals have been completed, a reduction and/or duplication process is performed by a local reproduction house. This step tends to be expensive; but since it only needs to be done once, the professional quality makes it worthwile. Have the jobber prepare sample results before providing him the entire set. The resulting maps will be 11" X 17" on heavy film. The background, strand, and subscriber information is produced on the back side of the film. This will permit erasure of the design information (drawn on the front side) without damage to the strand information.

When the process is complete, obtain all originals (and negatives if photo-reduction is used) and keep them on file for future use. Usually strand and background information will change very little. Have additional film copies made of maps which contain phase or franchise boundaries so that multiple sets of originals can be placed in separate files. Also obtain additional film copies to be used for separate intertie and interceptor trunk sets.

B. Design Information

After the 11" X 17" strand originals have been prepared and duplicated, design information is drafted on the front side of the film. Cables, amplifiers, passives, and taps are drafted between R.O.W. lines as much as possible. These items are shown only up to the match lines. If trunk and distribution cables are both present, draw trunk cable closest to strand or routing if possible. Power supplies and amplifier set-up information are drawn between streets to avoid clutter and improve readability.

Show local trunk and distribution only. Thru trunks, institutional cables, interties, and interceptor trunks should be drawn on separate original sets. Since small lettering items such as tap values will not have to undergo reduction, the readability of this information on the final prints is assured.

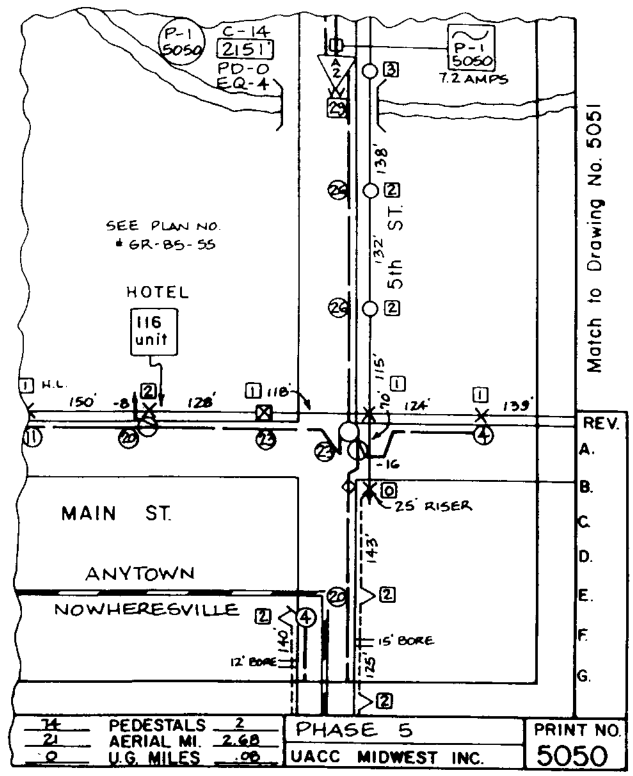


Figure 4. - Design Information

MAP SETS

Once drafting of the plant design is complete, phase boundaries can be added. If the maps are to be divided into separate sets by trunk phase, film copies of the strand originals are used for all sheets showing phase boundaries. The plant design is drafted on these copies to allow the phase sets to be filed separately. Paper print sets can now be made on an inexpensive blueprint machine or xerographic-type copier capable of the 11" X 17" size. Print sets are made for each field tech and the staker, and a set is provided for shared office use by other departments and staff. The map sets are bound into books which are small enough to handle and store easily in the front seat of a vehicle.

MAP MAINTENANCE

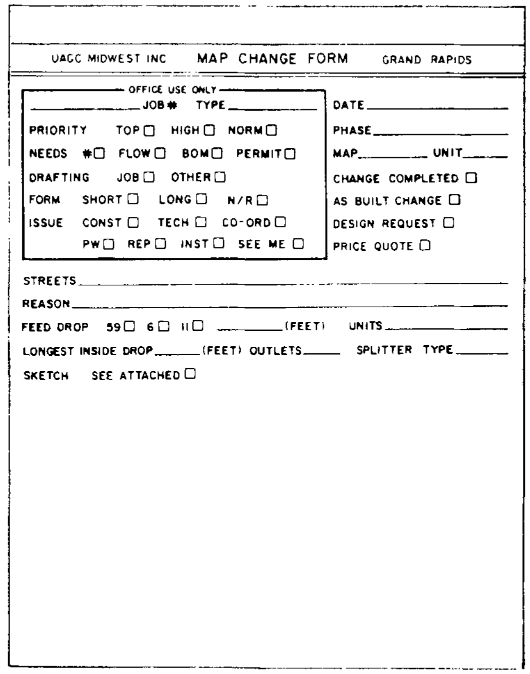
Much effort and expense goes into producing good system maps. If these maps are not properly maintained, this expense may have to be repeated after only a few years. The succession of neglect and re-mapping produces unreliable maps and high life cycle costs. Fortunatly, this circle can be broken by use of continuing revision and distribution coupled with a means of capturing data on plant changes.

A. The Map Change Form

To capture this data, a "map change form" is used. This multi-purpose form is made availiable to all field personnel. To use this form, the field person fills out the blanks provided for date, trunk phase, map number, and his unit (radio) number. If he has made a change in the plant, the change completed box is checked off. If the existing plant was found to be different from the map, the as built change box is checked. If design work is required to provide more signal or solve other problems, the box marked design request is used. If a customer has requested service and a plant extension is needed, the price quote box applies.

The address, street, and cross streets can be written on the line marked streets. If an explanation is required, a note such as "splitters at pole" is written on the line marked reason. A line is provided for the field person to describe drop cable types and lengths with blanks for the number of dwelling units and outlets per unit. This is particularly useful for prewire situations. The bottom half of the form has a space for a sketch, with a check box see attached if a copy of a system map is provided instead of a sketch. If signal level readings were made, they can be written on the sketch or map copy, near the device measured. A section marked office use only is provided to aid communications between the designer and draftsperson, if the department consists of more than one employee. This section allows the form to function as a cover sheet for the paperwork related to this particular job.

Since the main purpose of this form is to capture field data, accuracy and frequent use are stressed. Neatness and completeness are encouraged, but are of secondary importance.


UAGC MIDWEST INC MAP CHANGE FORM GRAND RAPIDS

OFFICE USE ONLY
______ JOB # TYPE ______
PRIORITY TOP ☐ HIGH ☐ NORM ☐
NEEDS # ☐ FLOW ☐ BOM ☐ PERMIT ☐
DRAFTING JOB ☐ OTHER ☐
FORM SHORT ☐ LONG ☐ N/R ☐
ISSUE CONST ☐ TECH ☐ CO-ORD ☐
PW ☐ REP ☐ INST ☐ SEE ME ☐

DATE ______
PHASE ______
MAP ______ UNIT ______
CHANGE COMPLETED ☐
AS BUILT CHANGE ☐
DESIGN REQUEST ☐
PRICE QUOTE ☐

STREETS ______
REASON ______
FEED DROP 59 ☐ 6 ☐ 11 ☐ ______ (FEET) UNITS ______
LONGEST INSIDE DROP ______ (FEET) OUTLETS ______ SPLITTER TYPE ______
SKETCH SEE ATTACHED ☐

Figure 5. - Map Change Form

8 1/2" X 11" Actual Size

B. Workflow

It is important to delegate the responsibility for mapping and map maintenance to an individual or department. Map work is too easily forgotten about if it does not receive prompt attention. The workflow method described herein provides for good map maintenance.

When the design and mapping department receives a map change form, several steps are followed. Here is an example of what typically happens. When a map change form comes in from the field, it is examined to determine if design work is needed. In this example more signal is needed at a pole to provide more tap ports. The system designer calculates an appropriate plant change, and sketches this change on a copy of the system map.

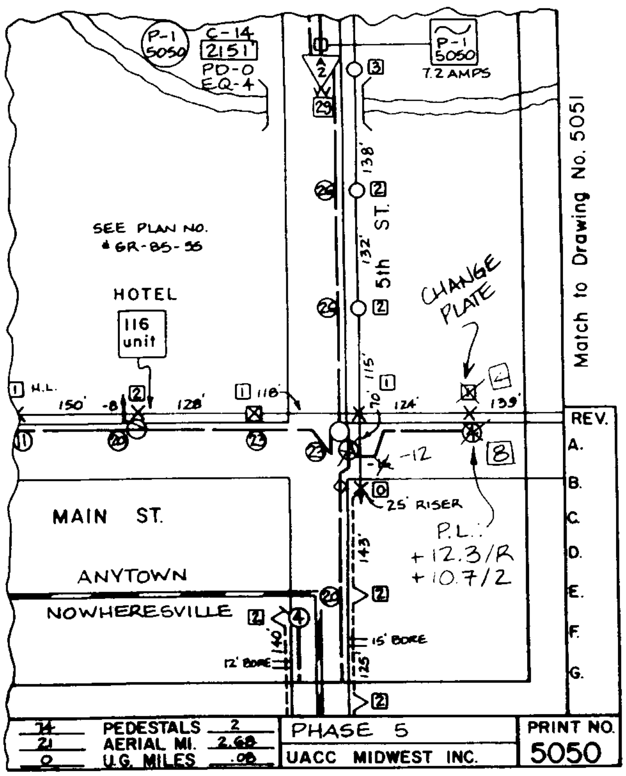


Figure 6. - Design Notes

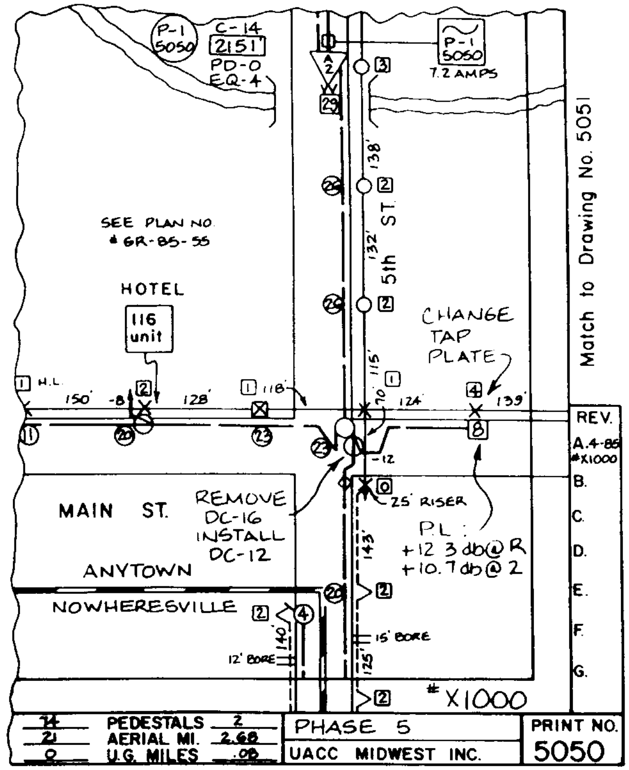


Figure 7. - Construction Notes

This sketch accompanies the map change form to drafting/administration. The 11" X 17" system map original is removed from its normal file and the ink work is altered to represent the eventual plant layout. At this time the revision date is placed on the original in ink. Construction notes are made in pencil to guide field work. A job number is assigned and printed in pencil on the original. It is important to use pencil so that the film will not be damaged later when these notes are removed. When the pencil notes are complete, the original is not returned to its normal file, but instead is placed in a "construction notes" (plans in progress) file. The originals are now ready for duplication prior to issue. (See Figure 7. - Construction Notes.)

Prints of the original with construction notes are made in preparation for issue. The notes that apply to the appropriate department are highlighted on the prints.

Two or more sets of prints are then issued to that department and become scheduled work. The field people who receive these prints have copies of the same sheets in their map books to use for "before and after" comparisions. (See Figure 8. - Issue.)

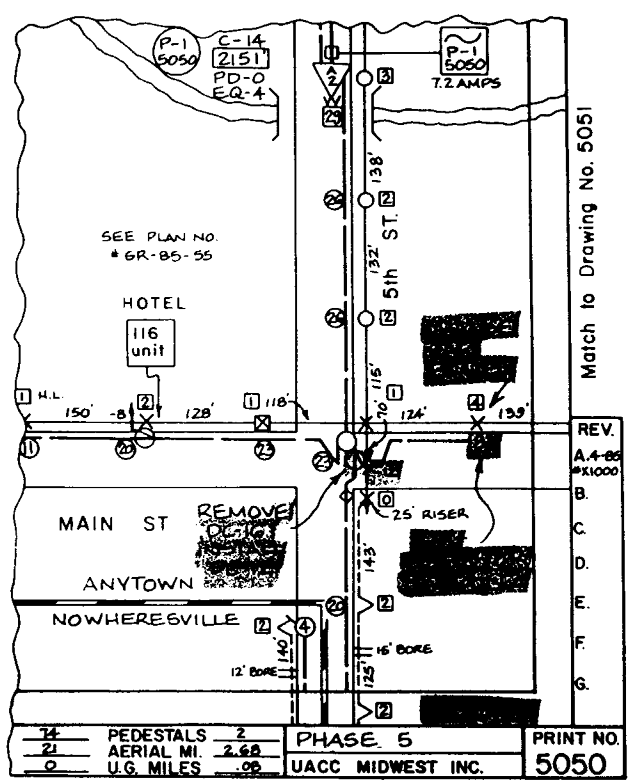


Figure 8. - Issue

When their work is done, they return one set of prints marked "completed", with any field changes noted on the prints. At least one set is retained by that department for use as a reference until revised prints are received. If two departments are involved (for instance construction and technical) the job is re-issued with a different set of notes highlighted on the prints. When all work is completed, one set of prints is returned with signal level measurements noted on them. If these measurements agree with calculated values, the job is considered complete. The mapping person or department then makes a record of job status, and releases the job to subscriber sales if required. If field changes were made in the course of the work, these are checked for correct design, and the original map is changed to represent the actual layout. The original is returned again to the construction notes file.

C. Revisions

Periodically (every three months recommended) all the originals are removed from the construction notes file. Pencil notes and job numbers are removed if work is completed. Prints are then made for all map sets. The originals can finally be returned to their regular files.

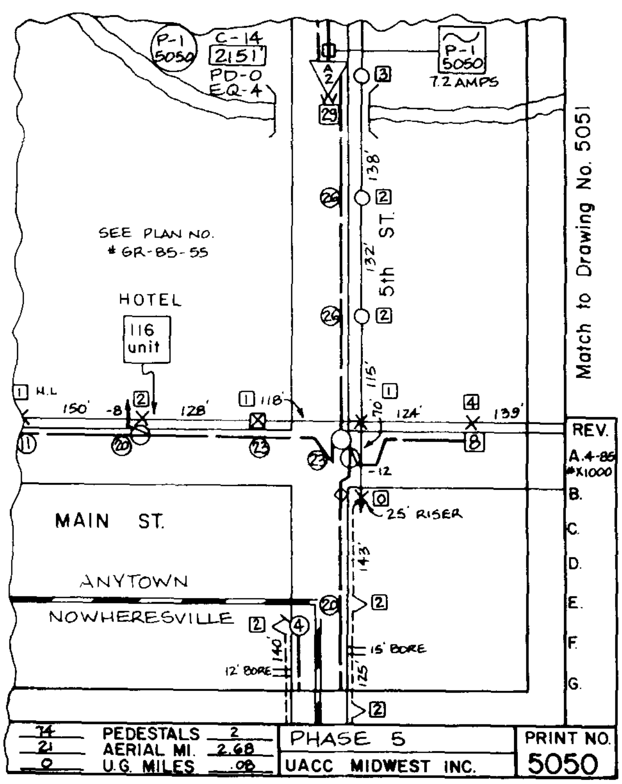


Figure 9. - Revised Map

This filing system requires two sets of storage, but is inherently fail-safe in that no map is ever returned to its regular file without revisions being provided to all users. When a technician or other map set user receives his revised prints, he discards each outdated print and inserts the new one in its place.

A list of map numbers is kept on file showing the most recent revision date of each map. This list is brought up to date each time revisions are run. It is used to check the currency of a map set that is returned, for instance, when an employee is promoted and another is hired as his replacement.

CONCLUSIONS

If these methods are adhered to, the map sets in the field will be accurate enough to be used to re-generate the system map originals in the unlikely event of an office fire or other natural disaster. With proper attention, good maps, like a fine wine, will improve with age.

ACKNOWLEDGEMENT

Thanks are extended to Don Peterson for his encouragement without which this topic would not be presented. Special thanks to Sherie Richardson for her artwork and her assistance in development of these methods.

MULTIPLE HOME TERMINAL UNITS:
SUBSCRIBER CONVENIENCE--SECURITY RISK

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ABSTRACT

The need of the subscriber to simultaneously operate multiple TV sets and/or VCR's from his cable service has led to significant use of multiple home terminal units (HTU). If a subscriber pays a lower fee for a secondary HTU that is authorized to receive the same premium service as his primary unit a risk exists that the unit will be sublet to a neighbor. For addressable cable systems using out-of-band data carriers, a master/slave configuration is proposed as a solution to the problem of subletting secondary units. The master/slave consists of two HTU's: the master used with the primary set and the slave used with the secondary sets. The slave unit does not function unless its address-control channel is protected by a master HTU. Thus, if the slave unit is used in a neighbor's home without its master, the secondary, or slave, unit will not function. Both master and slave HTU's can still respond with all addressable features. The uniqueness of the scheme lies in the selective blocking, by the master unit, of deauthorize commands directed at all slave HTU's. A high level of security is maintained without the requirement for complex, handshaking duplex data communications between the two HTU's.

INTRODUCTION

The home terminal unit (HTU) converts any cable channel to a channel that can be received by the standard TV receiver or recorder (typically Channel 3 or 4) and it descrambles premium channels for which it is authorized.

If a subscriber desires to utilize a cable channel which is outside of the usable band in his TV receiver or recorder, or which is scrambled, he must do so through an HTU. For simultaneous use of multiple TV receivers or recorders to receive different cable channels, one HTU per video device must be used. Thus, we find some subscribers utilizing multiple HTU's for the convenience of operating second TV sets and VCR's.

In systems where a substantially lower fee is charged for premium services received on a subscriber's second or subsequent HTU, a significant security risk is incurred. The lower second-unit fee can be the result of franchise agreement mandate or system policy.

Assuming that additional HTU's provided to a subscriber are identical to the initial unit, then they can be used on any outlet in the system to receive the service for which they are authorized. Thus one subscriber can pay a nominal fee for a second HTU authorized to receive the same premium service as his primary unit, and sublet this unit to a neighbor, thereby circumventing the normal premium service fee.

The security risk is strongly a function of the subscriber cost differential between initial and subsequent HTU's. Also, it is a function of the social norms in the area covered by the franchise.

For addressable cable systems capable of out-of-band data transmission, a solution to the risk brought on by low-priced second sets is a system in which the HTU provided as a secondary set will only operate in the presence of a primary set...a master/slave arrangement.

THE MASTER/SLAVE SOLUTION

Three approaches to master/slave configurations will be described: 1) master-to-slave control channel, 2) separate master-to-slave control line, and 3) control channel interruption.

1. Master-to-Slave Control Channel

Figure 1 shows a functional block diagram of the master-to-slave control channel configuration. The control channel is assumed to be 10.7 MHz in this example.

Master HTU. The master HTU has been designed to retransmit the control channel back onto the input cable at 10.7 MHz. The master HTU is controlled by the standard control channel at 104.7 MHz.* The 10.7-MHz channel is interrupted whenever the master HTU receives an inhibit command from the headend via the standard control channel. The inhibit command is sent to all master HTU's in the system as a group. The duration of the 10.7-MHz channel interruption is of sufficient duration to disrupt the following message which is directed to only slave HTU's. The 10.7-MHz channel operates continuously as long as the master HTU is powered.

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* 104.7 MHz is one of the FSK control data channel frequencies used in Oak systems. This data channel transmits a continuous stream of 64-bit message packets addressed to individual HTU's, or groups of HTU's.

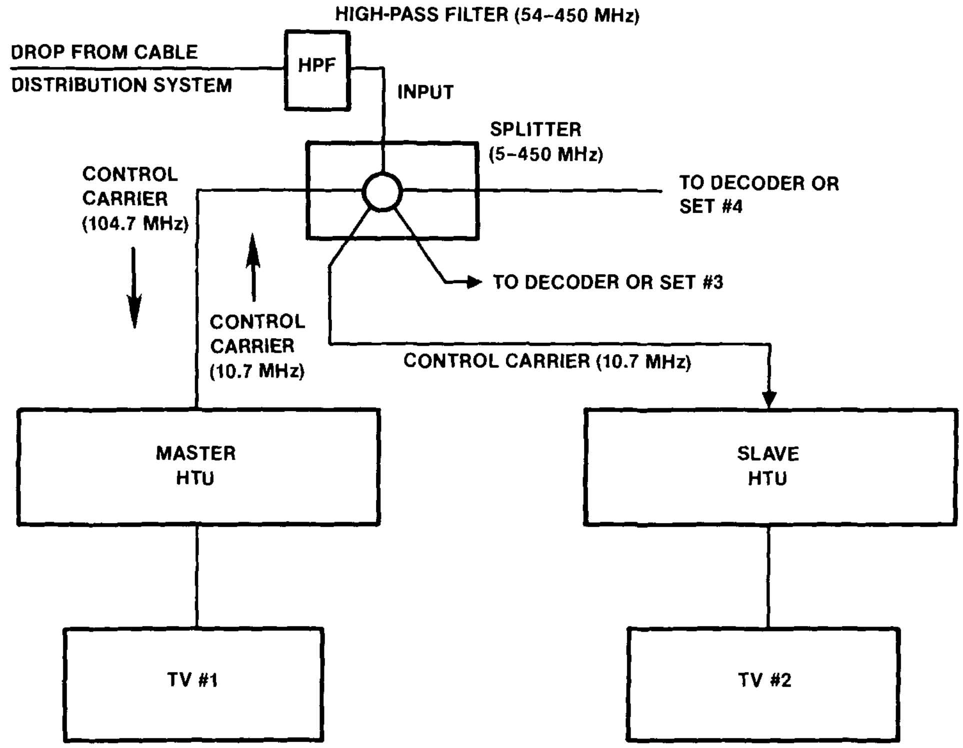

Figure 1. Master-to-Slave Control Channel

Slave HTU. The slave HTU is designed to receive the 10.7-MHz control signal retransmitted by the master HTU. The slave decoder can be addressed and controlled by the headend, provided that the control signal is received via the master HTU, which retransmits the 104.7-MHz control data at 10.7 MHz.

Periodically, deauthorize messages are sent to all slave HTU's as a group, preceded by an inhibit command sent to all master HTU's. If the slave decoder is receiving its 10.7-MHz control channel via a master HTU, then the deauthorize signal will have been inhibited and the slave will continue to function normally. If the slave is connected to the control channel by an independent converter, (i.e., without the master being present), then it becomes deauthorized following reception of the first deauthorize message.

Both slave and master HTU's are manufactured identically and shipped as master HTU's. At installation a message from the headend is sent via the standard control channel that will configure designated HTU's as slaves. Slaves thereafter respond to only 10.7-MHz control.

Splitter. The splitter is standard, except for the requirement to pass the 10.7-MHz signal. The 10.7-MHz control signal is retransmitted from the master HTU to the splitter. The 10.7-MHz signal passes through the splitter to its input port and is reflected from the high-pass filter in that line. It is then, in turn, passed to the other output ports.

High-Pass Filter. A high-pass filter is used to block the 10.7-MHz signal from entering the system by reflecting the signal back into the splitter.

2. Separate Master-to-Slave Control Line

Figure 2 shows a functional block diagram of the separate master-to-slave control line configuration. This system operates on the same inhibit/deauthorize principle described in the master-to-slave control channel configuration.

Master HTU. The master HTU has been designed to transmit a control signal to the slave HTU's that will disable the slave's control channel during a deauthorize message that follows an inhibit message. As in the master-to-slave control channel scheme, an inhibit signal is put on the control line by a master HTU whenever an inhibit command is received from the headend via the standard control channel. The inhibit command is sent to all master HTU's in the system as a group. The duration of the inhibit signal on the control line is of sufficient duration to disrupt the following message which is directed to slave HTU's. The control line inhibit function operates as long as the master HTU is powered.

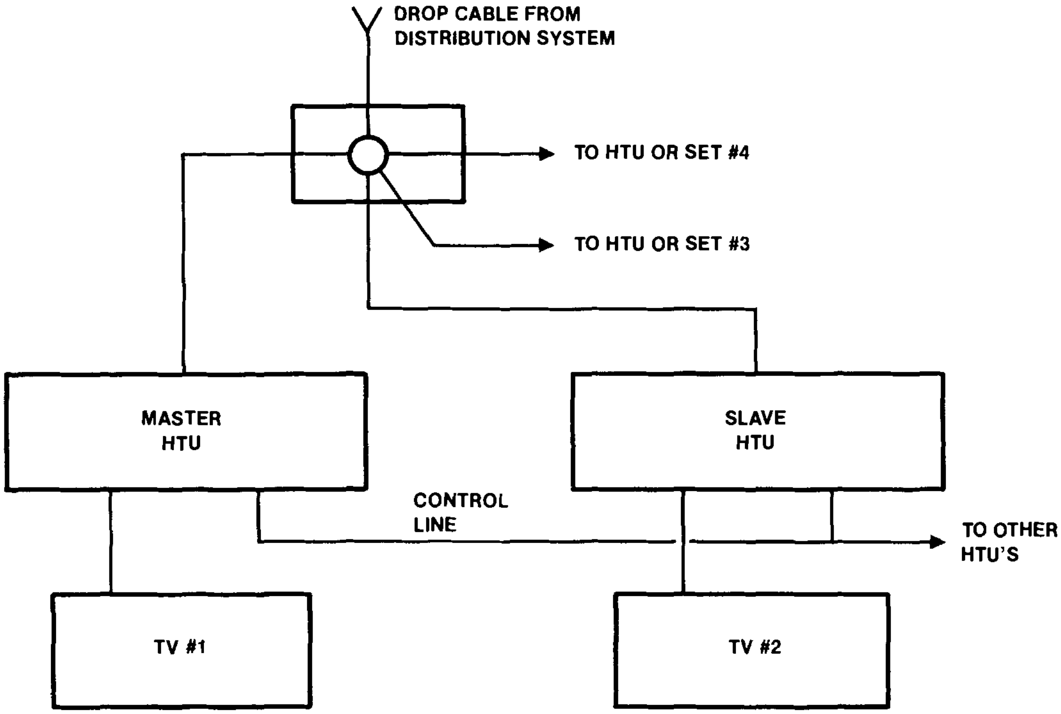

Figure 2. Separate Master-to-Slave Control Line

Slave HTU. The slave HTU is designed to respond to the control line inhibit signal. When this signal is present the standard control channel receiver is deactivated and no control messages can be received by the slave HTU.

Periodically the headend sends deauthorize messages to all slave HTU's as a group, preceded by a group inhibit command sent to all master HTU's. If the slave HTU is connected to the control line from the master HTU it will be protected from the deauthorize command and will continue to function normally. If the slave is not connected to the control line it becomes deauthorized following reception of the first deauthorize message.

Both slave and master HTU's can be manufactured the same and shipped as master units. At installation a message from the headend can be sent via the standard control channel that will configure designated HTU's as slaves.

3. Control Channel Interruption

Figure 3 shows a functional block diagram of the control channel interrupt configuration.

Master HTU. The master HTU has been designed to transmit a switching pulse on the input cable. This switching pulse is transmitted by the master HTU immediately following reception of an inhibit command from the headend via the standard control channel. The inhibit command is sent to all master

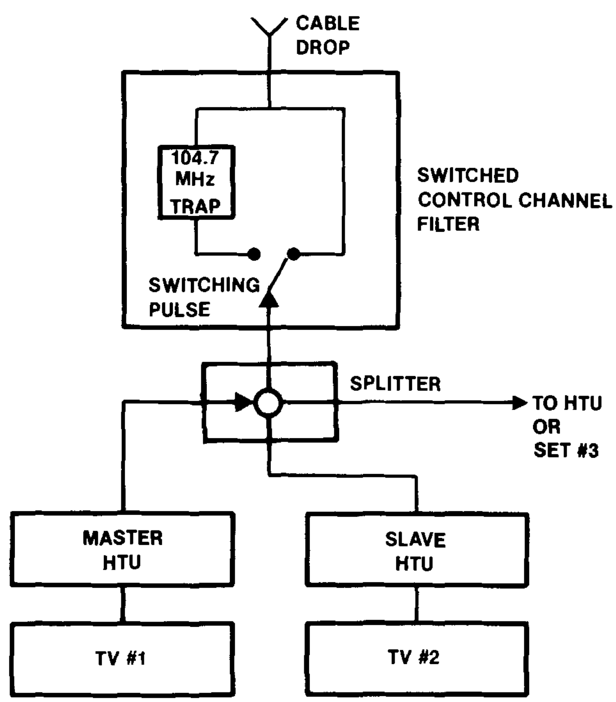

Figure 3. Control Channel Interrupt

HTU's in the system as a group. The duration of the switching pulse is sufficient to prevent the reception of the following message which is directed to all slave HTU's. The switching pulse operation is executed as long as the master HTU is powered.

Switched Control Channel Filter. The switched control channel filter is designed such that the signal from the cable drop normally passes directly through to a splitter, except when a switching pulse from a master HTU is imposed on the output port of the device, a control channel filter is switched into the line to interrupt the control channel. When the switching pulse is removed the device returns to normal operation, passing all signals on the cable. Another possible approach to designing this filter is to block all the RF signals on the cable for the entire pulse duration.

Slave HTU. In the control channel interrupt configuration, any addressable HTU that is system compatible can be used. At installation a message from the headend will be sent to the slave HTU to make it associate with the slave group. Periodically a deauthorize message is sent to all system slave HTU's as a group. If a slave is operated downstream from a master HTU-controlled switched control channel filter it will be protected from receiving the deauthorize command. If the slave HTU operates directly on the system it will deauthorize following reception of the first deauthorize message (see timing diagram in Figure 4).

MULTIPLE DWELLING APPLICATIONS

The control channel interrupt method can readily be extended to multiple dwelling situations where a large number of slave HTU's are required on the master HTU (see Figure 5). This can offer an interesting alternative to off-premises equipment in situations where unauthorized migration and use of home terminals are the principal concern.

There is no restriction to the number of slaves in one building. Each building would be treated as a separate group with its own group address. Thus, slave HTU's from one building would be useless in any other building. However, it should be pointed out that level differences in the cable spectrum between the trap on/off states of the switched control channel filter may create disturbances visible in the TV picture. Also, it does not prevent transfer of slave HTU's within the designated building.

MESSAGE SECURITY

Central to the above approaches is a technique of informing the master units of an impending slave disable command. In any system employing the described approach, the ability of a pirate to covertly mimic the master's message interruption process must be examined. The Oak approach to this danger, as well as other dangers of control channel manipulation (or tampering) is to encrypt all control channel messages using a time-varying

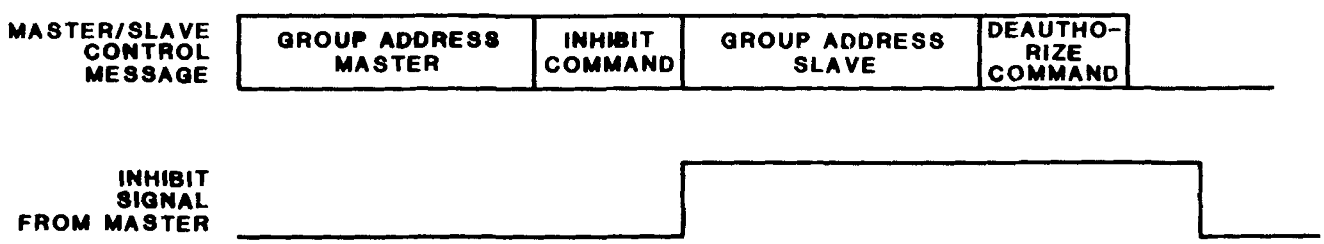

Figure 4. Timing Diagram

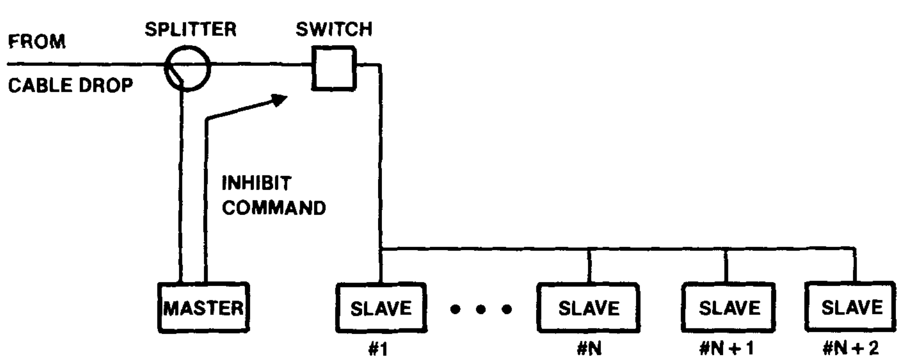

Figure 5. Extension to Multiple Dwellings

process. Thus a pirate will be unable to detect the slave disable warning message going to the master units. Patents are currently being filed for these approaches as well as the master/slave concept.

SUMMARY

The problem of secondary HTU theft for addressable cable systems is a major concern for system operators that offer lower rates for secondary HTU's. The master/slave solution will eliminate that risk.

The control channel method requires transmission of the control signal at 10.7 MHz instead of a switching DC pulse used by the other approaches. The advantages of this method are that there is no requirement for external hookups between the master and slave HTU's and that only RF signals are present on the cable.

The master HTU for the control line approach can also send a switching (DC-coupled) pulse via the RF cable instead of the external connection to each slave HTU. Several commonly used splitters tested were found to pass DC without significant degradation. During the pulse duration, a data channel message is transmitted to command the slaves to deauthorize. Thus, HTU's that are not linked to a master HTU sending such a pulse will be deauthorized for viewing. However, if the switching pulse is carried by the RF cable to each slave HTU, DC blocking devices must be used to avoid DC shorts in the cable throughout the subscriber's home. This can happen if the customer decides to hook up a VCR to the RF cable.

For both the control channel and the control line methods, the deauthorize command can be sent as frequently as desired by the system operator. While in the control channel interrupt method, the deauthorize command frequency should be limited to a minimum since the switched control channel filter may cause picture interference during switching.

For all three approaches described, the master and slave HTU's can be manufactured and shipped identically. At installation the HTU's can be reprogrammed from the central control computer to function as master or slave HTU's. The control message will utilize a time-varying encryption process to ensure maximum security. These techniques are currently under development at Oak Communications in San Diego.

OFF-PREMISES ADDRESSABILITY
SYSTEM DESIGN AND OPERATIONAL CONSIDERATIONS

Joseph P. Preschutti

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E-Com Products Division

INTRODUCTION

Off-premises jammer systems (including the Tier Guard System) have been receiving higher interest due to intangible benefits associated with improved customer satisfaction: the use of VCRs, multi-channel sound, additional outlets for extra TVs and FM radio, etc.

This paper describes system design concepts required to deploy the off-premises Tier Guard System in a variety of CATV systems. Differences from traditional tapped feeder concepts are highlighted.

In addition, financial models for initial installation costs and operational benefits are provided, showing the Tier Guard System to be a cost-effective design concept in a variety of systems including urban, suburban, rural, new build, rebuild and upgrade situations.

SYSTEM DESIGN

A cost-effective system design which takes full advantage of the characteristics of off-premises addressable equipment must take into consideration design rules and concepts which are different from the standard tapped-feeder concepts used in a traditional broadband system. Several categories of inherent differences are indicated, namely the clustering or grouping of outlets to take advantage of shared electronics, the resultant longer drops which are produced by this type of cluster design, powering methods and costs, and most importantly, limited deployment of active electronics.

Tapping

The purpose of a traditional broadband system design approach utilizing low-cost directional taps is to, at minimum, provide an outlet for every potential subscriber. The use of standard directional tapping devices in configurations having two, four and eight outlets results in deployment of 115-125% of outlets as a percentage of homes passed. This is a naturally cost-effective system design since the cost per port for a standard directional tap is very low.

The cost per port of an off-premises addressable system such as the Tier Guard System is quite low compared to an addressable converter or an off-premises addressable tuner. Consider, however, a hypothetical system design that treats the Tier Guard tap as a standard tap in a system that, for example, has 60% penetration and 120% deployment of outlets. This would result in deployment of two outlets for each subscriber and would double the cost of the Tier Guard implementation. This is clearly an undesirable situation.

A system design technique that achieves 70% to 80% utilization of deployed ports was devised to overcome this situation. An explanation of the concepts underlying this system design technique along with the advantages and disadvantages follows.

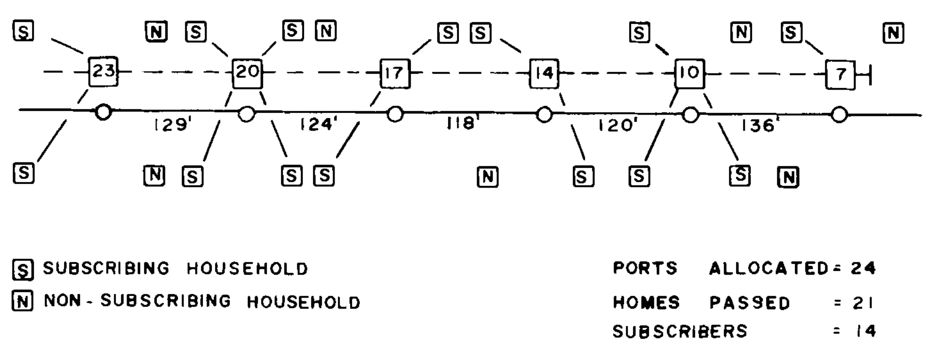

FIGURE 1
TRADITIONAL TAPPED FEEDER

Tapping Example

Figure 1 shows a sample design area with 21 homes passed, 14 subscribers, and six four-port taps allocated.

Figure 2 shows the same area with the Tier Guard off-premises system deployed with the following results:

1. End of feeder is reduced by one span.
2. Two active locations are utilized instead of six.
3. Sixteen ports are allocated to serve fourteen subscribers.
4. Two blank plate (TGT-0) locations are available for further expansion.

Advantages of the System Design

Several advantages are presented by this system design concept.

1. Efficient Port Usage

Deployment of active electronics and efficiency of active port usage is optimized, reducing installation costs.

2. Increased System Reliability

The shared electronics have reduced the number of active components in the system and reduced the number of serially-connected devices in the feeder.

3. Lower Tap Losses

This particular example shows a loss of 1.2 dB per TGT or 4.8 dB passive loss. The traditional passive losses in figure one totals 8.6 dB without the terminating 7 tap! This increases the efficiency of line extender use in the system.

4. Lower Cable-Bearing Strand Footage

The result of reducing each and every end of feeder in the system by one span has a dramatic effect on reducing cable-bearing strand footage, reducing installation costs.

5. Lower Passive Installation Costs, Fewer Connectors

As demonstrated by the examples presented in Figures 1 and 2, the traditional design required installation of six passives, one at each pole, while Tier Guard off-premises design required installation of four passives for the same feeder. This results in lower installation costs for the passives themselves and use of fewer connectors.

Limitations of the System Design

There are several limitations to this system design technique which should be identified by the system designer.

1. Longer Drops Required

In order to take advantage of the shared electronics of the Tier Guard System, the subscribers must be served from more concentrated tap points. As can be seen in the example, instead of providing services for two, three or four subscribers from each of six poles, active TGTs are deployed on a limited basis at only two locations. Service that would traditionally be provided from the poles adjacent to the Tier Guard tap must be handled by running an extended drop. The installation and materials cost for the longer drops must be added to the initial system installation cost for the Tier Guard system.

2. Added Power Supply Costs

The Tier Guard System is capable of being powered from the feeder system or, optionally, by the drops. Since the Tier Guard tap power consumption is quite low (14 watts for a TGT-8), powering from the feeder system is preferred. In this case, the initial

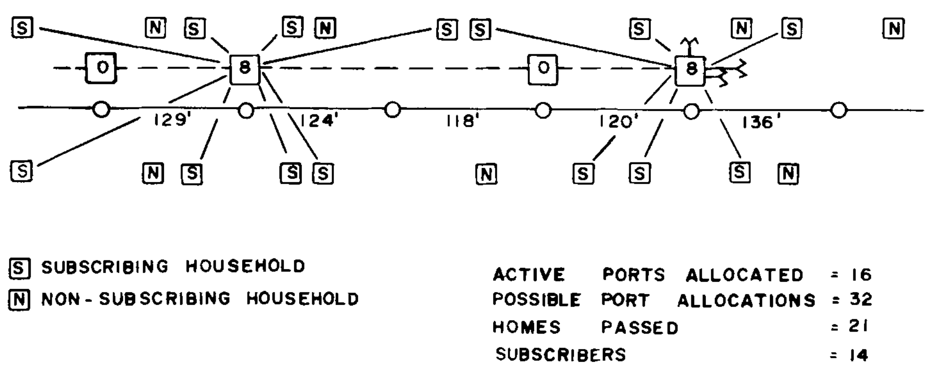

FIGURE 2
TIER GUARD TAP FEEDER DESIGN

installation costs will be increased by the added costs of power supply locations. A rough estimate for the number of additional power supplies required when using the Tier Guard System can be calculated based on the following assumptions for a moderately dense system of about 100 subscribers per mile:

A. 70% efficiency of power supply use.
B. 900 watts available from the power supply location (60 volts at 15 amperes).
C. 42 poles per mile.
D. 14 Tier Guard taps per mile (one every third pole).

With the above conditions, and further assuming that the powering system will be current-limited, not voltage-limited, 640 watts of power is available to power the Tier Guard system. At 14 watts per Tier Guard tap, 45 taps may be powered from a single power supply location. Assuming 14 active taps per mile, an additional power supply will be required every 3.2 miles of cable-bearing strand plant.

For those systems employing standby power, the cost of added power supplies might be reduced by using standby power on the trunk with traditional supplies in the feeder area.

Summary of Tier Guard System Design Rules

1. Deploy TGT-0s throughout the system, assuming each tap will be capable of providing an outlet for eight subscribers. This will typically result in 50-65% of the poles in the system having the capability to provide active TGT outlets. This will result in potential outlets for 100% of homes passed.

2. Populate only those TGTs required to service the projected penetration. Typically this will require active TGTs at only 50% of the locations indicated in Item 1 above, or, in other words, an active Tier Guard tap at every third pole in the system.

3. An objective for the system designer should be to achieve a minimum of 70% efficiency in active TGT port deployment. That is, seven out of every ten active TGT ports deployed should be used.

Implementations in Sparse Areas

The specified output level of the TGT is +15 dBmV at the highest frequency. This limits long drop lengths using RG-6 to approximately 300 feet. If the designer places TGT-8s optimally so that full reach is achieved in both directions along the feeder line, the minimum number of TGTs that can be deployed is about 10 units per mile. In systems which have only 30 or so subs per mile, efficient deployment of the system will rely on implementing system design techniques that minimize the number of TGTs required by extending the length of the drop. Two methods have been investigated. These are:

1. Use of a "Booster Amplifier" of a low cost variety which will allow drop levels to be increased to +23 dBmV in long-drop situations.

2. Use of 0.412" backfeed cable to lower the insertion loss of the drops.

Both of these alternatives have been selected by designers of off-premises systems using TGT.

Implementation in Upgrade Situations

The replacement, on a one-for-one basis, of existing taps with either a TGT-0 or an active TGT is a straightforward matter. The option to relocate line extenders remains with the system designer. In a system that is already over-extended (three extenders or more in series), it is possible to take advantage of TGT to reduce the number of extenders, increase reliability, and reduce maintenance costs. On the other hand, the designer may choose to leave intact existing line extender locations.

Upgrading with TGT theoretically requires extending the drop length of approximately 2/3 of existing drops to cluster existing subs for more cost-effective deployment.

CALCULATING THE INSTALLATION COSTS OF AN OFF-PREMISES TGT SYSTEM

In projecting the cost to deploy the Tier Guard System, the designer must consider several parameters. New systems, rebuilds and upgrades each have requirements which will affect system design, installation and deployment tactics. This section attempts to model the new-build situation and presents the variables that change the model for rebuild and upgrade scenarios.

New Build TGT Installation Cost Parameters

In order to accurately predict the installation cost of the Tier Guard System in a new build, it is necessary to quantify the following parameters:

1) Homes passed per mile
2) Projected penetration
3) Number of TGT-0s deployed
4) Number and value of active TGTs deployed (TGT-4, TGT-6, TGT-8)
5) TGT-0 installation costs
6) Active TGT installation and activation costs
7) Added costs of longer drops
8) Added power supply costs
9) Number of "plain vanilla" converters used taking into account cable ready sets

New Build Addressable Set-Top Installation Cost Parameters

In order to compare the installation costs of the Tier Guard System to a set-top addressable system, the following additional factors need to be quantified:

1) Lower distribution system costs with TGT due to lower cable-bearing strand footage, fewer taps, fewer extenders, fewer connectors, etc.

2) Number of addressable set-top converters used, taking into account how basic subs are provided service, additional outlet requirements and inventories, etc.

3) Use of "plain vanilla" converters

4) Added Drop Costs - Although a significant number (about 1/3) of the total drops in the system are

standard length, about 2/3 of the total will be longer than normal. Some of these longer drops will require a complete span to the adjacent pole location (about 50%) while the remainder can be handled by a half-span extension in drop length. Both material costs and added labor costs must be considered.

5) Combined distribution plant costs - The effect of the savings produced by fewer taps, lower strand footage, lower passive installation costs plus cost adders on the distribution plant including additional power supply costs are detailed for a specific design example at the end of this paper.

OPERATIONAL BENEFITS

Off-premises equipment should be deployed in many systems for reasons which vary in importance, depending on the unique characteristics of the individual system. The primary operational cost benefits which may be calculated directly from data available from operations are:

1) Reduction in theft of service losses
2) Reduction in hardware losses
3) Reduction in churn losses
4) Reduction in equipment repair costs.

In some systems the payback associated with only one of these benefits will justify the off-premises approach. In most systems a combination of these items will produce significant operational improvements which should be analyzed when a new build or rebuild of a system is being planned. A payback model for each of these benefits is presented in the following sections.

Theft-of-Service

One of the valuable benefits of an off-premises system is the increased revenues which can be generated by eliminating theft-of-service and converting non-paying subscribers to paying subscribers.

The following model calculates theft-of-service benefits on a per-subscriber basis using the initial subscriber count before service theft is eliminated as a basis. The following parameters are used as required data for the calculation:

Parameter	Equation Variable
Homes Passed per mile	HP
Penetration, %	PEN
Illegal Connections, % of HP	ILL
Illegals caught, % of ILL	CAUGHT
Illegals converted, % of ILL	CONV
Average takeout/sub/month, $	TAKEOUT

The number of converted subscribers per mile is calculated as follows:

(NEW) = (HP)x(ILL/100)x(CAUGHT/100)x(CONV/100) (1)
= new subs/mile

The additional revenue per mile per year generated (NEW $) is calculated as follows:

(NEW $) = (NEW) x (TAKEOUT) x 12 (2)
= $Mile/year

This additional revenue (based on original subscriber count) is as follows:

$/sub = (NEW $)/(HP)x(PEN/100) (3)

Theft of Service Example #1 (High Theft)

The following example presents an actual system which has a high theft-of-service problem, with the following parameters,

PEN	= 17% existing subscriber penetration
ILL	= 30% illegal connections
CAUGHT	= 100%
CONV	= 50%
TAKEOUT	= $20 average per subscriber per month

Justification for an off-premises TGT system installation is almost completely based on projected cash from improving penetration from 17% to 32% as follows:

(NEW) = (220)x(30/100)x(100/100)x(50/100)
= 33 subs per mile

(NEW) = 33 x (20) x 12 = $7920/mile
$/sub = $211.76 per existing sub per year!

Theft-of-Service Example #2 (Average Theft)

The previous example was an extreme (but real) situation in a problem system. An "average" urban system is presented below with the following numbers:

HP	= 220 homes/mile
PEN	= 50% of HP
ILL	= 10% OF HP
CAUGHT	= 100% Of illegals
CONV	= 25% of those caught
TAKEOUT	= $25/month

In this case,

(NEW)	= 5.5 new subs/mile
(NEW $)	= $1,650.00 per mile
$/Sub	= $12.50 per existing sub per year

In this "average" case, the improvement in revenue due to an off-premises system is still substantial, but one must also look at other areas for additional operational savings in order to justify deployment.

Reduction in Hardware Losses

The reduction in hardware losses when comparing an off-premises system to a set-top addressable system is a function of two elements:

1) The cost of in-home electronics is substantially reduced by the difference in cost between a "plain vanilla" converter and an addressable

converter ($40 versus $100).

2) Converter deposits represent a much larger proportion of total exposed cost. For example, with a $25 deposit, the exposure to a converter theft would be as follows:

Plain vanilla = $40 - $25 = $15
Addressable = $90 - $25 = $65

In other words, with a reasonable deposit on in-home electronics, the exposure to theft of equipment with off-premises equipment can be a fraction of the exposure with an addressable converter system.

Assuming a 15% hardware loss for theft-of-services, the following calculations can be made for the "average" urban system, taking into account an additional converter needed for additional outlets and no converter needed for a TGT system with a cable-ready set.

HP	= 220 homes/mile
PEN	= 60% of HP
LOSSES	= 15% of equipment annually
DEP	= $25 deposit on converters
% ADD	= 20% additional outlets
% Cable-ready	= 30% cable-ready sets

Hardware Loss, Set-top Addressable

Converters lost per mile = (HP) x (PEN/100) x (LOSSES/100) x (1 + ADD/100)

= (220) x (.6) x (.15) x (1.2)

= 23.76 lost converters/mile/year

$ lost/mile = $23.76 x ($90 - $25)

= $1,544.40 per mile per year

or, on a subscriber basis

$ lost/sub/year = $11.70/sub/year

Hardware Loss, TGT

$Converters lost/mile = (HP)x(PEN/100) x (Losses/100) x (1+ADD/100) x (1-cable loss/100)

= 16.63 lost plain converters/mile/year

$ Lost/mile/year = 16.63 x ($40 - $25)
= $249.48

$lost/sub = $1.89/sub/year.

Hardware Loss Savings

This represents an operational savings of $11.70 - $1.89 = $9.81 per sub per year!

CHURN ANALYSIS

Many systems have unusually high churn due to the nature of the community. Classic examples include resort communities, university communities, and the like. The off-premises Tier Guard approach has been, so far, universally advantageous in each of these types of communities analyzed to date.

Several transactions need to be identified in analyzing what this paper defines as churn. These are:
1) Disconnects
2) New Connects
3) Reconnects
4) Upconverts - to add a pay channel
5) Downconverts - to delete a pay channel

When comparing the TGT system to addressable set-top systems, the primary benefits of the TGT system are obtained by eliminating truck rolls for disconnects. When considering the TGT system instead of a trapped system in high churn environments, the reduction in up- and down- converts along with disconnects must be determined.

TGT vs Set-top Addressable Churn Cost Comparison

One of the key system operational strategies that should be employed in reducing the costs of churn with the TGT system is elimination of the need to make a service call to collect the converter. Since homes with cable-ready sets require no converter (the penetration of cable-ready sets will increase continuously in the future), this type of subscriber naturally does not require a truck roll. Since a "plain vanilla" converter is used in homes without cable-ready sets, it is assumed that a modest deposit will provide adequate incentive for an effective converter return policy.

Neither Up or Down converts of pay channels require truck rolls with either a TGT or an addressable set-top system. Also, quite naturally, a New Connect requires a truck roll with both systems. The key to a comparison in the operational costs of these two types of systems relies on comparing disconnect and reconnect losses.

The data required to calculate the operational benefits in this case are:

Parameter	Equation Variable
Homes passed per mile	HP
Penetration, %	PEN
Disconnects, % of subs	DISC
Truck Roll Cost, $	ROLL

Disconnect Costs

Since the disconnected subscriber is generally not a cooperative one, it is assumed that an average of 1.9 truck rolls/disconnect is required to retrieve the set-top addressable box, while no truck roll is assumed for the TGT system.

Example

The following example of a typical urban system s presented:

HP	=	220 homes/mile
PEN	=	60% of H. P.
DISC	=	20% of subscribers
ROLL	=	$25

TGT Churn Benefit (Moderate Churn)

The calculation for the churn benefit on a per-subscriber basis of the TGT system is as follows:

Churn Benefit = ((HP x PEN/100) x (DISC/100 x 1.9) x (ROLL))/(HP x PEN/100)

= (DISC/100) x 1.9 x (ROLL)

The first conclusion is that this churn benefit on a per-subscriber basis is independent of houses passed and penetration. The value of this benefit in this example (20% disconnect rate) is:

Churn Benefit = (.2) x 1.9 x $25 = $9.50/sub/year

High Churn Example

Systems that experience a high churn rate (100%) with the above truck roll cost will experience the following operational benefit with TGT versus an addressable set-top system:

Churn Benefit = (1.0) x 1.9 x 25
= $47.50/sub/year

REDUCTION IN EQUIPMENT REPAIR AND MAINTENANCE COSTS

The effect of the ideal TGT system on repair and maintenance costs is dramatic. The number of active electronics in a TGT system with no subscriber equipment is less than 20% of the electronics needed to deploy a set-top addressable system. Assuming that the cost to repair and maintain TGT hardware is 50% more than that for set-top addressable converters, the net result is still 30% of a set-top system or a 70% savings in maintenance and repair costs. An example of this scenario follows.

