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"SPACE 1999" AND CATV

David G. Reiser
Microdyne Corporation
Rockville, Maryland 20850

ABSTRACT: A generalized history of commercial satellite communications, with an eye to the future, is cited in this paper. As in all phases of modern society, it is important to know where we've been, where we are now, and where we might be going. The CATV industry is just starting to enjoy the benefits of satellite television. Our heritage is short but our future seems to be endless.

The domestic satellite system is adding a new dimension to CATV, and the further exploitation of this broadband capability is making available to the public novel and versatile communications services.

Early Bird or Intelsat I was the world's first communications satellite, and was placed in service in June, 1965. It made live transoceanic TV possible for the first time. In the eleven years since Early Bird, satellite capacity has been increased from 240 telephone circuits or one television channel to 6,250 telephone circuits or 20 TV channels. Space segment costs per telephone circuitry-year have dropped from about $32,500 in Intelsat I to less than $800 in Intelsat V.

We have seen the EIRP of the spacecraft increase from +15 dBw of Early Bird to the present +35 to +38 dBw of our current DOMSATS. With this hundred-fold increase in available signal, the terminal requirements on the ground have become less stringent. With regard to CATV receive only stations, this means smaller antennas and/or higher noise amplifiers at the front end. In that area, we have progressed from the cryogenically cooled MASER and paramps, to room temperature paramps and GAASFET amplifiers.

The typical earth stations for CATV/TVRO presently consist of a 33-foot dish with a gain of about 51 dB, a low noise amplifier with a gain of 50 dB and a noise temperature of about 240°K. These units coupled to a satellite EIRP of 35 dBw and a high performance TV receiver yield video signal to noise ratio in the order of 55 dB under ideal conditions.

The first Intelsat, or Early Bird as it was called, weighed in at launch at 150 pounds. It could handle 240 telephone channels, or 1 TV channel. In its early life, it was turned off during non-peak hours. Although no longer useful for communications, its beacon is still being tracked.

Intelsat II ushered in a new era for satellite communications. For the first time, more than two earth stations were able to use the same spacecraft simultaneously. Weighing in at 357 pounds, this satellite maintained the 240 channel and TV capability of Early Bird.

The year 1969 saw Intelsat III placed into orbit with a launch weight of 647 pounds. Many important firsts were designed into this spacecraft. Among them was an increase in channel capability to 1500 circuits or 4 TV channels, and mechanically despun directional antenna.

Intelsat IV is still giving us a 3750 channel capacity. Its launch weight was 3120 pounds and has a 208-inch overall height. A first for the IV series is in its two steerable spot-beam antennas, which results in a higher signal level being received on the ground.

The Intelsat IV-A series are the current work horses of the international system. Being quite similar to the IV series, these birds have a 6250 channel capacity and have 20 transponders as compared to 12 in earlier series. This is accomplished through the use of simultaneous reuse of the same frequencies.

The next generation of Intelsats will be the V series and will make use of the 12 and 14 GHz band of frequencies. At this time, sufficient additional information is not available for publication.

But what about the future? What can we expect to see as technology advances? While working at COMSAT Labs, I was privileged to work with the C.T.S. Satellite Experiment, a joint NASA and Canadian venture. COMSAT is just one of the many user/experimenters. This satellite uses the K-Band frequencies of 12 and 14 GHz. But, the two biggest advantages are that a parametric amplifier at 14 GHz is on board the spacecraft, and a 200-watt TWT is being used at 12 GHz. Both are working well.

Because of the higher frequencies used, the lower noise front end and the higher power used in the satellite, the terminal equipment on the ground can be smaller and less expensive. To the CATV operator, this boils down to antennas of about six feet in diameter and two-way capability with about a 100-watt TWTA for video transmission.

Western Union's TDRSS, or Tracking and Data Relay Satellite System is the only planned satellite system that extends into the 1980's. This system concept will make use of both C-Band (4-6 GHz) and Ku-Band (12-14 GHz) as does the proposed Intelsat V series. The advanced spacecraft designs planned for TDRSS will enable more people to reap the benefits of satellite communications.

There has been much talk of late concerning the use of lasers and laser technology for satellite communications. We may see this medium used for spacecraft to spacecraft linkages. However, because of severe atmospheric and water vapor attenuation, it is doubtful that we will ever see spacecraft to earth linkages made. Bear in mind that one small rain cloud can completely block out an optical link.

By the turn of the century, we may see many households with their own small earth terminal for the reception of TV, facsimile and telephone service. Within my own Amateur Radio Club, we are building a 2.3 GHz moon-bounced station. So, the basis for the advanced technology is here now. Let us hope that the private sector takes the ball and runs far. We all have a lot to gain.

As a final thought, if you are considering the implementation of Satellite TVRO, also consider that you may want to expand your system to a two-way capability at the present 4 to 6 GHz. And, with an eye to the future in the higher frequencies, select the passive components with the idea that you may upgrade to K-Band within five to ten years.

Satellite technology is changing our lives. We watch news and sporting events from the other side of the globe as they happen. A local television station in Atlanta, Georgia became a national outlet overnight. A great deal of hard work, perseverance and money have made this possible. We, in the cable industry, are indebted to those who have, and are continuing to make our world a little smaller and a whole lot friendlier.

ACKNOWLEDGEMENTS

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ADDRESSABLE CONTROL FOR LOOP-THRU WIRING

JOSEPH L. STERN

STERN TELECOMMUNICATIONS CORPORATION
485 Madison Avenue, New York, N.Y.10022

An increasing number of subscribers are being served by loop-thru wiring in apartment houses and a strong need exists for systems to control service to those subscribers. Two new devices, a flush-mounted wall-box intelligent tap and an addressable disconnect unit are now available to exercise control. The intelligent tap for loop-thru service is part of a complete system of addressable control for basic services and Pay-TV. The limited address disconnect device is offered as a means of cutting losses in problem locations.

Would you, an experienced cable operator, build and operate a cable system in a community where you could not get at your cable to service it, where the subscriber had control over the provision of the service, where the subscriber could decide to pay or not pay for service, and where the subscriber could walk away with your $40 or $60 converter/descrambler. Most of you say you wouldn't build and operate such a system, but many of you have, and more probably will. What has been described is essentially a modified MATV system, in an apartment house, where the wiring is in walls and/or in conduit, and is looped-thru from subscriber to subscriber.

As cable television moves into the urban markets more and more subscribers are added thru modification of the service being supplied in apartment houses by MATV systems. In the majority of cities the existing MATV system is improved to a minor degree and the loop-thru wiring of the system remains as the distribution system for the cable customers. Where this wiring is in conduit or in walls, in a finished building, it is very difficult and extremely costly to rewire or to replace and thus the desirable "home-run" concept is rationalized out to allow the "loop-thru" to stay, with all of its problems.

The problems are rather well known; lack of access to inspect and repair problems, and most of all, lack of control, particularly important today with high-fee services and high costs for the provision of the service of Premium TV and multi-channel services.

Last year the industry was greeted by the introduction of prototypes of outdoor addressable taps and their companion apartment-house versions for "home-run" wiring. These units, which I expect to see go into operation this year, serve an economically beneficial purpose for individual homes and for "home-runs" in apartments but do not lend themselves to the "loop-thru" type of wiring in their present configurations.

To meet the needs of the "loop-thru" wiring systems, two organizations are about to introduce control system devices that will allow the "inaccessable" apartment connection to be "accessable" from outside the apartment. With these new systems the CATV operator once more has control over the service he is providing; can provide it when it is desired and paid for, and can deny it when no longer desired or, when not paid for. Complete control without the problems of access can be provided, insuring payment for services rendered.

The first device which will soon surface, and indeed may be shown here at the convention, is the apartment house Intelligent Tap, IT-I. This unit is a companion to the four output Intelligent Tap, IT-4, and it fits into a standard wall box and offers the control of one subscriber tap, in a loop-thru apartment structure. The unit is a scaled down, miniaturized version of the IT-4, using exactly the same communications system, many of the same parts, and is fully compatible with the strand mounted, pedestal mounted or home-run apartment house IT-4 and IT-60 systems.

It is part of a total addressable tap system design to meet all needs of a cable system. It is also usable as a stand-alone package for apartment-house systems that are fed from an MDS receiver or a Pay-TV local origination package. Basically, it will first be offered as a basic service control unit, having a built-in tap, data-power logic system, and solid-state switch. A later version will add control of Pay-TV in addition to control of basic service, matching the features of the IT-4, simply by adding the Pay-TV modules to the existing package, which already contains all of the logic and control circuits required.

The Intelligent Tap system is designed with a simplicity and reliability that allows the packaging of a complete control system in a standard wall box, due to the lack of telemetry receivers, demodulators and multiple components to decode and control. The Intelligent Tap system achieves control by communicating with Data Power, or, more simply, sends data to the tap control as direct data, not using RF and, not subject to false operations due to RFI; CB equipment, spurious signals, receiver radiation.

The cable system is basically capable of carrying energy in two separate spectrums, the powering frequency spectrum, from about 30 hertz to 2,000 hertz, and the RF spectrum from about 5 megahertz to 300 megahertz. In the proprietary intelligent tap system, control data is sent as pulse with modulated and frequency shift keyed signals in the 60 to 120 hertz region, and is configured so that it appears to be a 60 hertz signal to all devices and power supplies that wish to look at a 60 hertz signal. The data signals provide the power requirements for amplifiers in the system and, in fact, allow them to operate more efficiently than usual due to its square waveform. The portion of the system not requiring power simply looks at this signal as data, and as data, it operates a single LSI chip directly, to control the services being supplied to the CATV system subscriber.

Control of the data is effected from a variety of optional control packages, ranging from a small manual entry calculator type of controller, thru an intelligent terminal/printer up to any type of business computer, local or remote, that may be used for a large system or group of systems. The speed of control is such that less than ten minutes is required to individually change the services supplied to each of 10,000 subscribers. The speed is slow enough to insure reliability under all types of operating conditions and fast enough to allow for per-program service control as well. The IT-I completes the system of subscriber control allowing individual homes, home-run wired apartments, loop-thru apartments, stand-alone Pay-TV systems and MDS systems to control their services and their cash flow.

A second device for control of loop-thru services is also available. This is a limited-address control system which can only turn service OFF. At first that may seem of little use, but its object is to permit the disconnect of service in a loop-thru system where access is denied, and also where the "barricaded" subscriber has an expensive converter and/or descrambler belonging to the cable system.

This device is called the "SQUIB" and is a one-time operable unit, which responds to a specific frequency, waveform and signal application to operate an irreversible circuit opener. It is designed specifically for operation with ten different addresses so that it can be used in systems where the cable drop is available just outside the home or apartment, as well as the more important case where the only access to the cable is at a floor distribution box, or the start of a "run" in the basement or roof-top area.

Control is effected from a small shoulder case mounted transmitter-controller, battery operated. The person initiating the "disconnect" simply opens the cable to the "run" or drop, screws the connector into his controller-transmitter, sets the control switch on the code letter designated for that particular subscriber, presses the "operate" button, and that's all; the service at that location is terminated, and no other subscribers are affected, once the cable is reconnected to the system.

The "SQUIB" unit itself is installed in the apartment wall box, can be fastened to the output connector of a wall box with a locking connector, can be mounted on a converter with a locking connector, or can be built into a converter or descrambler. It can be used to turn off service, or simply to disable a converter, to make it less desirable to "carry away" or to sell in the "Flea Market." All in all, the "SQUIB" offers another level of control for a heretofore inaccessible location.

Using good MATV wiring, or a loop-thru system no longer means losing control over revenue. Control systems are now available to give the operator what he needs to provide the same service, under the same conditions, in a loop-thru system as he does in a classical home-run system. These new innovations meet an industry need for servicing its customers needs, basic cable service, subscription Pay-TV service, per-program Pay-TV service, and stand-alone or MDS service.

An Investigation into the Problem of Character Generator Ringing or Second Image on Cable Systems

Alex B. Best

Scientific-Atlanta, Inc.

Abstract

Waveform testing is performed on a CATV Modulator–Home Receiver modem to investigate the problem of "ringing" or "2nd Images" which sometimes occur when video signals having non-standard baseband formats such as alpha-numerics are carried on the cable system.

Past attempts to solve the problem through the use of Data Filters is discussed as well as a different approach utilizing the technique of Time Domain Correction. A block diagram of the Time Domain Correction scheme is given along with a discussion of its operation.

This new technique is applied to the Modulator–Home Receiver modem and waveform testing is once again performed indicating the degree of improvement that might be achieved using this scheme.

Introduction

The increased use of alpha numerics on cable systems the past few years has brought with it an increase in the number of complaints describing a "second image" following the characters as viewed on the home receiver. The majority of character generators on the market today produce white displays on a dark or multi-colored background and all are capable of excellent "sharpness" and legibility when viewed on a wide bandwidth video monitor. However when this same information is converted to a standard television type RF signal in a CATV modulator and ultimately viewed on the home receiver the legibility may be impaired, the worst situation being when the white characters are followed by a distinct "second image" of the character and this "second image" is also lighter than the surrounding background. In many cases this "second image" has all the characteristics of a ghost; however as we shall later see, no reflections due to poor return loss are necessary to create the problem. Attempts in the past to solve this problem have taken the form of phase equalized 4.2 MHz low pass filters placed on the output of the character generators as well as various types of data filter modules placed at the input to the modulator. It is the purpose of this paper to determine why these past attempts to solve the problem have proved only marginally successful and finally to consider an entirely different approach to solve the problem utilizing the technique of time-domain video waveform correction.

Waveform Testing of a CATV Modulator–Home Receiver Modem

In an attempt to determine the cause of the "2nd Image" problem a CATV modulator was carefully checked for proper alignment and then subjected to video waveform testing when operated back to back with a precision television demodulator. The particular modulator used contained both the pre-distortion delay equalizer required by the FCC for color transmission on broadcast stations as well as baseband delay correction circuits to compensate for delay errors generated in the vestigial filter. The results of this back to back test is shown in Figure 1. The test waveforms chosen for these tests were the Multiburst signal because of its obvious sensitivity to response flatness and the 2T Pulse signal because of its sensitivity to delay errors.

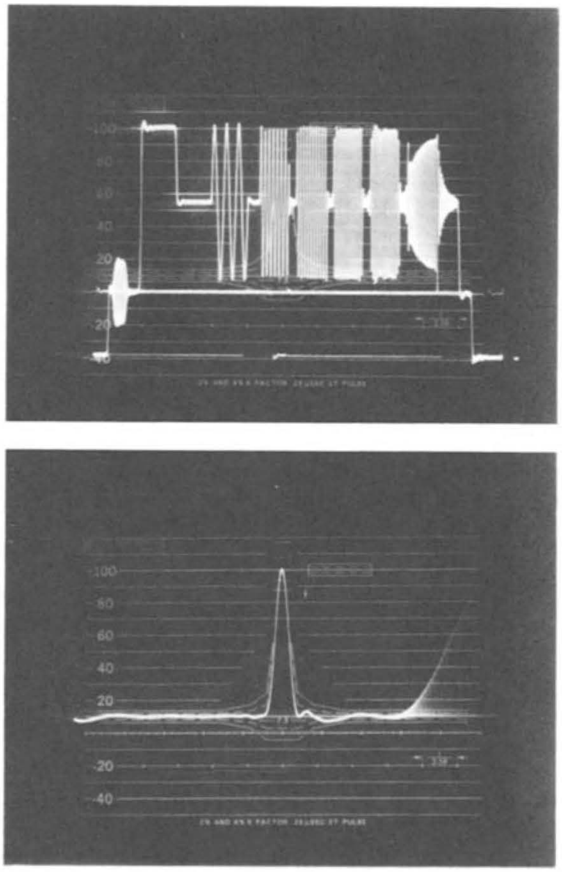


Figure 1. Multiburst and 2T Pulse Response – 6300 Modulator – 6250 Demodulator

From the photographs it can be seen that the overall amplitude response is flat to within a few tenths of a dB and the units produced a "K" factor of approximately 3%. The purpose of this exercise is to convince the reader that although the modulator is not perfect it certainly would be considered to be of good quality and at least typical of many modulators in operation in cable systems throughout the country.

The output of the modulator was disconnected from the input to the demodulator and then fed into the input of a home TV receiver. The home receiver used in these tests was a popular model of recent vintage. Although it certainly can't be argued that his particular receiver is the "average home receiver" it should at least be representative of the units in the field. To perform waveform testing on the TV receiver the back cover was removed and a buffer amplifier exhibiting a high input impedance and a 75 ohm output impedance was placed between the receiver luminance signal prior to being fed to the kinescope and the input to a waveform monitor. The receiver channel selector was set to be the same as the output of the modulator and then carefully fine tuned while feeding the receiver the modulator channel plus a lower adjacent channel sound carrier. The sound carrier was then removed and this modulator–"demodulator" pair was subjected to the same waveform testing as described for the modulator–precision demodulator pair. The results are shown in Figure 2.

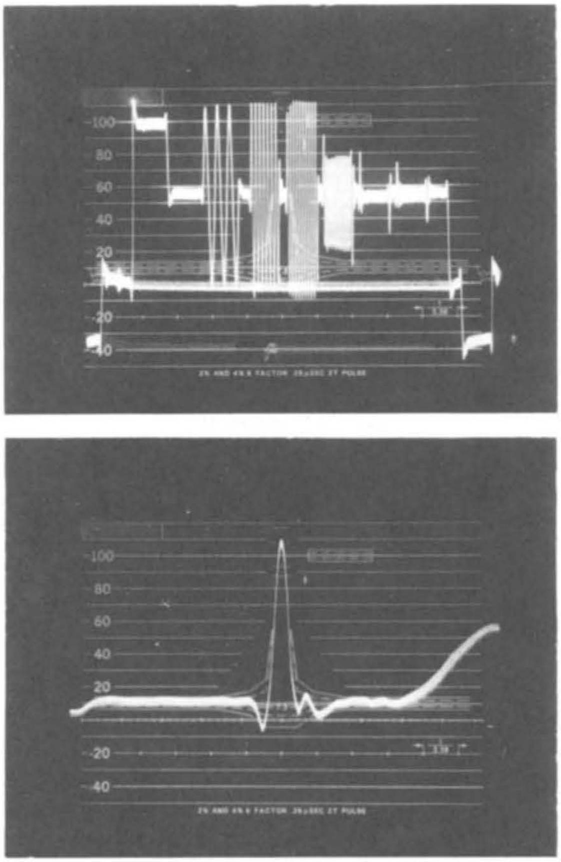


Figure 2. **Multiburst and 2T Pulse Response — 6300 Modulator — TV Receiver**

The multiburst response indicates a gradual peaking of about 1.5 dB from low frequencies to 2 MHz and a sharp cutoff between 2 MHz and 3 MHz. The 2T pulse response shows a leading undershoot and trailing overshoot giving a "K" factor of approximately 5%. Had the overall modulator-demodulator delay response been flat we would have expected fairly symmetrical ringing on either side of the 2T pulse having peaks displaced from the 2T pulse maximum amplitude by 1/cutoff frequency or about 400 nanoseconds. The combination of non-flat delay plus to a lessor degree some quadrature distortion has produced un-symmetrical ringing at the cutoff frequency. Careful viewing of even the 2T pulse on this receiver begins to show a trailing "2nd image."
As is well known the shape of the 2T pulse is carefully controlled to produce an energy distribution versus frequency which is approximately 6 dB down at 2 MHz and essentially zero above 4 MHz.

Consider the results of replacing the 2T pulse with one representative of those produced in some character generators. Such a pulse is shown in Figure 3. This pulse has rise and fall times of 15 nanoseconds and a width of 75 nanoseconds. It was produced by feeding the output of a Hewlett-Packard Model 214A Pulse Generator into the External Video In of a Telemet Model 3508 Test Signal Generator. It has an energy distribution which is flat across the 4.2 MHz video bandwidth of the modulator.