Ideal Repair & Maintenance Cost Savings

The following data is required in addition to previous data:

Parameter	Equation Variable
Addressable set-top failure rate, %	ADDFAIL
Addressable set-top repair cost, $	ADD$REP
Truck Roll Cost, $	ROLL
TGT failure rate, %	TGTFAIL
TGT repair cost, $	TGT$REP
Additional Outlets,%	ADD

Repair Benefit Value Calculation

Addressable set-top repair $ =

(HPxPEN/100)(1+ADD/100)(ADDFAIL/100)

(ADD$REP+ROLL)/(HP x PEN/100)

Again, the penetration drops out on a per-subscriber calculation, leaving :

Addressable set-top repair $ =

(1 + ADD/100)(ADDFAIL/100)(ADD$REP+ROLL)

Example: The following example is presented:

ADD	=	20% of subscribers with additional outlets
ADDFAIL	=	10% failure per year
ADD$REP	=	$20
ROLL	=	$25

Addressable set-top repair $ = $5.40/sub/year

The TGT system repair costs are as follows: assuming 80% efficiency of TGT outlets and average use of TGT-6s in the system design:

TGT FAIL = 10%
TGT $REP = $30

$$\text{TGT Repair \$} = \frac{(\text{TGTFAIL}/100)(\text{TGT\$REP}+\text{ROLL})}{(.8 \times 6)}$$

= $1.15/sub/year

This represents a substantial operational savings per subscriber each year. However, this also represents a boundary value condition in the future when most sets are cable-ready. At this point in time, assuming 20% or so existing penetration of cable-ready sets, the repair costs tend to be equal in both systems, because of the need to maintain and repair the "plain vanilla" convertors used in the TGT system. Depending upon specific system parameters, the TGT advantage is approximately $1.00/sub/year with a projected increase towards $4.05/sub/year as cable-ready sets increase in numbers.

EXAMPLE SUMMARY ANALYSIS

The following example is a computer program printout of a Tier Guard versus addressable set-top cost comparison for an urban system. The first "page" of the printout lists the various assumptions. The second page indicates initial system design considerations. In this section, the total effect on the distribution plant is added as one line. This includes reduction in strand footage, line extenders, taps, connectors, and increased power supply costs. Cost of longer drops is included as a separate item.

This particular situation indicates a slightly higher installation cost with a very quick payback favoring the off- premises approach.

TIER GUARD COST COMPARISON
versus ADDRESSABLE SET-TOP
URBAN SYSTEM

SYSTEM INFORMATION

Homes Passed	225.00
Penetration,%	45.00
Subscribers	101.25
Additional Outlets,%	20.00
Cable Ready Sets,%	20.00
Poles per Mile	42.00
Truck Roll Cost,$	25.00
Avg. Sub Bill/Month,$	25.00
Hardware Theft,%	15.00
Service Theft, % of H.P.	10.00
% Illegals Converted	25.00
Disconnects,%Subs/year	10.00
New Connects,%Subs/year	2.50
Reconnects,%Subs/year	7.50
Upconvert Pay,%Subs/year	10.00
Downconvert Pay,%Subs/year	10.00

ADDRESSABLE SET TOP INFORMATION

Addressable Price,$	100.00
Inventory,%	10.00
Failure Rate,%/yr.	15.00
Repair Cost,$	20.00
Customer Deposit,$	30.00

PLAIN CONVERTER INFORMATION.

Converter Price,$	40.00
Inventory,%	10.00
Failure Rate,%/yr.	15.00
Repair Cost,$	11.00
Customer Deposit,$	30.00

TIER GUARD INFORMATION

TGT Price,$	
TGT-8	590.00
TGT-6	550.00
TGT-4	510.00
TGT-0	40.00
TGT Inventory,%	5.00
Failure Rate,%/year	3.00
Repair Cost,$	30.00

INITIAL SYSTEM INSTALLATION CONSIDERATIONS

TGT SYSTEM COSTS

Poles per TGT (design spec)	3.00		These figures were derived from TGT tap utilization programs. Avg. subs/pole assumes min design goal of 50% H.P.
Avg. Subs per TGT Pole	7.23		
Total Active TGTs used	18.20		
TGT Tap Utilization			
TGT-8	9.80		TGT-0....Amount used to allow potential TGT outlets to achieve 100% H.P.
TGT-6	4.20		
TGT-4	4.20		
TGT-0	9.93		
TGT Cost per Mile	10631.00		
Cost per Sub	105.00		
Number, Plain Converters	106.92		Adl. Outlets, Cabl Rdy, Invtr
Total Converter Cost, $	4276.80		
Cost per Sub	42.24		
Total Cost, $ TGT +Conv.	14907.80		
Cost per Sub	147.24		
Plus Added Drop Cost, $	7.00		
Minus Distribution Plant, $	13.95		
		140.29	GRAND TOTAL TGT SYSTEM

ADDRESSABLE CONVERTER SYSTEM COSTS

% Subscribers Addressable	100.00		
% Subs with Plain Basic	0.00		
Number of Addressable Units	133.65		Addl.Outl, Inventory
Plain Units	0.00		=above with cable ready
ADDR. Cost	13365.00		
Plain Cost	0.00		
Total	13365.00		
Per Sub		132.00	.....GRAND TOTAL ADDRESSABLE

INITIAL SYSTEM COST DIFFERENTIAL 8.29

TIER GUARD OPERATIONAL BENEFITS

HARDWARE THEFT

% Converters Lost,Stolen	15.00		
	ADDR	TGT	
Addressable Converters,$	1403.33	0.00	
Plain Converters,$	0.00	160.38	
Total	1403.33	160.38	
PER SUB	13.86	1.58	
TGT ADVANTAGE			12.28

SERVICE THEFT

% Illegal Connections	10.00	
% Caught	100.00	
% Converted to Paying Subs	25.00	
Annual Revenue Increase,$	1687.50	
PER SUB		16.67

CHURN ANALYSIS, TRUCK ROLLS ONLY

Transactions			
Reconnects,%	7.50		Annual Percent of
Disconnects,%	10.00		Homes Passed
New Connects,%	2.50		
Upconvert,%	10.00		
Downconvert,%	10.00		
Truck Rolls	ADDR	TGT	
Reconnect	16.88	13.50	.........Addr.=1, TGT=0.8
Disconnect	42.75	0.00	.........No roll for plain con.
New Connect	5.63	5.63	Deposit covers loss
Upconvert	0.00	0.00	
Downconvert	0.00	0.00	
Total Truck Rolls	65.25	19.13	
Cost of Rolls,$	1631.25	478.13	
TGT ADVANTAGE		1153.13	
PER SUB			11.39

REPAIR ANALYSIS

	ADDR	TGT	
Cost of Repair			
Plain	0.00	577.37	
Addressable	902.14	0.00	
TGTs	0.00	30.03	
Total	902.14	607.40	
PER SUB	8.91	6.00	
TGT ADVANTAGE			2.91
ADDED POWER COST/SUB			2.26
TIER GUARD OPERATIONAL BENEFITS/YEAR TOTAL $			38.07

FINANCIAL SUMMARY

TIER GUARD vs ADDRESSABLE SET-TOP

Costs per Subscriber

	ADDR	TGT	
Initial Costs,$	132.00	140.29	
Cost Difference			8.29
Annual Savings,$	0.00	38.07	

PAYBACK, TGT vs ADDRESSABLE SET-TOP, Months		2.61
TGT COST ADVANTAGE	FIRST YEAR	29.78
	after FIVE YEARS	182.07

SUMMARY AND CONCLUSIONS

Off-premises systems such as the Tier Guard Tap can be effectively deployed in a variety of systems. Installation costs will vary depending upon projected penetration and subscriber count. Design techniques somewhat different from traditional tapped-feeder concepts need to be employed for cost-effective deployment of the shared electronics.

Installation costs are comparable to addressable set-top systems. Operational benefits result in very short paybacks on investment compared to addressable set-top systems. Benefits vary from system to system and a thorough analysis is justified on any system design opportunity, whether urban, suburban or rural, new build, rebuild or upgrade.

References

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POWERING THE OFF-PREMISES SIGNAL CONTROL SYSTEM

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ABSTRACT

The advantages and disadvantages of drop cable and feeder cable powering of off-premises signal control systems are discussed.

INTRODUCTION

The last three years have seen growing cable industry interest in various types of off-premises signal control systems - as evidenced by the papers being presented at this panel today.

I have grouped the various methods of off-premises control into two general categories: 1) Converter systems, where a signal conversion from the cable channel to the TV set channel is made off-premises and 2) Interdiction systems, where the channel conversion is made in or at the TV receiver and remotely addressed traps or jamming carriers are located off-premises.

One powering concern with these systems is the cost burden to the operator if the off-premises system is powered from the feeder cable or the cost burden to the subscriber if it is powered from the home. A second concern is the retrofitability of an off-premises system into an existing plant, if it will be powered from that plant. A third concern is safety if power is being supplied from the subscriber's home and if for any reason the integrity of the drop cable is lost, creating a shock hazard.

POWER CONSUMPTION

Six representative off-premises signal control systems have power consumptions per subscriber between 1.75 and 4 watts for interdiction systems and between 8.5 and 33 watts for conversion systems, with several of the latter in the 10-15 watt range. In this paper, I have assumed 3 watts for interdiction systems and 15 watts for conversion systems.

For a system designed for 80 subscribers per mile, the signal control power consumption would be 240 watts per mile with an interdiction system and 1200 watts per mile with a conversion system.

SYSTEM POWERING

A recent 106 passings per mile cable plant was designed by ATC for the 60 volt power supplies to supply 554 watts per mile, assuming a power factor of 95%. Of this power, 462 watts was amplifier usage and 92 watts was lost as heat in the trunk and feeder cables.

Approximately 15-20% of the power supplied by a 60 volt power supply is actually lost as heat in the trunk and feeder cables. For example, in carrying 10 amps through one mile of 3/4 inch copper clad aluminum center conductor GID cable, 380 watts are lost. With comparable 1/2 inch cable, 866 watts are lost.

The 60 volt power supply can have an efficiency of approximately 80% for non-standby power and as low as 40% for a standby powered supply. For the purposes of this paper, I've assumed an efficiency of 80%. The cost of power from representative power companies throughout the United States ranges from 5¢ to 15¢ per kilowatt hour, with a large number of the rates clustered around 8¢, the number I've used for this paper.

With all of these assumptions, and without any off-premises signal control consumption, this particular cable plant design should have a power cost of $486/per mile/per year.

When the off-premises signal control powering needs are added, and taking into account approximate factors for cable loss and power supply efficiency, interdiction would increase this system's power consumption costs by $252, a 52% increase, while a conversion system would increase the power consumption costs by $1,262, a 260% increase. This could represent a power cost, for signal security alone, of over $126,000 in a 100 mile system - and could be double this number if standby power supplies with 40% efficiency are used. In addition, this does not take into account the capital and makeready costs of additional power supplies nor the labor costs for their installation. Because a conversion system can cause the current in some feeder cables to increase as much as from .6 amperes to 9 amperes, there is also a possible power passing problem.

HOME POWERING

In this section, we will look at some examples of the drop cable voltage drop and power cost to the subscriber for home powering off-premises control systems, with a subscriber supplied voltage of 24 volts and a drop length of 100 feet.

If the drop is an RG-59 size foam dielectric cable with an aluminum foil sheath and a copper clad steel center conductor of 73 ohms per 1,000 feet loop resistance, a 3 watt interdiction system would cause a 0.95 volt drop in the drop cable with 3.12 watts being supplied by the subscriber. If we assume 80% efficiency on the voltage conversion in the subscriber's home, this would lead to a draw from the 117 volt line of 3.9 watts, at a cost of $2.74/per year. A 15 watt conversion system would have a 6.1 volt drop in the drop cable and a total power consumption of 25.2 watts, at a cost of $17.67 per year.

At this cost, some subscriber opposition may be encountered. However, the power consumption may be explained as not significantly greater than the approximately 20 watts that might be drawn by an in-home addressable converter. It could also be explained that the subscriber's fees would have to be increased by this amount, if the subscriber were not supplying this power.

If lower loop resistance is needed in the drop cable, we could use a similar construction RG-6 size cable of 48 ohms/per 1000 feet, which would cause a 3.5 volt voltage drop for a 15 watt conversion system, a subscriber power consumption of 21.9 watts, and a subscriber cost of $15.36 per year. Going all the way to an RG-6 with copper braid and a solid copper center conductor with a DC loop resistance of 14 ohms per/1000 feet could reduce the voltage drop on a 15 watt system to 0.9 volts and require a power consumption for the subscriber of 19.5 watts, at a cost of $13.68 per year.

Another subscriber powering concern is safety. The 24 volts we've used in these calculations is generally considered safe in an indoor environment. But because of the possibility of a small child picking up a broken drop cable while standing in a puddle of water, additional safety is recommended. Suggestions have included locking shields on drop cable connectors and warning labels on the cable, but the security shields do not prevent the broken drop cable problem nor do the warning labels answer the question of a pre-schooler picking up the broken cable. There are also some systems with higher power consumption or the need for longer drops that would like to run drop voltages as high as 50 to 60 volts.

One method of increasing the safety is by increasing or decreasing the power frequency. The most hazardous frequency for cardiac fibrilation, the primary cause of death from low voltage electric shock, is close to 60 Hz. If we reduce the frequency to DC, or more probably a few tenths of a hertz to avoid galvanic corrosion problems, or increase the frequency to approximately 10 kHz, the safety factor goes up by approximately five times, i.e., five times the voltage can be carried for the same level of safety.

An approach taken by one manufacturer is a circuit that will instantly interrupt the voltage leaving the in-home power device if the drop current is interrupted for any reason. In this particular system, when drop integrity is restored, the system will automatically restart if some other subscriber or subscribers are still supplying power to the off-premises device. If that subscriber was the only one supplying power, he may attempt to restart by pressing the "on" button. Power will come on for a maximum of 390 milliseconds, and if no data communications are established from the off-premises device within that time, the system assumes drop integrity has not been restored and the voltage is again interrupted. This timing is significantly shorter than the time required for a shock hazard at the voltages involved.

HYBRID POWERING

Another system suggested by some manufacturers is to divide the powering. The microprocessor and the communications circuits in the off-premises device are powered from the feeder cable but the actual conversion or interdiction equipment is powered by the subscriber. Although this does reduce both the cable powering problem and the home powering problem, it does still leave both and causes the operator the necessity of dealing with both.

RECOMMENDATION

I believe that the subscriber cost, safety, and drop cable voltage drop concerns with subscriber powering are much easier to solve than the capital and operating costs for system powering. System powering can be a particular problem in a retrofit installation, because of the need to install additional power supplies and completely recalculate system powering.

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REDUCING ATTENUATION OF TRUNK AND FEEDER CABLE

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ABSTRACT

The availability of 550 MHz systems may require reduced cable attenuation to maintain economical amplifier spacings. Coax attenuation can be reduced by using thinner aluminum walls, decreased dielectric constants or larger cable sizes. Since each approach can compromise reliability if done in excess, an optimum combination of each factor is necessary. The design and development of such a cable is described.

INTRODUCTION

The advent of 550 MHz systems has focused attention on the need to reduce trunk and feeder cable attenuations. Several approaches have been attempted with mixed results. This paper reviews various alternatives available to reduce coax attenuation and offers a solution to minimize the need to compromise established performance standards.

KEY FACTORS CONTROLLING ATTENUATION

Coax cable attenuation is determined by several variables:

1. Dielectric size (center conductor size has little affect on attenuation if the dielectric constant is not changed). (Figure 1),

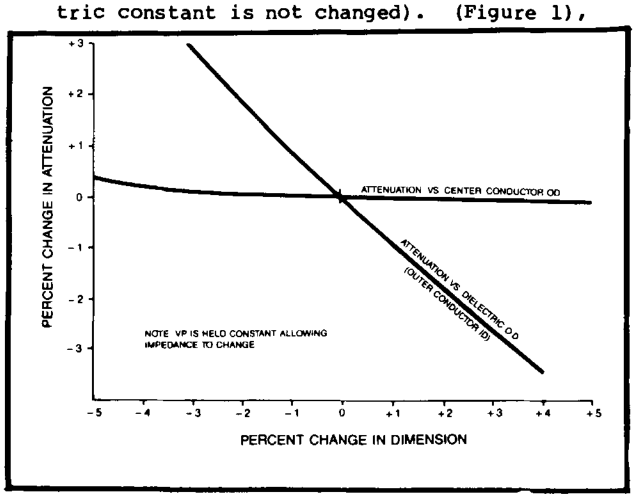


FIGURE 1. PERCENT ATTENUATION CHANGE VS. PERCENT DIMENSIONAL CHANGE

2. Impedance,

3. Center conductor and outer conductor conductivities,

4. Dissipation factor and percent velocity of propagation (VP) of the conductor coat and the foamed dielectric,

5. Structural return loss (SRL), and

6. Operating frequency.

With the exception of item 4, these factors have essentially been standardized in the cable TV industry: 1) Six standard attenuation levels plus a supertrunk; 2) Impedance of 75 ohms; 3) Copper clad aluminum center conductor with aluminum outer conductor; 4) SRLs specified in the 26-30 dB range, depending on system needs; 5) System frequency of 5-550 MHz.

However, even with these basic factors standardized, there are two remaining factors which can still be varied to reduce coax attenuation:

1. Reduction of the aluminum-sheath wall thickness, allowing a larger dielectric for the same cable outside diameter (OD) (Figure 2), and

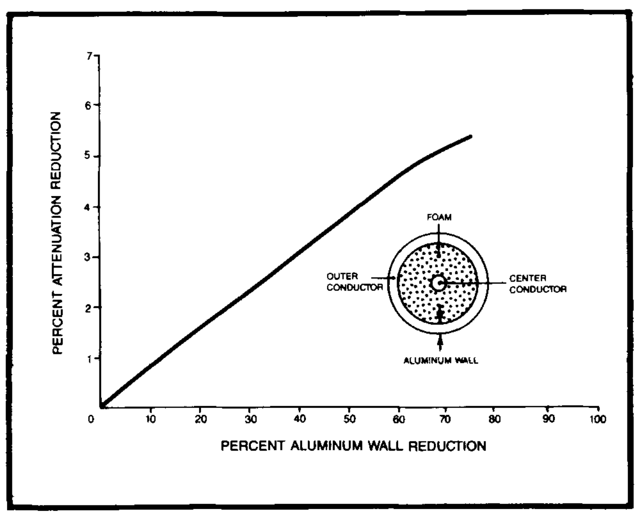


FIGURE 2. PERCENT ATTENUATION REDUCTION VS. PERCENT ALUMINUM WALL REDUCTION

2. Increased VP and reduced loss factor for the dielectric system (foam and center conductor coat) (Figure 3).

REDUCED ALUMINUM-SHEATH WALL THICKNESS

Reducing the thickness of the aluminum-sheath wall accomplishes two goals: a modest improvement in attenuation and a reduction in product cost if the sheath is thinned sufficiently. Figure 2 indicates the substantial aluminum wall reduction necessary for a given attenuation improvement.

The aluminum-sheath wall thicknesses currently in use for seamless products, as opposed to welded, have been standardized for all suppliers and have stood the test of time in both aerial and underground applications. The standard wall thicknesses (Table 1) are approximately 5 percent of the aluminum OD. Some of the welded reduced wall cables offer ratios as low as 2 percent of the aluminum OD.

Reducing aluminum-sheath walls must be approached with caution to avoid the following potential problems:

1. Increased sheath resistance (Figure 4) associated with grounding and powering problems,

2. Mechanical integrity as compared to full wall seamless,

3. Reduced corrosion life caused by a significant reduction in aluminum thickness and mass, and

4. Problems with coring and connector installation, including aluminum splitting near the

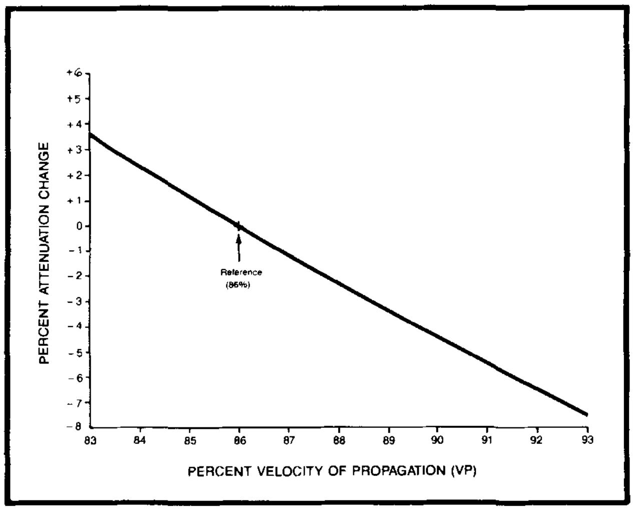


FIGURE 3. PERCENT ATTENUATION CHANGE VS. PERCENT VP

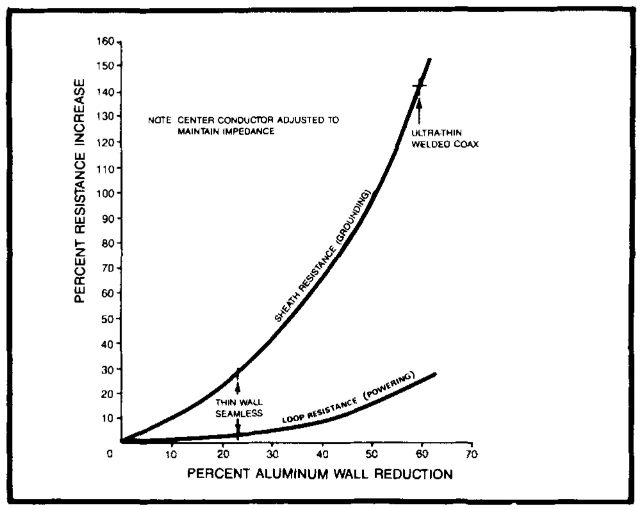


FIGURE 4. PERCENT RESISTANCE INCREASE VS. PERCENT ALUMINUM WALL REDUCTION

TABLE 1. WALL THICKNESS FOR STANDARD, THIN, AND ULTRA THIN CABLES

Standard Size	Standard Seamless Wall	Fused Disc Size	Thin Welded Wall	QR Size	Ultra Thin Welded Wall	New 90% VP Low Loss Size	Reduced Seamless Wall
0.412	0.025	0.440	0.020	---	---	---	---
0.500	0.025	0.500	0.020	0.500	0.012	0.480	0.021
0.625	0.031	0.650	0.022	---	---	0.565	0.023
0.750	0.036	0.750	0.025	---	---	0.710	0.027
0.875	0.039	---	---	0.860	0.016	0.840	0.030
1.000	0.055	1.000	0.033	1.125	0.021	1.160	0.040

connector after fatigue aging, field, abuse, temperature induced expansion/contraction, and servicing of amplifiers.

When attempting to reduce aluminum walls more than 15 to 25 percent, the unavailability of the required seamless aluminum dictates that the manufacturer resort to welded aluminum. Since the aluminum tape is substantially more expensive per pound than seamless aluminum, far thinner walls (as much as 60 percent thinner) are required to achieve an economic construction.

Most cable users prefer extruded seamless aluminum to welded aluminum tape. The full wall seamless product is felt to be inherently superior in terms of freedom from micro-pinholes and splits, and long-term corrosion resistance.

If the aluminum wall reduction from the standard thickness is kept to a modest 15 to 25 percent, economic and reliable seamless tubing can be used without having to resort to welded aluminum or excessively thinned aluminum walls.

LOWER LOSS DIELECTRICS

The two basic dielectrics being used in the cable TV industry are gas injected foamed polyethylene and spaced-disc air dielectric.

Spaced-disc air dielectric cable offers the highest VP at 93 percent compared to VP values of 85 to 88 percent which are typical of foamed dielectrics. Cable users have preferred the foamed dielectric cables because of their historical advantages in handling, moisture resistance and the availability of these cables with seamless aluminum.

In order to increase the VP and reduce the loss incurred by foamed dielectrics, the foam density must be reduced below current levels. At a typical foam density of 0.28 g/cc with an 86 percentVP, the dielectric is 70 percent air as compared to solid polyethylene at a density of 0.93 g/cc. In order to increase the VP to 90 percent, foam densities will have to be reduced down to approximately 0.18 g/cc (81 percent air) which is 36 percent lower than the already enhanced foams currently available.

Most manufacturers have experimented with these lower foam densities and abandoned their efforts because of several inherent problems:

1. Foam Softness - As the foam density is reduced, the effective hardness is also reduced, degrading cable handling characteristics.

2. Foam Integrity - Reducing foam density means increasing the volume of injected gas. Beyond a certain point, the foam density may remain essentially the same with the excess gas forming continuous pockets, voids, and open cells. These undesirable internal voids may lead to erroneous low flotation density measurements, even though the basic closed cell foam may actually be at higher densities. The objective is to achieve reduced foam densities without compromising the integrity of the foam structure.

Currently available foams are much harder than those that were introduced in the 1980 to 1982 period as manufacturers have developed the ability to utilize higher proportions of High Density Polyethylene (HDPE) as opposed to Low Density Polyethylene (LDPE). To complicate the situation even further for foam development engineers, design engineers require that even more HDPE must be used for the lower density foams to offset the inherent reduction in hardness that occurs.

CENTER CONDUCTOR COATING

One of the obstacles to achieving increased dielectric VP is the existence of a solid 66 percent VP polyethylene layer directly over the conductor. The proximity of this layer next to the conductor increases its influence on the overall dielectric VP. Typical coatings (Figure 5), from 0.004 to 0.010 thick, may degrade the overall VP by as much as 1.3 to 2.8 percent.

Although the center conductor coating should be as thin as possible to minimize attenuation, it cannot be eliminated entirely because it performs several key functions:

1. Provides corrosion and moisture ingress protection for the conductor,

2. Acts as an interface to uniformly bond the foamed dielectric to the conductor, preventing moisture leakage into the foam at this critical point,

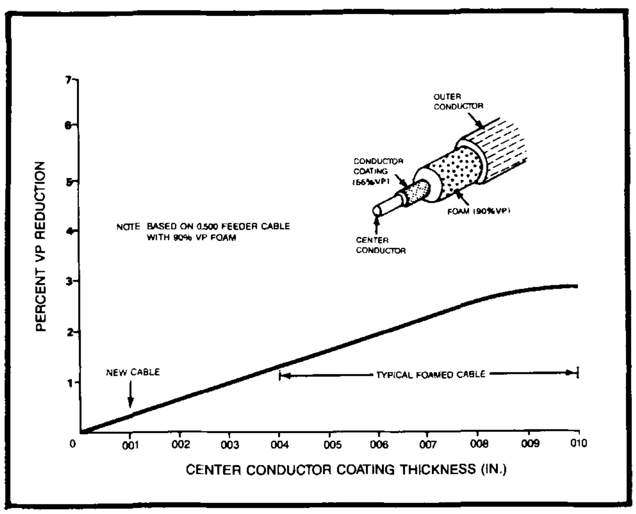


FIGURE 5. REDUCTION IN NET VP VS. CONDUCTOR COATING

3. Provides a controlled adhesion level to allow removal of the layer during connector installation, and

4. Helps in overall foam cell formation by anchoring the dielectric during the expansion process.

The coating can be applied by a variety of processes including dip coating, extrusion, electrostatic powder deposition, and chemical dip coating. Whichever is used, minimizing the coating thickness without compromising its basic function is needed to effectively reduce attenuation.

CAN THE FOAM DENSITY BE RELIABLY REDUCED?

In order to achieve 90 percent VP foam densities, an in-depth analysis must be made of all foaming parameters. Experimentation has shown that substantial improvements in the foaming process can be made if each of the basic components is optimized.

The key elements of foaming and their characteristics include:

1. POLYETHYLENE RESIN FORMULA - Compatibility of resins used (LDPE, LLDPE, MDPE, and HDPE), densities, molecular weight distributions, melt points, melt index, purity, and consistency.

2. EXTRUSION SCREW DESIGN - Shear rates, residence time, outputs, rpm, flow uniformity, temperature uniformity, mixing capabilities, and required temperature profiles.

3. SELECTION OF INJECTION GAS - Expansion pressure vs. temperature, plastic permeability, thermal flow, and injection characteristics.

4. FOAM NUCLEATING AGENTS - Particle sizes, decomposition products, inert vs. active, temperature activation profile, dispersive properties, and effect on dielectric loss.

5. EXTRUSION ADDITIVES - Lubricants, antioxidants, cell formation promoters, and property enhancers.

6. EXTRUSION TIP AND DIE TOOLING - Expansion ratios, pressures, and flow properties.

RESULTS OF FOAMING STUDY

Selection of the optimum combination of all these related variables is obviously a very complex and time-consuming process, especially considering the additional variables of extruder size and equipment variations. Such a program was implemented at Times Fiber Communications with successful results. A specific combination of the above parameters was determined which yielded a 90 percent VP foam with a high HDPE content, along with the required cell formation integrity to provide moisture resistance.

ENHANCING CABLE HANDLING CHARACTERISTICS

Even though the 90 percent VP dielectric exhibited surprising hardness in view of its significant reduction in foam density, it was not as hard as a standard density foam. As a result, further design enhancements to provide the exceptional handling characteristics that are required in the field were added:

1. BONDED DIELECTRIC - The dielectric was bonded to the aluminum to provide enhanced handling in addition to core pull-out protection during temperature extremes. A modified adhesive formula has been used to facilitate coring in preparation for connector installation.

2. BONDED JACKET - The jacket is bonded to the aluminum to further enhance handling and increase corrosion protection. The bonding agent is controlled so that no adhesive residue can be left on the aluminum surface and excessive removal forces are inherently avoided.

To improve cable handling characteristics, the cable must be made more resistant to the formation of wrinkles, ripples, and kinks. Typical tests to confirm improved performance include minimum bend radius, reverse bend testing, and expansion loop cycling.

Close study of an aluminum wrinkle usually reveals a section where the aluminum has been indented into the dielectric and an adjoining section where the aluminum has pulled away from the dielectric. In order to improve resistance to wrinkling, both of these tendencies must be resisted. The actual cable mechanics which explains how handling is improved from a hard dielectric, tough jacket, and bonding of both, is as follows:

1. Inward Wrinkling - The dielectric hardness must provide basic indent resistance. A bonded jacket assists further by inhibiting the indent portion of the wrinkle by attempting to "hold it back."

2. Outward Wrinkle - The dielectric bond is more critical than the hardness here, holding the aluminum in a cylindrical form and preventing it from "moving away." The jacket assists by acting as a tough barrier to the outward movement of the wrinkle. In addition, it also helps to distribute the stress of the bend, further protecting against wrinkling.

By using a reasonably hard dielectric which is bonded to the aluminum and a tough jacket which is also bonded to the aluminum, the 90 percent VP foam dielectric is able to exhibit the required handling characteristics.

ATTENUATION REDUCTION REDUCES CABLE OD

Described above is an increase in VP from 86 percent to 90 percent and a reduction in seamless aluminum wall by about 25 percent. The net affect of these changes is a 6.4 percent attenuation reduction with 4.5 percent provided by the dielectric and 1.9 percent provided by the slight thinning of the aluminum. Such a product would exhibit attenuations which were different from anything currently available. Thus, it could not be considered for a standard system design. In order to allow a cable user to benefit fully from the reduced attenuation capabilities, the cable must be reduced in size until the attenuation increases to a standard level (Table 2). In this way, the attenuation improvement is translated to a smaller cable with reduced cost and a standard attenuation level. Improved economies and cable interchangeability can thus be maintained.

Specific sizes and attenuation values are shown in Table 2. As is the case with other low loss coaxes, special connectors, coring tools, and jacket stripping tools (if used) must be specified. Such tools are now available as the cable development was coordinated with tooling suppliers.

SUMMARY

Previous attempts to reduce cable attenuation have been based on standard foam dielectrics with ultra thin wall welded aluminum or air dielectrics with thin wall welded aluminum. Optimization of the foaming process has produced an increased VP, low loss, economical coax with the following characteristics:

1. 90 percent VP low loss foam with good overall cable handling properties,

2. Closed cell, moisture protected high integrity foam,

3. Seamless aluminum with a moderately reduced wall, and

4 Bonded construction for enhanced handling and reliable operation during temperature extremes.

TABLE 2. NEW 90% VP FOAM
CABLE SIZES AND ATTENUATIONS
dB/100'

New Cable Size	300 MHz	450 MHz	550 MHz
0.480	1.32	1.64	1.82
0.565	1.13	1.40	1.56
0.710	0.91	1.13	1.26
0.840	0.78	0.98	1.09
1.160	0.59	0.75	0.84

SATELLITE TRANSPONDER OPERATION WITH VIDEO AND MULTIPLE SUBCARRIERS

Ned Mountain

Wegener Communications, Inc.

ABSTRACT

Over the past four years, extensive operational experience has been gained with multiple subcarrier technology. Driven by marketplace demands for low cost audio and data distribution capabilities, the development of the techniques of multiple subcarrier operation has reached a refined level. To date, over 100 channels on 40 transponders on eight different satellites are utilizing technology developing by Wegener Communications.

This paper will discuss in detail the technical principles behind multiple subcarrier operations. Areas that are of primary interest are composite deviation, modulation waveforms, occupied bandwidth and video degradation. Discussion of experiences with U.S. NTSC, European PAL and Intelsat half-transponder NTSC will be presented to illustrate the major points.

Application of multiple subcarrier technology will be detailed including audio channels of various bandwidths and data channels of various data rates. A detailed and flexible baseband plan is imperative to enable maximum transponder utilization. Examples of such plans will be presented.

The overall objective of this paper is to provide a clear understanding of transponder operation with multiple subcarriers and suggest ways in which the technologies can be put to use solving today's problems.

COMMENTS ON MULTIPLE SUBCARRIER THEORY

Analysis of Frequency Modulation starts out rather simple. If one assumes a sinusoidal modulating signal with constant frequency and amplitide, then the occupied bandwidth of an FM signal closely obeys Caron's Rule. This rule states:

OCCUPIED BANDWIDTH = 2(Peak Deviation + Modulating Frequency)

As the modulating signal becomes more and more complex, the precise occupied bandwidth becomes harder to predict. As of this writing, I know of no known precise method of predicting occupied bandwidth of a video FM signal containing multiple subcarriers.

Having no know mathematical model to go by, the next best thing is to empirically determine what can be expected as multiple subcarriers are added to a video signal. Over the past five years, Wegener Communications and its customers have conducted numerous exhaustive tests to insure that multiple subcarriers can be added with insignificant impact to primary video. While much of the work done by our customers is considered proprietary to them, some common results can be shared.

As a general rule of thumb, up to eight subcarriers can be added above video with no reduction in video deviation as long as the following rules are observed:

*All subcarriers are operated at a modulation index of 0.18 maximum. Typical range is 0.14 to 0.18.

*Wegener recommended frequency plan is followed.

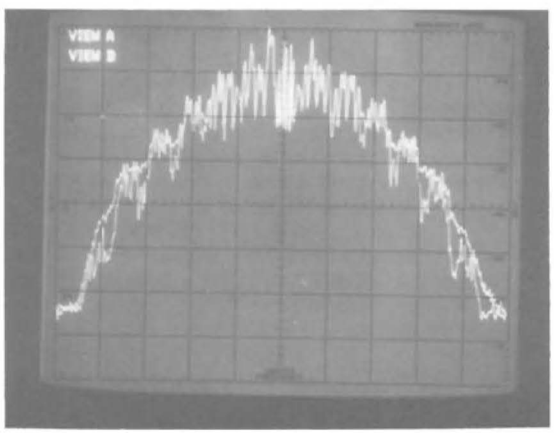
By keeping the modulation index of each subcarrier extremely low relative to the video deviation, the contribution to the occupied bandwidth of eight subcarriers is totally insignificant.

It is interesting to compare spectrum photographs of video signals with an without multiple subcarriers. Photograph #1 shows two modulation conditions superimposed as they were monitored at an uplink exciter output. Modulation source in one case was 75% color bars at 1.0V p-p and a conventional 6.8 MHz sound camera at a modulation index of 0.294. Superimposed is the same color bar signal, 6.8 MHz subcarrier and eight Wegener low level carriers each with a modulation index of 0.15. One minute peak hold was used in each case.

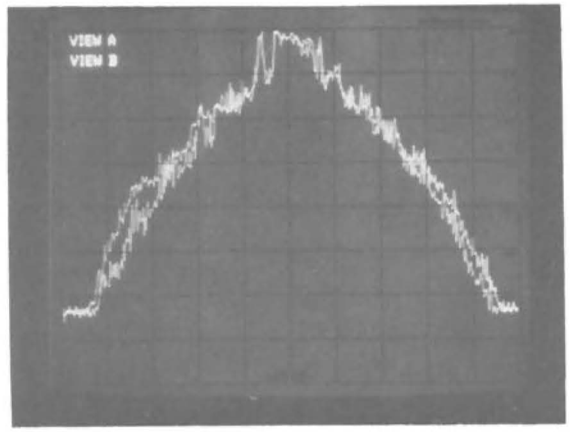
Photograph #2 is the same type of comparison using program video instead of color bars. Note that in both cases, the increased bandwidth is insignificant. In fact, the "spectrum spread" caused by the subcarriers is not really significant until you get approximately 40 dB below unmodulated carrier level.

Video Signal to Noise Ratios

Laboratory measurement of video signal to noise vs. subcarrier loading shows a very slight reduction in this parameter as the number of subcarriers is increased. The noise that was observed and measured is truly noise and not coherent beat products caused by intermodulation. Figure 1 is a plot of video signal to noise vs. subcarrier loading at four different receive carriers to noise ratios. (See Figure 1 on Page 5.)



Photograph #1 - 75% Bars/6.8 vs. Bars/6.8 and Eight Low Level Subcarriers at m = 0.15



Photograph #2 - Typical Video/6.8 vs. Typical Video/6.8 and Eight Low Level Subcarriers at m = 0.15

Threshold Effects

Another interesting observation is that multiple subcarrier operation has an insignificant effect on a system operating at threshold. One common test that we have done many times it to operate a system at threshold ("Sparklies") just apparent and vary the subcarrier load. As long as the IF bandwidth is wide enough to pass the video signal (30-32 MHz typical), the threshold point does not change by adding subcarriers if Wegener practices are not violated.

Commercial Acceptance

The practice of adding multiple subcarriers has now become widespread through North America based on the acceptance of the Wegener system. To date of 150 channels on 55 different transponders on ten different satellites are in full commercial service. No generic systems problems have ever occurred that can be attributed to multiple subcarrier operation. Acceptance is rapidly becoming worldwide with systems operating in the U.S., Canada, Japan, Australia and the United Kingdom.

RECENT TESTS

While many tests have been done by our North American customers, it is interesting to look at two somewhat unique subcarrier tests -- Intelsat Half-Transponder and European PAL.

Intelsat Half-Transponder

The transmission of multiple subcarriers with video via Intelsat Half-Transponder circuits represents perhaps the most stressful situation encountered to date. Due to the narrow bandwidth (17.5 MHz) for the high peak video deviation (7.5 MHz peak) the addition of multiple subcarriers can lead to problems if not done properly. In January 1984, Wegener Communications and ATN-7 Sydney, Australia conducted extensive tests between Paumali, Hawaii and Sydney, Australia with the objective of determining how many subcarriers could be added without affecting the video. It was found that up to six subcarriers can be added at a modulation index of 0.14 each with insignificant impact to video performance. Both ATN-7 and TCN-9 Australia currently oeprated half-transponder video circuits between the U.S. and Australia with Wegener Multiple Subcarrier Systems installed. Uses include primary program audio, stereo program audio and low speed data associated with the video feeds. As a result of these tests, Wegener Subcarrier Systems were used extensively by the BBC for the 1984 Olympic Games audio feed from Los Angeles to London. Additional information on Intelsat Half-Transponder tests can be obtained from the author.

European PAL Tests

Tests were conducted in April 1984 by Wegener Communications and British Telecom International to examine multiple subcarrier behavior with PAL I video on both ECS and Intelsat V. PAL I video extends to 5.5 MHz and subcarriers between 6.30 and 7.94 MHz were used. It was determined that ten subcarriers can be accommodated with insignificant impact into the video. The following data is from these tests.

VIDEO PARAMETER	SUBCARRIERS	
	0 Subcarriers	10 Subcarriers
2T Pulse K (%)	0.5	0.1
2T Pulse/Bar K (%)	0.0	0.0
2T Bar K (%)	0.8	1.1
C-L Gain Inequality (%)	-4.0	-2.0
C-L Delay Inequality (%)	10.0	4.0
C-L Crosstalk (%)	0.4	1.1
Differential Gain (%)	1.2	1.4
Differential Phase (°)	3.3	3.4
Time Line Non-Linearity	0.5	0.8

FIGURE 2 - Video Parameter Measurements with 0 Subcarriers and 10 Subcarriers

S/N	NO SUBCARRIERS	5 SUBCARRIERS	10 SUBCARRIERS
Unweighted	48.5 dB	48.0 dB	48.0 dB
CCIR Unified Weighted	60.5 dB	60.0 dB	59.0 dB
Luminance Weighted	60.5 dB	60.0 dB	59.0 dB

FIGURE 3 - Signal To Noise Ratio Comparisons at High C/N (C/N = 24.9 dB)

S/N	NO SUBCARRIERS	5 SUBCARRIERS	10 SUBCARRIERS
Unweighted	37.5	37.5	38.0
CCIR Unified Weighted	48.0	49.0	48.0
Luminance Weighted	48.5	49.5	49.0

FIGURE 4 - Video Signal To Noise at Threshold (C/N = 12.8 dB)

Based on these tests, multiple subcarriers are now in full commercial service on ECS-1. The first use is for stereo audio associated with Thorn/EMI's "Music Box" video programming using the Wegener Panda I system. Additional details on multiple subcarriers with both PAL I and PAL B video can be obtained from the author.

SUBCARRIER PERFORMANCE

If a few parameters are known about a given TVRO downlink, the subcarrier perforamnce can easily be predicted. Assuming that one can derive the basic C/N being received at the downlink, the following analysis should prove helpful in subcarrier calculations. Note that the analysis is for a 15 kHz program audio channel and that negligable terms have been eliminated from the classical equations. Assume a subcarrier deviation of 50 kHz peak by the audio signal.

GIVEN: TVRO C/N = 12dB (30 MHz BW)

DETERMINE: $C/N_o = C/N + 10\log BW = 86.8\text{dB-Hz}$

$$\begin{aligned}(C/N_o)_{sc} &= C/N_o + 10\log \frac{m^2}{2}\\ &= 86.8 + 10\log \frac{.18^2}{2}\\ &= 86.8 + (-17.9)\\ &= 68.9\text{dB-Hz}\end{aligned}$$

$$\begin{aligned}(S/N)_{audio} &= (C/N_o)_{sc} + 10\log \frac{3(Dev)^2}{2(bn)^3} + A_c\\ &= 68.9 + 10\log \frac{3(50\times10^3)^2}{2(5822)^3} + A_c\\ &= 68.9 - 17.2 = 51.7\text{dB} + A_c\end{aligned}$$

A_c Panda I ≅20dB: $(S/N)_{audio} \cong \underline{\underline{71.7\text{dB}}}$

A_c Panda II ≅40dB: $(S/N)_{audio} \cong \underline{\underline{91.7\text{dB}}}$

This shows that low level subcarriers are indeed capable of providing excellent program audio channels.

An interesting comparison is to take a conventional high level subcarrier operating with 2 MHz peak deviation. This would equate to a modulation index of 0.294 for a 6.8 MHz subcarrier. Thus:

$$(C/N_0)_{sc} = C/N_0 + 10\log \frac{m^2}{2}$$

$$= 86.8 + (-13.6) = 73.2\text{dB-Hz}$$

$$(S/N)_{audio} = 73.2 + 10\log \frac{3(237000)^2}{2(5822)^3}$$

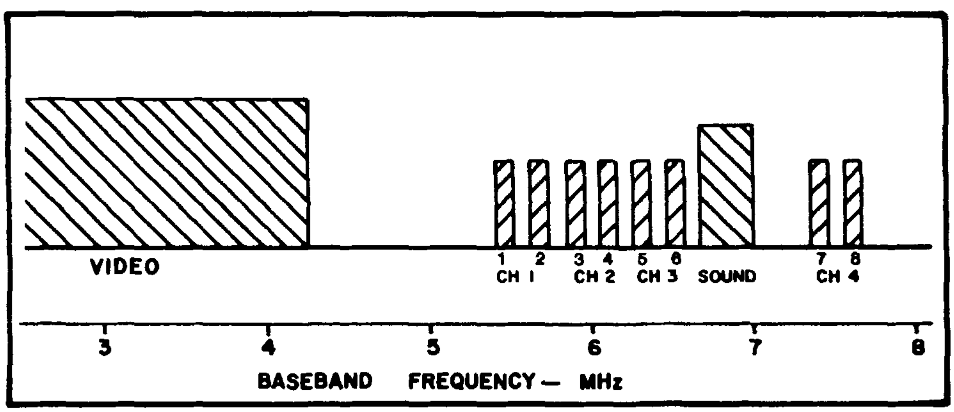
$$= 73.2 + (-3.7) = 69.5\text{dB}$$

The point of this example is to show that by utilizing clever baseband audio companding techniques, the subcarrier modulation index can be reduced to the range where impact on occupied bandwidth is insignificant while providing broadcast quality audio.

BASEBAND PLANNING

Wegener Communications has defined a standardized subcarrier baseband plan that allows for flexibility and expandability. As can be seen from Figure 5, there are eight spectral slots available for low level subcarrier energy. Each slot is spaced 180 kHz center to center. It should be noted that using 180 kHz constant spacing does not cause measurable intermodulation products to form as long as subcarrier modulation indices are kept low. Contrary to some recent writing, it is very undesirable to phase lock the subcarrier modulators. In fact, over 140 Wegener Subcarrier Channels are in operation worldwide and none of them are phase locked. Each 180 kHz slot can be used for one 15 kHz audio or further subdivided into individual 7.5 or 3.5 kHz slots. Individual carriers are used in all cases (no multiplexing due to S/N penalties) and power of individual carriers is adjusted such that they do not exceed that of a single 15 kHz audio channel per spectral slot.

Each slot can be used for data transmission as well -- and data and audio signals can be mixed adjacent to each other on the baseband. Data rates vary according to the modulation technique (AFSK, FSK, QPSK, etc.). For instance, it is possible to place a Dolby ADM digital stereo audio channel in two adjacent 180 kHz slots with a power equivalent to two low level subcarriers utilizing QPSK modulation.



CHANNEL	FREQUENCY
1	5.40 MHz
2	5.58 MHz
3	5.76 MHz
4	5.94 MHz
5	6.12 MHz
6	6.30 MHz
7	7.38 MHz
8	7.56 MHz
TV Sound	6.80 MHz

FIGURE 5 - Typical Baseband Plan - NTSC Video Plus 8 Subcarriers

An example of a very aggressive subcarrier baseband plan is shown on Figure 6. Note the mixture of 15 kHz audio, 7.5 kHz audio and various data channels. Yes -- it does work! (COURTESY UNITED VIDEO, INC.)

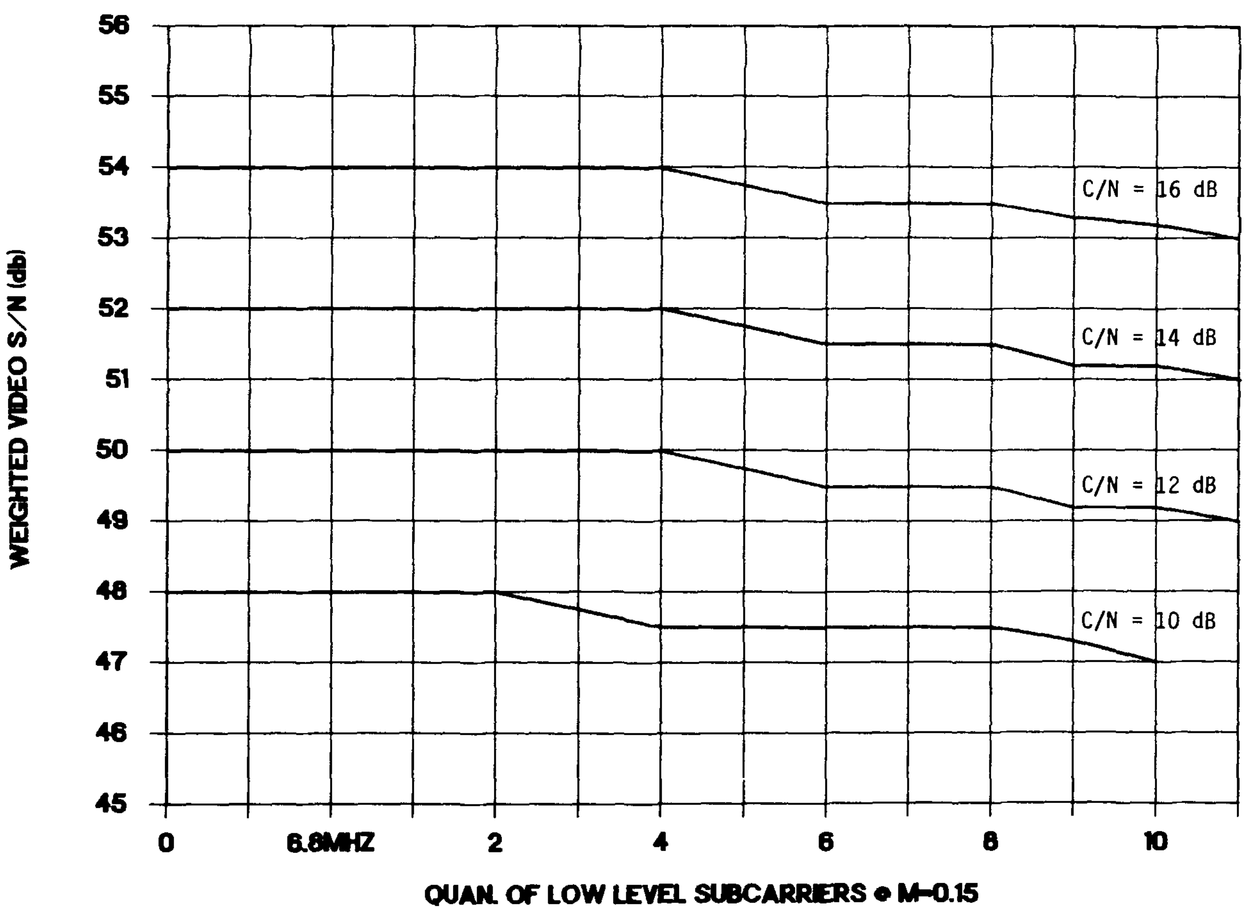
CONCLUSION

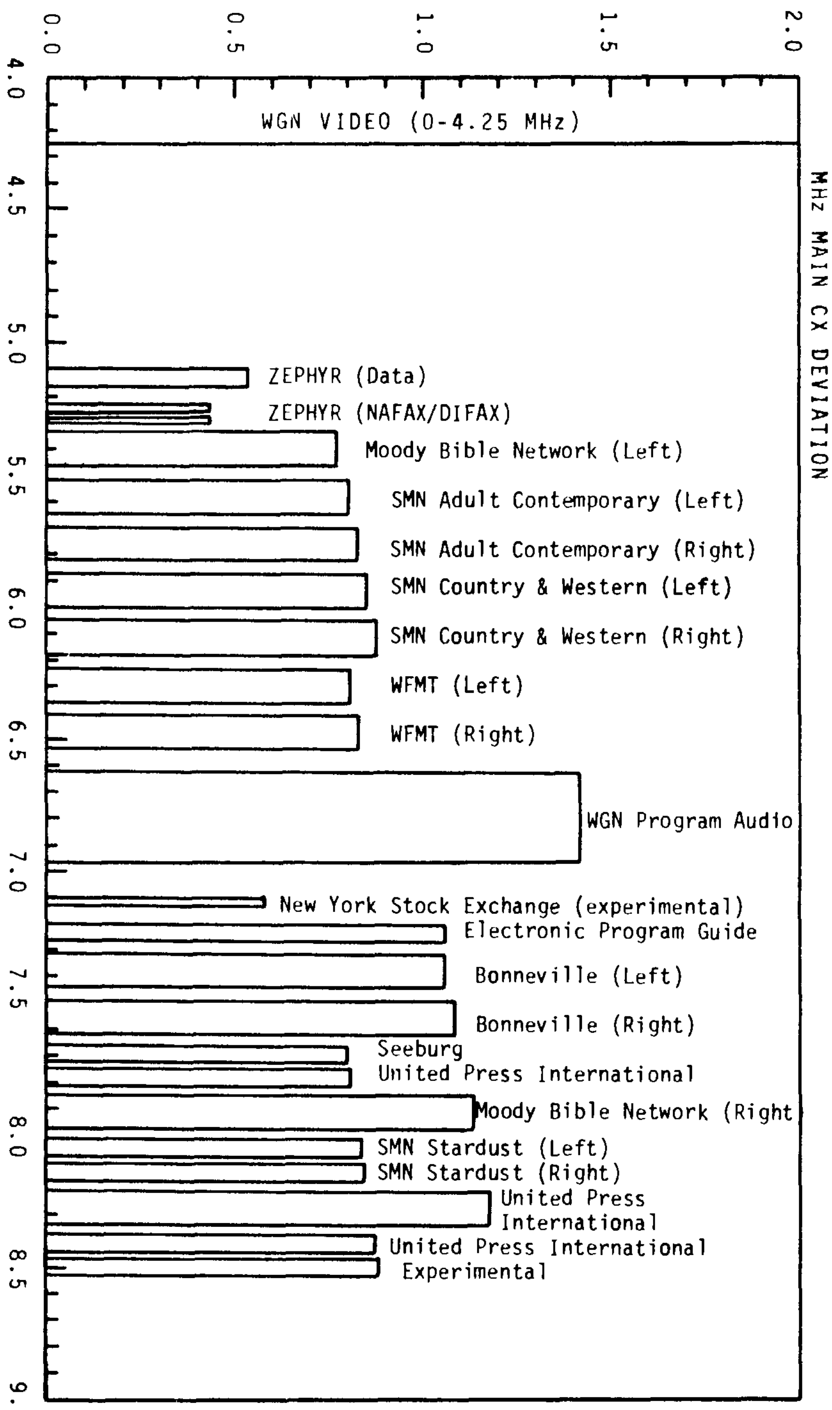
In spite of the complexity involved in analyzing video with multiple sub-carriers, the vast amount of data taken by Wegener Communications and our customers ove rthe past five years has given the entire satellite communications industry a very good feel for exactly what can be done. Several innovative solutions to communications problems have been developed using low level subcarrier technology. We see a steady continuation of this activity coupled with advanced system concepts in the future.

ACKNOWLEDGEMENTS

The author would like to thank Mr. Chuck Albert of Wegener Communications for the valuable assistance in preparation of data for this paper. The author would also like to acknowledge the pioneering efforts of Robert Placek, Heinz Wegener and Elias Livaditis. Without these three individuals, the field of multiple subcarriers would undoubtedly not be where it is today.

Fig.1- LOADING VS. VIDEO S/N





UNITED VIDEO INC.

FIGURE 6 - An Example of Aggressive Subcarrier Loading
(COURTESY OF UNITED VIDEO, INC.)

STANDARD METHODS FOR CALCULATION OF CARRIER TO NOISE RATIO IN MODERN CATV EQUIPMENT

Lamar West
Scientific-Atlanta, Inc.

I. INTRODUCTION

Carrier to noise ratio is a universally accepted figure of merit used to indicate performance of a cascade of CATV amplifiers. However, the calculation of system C/N has become somewhat confusing due to the lack of an industry wide method for specifying individual amplifier noise performance and calculating cascase noise performance.

This application note describes the individual amplifier parameters necessary for making cascade noise calculations. It also explains how those calculations should be made.

Section VII is a summary of noise calculations intended for quick reference when making performance computations.

II. BASIC DESCRIPTION OF NOISE

The textbook definition of noise states that noise is anything that corrupts or interferes with a desired signal. For the sake of this discussion we shall limit ourselves to random thermal noise. We shall not consider distortion products generated by the amplifiers as a result of passing the desired signals. We shall also exclude noise from ingress of signals generated outside of the CATV network.

Calculation of system carrier to noise is based upon a theoretical minimum noise floor. The noise floor is a result of thermal or Johnson noise associated with the characteristic impedance of the system, Zs.

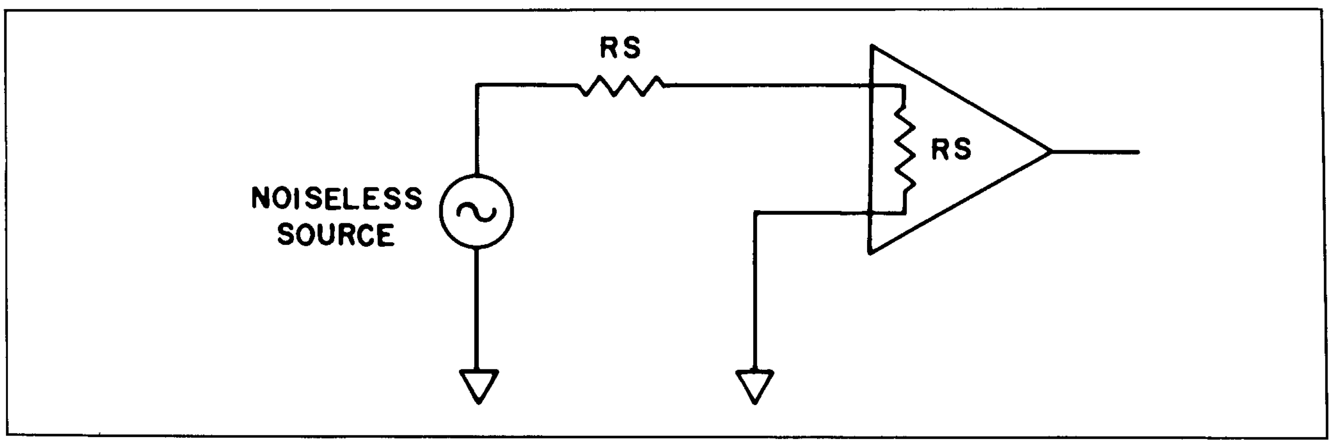


Figure 1.

The calculation of this theoretical thermal noise floor is done by assuming that an ideal noiseless signal source is connected to the input of an amplifier through a source resistance of Rs Ohms. It is also assumed that the amplifier has an input impedance of Rs consisting of an ideal noiseless resistor. See Figure 1.

The rms noise voltage associated with the source resistance is given by:

$$V^2_{rms} = 2(kTRs)\ B \quad (V^2rms) \qquad \textbf{(2.1)}$$

where

K = Boltzmann Constant, $(1.381\times10^{-23}\ J/^oK)$
T = Resistor Temperature, (290^oK)

R_s = Source Impedance (75 Ohms)
B = Bandwidth, ($4X10^6$Hz)

For our system Vrms = $2.2X10^{-6}$ Vrms
The noise power coupled into the input of the amplifier is given by

N = Input Noise Power =

$$V^2rms \left(\frac{Rs}{2Rs}\right)^2 \frac{1}{Rs} = k\ T\ B \qquad (2.2)$$

= $1.6X10^{-14}$ Watts or -59dBmV

Two useful parameters for determining amplifier noise performance are noise factor and noise figure.

Noise factor is defined as:

Noise Factor nf =

$$\frac{\text{Total Noise Power Output}}{\text{Noise Power Output Due to Rs}} \qquad (2.3)$$

$$\frac{Npo}{ApNpi} = \frac{Npo\ Spi}{SpoNpi} = \frac{Spi/Npi}{Spo/Npo}$$

Where Rs = Source Resistance

Npi = Noise Power at Input (due <u>only</u> to thermal noise in Rs)
Npo = Noise Power at Output
Spi = Signal Power at Input
Spo = Signal Power at Output
Ap = Power Gain of Device Under Test

Thus noise factor is a measure of the noise added by a device over and above that due to random electron motion in the source resistance.

Noise Figure = NF = (2.4)
$10 \log_{10}$ (nf) (dB)

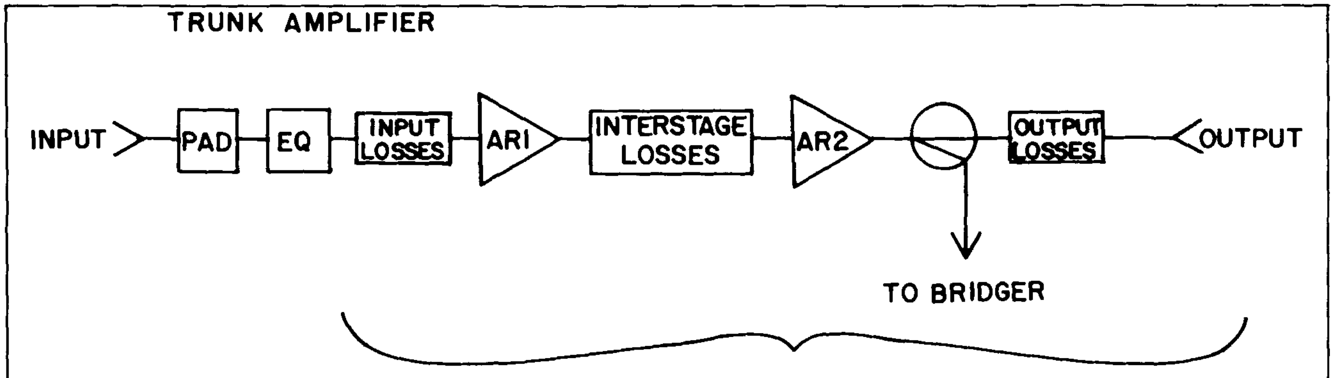


Figure 2.

III. INDIVIDUAL TRUNK CARRIER TO NOISE

The block diagram shown in Figure 2 is a simplified model of a trunk amplifier. This model can be used to calculate total trunk noise figure, total trunk operating gain and carrier to noise.

Step 1: Calculate Total Trunk Noise Figure.

Most CATV equipment manufacturers specify a trunk noise figure with OdB pad and OdB equalizer. To this number must be added the loss of the input pad and input equalizer. Additionally, some manufacturers fail to include any input losses before the first hybrid (AR1) and specify noise figure at this point. In this case the input losses (loss of seizure, diplex filter, input test point, AC bypass, etc.) must be added to obtain accurate results.

Total trunk noise figure = NF_{tt} (3.1)
= NF (OdB pad, OdB EQ)
+Pad loss
+EQ loss
+Input loss (if not included in manufacturer's Spec)

Step 2: Calculate Total Trunk Operating Gain.

The equipment manufacturer should also specify a typical operating gain with OdB pad and OdB equalizer. This gain specification must not be confused with recommended station operational gain (usually 22dB) or the station minimum full gain (which places the variable cable equalizer outside its normal operating condition). It must also be determined if this gain specification includes all input losses before the first hybrid

To obtain the total trunk operating gain one must subtract the input pad losses, the equalizer losses and the input losses (if any) from the typical operating gain.

Total Trunk Operating Gain = **(3.2)**

G_{tt} = Typical Operating gain
- Pad loss
- EQ loss
- Input loss (if not included in manufacturer's Spec)

Step 3: Calculate Carrier to Noise Ratio.

C/N for a single trunk station is given by the equation

$$C/N_{single} = Lo - (N_t + NF_{tt} + G_{tt}) \quad \textbf{(3.3)}$$

Where

Lo = Carrier output level
N_t = Thermal noise floor (-59dBmV)
Nf_{tt} = Total trunk noise figure
G_{tt} = Total trunk operating gain

Example 1: Calculate the carrier to noise ratio of a 22dB 450MHz trunk amplifier with the following parameters.

a. Trunk noise figure with 0dB pad and 0dB equalizer and including input losses = 8.0dB
b. Typical operating gain with 0dB pad and 0dB equalizer including all input losses = 24.5dB
c. 1dB input pad
d. 22dB 450MHz equalizer with 1dB of insertion loss at 450MHz
e. Output level at 450MHz = 33dBmV

Solution:

Carrier to noise is usually assumed to be worst case at the highest frequency of operation. This is a consequence of: 1) the dice characteristics of the transistors used in the amplifiers and 2) maximum loss in the cable occurring at high frequencies.

Step 1 (from equation 3.1)

NF_{tt} = 8dB + 1dB + 1dB = 10dB

Step 2 (from equation 3.2)

G_{tt} = 24.5dB - (1dB + 1dB) = 22.5dB

Step 3 (from equation 3.3)

C/N Single = 33dBmV - (-59dBmV + 10dB +22.5dB) = 59.5dB

IV. TRUNK AMPLIFIER CASCADE

A rigorous calculation of cascade carrier to noise becomes quite complicated. However, if it is assumed that the cascade is composed of identical amplifiers with identical pad and equalizer losses the solution reduces to a simple form.

Noise is a random process. Consequently noise sources combine on a power basis. The noise at the end of a cascade of n amplifiers is equal to the sum of the noise contributions from each of the individual amplifiers, i.e.;

Total noise for n amps = n(noise of single amp). (watts) **(4.1)**

or equivalently for dB

Total noise for n amps = noise of single amp + 10 Log_{10} (n) **(4.2)**

It is assumed that a CATV trunk amplifier cascade is unity gain. Consequently, the carrier level after n amplifiers is the same as after a single amplifier.

$C/N_{cascade}$ = **(4.3)**

$$\frac{\text{carrier level at end of cascade}}{\text{n x noise level of single amp}} =$$

or for C/N in dB

C/N cascade = C/N single amp - 10 Log_{10} (n)

Where n is the number of amplifiers in cascade.

Example 2: Calculate the C/N of a cascade of 20 amplifiers of the type in Example 1.

Solution: (From equation 4.4)

C/N cascade = 59.5 -10 Log_{10} (20) = 46.5dB

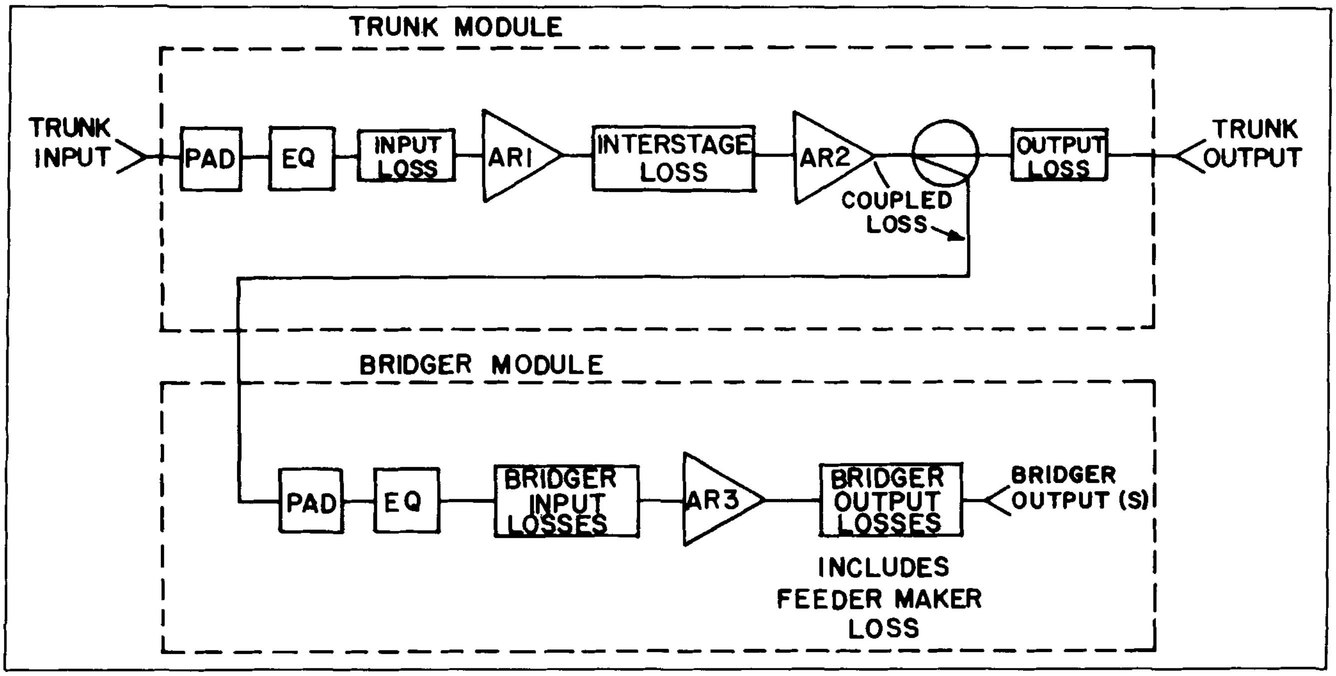


Figure 3.

V. TRUNK + BRIDGER C/N

Trunk and bridger C/N can be calculated by first calculating the C/N at the output of the trunk amplifier and then computing the additional degradation associated with the bridger module. (See Figure 3.)

Step 1: Calculate the Total Bridger Noise Figure.

As is the case with the trunk module the CATV equipment manufacturer will specify a bridger noise figure with 0dB pad and 0dB equalizer (this noise figure may or may not include input losses associated with the bridger). It is assumed that the bridger is cascaded with the trunk amplifier. Therefore, total bridger NF can be calculated by:

$NF_{brt} = NF_{br}$ (0dB pad, 0dBEQ) + input losses (if any) **(5.1)**
+pad loss + EQ loss + coupled loss
- trunk output loss

It can be assumed that the high gain of the bridger will make noise contributions from the output losses associated with the feeder makers negligible.

Step 2: Calculate the Total Bridger Operating Gain.

The total bridger operating gain can also be computed from the manufacturer's specified typical operating gain with 0dB pad and 0dB equalizer. It is again important to add in any input losses occuring before the first bridger hybrid if they are not already included in the manufacturer's gain specification.

Total Bridger Operating Gain = G_{brt} =

Bridger typical **(5.2)**
operating gain (0dB pad, 0dBEQ) - (pad loss + EQ loss + coupled loss - trunk output loss + feeder maker loss + bridger input loss (if not included by manufacturer))

Step 3: Calculate the Noise at the Bridger Output Due to the Previous Cascade.

Noise at the bridger output comes from two sources: 1) noise from the previous cascade and 2) noise produced in the bridger itself.

Noise at the bridger output due to the trunk cascade is related to the excess noise (noise in excess of the thermal noise floor) at the bridger input. However, for practical system conditions the difference between the excess noise and the total noise at the bridger input is negligible. This error can be ignored for the sake of simplicity with no ill effects on the final result.
Noise level bridger output due to trunk cascade = N_{bl} = **(5.3)**

carrier level at bridger output - trunk cascade output C/N

Step 4. Calculate Noise at the Bridger Output Due to the Bridger Itself.

N_{b2} = Level of noise at the bridger output due to the bridger itself = Nt + NF_{brt} + Gbrt **(5.4)**

Where N_t = thermal noise floor (-59dBmV for 75 Ohm system)

Step 5. Calculate the Total Bridger Output Noise

The total bridger output noise can be calculated by combining the two noise soures on a power basis.

N_{bt} = total bridger output noise level = **(5.5)**

$$10 \text{ Log}_{10} \left(10^{\left(\frac{Nb1}{10}\right)} + 10^{\left(\frac{Nb2}{10}\right)} \right)$$

Step 6: Calculate the Trunk + Bridger C/N

C/N_{tk+br} = trunk bridger carrier to noise = carrier level at bridger output - N_{bt}

Note that in these expressions all losses associated with the bridger input (coupled loss, trunk output loss, pad loss, equalizer loss, bridger input loss) all cancel out. It is therefore possible to ignore these losses so long as the bridger noise figure and bridger gain are specified with the amplifier in exactly the same configuration. This will not work if, for example, bridger input losses are not included in the bridger noise figure but are included in the bridger typical operating gain.

Example 3: **Assume that at the end of the cascade of example 2 there is added a bridger with the following parameters.**

a. NF of bridger with 0dB pad, 0dB equalizer, 1 way feeder maker including all input losses and ignoring coupled losses and ignoring trunk output losses = 7.0dB
b. bridger typical operating gain with 0dB pad, 0dB equalizer, 1 way feeder maker including all input losses and ignoring coupled losses and ignoring trunk output losses = 33dB
c. desired bridger output level = +42dBmV
d. 2 way feedermaker loss = 3.5dB at 450MHz)
e. equalizer loss = 1dB at 450MHz
f. pad value = 7dB
g. trunk output loss = 1.5dB
h. coupled loss = 14dB

Solution:

Step 1 (from equation 5.1)

NF_{brt} = 7.0dB + 7dB +1dB +14dB - 1.5dB = 27.5dB

Step 2 (from equation 5.2)

G_{brt} = 33dB - (7dB + 1dB + 14dB + 3.5dB - 1.5dB) = 9dB

Step 3 (from equation 5.3)

N_{b1} = 42dBmV - 46.5dB = -4.5dBmV

Step 4 (from equation 5.4)

N_{b2} = -59dBmV + 27.5dB + 9dB = 22.5dBmV

Step 5 (from equation 5.6)

$$N_{bt} = 10 \text{ Log}_{10}\left(10^{\left(\frac{-4.5}{10}\right)} + 10^{\left(\frac{-22.5}{10}\right)} \right)$$

Step 6 (from equation 5.6)

C/N_{tk+br} = 42dBmV - (-4.5dBmV) = 46.5dB

Note: Notice that the bridger has only a slight effect on the end of cascade noise performance.

Alternate Solution:

Since the noise figure and gain are specified under the same amplifier configurations (0dB pad, 0dB equalizer, etc.) the losses associated with the bridger input can be ignored.

Step 1

NF_{br} = 7.0dB

Step 2

G_{bt} = 33dB - 3.5dB = 29.5dB Note: The 3.5dB is feeder maker loss

Step 3

N_{b1} = 42dBmV - 46.5dB = -4.5dB

Step 4

N_{b2} = -59dBmV + 7.0dB + 29.5dB = -22.5dB

Step 5

$$N_{bt} = 10 \text{ Log }_{10} \left(10^{\left(\frac{-4.5}{10}\right)} + 10^{\left(\frac{-22.5}{10}\right)} \right)$$

Step 6

C/N_{tk+br} = 42dBmV - (4.5 dBmV) = 46.5dB

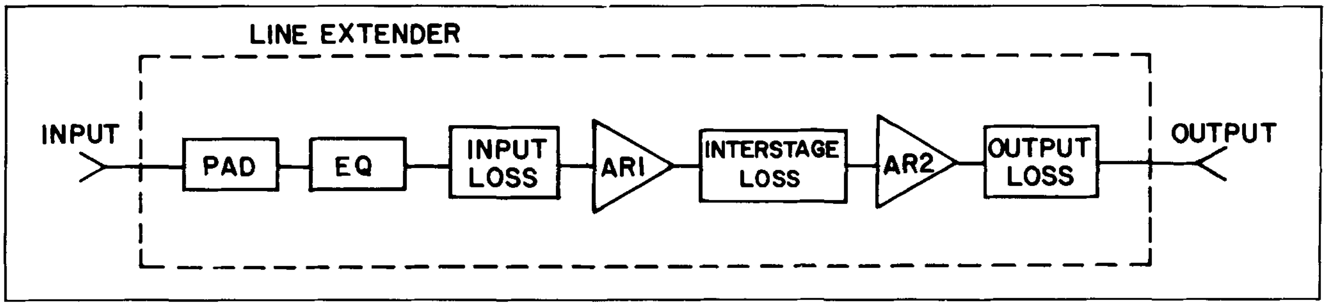


Figure 4

VI. TRUNK + BRIDGER + LINE EXTENDER

The line extender is handled in a similar manner to the bridger. There are two noise sources associated with the line extender 1) noise due to the previous cascade and 2) noise generated in the line extender itself. See Figure 4.

The equipment manufacturer should specify noise figure with 0dB pad and 0dB equalizer as well as typical operating gain with 0dB pad and 0dB equalizer. It is important that these specifications include all input losses to the amplifier.

Step 1: Calculate the Total Line Extender Noise Figure.

NF_{let} = Noise Figure (0dBpad, 0dBEQ) + input losses **(6.1)**
(if not included by the manufacturer)

Step 2: Calculate Total Line Extender Operating Gain.

G_{let} = Gain (0dBpad, 0dBEQ) - (input losses (if not **(6.2)**
included by manufacturer) + pad loss + EQ loss)

Step 3: Calculate Noise at Line Extended Output Due to Previous Cascade.

N_{le1} = Noise at L.E. output due to previous cascade = **(6.3)**
carrier level at L.E. output - previous amp C/N

Step 4: Calculate the Noise at the Line Extender Output Generated by the Line Extender Itself.

N_{Le2} = Noise level at the line extender output due to noise **(6.4)**
generated by the line extender itself
$= N_t + NF_{let} + G_{let}$

Where N_t = thermal noise floor

(-59dBmV in 75 Ohm system)

Step 5: Calculate Total Noise Level at Line Extender Output.

N_{let} = Total noise level at line

extender output = **(6.5)**

$$10 \text{ Log}_{10} \left(10^{\left(\frac{N_{le1}}{10}\right)} + 10^{\left(\frac{N_{le2}}{10}\right)} \right)$$

Step 6: Calculate Total Trunk + Bridger + L.E. C/N

$C/N_{tk+br+le}$ = total

trunk+bridger+L.E. C/N = **(6.6)**

carrier level at line extender output - N_{let}

Example 4: **Assume that the trunk cascade + bridger of example 3 is followed by a line extender with the following specifications:**

a. typical operating gain with 0dB pad and 0dB equalizer = 27dB (includes all input losses)
b. noise figure with 0dB pad and 0dB equalizer = 8dB (includes all input losses)
c. 6dB pad
d. equalizer with 1dB insertion loss at 450MHz
e. desired output level = +46dBmV

Solution:

Step 1 (from equation 6.1)

$NF_{let} = (8dB + 6dB + 1dB) = 15dB$

Step 2 (from equation 6.2)

$G_{let} = 27dB - (6dB+1dB) = 20dB$

Step 3 (from equation 6.3)

$N_{le1} = 46dBmV\ 46.5dB = -0.5dBmV$

Step 4 (from equation 6.4)

$Nle2 = -59dBmV+15dB+20dB - 24dBmV$

Step 5 (from equation 6.5)

$$N_{let} = 10 \ Log_{10} \left(10^{\left(\frac{-0.5}{10}\right)} + 10^{\left(\frac{-24}{10}\right)} \right)$$

$= -0.48dBmV = -0.5dBmV$

Step 6 (from equation 6.6)

$C/N_{\ tk+br+le} = 46dBmV - (-0.5dBmV) =$

46.5dB

VII. SUMMARY

A. Calculation of C/N for single trunk

1. Calculate total trunk noise figure

NF_{tt} = NF (0dB pad, 0dB EQ) + pad loss + equalizer loss + input loss (if not included by manufacturer)

2. Calculate total trunk operating gain

G_{tt} = trunk typical operating gain (0dB pad, 0dBEQ) - pad loss + equalizer loss + input loss (if not included by manufacturer)

3. Calculate C/N for single amplifier

$C/N = Lo - (N_t + NF_{tt} + G_{tt})$

where Lo = carrier output level
N_t = thermal noise floor (-59dBmV in 75 Ohm system)

B. Calculation of C/N for trunk amplifier cascade.

If the cascade is assumed to be composed of identical amplifiers and cable spans then the cascade C/N is given by:

C/N cascade = C/N single $-10\ Log_{10}\ (n)$

Where n is the number of amplifiers in cascade

C. Trunk Cascade + Bridger C/N

1. Calculate the total bridger noise figure

$NF_{brt} = NF_{br}$ (0dBpad, 0dBEQ) + pad loss + equalizer loss + coupled loss - trunk output loss + bridger input losses (if not included by manufacturer)

2. Calculate total bridger operating gain

G_{brt} = bridger typical operating gain (0dB pad, 0dBEQ) - (pad loss + EQ loss + coupled loss - trunk output loss + feeder maker loss + bridger input loss (if not included by manufacturer)

3. Calculate noise level at bridger output due to previous cascade.

N_{b1} = carrier level at bridger output - trunk output C/N

4. Calculate noise level at bridger output due to noise generated in bridger

$N_{b2} = N_t + NF_{brt} = G_{brt}$

Where N_t = thermal noise floor (-59dBmV in 75 Ohm system)

5. Calculate total bridger output noise level

$$N_{bt} = 10\ Log_{10} \left(10^{\left(\frac{N_{b1}}{10}\right)} + 10^{\left(\frac{N_{b2}}{10}\right)} \right)$$

6. Calculate trunk cascade + bridger C/N

C/N_{tk+br} = carrier level at bridger output − N_{bt}

D. Trunk Cascade + Bridger + L.E. C/N

1. Calculate the total line extender noise figure

NF_{let} = L.E. Noise Figure (0dB pad 0dB EQ) + pad loss + equalizer loss + input losses (if not already included by manufacturer)

2. Calculate the total line extender operating gain

G_{let} = Gain (0dB pad, 0dB EQ) − (input losses (if not included by manufacturer) + pad loss + equalizer loss)

3. Calculate noise at line extender output due to previous cascade

N_{le1} = carrier level at L.E. output − previous amp C/N

4. Calculate noise at line extender output generated by the L.E. itself

$N_{le2} = N_t + NF_{let} + G_{let}$

Where N_f = thermal noise floor (−59dBmV in 75Ohm system)

5. Calculate total line extender output noise level

$$N_{let} = 10\ \text{Log}_{10}\left(10^{\left(\frac{N_{le1}}{10}\right)} + 10^{\left(\frac{N_{le2}}{10}\right)}\right)$$

6. Calculate total trunk + bridger + line extender C/N

$C/N_{tk+br+le}$ = level at L.E. output − N_{let}

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STAR-SWITCHED NETWORKS IN CABLE TELEVISION

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ABSTRACT

A star-switched system design for a cable television network is a departure from the conventional tree-and-branch network design in that it eliminates a large percentage of trunk-and-feeder cable and electronics by replacing them with a drop star network. Costly converter equipment is placed outside of the subscribers' homes. As a result of relocating the converter equipment, the cable operator has a simple and virtually theft-proof service system. A star-switched system has far-reaching economic and performance benefits for the cable system operator at a cost that is competitive with a conventional system.

INTRODUCTION

Star-switched system designs are the result of technological advancements that have been made in digital electronics and in the cable television industry. Star switching in the digital format has been used by the telephone industry for over 10 years. That industry has reaped the benefits of advanced systems that have provided reliability and decreased expenditures for plant materials and operations. The cable television industry is now where the telephone industry was 10 years ago. Moving to star-switched design will allow the cable television industry to profitably exploit its technological advantages.

There are three main benefits that make star-switching desirable. The first benefit is the immediate and quantifiable results of eliminating signal and premium service theft. The CATV industry loses approximately 500 million to 1 billion dollars per year in revenues to signal theft and many more millions of dollars to theft and abuse of in-home equipment. For this reason alone the use of star switching can be justified. The second benefit is the improved performance and cost savings inherent in a system design that employs less trunk and feeder cable and fewer active line electronics than a conventional tree-and-branch design. The third major benefit is the convenience that arises from placing the bulk of the converter equipment off the subscribers' premises. Money and time are conserved by making the equipment accessible to the cable company personnel all of the time. This eliminates service-scheduling problems that can currently plague cable operators.

Other far-reaching benefits are derived from integrating star switching and addressing within the same system. An addressable system expands the operators' capabilities to change, develop, and offer increased services; to develop billing, maintenance, and diagnostic schemes to aid the operator in developing better and cost-saving policies. The development of such policies is only limited by the operators' ingenuity, creativity, and ambition to develop them.

As with any new technology, its developer must prove its value to the market. The developers of star-switched networks have an advantage in that the soundness of this type of design has been proven by its use in the telephone industry. The focus must now be on the cost benefits to the operator. Certainly, as the technology advances, the cost effectiveness of star switching will tip the balances in its favor.

BASICS OF STAR-SWITCHING

The design currently favored by the CATV industry is the tree-and-branch. This is a series layout that is essentially an unbroken length of trunk cable that starts at the headend and goes through the entire franchise area to cover all the homes in the area. Signals are tapped off the trunk via feeder cables to service subscribers.

The star-switched approach is a parallel layout. The whole service or franchise area is divided into a number of smaller service areas. Each smaller service area is built around an independent hub that is tapped off the main network.

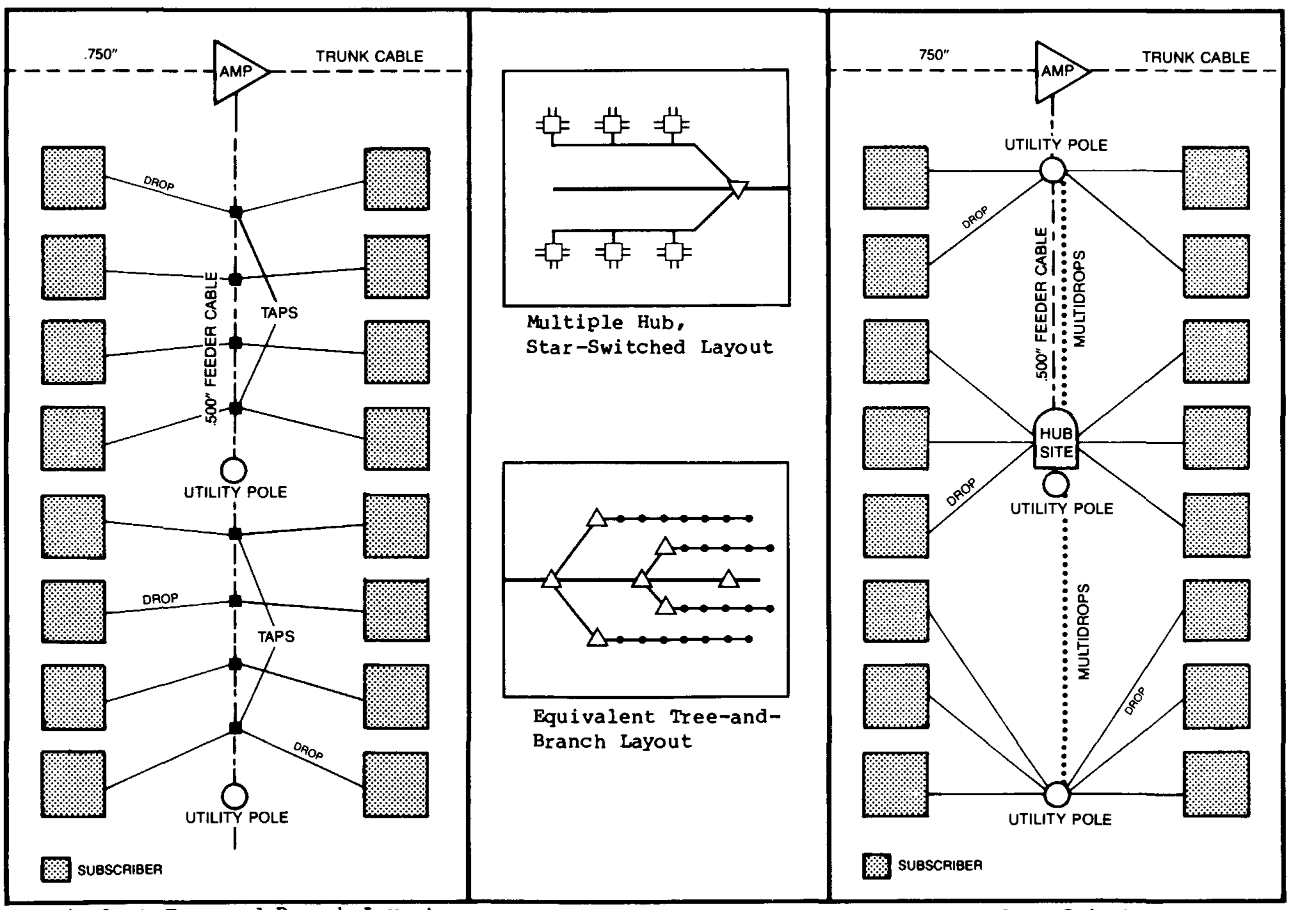
Radio Frequency signals (RF) are processed and distributed differently in the two systems; in a tree-and-branch design the full RF channel spectrum is transmitted over the entire backbone trunk and feeder. Drops are tapped off of the feeder and the full RF channel spectrum is sent to each subscriber. The subscriber's converter must then select a single channel from the full channel spectrum.

In a star-switched design, the full RF channel spectrum is delivered to each hub via the backbone trunk and feeder cable and not to the subscriber's residence. Economy is achieved because the full broadband RF spectrum is processed at the hub using a single high-quality, low-gain RF amplifier circuit. Only one RF channel low-frequency (two RF channels frequencies if a second set is used) at a time is authorized to leave the hub for the subscriber's residence. A digitally-based control circuit in the hub is the brain that directs the signals to each subscriber upon request. All channel and frequency conversion is performed at the hub, and only the firstand second-set channels are sent over the drop cable. For example, a channel change request is initiated by the subscriber. This request is transmitted upstream on the drop to the digital control circuit in the hub. The digital control circuit determines if that channel is authorized; if it is, the digital control circuit directs a remote switching unit to forward the channel downstream on the drop cable to the subscriber residence. Some drop cable problems may be avoided because of the single-channel, low-frequency RF transmission. Signal theft becomes impossible for anyone except the most perseverant because the conversion equipment is removed from the domain of the subscriber.

Figure 1 shows a typical layout for a star-switched and a conventional tree-and-branch design. In a star-switched layout, drop cables are not directly connected to the feeder lines as they are in a tree-and-branch layout. Rather, the hub serves as the junction point between the feeder cable and the drop cable. No taps are required in the feeder other than one that delivers 10 dBmV to the input of the hub. Instead, drop cables are first connected to the bottom of the hub enclosure or in some cases to a junction plate mounted near the hub then routed to the subscriber's residence using standard industry practices.

A star-switched system is comprised of three basic parts or equipment groups.

- o The headend group - this consists of the standard signal transmission equipment that is used to control the addressable portion of the system. For a one-way system (from the headend to the system only), an FSK generator is used; for two-way applications (back and forth from the headend to the system), a full two-way modem is added.



Equivalent Tree-and-Branch Layout

Single Hub, Star-Switched Layout

Figure 1

- o The hubs (local distribution groups) - these are the links between the headend and the subscribers. Each hub contains the RF amplifier and distribution equipment, data processing equipment, channel switching equipment, and other optional and peripheral equipment used in the system. The hub also serves as the physical junction between the backbone trunk and feeder network and the subscriber drop cables.
- o Subscriber group equipment - this final leg of the system consists of the drop cable that runs to the subscribers' residences and the interface unit with which the subscriber communicates with the hub. Often this equipment takes the form of a set-top interface unit and a hand-held remote unit which allows the subscriber added flexibility and convenience.

DESIGN CRITERIA

With this basic understanding of star-switched off-premises equipment and its configuration, the next step is to examine system design and layout.

A successful star-switched system is designed using the following parameters:

- o System Bandwidth - typical systems up to 550 MHz
- o Expected Penetration Rates - used to determine service area (cluster) size
- o Strand Maps - used to determine the size of cluster service areas and the amount of cable for the trunk and feeder interconnect network

Once this information is gathered, the design follows a four-step process:

1. Identify the cluster service areas
2. Determine the optimum hub locations within the cluster
3. Design trunk and feeder RF interconnect to the hubs
4. Determine system powering requirements

Unlike a conventional design in which trunk is laid out and the feeder is routed to pass by virtually every residence, the star-switched design starts by first identifying the groups of residences to be serviced from each hub site within the franchise area. These groups of residences are referred to as clusters. Once the clusters have been identified, a point is chosen in each cluster where the hub is to be located. The optimum point location is one that minimizes the amount of drop cable required in the service area without exceeding the limitation of the drop cable from the hub to the subscriber. After these points have been established, the trunk and feeder interconnect network is designed.

The actual mapping or layout of the star-switched network should be considered in three parts--clustering, hub placement, and backbone cable plant layout. Satisfying the clustering and hub placement part of the design process requires an understanding of the relationship between cluster size, hub size, and the density of homes in the franchise area.

HUB LAYOUT

A cable franchise is divided into cluster service areas with each cluster containing one or more hubs. Generally, cluster size is dependent on home density, hub capacity, practical drop length, and financial limitations. Choosing too large a cluster size for a low density area results in high drop cable cost because of drop cable lengths that are too long. Choosing too small a cluster size minimizes drop lengths but results in a large penalty for the additional hubs and trunk and feeder cable necessary to serve a greater number of hubs than is really needed. Different hub sizes allow for expansion at a hub site if expected penetrations are exceeded after the initial design without disturbing other areas of the design.

First, the number of residences that can be serviced by a particular size hub must be determined. Several calculations are made based on projected percentages of subscriber penetration and subscriber service requirements (first set service and second set service) to determine hub capacity. Allowances can also be made for expansion in the hub if penetration, over time, exceeds original predictions. This is the most critical step in system design, because it determines the limits of cluster capacity. Examples of sample hub capacity calculations are shown in Exhibit 1 using the following formula:

$$\text{Capacity} = \frac{(H_S)(P_E)}{(1 + S_2)(S_1)} \qquad (1)$$

where:

- H_S = Total number of slots at the hub
- P_E = Packing Efficiency*
- S_2 = The percent of 2nd sets in the cluster area as related to total penetration (expressed in decimal form)
- S_1 = The percent of 1st sets in the cluster area as related to total penetration (expressed in decimal form)
- Capacity = Homes passed per enclosure for a cluster

*** Packing efficiency is basically a growth factor. It is used to allow for additional slot space in a hub if growth is beyond the expected penetration rates. The more confidence that expected penetration rates will not be exceeded, the higher the packing efficiency should be. It is important to note that during initial construction only sufficient enclosure capacity needs to be planned; converter electronics can be added as a function of penetration.**

EXHIBIT 1 - CALCULATING HUB CAPACITY

VARIABLES

- o 50% 1st set penetration (S_1)
- o 15% 2nd set penetration (S_2)
- o 90% packing efficiency (P_E) (allow 10% growth in hub enclosure after expected penetration is achieved)

Example 1 - 8-slot hub enclosure

Capacity (No. homes passed per cluster/enclosure) $= \frac{(8)(.90)}{(1 + .15)(.5)} = 12$

Example 2 - 16-slot hub enclosure

Capacity (No. homes passed per cluster/enclosure) $= \frac{(16)(.9)}{(1 + .15)(.5)} = 25$

Example 3 - 32-slot hub enclosure

Capacity (No. homes passed per cluster/enclosure) $= \frac{(32)(.9)}{(1 + .15)(.5)} = 50$

Once the hub size has been determined, the next step is to identify these cluster service areas on the strand maps. At this stage, the limiting factor that governs the size of the cluster is the peak length limitation of the drop cable out of the hub to the subscriber's residence. Table 1 shows the length limitations for both a drop powered and non-drop powered star-switched system, using a single drop cable. Note that there are different powering schemes available to the system designer. This variety allows the designer to choose a powering format based on economic limitations and operator preference.

POWERING OPTIONS

Powering options available to a star-switched network are summarized as follows:

110 VAC power - Each hub is connected to the power network through an electrical riser. This approach is best utilized in system designs that are of high-density and that have closely spaced hubs which service many subscribers, typically 48 or more subscribers per hub. Such builds are apartment buildings, housing developments, or institutional applications where 110 VAC is readily available for powering the hubs. The in-home interface equipment takes its power from the subscriber's electrical circuit.

60 VAC cable plant power - Each hub is powered from the 60 VAC that exists on the backbone cable plant. Whereas with the 110 VAC powering scheme each hub would require its own riser, and possibly its own meter, the ratio of risers and meters to hubs is much smaller here because 110 VAC meters and risers are only needed to serve each trunk power supply. In turn each power supply can serve up to 10 hubs, depending upon the capacity of each hub. This method is best suited to urban builds in which smaller hubs are spaced farther apart and serve a lower concentration of subscribers. This powering scheme is also well-suited for "garden apartment" environments where it may be economically unfeasible to run 110 VAC lines to each hub location. In these situations numerous meters and risers would not only be costly, but would also pose a maintenance problem. As in the 110 VAC approach, all hub equipment is powered by the 60 VAC. The in-home interface equipment takes its power from the subscriber's electrical circuit.

TABLE 1 - DROP DISTANCE LIMITATIONS

Cable Type	Non-Drop Powered Maximum Drop Length (Ft)			
	1 TV SET	2 TV SETS	1 TV SET & FM	2 TV SETS & FM
RG-59	1090	600	680	540
RG-6	1350	750	850	675
Cable Type	**Drop-Powered Maximum Drop Length (Ft)**			
RG-6	1280	640	850	640

60 VAC cable plant powering/drop powering - Two separate power services serve each hub. The common hub electronics (RF amplifier, digital control circuit, and peripheral equipment) are powered by the 60 VAC the same way as in the straight 60 VAC method. The in-home interface equipment for each television set is powered by 30 VAC which is generated from the subscriber's power circuit. This approach eliminates the variable power consumption problem caused by the remote switching modules which are designed to be powered on and off along with the subscriber's television set. A constant and predictable load on the trunk allows the designer to load each cable plant power supply to capacity for most efficient operation. Drop lengths are especially critical here because of the increased power loss inherent in long runs. Depending on the size of the drop cable, the drop length may be limited by AC power loss as opposed to RF power loss.

SYSTEM COMPARISON

With an understanding of how a star-switched off-premises design is laid out and the relative differences from a conventional tree-and-branch system, the next topic is the actual equipment impact a star-switched design has over a conventional design.

Table 2 shows a comparision of trunk and feeder equipment for a standard tree-and-branch system and a star-switched system. These numbers were obtained from an actual sample design for a metropolitan build.

TABLE 2 - PLANT MATERIAL DESIGN AREA
(23.28 plant miles, 6843 homes passed)

	CONVENTIONAL	STAR-SWITCHED
Trunk Amplifiers	36	18
Line Extenders	124	27
Passives	1,218	944
Hubs	0	220
Connectors Trunk/Feeder	2,002	901
Drop Connectors	0	14,000
Cable		
500	121,270	89,623
750	35,671	24,432

The same geographic area is covered in both designs. The difference in the Bill of Materials is a result of the following:

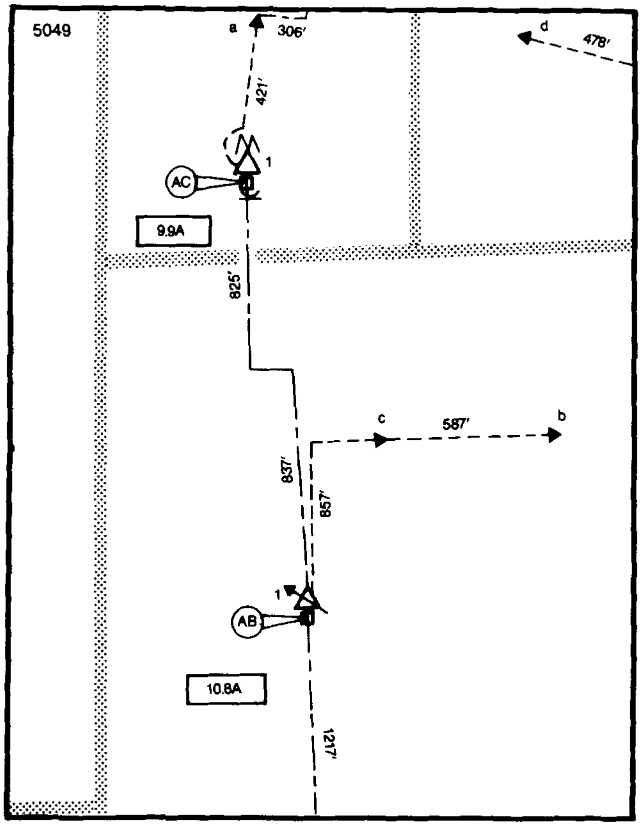
Each hub requires 10 dBmV input to service up to 32 subscribers or about 30 to 50 homes passed, depending on the expected penetration, which effectively replaces feeder line taps and feeder cable. Directional couplers feed the hubs so more reach is accomplished in the feeder lines because there is no flat insertion loss of taps thus more system reach is available without the use of many line extenders. The balance of the feeder leg coverage is accomplished with a 100 percent dedicated drop for each home passed or drops can be added incrementally with penetration. Of course, the approach taken for drop cabling depends on operator preference and various economic considerations. The main difference in the trunk amplifiers is that few, if any, trunk splits are required off the main cascades. Figure 2 shows a sample portion of the strand maps for the geographic service area described in Table 2. Both maps cover the same geographic service area. In both designs, feeder legs that do not have line extenders are not shown. The main cascade usually requires about 20 percent less trunk stations for the same geographic coverage; the total number of system trunk stations is usually about 50 percent less than in a tree-and-branch design.

SUMMARY

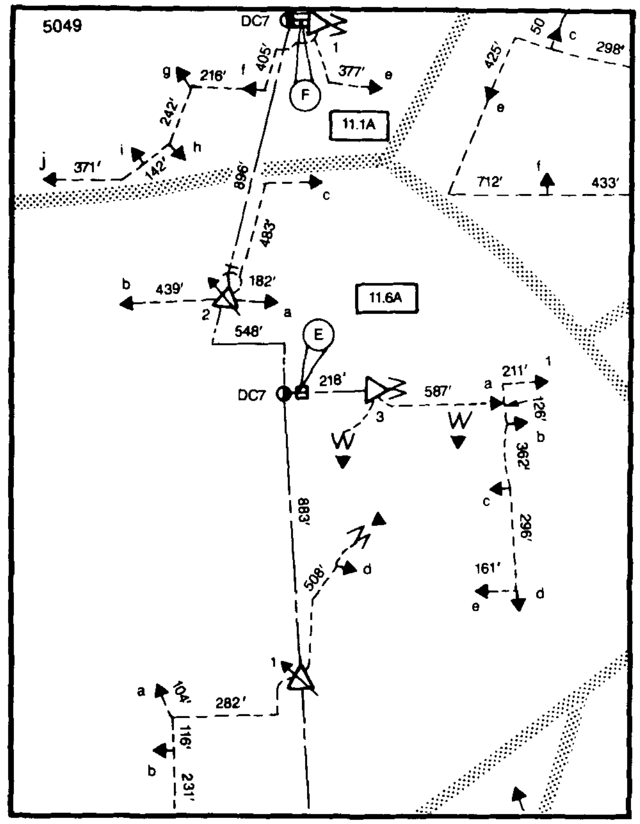
The rules for designing a star-switched system differ from those used to design a conventional tree-and-branch system. The emphasis in a star-switched system is placed on a set of criteria that allows the system designer many options in choosing his approach. Subdividing the whole franchise area allows each division to be designed and built separately, while still being controlled centrally. The impact of system expansion is limited to the areas that are expanding and not the entire system. The net effect of a star-switched system's design and operating features is simplicity and security. These are due primarily to the following:

- Fewer trunk and feeder system electronics in the total design.
- Considerably less trunk and feeder plant running the full 350 or 550 MHz spectrum in the franchised service area.
- No "tap-feederline" design calculations required at each pole location where there are potential subscribers.
- Interchangeable powering methods which allow the operator to choose the right method in the right location.
- Subscriber converter equipment located off-premises.

Experience has shown that the star-switched systems of today can be easily designed and can perform comparably to conventional addressable/scrambled cable systems at a competitive price.



Strand Map Section - Star-Switched Layout



Strand Map Section - Tree-and-Branch Layout

Figure 2

SUPERFLAT FEEDFORWARD TRUNK AMPLIFIER DESIGN

ROBERT M. BLUMENKRANZ

JERROLD/CENTURY III

ABSTRACT

It is well known that a cable system's performance depends to a large extent on the peak -to-valley response maintained along the cascade. As the peak-to-valley response begins to degrade, it becomes increasingly difficult to keep proper operating levels through the cascade. In the past, minimum cascade performance specifications have allowed a maximum peak-to-valley of (N/10)+1 at the end of the cascade. Other formulas have been used as well depending on the length of the cascade or on system sensitivity to changes over temperature. This performance specification could only be met after the module had been aligned in the system.

Prior amplifier designs allowed each amplifier to have a minimum peak-to-valley variation, which if allowed to propagate through the cascade, could result in additional alignment time required on the part of the field service technician. If the number of "mop-up" controls within the amplifier were too large, then the number of variables under the technician's control would increase. This resulted in a great degree of control over the cascade peak-to-valley,but with more variables the chance of detuning in the field was increased. In order to solve this problem a "superflat" amplifier would have to be designed which would allow the field technician to plug it directly into the cascade without requiring any additional field alignment.

This amplifier would require a peak-maximum peak-to-valley of less than 0.2 dB over the 50 to 550 Mhz bandwidth, in order to maintain a maximum of 2.6 dB peak-to-valley response at the end of a 16 amplifier cascade. If the amplifier could meet this specification on the bench it could then be installed into the cascade without any additional mop-up. The time required to obtain satisfactory system performancer would be decreased. If an amplifier should fail then replacing it would not require any system realignment. This paper will describe the basic design concepts and performance results of such an amplifier.

AMPLIFIER CONCEPTION

The superflat amplifier concept was introduced to improve the trunk cascade system performance while reducing field alignment time. The basic concept was to integrate the individual components of the feedforward trunk module into independent assemblies.

This permits the individual testing of subassemblies which make the complete module function. If each subassembly, such as the slope control, gain control, interstage equalizer, and feedforward stage can be individually tested and evaluated to a known standard, then accurate repeatable results may be obtained at the final module level.

THE BUILDING BLOCKS

The first requirement for this trunk amplifier would be a very flat feedforward gain block. The TRW FF224/FF124 stage met this requirement with the aid of Jerrold/Century III feedforward enhancement circuits (patent pending) which include feedforward thermal compensation networks. An excellent yield of feedforward stage "clones" satisfying the basic requirements of flatness and performance over temperature were used.

The feedforward gain blocks input and output matches were typically >= 20 db with a peak-to-valley response of +/-.15 dB between 50 and 580 mhz The typical crossmodulation observed in each feedforward stage was an average of -80 db at +46 dBmV when measured with a 6 db linear tilt. The C T B measurements appeared to be within the same range

The module's standard push-pull pre-amp cascode input I C. would have to be chosen based on flatness, noise figure, crossmodulation performance, and composite second order beat as measured at 547.25 Mhz. It appears that one limiting factor in the system design will be composite second order beats at the highest channels. This is due primarily to the contribution by the input stage when the gain and slope controls are operating with attenuation at cold temperatures.

The input I.C. chosen was a PHI 5517-21. This device combines excellent noise figure, ideal gain, low crossmodulation and composite beat products.

SPECIAL CONSIDERATIONS

The use of surface mount capacitors was essential in minimizing the series inductances and non-uniformities which result from the use of leaded bypass and coupling capacitors. The performance near 550 Mhz was dramatically improved and insertion loss throughout the board was significantly reduced at 550 Mhz.

AGC REQUIREMENTS

The basic block diagram as shown in Fig. 1 displays the complete feedforward amplifier and its associated AGC circuits which are used to maintain output levels constant with temperature related cable attenuation.