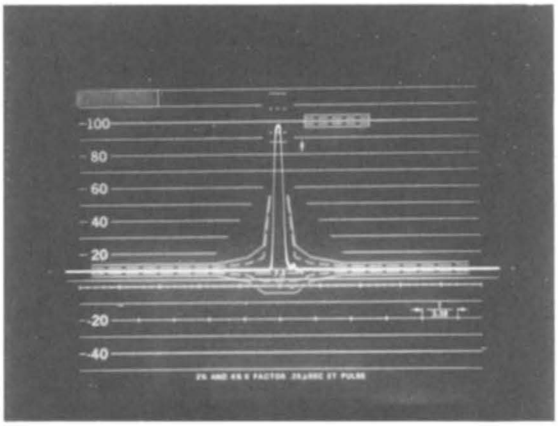
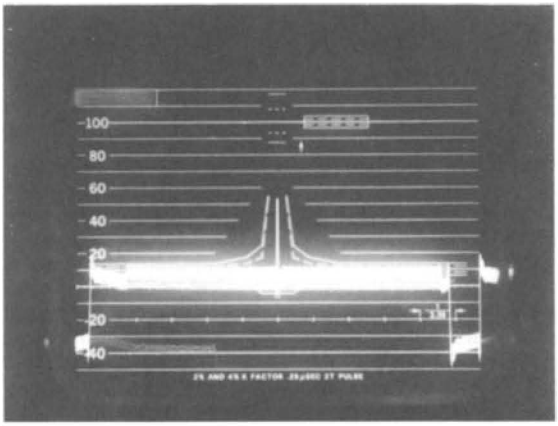
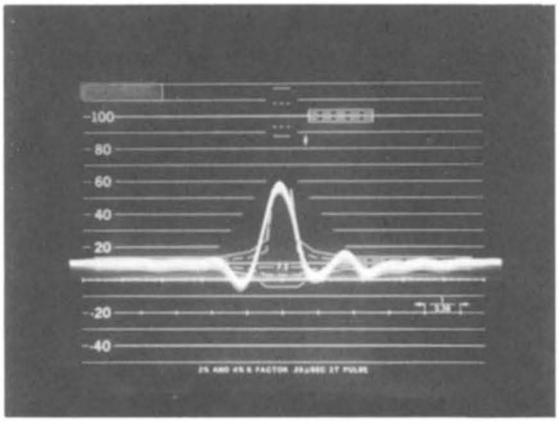


Figure 3. **"Character Generator Pulse" — 75 Nanosec Wide — 15 Nanoseconds Rise and Fall Times**



One Horizontal Line



Expanded View of Pulse

Figure 4. **"Character Generator Pulse" — CATV Modulator — Home Receiver**

The results of feeding this "Character Generator Pulse" through the CATV modulator–home receiver is shown in Figure 4.
In many respects it is similar to the 2T pulse response except

the amplitude of the undesired trailing transient response is a much larger percentage of the desired response. This increased amplitude of the "2nd Image" is due to the larger energy content of the "Character Generator Pulse" at the cutoff frequency of the system. Before we are too quick to judge the home receiver at fault let's replace it with the precision demodulator used to produce Figure 1. The results of passing the simulated character generator pulse through this pair is shown in Figure 5.

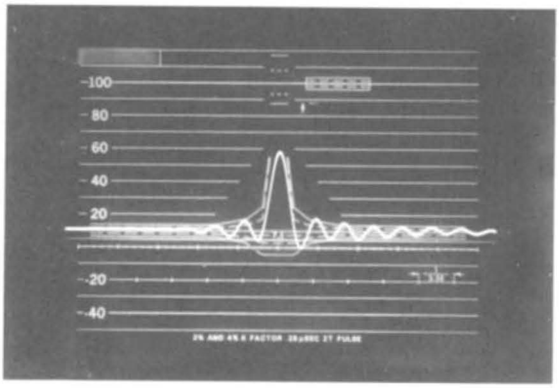


Figure 5. "Character Generator Pulse" – CATV Modulator – Precision Demodulator

As expected we have a more symmetrical ringing on either side of the desired response producing multiple images both proceeding and following the desired image. These undesired images are displaced from the desired one by 1/cutoff freq. = 1/4.2 MHz = 238 nanosec. Viewing the output of this demodulator on a high quality video monitor will produce multiple images which are even more difficult to read than when viewed on the home receiver. If we conclude that the modulator is not at fault and the demodulator is not at fault we must ultimately arrive at the conclusion that the problem is one that can best be described by the Theory of Information Rates. Simply stated: When the transmission bandwidth is less than the signal bandwidth some degradation of the signal always results. This degradation may or may not however result in the loss of information depending upon how the information is ultimately utilized. One solution to the problem would be to slow the rise and fall times and lengthen the width of the pulses produced by the character generators. This obviously would reduce the number of characters that can be displayed at any given instant and is highly unlikely since in many instances the character generators are fed directly to video monitors where the bandwidths and therefore information rates are not nearly so restrictive.

Frequency–Domain Waveform Correctors

In the case of bandwidth limited television channels past attempts to solve the problem have taken various forms. One such attempt was to remove the unusable high frequency energy content of character generators by placing a phase equalized 4.2 MHz low pass filter on their output. This solution can have little or no effect on the problem because as shown in Figure 2 signal frequencies above 2.5 MHz are not passed by the luminance channel of the home receiver.

There have also been developed by some modulator manufacturers a variety of "Data Filters" which basically was some form of low pass filter placed at the input to the modulator in an attempt to roll-off the high frequency energy content of the character generator signals. Usually their effect was only minimal or if anything produced a smearing effect as viewed on the home receiver. Later when colored backgrounds became popular these filters were rendered useless because of the loss of color saturation they produced. Further attempts to design data filters produced results such as that shown in Figure 7.

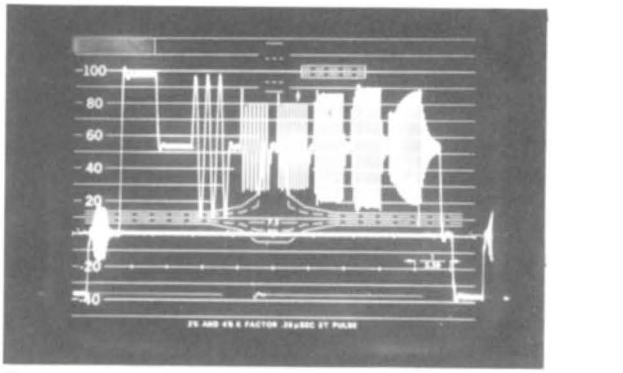


Figure 6. Data Filter Multiburst Response

This filter was designed to produce a more gradual system cutoff response but yet not reduce the color saturation of the background. The results of this filter proved to be more beneficial than that of the low pass type but there were still situations where this filter produced little or no results.

Time–Domain Waveform Correctors

Television transmitters, to a large extent, have identically the same problems in producing high quality alpha numerics on the home receiver as we do in cable systems. Their use however has been limited to producing station call letters, emergency messages, sports scores, etc. To provide improved legibility for these applications of alpha numerics as well as improve their overall transient response to normal video signals transmitter engineers have been utilizing a tool which we basically have overlooked in CATV. This tool is the Video Time–Domain Waveform Corrector. The time–domain approach to waveform correction aims directly at restoring a particular point in a waveform at a given time to the amplitude level it should be at that time, without recourse to frequency–domain considerations[1.]. Normally these devices were designed to correct distortions which had occurred in processing the video signal prior to being modulated on the RF carrier. To do so a correction signal is generated from the incoming distorted signal and then added to the distorted signal to produce a corrected outgoing signal. There is nothing however, to prevent these devices from taking a correct input signal and producing a pre-distorted output signal to correct for errors generated elsewhere in the system[2.]. One reason such techniques have not found widespread use in the CATV industry is due to their excessive price, usually costing many times more than the modulator itself. It should be pointed out that these machines provide a variety of signal conditioning functions and the use of such a device to produce increased legibility of alpha-numerics in cable systems would be an inefficient use of its overall capability.

I would now like to describe what I consider to be a novel approach to a solution of the problem utilizing time–domain pre-distortion techniques as described before but at a fraction of the cost. The system will only work with character generators producing white letters on a dark, colored or multi-colored background. It will not function with normal transmitted video signals. Such is not the case for the more expensive machines described above. The block diagram of the Character Generator Pre-distortion Waveform Corrector is shown in Figure 7. The input video signal from the character generator takes two paths. One path is through a buffer amplifier and finally an adder circuit where it appears at the output. This path provides no signal conditioning of any form to the input signal. The second path passes the input signal through a second buffer amplifier and then a 3.58 MHz notch filter which removes any color subcarrier energy which may be present on the signal. The sync negative video signal is then clamped at the sync tips to a positive dc

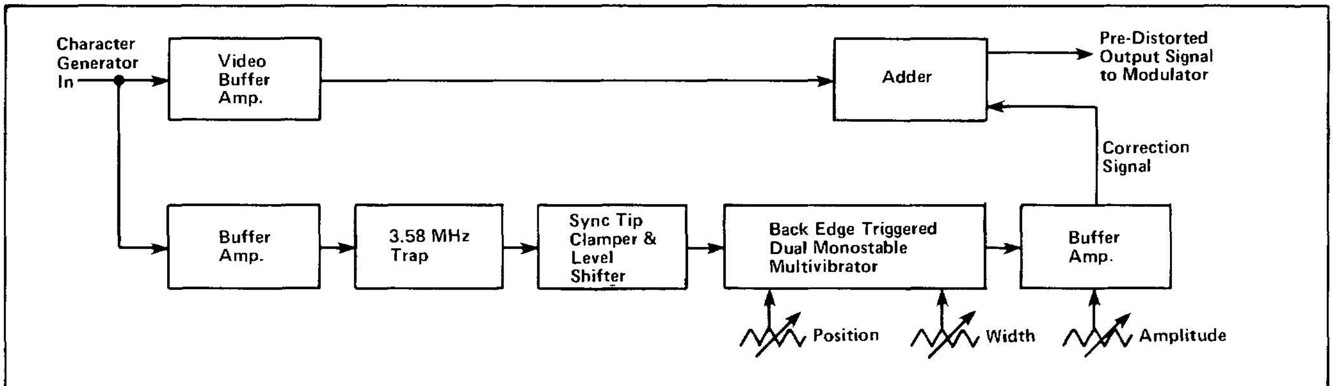


Figure 7. Block Diagram of Time Domain Character Generator Pre-Distortion Waveform Corrector

level set to cause the dual monostable multivibrator to be triggered only by the pulses which produce the alpha-numerics. The dual monostable multivibrator is configured to produce an output pulse every time a negative transition occurs on its input waveform. This output pulse is variable in its position, width and amplitude relative to the pulse which triggered its initiation. This output pulse is added to the unaltered character generator output signal to form the pre-distorted signal which ultimately is fed to the input of the CATV modulator.

To gain a better understanding of how such a system might operate in actual practice, consider the problem indicated in Figure 4 which shows a distinct "2nd Image." If we now feed the "character generator" pulse through the Time–Domain Pre-distortion Waveform Corrector before going into the modulator, careful adjustments of its controls would allow almost complete elimination of the "2nd Image." Examination of Figure 8 which is the demodulated output of the home receiver under these conditions indicates a much improved transient response with a complete elimination of the trailing "2nd Image" response. Shown in Figure 9 is the pre-distorted output of the Time Domain Waveform Corrector under these conditions.

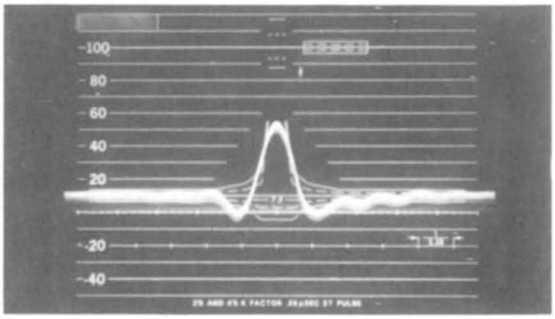


Figure 8. 75 Nanosecond Pulse – Character Generator Waveform Corrector – CATV Modulator – Home Receiver

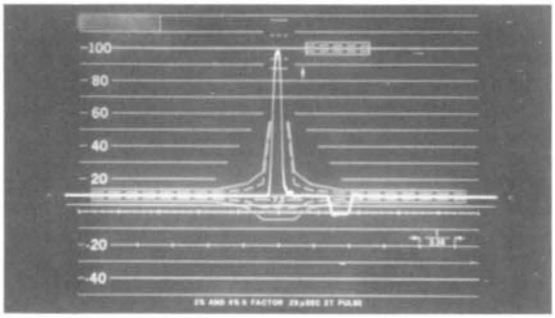


Figure 9. 75 Nanosecond Pulse – Character Generator Waveform Corrector – Waveform Monitor

The correction pulse follows the main pulse by about 400 nanoseconds and is opposite in polarity to the main pulse. Its width is about 100 nanoseconds. This correction pulse is generated each each time during the scanning of a horizontal line that a pulse is produced by the character generator. Since the correction pulse is initiated by the negative transition of the character generator pulse, its position relative to the back edge of this pulse will not vary, regardless of its width.

Conclusion

Past attempts at improving the legibility of alpha-numerics being viewed on home receivers fed from CATV modulators have generally been in the form of Data Filters. These attempts to improve the system transient response operate by altering the system in the frequency–domain.

This paper describes a technique whereby the overall system transient response is improved by altering the system characteristics in the time–domain. In our example the output of the character generator has been pre-distorted before going to the modulator by adding in a correction signal which ultimately cancelled the "2nd Image." It may be argued that the receiver used here was not an "average home receiver" and that different receivers would require a different amount of pre-distortion correction. This may well be the case, however my experience with this form of correction has indicated that receivers with greatly impaired legibility of alpha-numerics are much improved whereas receivers which had good legibility to start with have not been impaired.

The real advantage of this technique may well lie not in its ability to compensate for the "average home receiver" as indicated here but its ability to compensate for errors generated within the cable system itself. Differences in performance between character generators, CATV modulators, as well as system configurations which may include sub-lo runs from office to headend plus reprocessing all enter into the system performance. The time–domain correction technique can easily be adjusted to optimize the performance of any particular system. Such is not the case with Data Filters.

(1.) Mervyn W. Davies, "A Versatile Video – Waveform Corrector for TV Transmitter and Studio Applications," IEEE Transactions on Broadcasting, Vol. BC-19, No. 2, June 1973.

(2.) T. M. Gluyas, "TV Transmitter Luminance Transient Response," IEEE Transactions on Broadcasting, Vol. BC-20, No. 1, March 1974.

CATV APPLICATION OF FEEDFORWARD TECHNIQUES

Bert Henscheid and Patrick J. Birney

THETA-COM CATV
Division of Texscan Corporation
Phoenix, Arizona

ABSTRACT

Several papers and many articles have been written explaining what feedforward is, but little has been presented on just where such technology should be applied. It is not feasible in just any location, due to inherent operational limits and cost considerations. This paper presents the aspects which must be considered when applying feedforward to CATV systems. Analysis of operation in trunk, super-trunk, bridgers, and distribution positions are given. Conclusions are hypothetical since very little hardware currently exists.

INTRODUCTION

Feedforward amplifiers utilize a circuit technique whereby the output signal is compared to the input signal and the distortion components of the amplifier are cancelled. A significant improvement in amplifier linearity is achieved at the cost of increased circuit complexity. This paper leaves the discussion and analysis of feedforward to the references on the last page. The purpose here is to examine the performance versus cost consideration in system design.

SYSTEM ANALYSIS

Assuming that feedforward is a viable concept and can be developed into a technically consistent product, where are the system locations that can best utilize this improvement? Obviously, any distortion improvements are welcome in a system, but one must look at the economic considerations to determine if the improvement is worth the cost.

An assumption was made of the typical performance levels of a feedforward trunk, bridger, and line extenders based on preliminary development of actual circuits. These levels are shown in Figures A and B. These new performance specifications were inserted into computer programs of current system design. The assumption of compatible gain, spacing, powering, and AGC were also made. The system configuration included 20 trunk stations with a one output bridger at the last station and followed by two line extenders.

Figure C shows the results of the new system design with various combinations of feedforward modules. All the numbers shown were calculated at the end of the second line extender. Note that little improvement was made with FF in the trunk only, indicating that major contributions to distortion are made in the distribution lines. Obviously, if the assumptions in Figure B are true, the trunk alone would improve by the same amount as the basic FF modules.

Significant improvements were made in performance by putting feedforward in the bridger and line extenders while using standard trunk modules. A 3 dB improvement in cross modulation and composite 3rd order was achieved by using a FF bridger only and 5 dB improvement with a FF line extender only. Combined FF bridger and line extenders yielded 10 dB improvement over standard modules.

The next test involved assuming specific distortion levels as outlined in Table D and computing the available operating levels for the bridger and line extenders while maintaining trunk levels of +32 dBmV. Figure E shows the computed operating levels based on the system performance levels listed in Figure D. The last two feedforward configurations shown in Figure E yielded operating levels of +57 dBmV and +58 dBmV respectively.

Module Parameters \ Type of Amplifier		Trunk		Bridger		Line Extender	
		Std.	FF	Std.	FF	Std.	FF
Cross Modulation	dB	-93	-113	-61	-81	-63	-83
Carrier/Noise	dB	-59	- 59	-63	-63	-71	-71
Second Order IM	dB	-81	- 91	-65	-75	-67	-77
Comp C/TB	dB	-94	-114	-66	-86	-69	-89

1. 30 Channel Output Levels (2-D/E-13/J-R)
   Trunk - (28/30/32) dB
   Bridger - (43/45/47) dB
   Line Extenders - (43/45/47) dB

FIGURE A. STANDARD AND FEEDFORWARD MODULE SPECIFICATIONS

1. 10 dB improvement in 2nd order distortion over standard modules.
2. 20 dB improvement in X/mod and composite 3rd order distortion over standard modules.
3. The noise figure will be the same as a standard module.
4. Feedforward (FF) module cost parameters:

   A. FF Trunk Module — 29.5% increase over standard module
   B. FF Bridger Module — 27.9% increase over standard module
   C. FF Line Extender Module — 62.8% increase over standard module

TABLE B. "FEEDFORWARD MODULE ASSUMPTIONS"

CONDITION \ PARAMETER	Cross Mod	C/N	2nd Order	Comp. C/TB
Standard	-51.2	-45.9	-60.6	-55.9
FF Trunk Only	-52.8	-45.9	-61.4	-58.1
FF Bridger Only	-54.2	-45.9	-62.3	-58.7
FF Line Extender Only	-56.6	-45.9	-62.9	-60.3
FF Trunk and Bridger	-56.2	-45.9	-63.5	-61.9
FF Bridger and Line Ext.	-63.4	-45.9	-66.4	-65.7
FF All Modules	-71.2	-45.9	-70.6	-75.9

FIGURE C. SYSTEM DISTORTION LEVELS IN dB

These are unreal levels, since for 30-plus channels, +51 dBmV is a maximum due to limitations in the FF circuit. That is, the error amplifier starts contributing severe distortions above +51 dBmV which cannot be cancelled.

These two configurations were rerun with the output levels held at +51 dBmV. Figure F shows the additional system performance advantage under this condition.

System cost analysis was done by computing system cost savings by using higher distribution levels and comparing with a standard system. The increased cost of the complex feedforward module was estimated and subtracted from the system cost saving. These values are listed in Figure G. The bridger seems to be the only contributor to real cost savings, and is probably the easiest to implement. While the other combinations appear to be quite expensive, they do contribute to significant performance improvements. It is these improvements versus cost factor which must be weighed against system objectives.

SYSTEM PARAMETER	MINIMUM SYSTEM SPECIFICATION
1. 30 channel crossmodulation	-51 dB
2. 30 channel carrier-to-noise	-44 dB
3. 30 channel 2nd order	-60 dB
4. 30 channel composite 3rd order	-55 dB

TABLE D. "TYPICAL CATV SYSTEM SPECIFICATIONS FOR A (20 TRUNK/1 BRIDGER/2 LINE EXTENDER) CASCADE"

Configurations	Trunk	1 Port Bridger	Line Extender	Distribution Level Change
Standard	28/30/32	43/45/47	43/45/47	0
FF Trunk Only	28/30/32	44/46/48	44/46/48	+1
FF Bridger Only	28/30/32	45/47/49	45/47/49	+2
FF Line Extender Only	28/30/32	47/49/51	47/49/51	+4
FF Trunk & Bridger	28/30/32	46/48/50	46/48/50	+3
FF Bridger & Line Ext.	28/30/32	53/55/57	53/55/57	+10
FF All Modules	28/30/32	54/56/58	54/56/58	+11

FIGURE E. SYSTEM OUTPUT LEVELS IN dBmV

DISTORTION PARAMETER	ORIGINAL SYSTEM PERFORMANCE OBJECTIVES	FEED FORWARD IN BRIDGERS & LINE EXTENDERS	FEEDFORWARD IN ALL MODULES
30 channel cross modulation	-51 dB	-59.8 dB	-64.1 dB
30 channel carrier to noise	-44 dB	-45.9 dB	-45.9 dB
30 channel 2nd order	-60 dB	-64.7 dB	-68.9 dB
30 channel composite 3rd order	-55 dB	-63.1 dB	-69.3 dB

1. Specifications based on 20 trunk/ 1 bridger/ 2 line extenders.
2. System output levels

   Trunk = (28/30/32) dBmV

   Bridger = (47/49/51) dBmV

   Line extender = (47/49/51) dBmV

FIGURE F. ADDITIONAL SYSTEM PERFORMANCE ADVANTAGES FOR FEEDFORWARD CONFIGURATIONS LIMITED TO +51 dBmV

CONFIGURATIONS \ COST FACTORS PER MILE	SYSTEM COST SAVINGS W/FF	SYSTEM COST FOR FF MODULES	NET COST TO SYSTEMS
Standard	0	0	0
FF Trunk Only	-$17	+$52	+$35
FF Bridger Only	-$45	+$34	-$11
FF Line Extender Only	-$88	+$184	+$96
FF Trunk & Bridger	-$65	+$86	+$21
FF Bridger & Line Ext.	-$100	+$218	+$118
FF All Modules	-$100	+$270	+$170

FIGURE G. SYSTEM COST ANALYSIS PER MILE

SUPER TRUNK LEVELS	20/30/32	33/35/37	38/40/42	dBmV
XM	-87	-77	-67	dB
C/N	-46	-51	-56	dB
2nd O	-78	-73	-68	dB
C/TB	-88	-78	-68	dB

FIGURE H. FEEDFORWARD SUPER TRUNK ANALYSIS BASED ON 20 AMPLIFIER CASCADE

Feedforward amplifier techniques seem to be ideally suited for long super trunk applications. If feedforward were used in a super trunk system, the results in Figure H might be expected for a 20 amplifier cascade. The object of this is to improve the carrier to noise ratio enough so that the super trunk is transparent to all distortion parameters. The cost increase for a feedforward super trunk station is estimated to be 30%.