The A.G.C. circuits must be capable of pilot level control at 500Mhz. This required a strip line type filter which maintains stability while providing sufficient bandwidth attenuation for adjacent carriers. A high stability R.F. amplifier must be provided (a pair of Motrola MHW110 's) to guarantee sufficient gain and stability.

Shielding the A.G.C. section from the R.F. broadband section is extremely important in the feedforward module design because the signals present in the A.G.C. are at elevated levels and are capable of interfering with the low distortion feedforward signals. The high pilot filter, the A.G.C R.F. amplifiers, and the video amplifiers must be well shielded.

The 550 Mhz wide bandwidth will require a pilot near each end of the band for sufficient A.G.C. control. Pilot channels are 67.25 Mhz and 499.25 Mhz The module's broadband frequency response would have to be 50 to 580 Mhz, in order to allow sufficient guard band for 550 Mhz cascadeability

SLOPE AND GAIN CONTROL

To insure adaquate slope control range and linearity the pivot point for the slope control is hinged at 550 Mhz. with the low pilot channel controlling the slope. The slope control must introduce a minimum amount of insertion loss at the pivot point while allowing 20 dB return loss over the entire bandwith and over 8 dB of cable change.

AMPLIFIER FLATNESS CONTROL

An early design goal was to eliminate all "mop-up" controls from the module. However, due to a slight amount of low frequency roll off occurring in the feedforward stage, a single low frequency control was necessary. This control was set up at the bench level and required no further adjustment once in the cascade. The only other controls available for system alignment are the actual equalizers which are located at the input and interstage.

PERFORMANCE REQUIREMENTS

The design formula used for system flatness over temperature was dB = N/10+1. Therefore, in a 16 amplifier cascade the maximum peak-to-valley would be 2.6 dB worst case. If we assume that the room temperature peak-to-valley is 1.6 dB then we may allow a 1 dB change to occur over the temperature gradient, if we are to maintain a peak-to-valley response of 2.6 dB at the end of the 16 amplifier cascade. The response of each amplifier must therefore average 1.6/16 or .1 dB peak-to-valley at room temperature.

If each amplifier was bench aligned to .1 dB peak-to-valley, then we could install the modules without additional cascade alignment time. This precise requirement of accurate bench alignment means that an absolutely flat digitized reference be used so that the signatures within the sweep system can be completely cancelled out.

BENCH ALIGNMENT EQUIPTMENT

Fig 2 illustrates the bench alignment setup used to acheive the desired results. A sweep system that can resolve variations of .1 dB is described for this purpose. An adaquate bench alignment system that eliminates all response bumps attributed to the bench set up is absolutely necessary if the cascade is to be prealigned accurately. The procedure requires a sweep system with a digitized sweep reference and it must be logrithmic in its screen display inorder to produce a minimum resolution of .2 dB/per division

After the bench alignment in a common fixture, the modules were checked in their final connector chassis (mother board) which will be used in the cascade. Each trunk was aligned for 26 dB of cable at 550 Mhz.

THE CASCADE

Upon installation into the cascade, additional mop-up was not attempted until all sixteen modules were installed. Final cascade alignment was required on some of the modules to allow for slight equalizer adjustment since the cable spaceings in the cascade are not always identical to those used on the bench setup. The system flatness was very easy to control with minor equalizer adjustment on a few of the 16 amplifiers.. The interstage equalizer was the only variable required. A combination equalizer/"mop-up" board was designed as a plug-in replacement for the interstage equalizer, but its use was not required.

CASCADE PERFORMANCE

The room temperature response achieved was a peak-to-valley of 1.72 db (fig. 4). The discontinuities at 67 and 500 Mhz are due to the presence of pilot carriers during the sweep display interval.

The 16 amplifier cascade response at -25 degress F resulted in a peak-to-valley of 2.46 dB (fig. 3) and the response at +134 degrees F. was the worst case peak-to-valley of 2.6 dB (fig. 5). The composite 2nd order, composite triple beat, carrier to noise, and crossmodulation as observed at these temperatures are given in table 1.

CONCLUSIONS

It appears that improved system performance will be obtained when the system flatness is improved. If the peak-to-valley performance improves over temperature then the carrier-to-noise ratio will be smoother over the entire band Other system parameters are also affected and they improve directly as the response becomes flatter.

As the system response flatens we see less change in the critical parameters which affect the overall dynamic performance throughout the operating temperature range. Valuable experience has been gained concerning component size and layout considerations as they apply to bandwidths in excess of 550Mhz. The technology exists now to reduce system maintenance costs by improving the product.

We may now save valuable time and improve system performance through the use of accurate sweep methods, surface mounted components, superflat feedforward stages, and prealigned subassemblies. Together they may be combined into a "super-flat" trunk amplifier which approaches the theoritical limits in state of the art performance capability.

ACKNOWLEDGEMENTS

I would like to thank Mark Gibbons for his efforts in the cascade. Thanks to Ed Mitchell and Vic Tarbutton for their support and belief that these goals could somehow be acheived. Admiration for my fat Mac computer on which this paper was prepared.

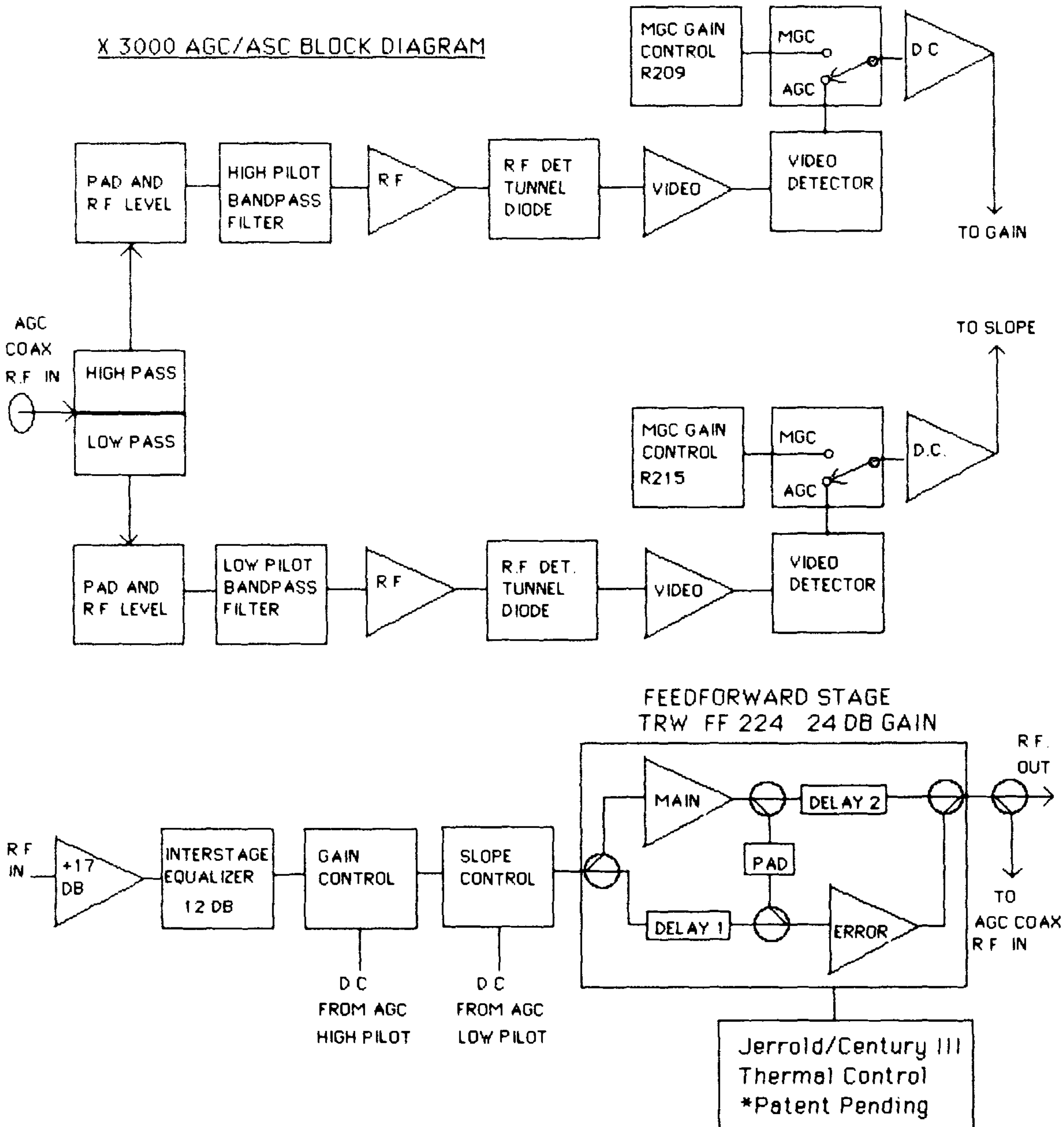

X 3000 AGC/ASC BLOCK DIAGRAM
MGC GAIN CONTROL R209
MGC
AGC
D C
PAD AND R F LEVEL
HIGH PILOT BANDPASS FILTER
R F
R F DET TUNNEL DIODE
VIDEO
VIDEO DETECTOR
TO GAIN
AGC COAX R.F IN
HIGH PASS
LOW PASS
TO SLOPE
MGC GAIN CONTROL R215
MGC
AGC
D.C.
PAD AND R F LEVEL
LOW PILOT BANDPASS FILTER
R F
R.F DET. TUNNEL DIODE
VIDEO
VIDEO DETECTOR
FEEDFORWARD STAGE
TRW FF 224 24 DB GAIN
R F IN
+17 DB
INTERSTAGE EQUALIZER 12 DB
GAIN CONTROL
SLOPE CONTROL
MAIN
DELAY 2
PAD
DELAY 1
ERROR
R F. OUT
TO AGC COAX R F IN
D C FROM AGC HIGH PILOT
D C FROM AGC LOW PILOT
Jerrold/Century III
Thermal Control
*Patent Pending

FIG. 1

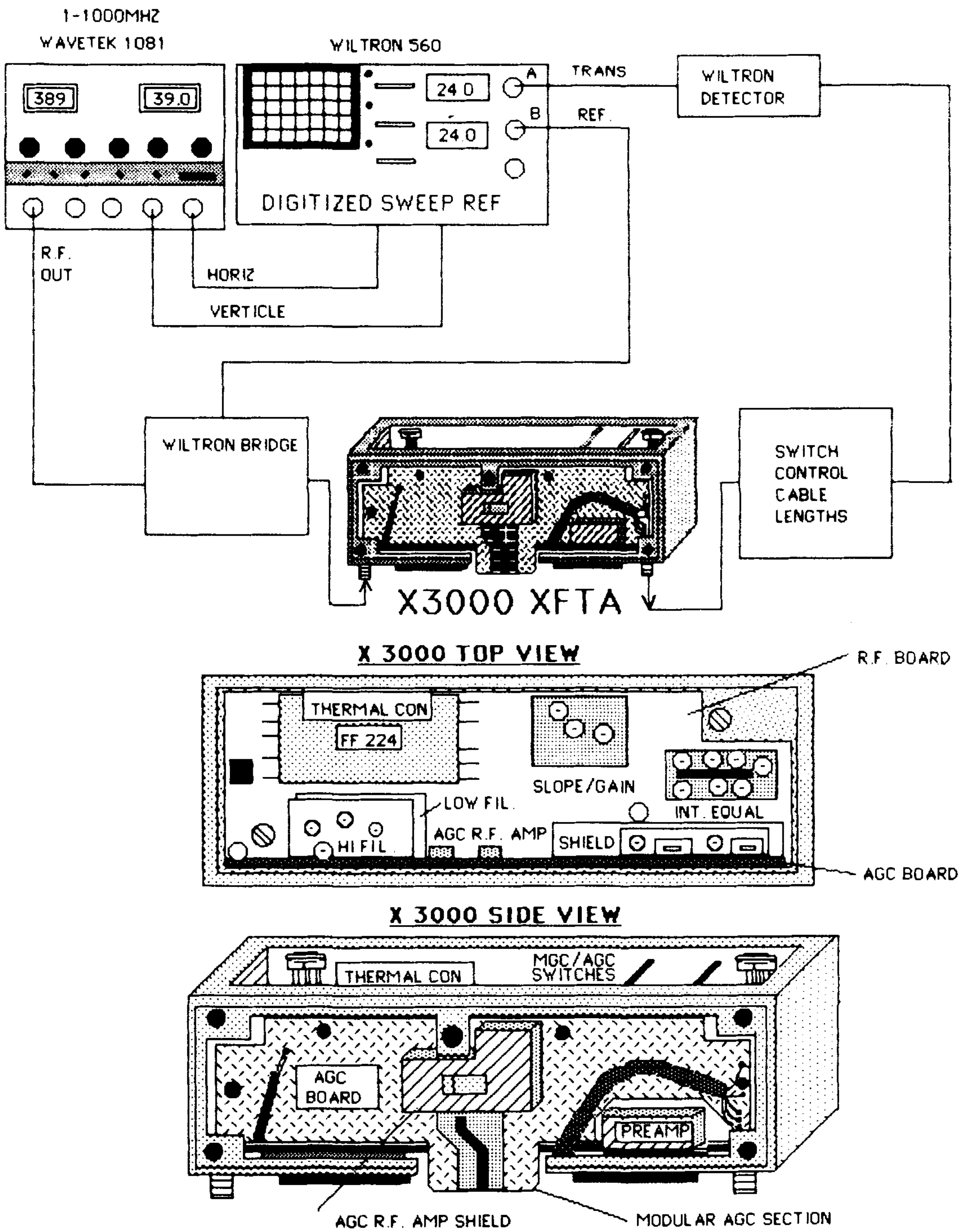

1-1000MHZ
WAVETEK 1081
WILTRON 560
389
39.0
24.0
24.0
A
B
TRANS
REF.
WILTRON DETECTOR
DIGITIZED SWEEP REF
R.F. OUT
HORIZ
VERTICLE
WILTRON BRIDGE
SWITCH CONTROL CABLE LENGTHS
X3000 XFTA
X 3000 TOP VIEW
R.F. BOARD
THERMAL CON
FF 224
SLOPE/GAIN
INT. EQUAL
LOW FIL.
HI FIL.
AGC R.F. AMP
SHIELD
AGC BOARD
X 3000 SIDE VIEW
THERMAL CON
MGC/AGC SWITCHES
AGC BOARD
PREAMP
AGC R.F. AMP SHIELD
MODULAR AGC SECTION

FIG. 2

TABLE 1

X3000-550 MHZ
TEMPERATURE TEST 3/21/85
LEVEL +39 DBMV TILT 6 DB

TEMPERATURE -25 F.

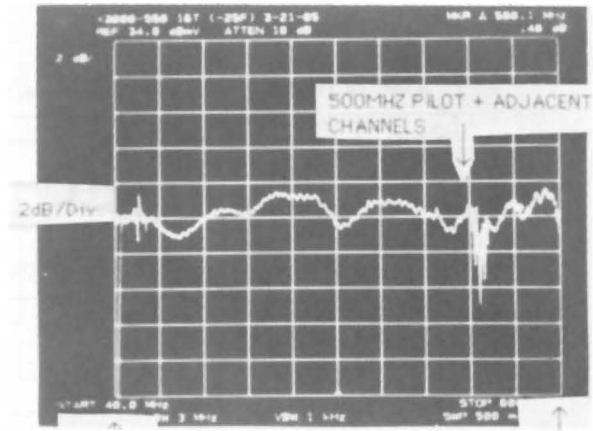
FREQ	C2ND	CTB	C/N	XML	XMH
55.25	70.5	71.9	51.0	59.9	60.1
175.25	71.2	64.5	51.1	60.8	61.0
211.25	67.2	63.3	51.5	61.5	60.7
295.25	70.4	61.9	52.5	61.4	62.2
343.25	69.8	60.0	51.5	62.4	62.0
397.25	66.1	58.2	51.7	63.5	62.9
445.25	65.4	57.3	51.1	64	63.5
487.25	72.0	57.3	52.3	64	64.5
547.25	65.3	61.4	52.6	62.3	62.9

TEMPERATURE +70 F.

FREQ	C2ND	CTB	C/N	XML	XMH
55.25	71.8	72.4	50.6	74.8	74.9
175.25	72.0	68.7	50.9	75.3	75.2
211.25	66.1	67.2	51.3	74.8	74.9
295.25	71.7	66.7	51.3	77.6	77.1
343.25	71.9	64.6	50.8	75.4	75.7
397.25	66.3	62.6	50.7	73.9	73.8
445.25	65.4	62.1	50.0	73.8	72.4
487.25	72.7	62.6	51.3	72.3	73.0
547.25	64.9	67.3	50.7	76.2	76.3

TEMPERATURE + 134 F.

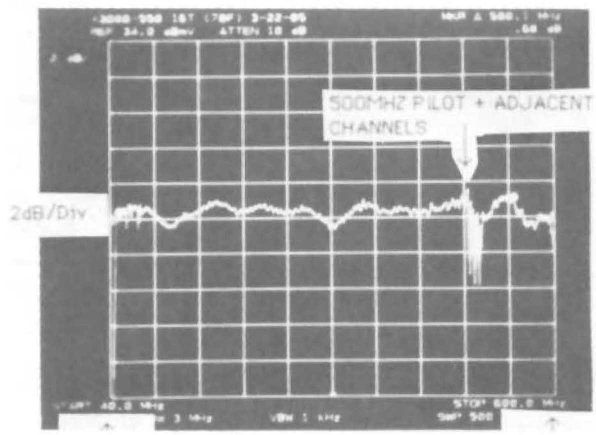
FREQ	C2ND	CTB	C/N	XML	XMH
55.25	70.8	72.3	50.3	72.6	72.4
175.25	65.9	67.0	50.4	71.0	70.9
211.25	67.0	66.4	50.3	70.8	70.5
295.25	71.5	65.3	50.4	71.2	71.4
343.25	71.8	63.8	50.4	68.8	68.6
397.25	67.6	61.8	50.0	67.0	66.7
445.25	66.8	61.3	50.0	65.8	65.7
487.25	72.4	61.5	50.8	65.3	65.2
547.25	65.0	63.4	49.3	63.9	63.9



50 Mhz 600 Mhz

FIG. 3

-25 DEGREES F 2.46 DB P/V



50 Mhz 600 Mhz

FIG. 4

+70 DEGREES F 1.72 DB P/V

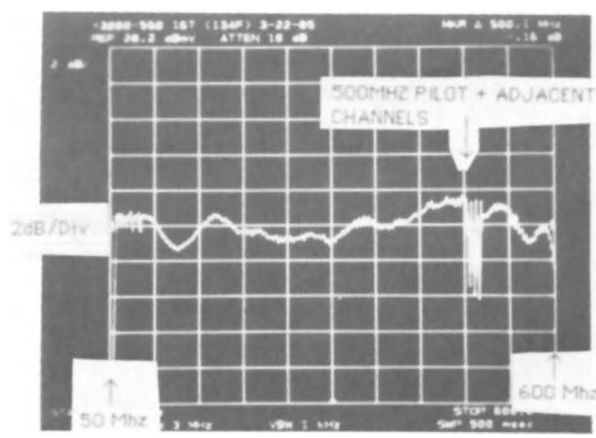


FIG. 5 +134 DEGREES F 2.6 DB P/V

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MR. ROBERT BLUMENKRANZ

Mr. Blumenkranz was born in Miami Beach, Florida on March 21, 1944. He received the Bachelor of Science degree in Electronics Engineering from the University of Miami, Coral Gables, Florida in 1967. While attending college he was employed at Communications Company (COMCO) and WTVJ-TV(CBS).

From 1967-1970 he designed Broadcasting facilities for severasl South Florida Radio and T.V. Stations, and acted as Chief Engineer and Technical Director of several.stations.

During 1970-1972 , he was Technical Director of Tel Car Corp. a Radio Common Carrier consisting of computerized pocket paging,mobile two-way , and communications systems.

In 1973 as senior design engineer he devoloped a scanning mobile telephone control head while working at Glenayre Electronics Ltd. North Vancouver, B.C.In 1974 he assisted in the construction of a 22 Mhz Radio Telescope at the Herzberg Institute of Astrophysics near Penticton, B.C. The following year he designed interactive two-way Pay Television systems for Vancouver and Toronto hotels with Mediatronics Ltd. Vancouver, B.C.

From 1976 to the present he has been with Jerrold/Century III Electronics, Inc. (formerly Anaconda CATV Ltd) as design Engineer Consultant He has developed and patented the Feedforward and other Trunk Amplifier Associated Systems.

Mr. Blumenkranz holds an F.C.C Radio Telephone First Class License and an Amateur Extra Class Amateur Radio License.

TECHNICAL CONSIDERATIONS OF TWO-WAY INTERACTIVE CATV

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ABSTRACT

This paper focuses on two-way data transmission over CATV. The types of services envisioned, their traffic statistics, as well as the trade-offs between centralized and distributed switching approaches are presented. Some protocol design issues are considered. Single-frame video transfer is discussed as a representative example of wideband traffic.

INTRODUCTION

Several different techniques for providing an alternative to the conventional analog wired local loop are expected to emerge in the next few years. CATV systems have a high potential for local distribution of information. This is understandable in light of the growth in cable penetration (approximately 41% of U.S. house holds, with gross revenues of about four billion dollars for basic cable services). Experiments with two-way interactive CATV have been under way for the last decade. A number of pilot projects are in operation. Examples of such projects are the Qube System by Warner Amex [1], and the INDAX System by Cox Cable [2].

The element common to the different CATV pilot project proposals submitted to the IEEE 802 MAN (Metropolitan Area Networks) committee [3] is that the CATV data system is treated as a Head-End (HE) centralized system. All input traffic (data) travels to the HE on an up-stream frequency, is frequency converted at the HE, and is then transmitted on the down frequency to its destination. Obviously, such an approach emerged from the currently operational entertainment CATV systems, and from the fact that current broadband local area networks, such as Sytek, WangNet and others, utilize similar approaches.

In this paper, we consider an alternate approach for two-way interactive CATV. It is based on a distributed store-and-forward network, with intelligent switches installed at different locations in the CATV plant. These switches (or nodes) must perform the usual packet-switched store-and-forward functions of routing, flow control, error correction and detection, etc. Databases (localized memory) may even be installed near these switches. The users contend in accessing the channel only to the nearest node. This reduces the number of users in contention for the channel, and as a consequence, the channel access problem becomes less critical than in the centralized case. Another obvious advantage is the efficient utilization of the CATV channel. The only drawback to such an approach might be the cost of the switch. Yet with economy of scale, the high rate of data growth, and the gain in channel utilization, this approach might be justifiable.

A set of protocols has to be established for communication over the CATV network. One possibility would be to adapt popular existing protocols such as X.25 for our use. However, it will be seen that several architectural features unique to the CATV network, suggest modifications that will enhance performance.

In CATV systems, a set of 6 Mhz channels are allocated exclusively for two-way activity. These may be further subdivided into broadband and narrowband channels to optimize performance for the various kinds of traffic encountered. Some possible strategies for channel allocation will be considered along with typical examples of traffic.

Single-frame video transfer capability is an interesting option made practical by the high-speed channels that are available on CATV systems. We will look at some typical applications which are expected to be of value to home and business users. Several alternative techniques for single-frame video transfer will be analyzed and comparative performance figures presented.

DESIGN CONSIDERATIONS OF TWO-WAY CATV

Figure 1 shows some design considerations for two-way CATV. Determination of the services envisioned over the system is essential in designing the system. These services could be classified into two generic types of data traffic: narrowband and wideband traffic. The specific bandwidth (or bit rate) requirements of each type would be determined from the kinds of services and applications foreseen. It would appear that at least two broad classes of data transmission must be considered. A narrowband group is represented by interactive bursty traffic, while the second

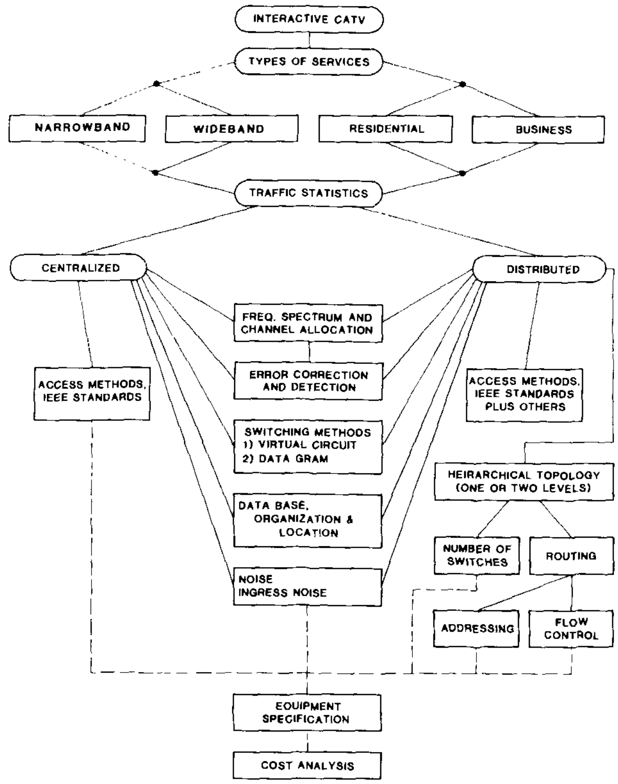

Fig. 1. Design Considerations of Two-Way CATV.

group consists of wideband information such as single-frame video transmission, facsimile communication, videotex, and file transfers. Another possible grouping might be residential and business services.

In many typical applications, users are basically interacting with databases. The databases could be located at the head-end, or in the "outside world" with access through a gateway; they could also be distributed at a number of nodes in the network.

Narrowband and wideband traffic statistics for the network have to be estimated for the services to be provided, and categorized into one of the two classes noted above, the expected length of messages, message inter-arrival time, the number of active subscribers during a busy period, and the mix of services used by the subscribers.

For both approaches, a number of frequency allocation strategies are possible: a single broadband data channel for each direction of traffic with TDMA structure superimposed, multiple FDM data channels (as implemented in the Cox Cable INDAX System [2], the Sytek broadband LAN system and others), or, possibly, two or more frequency subchannels, some for narrowband traffic, others for broadband traffic.

TYPES OF SERVICES AND TRAFFIC STATISTICS

The services foreseen on a two-way interactive CATV system could be classified as follows:

Information. Electronics news, Classified ads, Yellow pages, Employment opportunities, Insurance information, Travelogues/Airline schedules, Education, Income-tax tips, Online library/ encyclopaedia, Community news/Bulletin boards, Weather, "Do-it-Yourself" manuals.

Entertainment. Network programming, Interactive games, Trivia quizzes.

Financial. Banking services, Bill payment, Wall street news, Financial analysis newsletters, Archival database, Credit card verification.

Communications. Videotex, Teletext, Electronic mail, Digital telephone, Single-frame video transmission, Teleconferencing.

Computing. Programming, Data storage, Word Processing.

Miscellaneous. Telemonitoring (Medical alert, Security, Fire, Theft), Telecontrol, Telemetering, Catalog shopping (and shop-at-home).

The IEEE 802 Committee on Metropolitan Area Networks [3] has identified five distinct services to be addressed:

1) Bulk data transfer
2) Digital voice trunks and compressed video
3) Videotex and transaction processing
4) Low-speed terminal traffic
5) Local area network interconnect

Traffic statistics for the different services are generally not available since most of these services are still in the conceptual phase. Nonetheless, one can generate some reasonable numbers. We attempt to model a typical local CATV community and estimate the expected traffic during a day time busy hour. Only interactive (bursty) use is considered. This might represent carrying out "from-the-home" shopping, users accessing bank accounts, branch offices of a business communicating with one another, etc.

Consider a community of 1000 subscribers, with 900 homes and 100 stores/businesses. Let 400 homes and all 100 businesses access the system during the daytime busy hour. (Home users may be communicating with one another, with stores/businesses, or elsewhere in the larger network). This model would thus provide statistics for a portion of a typical CATV system. Businesses also communicate with homes, with one another, or elsewhere in the network.

a. Home User Traffic

Let each home use the network for a typical 15 minute session, with 5 interactive transactions carried out during this time. A transaction consists of 60 characters from the home terminals, with 400 characters being received in reply. One half of the stores/businesses are involved in these transactions. The average interactive information rate during this busy hour is thus:

400 homes x 5 transactions per hour x $\frac{460}{3600}$ char./sec ≈ 240 char. per sec.

b. Stores/Businesses

The remaining stores and businesses in a typical scenario might be grouped as follows:

a. One large business, 1000 transactions/hr., 80 characters outbound, 400 characters inbound, producing about 400,000 characters/hour or about 100 characters/second.

b. 50 small businesses, 1 terminal each, one 400-character transaction/2 min. or about 160 character/sec., total.

The total community traffic, averaged over the hour, is thus about 500 characters/sec. Other examples will be considered as well in the course of discussion.

CENTRALIZED APPROACH

Most of the proposed two-way interactive systems employ the centralized approach in which all users on the system share the same channel. (In the INDAX system, communities of users are assigned one narrowband channel each.) Once the user accesses the channel, he transmits his message to the Head-End on the Up-stream frequency. The message is then frequency converted to the down frequency and transmitted to its destination.

Such an approach has a number of drawbacks. First, all users in the system are accessing the same channel, and hence the access scheme becomes very critical and may result in a long delay for the user until he is successful in securing the channel. Second, it requires more channel capacity than a distributed scheme. This is due to the fact that all traffic must travel to the Head-end, even if the two communicating users are neighbors of each other. Lastly, a problem often encountered in a centralized scheme is the ingress noise that funnels back towards the Head-end from over 100,000 taps. This can be limited somewhat in non-random-access systems by "Bridger Switching" as employed in QUBE [1]. The Warner-Amex QUBE and Cox-Cable's INDAX are two examples of commercial systems employing centralized control. Other schemes proposed are essentially TDMA-based schemes, such as Reservation - ALOHA, a discussion on which follows later in this section. The Cox Cable INDAX [2] uses Carrier Sense Multiple Access scheme with Collision Detection (CSMA/CD). Because of the nature of the CATV environment, this access scheme significantly limits the bit rate as will be shown below.

CSMA/CD normally operates for wideband Local Area Networks (LAN) that cover a distance of 1 Km or less. A critical parameter in the design of CSMA/CD networks is the ratio, "a", of the round-trip propagation delay τ (in seconds) to the packet length, T (packet transmission time in seconds), $a = \tau/T$. This ratio, "a", must be much less than unity to ensure that all users may sense the channel correctly for prior transmissions before they begin to transmit. Otherwise, a large number of collisions will occur and this access scheme will degenerate to a random one. For local area networks, at distances close to 1 Km, the propagation delay is small compared to the packet length T and hence a is maintained very small. But in a CATV environment, where the geographical coverage may be 30-50 Km, the "a" parameter becomes too large for a wideband channel. Systems that propose using CSMA/CD overcome this problem by using narrowband (e.g., 28 Kbps in INDAX [2]) channels. They keep the packet length T, large, and hence "a", small.

The use of narrowband channels precludes high data rate traffic on the system. This defeats the very purpose of wideband CATV and works against the competitive edge which CATV potentially has over the data services provided by the telephone company.

We now examine the centralized approach further using a Reservation-ALOHA access scheme. The channel time is divided into fixed length slots. The length of the slots is determined by the length of data packets. Typically, users make requests for reserving a slot before transmitting. The slots are grouped into a frame of fixed length in which the first Y slots are subdivided into mini-slots during which reservation request packets may be transmitted. As shown in Figure 2, each slot is divided into V mini-slots, i.e., there are VY request slots in a frame. The length of the mini-slot is determined by the length of the reservation packet. The remaining slots in the frame (M slots) are reserved for data packets. The protocol behaves like normal slotted ALOHA at low channel utilization and moves gradually over to Time Division Multiplexing (TDM) as the channel load grows. This allows much better utilization of the channel and hence better throughput in heavy load conditions. A detailed description can be found in [4].

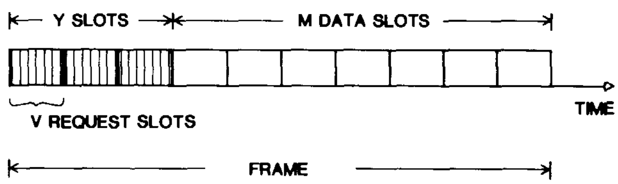

Fig. 2. Reservation ALOHA scheme.

A typical calculation has been performed for a 1 Mbps Reservation ALOHA channel. Assuming 10 char. request packets, 100 char. data packets, and an average message size of 6 packets, the optimal frame size is determined to be 53 slots, of which 3 slots are reserved for request packets and the rest for data. Each user will be transmitting data at a rate of 18.87 Kbps. In such a situation, the 1 Mbps channel can support a total traffic of 200 messages/sec without becoming unstable. The total number of users may be 2000 with each user initiating a traffic at a rate of 0.1 message/sec., or 20,000 users with each user initiating traffic at a rate of 0.01 message/sec.

We have looked at the performance of Reservation ALOHA as a typical centralized access scheme. This will be compared with a distributed control strategy in the next section.

DISTRIBUTED APPROACH

We consider two general cases of distributed control. In the first case, switches are installed only on a single main trunk [Fig. 3]. An appropriate location is at the bridger amplifiers on the trunk. In the second case, switches are installed on both the trunk and the branches [Fig. 4]. Locations of these switches could be both at the bridgers and at the splitters. We have carried out a detailed comparative analysis of both cases for an interactive, bursty traffic model. Details of the analysis appear in [5].

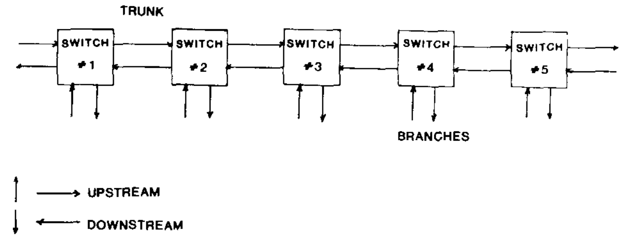

Fig. 3. Case 1; Switches only on the Trunk.

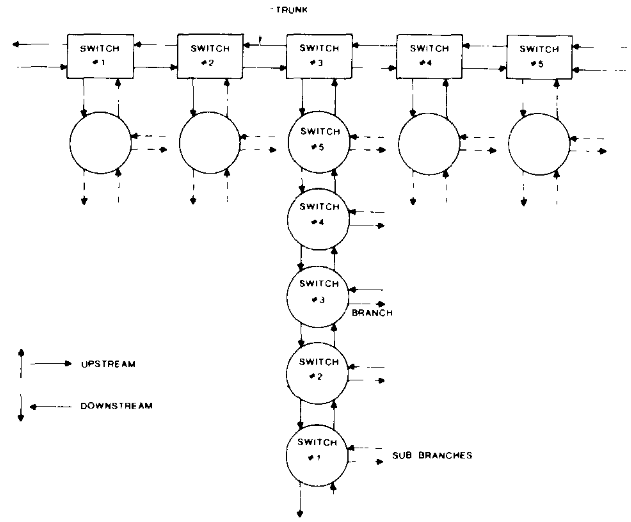

Fig. 4. Case 2; Switches on Both the Trunk and Branches.

In the analysis mentioned above, the network topology assumes one main trunk with 5 switches, 5 branches on the trunk (one at each switch location), with 5 sub-branches per branch. In case 1, we have a one-level hierarchy with switches only on the trunk for a total of 5 switches. Case 2 considers a two-level hierarchy with switches placed on the branches as well (at each of the sub-branch locations) for a total of 30 switches. In the traffic model assumed, each sub-branch inputs 0.1 Mbps of traffic for a total aggregate bit arrival rate or network load, over the 25 sub-branches, of 2.5 Mbps.

Consider the significance of the traffic assumed. For sub-branch traffic of 0.1 Mbps, average, and 450 character messages, the average message arrival rate per sub-branch is about 30 messages/sec. This corresponds to 300 subscribers/sub-branch, each inputting one 450 character message (5.5 lines of a terminal screen) every 10 seconds, or 1800 subscribers per sub-branch, each inputting a message every 60 seconds. The former case corresponds to a network with 7500 subscribers per trunk, the latter to 45,000 subscribers. The activity per subscriber is rather high, even in a busy-hour period, particularly if most of the subscribers represent single-family homes.

Consider an alternate example using the same numbers. Assume 900 home subscribers/sub-branch each inputting one 450-character message every 3 minutes. This provides an aggregate average sub-branch traffic of 5 messages/sec. Let an additional 25 messages/sec come from 10 large offices or businesses, each inputting an average of 2.5 messages/sec. Some of these "messages" could in reality be 450 character packets representing portions of a much larger file to be transmitted over the same channel as a non-interactive application. Other mixes of home and business traffic also result in the aggregate sub-branch traffic of 0.1 Mbps traffic assumed here.

It has been assumed that an originating data message is destined to any point on the network with uniform probability. Homogeneous message traffic statistics are assumed, with all users transmitting messages at the same average rate; messages are exponentially distributed in length, with the same average value at an originating point. Three performance measures are of interest. These are the: 1) trunk and branch flows throughout the network, 2) the throughput of each switch, and 3) the average message delay as a function of the total load on the network.

The results of the above mentioned analysis are summarized in Table 1 below. Note that the numbers given for average message delay implicitly include an access delay of 25 ms for case 1 and 13 ms for case 2. These numbers are based on the assumption that a Reservation ALOHA scheme is used for access.

TABLE 1. Comparison Between Different Approaches to Interactive CATV.

		DISTRIBUTED	
	CENTRALIZED	One Level Hierarchy (Case 1)	Two Level Hierarchy (Case 2)
Max Trunk Flow (Mbps)	2.5	0.6	0.6
Max Branch Flow (Mbps)	0.5	0.5	0.4
No. of Switches	1	5	30
Max Switch Throughput (Mbps)	2.5	1.7	1.6
Avg Message Delay (msec)	Not Possible	45	55

Note that the maximum trunk flow for the distributed approach (case 1 and case 2) is 0.6 Mbps. In the centralized case, the trunk would carry the full 2.5 Mbps which represents a significant increase of the data flow on the trunk. As a consequence, less channel capacity would be required for the distributed approach.

The centralized approach requires a trunk capacity of more than 2.5 Mbps. As an example, for a trunk utilization of 0.6 or less, at least 4 Mbps capacity would be required. The distributed approach, on the other hand, would require a trunk capacity of 1 Mbps or more, to keep the trunk utilization to 0.6 or less.

In case 2, each sub-branch inputs a traffic of 0.1 Mbps for a total network traffic of 2.5 Mbps. The resultant traffic flow on a branch varies from approximately 0.1 Mbps to 0.4 Mbps as opposed to 0.5 Mbps for the centralized approach or the distributed approach of case 1. On the trunk, the maximum traffic flow is 0.6 Mbps (similar to case 1) as opposed to 2.5 Mbps for the centralized case.

The maximum switch throughput for case 2 is approximately 1.6 Mbps in contrast with 1.7 Mbps for case 1 and 2.5 Mbps in the centralized case. Since the sub-branch channel capacity is 1 Mbps, its utilization is 0.1. This implies that the sub-branches are so lightly loaded that the simplest access strategies, such as random ALOHA would work well with relatively low access delay. For the range of traffic considered, the two-level hierarchy gives rise to a higher message delay than the one-level hierarchy. The store-and-forward process requires retransmission of each packet at each switch. There are now 30 switches, compared to 5 previously. Ultimately, the message delay for the one-level scheme will exceed that for the two-level hierarchy since the latter allows for more traffic to be input in the network.

Branch and trunk capacities in the distributed case are all 1 Mbps as noted earlier. In this case, the centralized system could not be used. Its apparent from Table 1 that the two-level hierarchy affords a slight improvement in branch flow and switch throughput. The average message delay has been increased, however, as well as the number of switches required. It would be our conclusion therefore, that for this traffic load, the one-level hierarchy is to be preferred.

ROUTING AND PROTOCOL ISSUES

So far we have only looked at performance issues. Ongoing work is addressing implementation issues as well. Paramount is the problem of designing a data-communication protocol appropriate for the distributed CATV environment.

Routing is a major issue in long-haul computer networks. At every node there are multiple routes for every source-destination traffic. In a CATV environment using a distributed approach, the routing problem is not as critical as in long haul networks, because of certain restrictions inherent to the tree topology of the CATV plant. At every node there is only one possible path for every source-destination pair.

The X.25 interface recommendation has been widely accepted worldwide. Ongoing work is considering the applicability of the X.25 protocol in the CATV environment. X.25 has originally been designed as an interface between a network and customer data equipment. We are looking at ways to adapt an extension of X.25 to network wide capability. The large number of users (20000-50000) motivates the need for a fast switching protocol. With the CATV tree topology and cascaded switches on the main trunk, a large number of virtual circuits must be supported on every switch. To reduce the processing overhead, we suggest a scheme [6] in which packet level acknowledgement and error correction is handled strictly on an end-to-end basis with minimal processing at intermediate nodes. This is a practical approach with the low error rate (< 1 x 10^{-9}) and high speed 1 Mbps on the CATV data channel.

CHANNEL ALLOCATION STRATEGIES

As previously mentioned, we consider two types of traffic, narrowband and wideband, for two-way CATV applications. Suppose that two TV channels, one for the upstream and one for the downstream traffic (6 MHz each) are allocated for two-way services. With a proper modulation scheme, we can achieve a bit rate of at least 6 Mbps over the 6 MHz TV channel. Then a possible strategy would be to divide the 6 Mbps into 2 sub-channels: a 1 Mbps sub-channel for the narrowband traffic and 5 Mbps for the wideband traffic. We use a 1 Mbps sub-channel to conform to the previous analysis. Further study would be required to make proper choices for the channel capacities.

a) The one Mbps sub-channel would be allocated to low-volume traffic where a user (at an interactive terminal) transmits or receives messages of 1 screen page length or less. From the foregoing analysis of the distributed approach with switches installed only on the trunk, the 1 Mbps channel can support a maximum aggregate traffic of 4 Mbps with average message delay of approximately 45 msec.

b) The 5 Mbps sub-channel would be allocated on a dedicated basis to bulk data transfer such as digitized single-frame video and file transfer (a discussion of single-frame video follows in the next section). A user, wishing to transfer a single-frame or a file, would send a reservation message (call set-up message) over the 1 Mbps narrowband channel, indicating the origin and destination of the single-frame or the file. This reservation message is sent to all switches along the origin-destination path reserving the 5 Mbps channel along this path. Note that with the distributed approach, there could be more than one origin-destination path set up at the same time as long as there is no overlapping between the paths. An example for the single-level hierarchy distributed case is shown in Fig. 5.

Consider a data file of 10 pages, 24 lines/ page, 80 characters/line. The data file has 19,200 characters or 154 Kbits. The transmission time over the 5 Mbps channel is 30.7 msecs.

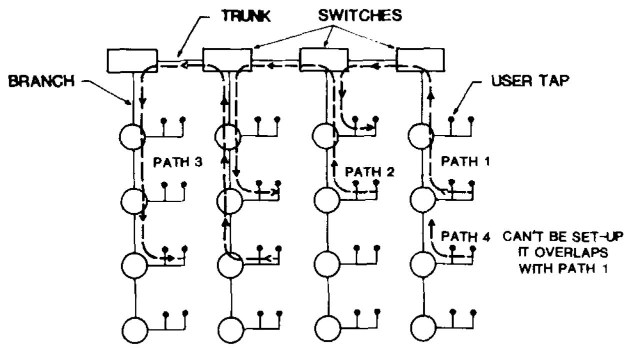

Fig. 5. Three Simultaneous Single-Frame Transmissions over the Mbps Sub-channel.

SINGLE FRAME VIDEO TRANSMISSION

We consider single-frame video transfer as a representative example of wideband traffic. The use of wideband CATV makes transmission of high quality single-frame video possible. Existing teletext and videotext systems, using conventional dial-up networks, of necessity are limited to simple graphics and mosaics. The use of single-frame video may be classified into two major categories:

(i) User-to-database applications: In this category, we would typically have uniformly distributed users accessing centralized databases. Typical applications incude illustrated 'How-To' manuals, art collections, numismatic and philatelic catalogs, car/appliance repair manuals, and travel brochures.

(ii) User-to-user applications: Here the traffic is of the user-to-user variety rather than from centralized databases. This could include multiple locations of a business exchanging video facsimile or teleconferencing, users sharing a picture of their favorite projects with other members of the cable community, signing up on a video dating service(!), or moving patient records between various departments of a hospital.

There are many ways in which single-frame video can be 'shipped' over the cable network. The choices are restricted somewhat by the limited number (typically 4 for sub-split entertainment systems) of return or upstream channels. We propose different strategies for handling each of the two classes mentioned above. The video information can be transmitted either digitally or in analog form.

Digital video has the advantage of allowing flexibility in transmission. It may be combined with other digital data, including voice, and sent out over dedicated circuit-switched channels. This requires more bandwidth than analog transmission, however, and additional hardware is required at the transmitters and receivers to handle the analog-to-digital and digital-to-analog conversions. Digital video may also be packetized and sent over store-and-forward networks.

Analog transmission for single-frame video in a CATV system would be carried out using a full TV channel reserved for this purpose. Reservation for the single-frame TV channel can be done through the 1 Mbps narrowband channel used for the interactive data traffic discussed earlier. As in the case of a single digitized frame, a number of simultaneous single-frame transmissions could occur as long as there is no overlapping between the routes (Fig. 5).

The first category, user-to-database, probably represents the bulk of the traffic. The source(s) may be located at the headend with 'n' broadcast channels allocated for this purpose. Consider the activity on one of these channels. A user interacts with a menu-structured database over the data channel to identify the sequence of video frames that he wishes to view on his home terminal. The frames would probably be stored on one or more video-disc player(s) under control of the database. Each frame, when available, is tagged with the user's address and transmitted over a shared broadcast (analog) video channel. All users expecting a frame, monitor this channel and when they see a frame tagged with their address, they acquire it (in a local frame storage device) for display. Assuming that frames are available to be transmitted at all times, and that NTSC video format is employed, 30 frames/sec may be transmitted, or stated equivalently, the system is capable of servicing 30 users every second on each channel. Each subsequent request for a new frame by a user is serviced similarly. The average delay (response time) is determined in large part by the traffic (request rate for frames) and the number of channels employed. The assumption of zero delay at the database can be satisfied in several ways: (a) Use a large number of source device working in parallel so that a frame is available on one of them at any given time. (b) Use a multiple frame storage device (high-speed) which queues up the frames to be transmitted, guessing the next frame in sequence if necessary.

The following example illustrates the performance of a typical channel:

Assuming a frame transmission time (including overhead) T, of 50 ms, and users requesting frames once every 30 sec., a peak load of 30/T = 600 users may be supported. If a typical user draws upon system resources for an aggregate of 30 min. over a 6 hour daily usage period, the average load that may be supported is 600 x 6 hrs/30 min = 7200 users.

In the example described above, the "users supported" are active users per channel per trunk. If the numbers are deemed acceptable, we see that a system with 4 trunks and 2 channels will support a peak load of 4 x 2 x 600 = 4800 users, and an average load of 57600 users.

In the second category, frames are transmitted from one user to another. Now the broadcast technique cannot work so a dedicated path must be set up between the source and destination. This may be in the form of a dedicated circuit (Circuit-Switching) or a virtual circuit (Packet-Switching) for the duration of a frame transfer. We look at each of these cases in some more detail.

In the circuit-switching scenario, a possible system would be one which uses circuit switches at each of the network nodes to handle the video traffic (fig. 5). The interactive data network can be used to establish and tear down circuits. A recent analysis of the blocking probability, under various load conditions, for this network-architecture, can be found in [7] which yields the following typical results.

Ex 1. #Active users = 8000
Switches = 5
#(Fdx)Channels= 3

With a traffic of	1 frame/100s	block.prob. =	6%
" "	1 frame/200s	block.prob. <	1%
" "	1 frame/1000s	block.prob. <	.1%

Ex 2. If the statistics are changed slightly to:

8000 home users transmitting 1 frame/1000s incl.
100 business users " 100 frames/1000s bp<.5%

If packet switching is used for the video transfers, digitized video is necessary. We assume here that the 1 Mbps data channel discussed earlier, will be used. A digitized video frame is typically 256 kbytes long. Sending this as one packet is not feasible. To break the frame up into smaller packets, the actual packet size would depend on the access scheme chosen. If 1000 bit packets were used, one frame would require about 2000 packet transmissions. On the 1 Mbps data channel, this corresponds to a total time of 90 seconds (2000 x 45 ms) to transfer the frame. Assuming that frame transfers are relatively infrequent, there may be little impact on network statistics. Even a single-frame transfer will nonetheless impact heavily on competing bursty traffic at the time of transmission unless it is spread out thinly over the packet stream. Larger packet sizes would help reduce delay but severely impact the buffer size requirements at the packet switch.

DISCUSSION

In this paper, we have covered some of the issues relating to the design of interactive CATV. The following are closing remarks:

- Distributed switching for data transmission over two-way CATV has a number of advantages over the centralized approach:

  a) it can carry more traffic over a channel with a given capacity

  b) it offers less message delay

  c) it appears to offer reduced ingress noise

- The single-level hierarchy (switches installed only on the trunk) seems to be appropriate for the time being. It requires fewer switches than the two-level hierarchy (switches on both the trunk and the branches) and provides a smaller delay at lower traffic levels. (The two-level hierarchy can accomodate potentially more traffic and can be attained in an evolutionary add-on manner).

- An efficient network protocol is needed to utilize the inherent advantages of the CATV tree topology with the cascaded switches.

- Single-frame video must be considered an important application which offers an advantage over existing systems. Both circuit-switched and packet-switched techniques may be used. If a packet-switching system completely distinct from the data network were to be used, it must be compared in cost and performance against an equivalent circuit-switched system.

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THE ADDRESSABLE SYSTEM CONTROL CHANNEL: WILL IT BECOME YOUR SYSTEM'S WEAKEST POINT?

Anthony Wechselberger

Oak Communications, Inc.

ABSTRACT

This paper will examine the communications channel of an addressable cable system from several standpoints, and bring into focus issues of critical importance as dependence on the "addressability" nature of modern systems becomes more central to their utility. Contemporary marketing trends indicate the future use of addressable boxes will involve extensive use of programmable or downloadable functions (tiering, tagging, addressable box features) in order to enable/disable box functions, facilitate pay per view, or other novel methods of generating revenue.

The following topics will be examined:

1. In-band versus out of band addressing architectures - Arguments can be made toward either technique. The advantages/disadvantages of each will be discussed.
2. Protocol - Control channel instruction sets will be examined with respect to requirements for versatility, growth, efficiency, and ability to tackle current and future needs.
3. Data Rate - Throughout issues relative to requirements for box installation, pay per view, decoder instruction processing speeds and head end computer architecture will be highlighted.
4. Error Control - This involves understanding why the robustness of system data channels to channel impairments is important.
5. Security - An often overlooked fact is that the data channels of addressable boxes is a doorway to service theft.

While the motivations for addressability originally focused on dealing with churn and late (or non) pays, current developments go beyond that. Examination of the relevant control channel issues will ensure that future system requirements aren't sacrificed by addressing limitations.

THE ADVANTAGES OF BASEBAND VIDEO SYNCHRONIZATION

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As television cable systems grow more complex, new problems arise and some become more prominent. One significant problem is co-channel interference. By aligning the synchronizing intervals of all channels, the subjective impairment due to crosstalk can be reduced. This can be accomplished by baseband processing with digital frame synchronizers. A digital frame synchronizer stores the incoming baseband signal and outputs it with the synchronizing interval aligned to that of a reference baseband signal. This storage and retrieval process takes place in the digital domain.

There are other benefits realized with the use of frame synchronizers. Title keying and channel switching techniques are simplified and improved. Since the synchronizing interval is replaced, improvements in post production editing and mixing are achieved. In addition, corrections can be made to the contrast, color and black level.

Co-channel Interference

Within cable systems, co-channel interference degrades signal quality as more channels are added to the system. One of the many factors which adds to these signal degradations is intermodulation distortion (IMD). IMD is caused when a signal with two or more frequency components passes through a non-linear device. The distortion is magnified as the input signal level increases. This can be readily seen on a spectrum analyzer.

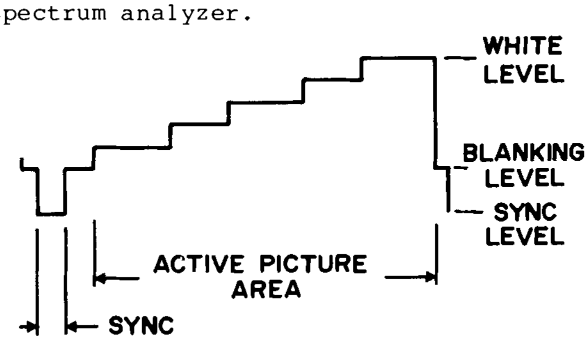

Figure 1.

Figure 1 shows one single horizontal scan line. This signal contains synchronizing and active picture information. The active picture starts with black, stepping towards white. Note that the sync area is below black.

NTSC signals are modulated using the vestigial sideband method. The RF envelope is maximum during sync (fig. 2). Maximum crosstalk occurs, therefore, during the sync interval. There are two benefits for having maximum energy transmitted during sync: (1) The television receiver located a great distance from the transmitter will maintain lock even when the picture may be very noisy and difficult to view. This was a very important feature in North America prior to the advent of cable distribution. (2) It provides a method of readily measuring the peak power output of the transmitter.

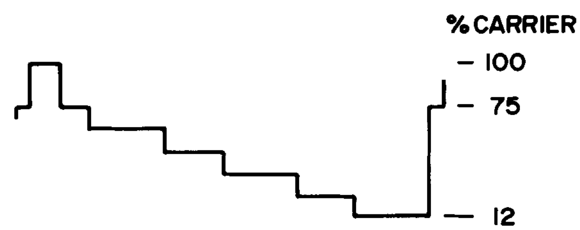

Figure 2.

When two or more non-synchronous TV channels are fed into a non-linear device, such as a line amplifier, the sync periods and hence the crosstalk will move with respect to each other. By matching all sync periods in the time domain, there will be less visible crosstalk in the active picture area. Observing the signal behaviour on a spectrum analyzer will show an apparent crosstalk increase unless the Z-axis of the analyzer is modulated with blankinq. This process of sync alignment (sync lock) must be done with digital frame synchronizers, one for each program channel.

Definition of Baseband Video Synchronizer

A synchronizer matches the timing of a program video signal to that of a master reference signal. This re-timing is done with digital processing techniques and makes use of the segmented nature of the video signal. In the synchronizing process, baseband video may be compared to a clock:

Color sub-carrier is the second hand
Horizontal scan is the minute hand
Vertical scan is the hour hand

The plant, where these signals are to be processed, needs a master reference clock which is obtained from the plant sync pulse generator. The program signal must be timed to this reference clock. Suppose the reference clock hands are pointing at 12:00:00 while the program clock hands are at 4:30:00. This means the program signal is ahead of the reference signal. In order to match the program signal with the reference, a delay of four hours and thirty minutes is needed. The numbers used here are for demonstration purposes only, since each vertical scan takes 17 milliseconds. The required delay can be easily obtained with digital techniques, whereas an analog solution is costly and impractical.

Variable Digital Delay

A variable digital delay device converts an analog signal into digital words. These words are stored in memory and later recalled to match the reference signal. The length of obtainable delay is a function of the size of the available memory.

To give another example, let us assume that the program signal is at 11:58:00 and the reference is at 12:00:00. Since the program signal cannot be advanced by two minutes, it must be delayed by eleven hours and fifty-eight minutes. To add more complexity to the problem, let us further assume that the program signal clock is moving faster than the reference clock. This means that at some point, when the reference clock is at 12:00:00, the program clock will be at 12:01:00. If we were to continue adding delay to match the two clocks, we would eventually require an infinite amount of delay. In the example just given, it would be simpler to drop twelve hours and only one minute of delay would be needed. This keeps the digital delay required at any given time to a minimum.

If the program clock is slower than the reference, adding twelve hours is necessary. Since the program signal is stored in memory, the last twelve hours can be repeated to match the two signals.

I have shown in the foregoing analogy that a video synchronizer uses digital memory to delay and thus align two baseband video signals. I will now briefly describe the Leitch DFP-3000N Digital Frame Processor. This unit contains a full four-field digital memory. Along with providing the necessary delay to synchronize baseband video signals, it also allows adjustment of various signal parameters. This is done on the unit's front panel, using a unique, micropro-cessor-controlled operator interface.

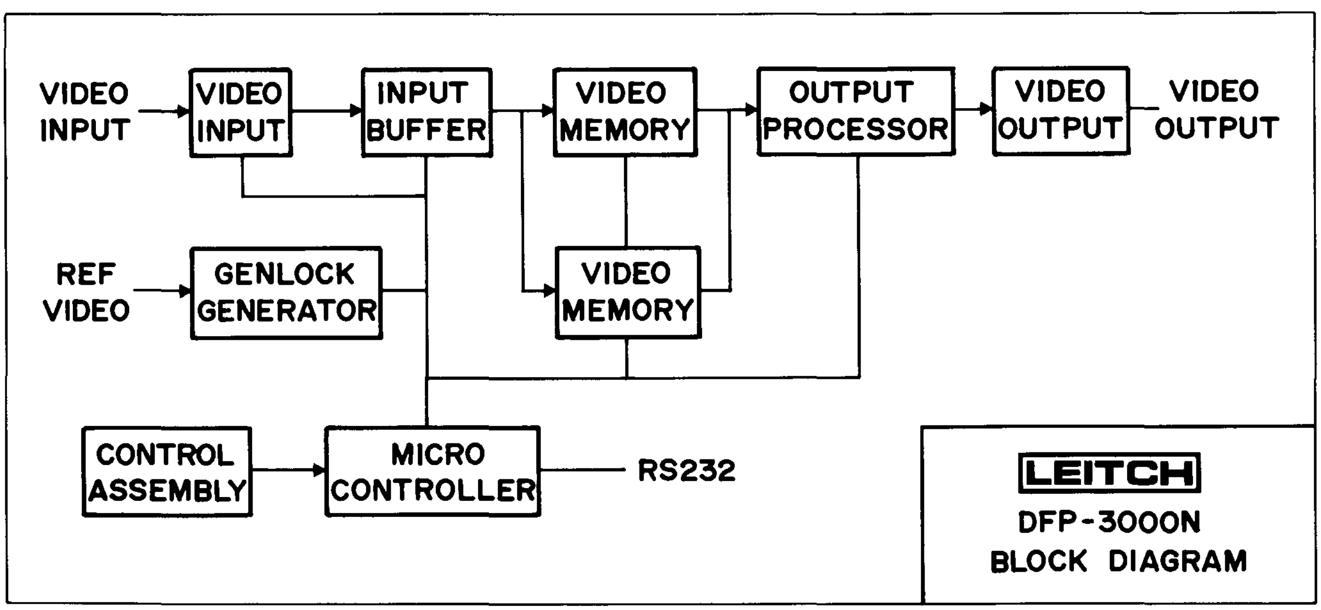

Figure 3.

Video Synchronizer Hardware

The block diagram of a Digital Frame Processor (figure 3) shows two signal inputs and a single output. The program video is fed into a differential input amplifier and then passed through a variable gain stage as well as a chroma gain stage. This signal is DC restored, passed to a sync stripper and also provides an input to an analog to digital converter (ADC). The ADC converts its analog input to an eight-bit word at a 14.3 MHz rate (four times the color subcarrier frequency). Both, video level and chroma gain stages, as well as the DC restoration stage (set-up) are digitally controlled by a microcomputer. The ADC has a fixed dynamic range, and in order to preserve optimum signal-to-noise ratio throughout the system, the variable processing functions are done in the analog domain and before the ADC (quantizing noise). This sampled data, as well as stripped sync, is passed to an input processor board.

The purpose of the input processor board is to convert the program signal data rate to that of the reference. Three first-in-first-out (FIFO) memories are used here and provide more than enough buffer memory in order to allow the synchronization of a single video line. One point of interest here: to save on the amount of memory needed, only the active portion of the video is stored. The sync and burst areas are re-inserted at the output of the system.

Once the program line of video is aligned horizontally with the reference signal, the video must be aligned at the frame rate. To achieve this, 768 kilobytes of memory is used. This memory is split between two boards. Each board has enough memory to store two fields of video. A new type of dynamic ramdom access memory (RAM) is used in the DFP-3000N with a configuration of 64K by one bit and a 256-bit internal shift register. Since there are 768 digital samples taken across each video line, three memory chips are cascaded to provide a 768-bit shift register. This shift register configuration requires only one write and read cycle per video line. Since these cycles require less than 1 microsecond, more than 60 microseconds are available for the microcomputer to access these video RAMs.

The system phase-locks (genlocks) to a reference input signal on the genlock generator board. This genlock generator passes control signals to a microcomputer controller and a blanking processor board. The blanking processor generates most of the signals needed to control the video memory.

The microcomputer receives information from the input and output processors to decide how much synchronization delay is necessary and, in turn, controls the two memory boards. The processor also reads the front panel control assembly as well as the remote panel to provide the necessary processing data to the input circuitry. The DFP-3000N was designed to sense both loss and change in the program signal. These sensors are noise immune and are fed to the microcomputer. The microcomputer correlates the sensed data and adaptively controls the memory. One example of this is how the system will control a non- synchronous switch of program video. The system may freeze the last good field of information until the input stage is re-locked to mask the locking process. It is important to note here that the system will always output stable sync and burst.

An RS-232C port on the microcomputer allows the user direct access to the video memory. Via this port the user may freeze a field or frame of video. This data can then be transferred to a host computer. After manipulation in the computer, the changed data are sent back to the Digital Frame Processor. All processing functions are available via this port. The plant that has several Digital Frame Processors may connect all of the RS-232C ports together through a computer. This allows control of each Digital Frame Processor from a single control point.

A variety of video test signals are also present within the microcomputer's firmware. These are used for diagnostics and calibration.

The synchronized video data from the memory is routed to the blanking processor. Here it is digitally filtered to maintain the correct color. With four fields of memory, the color is always correct without any horizontal shifts. The color is corrected only under field-freeze conditions. Sync and burst signals are now inserted into the data stream. This data is now passed to a digital-to-analog converter (DAC). The output of the DAC is again filtered, amplified and then appears at the 75 Ohm output BNC connector.

Other Benefits

Having described the hardware of the DFP-3000N Digital Frame Processor, I will now briefly discuss further benefits of synchronized syncs within a cable system. When all signal feeds are horizontally and vertically aligned, post production work, such as channel switching or insertion of local program material, becomes glitch-free. Title keying or news flashes can also be added on all channels at once with one generator, or by using the RS-232C port of the DFP-3000N.

The Digital Frame Processor doubles as a processing amplifier. Uniform picture quality on all channels is possible since each Digital Frame Processor allows corrections for color, contrast and brightness. Post production work is improved because the off-air sync and color burst is replaced with stable sync and burst.

A strong local channel is likely to plague a cable system. Its signal manages to interfere with its cable counterpart. Provided that the local station always maintains stable sync, the cable system could use the local channel as a locking reference to reduce blanking bar interference.

Phase-locked cable systems lock only the main carrier of all cable channels to a single reference. The color subcarriers cannot be phase-locked together unless the system is sync-locked. By using DFP-3000N Digital Frame Processors on all channels, not only will all the syncs be aligned, but all of the color subcarriers will also be synchronous. This again provides visible picture improvement.

The author wishes to thank Mr. George Adolph and Mr. Don Jackson for their help in the preparation of this paper.

THE CUMULATIVE LEAKAGE INDEX (CLI) MADE EASY

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ABSTRACT

The Advisory Committee on Cable Signal Leakage developed the Cumulative Leakage Index (CLI) in an attempt to provide a simple, positive means to assure that cable television systems do not interfere with aircraft navigation or communications systems. The CLI represents the best combined efforts of the cable industry, the aviation industry, the Federal Aviation Administration (FAA), and the Federal Communications Commission (FCC) to develop a measurement technique that, when fully employed, will allow extreme freedom for the cable operators to use any desired carrier frequencies on their cables.

For a well-maintained, leak-free cable system, the CLI requires little effort to accomplish. Measurements may be made either on the ground or in the air. Once the CLI has been analyzed and found to be in compliance, the cable operator has a high degree of assurance that no interference will be caused in the airspace.

BACKGROUND

Beginning in the early 1970s, the FAA, the FCC, and the cable television industry became increasingly concerned about the potential for cable television systems to interfere with critical air navigation or communications frequencies. Such a potential exists when cable systems use carrier frequencies within the "aviation band" (108 MHz to 137 MHz) and such cable systems radiate excessively. Only rarely were actual cases of interference reported; however, considering the possible consequences, the interference potential could not be ignored.

On February 10, 1978, the FCC chartered The Advisory Committee on Cable Signal Leakage (Advisory Committee) to examine the nature of the interference mechanisms and to recommend a regulatory approach. Through several field tests, both on the ground and in the airspace, the Advisory Committee found that ground-based measurements could be used to predict signal levels that aircraft would encounter. This prediction method was fully described in the Advisory Committee's final report, dated November 1, 1978. The system became known as the Cumulative Leakage Index. Most basically, the CLI uses ground-based measurements to statistically predict electromagnetic fields in the airspace.

The Advisory Committee's final report developed a CLI for 3000 meters above the cable system (I_{3000}) and then generalized that result to a CLI for an infinite distance above the cable system (I_{inf}). Although I_{3000} may be useful for borderline cases, it requires much more work to analyze. The actual distances between each leak and an imaginary point 3000 meters over the center of the system must be calculated and entered into the formula, along with leakage levels and a percentage factor for the amount of the cable plant actually measured. I_{inf} requires only a summation of actual leakage levels found, divided by the percentage of the cable system actually covered. The method of collection of leakage data is the same for either CLI.

Once the raw CLI has been calculated, it must be shown that $10 \log I_{3000}$ is less than -7 or that $10 \log I_{inf}$ is less than +64. If either condition is met, the system can be assumed to be producing a field of no more than 10 uV/m at 1500 meters above the cable plant. This level should not cause harmful interference to aircraft.

The CLI ground-based measurement technique can generally be used where the cable plant does not extend well above ground level. For example, a community of single family dwellings or relatively low commercial buildings would be a prime candidate for ground-based CLI measurements. An area of skyscrapers would be more suited for "fly-over" type measurements, as the CLI measurements will be accurate only when the measurements are made in close proximity to the cable plant.

For complete details on the CLI, the description in the Final Report of the Advisory Committee on Cable Signal Leakage (Final Report) should be studied. This paper deals with one "simplified" method of making the ground based measurements, as described in the Final Report. Although other implementation methods could be considered, the one described herein allows checking relatively large systems in a matter of hours.

WHAT IS THE CLI?

The Final Report describes the CLI in terms of simple formulas. Because the calculation for I_{inf} is much easier than for I_{3000}, we will consider only I_{inf}. The formula provided in the Final Report is:

$$I_{inf} = (1/P)(E_1 + E_2 + \dots + E_n)$$

where,

P = Percentage of cable system examined (expressed as a decimal)
E = Leakage level at 3 meters (uV/m)

The values for leakage are theoretically actual measured levels at 3 meters from the cable, as measured in accordance with Section 76.609 of the FCC Rules and Regulations. This would involve using a calibrated field strength meter, a resonant dipole, and an actual physical measurement at each leakage location. Although this would provide the most accurate results, the Advisory Committee developed a "simplified" method to make the measurements. The Final Report indicated that the shorter method gave sufficiently accurate results, as compared to the physical measurements at each location.

SIMPLIFIED PROCEDURE

The simplified method basically involves calibrating an "S-meter" in a vehicle against several measurements with the field strength meter and dipole antenna. The participants in the Advisory Committee used a commercial cable leakage detector as the receiver and a magnetically mounted quarter-wave dipole on the vehicle for the tests. Although the Advisory Committee did not try to record the data digitally, that would be a further refinement to the procedure.

To conduct measurements for a CLI, the Advisory Committee recommended that at least 75 percent of the cable system be covered, and that the worst part of the plant be included. Initially, the cable kilometers would be driven, while listening for high leakage on the leakage detector. When leakage of 50 uV/m or greater at 3 meters from the cable was suspected, then the vehicle would be stopped and a physical measurement would be made. After this had been done several times, a calibration chart could be developed to relate the S-meter readings to actual field strengths. Once sufficient confidence had been gained in the S-meter readings, then it would no longer be necessary to stop at each leak and take a measurement. The readings of the S-meter could simply be converted to equivalent field strengths. This simplification would allow a cable plant to be driven, without stopping, in a short period of time. The person making the measurements would merely need to record the maximum S-meter level for any leak suspected of being over the limit. Once back at the office, the engineer could convert the S-meter readings to field strengths and compute the raw and final CLI values.

ACCURACY OF PROCEDURE

The first question related to the accuracy of the simplified leakage measurement technique involves the lack of known distances between the leaks and the vehicle. The Advisory Committee felt that over a large number of kilometers, the variations in distance would average out. That is, sometimes the vehicle would be close to a small leak and thus the leakage value would be distorted to the high side. Likewise, some larger leaks might appear small due to greater distances between the cable and the measurement vehicle. Additionally, assuming that reasonable distances always remained between the cable and the measurement vehicle, any egregious leaks should be found by the system scan.

Second, the accuracy of the prediction of no interference to aircraft could be questioned based on the chance that an egregious leak might be missed with the procedure. The Advisory Committee found that single leaks of relatively high magnitude did not appear to cause excessive interference in the airspace. For example, a single resonant, sleeved dipole fed at trunk level could not be detected at 450 meters above one of the cable systems examined by the Advisory Committee. So, unless a large number of medium to high intensity leaks were missed, the chances of interference would be minimal.

OTHER CONSIDERATIONS

The Final Report described a method of automating the ground-based field strength measurements. At the time of the Final Report, computers and magnetic storage media were fairly expensive, so the Advisory Committee did not envision use of this technique for routine CLI measurements by cable operators. Since 1979, computers have become readily available to the general public at low cost. An improvement on the above described manual procedure would be for the data to be collected by a computer. This would nearly completely automate calculation of the CLI, except for the person driving the measurement vehicle throughout the cable plant.

When using the automated technique, the Advisory Committee used a "fifth wheel" on the vehicle to cause a measurement to be taken every 24 centimeters of distance traveled. This provided several measurements per wavelength and avoided biasing the results by having numerous measurements made at stop lights and few measurements made at highway speeds.

There are perhaps other techniques that can be implemented in the future that will further simplify the CLI. For example, it may be possible to change the measurement location scheme to make data collection easier. In the mean time, the CLI can serve to allow cable operators more freedom in operation on aeronautical frequencies.

Even though offsets from aviation frequencies appear to be an easier solution to the interference question, offsets can provide only a temporary solution. The FAA has "split" the aviation channels several times before. Another split will cause cable carrier channels and aviation channels to be coincident in frequency. Clearly, at that time, low leakage will be the only means by which cable can safely continue to use aviation channels. The time to begin a leakage reduction program is now, not when your system comes in conflict with the FAA.

The views expressed in this paper are those of the author and do not represent an official policy statement of the Federal Communications Commission.

THE ECONOMICS OF GOING ADDRESSABLE

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ABSTRACT

While many cable operators have become acquainted with the state-of-the-art features inherent in addressability, few are aware of the attractive cost and revenue benefits that accompany this technology.

This paper will present a computerized model that was developed to demonstrate the attractive financial benefits of addressability. It compares the decision to go addressable with more traditional CATV approaches, namely, plain and pay cable systems.

The comparison will be made in four key areas: capital investment, operating costs, new profit opportunities, and other addressable advantages (optional).

This is a flexible model capable of accepting individualized inputs and performing analyses based upon various system decisions such as upgrades, replacement equipment or new build. The model provides a customized payback analysis based on the areas of consideration. It can produce "pro-forma" income statements and associated net present value (NPV) analyses.

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INTRODUCTION

"The Economics of Going Addressable" (aka EGA MODEL) was originally developed by Jerrold's Subscriber Marketing department as a sales tool, and it has since evolved into a computerized model to examine the tangible "dollars and cents" benefits related to the implementation of addressability. The model was built into an electronic spread sheet using traditional approaches to Payback and Net Present Value analysis in order to facilitate ease-of-use and quick analysis turnarounds. It's real beauty lies in an inherent flexibility that allows any one analysis to examine the unique considerations of each individual system application.

This economic model can analyze system addressability on its own merits or in comparison to other cable technologies, i.e., plain, pay. Moreover, it effectively handles a large number of key system variables, such as subscriber base, pay revenues, service calls, etc.

EGA MODEL PARAMETERS

Use of the model is initiated by completion of a simple questionnaire (see Exhibit 1). The completed questionnaire provides the model with all necessary inputs for processing the analysis. The inputs considered include:

Type of Addressable Decision

Accounts for factors relating to a new build, upgrade, or replacement decision in relation to the presence or lack of existing product technology.

System Considerations

Information with regard to subscriber base, number of pay services, and converter/descrambler equipment provides input necessary to determine appropriate capital investment considerations.

Operating Cost Considerations

Cost data from previous experience (or estimation) provides a basis for analyzing potential cost savings derived from the decision to go addressable.

Revenue Considerations

Addressability's ease in handling multiple pay services, pay-per-view and impulse-pay-per-view provides consideration for enhanced system revenues.

Additional Factors

Where applicable, the model allows for consideration of some of the less tangible factors involved in cable operations such as theft of service.

EGA MODEL ANALYSIS

These inputs are then integrated and the model run. The following outlines the computations that the model goes through on the way to generating its final output.

Capital Expenditures	Computation/Assumptions
. Addressable Control System	System size and service offerings define chosen controller.
. Scrambler/Encoders	Number of additional scrambled channels times the cost per scrambler
. Addressable Converter/ Descramblers	Number of subscribers (or system TV sets) times the price of the addressable converter or price difference with the alternate converter technology.
. PROM Programmer & Miscellaneous	Summation of the cost for supporting peripherals.
. Converter Installation	Number of addressable subscribers (or system TV sets) times the cost per converter installation
..Total Capital Investment	Summation of Capital Expenditures
Operating Costs	
. Service Call for Pay Change	The cost difference between a per subscriber "truck-roll" (alternate technology) and addressable control computer keyboard entry are factored by a growth rate (%) due to the increased number of pay service offerings
. PPV Set-Up	The cost difference or cost adder (if no plans to offer PPV with alternate technology) is calculated as in "Service Call for Pay Change"; however, the required number of service calls are based on the PPV penetration rate.
..Total Savings in Operating Costs	Summation of Operating Costs
New Profit Opportunities	
. Growth	An annualized figure based on Basic monthly profit per subscriber times growth factor (% of base due to wider service offerings) times 12 months
. Lift	Calculated as in "Growth" item computation except Lift factor and profit are based on Pay Service considerations
. PPV	An annualized figure calculated by average PPV penetration times profit per event times number of events per year
..Total New Profit Opportunities	Summation of New Profit Opportunities

EGA MODEL SUMMARY

At this point, the aforementioned computations and totals are then summarized by the model's output (see Exhibit 2). Output from the model's analysis falls into four key areas:

Capital Investment

Determines and outlines investment in addressable equipment, and when necessary, installation, as required to accommodate "Type of Addressable Decision" and "System Consideration" factors.

Operating Costs

Examines addressability's efficiency in handling service authorization changes compared with alternative technologies, i.e., plain or pay systems.

New Profit Opportunities

One key advantage of addressability is the ease with which it handles a large number of subscriber services and events. If marketed properly, a wider offering of pay services will provide potential for growth, lift and pay-per-view revenues.

Other Addressable Advantages

The model has been used to factor in profit regained as a result of superior signal security afforded by addressable technology. The operator's own theft of service estimates and projections relating to the addressable advantage provided input for this optional analysis.

Once annualized, the total for all segments is summed. This summation provides a payback status after Year 1. From this point, the model easily performs payback analyses and can be carried even further to produce pro-forma income statements and Net Present Value (NPV) analyses.

CONCLUSION

The "Economics of Going Addressable" computer model provides an extremely flexible tool for examining the hard cash flow associated with the benefits of addressable technology. As noted earlier, the model is elaborate enough to generate pro-forma income statements and NPV analyses. It thereby integrates such additional considerations as depreciation and tax factors. Even when taken to this limit, the model leaves the operator with other positive, intangible factors to consider:

. Sale or write-off of existing converters

. Effectively using addressability to improve accounts receivables

. Future revenue growth from improvements in PPV and IPPV delivery methods and offerings

When these and other factors begin to become more tangible to the cable system operator, they (the factors) can and will be integrated into the model. Regardless, today's model still offers an excellent analytical tool for the financial justification of addressability for cable operators who need such information to lend credence to their justification when seeking support from investors and lenders. In brief, the model provided in "The Economics of Going Addressable" can be a useful and effective tool to establish sound financial proof for the decision to go addressable.

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NOTE: The Questionnaire and subsequent Output (Exhibit 2) are completed with fictitious data for demonstration purposes.

- EXHIBIT 1 -

"ECONOMICS OF GOING ADDRESSABLE"

QUESTIONNAIRE

I. TYPE OF ADDRESSABLE DECISION

A. Check One: [x] New Build [ ] Replacement [ ] Upgrade (Add-on Descrambler)
B. If addressability is being considered in comparison to the installation of another technology, check which one: [x] Plain [ ] Pay
NOTE: If nothing is checked in I.B.,the model will analyze addressability solely on its own merits.

II. SYSTEM CONSIDERATIONS

A. Enter Number of Subscribers: 5,000
B. Number of Pay Service levels: current 3 , with addressability 5
C. Enter Model and Cost (per unit) of addressable converter under consideration: Model ADD-1 , Cost $90.00 .
D. If applicable, enter Model and Cost (per unit) of alternative technology converter being considered (ref. I.B.): Model PLA-1 , Cost $40.00 .
Also, if trapping for Pay Service(s), enter: Model TRP-1 , Cost $3.00 (per trap) and check: Reusable [ ], Disposable [x].

III. OPERATING COST CONSIDERATIONS

A. Enter average cost per converter installation $15.00 .
B. Due to service level change, enter: cost per service call $15.00 , and number of service calls per year 2,500
C. Without addressability, would you offer PPV events? Yes [ ] No [x]
If Yes, enter number of events per year ________ and estimate average cost (including service,trap, installation, etc.) per subscriber, per event: Cost ________.

IV. REVENUE CONSIDERATIONS

A. Enter charge for basic service: $9.00 (per sub.) .
B. Enter average charge for Pay Services: $10.00 (per sub.) .
C. With Addressability, enter (or estimate) number of PPV event offerings per year 6 and average charge per PPV event $5.00 .
D. Enter percent of revenue operator retains on Pay Service programming 50% and PPV events 50% .
E. Addressability Growth Factors: Based on feedback received from current users, the following growth factors have been assumed by the model.
(NOTE: Factors (1) and (2) are based on a wider variety of Pay offerings as facilitated by Addressability's ease in accomplishing service change). If you disagree with any of the assumed growth factors, please enter your own estimate:
(1) 5% growth in subscriber base. Customer estimate ________%,
(2) 25% lift factor (25% of subscriber base). Customer estimate ________%.
(3) 15% penetration on PPV events. Customer estimate ________%.

V. OTHER FACTORS (Please describe in detail)

- EXHIBIT 2 -

"ECONOMICS OF GOING ADDRESSABLE"

OUTPUT

I. CAPITAL INVESTMENT:

.	Addressable Control System	$ 16,500	
.	(2) Scrambler/Encoders	$ 3,200	*1
.	(5,000) Addressable Converter/ Descramblers ($90/each)	$450,000	
.	Less (5,000) Plain Converters ($40/each)	($200,000)	*2
.	PROM Programmer & Miscellaneous	$ 3,000	
..	Subtotal	$272,700	
.	Converter Installation	0	*3
...	Total Capital Investment	$272,700	

*1 Required to accommodate 2 additional Pay Services with Addressability (See II.B. on Questionnaire).

*2 Since this sample analysis involves a new build where installation of alternative technologies is being considered, the cost delta between alternative converters is used.

*3 The cost of installation is a washout as it would also be required if the alternative was selected.

II. OPERATING COSTS:

– Service call for Pay change			
Plain System:			
. Cost of Trap	$ 3.00		
. Cost to Service	$ 15.00		
.. Sub-Total	$ 18.00	(x)	
. Subs requiring Change (per year)	2,500		
.. Sub-Total	$ 45,000		
Addressable System:			
. Cost to Service (Computer Entry)	$ 1.25	(x)	*4
. Subs Requiring Change (per year)	2,500	(x)	
. Growth Factor (due to increase in number of Pay services)	$ 1.25		
.. Sub-Total	$ 3,906.25		
– PPV Set-Up			
Addressable System:			
. Cost to Service (Computer Entry)	$ 1.25	(x)	
. Participating Subs (15% of Base)	750	(x)	
. Number of Events (per year)	6		
.. Sub-Total	$ 5,625		

... TOTAL SAVINGS IN OPERATING COSTS:

$45,000 (Pl.) - $3906.25 (Add.) - $5625 (Add.) = $35,468.75
Service Charge — PPV Set-Up

*4 Very conservatively estimates, one computer operator being paid $12.50/hr. making the change in 6 minutes. ($12.50/hr x .10 hrs = $1.25 per authorization change)

- EXHIBIT 2 -

"ECONOMICS OF GOING ADDRESSABLE"

OUTPUT

III. NEW PROFIT OPPORTUNITIES:

- Growth			
. Sub Growth (5% of Base)		250	(x)
. Monthly Profit per Basic Sub (50% of $9.00)	$	4.50	(x)
. Annualized		12	
.. Sub-Total	$	13,500	
- Lift			
. Sub Lift (25% of Base)		1,250	(x)
. Monthly Profit per Sub Pay Service (50% of $10)	$	5.00	(x)
. Annualized		12	
.. Sub-Total	$	75,000	
- PPV			
. Participating Subs (15% of Base)		750	
. Profit per Sub Event	$	2.50	
. Number of Events (per Year)		6	
.. Sub-Total	$	11,250	

... TOTAL NEW PROFIT OPPORTUNITIES:

$13,500 (Growth) + $75,000 (Lift) + $11,250 (PPV) = $99,750

IV. YEAR ONE SUMMARY:

(-) Capital Investment	($272,700.00)
(+) Operating Cost Savings	$ 35,468.75
(+) New Profit Opportunities	$ 99,750.00
Payback Status after Year 1	($137,481.25)

V. PAYBACK ANALYSIS:

($272,700)/135,218.75 = 2.02 years.

THE IMPACT OF MULTICHANNEL TV SOUND ON THE CABLE SYSTEM HEADEND

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ABSTRACT

Although the Federal Communications Commission (FCC) did not rule on a Multichannel Television Sound (MTS) standard, they did protect the Electronic Industry Association's (EIA) recommended system. As such, the FCC has created a de facto standard for the transmission and reception of MTS.

This paper summarizes the effect of the MTS de facto standard on the cable system's headend equipment. Although other cable carriage schemes are in use today to supply satellite stereo services, this paper will only consider in-band carriage of the MTS signal. No judgements will be made concerning the audio performance of the MTS signal. Also discussed will be an overview of the modifications and equipment necessary for upgrading the headend to accommodate the MTS signal.

Since the FCC recently decided to indefinitely delay the decision to impose cable must-carry for MTS, no attempt will be made in this paper to anticipate any future FCC decision concerning this issue.

THE HISTORY OF MULTICHANNEL TELEVISION SOUND - A BRIEF CHRONOLOGY

In 1961, the Federal Communications Commission (FCC) decided on and approved a single stereo transmission system for FM radio. More than two decades later, in a time when Federal intervention was being downplayed, the FCC approved the use of sub-carriers for AM stereo, but did not choose a single AM stereo radio transmission system. Rather, they allowed the marketplace to decide. On March 29, 1984, the FCC approved the expanded use of the television aural baseband for stereo, second language service, and any other broadcast or non-broadcast purpose and also, like AM stereo radio, did not decide on a particular transmission system. To avoid a repeat of the present AM stereo radio controversy, however, the FCC protected the EIA's recommended MTS system and, in effect, created a de facto standard.

All problems solved, right? Not quite. During the decades which followed FM stereo radio, an entire cable television industry was developing. By 1984, more than 30 million subscribers were being served by over 7000 cable systems throughout the nation. These systems employ various generations of equipment and technology. Many are small 12 channel systems with limited bandwidth and outdated technology, while others have excess capacity and utilize state-of-the-art technology. Regardless of the available bandwidth or technology employed, these systems will have to deal with the issue of MTS. The driving forces behind cable system implementation of MTS could be any or all of the following:

1) A future must-carry mandate from the FCC.

2) Subscriber demand.

3) Revenue generation.

4) Franchise requirement.

Must-Carry Mandate

The decision regarding whether cable systems should be forced to carry the MTS signal, and in what format, was indefinitely delayed recently by the FCC. The cable industry had strongly argued against must-carry on the grounds of system incompatibility and resultant high cost to upgrade. The broadcast industry, on the other hand, had argued that copyright laws prohibit the modification of protected programs and, therefore, cable systems should be required to supply the MTS signal to the subscriber. The FCC compromised by directing its Mass Media Bureau (MMB) to annually monitor market penetration of MTS braodcasts and MTS compatible receivers. The MMB was also directed to monitor the voluntary implementation of MTS by cable systems. In the meantime, the must-carry issue will remain open until such time the FCC solicits a new round of comments on the subject. Cable operators should, therefore, not overlook the possibility of a future must-carry mandate from the FCC.

Subscriber Demand

Most TV receiver manufacturers have recently announced the availability of multichannel sets. Some consumer electronics manufacturers have also announced availability of MTS adapters to convert monophonic sets to stereo. These announcements have undoubtedly created a consumer awareness of MTS. With this awareness comes unrealistic expectations from the cable subscriber that they will soon be receiving MTS via cable. Subscriber demand for MTS, whether founded or unfounded, will be a factor which cannot be overlooked by the industry.

Revenue Generation

MTS consumer awareness and resultant demand has created an opportunity for operators to generate additional revenue. Broadcasters are well aware that advertising revenues can be increased when native language programming is accompanied by native language commercials. Cable operators serving non-English speaking communities, in the same way could increase their advertising revenues by utilizing the second language program of the MTS standard. Major networks have already test-marketed bilingual broadcasts in non-English speaking markets and have had excellent results.

Those ignored stereo satellite services could also be offered in or out-of-band for additional revenue. For the consumer not sold on cable, these expanded audio services could help add subscribers and increase penetration.

Franchise Requirement

Although program material with bilinqual audio is limited in its availability at present, major city systems, in the future, may be required by franchising authorities to carry second language service for non-English speaking residents. The transmission of MTS will proliferate the availability of bilinqual programming as broadcasters seek to expand their market penetration and advertising revenues.

THE MULTICHANNEL TELEVISION SOUND SYSTEM

The objective of the EIA's Broadcast Television Systems Committee (BTSC) was to arrive at a single multichannel television sound transmission standard which would incorporate a compatible main channel, a full quality stereo sub-channel, a lesser quality seperate audio program (SAP) sub-channel and the potential for a professional sub-channel for telemetry purposes. Following initial testing, it was determined that some form of noise reduction would be necessary to compensate for the lower signal-to-noise ratio associated with the wider audio bandwidth of the MTS signal.

Of the three proposed transmission systems considered by the EIA, a single system was recommended which met the above objectives. As illustrated in Figure 1, the recommended BTSC MTS system consists of a main channel containing both left and right audio signals. The main channel pre-emphasis, bandwidth and audio deviation are identical to the current monophonic standard, i.e. 75 usec, 15 KHz and $\pm$25 KHz respectively, and is therefore fully compatible with non-stereo TV receivers.

To separate the left and right audio signals, the stereo sub-channel contains the difference of left and right and has an effective bandwidth of 15 KHz with a sound carrier deviation of $\pm$50 KHz. The combined audio deviation of the main and stereo sub-channel is $\pm$50 KHz, since by definition, both signals cannot be maximum at the same time. The stereo sub-carrier uses double sideband suppressed carrier amplitude modulation with the sub-carrier locked to twice the horizontal scanning frequency. Dbx companding or noise reduction is added to this channel to improve the signal-to-noise ratio. The companding process also provides an improvement to the usual pre-emphasis technique for the stereo sub-channel. A pilot signal at the horizontal scanning frequency, causing a deviation of $\pm$5 KHz, provides the necessary reference signal to control the stereo decoder in the TV receiver.

The SAP sub-carrier is locked at 5 times the horizontal scanning frequency and is frequency modulated with a bandwidth of 10 KHz and audio deviation of $\pm$15 KHz. To boost the signal to noise ratio of this carrier, dbx companding is also incorporated and provides an improvement to the usual pre-emphasis technique. Finally, the professional sub-channel has its sub-carrier located at 6.5 times the horizontal scanning

THE BROADCAST TELEVISION SYSTEMS COMMITTEE (BTSC)
MULTICHANNEL TELEVISION SOUND SYSTEM

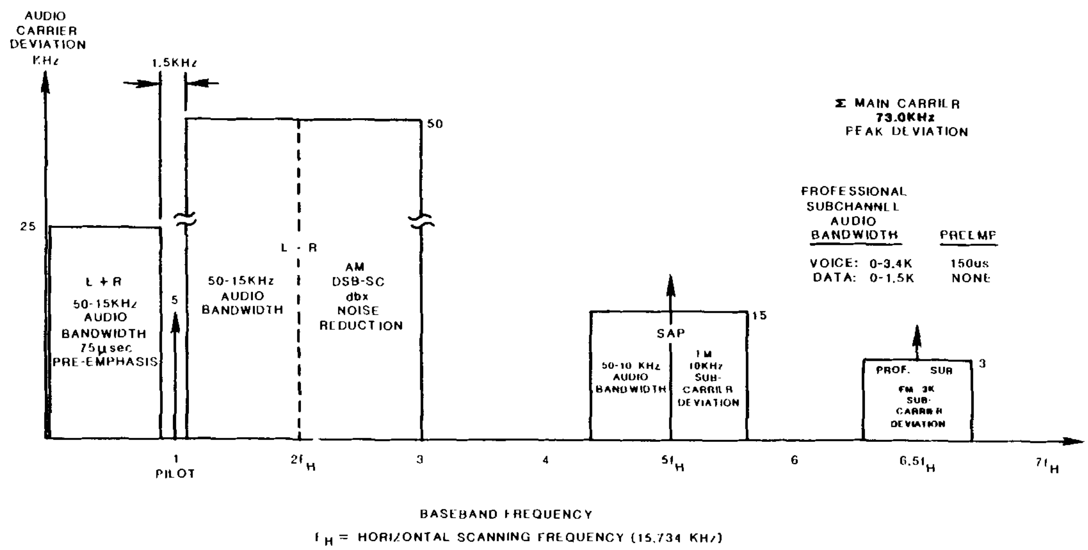

FIGURE 1

frequency and has a bandwidth of 1.5 KHz to 3.4 KHz (depending on the type of modulating signal) and audio deviation of $\pm$3 KHz.

IMPACT OF THE BTSC MULTICHANNEL TELEVISION SOUND SYSTEM ON THE CABLE SYSTEM HEADEND

The cable system headend has experienced many technological changes over the last 25 years. From the earliest strip amplifier processing, utilizing vacuum tubes, to today's surface acoustical wave (SAW) filter processing utilizing integrated circuitry, the headend has evolved to meet the increased performance and bandwidth requirements of today's sophisticated systems. Because of the various technologies of headend systems in operation today, the BTSC MTS system will impact each in different ways. Three types of off-air headend processing are in varying use today: strip amplifier processors, demodulator-modulator baseband processing and heterodyne processors. Figure 2 summarizes the impact of the MTS signal on each type of headend processing method.

Strip Amplifier Processors

Strip amplifier processors are typically associated with small channel systems and over the years have gradually been replaced with heterodyne processors. The expanded bandwidth of the BTSC MTS system may not pass the sound trap of the strip amplifier processor without distortion, and thus, only the main channel (L + R) signal would be unaffected. Depending on the particular design of the strip amplifier processor, modification to the sound trap circuit may be possible so that both the main channel and the stereo sub-channel would have acceptable distortion. Most likely it would not be possible to pass the SAP sub-channel. However, caution should be given to the effects that widening the sound trap will have on the video passband. Widening the sound trap will decrease the video passband. It is recommended that the strip amplifier processor manufacturer be consulted to determine if the design will support a modification for MTS and to what extent the modification will support MTS, i.e: main channel, stereo sub-channel and SAP or just the main channel and stereo sub-channel.

Demodulator-Modulator Baseband Processing

This type of processing utilizes a demodulator to convert the received off-air signal to an intermediate frequency (IF) and then to baseband. The baseband signal is then fed to a modulator which remodulates the signal to the desired cable channel frequency. The demodulator incorporates an IF sound trap network which is designed to remove any residual IF sound from the IF video signal. This trap may not handle the wider bandwidth MTS signal and, therefore, may

MTS HEADEND IMPACT

HEADEND PROCESSING METHOD	SOUND TRAP BANDWIDTH MODIFICATION	SOUND IF BANDWIDTH MODIFICATION	AUDIO MODULATION BANDWIDTH MODIFICATION	AUDIO DISCRIMINATOR BANDWIDTH MODIFICATION	PRE-EMPHASIS DISABLE	DE-EMPHASIS DISABLE
STRIP AMPLIFIER	X	N/A	N/A	N/A	N/A	N/A
BASEBAND DEMODULATOR-MODULATOR	X (Demod. Only)	X	X (Mod. Only)	X (Demod. Only)	X (Mod. Only)	X (Demod. Only)
HETERODYNE PROCESSOR	X	X	N/A	N/A	N/A	N/A

Figure 2

distort the video. De-emphasis must also be disabled to eliminate incompatibility with the stereo sub-channel and SAP. The audio detector and baseband circuits must also be checked for sufficient bandwidth for compatibility with the MTS signal.

Concerning the modulator, the increased bandwidth of the MTS signal will require a modification to the audio modulation circuitry. The Jerrold Commander IV modulator, model C4MS, for example, has been modified to increase the baseband audio bandwidth to accommodate the MTS signal. The pre-emphasis was also made operator selectable so it could be disabled when modulating with an MTS signal. Both the audio bandwidth and pre-emphasis modifications on the Jerrold C4MS modulator were made to the audio modulator module (CAM). This module is a plug-in type and can be quickly and easily replaced in the field with a MTS compatible version (CAMS) for Commander III and IV modulators.

Heterodyne Processors

The heterodyne processor is the workhorse of headend off-air signal processing. Since demodulated baseband video and audio signals are not typically utilized in the headend, the heterodyne processor can process and channel convert an off-air signal more cost effectively than a demodulator-modulator system. The heterodyne processor heterodynes or mixes the off-air signal with a signal from the local crystal controlled oscillator to produce a stable IF. The IF is then amplified and heterodyned back to a particular cable channel frequency. As in the case of the demodulator, the bandpass of the sound trap must be increased to accommodate the wider bandwidth MTS signal. The sound trap bandpass on the Jerrold Commander IV processor, model C4P, for example, was increased to accommodate the MTS signal. It is important to note that subjective testing has shown that with accurate alignment all generations of Jerrold Commander series processors (CI through CIV) can be used to process the MTS main channel and stereo sub-channel signals with minimal impact on performance.

When the sound trap is widened to accommodate the MTS signal, the video IF passband is slightly decreased. In the case of the Jerrold Commander IV processor, the overall video IF bandwidth was reduced from approximately 4.2 MHz to 4.0 MHz relative to the picture carrier. This has been found to have no effect on subjective resolution, even on "full bandwidth" type receivers. For full compatibility with the MTS signal, Jerrold Commander III and IV processors can be field upgraded by replacing the IF amplifier module (CIA) with an MTS compatible module (CIAS). This module is located in the center slide-out drawer of the processor and replacement can be easily accomplished without removing the unit from the cabinet or rack.

THE MTS COMPATIBLE HEADEND SYSTEM

Figure 3 illustrates a typical headend system designed to process the MTS signal in-band. Off-air MTS signals are processed by a modified heterodyne processor. Processing satellite signals in the MTS format will be more difficult than processing off-air MTS broadcasts. Since stereo satellite services utilize various stereo transmission formats and are not expected to be standardizing in the near future, a compatible stereo decoder/demodulator will be necessary to provide baseband audio inputs to a MTS

MULTICHANNEL TELEVISION SOUND (MTS) HEADEND SYSTEM

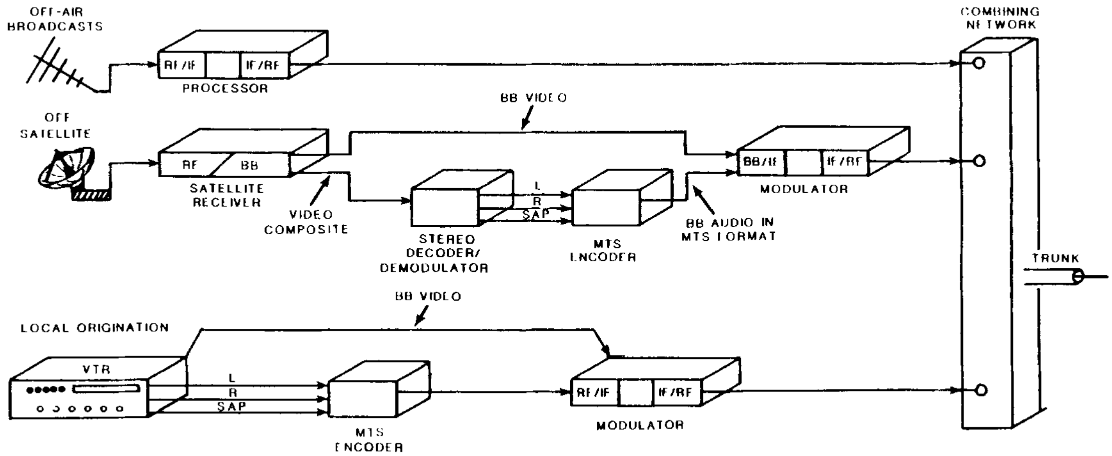

FIGURE 3

encoder. The MTS encoder generates the MTS baseband audio signal and would incorporate the necessary dbx companding and pre-emphasis. The MTS baseband audio signal is then fed to the audio input of the modified modulator and up-converted to the particular cable channel frequency. Local origination baseband audio inputs would be directly connected to the MTS encoder and then to the modified modulator. All signals would then be combined, as usual, before distribution.

CONCLUSIONS

Regardless of any future FCC decision concerning MTS must-carry for cable systems, market demand will be a driving force for determination of the cost versus technical feasibility and revenue potential of MTS implementation. With almost 1600 U.S. TV stations, including permittees, on record in 1984 and preliminary industry surveys indicating that more than 40% are planning to add MTS, means that more than 600 geographic areas will be soon served by MTS broadcasts. Taking a conservative average of 5 off-air channels carried per cable system, and cutting in half the industry surveys for broadcasters adding MTS, yields the fact that at least 1 must-carry off-air channel in every cable system will be broadcast soon in the MTS format. How soon is unknown. However, it cannot be overlooked that 1985 will begin with at least 15 TV stations regularly broadcasting MTS. These stations will ultimately affect at least 1 cable system in 20 or over 350 systems at the start of 1985.

As broadcasters add MTS capability and promote it accordingly, the cable subscriber will become very aware of MTS program availability and the availability of MTS TV receivers. It is expected that over 2 million MTS capable TV receivers will be sold in 1985. Some receiver manufacturers have even announced that MTS decoders may be standard in all receivers within 2 years. This will mean that the same questions that operators had to face when subscribers asked why their new "cable-ready" set could not give them premium services at basic rates or why their TV remote control was rendered useless when they added cable must again be faced when their subscriber asks why his $1,000.00 stereo TV set will not receive the stereo off-air broadcast the manufacturer promised. Even more serious will be the problem of retaining the subscriber when he reconnects his off-air antenna and enjoys the "free" stereo broadcast. It is time that cable operators look at ways to turn the MTS "problem" into an "opportunity" for additional revenue and/or increased subscriber penetration.

THE IMPACT OF THE NEW FCC FREQUENCY RULES ON CATV HEADEND SYSTEM DESIGN AND OPERATION

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The report and order of October 26, 1984, amended part 76 to add cable carrier frequency requirements for operation in the aeronautical radio bands. While these new rules provide for universal compatibility with aircraft radio operations and eliminate the need for channel by channel approval, they also present new technical problems for the headend equipment manufacturer and the headend system operator. The newly specified carrier frequencies are offset from the standard assignments but the greatest source of difficulty will be the increased frequency accuracy requirements. In some cases, the rules cannot be met with conventional circuit technology or system design methods.

An assessment of the effect of these rules is presented. The impact on headend product design and specifications is reviewed. Changes in headend system design concepts, operating conditions, channelization strategies and maintenance requirements are discussed. The special case of HRC system operation and the new requirements for reference frequency generators is explained. Finally, consideration is given to the implications for existing headend systems and to possible effects on broadband system and subscriber terminal operation.

INTRODUCTION

For some time, the Federal Communications Commission has sought a permanent solution to the problem of controlling the use, by CATV systems, of frequencies within the bands allocated for aeronautical communications and navigation uses. The first report and order of July 27, 1977, was an interim solution based on minimum offset or separation from emergency frequencies and locally used aircraft communications and navigations frequencies.

In the FCC's second report and order of December 17, 1984 a fundamentally different approach to the aeronautical interference problem was adopted. This new approach, based on the concept of precision frequency offset, places every potentially offending carrier at a frequency that is halfway between two FAA navigation or communication frequencies. If this frequency interlacing is done with enough precision, then there will be sufficient separation between any aeronautical frequency and the potentially interfering cable frequency to cause the interference heterodyne beat to be inconsequential. By placing this requirement on all cable carriers that fall within aeronautical bands, the minimum separation is assured regardless of the specific aircraft or cable frequencies in use. This otherwise 'clean' concept is somewhat soiled by the fact that different frequency spacings are used in the aeronautical communications bands (25 KHz) and navigation bands (50 KHz). This in turn requires CATV carriers falling into these bands to be offset differently. The overall advantage of these new rules, then, is that the methodology is completely universal, that the need for individual frequency use clearances is eliminated, and that enforcement is simplified.

REVIEW OF THE FREQUENCY RULES

The original rule was adopted to control the accuracy of adjacent carrier spacings. It continues to apply to the frequency of picture carriers for CATV channels which do not fall into aeronautical bands. The requirement is specified in section 76.605 of the FCC rules: "The frequency of the visual carrier shall be maintained 1.25 MHz +/- 25 KHz above the lower boundary of the cable television channel . . . ". This +/- 25 KHz accuracy has been used as the basic frequency accuracy requirement for CATV headend modulators and processors.

The Original Aircraft Band Rules

The first rules for the useage of aeronautical frequency bands were established by the first report and order of July 1977. These rules are based on minimum frequency separation from emergency frequencies and from aeronautical frequencies in use within 60 nautical miles of any part of the CATV system. Specifically, part 76.610 required system carriers to be offset by at least 100 KHz from the emergency frequency 121.5 MHz and active frequencies in the aircraft communications bands at 118-136 MHz, 225-328.6 MHz and 335.4-400 MHz. A 50 KHz minimum offset was required from emergency frequencies 156.8 MHz and 243 MHz and active aircraft navigation frequencies in the 108-118 MHz and 328.6-335.4 MHz bands. It was the responsibility of the system operator to determine which frequencies were in operation within 111 kilometers of the system and to obtain a clearance to use each such FAA band carriers. Later changes in local aeronautical frequency usage had to be accommodated by the operator in the same way.

The New Rules for Aeronautical Band Frequency Useage

The current rules, specified by part 76.612, were adopted in late 1984. 76.612 applies to all CATV carriers at a level at or above 38.75 dBmV at any point within the distribution system that fall within the aeronautical bands 108-136 MHz and 225-400 MHz. These bands correspond to CATV channels 14-16, 24-53, 98 and 99, using EIA IS-6 numbering. The magnitude of the required frequency offset depends upon whether the carrier in question falls within an aeronautical communications or navigation band.

Standard aircraft communications frequencies are assigned every 25 KHz while air navigation channels occur every 50 KHz. Therefore, CATV carriers falling into communications bands (channels 14-16, 24-41, 43-53) must be offset by 12.5 KHz while CATV carriers falling into navigations bands (channels 98, 99, 42) must be offset by 25 KHz. In both cases, the maximum error permitted for the offset frequencies is +/- 5 KHz.

Harmonically related carrier operation is covered by a separate provision which requires that the fundamental frequency from which all picture carrier frequencies are derived must be 6.000300 MHz with an accuracy of +/- 1 Hz.

The progression of rules and their effects on system operation is summarized in Table 1.

SYSTEM OPERATION WITH HARMONICALLY RELATED CARRIERS

HRC systems and other coherent carrier systems will meet the new specifications if locked to a reference frequency generator which itself meets the new frequency and stability requirements. By far the most technically difficult of these is the requirement for the HRC reference frequency. The maximum allowable error for the 6.000300 MHz reference of 1 Hz is

	Non-Aviation Band Rules (pre-1977)	1st Report and Order (1977)	2nd Report and Order (1984)
Frequency accuracy	+/- 25 KHz	+/- 25 KHz	+/- 5 KHz in aircraft bands
Frequency offset in COM bands	n.a.	100 KHz offset from active COM band frequencies	12.5 KHz offset from all COM band frequencies
Frequency offset in NAV bands	n.a.	50 KHz offset from active NAV band frequencies	25.0 KHz offset from all NAV band frequencies
HRC system special considerations	none	conflicting ch. frequencies cannot be used	basic ref. freq. is 6.0003 MHz +/- 1 Hz
IRC system special concIderations	none	conflicting ch. frequencies cannot be used	cannot phaselock chs. 42, 98, 99: wrong offset

Table 1 - FCC Frequency Rules Progression

the same as 1.67 x 10-7 or 0.16 maintained within this limit over a practical operating temperature range and over a reasonable service interval. It has been frequently suggested that a rubidium frequency standard is the only means for accomplishing this. A rubidium standard based reference would, in fact, meet the requirement with a large margin, having a long term stability of about 0.0001 parts per million per year. A most cost effective solution is available in the form of a precision ovenized quartz crystal oscillator. These are available with long term stabilities as high as about 0.034 parts per million per year, which corresponds to a calibration life of about 5 years. It should be noted that individual headend channel modulators and processors should not require modification since the outgoing frequencies are determined entirely by the reference generator and the small frequency shifts should be well within the capability of any existing phaselocking system.

SYSTEM OPERATION WITH INCREMENTALLY RELATED CARRIERS

A reference frequency generator for IRC operation must produce a comb of carriers whose frequencies conform to the FCC rules for aeronautical communications bands. In other words, they must be offset from normal assignments by 12.5 KHz with an accuracy of +/- 5 KHz. Note that it is not necessary that all comb signals be accurate to within +/- 5 KHz, only those that fall between 120 and 400 MHz. Since channels 42, 98 and 99 are actually within aircraft navigation bands rather than communications bands, the FCC frequency rules for these bands are not met when these channels are phaselocked to the reference comb. The result is that for IRC operation, these channel assignments are unusable. As with HRC system operation, compliance with FCC rules results from the use of an FCC specified comb generator and does not require modifications to modulator or processor equipment. In the case of phaselocked i.f. to channel converter systems that also have a non-phaselocked crystal controlled mode of operation, an operator may desire to make modifications to obtain FCC compliance in this mode if it is used for backup operation. Phaselock type converters used in crystal controlled mode for non-phaselocked applications must be modified.