CONCLUSION

This paper has summarized the economic and performance factors associated with feedforward type amplifiers. The economics of the FF system configurations presented in this paper may seem on the surface to imply that a FF amplifier is too costly to incorporate into CATV distribution systems. This is basically true if you only consider the initial amplifier costs associated with such a system. The increase in system performance with a FF type system is worth considerable attention when you consider other system factors such as:

1. Increased customer satisfaction associated with better pictures quality.
2. Increased system performance tolerances over temperature.
3. Lower system maintenance associated with a lower number of active devices per mile.

The increased cost of the FF amplifiers must be carefully weighed against the system advantages listed above. It is very difficult to assign a dollar value to these system advantages. Since the primary function of a cable system is to provide a service to its customers, we must assume that by increasing the quality and reliability of the service, that the final result will be increased revenues.

The degree to which these amplifiers will be used in the near future will be a function of the system operators requirements. The FF super trunk applications seems to be the first logical approach for FF amplifier modules. The next step may be to develop a FF bridger module which is compatible with existing bridger modules. In this manner, the operator can drop in a FF bridger in his existing system and improve the performance of his system at a very nominal cost.

In summary, the FF amplifier has definite system advantages over conventional type amplifiers.

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CHARACTER GENERATOR PROGRAM TECHNIQUES

Shirley L. Rohn

Cox Cable TV of Spokane
Spokane, Washington

The variety of information, which can be categorized, formatted and displayed by character generation, is almost limitless. The most common, of course, is the radio broadcast wire. However, other sources presently used are: NOAA, National Weather Wire, the financial wire, and NYSE and AMEX, stock quote wires, plus the horse racing wire.

The above information displayed is exceedingly important. However, probably the most exciting information displayed, and the most viable customer support of the cable system in character generation, is community information.

Examples of computer to computer data displays include comparison shopping, traffic information, listings from state or private employment agencies, air line schedules and recreation facilities availabilities.

Through computer patterns or pictures, color coding, and the selecting of proper background music, the Character Generation Channels exude personality, clarity and imagination, which create viewer longevity.

To reduce operating overhead within your system, remote keyboards can be located throughout the community to gain the civic, educational and general information input. These remote keyboards can also generate revenue through placement and advertiser locations. This list of information categories is merely a starting glossary. It is suggested that you keep the categories relevant to your community.

Another possibility is time-shared information, i.e. consumer shopping, 9:00 a.m. - 2:00 p.m.; financial analysis, 2:00 p.m. - 9:00 p.m.; classifieds from 9:00 p.m. - 9:00 a.m. Also, information can be combined on a single channel that's split when an off-air channel goes dark.

Psychology, reasoning and demographics play a major role in character generation programming.

Let us discuss psychology and reasoning in relation to programming, as well as it's relevance to character generation. Psychology plays a major part in viewership, both consciously and subconsciously.

For instance, if there is space available on the financial channel and you are maxed out on your weather channel, logically speaking, it makes sense to put the skiing and sailing reports on the financial channels. The psychology behind this is simple, both sports are generally enjoyed by middle or upper middle class people. And statistics show that these people are more attuned to the world of finance.

The best channel to appendage the local sports calendar is the local/state news channel. A community minded person will be more interested in local sports, as well as local/state news and emergency numbers on the World News Channel.

In programming the classified ad channel and community information, interest is kept at a peak, if every fifth or sixth page of classified ads, a page appears regarding community information.

In reading printed information on a tv screen, it is necessary to understand the effect that colors have on the eyes. Red is an exciting color, green causes glare and difficulty in focusing and reading, blue is a relaxing color and information printed on this background is easily read. Keeping all of this information in mind, it is obviously wise to place blue behind the most often read and viewed channels. Red for highlighting and news reports, and green for the quick reference channels, such as the program guide. All channels should be color coded, so that in time of need, local city emergency numbers can be located by colors rather than a converter number, which may be difficult to read in time of stress. or trauma.

Background music used, should be just that, background music and should enhance not distract from the channels. The stations selected for background music, should be relevant to the franchise and the most popular stations with the entire community should back your most heavily viewed channels. To those quick reference channels, add the least listened to stations for selection and variety.

Psychologically speaking, people like to be entertained, especially with pictures. It would be idealistic to think that all of our subscribers would read printed information with as much enthusiasm, as we do. Therefor, patterns or pictures at intervals, of every fifth or sixth page with information in the body of the picture, whenever possible, are new and clever ways of retaining the viewer's interest.

Using characters symbolic of the picture, for example; to advertise a boat show in the community. Such as, a sailboat with sails made with the letter 's', poles of 'p's', and the body of the boat with 'b', one has entertained the subscriber and caused him to think, as well. Hence, the term, the 'thinking man's pictures'.

Updating these pictures as deemed necessary, and using patterns and information whenever possible, make an otherwise printed page of information, exciting as well as informative.

The biggest problem for the programmer, occurs when he or she holds the character generator or computer in awe, and totally allows it to overwhelm them. There is no mystic about a computer. Respect it, use it, like it and even grow to love it, then everything will fall into place.

Other problems only occur when

A. Information is allowed to become stale.
B. Program format is changed too frequently.
C. Information displayed has no relevance to the franchise area.

In the cable industry, we are no longer just a clearer, brighter picture, but we are additional programming and character generation in major markets. Character generation now plays a major role in the cable industry. It makes viewing both interesting and educational for everyone. I can not conceive the future, in the major market of the cable industry, without the advent of character generation.

Character generation has put television back in the hands of the community. It is that special, needed, unique touch, like local origination, that binds the cable subscriber to the cable system.

IN SUMMATION

Character Generation in it's adaptation cable is a viable mode for customer support. Through properly programmed information, relevant to the franchise area, customer relation are strengthened, improved and marketed.

Used intelligently, the character genera can function as the barometer between the cab system and the subscriber, creating enthusias loyalty and longevity.

There is no room in the cable system for apathy or complacency, as the character generators may well be the cohesive link and sustaining support missing for years in the cable industry.

We are only on the threshold of Character Generation Programming, therefore, it boggles the mind to think of it's versatility as we realize it's vast possibilities.

Comparison of Performance Criteria of Five and Ten Meter Earth Terminals.

Jim Hart

Scientific-Atlanta, Inc.

Abstract
Geostationary satellite communications links have found wide use in CATV during the past two years. Until recently, only 10 meter diameter antennas have been employed for domestic video receive terminals. Careful study and consideration of all requirements of the communications industry has now shown that smaller diameter antennas of 4.5 and 5 meters will satisfy requirements for a percentage of the 48 contiguous states. Consequently, the FCC has stated that they will approve those terminals which employ smaller antennas if the applicant outlines his requirements and gives adequate proof that those requirements are met. This paper is a comparative analysis of 5 and 10 meter antenna receive terminals and shows tradeoffs which must be considered for various locations in the 48 contiguous states.

1.0 Introduction
This paper is a presentation of operational characteristics of 5 and 10 meter earth terminals in graphic form. Supporting derivations are given where it was felt that a greater depth of understanding the data would result. Certain assumptions were made on characteristics which have negligible effects on the results. These assumptions are carefully outlined in each section. The last sections deal with the summation of the earth terminal degradation and that due to the CATV system. The overall performance of the headend and distribution system is the important aspect for cable operators. The paper is developed in a sequence which should be easy to follow step by step. Taking information out of context without understanding the foundation presented in previous sections is not recommended in this case.

2.0 Overall Considerations
Basically the requirement of an overall link is a quality picture at the final destination - the viewers home. Many factors affect the ultimate picture quality. Generally, the downlink and CATV distribution system have the greatest impact on signal quality. This, of course, assumes that the studio quality is adequate. The purpose of this paper is not to analyze link degradations but to compare typical 5 and 10 meter receive terminals and their performance in a complete system. To accomplish this task without getting deeply involved in system analysis, a set of degradation allowances which are presently under consideration by the FCC and others will be utilized. Figure 1 is a summary of these allowances. First, the downlink is analyzed under clear sky conditions. The basic allowance of 3.65 dB is then subtracted from the main IF carrier-to-noise ratio (C/N), and the result is considered a worse case condition. This worse case condition will be accepted if the C/N falls equal to or above the receiver objective threshold (threshold being defined as the point where S/N ratio is worse by 1 dB than the projected asymptote at high C/N). This allowance and its prescribed use is not to be considered final and is subject to change, but it provides a convenient method for this comparison.

FCC Recommended Satellite Link Degradations

Parameter	Nominal (dB)	Random (dB)
EIRP	0	0.15
Satellite Degradation	0.4	0.4
Atmospheric Absorption	0.1	0.1
Polarization Loss	0.1	0.1
Rain Attenuation	0	0.2 (1)
Pointing Error	0.3	0
Wind	0	0.4
Antenna Gain	0	0.2
Earth Station Degradation	0	0.35
Interference	1.0	0 (2)
FM Threshold Margin	1.0	0
	2.9	0.75 (3)

(1) Or as appropriate for given location
(2) Or Calculation
(3) Combined on a Root Sum Square basis

Figure 1

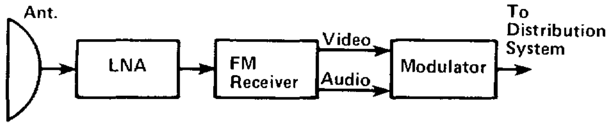
3.0 Downlink Considerations

3.1 System Noise Temperature
Figure 2a is a simplified block diagram of a receive terminal. Figure 2b assigns gain and noise temperature quantities to each contributing element of the terminal.

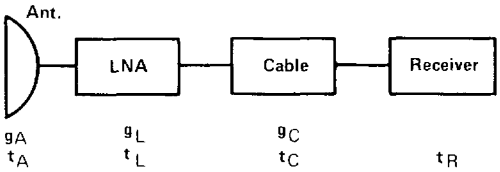
System noise temperature at the antenna flange is given by:

$$t_S = t_A + t_L + t_C/g_L + t_R/(g_L g_C)$$

where t_S = System noise temperature at antenna flange °K
t_A = Antenna noise temperature °K
t_L = LNA noise temperature °K
t_C = LNA to receiver cable noise temperature °K
t_R = Receiver noise temperature °K
g_L = LNA gain ratio
g_C = Cable gain ratio



Receive-Only Earth Terminal
Figure 2A



Gain-Noise Temperature Diagram
Figure 2B

Figure 3a presents the system noise temperature of a Scientific-Atlanta 5 meter system versus LNA noise figure. The following typical variables were assumed:

Cable Loss = 6 dB (200 feet)
LNA Gain = 47 dB (Minimum)
Receiver NF = 12 dB
Antenna t_A = 20° K (30° Elevation)

Figure 3b is the same data for a 10 meter system assuming:

Cable Loss = 6 dB
LNA Gain = 47 dB
Receiver NF = 12 dB
Antenna t_A = 28° K

The overall noise temperature is affected only a very small amount by variations in these assumed quantities at different sites, and the preamplifier is the dominate factor.

The small difference in the 5 and 10 meter cases is due to the type feed utilized and the sidelobe patterns of the two antennas.

The 10 meter antenna utilizes a focal-point feed to achieve a superior sidelobe pattern at the expense of greater loss in the waveguide run to the feed. Optimization for interference rejection is desirable because, as will be shown, gain in the 10 meter case is available for tradeoff.

3.2 Receive System G/T
The receive system G/T is given by:

$$G/T = G_A - 10 \log t_S$$

where G/T = Receive system Gain/Noise Temp in dB/° K
G_A = Antenna gain at flange in dB
t_S = Flange system noise temperature in ° K

Figures 4a and 4b show the G/T curves for the 5 and 10 meter case versus LNA noise figure. Assumptions in addition to those in Section 3.1 were:

G_A = 44.5 dB (5 Meter)
G_A = 50.2 dB (10 Meter)

Due to nearly equivalent noise temperatures for the two antennas, the G/T difference is almost entirely related to the gain difference.

G/T is a quality factor which is directly related to performance and cost of video earth terminals.

3.3 Main IF Carrier-to-Noise Ratio
The next important parameter is the receiver IF carrier-to-noise ratio (C/N). Noise of an FM link can be divided into two categories for understanding the process even though both are derived from the same source - thermal noise.

First, there is carrier power to noise power density given by:

$$(C/N_O) = EIRP - Lp + G/T - K$$

where EIRP = Effective isotropic radiated power dBw
Lp = Path loss in dB
G/T = System G/T in dB/° K
K = Boltzmanns constant (-168.6 dBw/MHz/° K)

This (C/N_O) affects (S/N)v on a one-for-one basis when the link is operated well above threshold, and

$$(C/N) = (C/N_O) - 10 \log b_{IF}$$

where b_{IF} = Effective main IF noise bandwidth in MHz

This (C/N) determines the threshold of the receiver.

Path loss is given approximately by:

$$Lp = 96.6 + 20 \log f + 20 \log d$$

where f = Frequency in GHz
d = Distance in miles

Secondly, when an FM system is operated near or below threshold, the peaks of noise reduce the instantaneous sum of signal-plus-noise to near zero. Under these conditions, the FM discriminator becomes unable to determine the instantaneous phase of the carrier, and impulse noise appears in the detected signal. This results in a greater than one-for-one variation in S/N and the characteristics of this impulse noise is different than that of the previously demodulated thermal noise. The impulse noise appears very rapidly below threshold, and it causes serious degradation to picture and audio quality. For this reason, it is necessary to operate FM systems above threshold for quality performance.

Figures 5a and 5b give the C/N ratio for a clear sky. Assumptions in addition to those in Sections 3.1 and 3.2 were:

L_p = 196.0 dB
b_{IF} = 39 MHz

The IF filter is an INTELSAT 36 MHz type. An improvement in the margin against threshold of 0.8 dB can be obtained for those marginal cases by utilization of an INTELSAT 30 MHz filter; however, no benefit in the ultimate S/N results in this move since S/N ratio is not a function of IF bandwidth when operating above threshold as will be later shown.

Figures 6a and 6b show the C/N ratios including the 3.65 dB degradation of Figure 1. Two threshold lines are shown. The upper line represents a standard Scientific-Atlanta 414 receiver. The lower line is the same receiver with threshold extension included. Again it must be remembered that threshold extension does not improve the ultimate S/N ratio except when operating down near and below threshold. This will be shown in later S/N curves.

3.4 Threshold

Figures 7a and 7b give the threshold characteristics of a Scientific-Atlanta 414 receiver with and without threshold extension. In each case, threshold is defined as the C/N where the S/N curve departs 1 dB from the high C/N asymptote. Note that this occurs at 9.3 dB for no extension and 7.3 dB with extension. Also note that S/N at these points are 47 dB and 45 dB respectively.

Threshold extension has carried threshold to such a low C/N that S/N ratio is becoming the limiting factor. Most CATV systems are operated with headend S/N of greater than 45 dB; therefore further improvement in C/N performance by reducing bandwidth must be done keeping in mind that the 45 dB S/N will drop even lower. This may or may not be desirable for a particular CATV cascade. Curves to follow will aid in making this decision.

3.5 Video Signal-to-Noise Ratio

The video signal-to-noise ratio (S/N)v is given by:

$$(S/N)_v = \frac{C}{N_o}\left[\frac{12(\Delta Fs)^2}{b_n^3}\right]$$

where C = Carrier power in watts

N_o = Noise power density at that point in the receiver where C is measured

= $K\ t_s$ in Watts/MHz

K = Boltzmann's constant (1.3806×10^{-17} W/MHz/°K)

t_s = System operating noise temperature referred to that point in the system where C is measured in°K

ΔF_s = Half the peak-to-peak deviation produced by that part of the video waveform defined to be the signal in MHz

b_n = Noise bandwidth of the baseband filter function representing the combination of the de-emphasis network, measurement bandlimiting filter, and weighting network with respect to triangular noise in MHz

= 1.574 MHz for CCIR weighted

Figures 8a and 8b give the $(S/N)_v$ for the 5 and 10 meter cases clear sky. The assumptions are as previously stated in addition to:

$$\Delta F_s = (.714)\ (10.75\text{ MHz}) = 7.68\text{ MHz}$$

Video systems presently in use in this country are using this deviation. Note that two curves exist on Figure 8A. The dotted case shows the effect of threshold extension. Note that no change occurs above threshold. It is true, however, that the small change which does occur near threshold is of extreme importance since impulse noise is removed. Threshold extension has no use in the 10 meter case under these assumed conditions as shown in Figure 8b.

Figures 9a and 9b give the $(S/N)_v$ after application of the 3.65 dB degrading factor to C/N. Note that above threshold the curves have simply moved down by 3.65 dB, but at and below threshold the effect is much greater due to impulse noise. In these curves the advantage of threshold extension can be seen even in the 10 meter case to a small degree.

3.6 Audio Threshold

Figure 10 gives the audio threshold characteristics of the Scientific-Atlanta 414 receiver. The unweighted audio $(S/N)_A$ is shown versus main IF C/N. Note that audio threshold occurs at about 7.6 dB (C/N). Assumptions are:

Subcarrier on Carrier Deviation = 2 MHz Peak
1 kHz Test Tone on Subcarrier = 75 kHz Peak

It is important to note that the deviations of video and audio are well chosen since audio thresholds at a near equal C/N as video with threshold extension. Any reduction in the audio deviation rules out any use of threshold extension since it has little effect upon audio threshold in this case.

3.7 Audio Signal-to-Noise

Figures 11a and 11b give $(S/N)_A$ for the 5 and 10 meter cases. These curves were derived from Figures 5 and 10.

Figures 12a and 12b give $(S/N)_A$ for the 5 and 10 meter cases including the 3.65 degrading factor. These curves were derived from Figures 6 and 10. No mention is made of threshold extension since it has been shown that it affects $(S/N)_A$ very little.

3.8 Overall CATV System Video Performance

This section deals with the heart of the matter. What counts is the result at the home. The earth terminal and CATV system share in the overall degradation.

How is the CCIR (S/N)v at the output of the headend FM receiver related to the NCTA (S/N) which would produce the same quality picture if the noise source were thermal noise in the distribution system? The best thing to say is that they are essentially equivalent. However, if we are considering an objective CCIR measurement at the output of an ideal home receiver (or in the case treated by Straus[2]) and are concerned about tenths of a dB, the answer is that

Equivalent NCTA = Headend $(S/N)_v$ + 0.3 dB

because as shown by Straus

Equivalent NCTA = Home Rcvr CCIR $(S/N)_v$ + 0.2 dB,

and

Home Rcvr CCIR $(S/N)_v$ = Headend $(S/N)_v$ + 0.1 dB

The latter relation results from the effect of the rolloff of the Nyquist filter in the ideal home receiver on de-emphasized triangular noise between 4 and 4.2 MHz.

Figure 13a shows the combined noise of the headend receiver and the distribution white noise. It is important to note again that receiver baseband S/N of 45 dB (which results at threshold with threshold extension) will have an impact on most CATV systems - especially those which are operating at NCTA (S/N) of 45 dB and better.