NON-PHASELOCKED SYSTEM OPERATION

The output frequency requirement for non-phaselocked systems amounts to meeting the COM band and NAV band offset rules on a channel-by-channel basis. Channels 14-16, 24-41, and 43-53 must be offset by 12.5 KHz and channels 42, 98 and 99 must be offset by 25 KHz.

Crystal Control of Output Frequency

For any crystal controlled headend equipment the required offset can be obtained by replacing the crystal that controls the i.f. to output channel frequency conversion. Obtaining the required frequency accuracy will be more difficult. The frequency inaccuracy of a crystal oscillator is comprised of two factors: the initial or setting accuracy and the drift. The important components of drift are the aging rate, which may be significant for long term operation, and the temperature stability, which determines the environmental requirements. Both the crystal characteristics and the oscillator circuit design influence these factors. Crystals used in premium headend converters have a setting accuracy of 0.001% which corresponds to a 4.4 KHz error at channel 53. Since this error nearly equals the FCC accuracy spec without even having allowed for circuit error or drift errors, it is necessary to be able to trim the frequency in circuit to compensate for the crystal error. This means, in this case, that a crystal oscillator design that permits the oscillation frequency to be pulled a few kilohertz may be advantageous. The acceptable limit on initial error is a matter of judgement; the smaller the setting error the more room for subsequent drift.

Headend Modulators

The two sources of frequency error in a modulator are the generation of the i.f. picture carrier and the i.f. to channel frequency conversion. In general, the modulator's internal crystal-controlled 45.75 MHz oscillator should not be a major source of frequency error. Acceptable accuracy for the i.f. to channel upconversion should be possible by a combination of precise setting of crystal oscillator frequency and control of the equipment operating temperature. A practical error budget might allocate 0.5 KHz to basic i.f. error, 1.5 KHz to upconverter l.o. basic error and 3 KHz to total drift error. Where i.f. program switching is used the external i.f. picture carriers must also be precise in frequency. Off air processors present a special problem in i.f. frequency control, as we shall see.

Headend Processors

The problem of frequency conversion error is compounded in heterodyne RF processors because these devices employ at least two frequency conversions, each with an associated frequency error. This means that a heterodyne processor is fundamentally twice as inaccurate as a modulator so that each conversion would have to be twice as accurate. In many cases, the input conversion will be from a UHF channel requiring an l.o. frequency as high as 847 MHz. This further reduces the allowable l.o. tolerance because a total input conversion frequency error of 2 KHz corresponds to an l.o. accuracy of about 2.5 part per million. Adding to all of this is the realization that the broadcast signal itself can contain a significant frequency error, either from an assigned +/- 10 KHz offset or from the basic inaccuracy of a low grade source. While it may be possible to select an input conversion crystal that compensates for the broadcast offset and an output crystal that provides for the FAA offset and then trim and maintain the frequencies of both oscillators within very small errors, this is certainly not a comfortable, confidence inspiring approach.

There are other methods for accommodating broadcast channels that produce no more difficulty or risk than with origination channels. The first and easiest is strategic: Don't convert broadcast channels to aeronautical band channels. If VHF and UHF broadcasts can be placed onto channels 2-13 and 17-23, the nineteen channels <u>not</u> subject to the rules, then the processor problems are neatly avoided. Where this is impossible, demodulator-modulator processing is an effective solution. An additional approach utilizes processors equipped for output phaselock. If such a processor is phaselocked to a reference generator whose frequencies meet the FCC rules then the other sources of frequency error in the processor are automatically removed. If several such processors shared a comb generator, the cost per channel might compare favorably to the demod-remod approach.

UPGRADING EXISTING HEADENDS

Channels that were in operation or were approved when the new rules became efective are grandfathered under the old rules until January 1, 1990. Grandfathering is applied on a frequency basis rather than a system basis so that new channel additions to a grandfathered system that fall into the aeronautical bands must comply with the new rules for frequency usage. In addition, systems extending their service radii or adding communities will fall under the new rules so that operators will want to upgrade to the requirements of 76.612 well before the 1990 deadline.

In systems employing harmonically related or incrementally related coherent carriers, the headend output picture carrier frequencies are determined by the reference comb generator. If a comb generator is employed whose frequencies conform to the FCC rules, then the system carriers will also conform and no changes to the headend equipment are required. The small offsets from the normal picture carrier frequency assignments should not be incompatible with tuning or phaselock operation of the headend i.f. to channel converters.

Harmonically Related Carrier Headends

HRC comb generators employ a single 6 MHz oscillator plus circuitry to generate harmonics of this basic 6 MHz signal. Such a comb generator is made FCC compliant by substituting a precision 6.000300 MHz oscillator unit for the conventional crystal oscillator. The precision oscillator unit may be located within the comb generator's chassis or external to it, depending on a particular manufacturer's preference. As an example, Jerrold's Model CPG-HHS comb generator is produced from the non-FCC version by installing a precision oscillator unit within the main chassis of the comb generator. The precision oscillator is powered from the generator's internal DC supply and its output is connected to the comb generation module via the existing plug-in coaxial interface. The comb module is internally modified such that the harmonic generation circuit is driven by the external (to the module) 6.0003 MHz signal instead of the built-in crystal oscillator. It should be possible to similarly modify other existing HRC comb generators.

Incrementally Related Carrier Headends

IRC comb generators also use a crystal controlled 6 MHz oscillator and harmonic generator to produce a basic comb signal. This comb is combined with a second crystal controlled local oscillator signal to produce a final comb with a 1.25 MHz offset fom the HRC comb. The additional frequency shift required for compliance with the rules for operation in aeronautical communications bands is obtaied by replacing the second l.o. crystal. The actual crystal offset will depend on circuit design details. It is necessary that both the 6.000 MHz and second l.o. crystal oscillator frequencies be set very precisely and that both oscillators exhibit sufficient stability to permit operation over a practical temperature range and for a reasonable period of time without retrimming.

The Jerrold Model CPG-IHS IRC reference generator will serve as an example. In the predecessor model, a 6.000 MHz crystal oscillator is used to generate a harmonic comb that extends to 198 MHz. This is mixed with a 253.25 MHz local oscillator to generate an IRC comb extending from 55.25 MHz to 451.25 MHz. The 253.25 MHz l.o. is the result of doubling the frequency of a 126.625 MHz crystal oscillator. The aeronautical communications bands 12.5 KHz offset is introduced by utilizing a 126.63125 MHz crystal to generate a second l.o. frequency of 253.2625 MHz. Circuit modifications are made to improve the temperature stability of both oscillators and each is set very accurately on frequency. The reference frequency most susceptible to error is channel 53 which corresponds to the 24th harmonic of 6 MHz. This means that the maximum frequency error attributable to the 6 MHz oscillator is 24 times the actual error at 6 MHz. This oscillator is set to an initial error of less than 40 Hz so that its contribution to the initial overall error is less than 1 KHz. Any error in the second l.o. frequency is added directly to each reference frequency therefore this oscillator is trimmed to within 1 KHz of the 253.2635 nominal frequency.

OPERATION AND MAINTENANCE

The adoption of the new FCC rules for frequency usage further increases the value of thoughtful headend system preventative maintenance. Assuring compliance with 76.612 may require upgrading both the equipment environment and the maintenance and adjustment procedures.

Frequency Monitoring

Monitoring of channel-by-channel output levels is a routine maintenance activity for most headend systems. Monitoring of picture carrier frequencies has become equally important. The accurate measurement of these frequencies is substantially more difficult, however. In general, it will be desired to measure the carrier frequencies using the same headend system common test point that is used for level monitoring. A frequency counter cannot be connected directly to the system test point because many r.f. carriers are present and because counters in general do not function predictably with amplitude modulated signals. The usual solution to this measurement problem is to use the transfer oscillator or 'zero beat' method in which a stable CW generator is adjusted until its frequency accurately matches that of the picture carrier in question and then the generator's frequency is measured with the counter. The frequency matching is done by combining the generator output with the system test point output and observing the combined signals with a spectrum analyzer. None of these three pieces of test equipment are commonly found in use in today's headends. Considering the need, the reemergence of specialized frequency measurement equipment seems likely. As is the case for system levels, it is recommended that the frequencies be measured and logged often and on regular intervals until drift behavior is characterized and atypical units are identified. An initial interval of one week is suggested, after which the interval can be increased in accordance with the measured long term drifts.

Operators of IRC or HRC coherent carrier headends will have an easier time of it. For IRC systems, a single picture carrier frequency measurement will generally suffice. The carrier to be measured will depend upon the design of the reference comb generator. In the case of Jerrold's CPG-IHS-450, the largest frequency error will occur at the aviation band picture carrier that is furthest from 253.2625 MHz. For example, on systems with channel carriage extending to 400 MHz or higher, the frequency of channel 53's picture carrier is measured. If its error is less than +/- 5 KHz then all phaselocked aircraft and channels will meet the rules as well. In cases where selected IRC channels, such as channel 42, are not locked to the reference comb, these channels must be individually measured as for the standard headend system above.

In the case of an HRC headend system, a single measurement of the 6.000300 MHz standard is all that is required. The time base of a frequency counter that would be used to check the HRC reference would have a stability that is similar to that of the reference being checked. Consequently, this frequency counter must have been calibrated recently enough so that its error is small compared to the required measurement accuracy. A minimum frequency counter accuracy of 1 x 10E-8 or 0.01 parts per million is recommended. It is also desirable that the calibration be traceable to the National Bureau of Standards. The time interval between measurements will depend somewhat on the expected drift rate of the precision reference but a three month cycle seems desireable in any case.

Frequency Adjustments

The magnitude of the frequency errors permitted under the new rules is several times less than previously allowed, therefore the need for occasional frequency trimming will be real. Vigilant and careful logging and analysis of frequency drift data carriers and reference generators will allow the frequency adjustment needs to be forecast and planned. Output converter adjustment will consist of trimming the crystal controlled local oscillator frequency until it is close to its nominal value in order to obtain maximum tolerance for future long term drift. The crystal oscillators in an IRC comb generator would be similarly reset to nominal frequencies. While a frequency counter with an error of 1 part in 10 million will suffice for the other measurements and adjustments, remember that an order of magnitude greater accuracy is required for HRC reference measurements and recalibration adjustments, due to the very stringent 1 Hz maximum allowed error. When indicated by the measured drift data, the quartz crystal based precision HRC reference oscillator unit should be retrimmed to 6.0003000 MHz +/- 0.1 Hz.

Headend Environment Temperature Control

Regulating the temperature of the environment in which electronic equipment is installed is always advisable in terms of long term reliability or failure rate. Nevertheless, this practice is still not followed in all headends. The need to maintain very high standards for headend frequency accuracy brings temperature control closer to necessity. In a recent study of the temperature drift behavior of headend systems and equipment, it was found that by reducing the environmental temperature limits from the typical unregulated values to a 15 to 40 degree range, the amount of temperature drift associated with temperature variation was halved. This provides greater margins for long term aging drift and initial setting errors. This temperature range is well within that of a typical controlled headend and should not impose any additional requirement there. Operators of headends without control will certainly find their maintenance chore increased.

CONCLUSION

New FCC regulations for the carriage of aeronautical navigation and communications band frequencies on CATV distribution systems are in effect. Compliance with these rules places burden on both equipment manufacturers and system operators. Equipment manufacturers must modify and respecify current headend product designs in accordance with the details of part 76.612. Future products must have compliance built-in.

System operators will have to recognize and implement new headend preventative maintenance procedures, including environmental temperature control, to minimize the risk of frequency rules violations. For long term compliance, some periodic re-optimization of frequency determining circuits will be a fact of life.

THERMAL CHARACTERISTICS OF MODERN FEEDFORWARD CATV AMPLIFIERS

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INTRODUCTION

CATV system performance has become extremely important in recent times. Previous amplifier technologies have proven inadequate to meet the new performance demands required for competitive system operation. Feedforward technology has matured so that it can now meet these performance demands while offering reliable system operation.

Previous attempts at feedforward have been unable to operate at a sufficient level of reliability to make them practical. One of the most devastating factors limiting reliability was thermal variations. This application note deals with this problem and presents the manner in which modern single hybrid approaches have eliminated it.

SECTION I: STATION THERMAL CHARACTERISTICS

The reliability of the active components within a trunk station is directly related to the average component operating temperature. The introduction of feedforward has resulted in a significant increase in the power dissipation of a trunk station. Consequently, thermal design of the station has become a significant factor in station performance and reliability.

The following is a brief presentation of the thermal analysis of a particular trunk station (Scientific-Atlanta) loaded with feedforward electronics. The presentation deals with a fully loaded station under extremely severe operating conditions and therefore is intended as a worst case analysis. Most station configurations will result in significantly lower power dissipations and operating temperatures due to less electronics and lower ambient temperatures. Moreover, the conclusions drawn may not be applicable to other manufacturer's equipment.

The calculations presented are for a housing aerially mounted in a 50°C (122°F) environment with the sun shining directly on the finned strand side external housing surface. The solar radiation absorption encountered in this configuration is approximately equivalent to assuming an ambient temperature environment of +60°C (+140°F) with no solar loading.

There are four <u>major</u> sources of power dissipation in the fully loaded feedforward trunk station:

1.	Power Supply Module	16.3 Watts
2.	Feedforward Trunk Module	21.6 Watts
3.	Feedforward Bridger Module	20.4 Watts
4.	Reverse Module	5.3 Watts

The station is designed so that all of these modules mount directly to the finned external walls of the station. Note that this manufacturer's station has unusually large external surface area.

A fully loaded feedforward trunk station was instrumented with eleven thermocouples so that internal temperatures could be measured. A twelfth thermocouple was used to measure the ambient temperature. Measurements were taken at +21°C (+70°F). A summary of the thermocouple locations and measured temperatures follows:

<u>Trunk Amplifier (450MHz FF)</u>

1. Module Air (in area of FF block) 122°f (50°C)
2. FF Block Sink (side of block near top) 126°F (52.2°C)
3. Bottom of Module Heat Spreader (under FF block) 121°F (49.4°C)
4. Housing Beneath Trunk Module 113°F (45°C)

<u>Bridging Amplifier</u>

5. Module Air (in area of FF block) 120°F (48.8°C)
6. Bottom of Module Heat Spreader (under FF block) 120°F (48.8°C)

<u>Automatic Control Module</u>

7. Module Air 130°F (54.4°C)

<u>Status Monitoring Transponder</u>

8. Module Air 131°F (55°C)

Transformer

9. Core 136°F (57.8°C)

Power Supply Module

10. Module Air (around voltage regulator) 128°F (53.3°C)
11. Housing Beneath Module 101°F (38.3°C)

The feedforward gain block is mounted to a module heat spreader which is in turn mounted to the outside station housing wall. The data presented above can be used to calculate thermal resistances of these interfaces. The module heat spreader is required to accommodate the modular design of the Scientific-Atlanta trunk station.

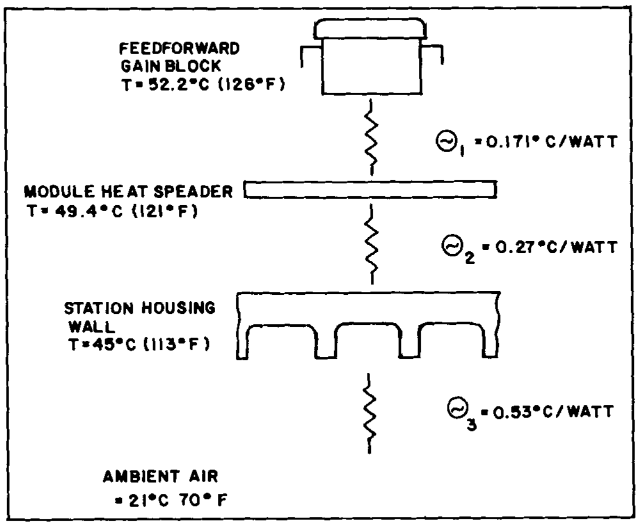

FIGURE 1

There are three forms of heat transfer within the trunk station and from the station housing to its environment - conduction, convection and radiation. Conduction and convection are essentially linear with respect to the temperature gradient (delta T) between the station and ambient. Radiation transfer is proportional to delta T raised to the fourth power (radiation becomes more efficient at higher values of absolute temperature). It has been shown that conduction is the major source of heat transfer in a trunk station. Consequently, it can be assumed as a worst case analysis that there is a constant temperature rise internal to the station with respect to outside ambient.

The measured data indicates a feedforward hybrid heat sink temperature of 52.2°C (126°F) with an outside ambient temperature of 21°C (70°F). If we assume a constant temperature delta between the inside of the station and outside ambient of 31.2°C (56°F) and we assume that the maximum ambient temperature is +60°C (+140°F) then the maximum feedforward heat sink temperature will be 91.2°C (196°F). Note: this number includes thermal input from solar radiation.

SECTION II: THERMAL CHARACTERISTICS OF THE FEEDFORWARD GAIN BLOCK

A major source of problems with previous attempts at developing a broadband feedforward amplifier for CATV applications has been the construction techniques utilized. Feedforward gain blocks consisted of two conventional dual push-pull hybrid amplifiers, two lumped element or distributed element delay lines, four discrete directional couplers and miscellaneous elements for fine-tuning response. This approach suffered from performance degradation as a result of several parameters, among which are: thermal variations, mechanical shock and time.

The single hybrid approach has the advantage of superior performance with respect to the above parameters. Hybridization has inherent to it the advantage of improved reliability over a discrete approach due to the elimination of many mechanical and electrical interfaces. The components used in such an approach are of significantly lower mass and are mounted in a manner that results in greater immunity to mechanical shock. Most importantly the package has been designed with special attention paid to thermal characteristics resulting in an actual reduction of worst case transistor die operating temperatures over a discrete two-hybrid approach.

The single hybrid feedforward package has significantly larger heat sinking surface area than the combined surface area of two conventional push-pull hybrids. The heat sinking area of a conventional hybrid approach is given by twice the heat sink area of a push-pull hybrid or (see Fig. 3):

$$Area_{hs} = 2 \times 0.320in \times 1.775in = 1.136in^2$$

The heat sink area of the single hybrid feedforward block is given by (see Fig. 2):

$$Area_{hs} = 2.068in \times 1.18in = 2.440in^2$$

or more than twice the heat sinking area.

Experimental data has been taken to confirm the superior thermal characteristics of the hybrid feedforward gain block. The details of this measurement follow:

1. Thermal Scan Fixture for the Feedforward Package

The package is mounted on a base plate in the same kind of arrangement as it is being used in the field. (Figure 4) A hole is made through the base plate and the package to monitor the infrared emitted by the transistor dice. The whole fixture is mounted on a temperature regulated base. Thermocouples, situated in the package near the base and on the base plate are used to monitor the package temperature.

2. Principle of Measurement

An infrared microscope with a 15X objective (giving a spot size of approximately 2 mils) is focused on the hottest point of each die. A reading of the radiation emitted by the die is recorded. The power is then shut off and the whole package is brought to a temperature that gives the same reading. This temperature is the die temperature measured by the I.R. microscope.

3. Transistor Temperature in the Feedforward Amplifier

The power dissipation of the output stage transistors of the amplifier gain blocks are shown in Figure 5.

The temperature of the four transistors, Q1 through Q4, of the error amplifier have been recorded for 2 different case temperatures.

The maximum die temperature is $+142^{o}$c when the feedforward case temperature is $+100^{o}$c.

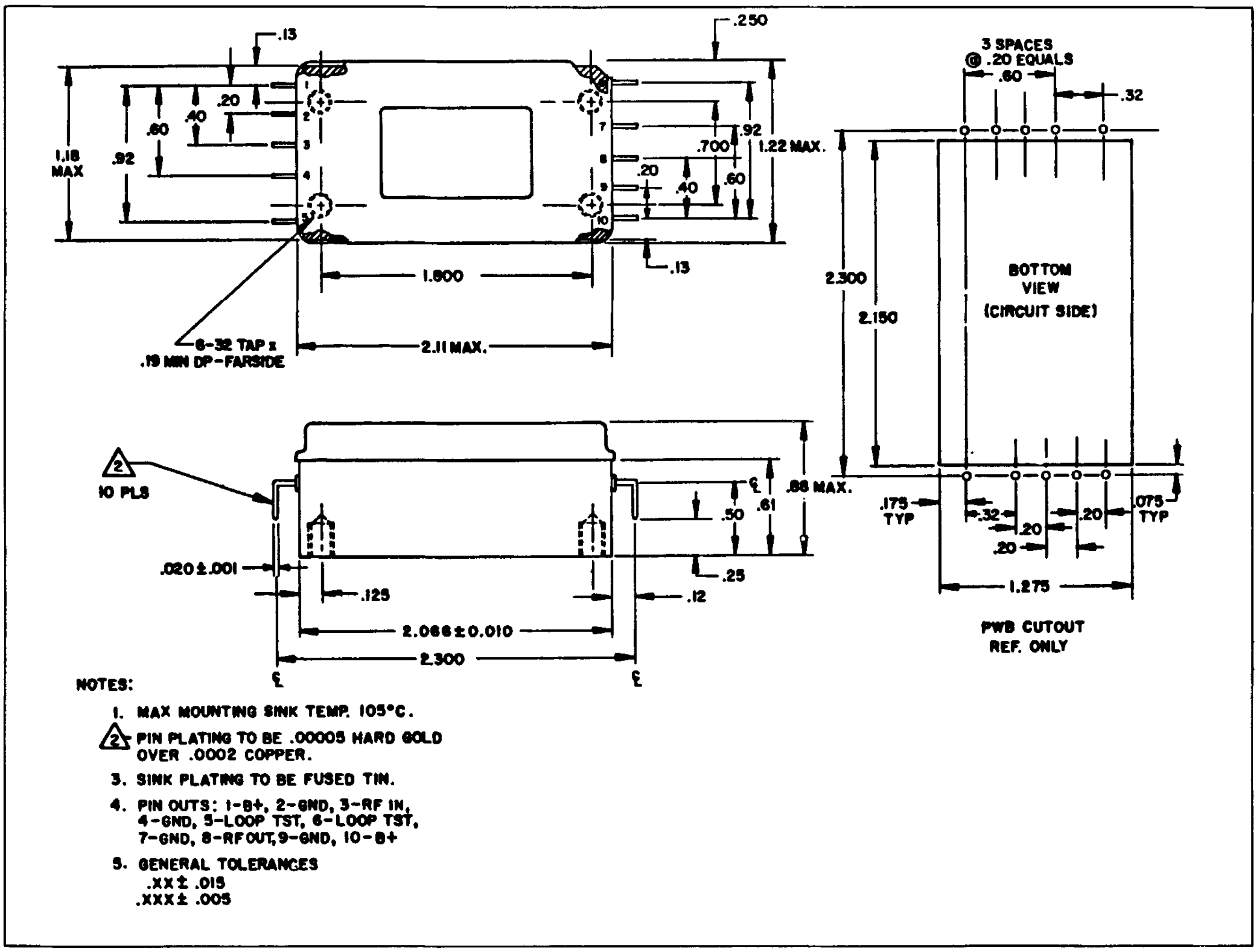

FIGURE 2

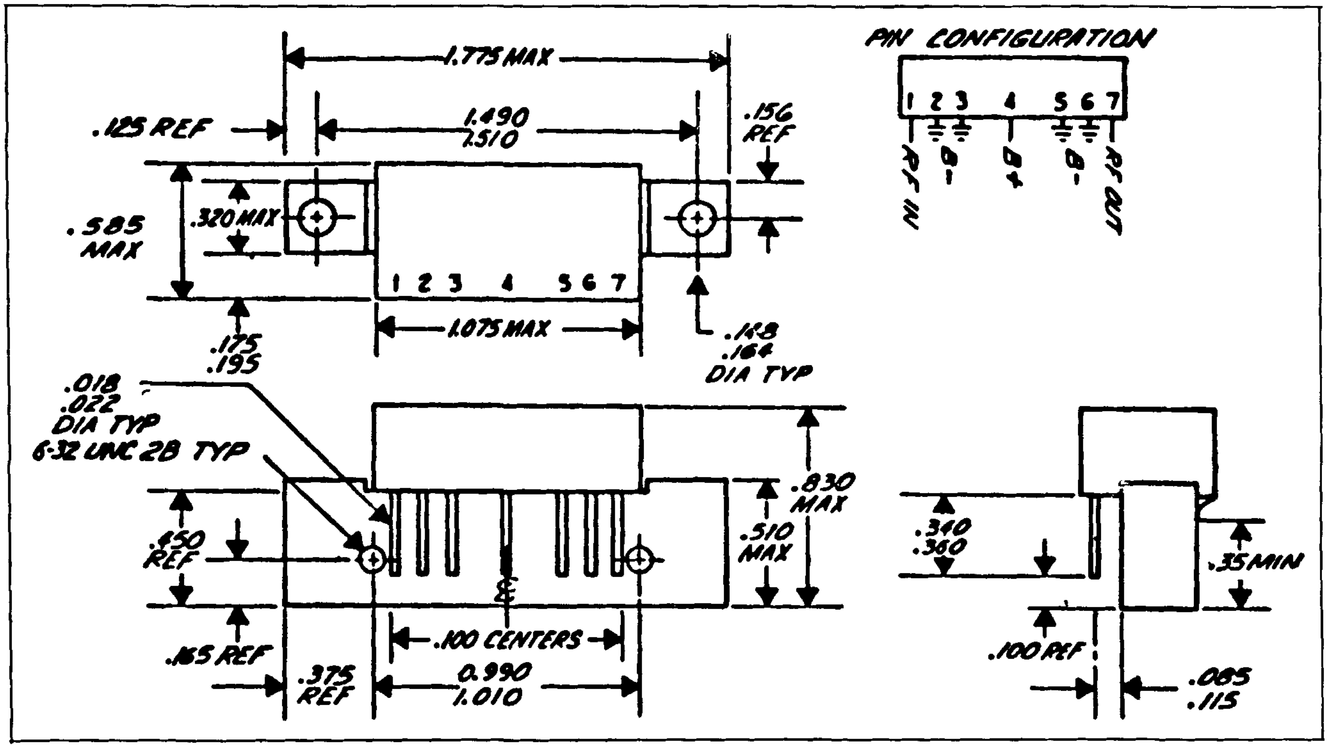

FIGURE 3

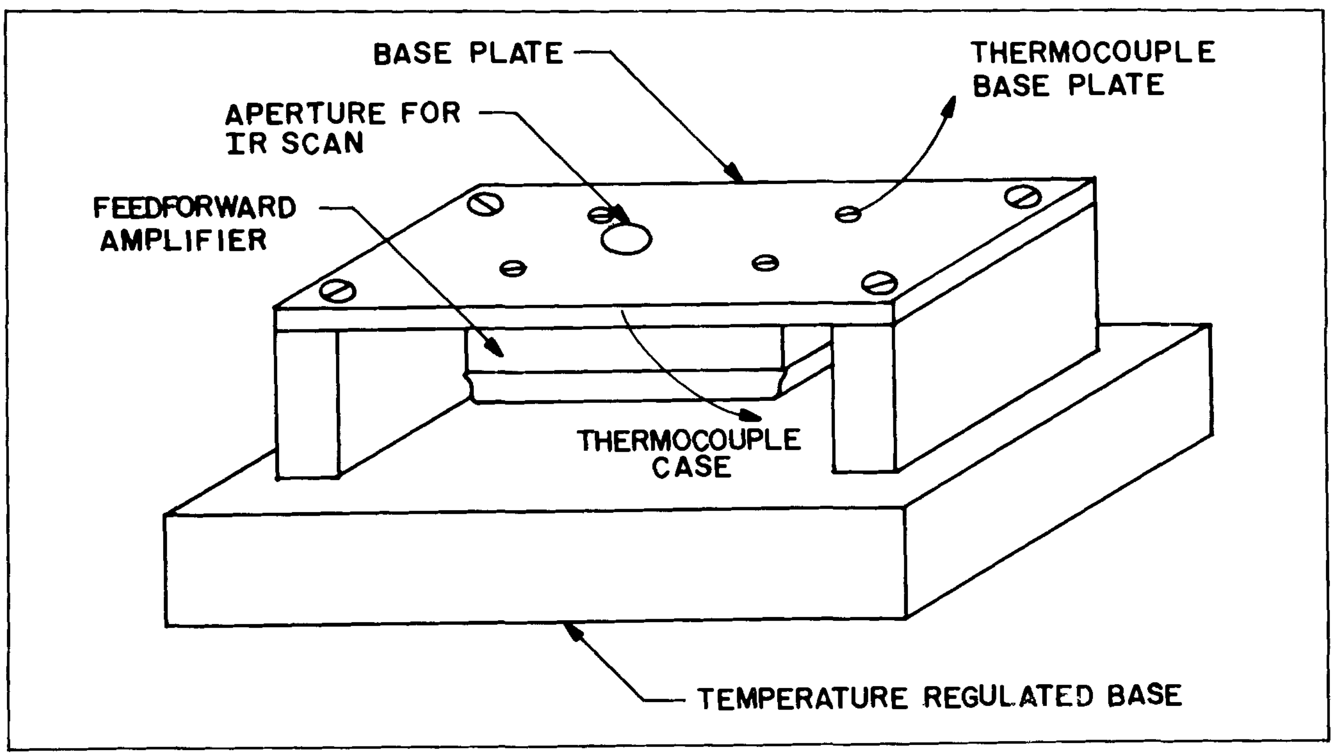

FIGURE 4 THERMAL SCAN FIXTURE FOR THE FEEDFORWARD PACKAGE

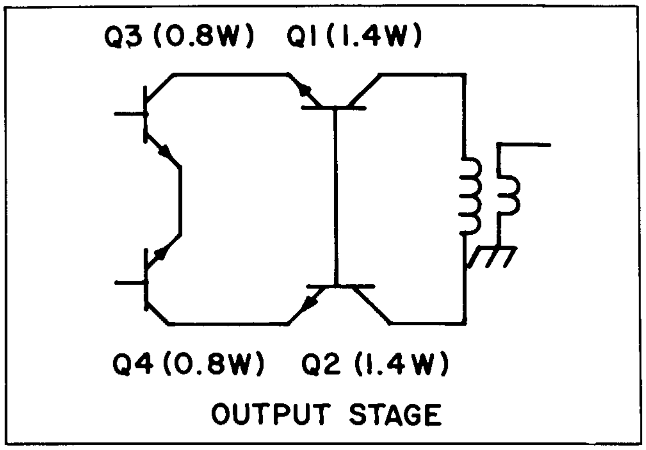

FIGURE 5

POWER DISSIPATION OF THE OUTPUT STAGE TRANSISTORS

	+65°C CASE		+100°C CASE	
	TEMPERATURE	θjc	TEMPERATURE	θjc
Q1	+100°C	25°C/W	+140°C	29°C/W
Q2	+105°C	29°C/W	+142°C	30°C/W
Q3	+ 89°C	30°C/W	+124°C	30°C/W
Q4	+ 89°C	30°C/W	+128°C	35°C/W

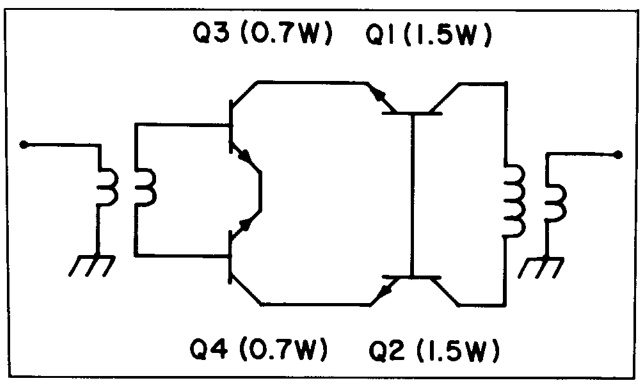

FIGURE 6

POWER DISSIPATION IN STANDARD CATV AMPLIFIERS

	+65°C CASE		+100°C CASE	
	TEMPERATURE	θjc	TEMPERATURE	θjc
Q1	+115°C	33°C/W	+151°C	34°C/W
Q2	+120°C	36°C/W	+159°C	39°C/W
Q3	+ 89°C	34°C/W	+125°C	36°C/W
Q4	+ 85°C	28°C/W	+120°C	28°C/W

4. Comparisons with Standard CATV Modules

The standard biasing for CATV amplifiers is shown in Figure 6.

Measurements were made on an 18dB gain block using the same transistors as in the feedforward amplifier. The results were:

1) Thermal resistances are on the average 4°C lower in the feedforward package than in the standard CATV package.

2) The hottest die temperature in the feedforward amplifier is 14°C lower than in a standard CATV amplifier for the same case temperature.

3) It has been shown by over two years of reliability data that a junction temperature of +150°C will result in a mtbf in excess of 142 years. The worst case junction temperature seen by the hybrid feedforward gain block mounted in a Scientific-Atlanta trunk station is significantly less than +142°C. The resulting reliability far exceeds the requirements of a CATV amplifier.

SECTION III: FEEDFORWARD PERFORMANCE AS A FUNCTION OF OPERATING TEMPERATURE.

Feedforward distortion performance is the result of extremely fine adjustment of the amplitude and phase characteristics of the two feedforward R.F. signal loops. De-tuning of these signal loops will result in a serious degradation of distortion cancellation.

Previous attempts at feedforward have been seriously impaired by the effects of temperature on the feedforward cancellation. The two hybrid push-pull amplifiers maintained their own independent thermal operating characteristics. The delay lines suffered as a result of mechanical variations from thermal expansion and contraction. Consequently, distortion cancellation suffered serious reduction as the amplifier's operating temperature changed.

The single hybrid approach to feedforward has virtually eliminated these problems. The two push-pull R.F. amplifiers are of a special design that includes thermal compensation to stabilize amplitude and phase response. Moreover, both amplifiers are mounted to the same heat sink to ensure temperature tracking. Delay lines are fabricated on a single ceramic substrate and mounted to a single heat sink for temperature tracking.

RF amplifiers and delay lines are measured in an automatic network analyzer station and matched by computer sorting. This eliminates the need for numerous manual tuning adjustments that suffer as a result of temperature variations. Hybridization also results in the elimination of interconnections and a reduction of size in components, both of which suffer as a result of thermal variations.

The hybrid feedforward amplifiers are tuned at an elevated temperature close to be the center of the operating range. This minimizes distortion degradation at both temperature extremes.

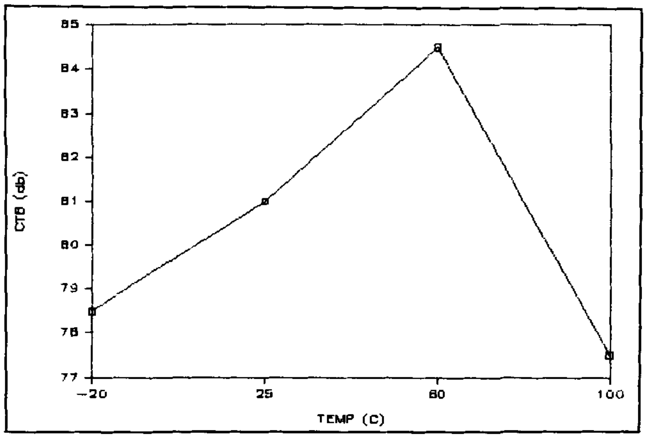

FIGURE 7

Figure 7 is a graph depicting the Composite Triple beat performance vs. heat sink temperature of a typical hybrid feedforward gain block. The measurement was made at 445.25MHz with full 450MHz channel loading at an output level of +48dBmV with +3dB of linear tilt. The graph demonstrates how tuning at an elevated temperature tends to equalize the distortion performance degradation at the temperature extremes.

CONCLUSION

The feedforward concept has been around for many years. However, only in the past year have advances in hybrid amplifier technology made a reliable broadband feedforward CATV amplifier possible.

A feedforward station design must include consideration of thermal factors as these factors impact both distortion performance and reliability. One must consider how much heat is generated and how effectively this heat is removed from the station. As the analysis indicates, when these factors are carefully considered the feedforward station becomes a practical reality.

ACKNOWLEDGEMENTS

I would like to thank Mr. Jack Powell and his saff at TRW RF Devices Division for their help in obtaining data regarding the transistor dice operating temperatures within the hybrid RF amplifier.

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TOTAL CABLE TV CUSTOMER SERVICE

Sharon C. Thompson

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ABSTRACT

Simply staffing the operations based on historical trends and marketing is not enough. The work flow between the field and the office must be taken into consideration when accurately staffing. Inefficient operating procedures can create a false need for manpower. Also, excess headcount can camouflage the "real" operating requirements. Often there is no time to evaluate and correct these problems on the short term. The long term result is a band-aid approach, i.e., treating the symptom, not the disease. As an example, if not managed, the following can significantly increase telephone traffic and truck trips (therefore, justifying more staff):

1. Scheduling of demand maintenance and installation appointments; prevent over and under booking.

2. Daily commitment of installation and demand maintenance manpower.

3. Control of field work orders.

4. Paperwork is current: correspondence, work orders, etc.

5. Reconcile field activity with subscriber account.

6. Service calls and installations that require second and third field trip follow-ups.

This paper will show how the lack of control in these areas will produce high abandonment rates, missed appointments, paperwork backlog, no audit trail, low morale, work flow deterioration, and increased headcount.

INTRODUCTION

Total customer service in cable TV must include a tight relationship between the field and the business office. Intellectually, we know that these areas impact one another; however, often they operate daily as separate entities. It is natural for people, let alone departments, to deal with immediate issues facing them each day. Supervisors and management are responsible for developing procedures that raise the consciousness among departments. Employees should know how their job impacts another area of the company. Departments which operate separately cost the company by duplicating efforts and by repeatedly solving the same problem. This paper will show how the office and field can work as one organization and maintain its unique qualifications. The functions specifically addressed here include:

1. CUSTOMER SERVICE: All telephone traffic except reception problems.

2. SERVICE REPAIR: Telephone calls from existing subscribers with reception problems.

3. DEMAND MAINTENANCE (DM): Field technicians who service existing subscribers on a scheduled date.

4. INSTALLATION: In-house and contractors delivering all levels of CATV service on a scheduled date, e.g., new connects, reconnects, upgrades, downgrades, and voluntary disconnects.

5. DISPATCH: Includes monitoring, expediting, and close out of DM and installation work.

Across the country, cable companies are organized differently, yet the functions are basically the same. The attention is not on how a cable system is organized, but how the functions operate within the reporting structure.

The popularity of cable TV has produced systems with 100,000+ subscribers. This includes two-way service, one-way addressable, and basic converters. Also, the majority of systems are on automated billing computers. Regardless of growth or sophistication, simple operating goals will produce satisfied subscribers and reduce costs. Like the term elegance, customer service should be defined as making the most effect by the least means. This paper will cover the basics of (1) operating criteria, (2) a fundamental foundation, (3) general work flow, (4) problems, and (5) recommendations and conclusions. With these issues managed, one can calculate realistic manpower requirements.

OPERATING CRITERIA

There are operating goals that are the essence of the general work flow. Procedures should be developed to maintain the following office and field operations:

1. Complete all subscriber telephone transactions in one contact.

a) Adequately furnish each telephone workstation with supplies, documentation, training, and any resources necessary to complete the job. There should be no reason to leave a workstation except breaks and lunch.

b) Eliminate transferring calls. Cross-training should provide the representative with the resources to complete any call. Frequent requests by the subscriber to speak to a supervisor indicate a performance problem for a particular phone representative. Support this with training and counseling.

c) Minimize outgoing phone traffic. Promise a call back only when absolutely necessary. You must be prepared to deliver that commitment the same day. Generally, a call back is offered during a very busy period. Before a return call is made, a second (third, fourth!) call is received. Call backs create incoming traffic. They camouflage productivity by indicating that a representative takes a high quantity of calls. If you cannot call back as promised, you have irritated the subscriber and damaged your credibility.

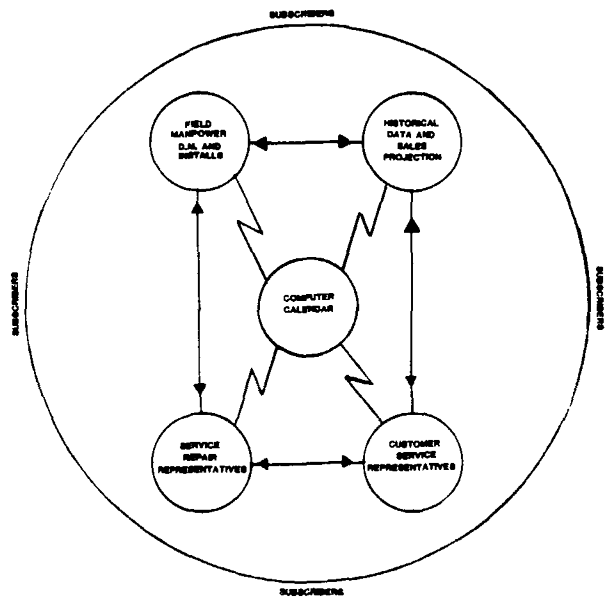
2. Meet your commitments. Simply stated, any agreed upon appointment with a customer, DO NOT MISS.

3. Complete each field work order in one trip. Re-trips and follow-up work are costly, reduce productivity, irritate the subscriber, create phone traffic inquiring about status, and are difficult to monitor. Excessive follow-up work can indicate problems with creating orders with incorrect type of work, lack of inventory, inexperienced field technicians, etc.

4. Balance the daily field activity with the business computer. At the close of each day, the business computer should reflect an exact status of all work performed. This includes completed work, no access, cancels, reschedules, follow-up work required, and missed appointments. The bottom line is that every work order that leaves the office in the morning is accounted for in the computer at the close of each business day.

FUNDAMENTAL FOUNDATION

The goals and operating theme have been defined. We are ready to put in place basic blocks upon which on-going business is built. Also, we are prepared to assume that the primary source of our business is initiated by the subscriber. Refer to Figure 1.



Fundamental Foundation
Figure 1

Note the outer circle that encompasses the business operation. All functions within the circle work to maintain existing or acquire new subscribers. Often these functions begin to operate separately. They view one another as the cause or result of their work. Departments gradually lose focus of total subscriber service. The functions within the large circle have equal responsibility.

Sales projections and historical data (top right circle) provide an estimation for field manpower requirements. Sales projections indicate the amount of activity that will result in increased (new build, remarket) or decreased (mature market) installation. Historical data is documentation that indicates previous service and construction activity. Finally, good estimations assist in forecasting. The quantity of business and manpower to accomplish it have a direct on-going relationship. The normal operation requires time to absorb increased activity in the work flow. Failure to plan ahead for sales campaigns and new builds creates paperwork backlogs, overtime expense, missed appointments, loss of credibility, and increased phone traffic from irate subscribers.

The computer calendar (center circle) is a very potent tool in meeting commitments. The manpower plus the amount of work per man equals the number of appointments available to schedule. Control of this formula is central to total customer service. The telephone volume serves as a barometer of subscriber demands. Therefore, the scheduling of appointments requries daily review between the telephone representatives AND technical operations. To illustrate this point, subscribers do not stop calling in for service and installation when there are vacations, sick time, and terminations. In short, telephone volume does not decrease or increase with changes in manpower. The operations must accommodate fluctuations by revising the calendar daily. This allows for diverting manpower, obtaining back-up, or reducing the number of appointments not committed. Please Note: Once we have agreed to a schedule and appointments have been set up, technical operations must meet that commitment!! Rescheduling is not an acceptable means for adjusting overbooking. Indicators of overbooking include missed appointments, excessive reschedules, unreliable manpower, and increased phone traffic from irate subscribers. Installers, contractors, and DM technicians without work indicate underbooking. Both cost the company money. Please observe that every function has direct communication with the computer calendar. Employees must be able to speak with confidence about scheduling. This improves morale, company integrity, and subscriber rapport.

The bottom two circles have a constant relationship with one another--Customer Service and Service Repair. Both groups serve as back-up to one another. Phone representatives can directly effect increases or decreases in phone volume. He/she can cause a missed appointment or unnecessary field trip with a few careless seconds on the phone. The work order is the only connection between the subscriber and the technician. Inaccurate or incomplete information on the address, telephone number, or the type of work to be done can take a technician an hour out of the way. Field people are paid to do the job outlined on the work order. Spending time searching for an address, locating adults to be present, or performing unscheduled tasks put a severe time constraint on the remaining work load. Usually a customer is missed or rescheduled. Both telephone representatives and technical operations are equally responsible for meeting commitments.

The basis of a sound service organization is communication among all functions. The computer calendar is a vehicle used to control and facilitate service. These basic blocks are the fundamental foundation of a general operating work flow.

GENERAL WORK FLOW

The bulk of the business activity should be organized into one consistent operating procedure. The general work flow will include two main types of work orders--installation and DM. Disconnects will not be addressed here because the operation strives to cancel the order and retain the subscriber. There are several types of installation work orders, e.g., new connects, reconnects, upgrades, and downgrades. Although they represent different time, materials, and skill, both DM and installation work orders have the following in common:

- o The subscriber requests the work to be done.
- o The majority of requests are received via telephone to Customer Service and Service Repair except direct sales. However, after contact is made, the work order is handled the same way.
- o Both types of work orders require a scheduled appointment.
- o Both types of work orders require a field trip by a qualified technician.
- o Both types of work orders require a satisfactory resolution (e.g., completed, no access, rescheduled, cancel) and rarely a missed appointment.
- o Both work orders must be closed out in the business computer. Installs activate or revise billing. DM records service history.

Based on this common treatment of work orders, an efficient work flow can be developed. It is within the work flow that specific detailed procedures should be refined such as distribution of work, forms, inventory, etc. These procedures will be left to the creativity and efficiencies of each unique cable operation. However, control of the work order once in the field relies totally on communication to the office. There are two areas that require special attention and close follow-up:

1. Field technicians (contractors included) must update regularly during the scheduled work day via phone or radio. Except disconnects, all work orders should be updated after every two (2) jobs. Disconnects can be updated at least twice in the morning and twice in the afternoon.

2. The dispatch office closes out the work order during update or shortly afterwards. Close out of all work in the business computer is done before the end of the day.

These two guidelines provide the entire operation with the following:

- o A real time environment that communicates the status of a commitment the same day it was completed. There is no waiting for the business office on resolutions. This is critical for telephone representatives, sales, and expediting problem follow-up.

- o Keeps the operation current. Removes the need for catching up on yesterday's work. Reduces backlog of paperwork.

- o Information is more reliable with direct contact between the field and dispatch. Revisions can be done on-line while the information is still fresh.

- o Problem work orders and follow-ups can be taken care of the same day or scheduled immediately after update. Subscribers are not kept waiting longer for a second commitment.

- o No accesses, reschedules, and cancels can be verified immediately while the technician is on the line. This reduces storing paper and increases the likelihood that another arrangement can be made with the subscriber.

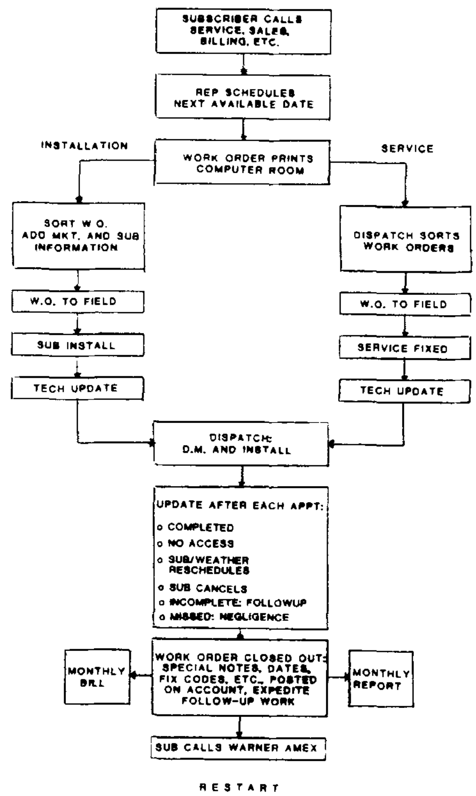
- o Monthly reports accurately reflect the field activity.

It is cost effective to develop an operational work flow that encompasses the treatment of most work orders. Secondly, exceptions and emergencies should be expedited through the exact same process. If there are severe public relations problems or critical complaints, a special task force is not the answer. Operations that create special task forces to tackle problems and critical complaints usually end up the refuse dump for unpleasant issues. Special task forces relieve the obligation to provide quality service from the rest of the operation. It costs manpower and reduces efficiency to maintain separate functions to perform the same task. The entire organization should operate as a special task force. Again, emergencies and special work should be done by expediting the normal procedures within the existing operation. Integrate this responsibility into lead and supervisor job descriptions.

Please refer to Figure 2 for a diagram of the general work flow outlining some of the areas noted so far.

The diagram recaps the operational flow of a scheduled work order. It notes the following: Subscribers want and request a type of service; a telephone representative can schedule for the next available date based on an agreed calendar; computer prints concise work orders; the work orders go to the field on schedule; installs and service calls are resolved satisfactorily; regular updates from the field to the office convey status the same day; dispatch closes out the work before day end; and finally, at month end, accurate bills and reports are generated.

This work flow recycles with every request. To accommodate this operation, changes must be made in both the field and office procedures. One-sided procedures usually fail. For example, if dispatch is to close out work and convey the status of each work order, the technician must update regularly. Both office and field must cooperate for a successful operation.



General Work Flow For
Scheduled Work Orders
Figure 2

PROBLEMS

Problems have a chain reaction effect. One problem generates another and so on. This makes it difficult to identify which problem to resolve first. Problems are not unique to one function or department. A problem that reaches severe proportions will impact other functions directly or indirectly. We should be alerted when problem solving becomes the accepted standard of operation. Solid procedures are to be developed on the rule rather than the exception. Departments can develop work flows that absorb problems and quickly return to normal operations. The following are problems that are symptomatic of weak operating procedures.

1. PAPERWORK BACKLOGS: This includes mail, work orders, reschedules, data base maintenance, etc., and is defined as any work to be done that is over 24 hours old. Backlogs cannot be helped during high activity periods, but they should not be tolerated regularly. Hidden in backlogs is outdated information, irate subscribers, billing problems, service problems, and potential subscribers. An operation consistently behind schedule can justify overtime and manpower with legitimate quantities of work. Also, operating in a "catch up" environment strains the employees. Employees do like to feel that the job is getting finished on time and correctly.

2. MISSED APPOINTMENTS are defined as not meeting scheduled appointments without notifying the subscribers. Consistent broken promises to the subscriber indicate negligence from both the field AND office. Often the business office feels that once the work order goes to the field, their responsibility to the subscriber ends. THIS IS NOT TRUE!! The majority of missed appointments result from overbooking appointments, incomplete work orders, and irresponsibile field personnel. The dispatchers cannot force field technicians to do their job; however, they can insure that we are meeting our commitments by monitoring and alerting supervisors of potential missed appointments. Advanced warning allows time for diverting manpower, recruiting back-up help, or as a last resort, have the dispatcher call and reschedule. Missed appointments should be no more than 1% of the total monthly fielded work orders within each DM and installation department.

3. INCREASED TELEPHONE VOLUME: Fluctuations in phone traffic caused by sales campaigns, service interruptions, and billing cycles are considered typical. Telephone representatives should absorb these fluctuations into the normal work load. It is counterproductive to launch a sales campaign if the operation cannot handle the telephone volume. At this time, we are more interested in non-typical reasons for high telephone traffic, i.e., poor service. Missed appointments, excessive downtime for outage repairs, data entry errors that create billing and service problems, ignored phone messages, sloppy workmanship, backlogs, etc., all negatively stimulate the subscriber to call in. Staffing the phones based on inflated telephone traffic does not resolve any of the problems mentioned. In short, increased phone volume does not justify additional headcount. Likewise, an increase in headcount does not guarantee improved customer service.

4. NO AUDIT TRAIL: It is difficult to resolve problems if you cannot locate the source. Departments that operate independently have defined lines of where responsibilities begin and end, thus a void is created. This is where issues such as missed appointments, follow-up field trips, and correspondence fall between the cracks. From the time a work order is created until closed out, it can pass through several departments. As a work order travels, a check and balance procedure should be put in place. This will identify who, what, when, where, and how the subscriber was treated. Most of the time, we have to recreate the entire situation to resolve the problem. Audit trails assist in preventing the problems from recurring.

5. UNRELIABLE MANAGEMENT REPORTS: It is very likely that if Items 1 through 4 are on-going in the operation, reports will be inaccurate. Strategic planning and budget forecasts cannot be effectively completed from reports that do not portray the operation correctly.

6. WORK FLOW CRUMBLES: When the normal work flow fails to produce results, it is replaced by survival procedures. Employees generally want to do a good job. To continue working in a hectic environment, employees begin to rely on other resources. These measures may not be efficient or cost effective; however, they do set the subscriber service. In severe cases, the work flow becomes Darwin's theory--survival of the fittest. Employees are either overworked or cruising along enjoying anonymity in the crazy environment. The goal is to work smarter, not harder.

RECOMMENDATIONS AND CONCLUSIONS

There is no magic formula for reducing headcount and increasing productivity. There are areas that may require minimal improvements, while others require a serious effort. To successfully implement change, consider the following:

1. Review the operation during low and high activity periods.

2. Draw conclusions based on improved productivity and normal work load.

3. Obtain feedback from other departments.

4. Invite other departments to cooperate in any changes to the work flow.

5. Develop detailed procedures and implement during a time conducive to change.

Telephone representatives, dispatchers, installers, and demand maintenance technicians are all responsible for each subscriber. Sharing responsibilities allows for each area of expertise to grow. The "team effort" is clearly the key to total customer service. Management is responsible for a work flow that accommodates this effort. The following are firm guidelines on which to develop procedures. These areas promote the relationship between the office and the field.