3.9 Overall CATV System Audio Performance

Figure 13b gives a curve similar to 13a for the overall audio performance. The earth terminal noise was power added to the CATV distribution system noise contribution to obtain the overall result. The audio (S/N) for the CATV system is given by:

$$(S/N)_A = \frac{C}{N_o}\left[\frac{3}{2}\ \frac{\Delta F_A{}^2}{b_{NA}{}^3}\right]$$

where C = audio subcarrier power in watts

N_o = noise power density in watts/MHz

ΔF_A = half the audio peak-to-peak deviation in MHz

b_{NA} = triangular noise bandwidth of baseband response function for 75 μs de-emphasis with 1 kHz crossover with ideal rectangular 15 kHz band-limiting filter

= 5.82×10^{-3} MHz*

The assumption for Figure 13b was:

ΔF_A = .025 MHz

*This noise bandwidth corresponds to a de-emphasis advantage of:

30 log (15 kHz/5.82 kHz) = 12.3 dB

The figure of 13.2 dB often cited for 75μs pre-emphasis is for unity pre-emphasis gain at dc. It must be reduced by the 0.9 dB insertion loss necessary to put the pre-emphasis corssover at 1 kHz.

Also it was assumed that the aural subcarrier was run at -15 dB with respect to the video carrier on the CATV system.

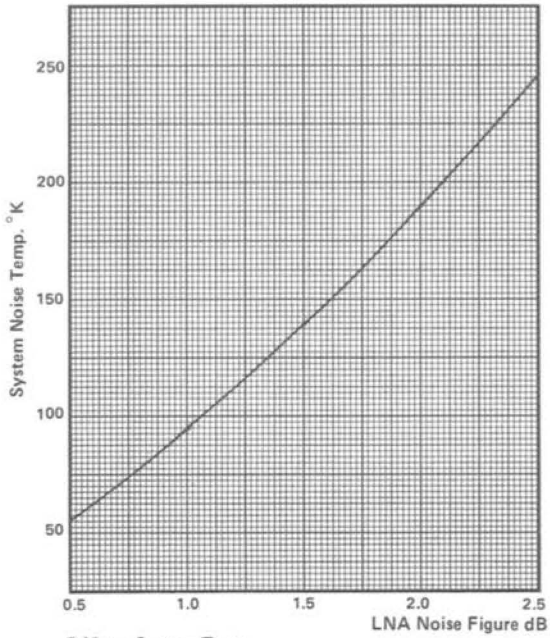
It can be noted in Figure 13b that almost all the degradation of audio occurs in the satellite link, but the quality is still quite good.

4.0 Conclusion

The quality of a video link by satellite is governed by many factors. It is important for the individual operator to consider his requirement and buy the system best suited for his needs. Careful consideration must be given to threshold and the overall performance desired. Other considerations such as terestrial interference must be looked at on an individual basis.

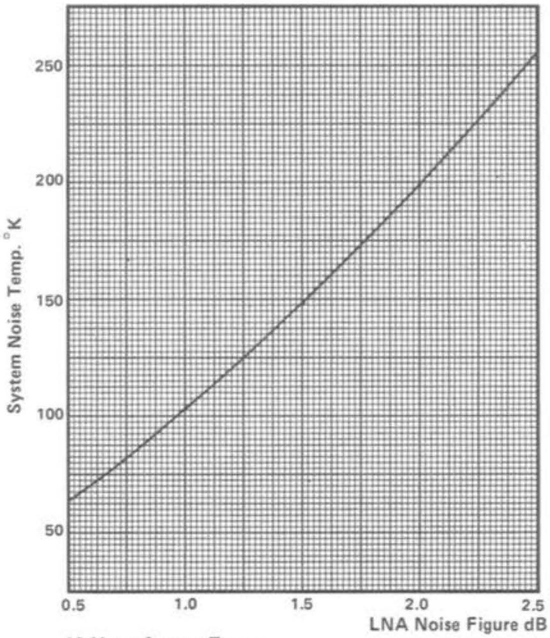
5.0 Acknowledgment

My sincere appreciation is expressed to Dr. Larry Clayton, Heinz Wegener, and Elias Livaditis for their invaluable support in writing this paper.



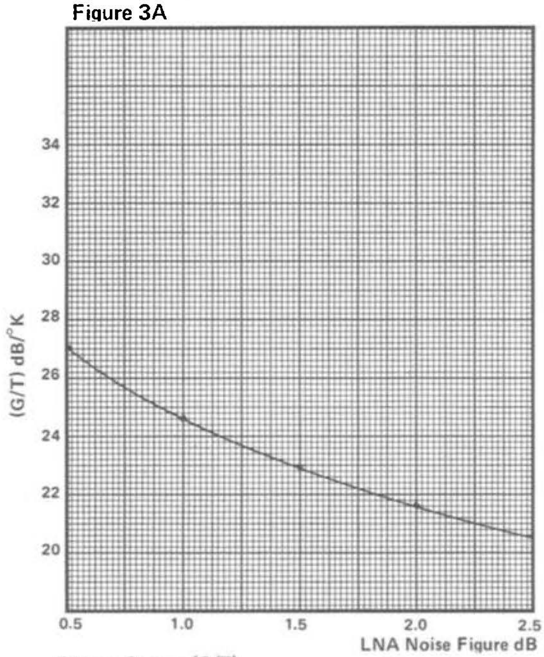
5 Meter System Temp

Figure 3A



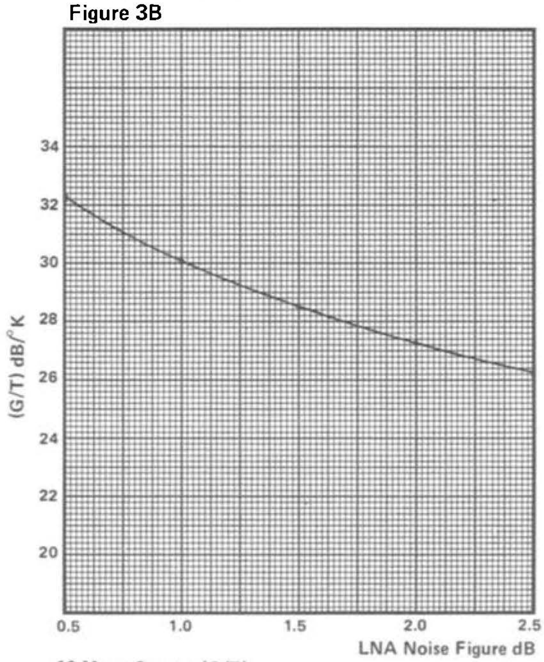
10 Meter System Temp.

Figure 3B



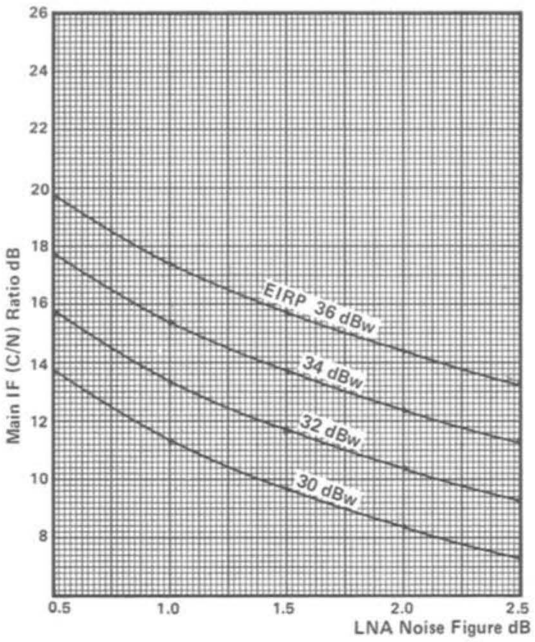
5 Meter System (G/T)

Figure 4A



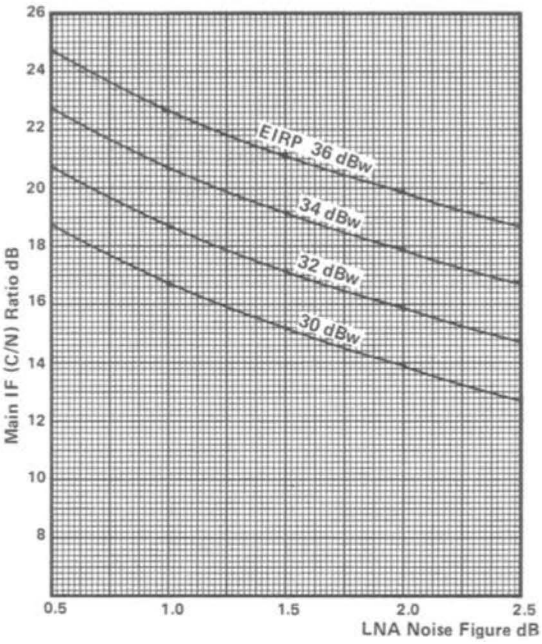
10 Meter System (G/T)

Figure 4B



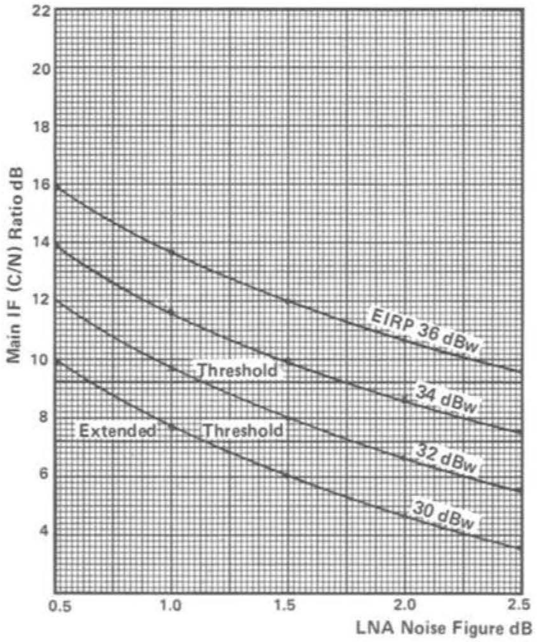
5 Meter System Clear Sky (C/N)

Figure 5A



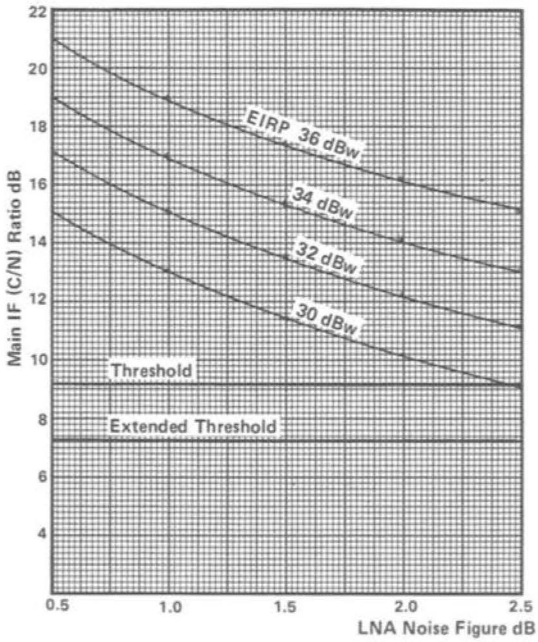
10 Meter System Clear Sky (C/N)

Figure 5B



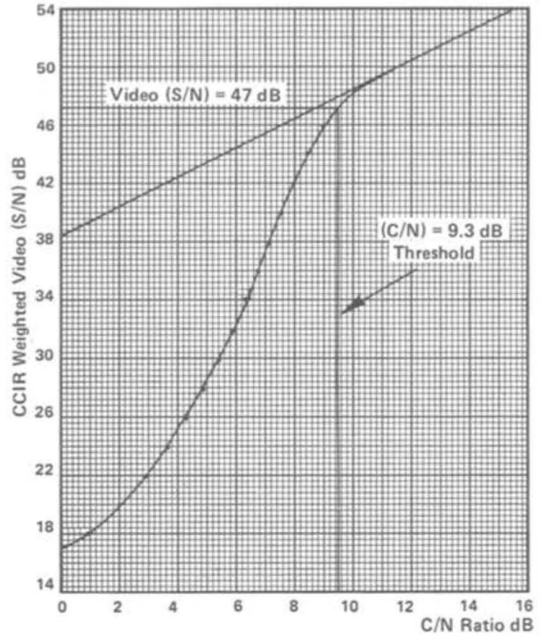
5 Meter System Degraded (C/N)

Figure 6A

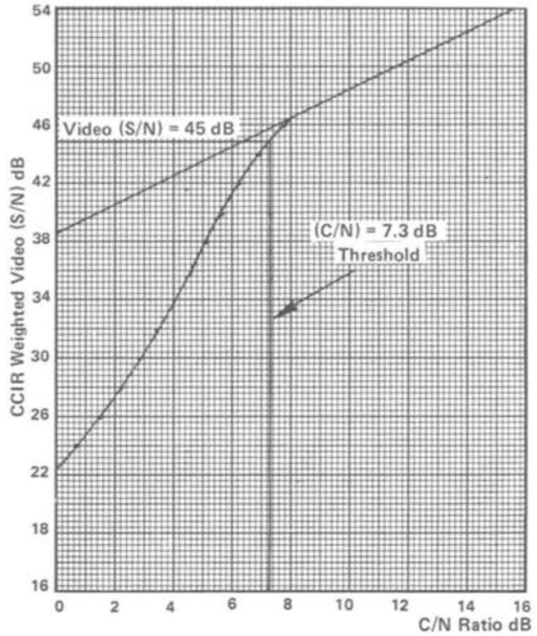


10 Meter System Degraded (C/N)

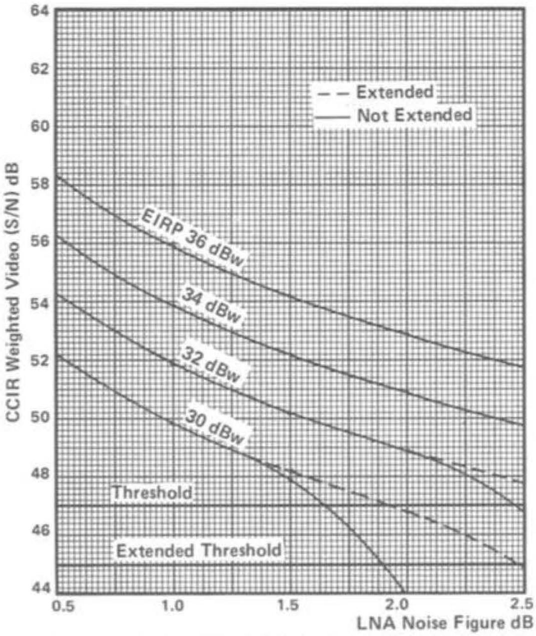
Figure 6B



Video (S/N) vs. Main IF (C/N)
Without Threshold Extension
Scientific-Atlanta 414
Figure 7A

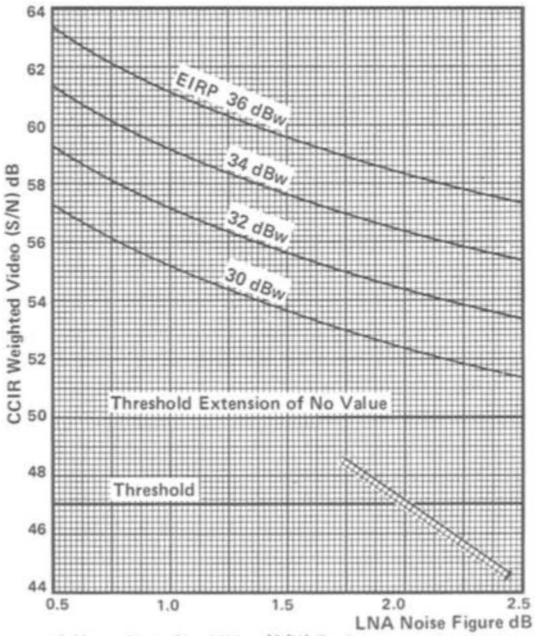


Video (S/N) vs. Main IF (C/N)
With Threshold Extension
Scientific-Atlanta 414
Figure 7B



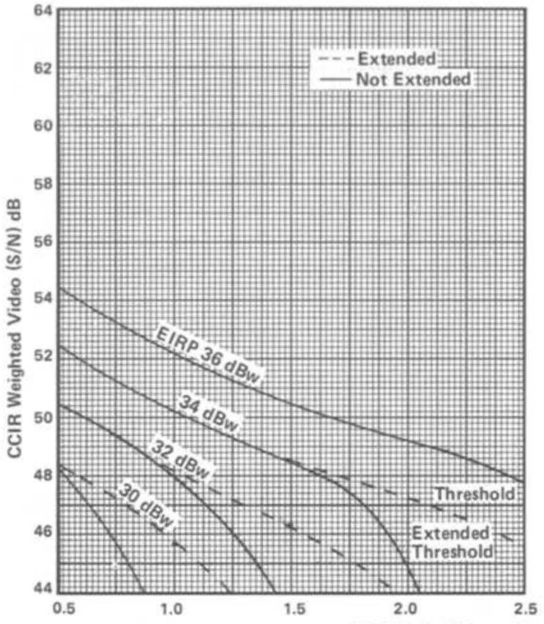
5 Meter Clear Sky Video (S/N) Ratio

Figure 8A



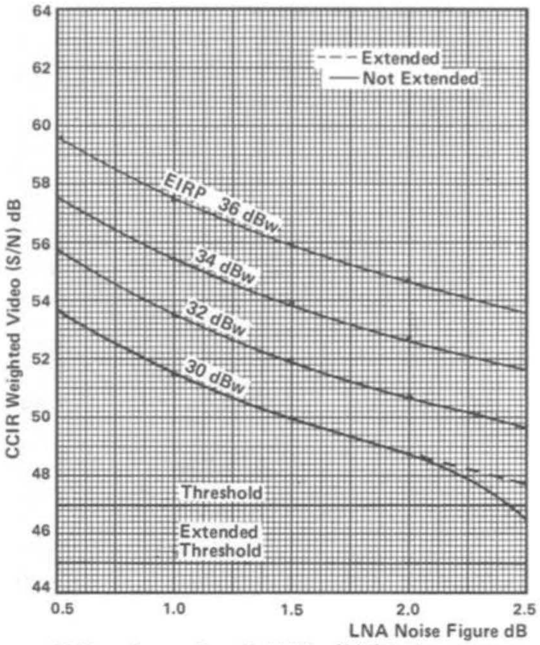
10 Meter Clear Sky Video (S/N) Ratio

Figure 8B



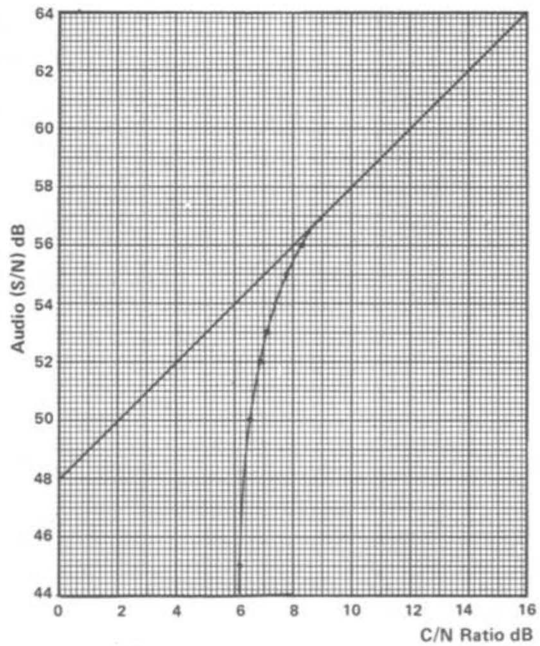
5 Meter System Degraded Video (S/N) Ratio

Figure 9A



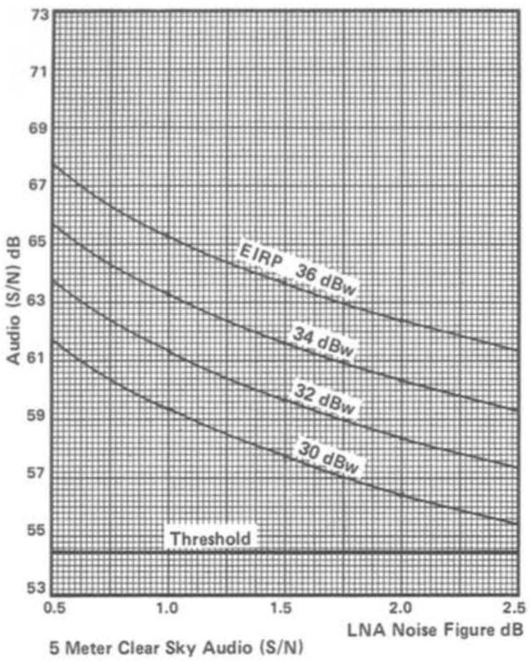
10 Meter System Degraded Video (S/N) Ratio

Figure 9B



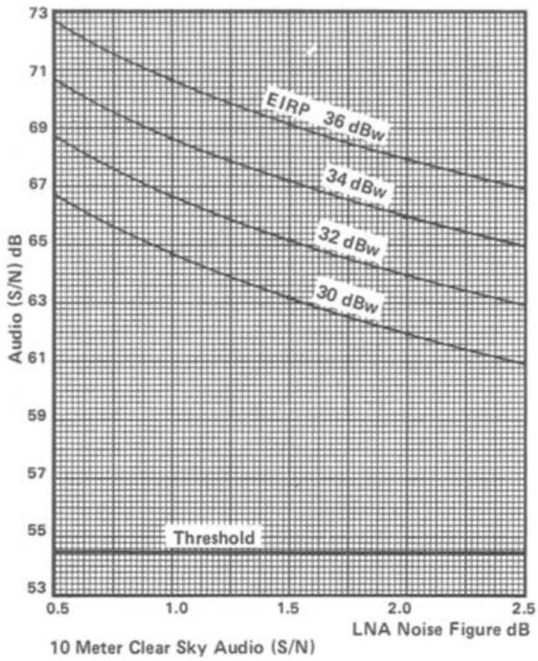
Audio (S/N) vs. Main IF (C/N)
Scientific-Atlanta 414

Figure 10



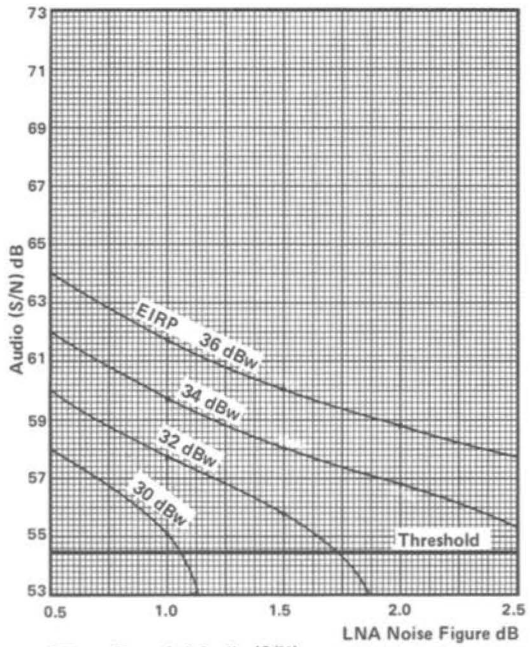
5 Meter Clear Sky Audio (S/N)

Figure 11A



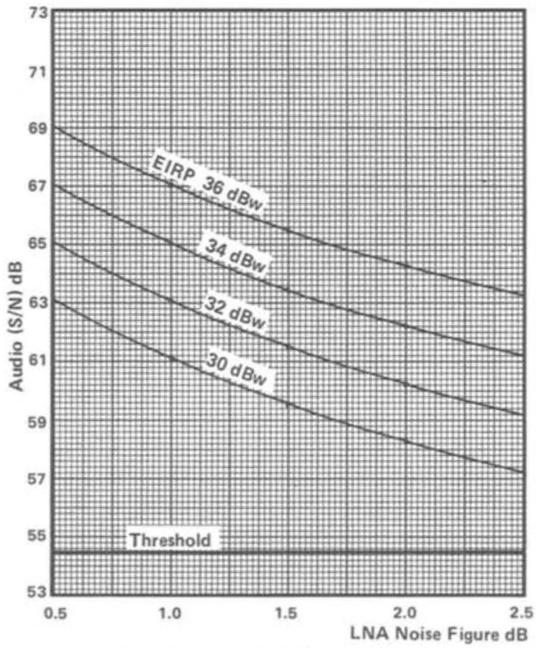
10 Meter Clear Sky Audio (S/N)

Figure 11B



5 Meter Degraded Audio (S/N)

Figure 12A



10 Meter Degraded Audio (S/N)

Figure 12B

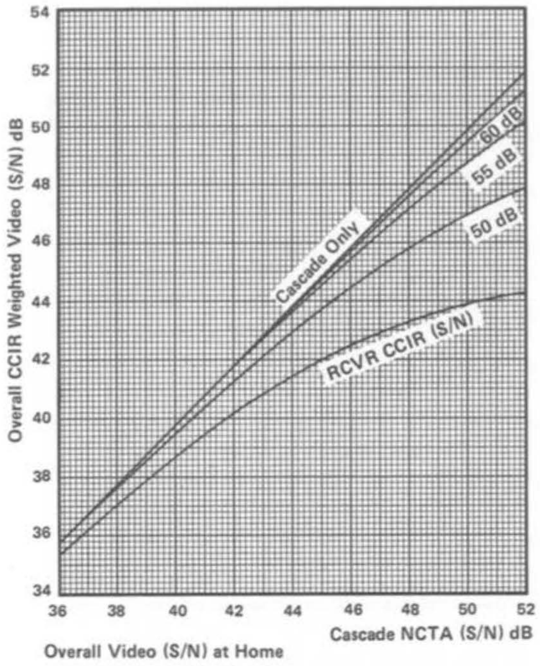


Figure 13A

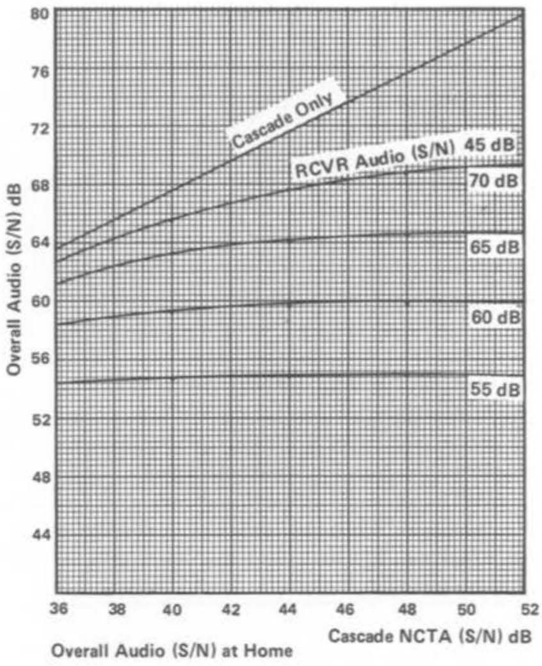


Figure 13B

References

1. L. Clayton, "FM Television Signal-to-Noise Ratio" IEEE Transactions on Cable Television, October 1976, p. 25-30.
2. T.M. Straus, "The Relationship Between the NCTA, EIA, and CCIR Definitions of Signal-to-Noise Ratio" NCTA 1974, p. 58-63.

EARTH STATIONS IN SMALLER PACKAGES

CARL VAN HECKE

ANDREW CORPORATION

Why are small aperture earth stations so popular? - economics and ease of location. What can a small aperture earth station provide to the cable operator? This paper will analyze the performance of earth stations employing antennas with diameters smaller than 9-metre, with emphasis on the 4.5-metre size. Impact of adjacent satellite and terrestrial interference to these smaller antennas and the effect on system G/T is discussed. Economic trade-offs between antenna and low noise amplifier are presented. Carrier-to-noise ratio of the system as it relates to receiver threshold is also discussed.

Declaratory Ruling 76-1169, issued by the FCC in January of 1977, permitted the use of smaller aperture antennas to provide TV to cable operators. Antennas as "small as 4.5 metres" (15 ft.) were considered capable of delivering acceptable quality performance in certain areas of the Continental United States. The use of smaller aperture antennas for satellite communication to the United States is not new, however, with this ruling. Four-and-one-half-metre antennas have been providing single-channel-per-carrier transmit and receive service in the Gulf of Mexico on an oil platform, and in the "Bush" of Alaska. Also Canada, who shares the same satellite orbit space with the United States, has in service 8-metre (26 ft.), 4.5-metre (15 ft.) and 3.7-metre (12 ft.) antennas.

Concern over the use of small aperture earth station antennas centered around two areas - adjacent satellite interference and terrestrial interference. With satellites spaced just 4° apart in orbit, there was concern that smaller antennas, with their broader beams and lower gain, would permit unwanted signals from adjacent satellites to "get into" the antenna and interfere with the wanted signal. Also, since the 4 GHz downlink satellite band is the same as used by terrestrial microwave common carriers, there was concern that interference from these systems would also "get into" the antenna and interfere with the satellite signal. The FCC, therefore, established performance objectives for earth station antennas in Paragraph 25.209 of the FCC Rules and Regulations. Generally, an earth station antenna must have sidelobes

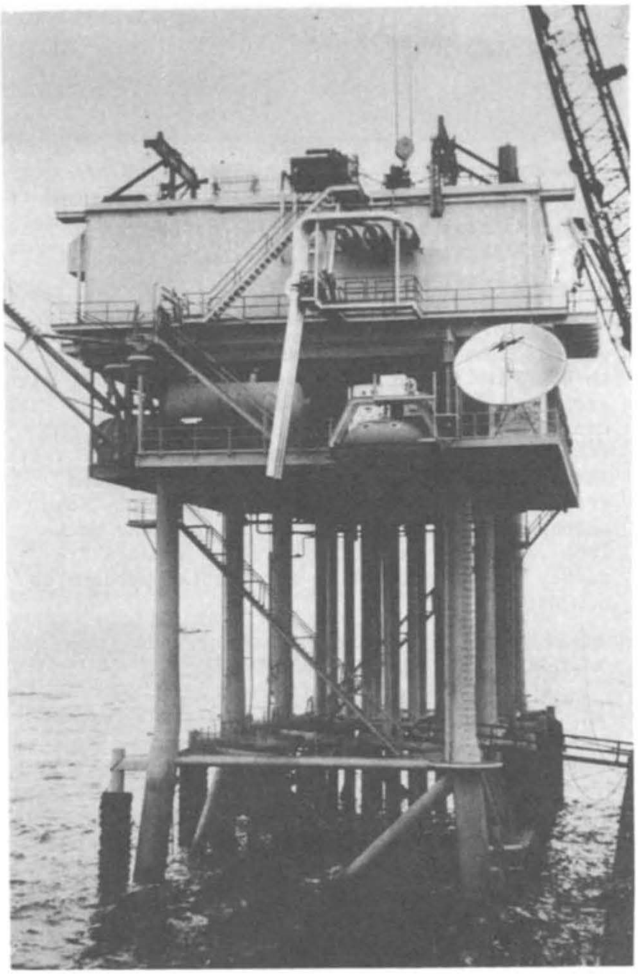


Figure 1

Oil rig in Gulf of Mexico using 4.5-metre earth station antenna

that, when smoothed, fall beneath an envelope defined by 32-25 log θ, where θ is the angle off boresight out to 48 degrees. See Figure 3.

It is assumed that if an antenna meets this criteria, the interfering levels from adjacent satellites and terrestrial interference will be low enough to permit acceptable service. It

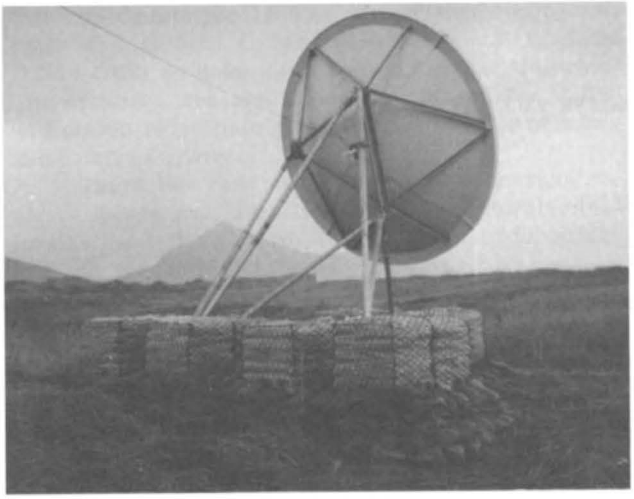


Figure 2

Alaskan "Bush" terminal using 4.5-metre earth station antenna

was also assumed that it took a big antenna to do this. This is not necessarily the case and, with proper design, antennas down to 4.5-metre in size can realize pattern control which provides the required interference protection of the FCC rules. This can be done while retaining much needed efficiency (higher gain) of the antenna. Some antennas also provide improved wide- and back-lobe radiation characteristics to enhance frequency coordination with terrestrial systems in congested areas.

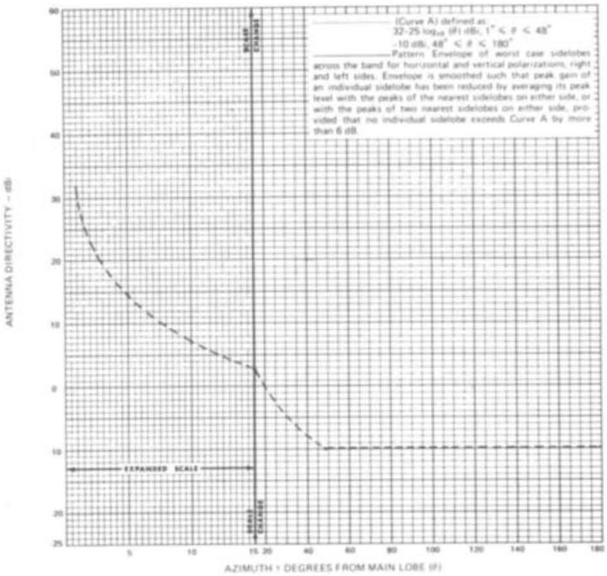


Figure 3

Pattern envelope required by FCC for earth station antennas.

The FCC stated in their Declaratory Ruling that antennas of diameters down to 4.5-metre could meet the interference criteria. This permitted new and interesting possibilities to the cable operator - the most important economic. Not only is the basic cost of the antenna less (approximately 1/4 the cost of a 10-metre antenna), the economics of placing the antenna (transportation, land, foundation, erection) are also less.

But there are other ramifications that must be considered with smaller sized antennas and the FCC has recognized these in their Declaratory Ruling. Smaller antennas have lower gain, and to deliver the required signal level to the receiver requires that the low noise amplifier be properly chosen. The performance capabilities of any receive earth station are determined by the satellite effective isotropic radiated power (EIRP) and the station's figure of merit (G/T). The EIRP for any location is fixed so the cable operator must rely on the station's G/T to provide the proper signal. The earth station's figure of merit is a function of antenna gain and system noise temperature and is defined as:

G/T = Antenna gain -10 log (system temperature)

System noise temperature includes sky noise, antenna noise, and amplifier noise. To produce a better G/T requires reducing the system noise temperature or increasing antenna gain, or both. There are limits to both, however, with antenna gain generally being limited by reflector size and feed configuration. The system noise temperature is generally controlled by the choice of amplifier.

Sky noise is a function of antenna elevation angle. The earth is warmer and, therefore, noisier than the sky. As the antenna elevation angle is lowered, the antenna picks up more of the earth noise, making the system noisier. Antenna elevation angle depends on location and is fixed depending on what satellite the antenna is to look at. System noise temperature is lowered by choosing an amplifier with lower noise temperature.

The cable operator must carefully choose the proper antenna and low noise amplifier combination. The antenna is chosen to maximize gain, while meeting the required pattern envelope, and the amplifier is chosen to reduce noise level. This is shown graphically in Figure 4.

The Appendix to the FCC Declaratory Ruling suggests a 14 dB carrier-to-noise ratio, which would deliver a 52 dB signal-to-noise ratio. A 14 dB C/N would provide a 3 dB margin over an 11 dB receiver threshold.

Assuming a 14 dB C/N is acceptable for pay TV distribution, then the feasibility of achieving such a C/N ratio economically must be reviewed. The C/N available in an earth station terminal is determined by a number of external influences,

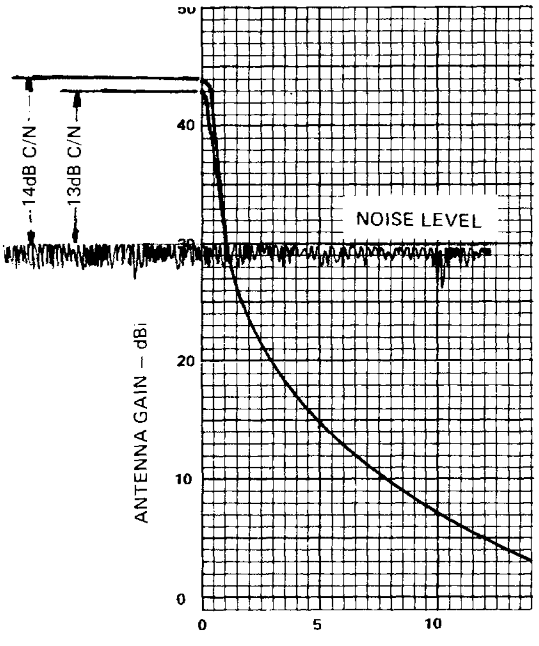


Figure 4

Antenna gain and noise level determine C/N

including carrier-to-noise ratio of the uplink to the satellite $(C/N)_U$, carrier-to-noise ratio of the earth station due to thermal and downlink characteristics $(C/N)_D$, and carrier-to-interference levels caused by adjacent satellites, terrestrial interference, transponder intermodulation, cross polarization, etc. In the Appendix to their Declaratory Ruling, the FCC has assumed an antenna with 43.7 dBi gain satisfying the FCC pattern requirements. Other antenna types are available offering various gain values. Figure 5 shows a tabulation of the parameters used in the Appendix to the FCC Ruling, along with the same calculated values for a 44.0 dBi gain antenna, and a 43.0 dBi gain antenna. Calculations and assumptions are based on the Appendix to the FCC Declaratory Ruling and Order, FCC76-1169. All antennas meet, or are better than, the FCC 32-25 log θ envelope requirement, and calculations are based on 4° satellite spacing. A second set of calculations has been performed assuming a 2 dB margin over receiver threshold of 11 dB for a 13 dB C/N, and is also shown in Figure 5.

The results indicate that in order to achieve a 14 dB $(C/N)_{TOTAL}$, the earth station terminal G/T must be designed to achieve a $(C/N)_D$ of 15.8 dB, or 15.2 dB, or 15.0 dB, depending on antenna gain and pattern performance.

The $(C/N)_D$ is a convenient value to work with as it is determined by the satellite EIRP, noise bandwidth of the receiver, and G/T of the earth station. The relationship between G/T and EIRP has been graphically represented in Figure 6, assumint both 30 MHz and 36 MHz noise bandwidths using the following formula:

$$G/T = (C/N)_D + 10 \log (\text{receiver bandwidth}) - EIRP - 32.4^*$$

*Includes 196.2 dB path loss, Boltzmann's Constant (-228.6 dBw/°K)

The EIRP values for current DOMSATS average 33 to 34 dBw on a nationwide basis. There are, of course, areas which have radiated power significantly above or below these values, depending on transponders used and location. Assuming a receiver IF bandwidth of 30 MHz, and an EIRP of 33 dBw, a $(C/N)_D$ of 15.2 dB can be achieved by using earth station terminals with G/T equal to 24.5 dB/°K. Those areas with higher EIRP for transponders of interest have an advantage of higher performance or lower terminal cost. The reverse follows for those areas with lower EIRP.

There are limits on the G/T that can be achieved by an antenna/LNA system. The limits are determined by antenna gain and systems noise temperature. In order to achieve a G/T of 24.5 dB/°K with a 44 dBi gain antenna, the maximum system noise temperature tolerable would be 90°K. Figure 6 represents graphically the relationship between G/T and noise temperature based on various antenna gains.

The antenna noise temperature is 22°K at 30° elevation, requiring an LNA with a 68°K noise temperature. This is achievable with current parametric amplifiers. With 43 dBi of gain, the maximum system noise temperature tolerable would be 70° K. The antenna noise temperature is 30°K at 30° elevation, requiring a parametric low noise amplifier with 40°K noise temperature. It is important to note that the gain of the antenna directly affects the G/T of the system. Therefore, any increase in gain for a given small aperture terminal can provide a straight-through increase in $(C/N)_D$ which results in either higher fade margins or lower LNA cost.

If the EIRP is 34 dB, and the $(C/N)_{TOTAL}$ reduced to 13 dBi (2 dB margin over 11 dB threshold), then $(C/N)_D$ would be 14.4, 13.9, or 13.8 for the three 4.5-metre antennas being considered. Figure 5 indicates the system G/T must be 22.5 dB assuming 30 MHz IF bandwidth. Systems noise temperature would have to be 140°K for a 44 dBi gain antenna and 113°K for a 43 dB antenna. LNA temperatures would have to be 118°K and 83°K, respectively.