1. THE BUSINESS OFFICE CENTRALLY CONTROLS PAPERWORK. Specifically, opening/closing of work orders, rescheduling, and expediting follow-up work.

2. SAME DAY CLOSE OUT OF ALL WORK ORDERS.

3. CONTROL THE SCHEDULE CALENDAR. Buffer the schedule manpower. Technical operations and telephone representative supervisors must mutually commit to the schedule.

4. HIRE QUALITY CONTRACTORS and monitor their performance. Contractors must follow the same policies as in-house installers for quality service. Levy fines for failure to update work or incorrect work order information. Provide incentives by giving quality contractors work that pays more per piece, e.g., new connects vs. upgrades. Terminate contractors that are not subscriber-sensitive.

5. ELIMINATE ALL BACKLOGS.

6. REVISE AND RECONCILE MONTHLY MANAGEMENT REPORTS. Review the reports. Verify that the data is useful to the current and future operation. Delete information that is not. Confirm the what, when, where, and how the information is compiled and ease of maintaining. Audit the report by taking a sample and confirm that it actually represents the operation. Finally, after the review, revise, distribute, and maintain the report's integrity. Automate whenever possible.

7. AUTOMATED TELECOMMUNICATION SYSTEMS can handle outgoing telephone traffic demands. These systems are moderately priced and can improve the quality of service. Recommended uses include (1) appointment confirmation on DM and installation calls, (2) quality control of DM and installs, and (3) outage fix verification. Other uses have been sales promotions, and "soft" collection calls for non-paying customers.

TRADEOFFS IN MULTICHANNEL MICROWAVE SYSTEM DESIGN

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ABSTRACT

The recent development of the Hughes AML® Microwave Line Extender block upconversion type multichannel transmitter provides additional options for the CATV system designer. To optimize the overall system, it is necessary to understand both the capabilities and limitations of this new type of AML transmitter. Power output may be traded off against composite triple beat. Secondarily, transmitter gain and noise need be considered with regard to desired triple beat performance. The impact of the microwave subsystem tradeoffs on the overall CATV system must also be taken into consideration since the block upconversion type microwave system is not nearly as "transparent" as the standard AML system. When these factors are properly evaluated, the all solid state, outdoor mounted AML Line Extender transmitter can provide attractive solutions to various CATV system design problems. Several recent implementation examples are described.

INTRODUCTION

Utilization of AML microwave within CATV systems has for many years been an established means of providing the local distribution of a large number of television signals from a central point to a multiplicity of microwave receiver hubs from which the signals are transmitted by cable to the individual subscribers. In such systems, the primary reasons for utilization of the microwave is to achieve better signal quality than would be possible with a long trunk amplifier cascade and to derive the economic benefits associated with the centralization of the headend processing functions. Recent developments have made possible the extension of these benefits to smaller systems and subsystems where utilization of traditional AML transmitters would be uneconomical due to the limited number of subscribers serviced through the microwave path.

The standard AML transmitter separately converts each VHF TV signal to microwave and then provides a passive microwave combining network to minimize distortion and maximize power output. This design is an outgrowth of the severe limitations experienced with the experimental block upconversion 18 GHz AML in the late 1960s. With the recent advent of medium power microwave GaAs FET technology, it has been possible to return to the simpler block upconversion techniques while achieving modest output power and acceptable intermodulation distortion within an outdoor, all solid state, transmitter unit. Applications of such a "Microwave Line Extender" transmitter to CATV system design include the surmounting of a natural barrier such as a river, the repeatering of a microwave path where direct line of sight between the central transmitter and the ultimate receive point is unavailable, the temporary restoration of service during planned outage or rebuild, and the feeding of the microwave signal to small isolated pockets of potential subscribers who cannot be economically serviced by alternative means.

AML TRANSMITTER COMPARISONS

The forerunner of the now familiar CARS band AML microwave system was an experimental 18 GHz AML system which operated within the Teleprompter Manhattan CATV system in the late 1960s.[1] This 12-channel system utilized separate low and high band block upconverters which in turn fed a high power traveling wave tube amplifier at the transmitter output. A block diagram of this transmitter[2] is shown in Figure 1. The high power amplifier had a saturated output capability of 250 watts and had to be liquid cooled to prevent it from overheating. Despite this high saturation power capability, the amplifier had to be backed off to a mere 50 mw (17 dBm) per channel output in order to obtain the desired synchronous crossmodulation performance in this 12-channel system. A consequence of this large backoff was that the C/N was limited at the transmitter to a maximum of 45 dB. A more serious drawback was the maintainability difficulties of the freon cooled TWT. Fortunately, the 1969 FCC decision[3] establishing the CATV local distribution service and allocating it into the 12 GHz CARS band necessitated a complete redesign of the microwave system.

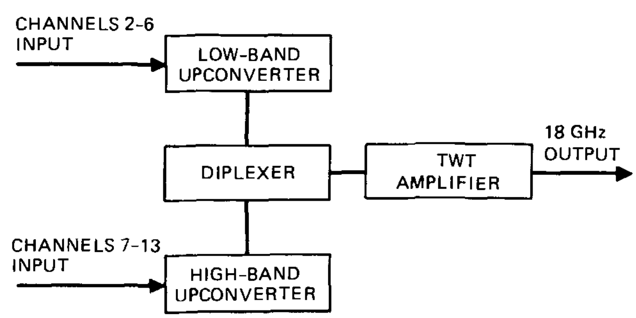

Figure 1 Block diagram of experimental AML transmitter (circa 1968).

With the bittersweet experience of the early 18 GHz AML transmitter in mind, the CARS band AML transmitter design introduced at the 1971 NCTA convention was based on a channelized high level upconverter approach.[4] A block diagram of the original two-bay MTX-132 transmitter, which soon became the industry workhorse, is shown in Figure 2. The individual VHF input signals are separately processed and provided to each upconverter input. A 40-watt klystron feeds up to eight separate parametric upconverters (a fail-soft redundancy feature allows the klystron output to be divided among 16 upconverters) with the required high level microwave "pump" power. Each upconverter incorporates a high Q bandpass filter to select the desired upper sideband mixing product at the upconverter output. The filter performs two additional key functions; it provides approximately 14 dB attenuation of the undesired $2f_{video} - f_{audio}$ third order mixing product which falls in the next adjacent lower channel and it also allows circulator multiplexing of the various channels when channel separation is greater than 10 MHz. "Magic Tees" are then utilized to multiplex adjacent channel circulator strings. As a consequence of the 3 dB hybrid combining, the number of outputs is doubled for each layer of Magic Tee combining. Thus in the 16-channel, two-bay configuration shown, there are four outputs, each carrying all 16 channels. This basic block diagram has remained unchanged as the required number of channels has increased over the years. With four bays, up to 32 channels can be accommodated and eight outputs are provided. The eight-bay configuration offers 64-channel capability at each of 16 outputs.

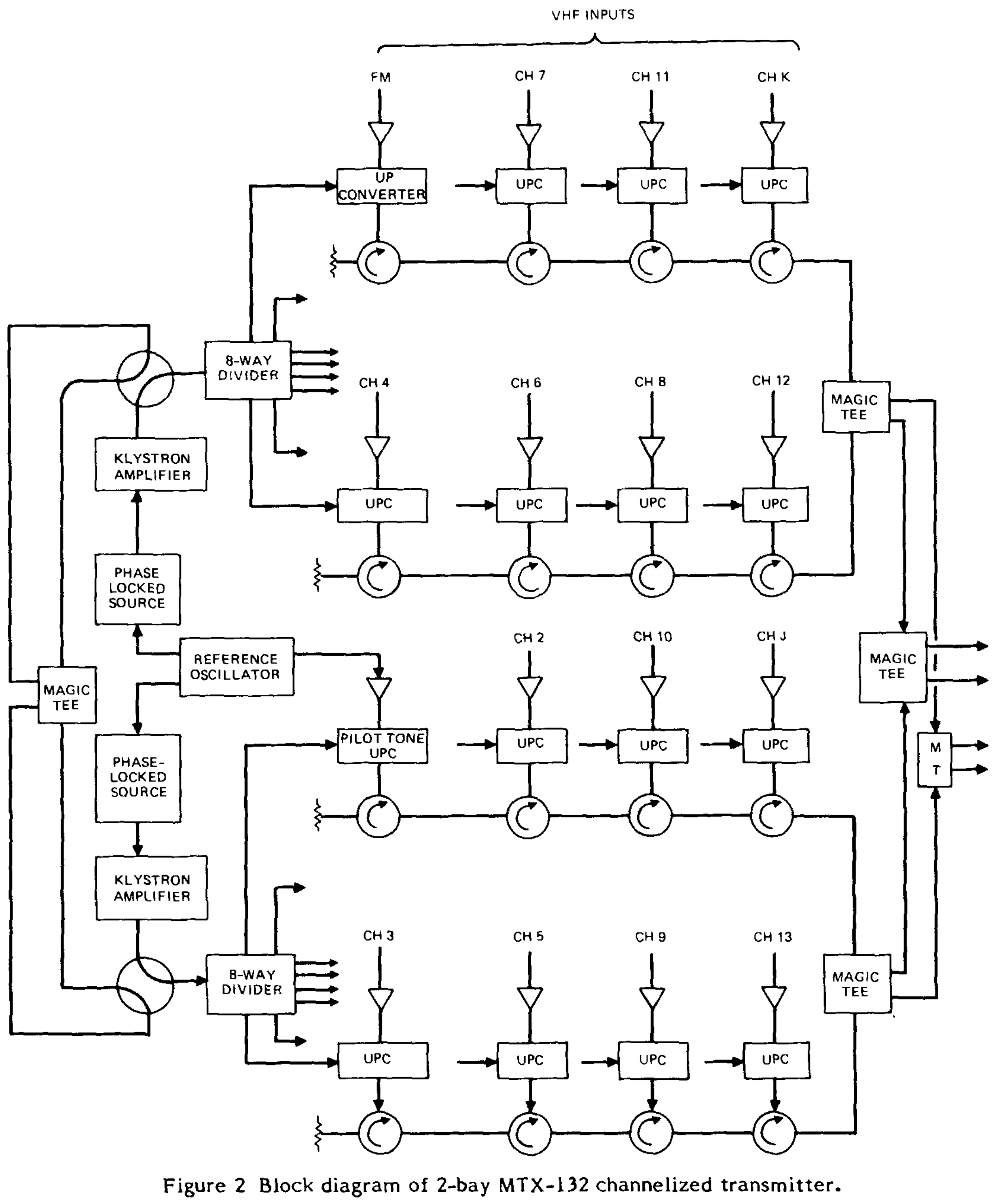

Figure 2 Block diagram of 2-bay MTX-132 channelized transmitter.

Table 1 summarizes the MTX-132 transmitter performance capability. The power output is limited by third order distortion in the upconverter which creates the undesired $2f_v-f_a$ beat falling in the lower adjacent channel and the $f_v \pm (f_a - f_c)$ beats which fall in-channel. The specification stipulates that these beats are at least 58 dB down when the audio carrier is 17 dB down and the color subcarrier is 20 dB below the video. Since channel combination is strictly passive, no interchannel beat products are created in the AML MTX-132 transmitter. On the other hand, in both the AML receiver and in the cable system trunk and distribution amplifiers, video/audio and video/audio/color beats are essentially negligible because these broadband units must be designed to handle the much higher level multichannel video beats. Thus in designing the overall CATV system, there is nothing to tradeoff with respect to the transmitter output. The only microwave system tradeoff arises from the AML receiver which is specified to provide an 81 dB, 54-channel composite triple beat for a C/N of 53 dB. By changing the receiver AGC setpoint, the normal two for one trade between C/N and C/CTB can be made.

As the number of channels gets larger, both the size and cost of the MTX-132 transmitter necessarily increases. The number of available outputs may also be well in excess of the number of receive sites which are to be implemented. Clearly, for applications involving only one or two outputs and where cost is all important, the channelized transmitter approach for a very large number of channels is no longer an optimum solution. What if one returns to the simpler block upconversion approach? Fortunately, because of recent developments in medium power GaAs FETs, output levels which are usable for moderate path length microwave applications can be obtained provided antenna waveguide run losses are kept to a minimum. Table 2 summarizes the OLE-111 AML Microwave Line Extender output for a composite triple beat specification of 65 dB. Comparing this to Table 1, one sees a difference of up to 18 dB between the OLE-111 single output and any one of the multiple outputs from the MTX-132. Even if one were to allow a 4 dB waveguide loss advantage for the outdoor mountable OLE-111 transmitter, the power difference is still a husky 14 dB. Furthermore, a 65 dB composite triple beat might appear

TABLE 1

MTX-132 AML TRANSMITTER PERFORMANCE SUMMARY

No. of Channels	No. of Racks	No. of Outputs	Power Output* (dBm)
8	1	2	+16
16	2	4	+13
24	3	4	+12
32	4	8	+10
40	5	8	+9
48	6	16	+7
56	7	16	+7
64	8	16	+7

*For on-channel and adjacent-channel beats down 58 dB with audio -17 dB and color -20 dB below video.

TABLE 2

OLE-111 AML TRANSMITTER POWER OUTPUT - "TRANSPARENT" CTB OPERATION*

No. of Channels	Power Output (dBm)
12	-3
24	-6
35	-8
54	-10
60	-11

*"Transparent" operation defined as 65 dB composite triple beat (CTB) measured with CW carriers. Power output would be 4 to 6 dB greater if specification were given for modulated carriers.

to eat substantially into the NCTA recommended[5] CATV system CW CTB goal of 53 dB. Fortunately, this is not the case since power addition of the microwave FET amplifier generated CTB, rather than voltage addition with the CTB generated in the remainder of the cable system, can be anticipated. More about this later. If, then, one accepts that power addition will apply, the OLE-111 would contribute only 1/4 dB to the overall system CTB and can be considered as essentially transparent just like the MTX-132 transmitter. Nevertheless, the block upconverter type OLE-111 transmitter is clearly not even in the same performance ballpark as the channelized MTX-132 transmitter.

OLE-111 TRANSMITTER DESCRIPTION

The above related performance limitations exist despite the fact that the OLE-111 transmitter utilizes a state-of-the-art two-watt FET power amplifier. As shown in Figure 3, this output stage is preceded by a driver amplifier. Just as the power amplifier determines the transmitter CTB, the low noise driver amplifier in conjunction with the manually adjustable microwave gain determines the transmitter output noise level. The broadband microwave signal is generated in the mixer which combines the input VHF with a high level local oscillator. The upper sideband is selected by the image reject filter while the notch filter provides additional rejection of the local oscillator leakage. All of the microwave components benefit from the tightly controlled temperature environment provided by the field-proven (in the AML receiver) gravity gradient freon thermal control system. The constant temperature keeps the amplifier gains, and hence both output power and CTB constant. The temperature control also keeps the notch filter from detuning, thereby ensuring compliance with the FCC spurious emission requirements throughout the full -40°F to +120°F outdoor temperature range.

The VHF input sections of the AML Microwave Line Extender consist of totally passive components which provide for insertion of an internally generated 74 MHz pilot signal which is required when the AML phaselock receiver is utilized in the microwave link. Independent VHF level adjust attenuators are provided to set both signal and pilot tone to the desired microwave output levels. A built-in calibrated transmit monitor provides a

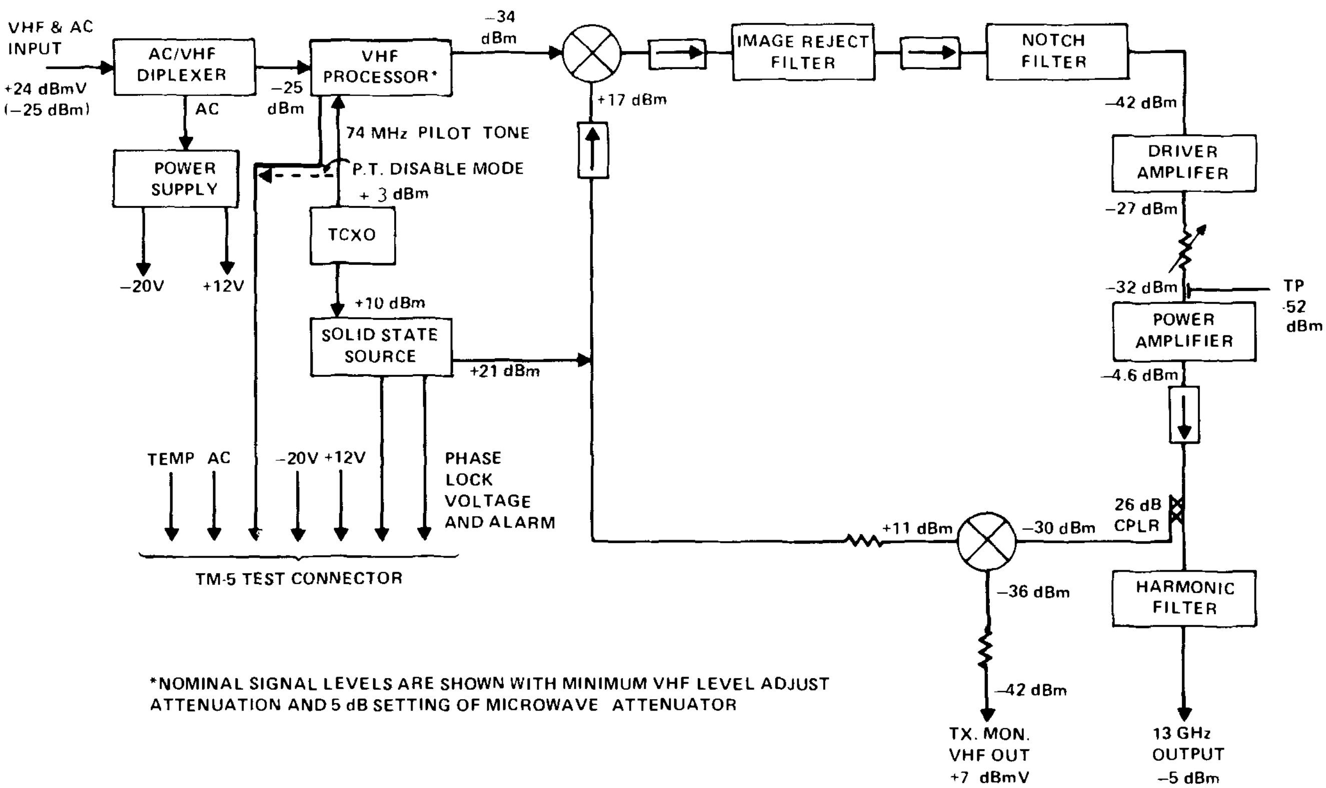

Figure 3 AML OLE-111 block diagram.

convenient test point at VHF frequency which can be used to check the transmitter power output external to the transmitter enclosure. A multipin test connector is also brought to the outside of the transmitter to enable routine maintenance monitoring of various voltages just as in the familiar outdoor AML receiver. However, a different test connector, which also allows monitoring of the temperature controlled crystal oscillator (TCXO) frequency, is utilized. This facilitates the once-a-year frequency measurement mandated by the FCC for microwave transmitters.

The OLE-111 transmitter is cable powered from 30 or 60 volts. A ferroresonant transformer and dc regulators convert this input to the desired internal operating voltages. The ac/VHF diplexer which separates the input ac and VHF is identical to that used in the outdoor AML receiver as also is the transmitter enclosure.

OLE-111 PERFORMANCE TRADEOFFS

If the OLE-111 were to be operated at the power levels summarized in Table 2, the microwave path length would be severely restricted, particularly for a large number of channels. For instance, using 10-foot antennas, the receiver input for a 54-channel application at a range of five miles is barely -47 dBm so that a standard 53 dB C/N cannot be maintained. However, since the path is short, microwave system availability to the commonly accepted 35 dB C/N level would still be excellent for average rainfall areas.

To improve the range capability of the block upconversion type transmitter, one can trade off CTB for power output. Just as with CATV amplifiers, a normal two for one tradeoff exists. This is illustrated by Figure 4. Note that all CTB performances are specified with CW carriers just as for CATV amplifiers. If the specification were in terms of modulated carriers, either the CTB would appear to be an 8 to 12 dB better number, or the power output would be 4 to 6 dB higher (5, 6, 7) but the actual transmitter performance would clearly not be thereby improved. In any case, increasing the transmitter power output will mean that it is no longer "transparent" if the 53 dB system CW CTB is required.

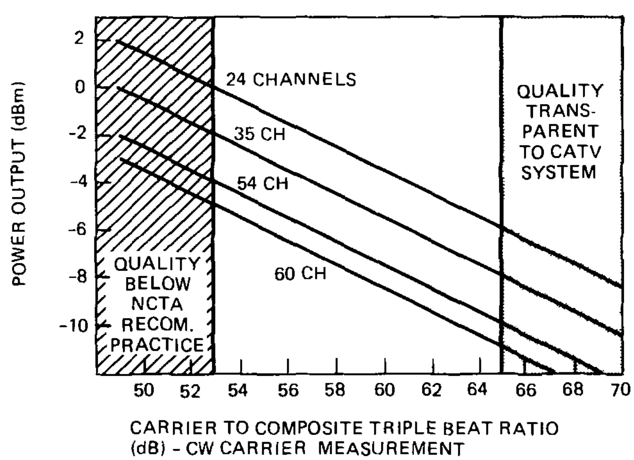

Figure 4 2 for 1 tradeoff of C/CTB for power output in OLE-111 block upconversion transmitter.

A second performance tradeoff involves transmitter gain and noise output. The maximum transmitter gain is specified to be a minimum of 20 dB. For instance, if -10 dBm output is desired, a -30 dBm (+19 dBmV) input will guarantee that this output can be obtained. However, with maximum microwave gain the noise output would typically be -60.5 dBm in a 4-MHz bandwidth and thus the C/N at the transmitter would be 50.5 dB. By setting the microwave interstage attenuator to 8 dB, the noise output is reduced to -66.5 dBm (noise from the power amplifier now contributes non-negligibly to the total noise output) and the transmitter C/N is improved to 56.5 dB for the same -10 dBm output. The VHF input may now have to be +27 dBmV to ensure this output. In either case, the transmitter noise power adds to the receiver noise as shown in Figure 5. The microwave system C/N is least affected by transmitter noise during deep fades since the transmitter noise is attenuated along with the signal.

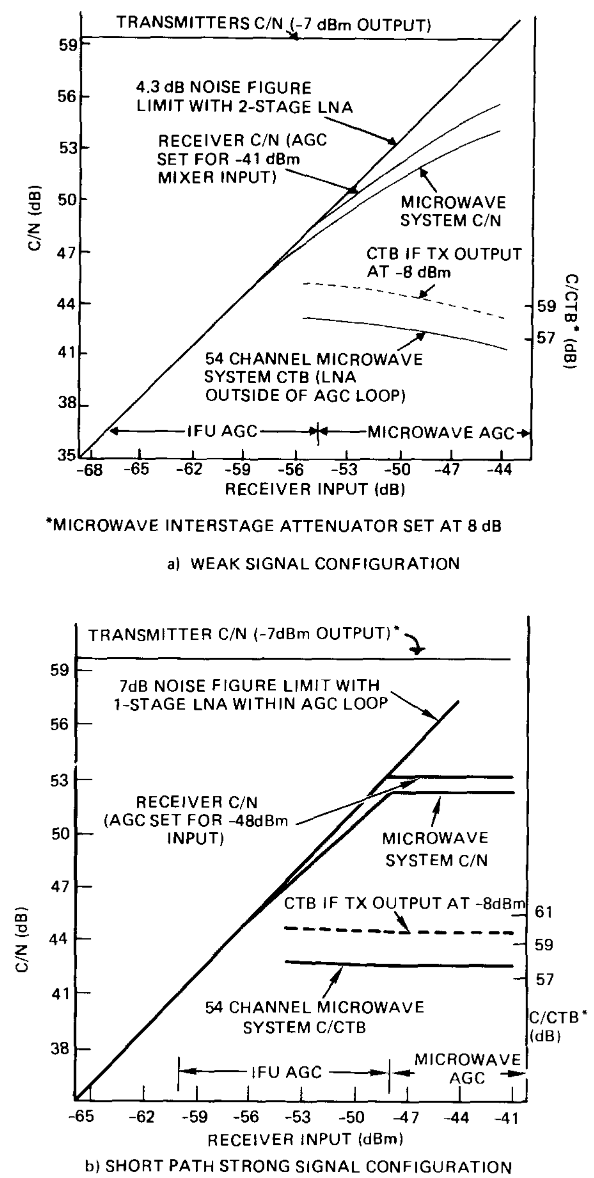

Figure 5 Microwave OLE-111 system C/N and C/CTB vs. receiver input (path fade).

As the microwave gain is decreased and the output maintained constant, the contribution of the mixer and the driver amplifier to CTB becomes evident as shown in Figure 6. The interesting phenomenon illustrated by this performance is that the curve is in almost perfect agreement with a calculation of CTB based on power addition. It had been assumed that the mixer, being an essentially different type of device than the FET amplifiers would power add its CTB contribution, but if the FET driver CTB had voltage added to the FET power amplifier CTB as expected, the transmitter CTB degradation at 10 dB interstage attenuator setting would have been a readily measurable 3.2 dB instead of 1.2 dB. A possible explanation is that the relative phase of the third order distortion products is randomly different when created in the power amplifier as compared to the mixer and driver amplifier combination. In any case, since CATV system VHF amplifiers are substantially different from microwave FET amplifiers, a realistic approach to system design should assume power addition of the CTB created at microwave to the CTB created at VHF. A further verification of this assumption has been provided by a laboratory experiment in which the CTB of the Microwave Line Extender was observed to power add, rather than voltage add, to the CTB of the AML receiver.

SYSTEM APPLICATIONS

The Microwave Line Extender may be used in a variety of applications involving different types of situations. One such recent application which typifies the surmounting of natural obstacles was for a 6.6 mile path across Monterey Bay. The system carries 35 channels and can provide very high quality pictures because the CATV trunk cascade is only three amplifiers long as shown in Figure 7.

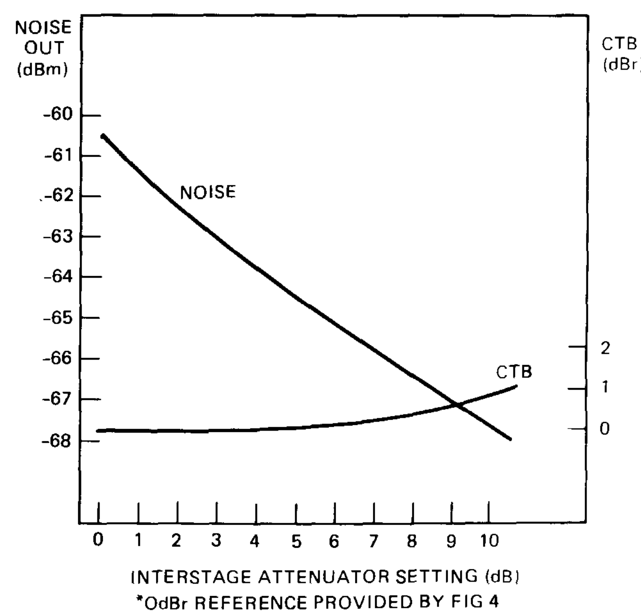

Figure 6 Noise and CTB vs. microwave gain (RF attenuator) at fixed output.

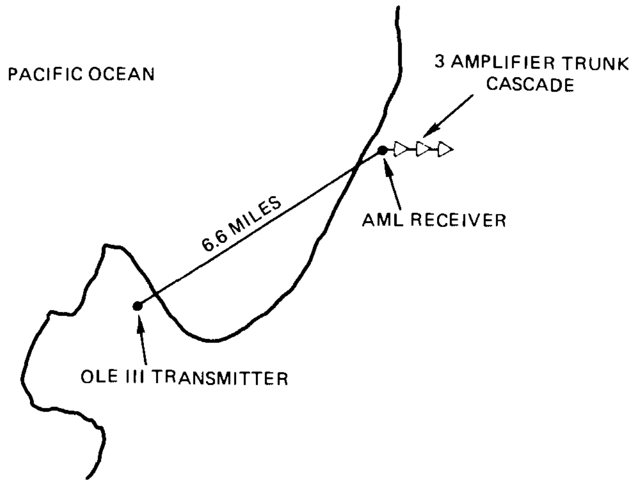

Figure 7 OLE-111 application across Monterey Bay.

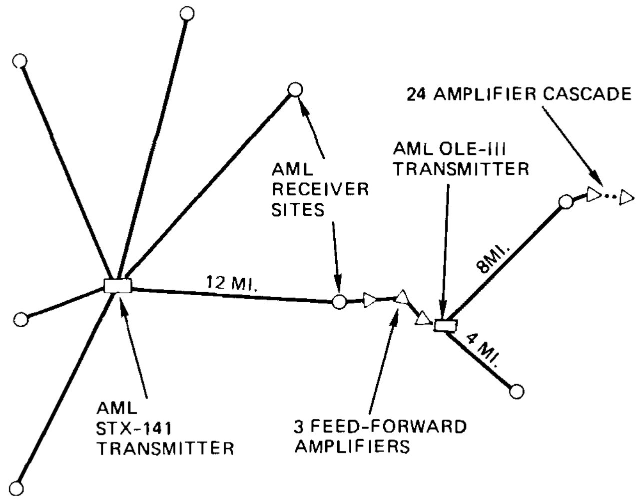

Figure 8 OLE-111 microwave repeater application in Oklahoma.

A second type of application is one involving repeatering of a microwave signal where the original AML transmitter does not have a direct line of sight to the ultimate receive point. An example is provided by a system in central Oklahoma. One of the receiver sites of a STX-141 microwave network feeds three feed forward trunk amplifiers carrying 21 channels. At this point, the cable is connected to the AML OLE-111 input. The Microwave Line Extender output is split by a 6 dB coupler which feeds paths of eight and four miles. As shown in Figure 8, at the receive point of the eight-mile path, the signals feed into a trunk amplifier cascade which is 24 amplifiers deep.

A third type of application involves the utilization of the OLE-111 as a frequency agile transmitter providing an emergency backup for a large channelized AML transmitter. In a not yet installed major urban application, the Microwave Line Extender provides backup for any one of 48 STX-141 channels being fed to four different receive sites. In single-channel applications, the high third order intercept point of the OLE-111 allows an output of +18 dBm while maintaining a 58 dB $2f_v - f_a$ intermodulation ratio. Unlike the situation which prevails with channelized transmitters, this intermodulation product cannot be suppressed with a filter in the broadband OLE-111. For the STX-141 backup application, the +18 dBm output is somewhat mismatched to the +23 dBm available from the STX-141 at this level of multiplex combining. A more optimum OLE-111 operating level for this case is +20 dBm which will result in 57 dB C/I in the channel just below that which is temporarily assigned to the OLE-111. Intermodulation in the OLE-111 channel resulting from products generated by the adjacent STX-141 channels will be better than 55 dB. The OLE-111 output capability is generally better matched to the MTX-132 channel module than to the high power STX-141. Figure 9 shows how the OLE-111 might be multiplexed into the 54-channel MTX-132 transmitter. Note that if the OLE-111 were to share a circulator combining string with other channel modules, it could neither provide backup to any such channels nor to the next adjacent frequency channels.

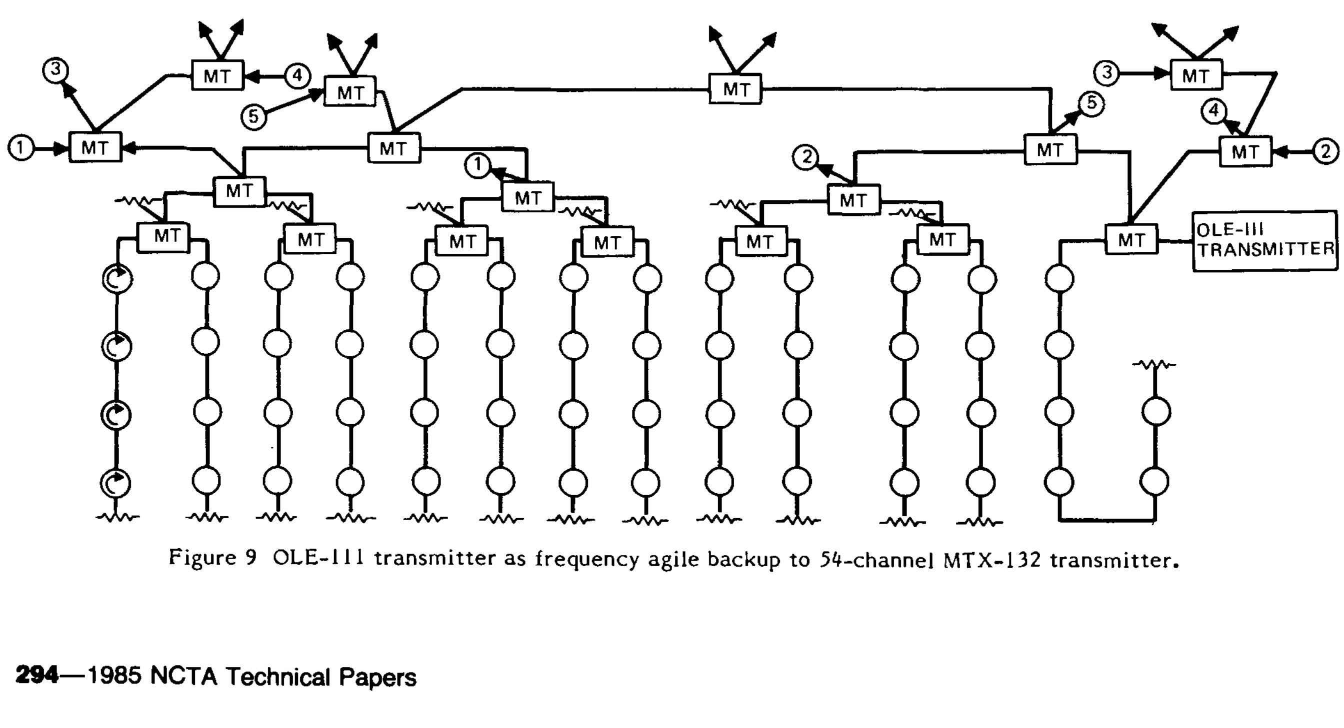

Figure 9 OLE-111 transmitter as frequency agile backup to 54-channel MTX-132 transmitter.

SUMMARY

A question which is often asked about the OLE-111 is: How far will it go? The answer, as we have seen, depends on a number of factors. The most important of these factors includes the number of channels and the signal quality expected at the end of the microwave link. This, in turn, will depend on the performance capability of the cable plant and on the required "last subscriber" picture quality. The largest acceptable antenna size will also play a key part in resolving the question. Once the major parameters are determined, the system can be optimized by trading power for CTB at the transmitter. If sufficient VHF input is available, microwave gain is reduced for best transmitter C/N. Selection of the receiver configuration usually dictates an LNA outside of the AGC loop for lowest possible noise figure. The receiver AGC threshold is then selected for further system optimization. Conservative CTB calculations are based on voltage addition of contributing VHF elements, including the AML receiver's mixer-amplifier followed by power addition to the voltage-added microwave distortion of the OLE-111 and the LNA preceding the receiver.

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USER FRIENDLY CABLE STEREO MODULE

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ABSTRACT

This paper describes the W & S Systems' SM-2001 cable stereo module. We would like to explain what it is, how it works, and where it can be used. The basic function of this unit is to provide access to stereo signals delivered in the FM format (88.1 + 119.9 mHz) on many cable systems in a user-friendly, convenient way. It contains an EEPROM which allows it to be custom programmed for any cable system delivering FM format transmissions. It is our opinion that it can be used in any cable system without modification to the headend or the system.

WHAT DOES IT DO?

There are three modes of operation for the SM-2001:

- o TV stereo mode
- o TV mono mode
- o FM radio mode

The TV stereo mode provides for delivery of the typical simulcast FM format transmissions that are available on cable for a wide variety of cable services. We expect that this mode would also be used to deliver BTSC format, off-air transmissions after they are converted into the FM format for inclusion into the FM band map. To access this mode, the users, through the remote control, simply enter the channel number of the station they desire, and the SM-2001, upon reception of this channel, identifies the channel number and locates in the EEPROM the corresponding FM band frequency that it should tune to for finding the associated audio.

The unit also has the intelligence to recognize the absence of the FM pilot signal. If that is not available at the tuned frequency, then it will default back to what is called the TV mono mode. This feature allows the system operators to preplan their FM formats to accommodate the future expansion of stereo services for both off-air, i.e., BTSC format transmissions, as well as for expansion of new premium simulcast-type services.

The TV mono mode provides access to the normal audio signals that are carried as intercarrier signals along with the video. When using this mode, the SM-2001 uses an intercarrier receiver tuned to either channel 2, 3, or 4, depending upon the channel output of the converter. In this mode, the audio is the mono audio that is provided to the TV set. However, since this audio signal is processed by the SM-2001, remote volume control is provided along with a feed to either of the external devices that are connected to the SM-2001. Fidelity is also improved due to the wider band audio systems.

The FM radio mode provides access to the FM format radio stations that are carried on many cable systems. To use this mode, the TV and converter are normally turned off by activation of the power on/off button of the remote control; then, any two-digit channel entry turns on the SM-2001 in the FM radio mode. The FM radio map is programmed into the EEPROM so that by using the channel up/down buttons, the users can sequence through the various FM radio signals that are provided on the cable, or the users can directly enter a channel number corresponding to their favorite FM radio source.

WHAT'S INSIDE?

Like many communications units designed today, the SM-2001 is a collection of RF and audio circuits surrounding a microprocessor which determines their functionality. Basically, the micro receives all of its control commands from the infrared receiver circuit.

There are some other signals derived out of the stereo processor circuit to which the micro also responds. The micro then controls the selection of the FM tuner or the TV tuner. The selected sound is then processed into either stereo left and right or mono signals, that is, the same signal from each of the left and right connection points passed through a pilot filter to eliminate the 19 kHz pilot frequency to a volume control circuit. This then is again controlled by the micro via the infrared receiver to buffer circuits that provide dual outputs for use or connection to VCR's and/or to amplifiers or powered speakers for listening to sound.

as well as that of the TV tuner. The output of the tuners is passed through appropriate IF filters mixed together and fed to a discriminator circuit and associated audio processing to recover the mono or stereo sound that comes out of the discriminator. The audio processor also includes a gain change circuit to account for the different deviations that are used to drive the audio signals from both the FM and TV tuners.

In order to improve the recordability of the sound, a pilot filter is incorporated to reduce the pilot component that is found within the audio signal. After the pilot filter, one pair of signals is split off through a buffer for access or use by VCR recording equipment. The signal is also fed to an electronic volume control circuit. This is controlled by the micro via the infrared. Consequently, it is buffered again to provide a signal for feed either to a hi-fi system or to a set of powered speakers.

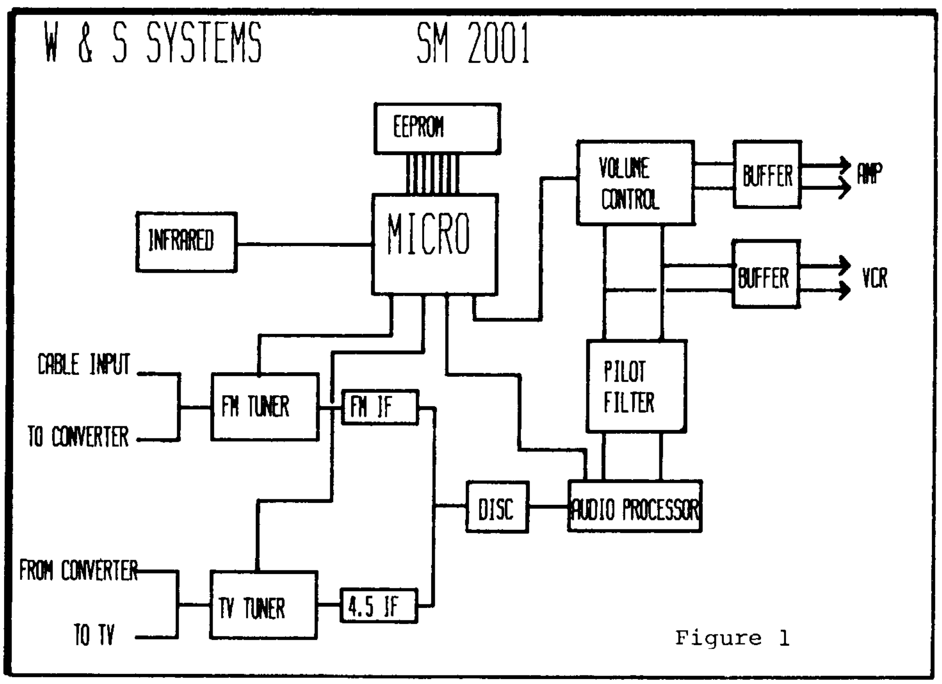


Figure 1

To minimize insertion loss, dual tuners are provided. Each of these tuners simply taps out a small portion of the signal from the input/output connection as shown on the block diagram. The micro controls application of power to the tuners, which results in the appropriate section being activated for use. In addition, the micro controls the frequency selection of the FM tuner

An important note is that the signal from the "CABLE" input connection to the "TO-CONVERTER" connection is simply a piece of wire with the FM tuner input attached to that wire. The same is true for the connections for the "FROM-CONVERTER" input to the "TO-TV" output connection.

The FM receiver is capable of tuning over a range of 88.1 to 119.9 mHz.

HOW DOES IT WORK?

Although the microprocessor controls all the functionality of the SM-2001, it does so based on data loaded into an EEPROM. The data loaded into the EEPROM tells the unit the frequencies it has access to that correspond to the given channel numbers, as well as possible frequencies it may have access to in the future. Stored in the EEPROM are also some other data, such as the input frequency for the use in the TV mode to match the converter output, as well as some other functional characteristics of the SM-2001.

Figure 2

ENTRY CHANNEL #	MONO TV AUDIO	STEREO CH 1	STEREO CH 2	STEREO FM
02	02	102.5	99.7	90.5
03	03	-----	-----	93.5
04	04	88.1	-----	88.5
→ 05	05	-----	100.1	100.5
06	06	97.3	97.7	88.9

SM 2001 TV-STEREO-FM CHANNEL MAP

Figure 2 shows a typical portion of the EEPROM map. Examination of this map shows that there is no special order for the frequency assignments, and, in fact, the frequency does not have to be assigned for each of the TV channels. The way the unit operates is that after it receives an entry channel number from the remote control (for instance, we've indicated a 05), then the microprocessor looks into the appropriate memory location in the EEPROM to determine if an FM channel has been assigned to provide stereo or other alternative audio. As you can see, for Entry Channel 5 under the first Stereo Channel 1, it is blank.

When the entry 05 is made, the microprocessor examines that memory location and, finding that it's blank, defaults to the TV mode (i.e., it switches to the use of the TV receiver portion of the SM-2001) providing mono sound that is tuned by the converter. Pressing the CH 1/CH 2 button on the remote control will then cause the micro to examine the secondary memory location, which contains a frequency of 100.1 mHz. By pressing the CH 1/CH 2 button, it will tune to 100.1 mHz. You will also notice on this channel map that there is a list of stereo FM frequencies, again with no specific pattern.

To access the stereo FM mode, the unit is turned off using the power on/off switch on the remote control, which also should normally shut off the TV set. Then, a channel entry is made. For instance, if we select 05 again, when 05 is entered, the unit will automatically turn itself on and tune to 100.5 mHz and provide that sound from its output terminals. Selection of the other channels (02, 03) will also give the corresponding frequency assignments.

SYSTEM CONSIDERATIONS

The SM-2001 has been designed to work with cable systems as they are presently configured today by maximizing the usefulness to both the cable system operator and the user without requiring any system changes. When the initial concept was proposed, we investigated many cable systems to find out how they would handle stereo. During this investigation, we found that many cable systems were actually carrying many more FM services than publicized. Unlike other equipment that is connected to a cable system, which requires either headend modifications or new pieces of headend gear to properly utilize them to generate revenue, we decided that the best approach for the SM-2001 was to use an approach that required no system changes and that could be fitted into cable systems on a spot-by-spot basis without the operator either having to spend extra money to make headend modifications or changing what he is doing every day with providing the FM radio and simulcast services. The flexible mapping feature that is carried in the EEPROM for the SM-2001 provides the ease of application to serve many cable operators and yet provide the customer with an attractive package of benefits such as volume control, FM radio, and auxiliary or bilingual sound, without requiring any system modifications by the cable operator. The use of the EEPROM also allows the cable operator to preplan for expansion of these FM services and to locate them in a frequency spectrum that is not normally tuneable by off-the-shelf FM radio receivers. Thus, if the cable operator wanted to, he could plan ahead for some premium audio services. This could potentially generate additional revenue in addition to that which might be available from providing the remote volume control via the existing remote control used for the converter.

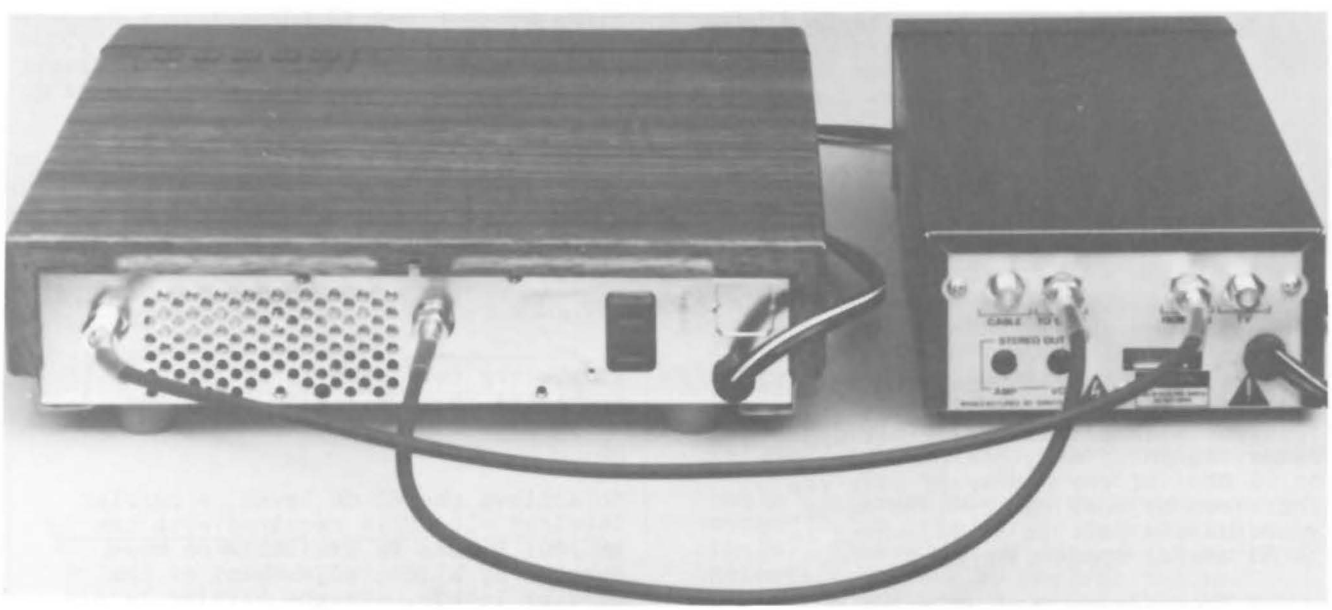
SYSTEM INGRESS/EGRESS

Another advantage of the SM-2001 approach is that it has been designed to have very little, if any, insertion loss. This eliminates the need for a splitter and reduces the probability of ingress or egress in the system. The coaxial feed to the SM-2001 is fully shielded and protected while it travels through the box to the TV set. As a result, instead of using a splitter which would reduce the signal to the converter, the SM-2001 introduces only a very slight insertion loss. The amount of signal required for the FM and the TV tuner is all that is required for all correct operation. Thus, in effect, the system can be closed up and the introduction of stray signals (via faulty FM hookups using 300 ohm twin lead or using zip cord) are eliminated since all the connections are properly handled through F connectors using coaxial cables.

SIGNAL LEVEL

As all cable system engineers know, the carrier level has a lot to do with the quality of the video product that you deliver to the users' homes. This is also true for FM signals. Just as when the carrier level of the video is reduced and the picture becomes snowy, that will also happen to an FM signal. As the carrier level is reduced, more noise in the system will be "picked up." Our goal for the SM-2001 is to provide at least a 60 dB signal-to-noise ratio with an input level of -10 dB mV.

There have been many questions raised with regard to the sufficiency of the 60 dB dynamic range number. The typical argument used in this case is that the compact disk establishes the standard for signal-to-noise ratio. While it is true that the compact disk has a very highly advertized dynamic range, one must remember that dynamic range is a digital process and is not totally available to the listener. For instance, with a compact disk, assume that one would try to use the full dynamic range of the 16 bits. If one would try to generate a sound level



Typical Connection

using the lowest bit simply by toggling that bit on and off, one could produce the correct frequency; but, by simply toggling that bit on and off, one does not produce a sine wave at the frequency; one produces a square wave. If one wants to produce a sine wave at that frequency, he has to use more than one bit. Let us assume that in order to generate a quality sine wave, four of the lowest significant bits would be required. This would produce one of eight levels since one of the bits must be assigned as a polarity bit. This is depicted in Figure 3, which shows the harmonic distortion spectrum as a function of the number of bits used in a quantization.

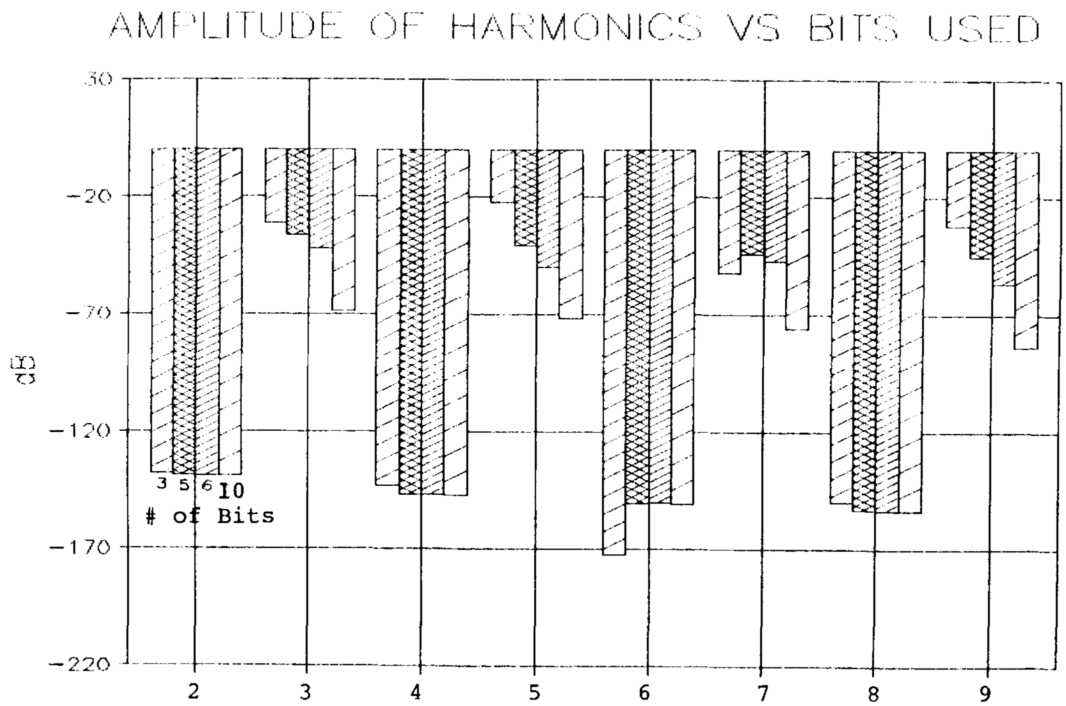


FIGURE 3

Therefore, if four of the sixteen bits are used as the minimum level, this results in an actual twelve-bit dynamic range, which is only one part in 2,048 or 66 dB. If the number of bits was increased by one, the dynamic range would be one part in 8,096, which is a 78 dB useful dynamic range.

If we then assume that we raise the volume level to a point where the noise is just barely perceptible or barely not perceptible and then add the useful dynamic range or the signal power level on top of this noise level, then we can see how much dynamic range is useful to us. There are well-published figures with regard to the ambient noise level both in residences and other typical environments. The number quoted most often is that the average residence has a noise level of somewhere around 40 dB relative to .0002 microbars as zero dB. The typical jet airplane in a takeoff configuration at 50 feet off the end of the runway produces a sound level of about 120 dB on this same scale. So the dynamic range between matching a jet airplane and a typical residence is about 80 dB. On the same scale, a typical orchestra playing its loudest music generates a sound level of about 100 dB, which then relates to about a 60 dB dynamic range. That is, if you try to listen to a live orchestra in your living room, you would have a useful range of about 60 dB.

To achieve the 60 dB level, a carrier level of -10 dB is required with the SM-2001. This is available on most systems by slight adjustment of the carrier levels. If the carrier levels are held at the typical setting of -15 dBmv, then you can expect a signal-to-noise ratio of about 55 dB.

FREQUENCY RESPONSE

Another advantage of the SM-2001 is that it offers, using the FM broadcast format, a significant increase in useful frequency response over that available either with mono television sets or with a typical BTSC television set. The main difference would be an extension both in low frequencies and in the high frequencies of the useful audio band width. With either a mono TV or a BTSC television, the pilot carrier is set at the same frequency as the horizontal frequency. Since the pilot is the factor that determines the absolute upper limit of the frequency response, that then limits the available band width through the transmission system.