It is recognized that changes in modulation technique and threshold extension receivers may alter minimum performance characteristics of small earth station terminals. However, the performance characteristics should be specified in a format which clearly identifies the operating margins of the system (i.e., $(C/N)_{TOTAL}$, G/T, and EIRP of the actual location of the terminal).

In the past, video signal-to-noise ratio was used to specify systems performance. This procedure was certainly valid for terminals operating well above threshold or impulse noise levels. However, for the small earth station terminals, fade margin above threshold is critical. Therefore, performance criteria should be established based on components that determine the system G/T; namely, $(C/N)_D$ and fade margin.

CONCLUSION

The Federal Communications Commission has released Declaratory Ruling and Order, FCC76-1169, authorizing the use of 4.5-metre earth station antennas for TV receive-only applications, providing the applicant submits certain supplemental information with his filing. This supplemental information includes detailed calculations of the expected station performance. The Ruling indicates that the calculations should consider EIRP, carrier-to-interference, and carrier-to-noise. It is clear that the FCC intends good engineering practice be incorporated in the design of 4.5-metre earth station terminals to assure good delivered signal quality. This paper concludes that improved antenna gain delivers similar improvement to carrier-to-noise level with resultant improvement in delivered signal-to-noise ratio or increased fade margin. An increase of 1 dB in antenna gain yields a similar increase in carrier-to-noise ratio, making it easier to achieve the FCC objectives.

Antenna	FCC Case 32 – 25 Log θ	Andrew HP 4.5M ESA	4.5M Prime Focus
Gain	43.7	44.0	43.0
Elevation Angle	30°	30°	30°
T_A @ 30°	30°K	23°K	30°K
G_A 4° (avg. dBi)	16.94	12.10	6.10
G_A 8° (avg. dBi)	9.42	4.5	-0.6
G_A 12° (avg. dBi)	5.02	1.0	-6.3
G_A 16° (avg. dBi)	1.89	-7.0	-5.7
$(C/I)_D$	22.1	27.9	32.6
$(C/I)_U$	35.6	35.6	35.6
$(C/I)_{ADJ.\,SAT.}$	21.9	27.2	30.8
$(C/I)_{INT}$	26	26	26
$(C/I)_{TER}$	25	25	25
$(C/I)_{TOTAL}$	19.2	21.2	21.9
$(C/N)_U$	27.2	27.2	27.2
$(C/N)_D$ for $(C/N)_{TOTAL} = 14$	15.8	15.2	15.0
$(C/N)_D$ for $(C/N)_{TOTAL} = 13$	14.4	13.9	13.8

$$(C/N)_{TOTAL} = (C/N)_U \boxplus (C/N)_D \boxplus (C/I)_{TOTAL}$$

$$(C/I)_{TOTAL} = (C/I)_{ADJ\,SAT} \boxplus (C/I)_{TER} \boxplus (C/I)_{INT}$$

$$(C/I)_{ADJ\,SAT} = (C/I)_U \boxplus (C/I)_D$$

where:

T_A = antenna noise temperature including sky noise

G_A = antenna gain at 4° satellite spacing

$(C/I)_D$ = carrier to interference on downlink due to adjacent satellite interference

$(C/I)_U$ = carrier to interference on uplink due to adjacent satellite interference

$(C/I)_{ADJ\,SAT}$ = carrier to interference due to uplink and downlink adjacent satellite interference

$(C/I)_{INT}$ = satellite internal interference

$(C/I)_{TER}$ = terrestrial interference

$(C/I)_{TOTAL}$ = total carrier to interference level due to adjacent satellite interference, internal satellite interference and terrestrial interference (objective ⩾ 18 dB)

$(C/N)_U$ = uplink carrier to noise (thermal)

$(C/N)_D$ = downlink carrier to noise (thermal)

$(C/N)_{TOTAL}$ = total carrier to noise level due to uplink and downlink thermal carrier to noise and total carrier to interference (system design objective ⩾ 13 or 14 dB)

FIGURE 5

Table of calculated carrier-to-noise ratios
for three 4.5-metre antennas

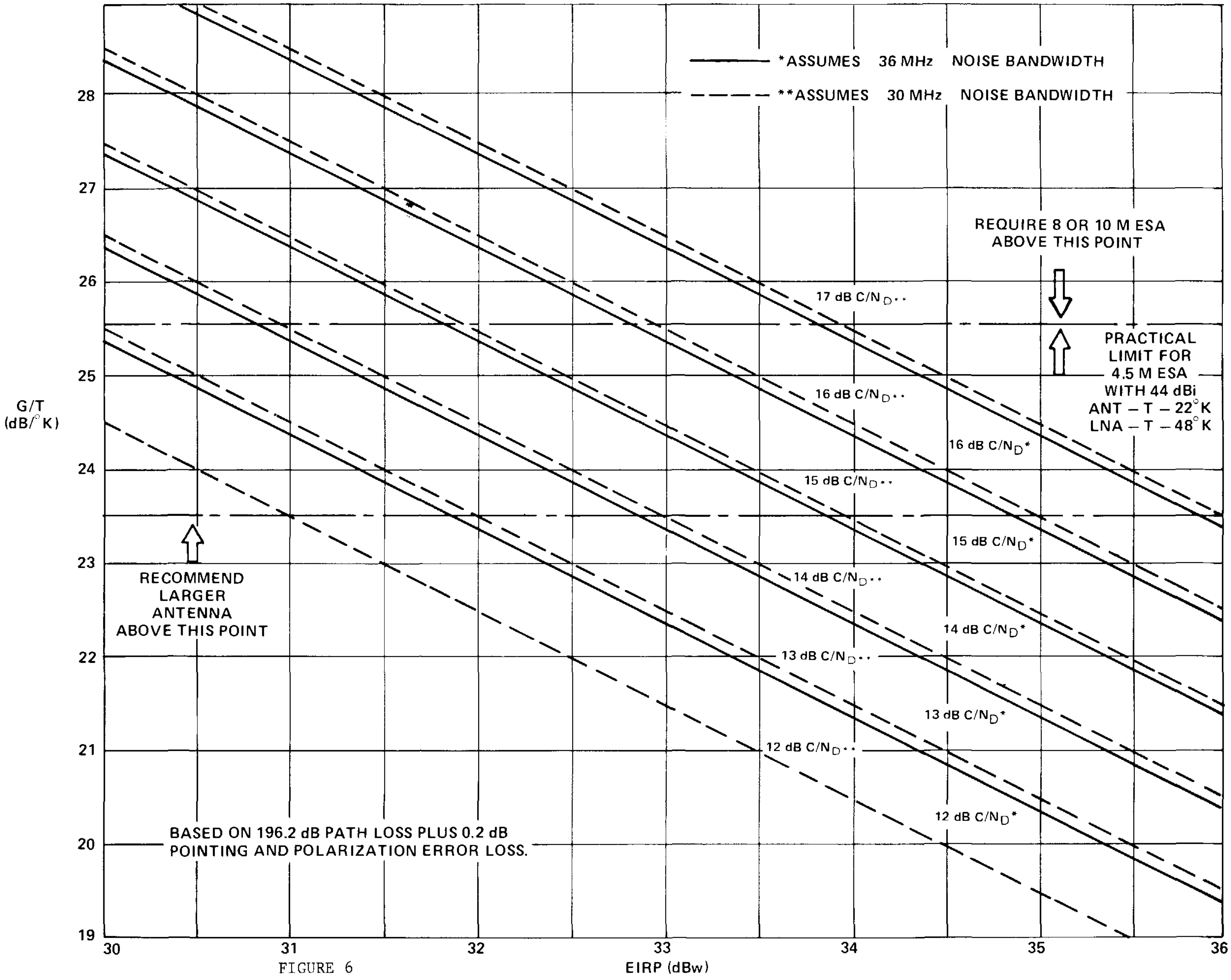


FIGURE 6

Graphic representation of G/T vs satellite EIRP

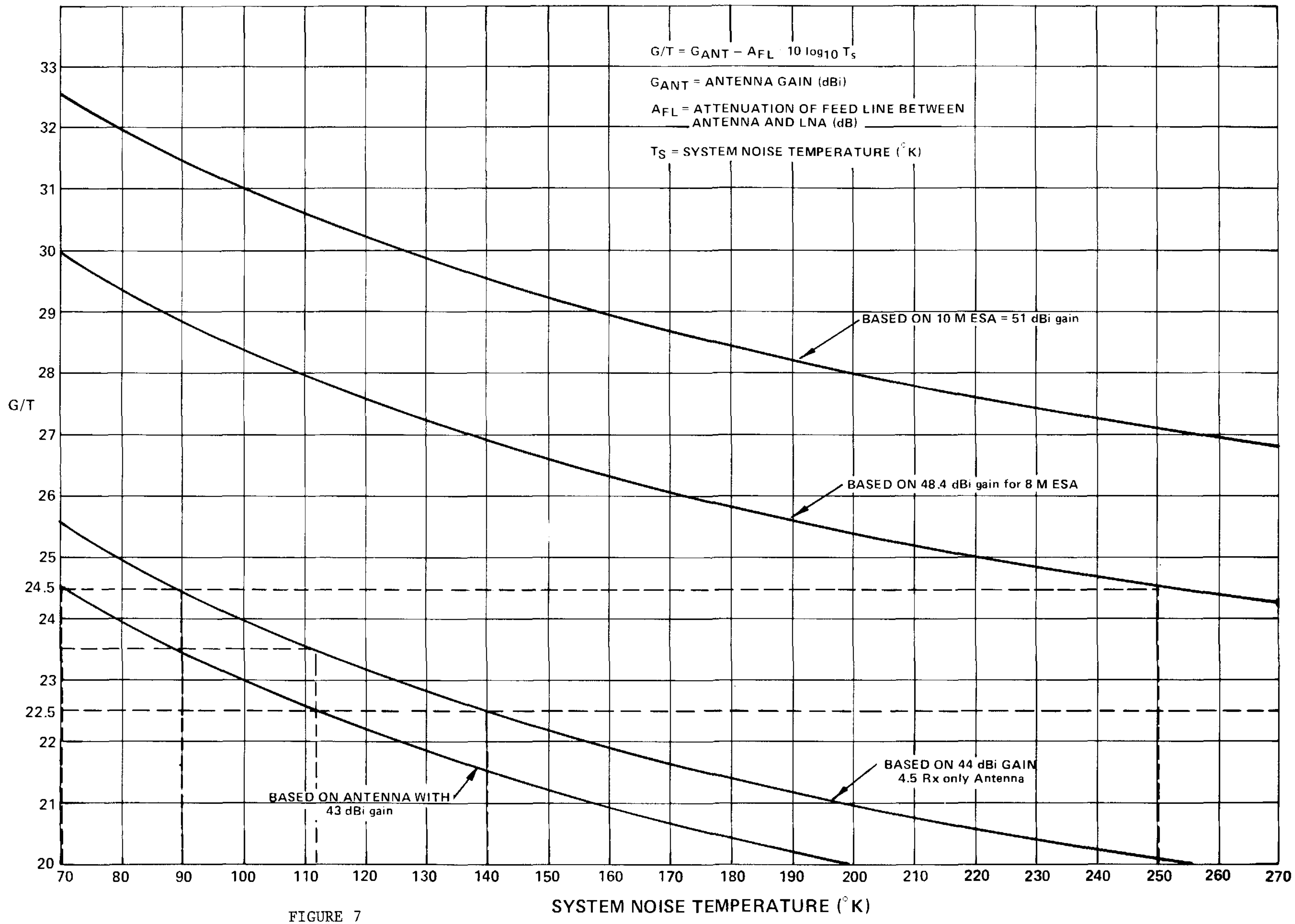


FIGURE 7

Graphic representation of G/T to system noise temperature

GENERAL PURPOSE COMPUTERS FOR CABLE TELEVISION SYSTEMS

Raymond E. Daly IV

Federal Communications Commission
Washington, D. C.

NOTE: Statements in this paper are those of the author and do not necessarily represent the position of the Federal Communications Commission.

ABSTRACT

Computers have a significant place in cable television systems. For example, a general purpose microcomputer/video synthesizer could be a practical first step in developing viable interactive (two-way) cable television systems. A working microcomputer/video synthesizer is demonstrated at the presentation of this paper. The paper will endeavor to show that the difficulties in creating such computer systems arise in developing the computer programs (software), not in the computer equipment (hardware).

Hardware. A computer in every headend is now a possibility. Powerful microcomputers developed by the personal computer industry can be purchased for about $2,500 or less. Some computer basics are explained to indicate the simplicity of a minimum microcomputer circuit.

Software. The potential applications of microcomputers to cable television systems are staggering. Applications such as "cable television games" and non-duplication switching are just two possibilities. But in implementing any such microcomputer system, the development of the necessary computer programs may be the major expense.

INTRODUCTION

Computers are finding a place in the home. Over 20,000 consumers have purchased computers for their own personal use. The author decided to consider how such computers could be used in a cable television system.

MICROCOMPUTERS IN HEADENDS

A computer in every headend is now a real possibility. While the cable television industry has been concerned with satellite technology, the electronics industry has developed and fallen in love with a large-scale integrated (LSI) circuit: the microprocessor. Though these devices are generally something less than a "computer on a chip," as they are often touted, they have nonetheless resulted in a revolution. One of the products of this revolution is the microcomputer at a low cost.

Microcomputers do not carry a big price tag. Business computers can cost millions, but for a cable television system, a useful and complete microcomputer can be purchased for considerably less. For about $2,500 or less, a cable television system can buy a powerful microcomputer.

This raises the question, "What would a computer be used for at a headend?" An example of a microcomputer application which could be used on a cable television system is demonstrated with the presentation of this paper. The demonstrated microcomputer system simulates a subscriber playing a video game over his local cable television system from his own home.

Two-way capacity is not required on the cable television system. The only equipment needed for this "cable television game" would be located at the headend. At the headend, a microcomputer would be interconnected with a standard telephone line. The computer generates a color video signal as the output. This particular system is capable of color graphics as well as alphanumeric characters. In other words, it can display on a television screen letters, numbers, and color symbols. There is no equipment needed in the subscriber's home, provided that the subscriber has a push-button telephone.

It works very simply. The subscriber tunes his television set to the channel dedicated by the cable television system for "cable television games." On this channel a telephone number appears which the subscriber calls. The computer answers the phone and asks the subscriber, via the television channel, which game the subscriber wants to play. The subscriber responds by pressing a button on the telephone and the game instructions are given. The subscriber plays against the computer until a winner is decided. Then the computer hangs up and waits for another subscriber to call.

This computer system could also be used as a non-duplication switcher at user-selected time intervals. One could set the switcher from any push-button telephone by watching a dedicated cable television channel, and access to the switcher could be controlled by a private access code. This remote control feature would be particularly helpful when a sporting event runs overtime. If while watching a game it was apparent that the show was going to run over, a cable system employee could call the computer at the headend to change the switcher before the game was blacked out.

This system can be expanded. Add another phone line and two subscribers can play a game against each other over the cable system even though they may never meet each other in person. Another application is that subscribers could request health and safety information. Educational programs could be included. Some type of library service could be offered to the public. When used in conjunction with addressable taps, this system could be used by subscribers to order pay television programs on a per-program basis.

There are many other possible applications of a computer in a cable television system. Some traditional automated services presently used on cable television systems can be done with a computer, e.g., weather information, bulletin boards, and television program guides. On the television program guide the computer could automatically delete old or out-dated information such as television programs which were already over. The same thing could be done on the bulletin board. Also, messages could be displayed on the bulletin board only during certain times of the day, if this were desired. Though it may be impractical, a sophisticated weather system could be programmed to forecast the weather on the basis of past and current weather information.1/

Business applications could also be done on a cable television microcomputer. Subscriber billing, payroll, inventory, and bookkeeping could be managed on a sophisticated microcomputer system. Other cable system records, such as trouble call reports, could be stored in computer files. With this varied information, the computer could analyze the data and produce reports as needed.

Other functions can also be performed. Satellite earth stations and microwave functions could be monitored and controlled. The computer could be used for engineering problems and needs. If a signal processor failed, the computer could sense this and switch in a standby processor. The computer could do headend security and tower lighting monitoring. And a computer will be required for addressable taps and for two-way cable applications.

One might assume that one computer would be needed to do each different type of job: one to play the "cable television games," another to do non-duplication switching, et cetera. This is not the case. The general purpose computer can do a variety of tasks, seemingly simultaneously. It is this ability which makes general purpose computers practical for cable television headends.

PERSONAL COMPUTERS

Such computers are available today. Cable television systems can use the microcomputers, peripheral devices, and other products developed for the personal computer market. A large selection of these computers is available from many personal computer manufacturers. In addition to these manufacturers, there are over twenty-five other manufacturers of peripheral equipment (accessories).

Personal computers offer other benefits in addition to their availability and low cost. First, the personal computer field makes significant use of video displays on home television receivers. These are the same television sets that cable television systems deliver their signals to. Many different character displays and some sophisticated color graphic displays are being sold to computer hobbyists. The cable television industry could use these products without having to develop their own products.2/ A side benefit of the reliance of computer hobbyists on video displays is that many of the hobbyists' programs are written for such displays and could be adopted for use in a cable television computer system.

Second, personal microcomputer stores are being established across the country. These stores can be a valuable resource for cable television systems. Not only can they provide current information and sell imcrocomputers, but they could service microcomputers used in cable television systems.

Third, the literature on personal computers is readily available and abundant. Several magazines are specifically dedicated to the personal computer field. There are also many books available which deal specifically with microcomputers. And manufacturers will gladly furnish literature on their products. Following this paper is a partial listing of these books and magazines including all those referenced in the preparation of this paper.

Fourth, an *ad hoc* standard has evolved which allows various computer circuit boards to plug into different personal computers adhering to the standard. This standard has prompted many manufacturers to enter the field and has resulted in a wide variety of products at competitive prices. To date this standard has no agreed upon name, so products are advertised as "Altair/IMSAI compatible" or as "using the standard S-100 bus." In other words, the product is compatible with the first hobby computer: the MITS, Inc. "Altair 8800" microcomputer.3/

And lastly, though the personal computer industry is relatively new, one can say it has a bright future. One of the indications of this is that the industry has products that have "second sources."4/ In other words, the same product is available from more than one manufacturer. Furthermore, a recent study indicates that the industry is expected to grow at a rate of 32.7% per year.5/

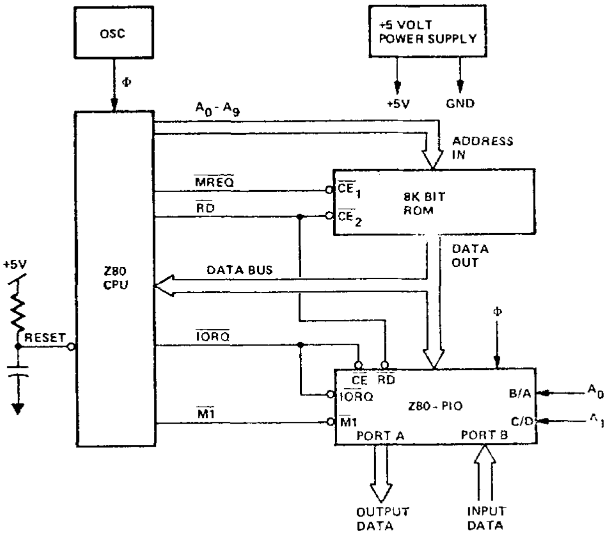
COMPUTER BASICS

For a better appreciation of just how simple computers can be, some computer basics will be explained. Just the word "computer" seems to scare many people. Advertisers have used it to awe us, and large corporations use it to bill us. And it is a scapegoat for many mistakes. But computers can be quite simple and a microcomputer circuit need not be complex.

Actually computers are stupid. They can only do a surprisingly small number of things and one must give them precise instructions in a numeric code and logical order. But the power of a microcomputer is that these instructions can be executed in millionths of a second (i.e., microseconds). Therefore, a computer becomes useful when a series of instructions, known as a computer program, is executed. The speed of a computer becomes painfully clear when, after hours have been spent in creating a program, it is completed in a blink of the eye.

But nonetheless the computer is quite simple. It consists of only three elements: input/output (I/O) devices, memory, and the CPU. The I/O devices interface the computer to the "real world." Their function is to input and output information. The memory stores the computer programs and data. The programs are stored in a numeric code, as is the data. Generally the more memory the computer has, the more powerful it is. The CPU is the heart of the computer. Its function is to obtain instructions (and data) from the memory and perform the desired operations. These operations include input/output routines to receive or send data. For example, a set of instructions might require data to be input from keyboard and stored in memory. Then more data is entered from the keyboard, added to the stored data, and the result sent to a printing device. This would stimulate an operation of a calculator.

A microcomputer circuit can be constructed quite simply with a microprocessor and some other large-scale integrated (LSI) circuits. In the following circuit diagram, a minimum microprocessor circuit is depicted which is based on the Zilog Z80 microprocessor and its associated input/output circuit. The other three components of this circuit are a memory device, an oscillator, and a 5-volt power supply.



A MINIMUM MICROCOMPUTER CIRCUIT

The input/output circuit for this example is the Z80-PIO LSI circuit. Though in this example only one I/O circuit is used, the microprocessor has the capacity to use 256 input/output ports. An input/output device can require one or more ports for operation. Examples of I/O devices with which a computer can interface are: keyboards, LED and LCD displays, magnetic tape recorders, teletype machines, typewriters, clocks, switchers, paper tape readers and punchers, telephone modems, floppy disks and video displays (television screens).

This computer circuit uses a ROM memory. There are three major types of LSI memory devices: ROM's, PROM's, and RAM's. ROM's are read-only memories which have their contents determined in the manufacturing process and can not be altered thereafter. PROM's are programmable read-only memories whose contents are determined by the user and erasable only by special devices and not during normal computer operations. RAM's are random-access, read-write memories into which the user can read data and store data by writing over the old data during the normal computer operations. RAM's lose their data when they are disconnected from the power supply, but ROM's and PROM's do not. A PROM or a RAM circuit could easily be inserted into this microcomputer circuit.

A memory device works simply. The device consists of many cells. A signal is sent to the device indicating which cell(s) is of interest. Another signal is sent to indicate whether the cell(s) will be read or written into. If "read" is indicated, the data stored in the cell is sent out of the device. If "write" is indicated, the data is sent to the device and is stored in the cell(s). The microprocessor has the capability of addressing over a half-million individual cells or 65,536 bytes (one byte = 8 cells or bits).

The two other parts are the oscillator and the 5-volt power supply. For low speed operation an RC oscillator can be used while at high speeds a crystal is needed. The only requirement for the power supply is that it be well regulated.

The microprocessor is the most important component of the microcomputer; it is what makes a computer a microcomputer. The processor reads instructions from memory, performs instructions, reads and writes data from and into memory, and inputs and outputs data to the "real world" via the input/output circuits.

The Z80 microprocessor was chosen for this example for several reasons. First, the Z80 has an instruction set which is compatible with the Intel 8080A instruction set.6/ This allows computer programs written for the 8080A to work on the Z80. This is important because the 8080A appears to be the electronics industry standard.7/

Second, the Z80 requires less complicated circuitry than the 8080A processor. While the Z80 requires only a single 5-volt power supply, the 8080A requires a 5-volt, a +12-volt, and a -12-volt power supply. The Z80 also needs a less complicated oscillator than the 8080A and is capable of higher and slower speed operations.

Third, the Z80 may become the new industry standard. It has been heralded as the "third generation" microprocessor and it has all of the features of the 8080A plus more.8/ But only time will tell.

But this minimum microcomputer circuit does not make full use of the capabilities of the microprocessor. The memory and the input/out capacity are restricted. A more sophisticated circuit is needed to take full advantage of a microprocessor and to have some flexibility. Though one could design such a circuit, as many hobbyists have, there is no need to do so. Many microcomputer systems, which make full use of the microprocessor's capabilities, are available either as kits or fully assembled. As indicated previously, a powerful microcomputer for a cable television system would cost $2,500 or less.

SOFTWARE

But the hardware is only half of what is needed. In order to use the computer, computer programs are required. This is a problem since programs are not yet available for cable television applications. Even if programs were available, they would most likely require some modification. This is because programs are written to be stored in a particular memory location and to work with certain I/O devices with these devices in a certain arrangement. A cable system's computer might have another program in a given memory location, the necessary I/O devices might not be available, or these devices might be arranged differently. A computer firm could write the programs or one could learn to write the programs.

Learning how to program is neither impossible nor difficult. A good way to get a taste for programming is to buy a programmable calculator and play with it. These calculators now sell for as little as $80. Most of the programmable calculators are sold with a helpful instruction book.9/

Or one could by a microcomputer just to learn programming. Such a computer can be bought for less than $500. Or one could take a microcomputer course. An advantage of these two methods is that one learns the actual numeric code of the computer instructions (machine language).

Another alternative is to buy a personal computer system with the capability of using a higher level computer language such as BASIC. BASIC is fun and easy to learn. It uses English and not numeric codes and many programs are available in this language. There are many books available which teach computer programming with BASIC. This method is more expensive than either of the previous two methods but one has a very powerful computer system at the end. The disadvantage of this method is that it does not teach one the machine language which will have to be learned sooner or later.

There are countless other ways. Anyway it is not too difficult but it is costly. Not only is money spent on hardware, but it is time-consuming. But it must be fun since over 20,000 people have spent about $2,000 each to have their own computer to program.10/

CONCLUSION

Computers are now affordable and can be very useful in cable television headends. The computer hardware is available at a low cost and is not a problem. The difficulty is the software. It takes time and money to write programs and this expense may be more costly than the hardware.

FOOTNOTES:

1/ "Do It Yourself Weather Predictions" by Michael R. Firth, Byte, December 1976.

2/ Specifications on the video signal of personal computer devices are not often given, so it is not known what, if any, modification would be required for use on a cable television system.

3/ There are several manufacturers of personal computers who do not follow this standard. One such manufacturer has recently written an article critical of the standard: "The Jupiter II" by Dennis Brown, Kilobaud, March 1977.

4/ "n Source" by R. D. Boudinot, Byte, May 1976.

5/ "Electronics Newsletter" Electronics, January 20, 1977.

6/ There is an exception. See "Will the Z80 Crush All Competitors?" by Carl Galletti, Kilobaud, February 1977.

7/ "The 8080 looks like a bandwagon" Electronics, June 24, 1976.

8/ "Will the Z80 Crush All Competitors?" *op. cit.* "Is the Z80 the Wave of the Present?" by Pat Godding, Kilobaud, January 1977. "The Circuit for Z80's" by Dr. Robert Suding, Byte, September 1977. "Microprocessor Update: Zilog Z80" by Burt Hashizum, Byte, August 1977.

9/ A good primer is "Programming? It's Simple" by Peter A Stark, Kilobaud, January 1977.

10/ "Publisher's Remarks" by Wayne Green, Kilobaud, March 1977. Articles such as "Home Input" by David Gumpert, Wall Street Journal, February 4, 1977, have indicated that "up to 100,000" people have home computers. This may be much too high of an estimate.

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books:

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TTL Cookbook and TV Typewriter Cookbook, by Don Lancaster, published by Howard W. Sams and Company, Inc., Indianapolis, Indiana 46268.

Scelbi's '8080' Software Gourmet Guide and Cookbook, by Robert Findley, published by Scelbi Computer Consulting, Inc., 1322 Rear-Boston Post Road, Milford, Connecticut 06460.

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IS YOUR SYSTEM PAYING TOO MUCH FOR PLANT POWER?

James K. Waldo
Rocky Mountain District Engineer

Teleprompter Cable TV
El Paso, Texas

In a time when power is paid for at a premium, there is no reason for you to pay more for power at your system than you actually use, and if each separate power supply is not individually metered chances are you are. In order to avoid over payment, you must begin to think in terms of conservation and monitoring of actual power use. With those two elements at hand, chances are you can successfully negotiate changes in your contract with your local power company. By monitoring the actual amount of power consumed with a kilowatt meter, you can show local representatives the actual amount of power you have used. If you are afraid of disrupting relations with the power company, don't be. Over the past several years they have become used to such things. But with careful metering of your power system and a tactful approach to power company representatives, you could reduce the amount you pay for electricity by a substantial sum.

There are several ways to approach your local power company in the event you suspect you are paying too much for system plant power. The methods that will be described in the subsequent transcript have been used successfully. Systems presently metered at each power supply should be paying for only that power actually consumed.

When you are sure you are paying too much for power, how do you approach and prove your suspicions to the power company? What reactions should you expect?

If each system power supply isn't metered, chances are you are paying too much.

Step one - if you're going to be successful, train your mind to think as follows: How much power is consumed at the primary of the power supply? How much power is consumed at the primary of the power supply under no load? How much power is consumed at the primary with only one trunk station? One trunk station with an extender, etc.? Relative to system plant power costs--why should we think only of consumed power at the primary of each main supply and not system amplifier power requirements? Is the primary of your system power supply really relative to the primary of your home fuse or circuit breaker box?

Some of you are probably asking yourselves, "Why now should I stir-up my company's or my relationship with the local power company? Why should I cause embarrassment to my company, or myself, or my predecessor?" The answer is simple. If you aren't paying too much you don't have to create waves. If you ARE paying too much you are obligated to your company, if not yourself, to get the power costs reduced. You have already paid too much over a period of time. No one likes paying for a dead horse.

Call your local power company commercial representative to set-up a meeting, the first on your own home ground. After introductions are over and the coffee is poured, explain to the representative that you are paying too much for system plant power. When you explain how you know, the representative will no doubt defend the present contract between your company and his. And well he should; a signed agreement or contract is usually legal and binding in any man's language. However, most power companies in my experience want to charge only for the power their customer consumes and will be concerned. The old standard, "If you aren't satisfied with your present billing, you can meter each power supply location," is seldom heard anymore. The cost is more than both parties are normally willing to bear.

Prior to any meeting with the power company we assume the following has been done on the bench only: Using a VOM or DVM of known calibration measure the voltage drop across a one ohm wirewound resistor connected in series on the primary of the power supply. The resistor should have a wattage rating somewhere between 25 and 50 watts with a tolerance of 1 to 5%. This voltage drop reading divided by the known series resistance of one ohm equals the current in the circuit of the power supply under no load. Record this current reading.

Connect each type of amplifier used in your system individually to the secondary of your power supply. Again, this is done on the bench only. Each different amplifier now creates a different load to the power supply. For each case again read the voltage drop across the one ohm resistor. The new reading divided by one is the new current requirement of the circuit.

Once the current requirement for each device is recorded,(See Example 1) simply determine how many devices you have on a power supply from your system maps or field observation, then multiply the total of each type of amplifier by its individual current requirement. Now total all current requirements for the total current requirements of all amplifiers. Don't forget to include the no load current requirement of the power supply alone. (See Example 2.)

Example 1 (using Jerrold Starline equipment):

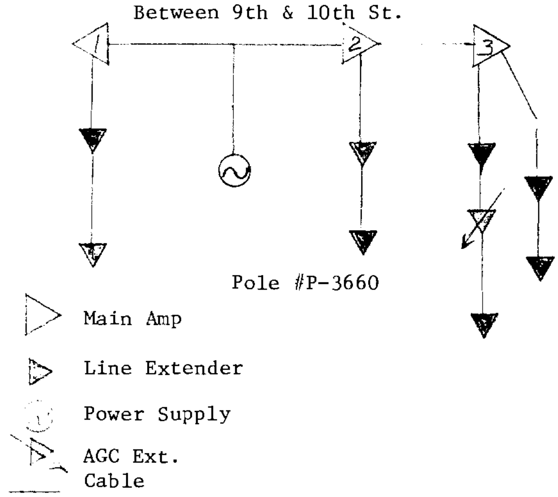
SPS-30/60	Power Supply	1.15 amps
SP-1	Trunk/AGC/Dist. Amp	.17 amps
SP-2	Trunk/Dist. Amp	.15 amps
SP-3	Trunk/AGC Amp	.10 amps
SP-4	Trunk Amp	.10 amps
SP-5	Distribution Amp	.10 amps
SLE-300	Line Extender	.09 amps
SLE-300A	Line Extender	.15 amps

(The above current drains are approximated.)

It's a fact that all power transformers have some inductance. And when inductance is operating in an AC circuit, voltage and current are out of phase to some degree. Whenever the current leads or lags the voltage, the power factor in the circuit decreases. It has been written that for most power supplies - if 60 HZ AC is used - the power factor can be disregarded as negligible. This may be true if we were concerned with only one power supply and/or unregulated transformers. In a cable system, of course, we are concerned with several main power supplies and possibly hundreds of power packs, all of the regulated type normally. My experience with Jerrold systems is that a power factor of approximately .9 (90%) exists on the primary of the main power supply and I have used this number. I have not considered the trunk and distribution cable in the system because of its negligible effect.

Example 2: Power Supply Number 9

Power Supply Number 9
On 7th Ave. East
Between 9th & 10th St.



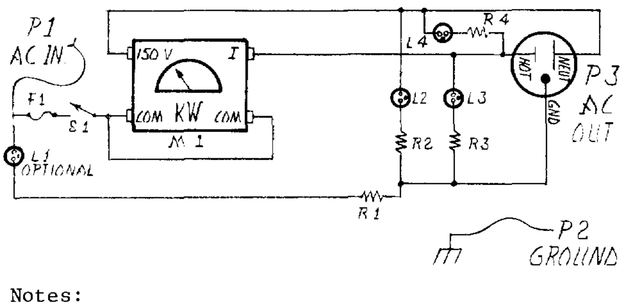
		Amt.	Current Rqd.	Total Current Rqd.
SPS-30/60	Power Supply	1	1.15A	1.15A
SLE-300	Extenders	8	.09A	.72A
SLE-300A	Extender/AGC	1	.15A	.15A
SP-1	Trunk/AGC/Dist. Amp	1	.17A	.17A
SP-2	Trunk/Dist. Amp	1	.15A	.15A
SP-3	Trunk/AGC Amp	1	.10A	.10A
	Subtotal			2.44 Amps

Kilowatt hour consumption per month equals -- P=EI=117.5 volts x 2.44 amps=286.7 watts x 24 x 30.4=209,176 watts per month ÷ 1000 = 209.18 KWH per month x .9 (90%) power factor equals 188.3 KWH per month.

Another method, and the most accurate, of determining the power consumed at the primary of a power supply is by using a kilowatt meter. This method is virtually the same type used by the power company metering your supply. The procedure is as follows: Connect a Weston kilowatt meter to the primary of the power supply under test. Read and record the results as indicated on the meter. The meter is a model 432, part number 9902007. The 432 has the following ranges: normal volts 300/150, normal amps 10/5, watts - maximum 3/1.5KW and a minimum 1.5/.75KW and does this through the use of two scales both of which are mirrowed. This meter sells for about $400 and is accurate to ± .5%.

Each reading should be monitored with the meter in its calibrated position, either horizontally or vertically, before recording. This reading times 24 x 30.4 ÷ 1000 equals the KWH per month. When using the kilowatt meter, power factor can be disregarded as the meter is reading true power, not apparent power. This method is normally more acceptable to the power company. Once this method is accepted, the power company will normally want to take a random 15% sampling once a year for varification. See Diagrams 1 & 2.

Diagram 1: Wattmeter Adaptor



Notes:
F1 - 20A slow-blow, may use breaker for F1 & S1
L1 - L4 & R1 - R4 - Neon Panel Lamps may use a commercial outlet tester for L2 - L4
M1 - Wattmeter, ±0.5%, Weston Model 432: #9902007 (1.5KW + 750W) or #990100B (1.5KW)
P1 & P2 - Heavy duty alligator clips, P1 has a large insulated cover

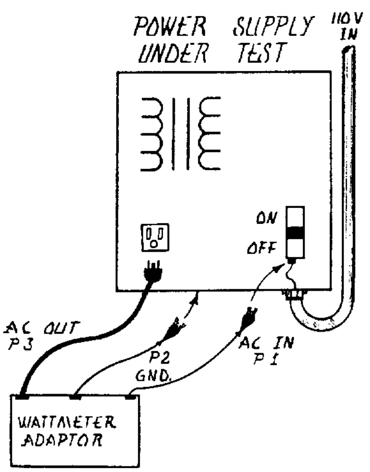
Notes for Diagram 1 continued:

P3 - 115V, 25A 3 wire plug with strain relief
Note: There is no connection between the power wiring and chassis ground.

Outlet Test:

L2	L3	L4	
Off	On	On	OK
Off	On	Off	Open Neutral
Off	Off	On	Open ground, Hot & Neutral may be reversed
On	Off	On	Hot and Neutral reversed

Diagram 2: Supply Under Test



The adaptor measures power without outages by paralleling the breaker in the supply. When the breaker is turned off, power goes through the meter to the outlet in the supply.

Operating Insturctions:
1. Turn switch off. Connect ground clip.
2. Connect AC out plug to outlet. If the test lights show the outlet is improperly wired, repair it before proceeding.
3. Connect AC clip to line side of main breaker.
4. Turn switch on, then turn breaker off.
5. Measure power, the meter must be flat or upright. The meter reads correctly when the pointer covers its reflected image.
6. Turn breaker on, then turn switch off.
7. Disconnect AC clip, then AC plug, then ground clip.

SAFETY FIRST

It is recommended that this testing is done with TWO men.
Do not test during rain or snow.
Always connect the ground clip.
Check that the switch is off before connecting or disconnecting the unit.

Power consumed at the primary of a main power supply is directly related to power consumed in your home as recorded on the power company kilowatt hour meter attached to the side of the house. Both are measured prior to the subsequent system and therefore encompass all of the power consumed by both systems.

In summary: Don't expect to negotiate a new contract during your first meeting with the power company. Chances are the commercial service representative won't understand most of what you say. Most representatives will want something in writing to take back to their leader. Yes, I mean all of your calculations and accusations in writing. You will no doubt have several meetings before an agreement is reached.

Try and determine the basis of your last or existing contract so you can show the power company the obvious mistakes and how they came about. If you can prove tactfully why the past method of calculation is a mistake, it will be to your benefit.

Remember the simplest method of showing actual power consumed, short of power company kilowatt hour metering, is by using the Weston kilowatt meter. Total up the consumed kilowatt hours per month for each station and divide this number by the number of stations. This then is the total average kilowatt hours consumed by each station. The billing for one station then times the total stations is your total cost per month.

The second and least desirable method, which is performed on the bench only, is to calculate via a one ohm resistor connected in the primary of the supply, the current demand first for a no-load power supply and then each subsequent required piece of electronics. These current cunsumption requirements obtained on the bench for each type of electronics used in your system are then directly equated to your power supplies in your system and its associated electronics. The total current times the primary voltage (E.I.A. standard approximately 117.5 volts) equals the watts. This number x 24 x 30.4 (30.4 equals the average days in a month) divided by 1000 times a power factor of 90% equals the KWH for the month for that supply.

Instead of using each individual amplifier current requirement, I have been most successful in using the highest requirement for a trunk station times all trunk stations and the same for extenders. This seems to satisfy the power companies and leaves room for unanticipated sheath currents and an amplifier failure of some sort causing excessive current requirements.

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PROVIDING LIFE, PROPERTY, AND FIRE PROTECTION THROUGH CABLE TELEVISION: NEW SERVICES THROUGH ADVANCED TECHNIQUES

John Daniel Fannetti

City of Syracuse

The paper suggests that the provision of security/alarm services by cable television operators might be used to: 1) generate additional revenue for the cable television operator; 2) increase CATV penetration levels in urban areas; 3) effectively utilize some of the extra bandwidth available on urban cable systems; and 4) provide field experience with the implementation and marketing of two-way services.

I. INTRODUCTION

In recent years, the cable issue has evoked considerable controversy, as urban centers throughout the country examine its various facets, in determining its application to their needs.

For many years, the cable was the sole means by which television was introduced in those areas which, for various reasons, could not bring in over-the-air signals. Thus, it served as an entertainment media, and virtually nothing more. Now, after a prolonged infancy, the cable industry has finally grown up; and far-sighted operators throughout the country are beginning to ask if and how the cable can assist them in better serving their subscribers; and , of course, how they, the operators, will be affected. How does the operator go about providing two-way cable to subscribers, particularly those in urban areas? And last, but certainly not least, will a two-way communications system prove economically feasible? These are but a few of the areas we will explore.

The possibilities are endless; the future, challenging. As the demand for services increases, we must look to modern technology to satisfy these needs. Thus, the operator can no longer be content to simply provide cable television to his subscribers. To remain competitive, it is imperative that he look to new areas that he can explore, new services he can provide.

We can now wire up entire areas, urban and suburban, for a two-way communications system that can satisfy the needs of today's society, making it possible for the operator to realize more revenues as he provides more services. In this way, we can give the cable industry the impetus it has long needed to move forward. The cable industry -- any industry -- can ill afford to become stagnated. Progress is essential for survival.