In a much more practical sense, though, this upper limit is achieved only by using very carefully designed and very expensive filters to eliminate the pilot while letting the audio band width approach the pilot as closely as possible. In practical designs this is not done, and in typical mono TV sets, as shown in Figure 4, the upper band width rolls off somewhere below 10,000 Hz. Measurements of recent BTSC television sets indicate that they will have an upper band width of about 10,000 Hz. However, with the FM format, because it has a 19 kHz pilot frequency versus the 15 kHz used for BTSC, then full band width, with practical circuit designs, is available up to 15,000 Hz.

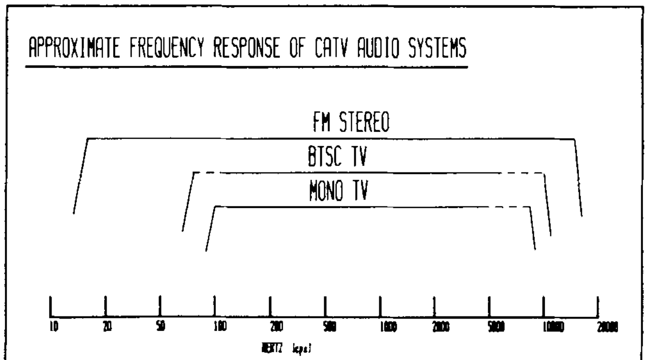


Figure 4

At the low end, most television sets are designed to assure that hum or buzz is not bothersome. As we all know, the intercarrier approach used for the audios associated with video will generate buzz if modulation levels are not carefully adjusted; therefore, there is a lower frequency limit that is about the field rate used for the low-end cutoff point for most television receivers. With the FM format, however, this limitation does not exist, and the low-end band width can be extended down to 35 Hz or below.

BTSC

Another system consideration that cable operators will have to contend with is the application or the carriage of BTSC on their cable systems. It appears that there is sufficient data available to indicate the BTSC will have a series of problems associated with it as it's trying to be transmitted on cable systems. These problems range from reduction of stereo separation to the point of being nonusable as stereo, to the problems of the BTSC interfering with the video portion of the signal. We would propose that for cable systems wanting to carry off-air stereo transmissions, they simply add that audio information to their cable system in the FM format, using a standard modulator after the BTSC stereo has been brought to base band as left and right signals. It is expected that this will be the lowest cost, most beneficial approach for cable systems to handle BTSC stereo.

SUMMARY

In summary, we have basically described the W & S Systems' SM-2001, providing the technical description and the basic operational specification. We've described how it works without implementing changes in the system headend or making any major changes to the cable system. This unit allows cable operators to provide stereo either on as broad or as narrow of a basis. This would be determined as is necessary to develop markets and to provide a new unique opportunity to cable's marketing people. We also believe that the SM-2001 provides superior performance when compared to the other alternatives being offered in today's marketplace.

USING SERVICE CALL MEASUREMENT TO IMPROVE OPERATIONS

Richard N. Clevenger
Vice President

COX CABLE COMMUNICATIONS, INC.

ABSTRACT

This paper describes the implementation of a comprehensive, Company-wide program of service call reporting and measurement. This program provides uniformity in definition of causes of service calls as well as a measurement mechanism that provides for comparative performance ratings across all systems. The program is tailored for highlighting the causes of service deficiencies and provides the ideal mechanism for monitoring the effectiveness of corrective programs.

This comprehensive program has allowed for the accumulation of a highly-detailed historic data base. This data base is proving to be an invaluable tool in many ways. For example, decisions on purchases of new equipment are more easily made with the statistical knowledge of which manufacturer's products provide the best performance over time in a given operational environment. Staffing levels are now more accurately established based on predictable workloads. The best technical operations department structure for a given technology group in a given market is no longer a matter of conjecture.

Finally, the service call performance data base is analyzed against other parameters (e.g. customer satisfaction and operational expenses) allowing insight into the mechanics of providing the best possible service to our customers in the most cost effective manner.

INTRODUCTION

The traditional approach of evaluating the quality of service a subscriber receives is to measure cable distribution system compliance to prescribed technical standards, as mandated by the franchise and the FCC. This form of evaluation, though scientifically correct, only provides a means of appraisal during the actual process of testing. Lacking is the appraisal from day-to-day, month-to-month, and year-to-year of the systems performance as experienced by the subscriber.

To fill the shortfall left from periodic "proof of performance" testing and a schedule-driven preventive maintenance program, Cox developed a demand driven technical appraisal program utilizing service calls as the instrument for establishing demand. By counting, classifying, comparing and analyzing service calls, a comprehensive management tool has been developed with results reaching far beyond merely supplementing our preventive maintenance programs.

While this may seem to be an unconventional approach, the results speak for themselves. But more significantly, a new era of customer awareness infiltrated all levels of the organization. A continuity of functional responsibility and a sharing of ideas replaced independent spheres of activity and frequently disjointed or fragmented operating groups. It has clearly been established, through our experience, that a service call tracking program can be the catalyst for organizational reinforcement and improved customer service.

During the third and fourth quarter of 1983, Cox's Management and Engineering Staff nationally embarked upon the development of a "grass roots" Service Call Tracking Program. The goal of the program is to utilize the tabulation of service call statistics as the "corner stone" of a program that would evolve over time into a multi-element engineering and plant operations management tool to improve the effectiveness and efficiency of the engineering and technical disciplines within the Corporation. This was accomplished using a participative task force approach, beginning at the systems, then grouping systems into geographical identifiable regions and ultimately consolidating nationally. The objective of the "grass roots" development program was to secure a uniform set of measurement indices which were compatible and applicable across the spectrum of all systems regardless of their technological classifications.

SERVICE CALL TRACKING PROGRAM COMPONENTS

The fundamental components of the Service Call Tracking Program are segmented into three sections:

- o Service call statistics collection and reporting
- o Review of consolidated measurements and results
- o Multivariate analysis

Service Call Statistics Collection and Reporting

The procedural foundation for the collection of statistics is a Cox Standard Practice and Procedure outlining the specific process for coding, counting and reporting service calls. The Standard provides a functional description and a definition of each working component of the tracking program. Omitted is a treatise on trouble shooting techniques, leaving this facet to be reinforced within Cox's Regional Training Centers via written Training Modules. The Standard prescribes three instruments that specify the uniform structure for collection of statistics and field reporting:

- o A standard service call form, (Exhibit 1)
- o A standard prescribed set of symptom, fault, and solution designations with numeric identifier codes, (Exhibit 2)
- o A Monthly Summary Report used for submission of the aggregate occurrence of fault codes. (Exhibit 3)

The Standard provides generic procedural guidelines for various aspects of handling customer inquiries:

- o General conduct guidelines for service technicians in the subscriber's home and during the service call resolution process,
- o Detailed instructions for the documentation required on service calls and the Service Call Tracking Reports,
- o Subscriber inquiry handling instructions for Customer Service Representatives and service call dispatching procedures,
- o System outage reporting and logging.

Additionally, documented within the body of the Standard is the method for evaluating and classifying individual service calls. Of particular importance are the operational instructions ensuring uniformity in the measurement period, "cut off" dates, and the method for qualifying multiple subscriber service calls for counting purposes which are the resultant of a common reported service deficiency.

Each service call receives three problem identifier codes during the processing cycle, yielding the following information:

- o Symptom - A description of the problem noted by Customer Service Representative, ascertained from the subscriber's description of the reported service deficiency,
- o Fault Code - An identification of the major fault found by the service or maintenance technician at the time of resolving the service deficiency,
- o Solution Code - A description of the corrective action taken by the service or maintenance technician.

Each of the numeric codes corresponds to those listed in Exhibit 2.

Of the three problem identifier codes associated with each service call, only the summation of the "fault" code is reported on the Monthly Service Report. The analysis of other codes is left to the supervisors at the systems to summarize and incorporate into their management and training programs.

Consolidated Measurement and Reporting

Each system's Monthly Summary Report is forwarded by submission of computer disk, MCI Mail or hard copy to Corporate Engineering for consolidation. All of the Monthly Summary Reports are received no later than the 10th of the following month to allow a timely receipt of the returned consolidated results. The consolidation process is IBM PC-based with the intertie capability to the Corporation's Management Information System data base enabling the analysis of the service call statistics "real time" relationship among other system operating parameters.

Before the end of the next reporting month, a packet comprised of the Company-wide consolidation of Service Call statistics accompanied with one or more selective subject reviews is distributed to each system and plant operations manager.

Reviews Distributed:

I. Fault Code Summaries

A tabulation of a single month's major fault code categories, percentage of total calls for each, and percentage of subscriber base for each. (Exhibit 4, A & B)

II. Trend Analysis

Utilizing a combination of consolidated and categorical statistical inquiries, reports are generated to indicate trends, both with univariate fault code and bivariate fault code comparisons, e.g. technology group vs. fault code. (Exhibit 5, A&B)

The objective of trend analysis information is to provide system management and supervisory personnel with performance ratings enabling them to monitor the effectiveness of correct programs and an overview of plant or field operations.

Two illustrative examples of the types of trend analysis provided are:

- o Total service deficiencies by category or subcategory per month and/or by quarter as a percentage of total subscribers and/or percentage of total deficiencies-annualized.

- Total service deficiencies by category or subcategory per month and/or quarter as a pecentage of total subscribers and/or percentage of total deficiencies presented within and across technology groups-annualized.

To add clarification to the reviews, trend analysis information is presented by technology group designations.

Technology group designations are prescribed by the system bandwidth:

- Group I - 220 MHz Systems
- Group II - 240-270 MHz Systems
- Group III - 300-330 MHz Systems
- Group IV - 400-440 MHz Systems
- Group V - 500-550 MHz Systems

III. Comparative and Correlative Reviews

Staying with a categorical format, comparisons are generated exemplifying variances between systems. As an additional component, the comparisons are structured to be the culmination of the extraction and correlation of fault codes to statistics with several data bases:

- Current and historical Monthly Service Call Summaries,
- Individual system equipment profiles,
- System demographic profiles,
- System monthly financial/staffing profiles
- Customer satisfaction surveys
- Other selected circumstances such as system age, geographic location, service offerings, and so forth.

Two illustrative examples of the composition of the reviews are:

- The distribution of service deficiencies by major fault code category as a percentage of total service calls, or percentage of total subscribers compared/correlated within and across technology groups, regional location, equipment vendor and etc. (Exhibit 6, A&B)

- A distribution of service deficiencies by subcategory of a major fault code as a percentage of total service calls, or a percentage of total subscribers compared/correlated within and across technology groups, equipment vendor, environmental characteristics, system topology, installation practices and etc. (Exhibit 7, A,B,& C)

These reviews are formulated with the objective of providing the system management and supervisory personnel guidance in planning, development and implementation of subscriber service enhancement and plant upgrade programs.

Multivariate Analysis

The multivariate analysis deals with the simultaneous relationship among several operations variables. In other words, multivariate analysis techniques differ from univariate and bivariate analysis in that it directs attention away from the analysis of the mean and variance of a single variable, or from the "pairwise" relationship between two variables, to the analysis of the covariances or correlation reflecting the extent of relationship among three or more variables.

The analysis work is utilized in developing long range strategies and plans through higher resolution studies of plant performance statistics.

An example of the applications and resultant benefits gained from multivariate analysis is best presented by outlining a potential example of its utilization in the selection, implementation and maintenance of set-top terminals. The analysis is likely to be time-phased study dependent upon the sequence of events, availability of data and the changes in outcome and process objectives. Three phases of concentration could follow these lines:

- Multivariate analysis of existing installed base of set-top terminals correlated to:
  - ambient environment
  - equipment vendor
  - internal versus external subcontractor repair expense
  - equipment age
  - "churn" and "spin" of services
  - inventory requirements
  - system topology and design criteria
  - set-top terminal failure mode profiles

- Multivariate analysis of the proposed equipment to be procured correlated to:
  - pertinent results from the multivariate analysis of the companies experience with set-top terminals, as determined from the initial study
  - life expectancy versus depreciable life profiles
  - subscriber acceptance and required level of functional training

- Ongoing multivariate analysis of the newly installed equipment correlated to:
  - repair expense
  - inventory levels
  - equipment age
  - occurrence and intensity of fault codes
  - ambient environment
  - subscriber satisfaction

The ongoing analysis after installation provides the information to forecast maintenance expense, replacement timetables and the activation of warranty contingencies.

With the information produced through the reports, reviews and analysis, the resultant data is utilized to formulate, test and direct the strategic plans to provide the best possible service to our subscribers in the most efficient manner. Cox is currently utilizing the data base to direct these Engineering activities:

- o Training
- o Rebuild decisions
- o Purchasing agreements
- o Standards and practices
- o Equipment selection
- o Warranty enhancements and monitoring
- o Engineering audits
- o Monitoring results of modification programs
- o Identification and monitoring of corrective programs
- o Monitoring for external environmental impacts on plant
- o Derivation of preventive maintenance programs

A significant benefit of the program is the ability to get instant feedback, more accurately forecast expected results, and the allocation of internal and external resources. Cox's Engineering now has the ability to establish quantifiable expected results of it's Engineering programs. Additionally, we have the ability to reappraise these programs periodically during implementation affording us the opportunity to maximize benefits, minimize the financial impact, and make mid-course corrections as required.

Future Enhancements

The evolution of the program has been planned through the next five years. Significant capital expenditures have been made for hardware and software to further develop the statistics data base and data base management software capabilities. A CADD based system design and mapping program has completed it's first year of implementation. Programs to couple status monitoring, dispatching and customer service files are staged.

What is the eventual benefit? It is within the scope of the program, by accumulating intervals between repairs and calculating the present value of amounts of moneys expended for repairs, to prescribe when and where rebuilds should be undertaken. By referencing repairs to a pole or pedestal in the data base, rebuild determinations could be narrowed to a distribution line.

All of these features offer potential for improved financial performance, extended useable equipment life, and even better customer service.

SUMMARY

In summary, though at first the implementation of the tracking of service calls seemed a mammoth undertaking, time has seen refinements in the process. Management and data entry of the program by Corporate Engineering requires less than 50% of a single staff members time. The "upside" gains have more than offset the inconvenience and incremental cost. Cox, in 1984, achieved a 29.6% reduction in total service calls. Based on a valuation by truck roll, this is an equivalent reduction in cost of $477,000 per month. The resultant recovered manhours is being converted into stronger preventive Maintenance Programs and additional time devoted to training. All this equates to a received benefit in the form of better service to our subscribers.

An important point to note with a management tool of this nature, no specific tolerance limits of satisfactory performance were required or established. Rather, the motivation to continually strive for improvement upon the most current optimal performance achievements is the implied standard.

EXHIBIT 1

STANDARD SERVICE CALL FORM

Cox Cable Communications

SERVICE ORDER

Appointment:
Date: ________ Time: ________
Report Date: ________ Time: ________

System: ________ Grid: ________
Customer's Name: ________
Address: ________ Zip: ________
Phone Number: ________ Other: ________

Problem Symption(s):	Representative's Findings:
Code: ________	Code: ________
Serv. Level: ________	Serv. Level: ________
Comment: ________	Comment: ________
By: ________	By: ________

Solution Code: ________ Completion Date: ________ Time: ________
By: ________ Employee # ________
Supervisor/System Engineer Review: ________ Date: ________
T R Code: ____ , ____ , ____
Rescheduled Appoint.: Date: ________ Time: ________ By: ________

CUSTOMER FREQUENCY RESPONSE PLOT

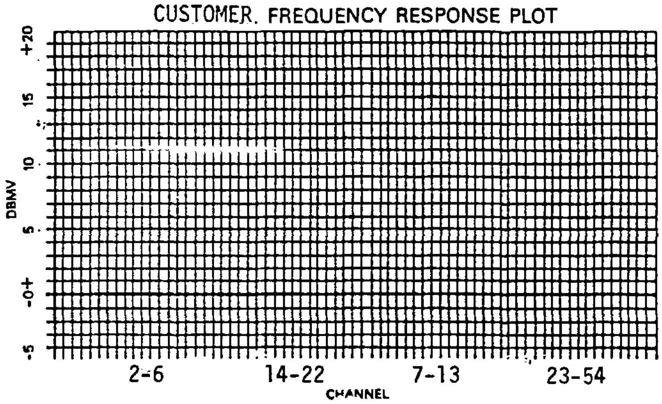


EXHIBIT 2

TROUBLE CODES

SYMPTOM (000)

001 NO PICTURE
002 SNOW
003 WAVY LINES
004 GHOSTING (DPU)
005 FLASHING
006 FADING
007 AUDIO BUZZ
008 NO COLOR
009 SCRAMBLED PICTURES
010 CHANGING CHANNELS

MAJOR FINDINGS (000)

HEADEND (100)

101 ELECTRICAL EQUIPMENT
102 OFF-AIR SIGNAL
103 MICROWAVE FADE
104 MICROWAVE FAILURE
105 POWER FAILURE
106 TVRO FAILURE
107 STUDIO
108 COMPUTER

SYSTEM (200)

201 FEEDER CABLE
202 TRUNK CABLE
203 SPLICE/CONN. PROBLEM
204 PASSIVE FAILURE
205 LEVELS BAD
206 LINE EXTENDER/BRIDGER
207 TRUNK AMP
208 POWER SUPPLY
209 POWER OUTAGE
210 TAP FAILURE

DROP (300)

301 TRANSFORMER
302 SPLITTER/FM TAP
303 DROP CABLE
304 TRAP
305 CONNECTOR
306 GROUNDING
307 A/B SWITCH
308 BAD INSTALL

CUSTOMER (400)

401 CUSTOMER TERMINAL
402 FM RCVR PROBLEM
403 COURTESY CALL
404 TAMPERING
405 NO PROBLEM

ADMINISTRATIVE (500)

501 DISC IN ERROR
502 CLERICAL ERROR

CONVERTER (600)

BASIC

601 FAILURE
602 EDUCATE CUST
603 REMOTE

DESCRAMBLER

604 FAILURE
605 EDUCATE CUST
606 REMOTE

ADDRESSABLE

607 FAILURE
608 EDUCATE CUST
609 REMOTE

NOT HOME (700)

SOLUTION (000)

001 REPLACED
002 SET LEVELS
003 REMADE CONNECTION
004 RESTORED POWER
005 REPLACED FUSE
006 CHECKED WITH MONITOR
007 INSTALLED SWITCH
008 ADDITIONAL WORK REQUIRED-NOTIFIED DISPATCH
009 RECONNECTED

Cox Cable Communications

EXHIBIT 3

Figure 2-3

MONTHLY SERVICE CALL REPORT

Month / Year ____/____

SYSTEM ______________________ NO. TOTAL SUBS __________

PLANT MILES AERIAL ______ + UNDERGROUND ______ = TOTAL ______

PLANT AGE ____ Yrs. REBUILT ____% ____% of Customers have Converters

PLANT VEHICLES ____

HEADEND (100)

101	ELECTRONIC EQPT	____
102	OFF AIR SIGNAL	____
103	MICROWAVE FADE	____
104	MICROWAVE FAIL	____
105	POWER FAILURE	____
106	TVRO FAILURE	____
107	STUDIO	____
108	COMPUTER	____
	SUBTOTAL	____
	% OF TOTAL CALLS	____ %

SYSTEM (200)

201	FEEDER CABLE	____
202	TRUNK CABLE	____
203	SPLICE/CONNECTOR PROBLEM	____
204	PASSIVE FAILURE	____
205	LEVELS BAD	____
206	LINE EXTENDER/ BRIDGER	____
207	TRUNK AMP	____
208	POWER SUPPLY	____
209	POWER OUTAGE	____
210	TAP FAILURE	____
	SUBTOTAL	____
	% OF TOTAL CALLS	____ %

DROP (300)

301	TRANSFORMER	____
302	SPLITTER/FM TAP	____
303	DROP CABLE	____
304	TRAP	____
305	CONNECTOR	____
306	GROUNDING	____
307	A/B SWITCH	____
308	FAULTY INSTALL	____
	SUBTOTAL	____
	% OF TOTAL CALLS	____ %

CUSTOMER (400)

401	CUST TERMINAL	____
402	FM RCVR PROBLEM	____
403	COURTESY CALL	____
404	TAMPERING	____
405	NO PROBLEM	____
	SUBTOTAL	____
	% OF TOTAL CALLS	____ %

ADMINISTRATIVE (500)

501	DISC IN ERROR	____
502	CLERICAL ERROR	____
	SUBTOTAL	____
	% OF TOTAL CALLS	____ %

CONVERTER (600)

	BASIC	
601	FAILURE	____
602	EDUCATE CUST	____
603	REMOTE	____
	DESCRAMBLER	
604	FAILURE	____
605	EDUCATE CUST	____
606	REMOTE	____
	ADDRESSABLE	
607	FAILURE	____
608	EDUCATE CUST	____
609	REMOTE	____
	SUBTOTAL	____
	% OF TOTAL CALLS	____ %

NOT HOME (700)

SUBTOTAL	____
% OF TOTAL CALLS	____ %

SERVICE CALL TOTAL ____

BACKLOG

BEGINNING	____
CALLS REC'D	____
CALLS CLEARED	____
ENDING B'LOG	____

SYSTEM OUTAGE

QUANTITY	____
MAJOR	____
MINOR	____
STANDBY PO SUPPLIES %	____
POWER CO RELATED	____

CALLS CLEARED	#	%
WITHIN 1 DAY	____	____
WITHIN 2 DAYS	____	____
LONGER	____	____
TOTAL CLEARED	____	____

SERVICE CALL SUMMARY

SYSTEM CALLS PER PLANT MILE (200)	____
SYSTEM CALLS PER SUBSCRIBER	____
DROP CALLS PER PLANT MILE (300)	____
DROP CALLS PER SUBSCRIBER	____
CONVERTER CALLS PER PLANT MILE (600)	____
CONVERTER CALLS PER SUBSCRIBER	____
NON-SYSTEM CALLS PER PLANT MILE	____
NON-SYSTEM CALLS PER SUBSCRIBER	____
SERVICE CALLS PER PLANT MILE	____
SERVICE CALLS PER CUSTOMER	____

Due to Atlanta by 5th.

PREPARED BY ______________________

Plant Manager Review ______________________

FORM 01⁻⁻ ⁻

Page 11 of 16

EXHIBIT 4

4-A

MAJOR FAULT CODE SUMMARY CONSOLIDATED

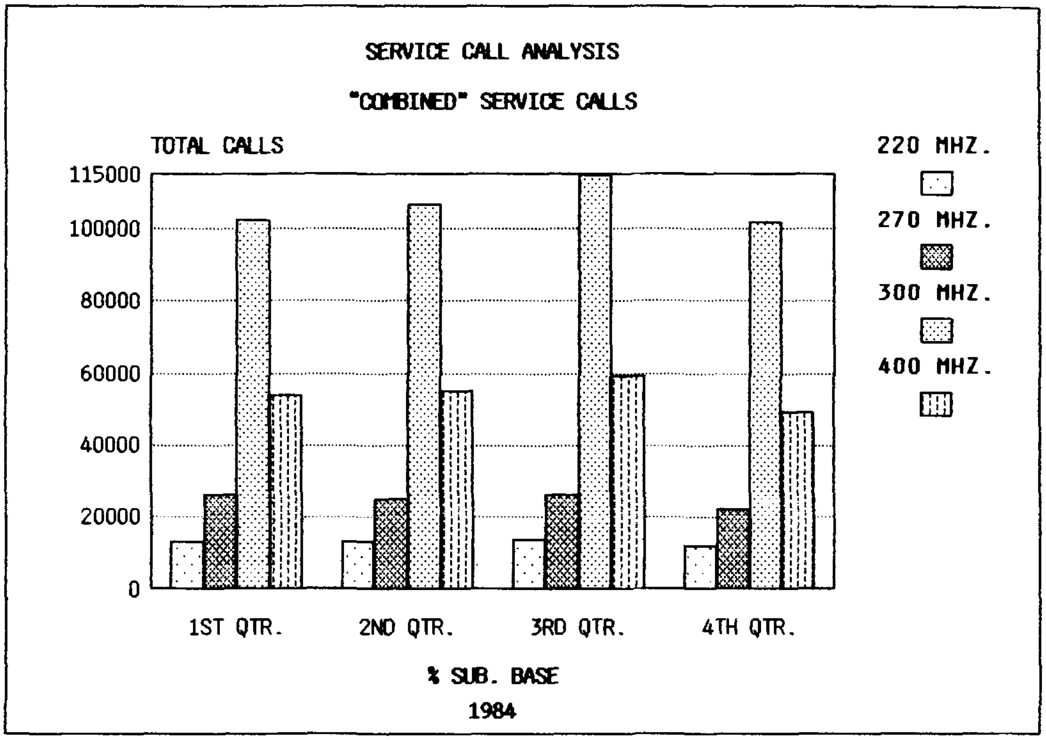
BASIC SUBS		HEADEND	SYSTEM	DROP	TOTAL CUSTOMER	BY ADMIN	CATEGORY CONV	NOT HOME	TOTAL	%OF SUB BASE
1544513	OCT 83	300	6198	17324	19386	2193	20451	6243	72095	4.67%
1563792	NOV 83	343	5689	17368	19280	1955	19657	6016	70308	4.50%
1581064	DEC 83	561	5144	16700	16983	1826	17795	6314	65323	4.13%
1589415	JAN 84	264	6035	17248	17672	1600	21409	5477	69705	4.39%
1600493	FEB 84	264	4595	16671	15876	1970	19497	5407	64280	4.02%
1620962	MAR 84	165	4175	16529	14786	2091	17718	5473	60937	3.76%
1633882	APR 84	198	4702	18253	16157	2456	19719	5629	67114	4.11%
1643384	MAY 84	215	4706	18313	16543	2172	18462	5407	65818	4.01%
1644047	JUN 84	198	5229	17927	15704	1985	19918	4926	65887	4.01%
1656027	JUL 84	142	5518	19033	16613	2000	21745	5279	70330	4.25%
1658299	AUG 84	158	5334	18444	16961	2407	21973	5225	70502	4.25%
1668750	SEP 84	144	5139	19390	17164	2446	22575	5752	72610	4.35%
1683867	OCT 84	116	4843	17996	15439	2028	19229	5009	64660	3.84%
1696696	NOV 84	134	4400	16921	14822	2050	18381	4876	61584	3.63%
1702221	DEC 84	156	4211	15497	14074	1852	17780	5038	58608	3.44%
1506285	JAN 85	231	4071	15269	13493	1671	14885	4221	53841	3.57%
1511031	FEB 85	97	4904	15867	14293	1954	16462	4567	58144	3.85%

4-B

MAJOR FAULT CODE SUMMARY SYSTEM "X"

BASIC SUBS		TOTAL BY CATEGORY (100)	(200)	(300)	(400)	(500)	(600)	(700)		TOTAL	%OF SUB BASE
59570	OCT 83	74	1051	487	1624	65	737	142	0.76	4100	7.02%
59755	NOV 83	100	688	1081	1153	63	661	8		3754	6.28%
60092	DEC 83	305	910	841	1049	27	470	19		3621	5.95%
61815	JAN 84	55	826	1112	1159	67	765	1	0.75	3985	6.45%
60548	FEB 84	18	537	1299	1048	85	868	199		4054	6.70%
60604	MAR 84	4	542	1151	985	101	711	129		3543	5.85%
61677	APR 84	12	498	1197	1198	77	584	223	0.75	3789	6.14%
63000	MAY 84	67	433	1512	1495	93	725	257		4582	7.27%
64000	JUN 84	6	312	1309	1099	109	597	71		3503	5.47%
64282	JUL 84	14	379	1152	983	81	446	75	0.63	3130	4.87%
63960	AUG 84	7	258	1078	757	115	557	176		2948	4.61%
62063	SEP 84	4	352	1487	1009	136	601	325		3914	6.31%
61280	OCT 84	1	252	1341	734	123	439	333	0.60	3223	5.26%
61150	NOV 84	7	210	1103	627	95	514	333		2889	4.72%
61079	DEC 84	1	240	1126	658	83	667	411		3186	5.22%
925675		675	7488	**********		1320	9342	2702		54301	5.87%

EXHIBIT 5


SERVICE CALL ANALYSIS
"COMBINED" SERVICE CALLS
TOTAL CALLS
115000
100000
80000
60000
40000
20000
0
1ST QTR.
2ND QTR.
3RD QTR.
4TH QTR.
% SUB. BASE
1984
220 MHZ.
270 MHZ.
300 MHZ.
400 MHZ.

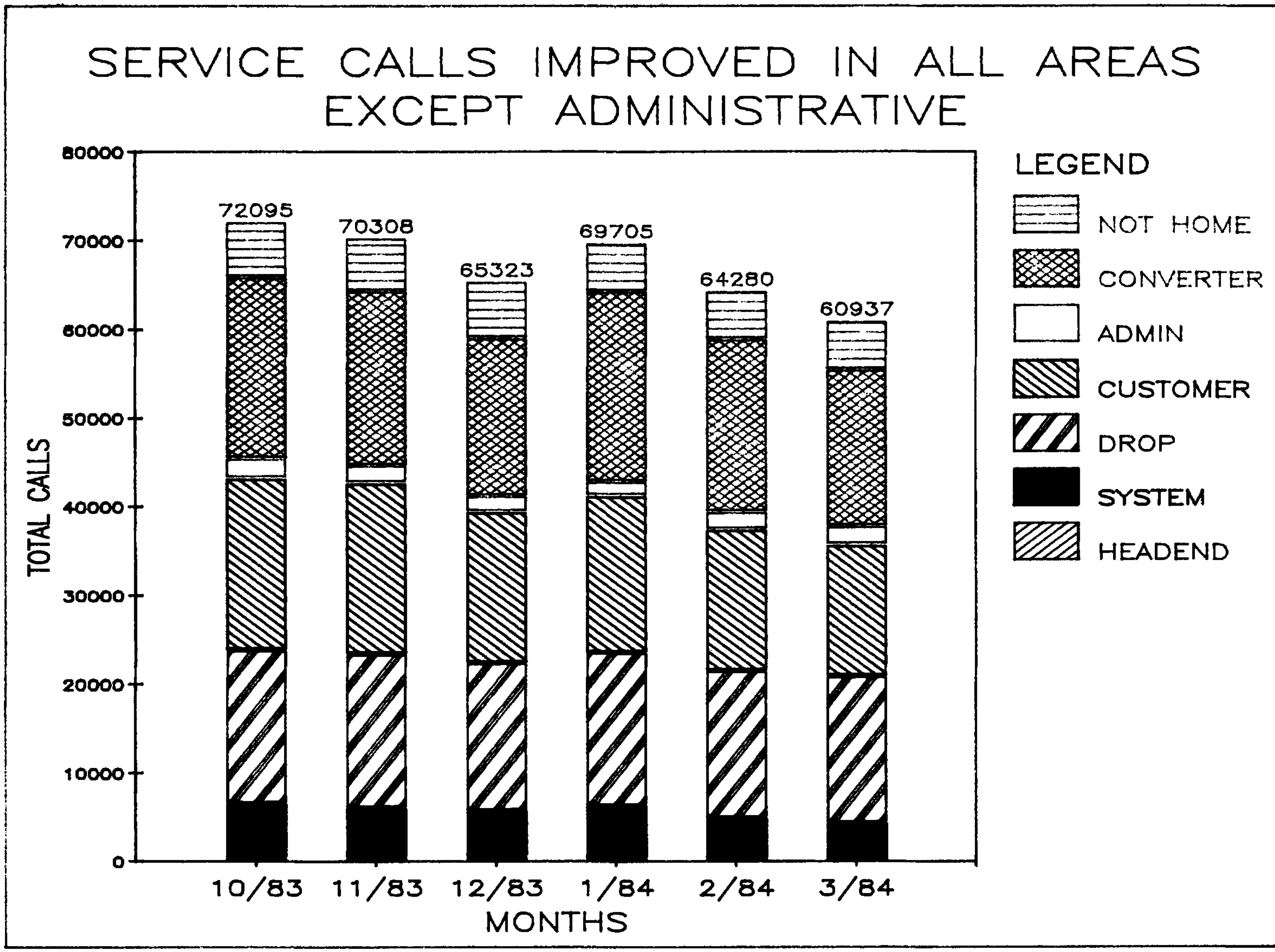
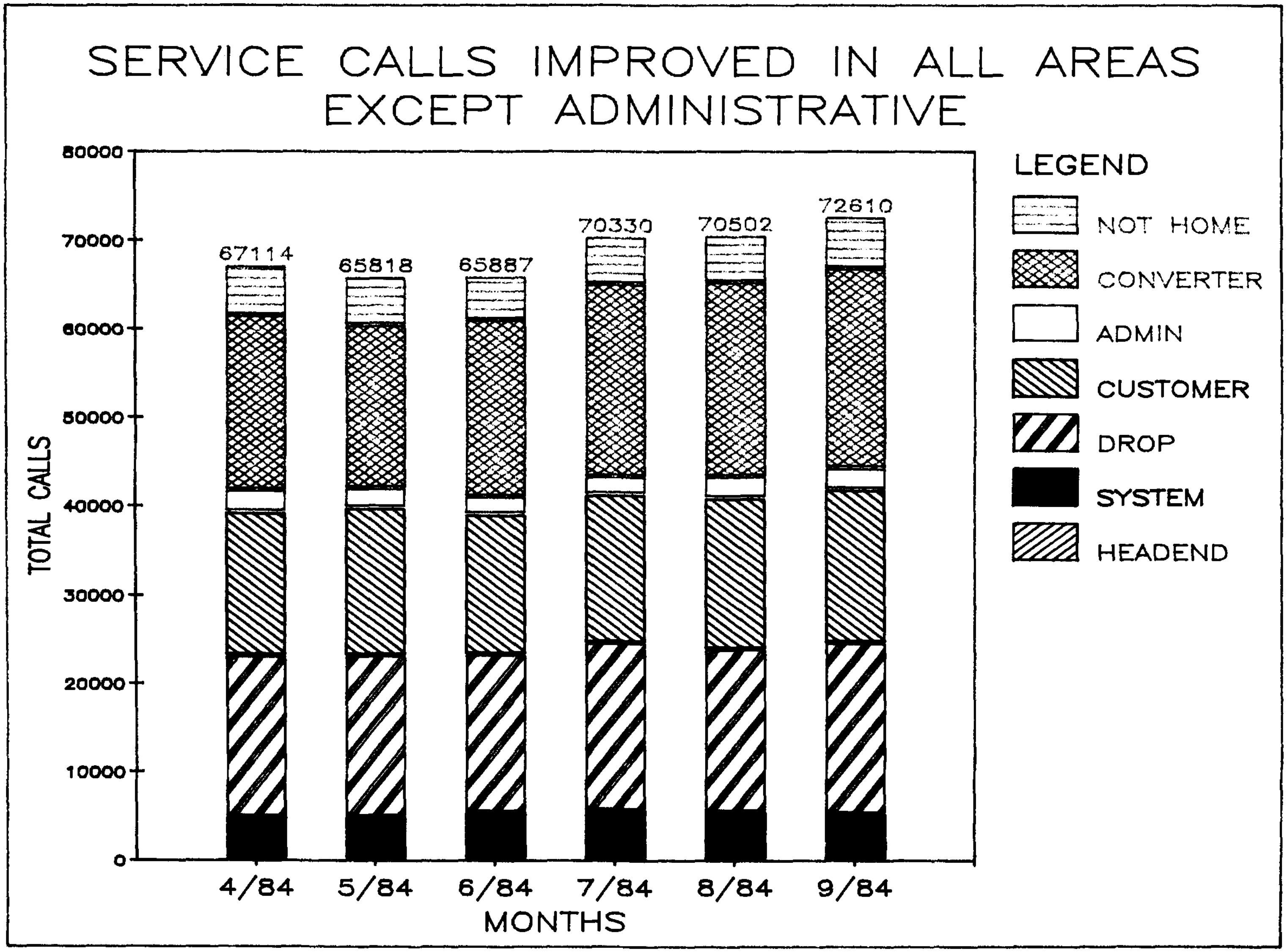


EXHIBIT 5-B, MONTHLY TREND ANALYSIS


SERVICE CALLS IMPROVED IN ALL AREAS
EXCEPT ADMINISTRATIVE
TOTAL CALLS
80000
70000
60000
50000
40000
30000
20000
10000
0
67114
65818
65887
70330
70502
72610
4/84
5/84
6/84
7/84
8/84
9/84
MONTHS
LEGEND
NOT HOME
CONVERTER
ADMIN
CUSTOMER
DROP
SYSTEM
HEADEND

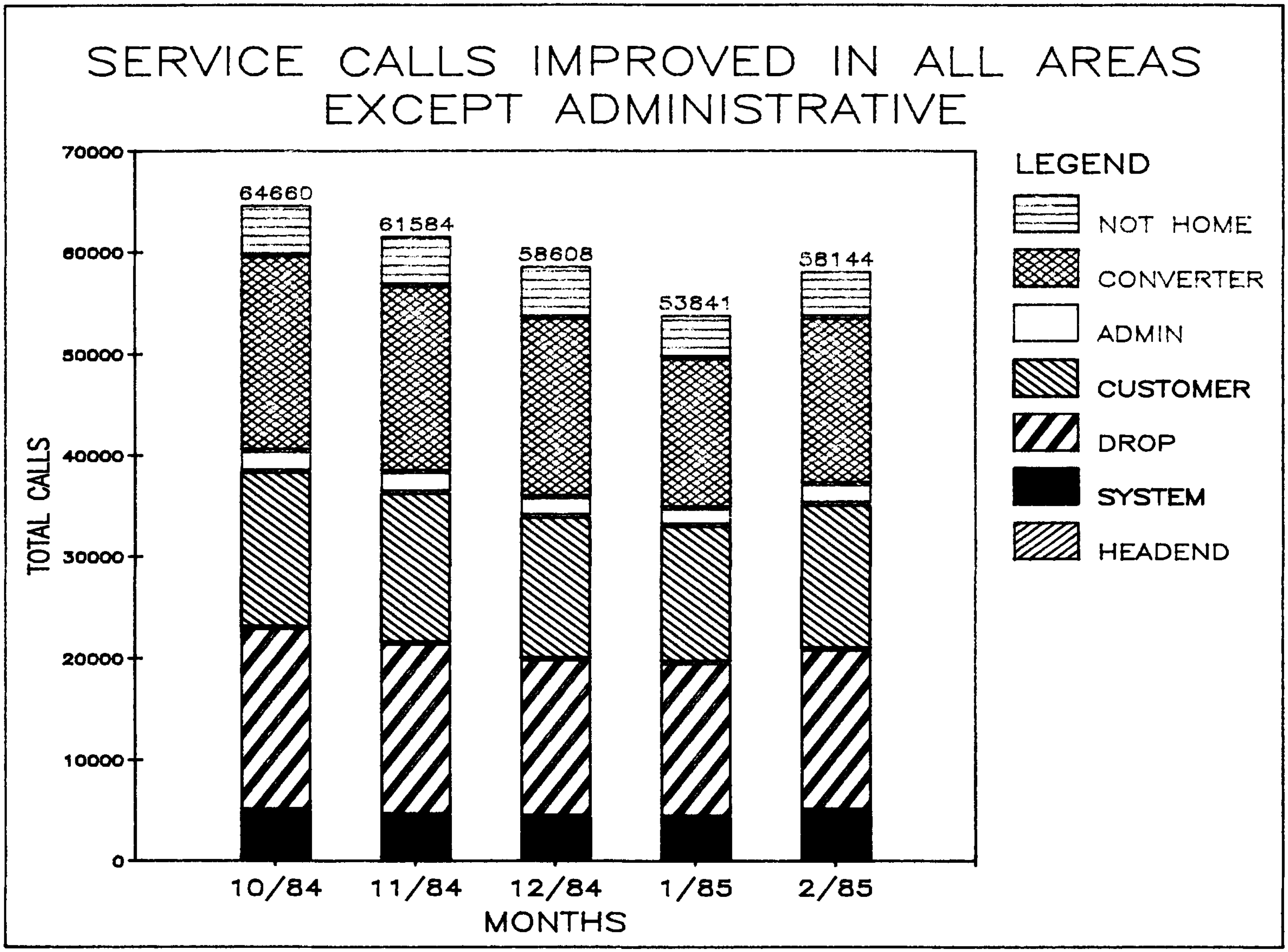
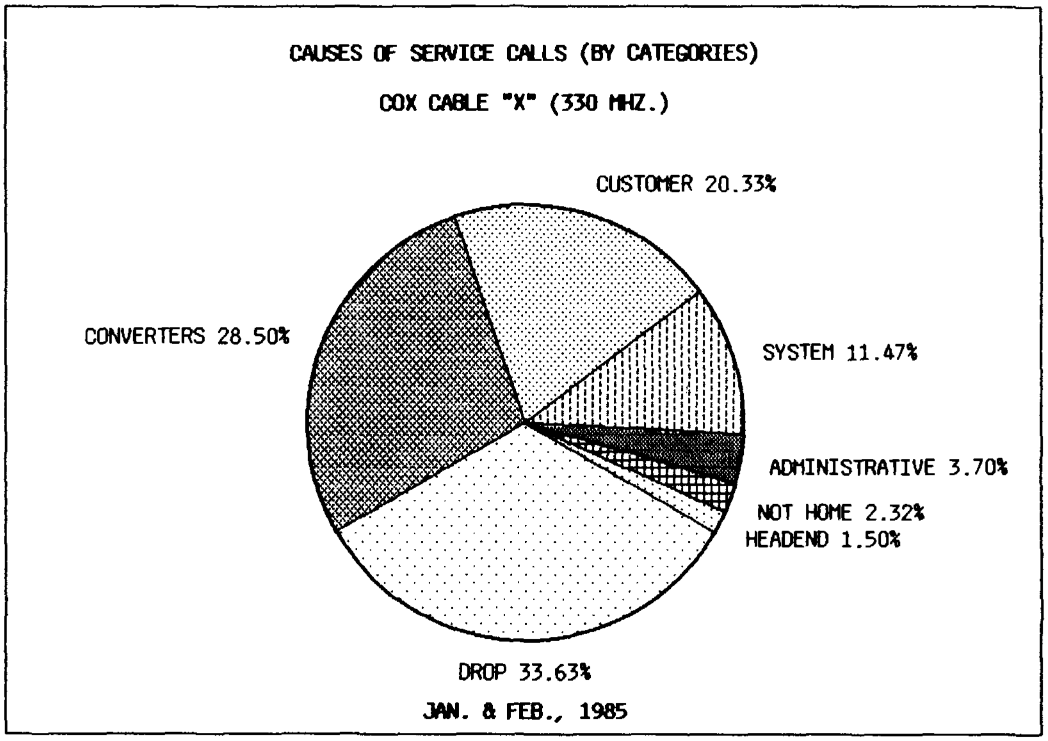

SERVICE CALLS IMPROVED IN ALL AREAS
EXCEPT ADMINISTRATIVE
TOTAL CALLS
70000
60000
50000
40000
30000
20000
10000
0
64660
61584
58608
53841
58144
10/84
11/84
12/84
1/85
2/85
MONTHS
LEGEND
NOT HOME
CONVERTER
ADMIN
CUSTOMER
DROP
SYSTEM
HEADEND

EXHIBIT 6-A



6-B

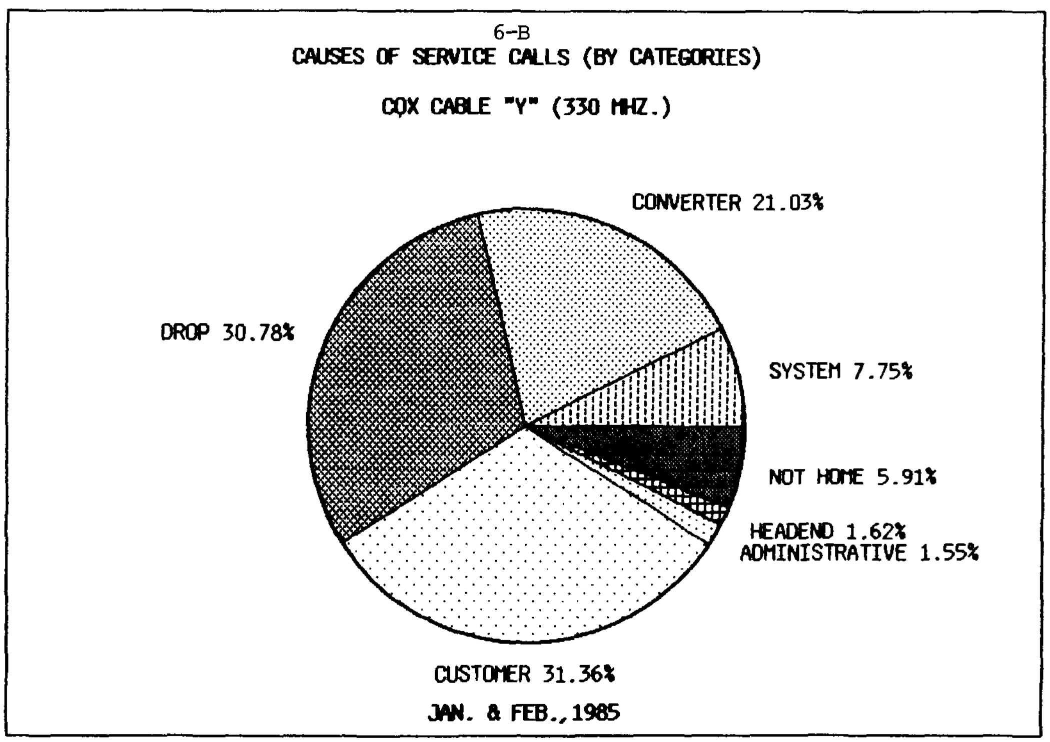
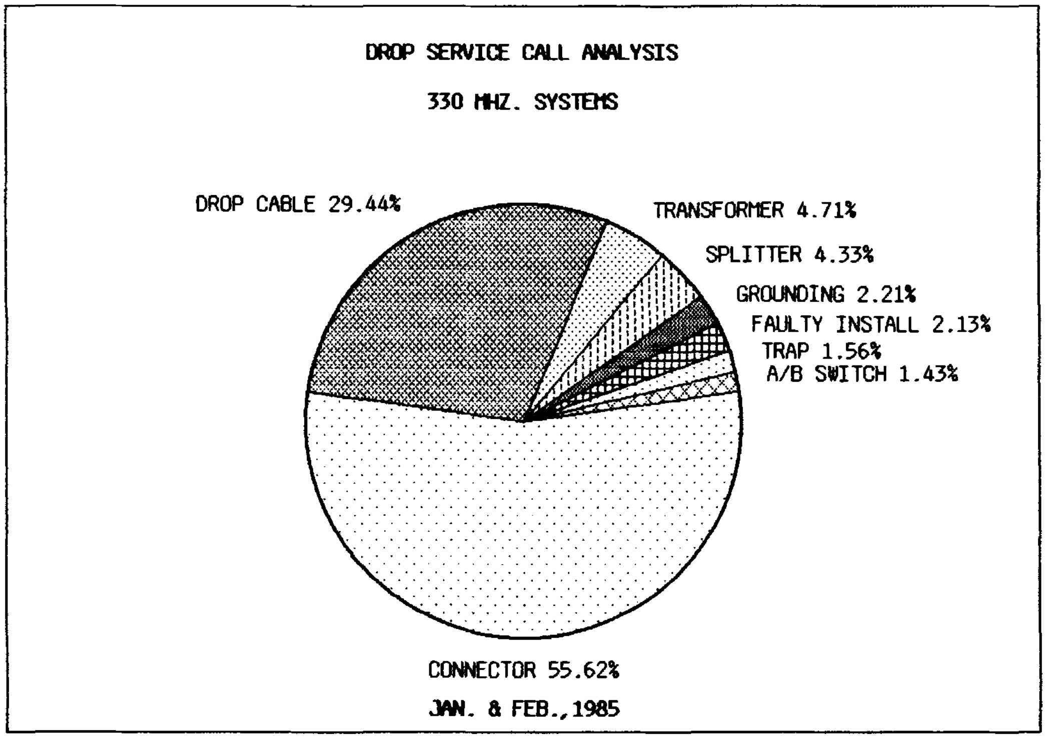
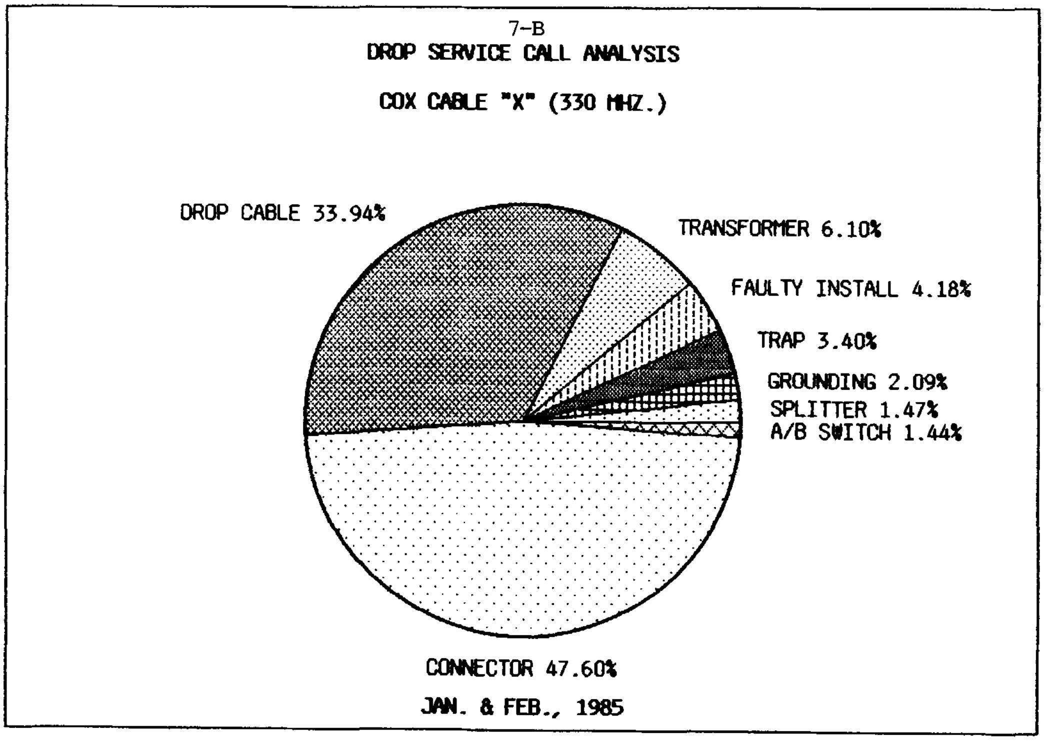


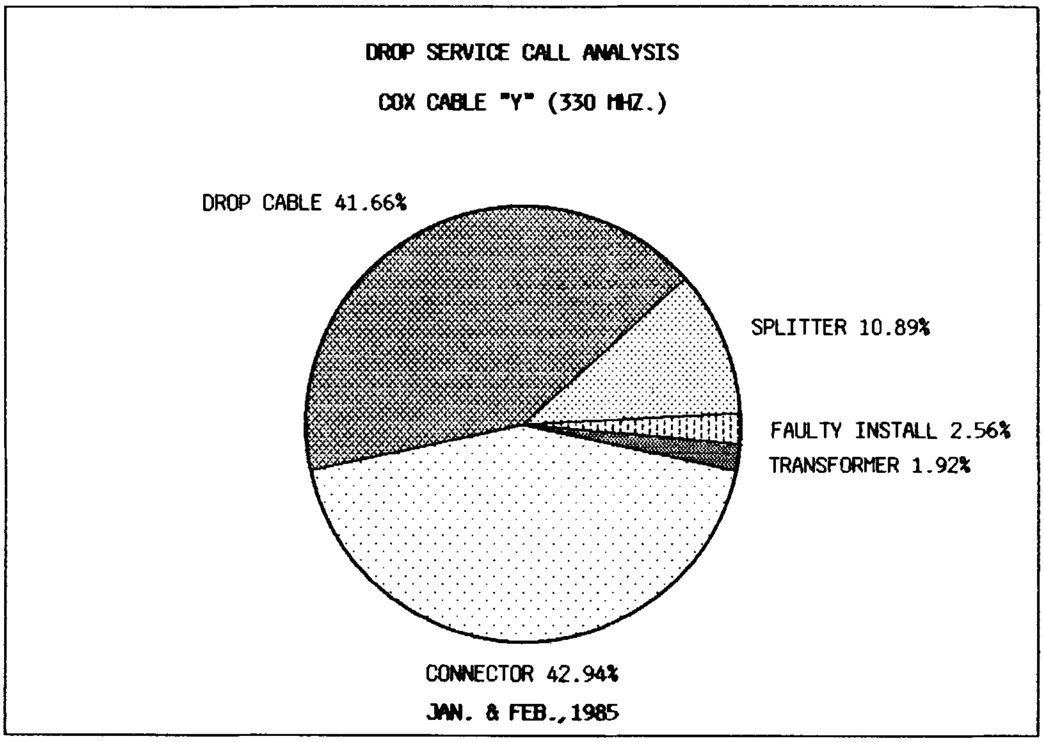
EXHIBIT 7-A



7-B



7-C


DROP SERVICE CALL ANALYSIS
COX CABLE "Y" (330 MHZ.)
DROP CABLE 41.66%
SPLITTER 10.89%
FAULTY INSTALL 2.56%
TRANSFORMER 1.92%
CONNECTOR 42.94%
JAN. & FEB., 1985

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