In this discussion, we will take a look -- a long, serious look -- at the various aspects of two-way communications: what can be accomplished in the field; how it can be done. Bear in mind, however, that this is only the beginning of a new era; we have only "touched the tip of the iceberg."

II. INTERACTIVE CABLE SERVICES: KEY TO THE URBAN MARKET

Perhaps the area that evokes the most interest from the most people, both potential urban and suburban subscribers, is that of public safety. As we all know, the burglar and, particularly, the fire alarms, have come into more prominence, as the news media daily recounts tragic incidents involving loss of human life, particularly through fire. Many, perhaps we should say most, of these lives would not have been lost had the victims had the protection of an alarm system which could simultaneously alert the subscriber and the proper authorities to an impending danger before it becomes life-threatening. Upon alert, the authorities could immediately dispatch the proper assistance, with virtually no loss of time. In situations where time is of the essence, this could mean the difference between life and death.

Because the public has become increasingly aware of the need for adequate protection,security alarms have realized a surge in popularity, with many selling at a brisk pace, regardless of the expense involved or their degree of effectiveness. The demand is particularly acute in urban areas, where the need becomes increasingly apparent. This is where the two-way cable comes in. Through the use of the two-way cable, the operator can provide subscribers with an alarm service which would not only be low in cost, but which would employ the latest in technology, to give it the greatest degree of effectiveness. This, in turn, would make it attractive to the potential subscriber and, subsequently, more lucrative for the operator.

Apart from provisions for security as part of the urban cable package, the number of other applications for interactive cable in metropolitan areas is almost limitless.

Such areas as utility monitoring, traffic control, visual monitoring of high-crime areas, pollution monitoring, power load monitoring and meter reading -- all these areas could be well served through two-way monitoring via cable. In addition to this, a tie-in with colleges and with other learning centers could provide at-home instruction for those unable to attend formal classes. Through use of the two-way cable, the public spirited citizen could actually "sit in" on and even actively participate in public hearings, legislative sessions, etc.

All of this is now possible. The time has come when pulbic services can and should be made readily available to all; and this can be done through the implementation of a highly sophisticated, technologically advanced telecommunications system. The urban centers, with their high density population, are prime areas for implementing such a system. This could be a boon to the cities, as they would become more attractive to the people, while permitting the operator to realize ample profit, both by reason of the high penetration possible and because of the appeal to the potential subscribers of the many and varied services he could offer.

The wideband width inherent in broadband communications makes such systems veritable superhighways for transportation of multiple audio, video and data channels. Thus, the multichannel capacity of a two-way broadband system allows for a diversity of offerings to the sophisticated urban subscriber that cannot be duplicated, or offered as inexpensively, by conventional communications systems, such as those of Bell Telephone. It is this fact which makes two-way telecommunications such a viable source of revenue for the urban cable operator.

How does the cable operator go about utilizing the cable, so that it is attractive to the potential subscriber and, thus, lucrative to him? Obviously, the first step would be to implement a city-wide system with a two-way capability. This would enable the operator to provide cable television immediately, and then to offer additional services, such as security alarms first on a limited basis to designated area, and then city-wide, on demand, at intervals compatible with the rate of financial return and public acceptance of the new services offered.

New services, by definition, will provide new experiences for the public which may well be attractive enough by themselves to gain widespread acceptance of interactive CATV.

The technical feasibility of such interactive systems has been demonstrated through comprehensive testing in El Sequndo, California, by Theta-Com, and in ToCom II's computer-controlled broadband system in Woodlands, Texas.

At some point after implementation of interactive services, it is more than possible that many existing services could be diverted from their traditional manner of function to cable. An excellent example of this is data processing, now handled by the telephone company. This area is easily adaptable to cable.

Once there has been significant acceptance of some of the services offered, as has been demonstrated in Woodlands, it becomes easy for the operator to justify added investment in the system, based on potential revenues.

III. ELEMENTS OF INTERACTIVE BURGLAR/FIRE SECURITY SYSTEM

The telecommunications system, as heretofore described (See Figure #1), consists of five primary elements, which may be defined as follows:

1. Computer-controlled Central Data System(CDS);
2. Multiple Headend Hub and Interconnection (Transportation) System;
3. Bi-directional Cable Distribution Network;
4. Interactive Home Terminal Units (H.T.):
5. Wireless Sensor Alarm Systems.

The Central Data System is comprised of a central computer with bulk memory, a hard-wire control and computer display console, data transmitters, data receivers, modems, teleprinters and other associated peripheral devices. Located at the headend, the CDS is capable of interrogating, receiving responses and acting on those responses, from >60,000 home terminal (microcomputer) units every six seconds.

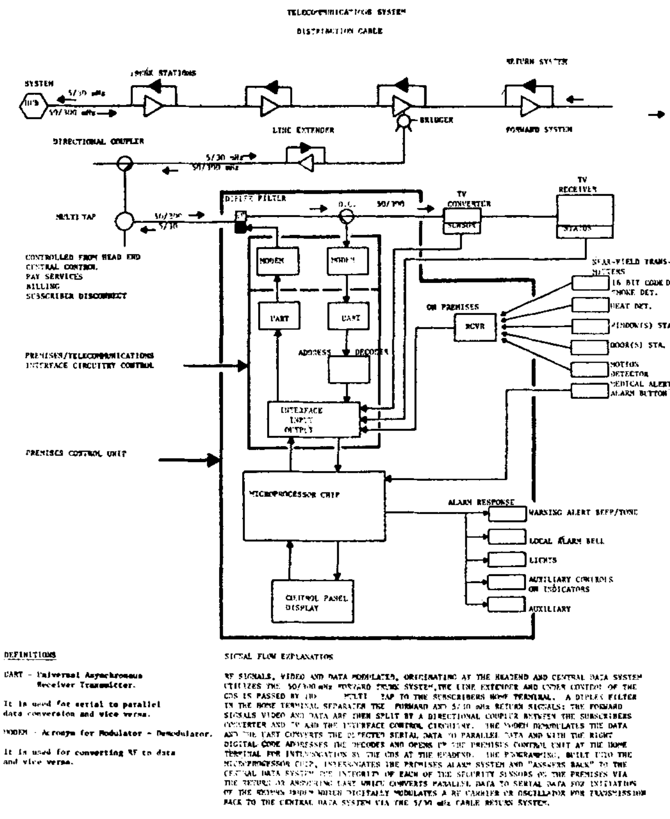


Figure #1

The Multiple Headend and Interconnection System consists of three hubs, one of which will be designated as a Master Headend. These hubs are to be interconnected by trunk cables or AML microwave links.

The Master Headend includes a nearby array of VHF and UHF atennae, the electronic control center for amplifying the broadcast signals received from the antennae and the Central Data System (CDS). The broadcast signals of UHF frequencies will be converted to VHF frequencies in the master headend's electronic control center and then transmitted throughout the cable distribution system.

The Transportation System, which interconnects the master headend/hub with its two "slave" hubs, provides channel space for the transmission of signals from the master headend to each of the sub-headends. In addition, these interconnections permit the exchange of video signals, using a two-way video channel from each sub-headend to the master headend.

The Distribution System distributes the combined signals from the multiple headend/hub interconnection (transportation) system and the Central Data System to the subscriber, within the frequency spectrum of 50 MHz to 300 MHz.

The Home Terminal Unit (H.T.) is located in the subscriber's home, and has its own unique identification. There are individual identification codes for each home terminal. The home terminal responds with a digitally encoded signal when interrogated by the CDS.

The Wireless Sensor Alarm System consists of varied numbered miniature radio sender modules, which may be located at door locks, windows, or other openings. It also incorporates other detection devices; such as, ultrasonic motion sensors and fire detectors.

IV. SYSTEM DESCRIPTION AND DESIGN

Probably the single most important effort in our development of an economically feasible, centrally-controlled alarm system is the design of a low-cost microprocessor.

Various corporations have indicated an interest in producing a microprocessor chip that would include all parameters needed. At least one company has developed, within a single chip, a microcomputer containing a clock, 1,000 words of read-only memory, 65 words of random access memory, a program counter, an accumulator and several other housekeeping registers, as well as output latches for both addressing purposes and for an off-board digital display. The quoted price for this microcomputer is approximately $3.10, in quantities of 50,000 pieces.

The microcomputer (See Figure #2) has the capacity to keep track of up to 32 sensors in the home, including windows, intrusion centers, switch mats, etc. It can thus alert the occupant of any unsecured condition, such as an open window, for example. The user subsequently has the option of either closing the window or leaving it open. The computer automatically adapts, at the time of the alarm, to the best remaining conditions, in the event of a possible intrusion or in case of fire.

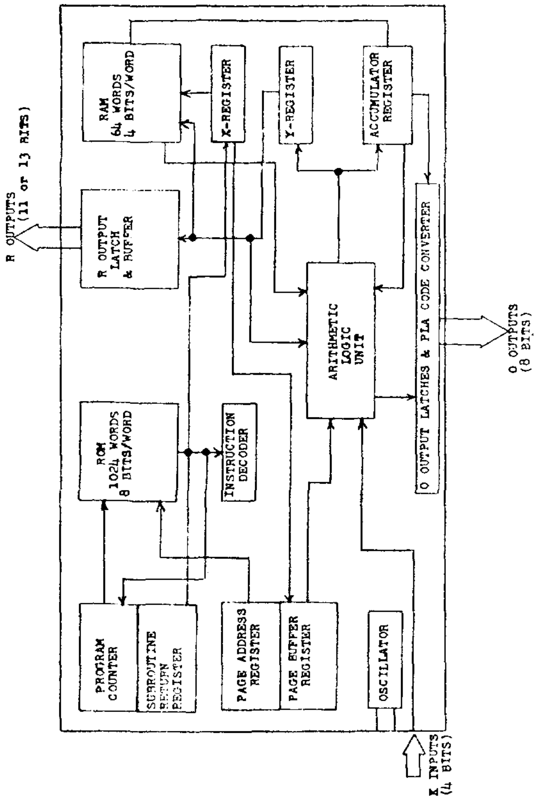


Figure #2

In addition to providing security alarms, the microcomputer has many more functions. Perhaps one of the most important is its capability to summon emergency medical assistance. Should a medical emergency arise, a medical alert button initiates a message to the Central Data System, which, in turn, informs the proper emergency unit.

Note: The microcomputer may also be used to track auxiliary inputs, in which capacity it can serve to notify the user of such existing conditions as freezer failure, a stove which has been left on, or a garage door open, etc. While the auxiliary inputs do not cause an alarm, they can send the information to the central processor, which, in turn, sends it back to the user on demand.

The subscriber's home terminal unit houses three distinct elements: a microcomputer; a multi-channel receiver; and a front control panel. The latter consists of a medical alert button, a 5-position key switch, a fire alarm reset button, and a single character light-emitting diode display (LED), whose function is the identification of each remote sensor by an assigned panel number.

The home terminal is the interface between the Central Data System, the CATV System, and the remote sensor in the subscriber's home. This can best be explained by describing the specific functions of the various controls on the front panel of the home terminal.

The five key switch positions on the home terminal unit may be defined as follows:

1. Normal - This position arms the system for interactive response with the Central Data System, and is the position which must be assumed for normal day-to-day system functions.

2. Full Test - In this test position, a calculator-type keyboard, depressed by the subscriber, instructs the microprocessor to initiate a full test of the subscriber's alarm system. All sensor system functions will perform normally as described in Position 1 (fire, burglar and medic alert), and notification of the "Full Test" condition will be included in the home terminal response to the interrogation by the Central Data System.

3. Local Test - This test position notifies the Central Data System that the home sensor is undergoing local tests.All sensor system functions will perform normally, but the return modem will be inhibited, so that no alarm message will be transmitted back to the CDS. The front panel display will indicate results of the local test.

4. Memorize - This position allows the system operator to set the user's home terminal code for various services, at the request of the subscriber. For instance, should the subscriber's system contain a fire alarm code and he requests one for burglar detection, the system operator can code the new data into the microcomputer. This can also be done should subscriber later request a medical alert or any other available code.

The system identification numbers are inserted into the microcomputer's memory by the system operator, for easy recognition by the Central Data Ssytem. This is accomplished through a calculator-type keyboard, located on the control panel. The system operator will assign channel numbers to his sensors during initial system installation, or subsequent to the addition of new sensors, at the subscriber's discretion. This data is inserted by the system operator, by a single triggering of the desired sensor. When loading is complete, the sensor will "beep", signalling the end of "Memorize" operation. The switch should then be returned to "Normal" position.

5. Channel Select - Switching between "Memorize" position and this one increments the channel number currently being displayed. Thus, the desired channel can be selected before activating a sensor to record its identification code. Once this has been done, the system operator returns the switch to the "Normal" position, which arms the home terminal for normal operation.

The sensor display, located on the home terminal unit, displays various information and has, as its prime function, the indication of sensor activation, for the subscriber's information.

Each individual display represents a distinct channel, corresponding to a specific sensor category. The categories of sensor channels include boundary sensors, internal sensors, emergency sensors, fire sensors, auxiliary emergency sensors, auxiliary control sensors and arming/disarming sensors. Thus, when the user locks or unlocks his front door, the particular channel to which the door's sensor has been assigned will display for a short time at the home terminal. During an actual alarm, the channel initiating the alarm will be displayed.

In addition to the above functions, a seven-segment display will flash for twenty seconds, thereby disclosing any sensor with an unsecured condition, such as an open door, once the door has been closed and the system subsequently armed. Accompanying this will be an audio alert, a "beep", that will inform the resident of the unsecured condition and its location.

Eight available codes are included in the system. These include individual numbers for fire/smoke, burglary emergency, auxiliary emergency , radio frequency interference, a battery sensor and low voltage monitor, an auxiliary control channel, and incorporation of two additional auxiliary control functions. Each of these will automatically send a digital message over the coaxial cable to the Central Data System.

New home terminal techniques and refinement of logic arrangements are being explored, to reduce the probability of user-caused false alarms. It has been determined that optimum results could be achieved should the user be given a single control, to be activated by the user in a way relevant to and compatible with his normal living routine.

V. THE WIRELESS SENSOR ALARM SYSTEM

It is an accepted fact that installation costs account for a probable 50% of the total cost of a fire and burglar alarm system. This is primarily due to the expense involved in running wires from the sensors to the home terminals. For this reason, it becomes apparent that the obvious choice for installation in an existing structure is a wireless alarm system, with its inherent low cost. A wireless technique can, without a doubt, significantly reduce the cost of an alarm system, making it more attractive to the cable operator.

There are many miniature wireless alarm systems currently on the market. For the most part, the reliability of these systems hinges on the very low market penetration which now exists for these items. The cost, while not prohibitive, is not at this time sufficiently low to warrant any foreseen flooding of the market. Consequently, it is unlikely that more than one system would lie within detection distance of another. It is anticipated, however, that should a low-cost, reliable system be made available, a significant market penetration would result. It is likely that this dense alarm population would result in a great deal of cross-talk between these wireless systems, and this could further aggravate an already serious false-alarm problem.

Therefore, means must be sought to minimize cross-talk between radio systems operating within close proximity, as for example, in an apartment complex, where up to 50 or more sensor transmitters might be operating on the same frequency, within a 200 ft. distance of each home terminal.

To accomplish this, we have investigated two basic approaches:

1. A digital coded technique, providing up to 32,000 different codes;
2. Use of a limited-distance transmitter, which exploits near-field radiation phenomenon.

Mathematical expressions define this latter phenomenon and reveal that within the near-field, certain terms in the radiation equation drop off very rapdily, and with distance, as compared with the so-called far-field term normally employed in radio communications systems. Furthermore, in the near-field, these fast-dropping terms are substantially GREATER in strength than are the far-field terms. Therefore, one obtains a high energy RF volume immediately surrounding the transmitter element, but this rapidly drops off with distance. By proper choice of radio frequency, one can take advantage of the near-field effect to limit the radiation distance within a prescribed volume.

"An experiment was done by the Aerospace Corproation in Washington, D. C. in which the equipment was constructed and tested (See Figure #3), utilizing both the digital coded technique and the near-field idea. Both were successful. In the case of the near-field device, the probability of detection in excess of 95% was achieved at a distance of 35-40 feet. But this probability reduces to near zero at a distance of 60 feet, as desired. Using conventional radio techniques as employed today, the probability of signal detection falls off more slowly. For example, a 95% probability at 40 feet might only reduce to approximately 85% at 60 feet, and such a system would, consequently, suffer more interference due to the other transmitting devices in the vicinity. Either the near-field or the digital, or both together, are promising for further application."[1]

The wireless sensor alarm system includes up to 32 miniature radio sender modules, which may be located at door locks, windows, or other openings. It can also incorporate other detection devices, such as ultrasonic motion sensors or fire detectors. The home terminal, incorporating a microprocessor and radio receiver for detection of the radio module output message, will accomplish a prescribed logic sequence, generating signals to the Central Data System.

Each radio sender module transmits a unique 15-bit permanent identification code and a 1-bit status message as a binary sequence (16 bits total). The microprocessor in the home terminal will recognize the identification code of each sender module associated with its system. Subsequently, the triggering of any radio sender module will be detected by any alarm receiver lying within a distance of 40-50 feet from the sender. However, the receiver programmed for this particular sender code is the only one that will react to this transmission.

There exist at least 32,000 sender code combinations. Therefore, the probability that more than one alarm system will respond to any specific radio module sender is negligible.

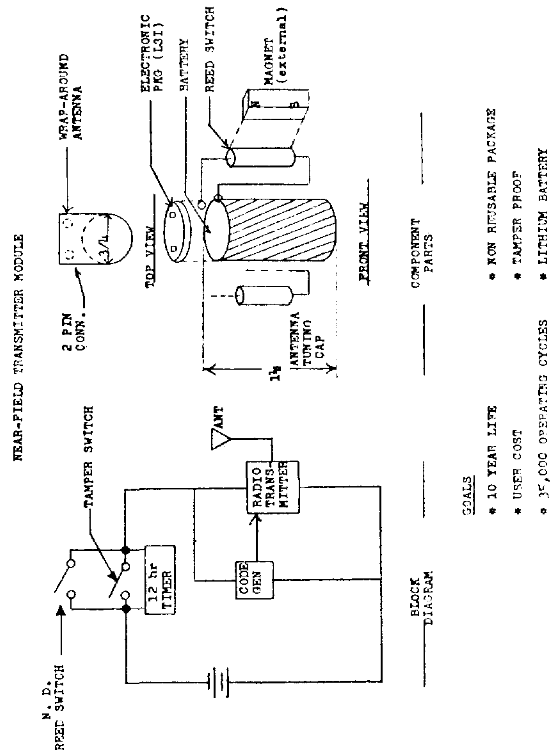


Figure #3

VI. CONCLUSION

The interactive, two-way cable concept, as outlined in this discussion and demonstrated so effectively in Woodlands, Texas, serves to reinforce and emphasize the fact that the cable can and ultimately will prove the most economical and technically sound means of accommodating the demand for public safety, health care, and at-home services.

As an increasing number of our major cities search for ways to halt the on-going exodus to suburbia, it becomes evident that the cities must have more to offer -- more services, adequate protection -- to make them attractive to the people. The cable, with its easy adaptability and proven feasibility, can provide these services, via a sophisticated telecommunications system. In this way, will our cities come alive again, as they once more become the hubs of activity.

For the private cable operator with the foresight to act on this coming demand, broadband telecommunications offers a vast frontier for economic development.

1 Aerospace Corporation.

*Information for this paper supplied by the ToCom Company and the Aerospace Corporation.

RELIABLE DESIGN FOR FIELD INSTALLATION AND TESTS

A. Lochanko

AEL Inc.
Lansdale, PA

The Wilson, NC CATV system is analyzed demonstrating the successful design concepts for an overall system and its trunk stations. The signal path is traced from the head end, through the main trunks, and finally to the subscriber's TV set. A trunk amplifier station is analyzed demonstrating the interplay of electrical and mechanical design concepts. System performance tests verify the conceptual soundness of the design approaches described; the result is an environmentally stable, low maintenance CATV system yielding pictures of exceptional quality.

INTRODUCTION

Today's economics require a CATV system to provide more than just low initial cost. The system must be highly reliable, deliver high picture quality, and ensure low maintenance costs.

Also, adequate margins must be provided, through conservative design and specifications at all levels, to allow for an increase in channels carried, alignment errors, test equipment miscalibration, and system expansion.

AEL Inc. has recently installed a high-reliability low-maintenance CATV system in Wilson, North Carolina. The system is a single-cable sub-split type having a total cable length of 116 miles. It incorporates 80 bidirectional trunk stations and 300 line extender stations. Currently, over 4000 well satisfied subscribers are served by the system which is intended to serve up to 7000 subscribers.

The system's electronics installation was started in May 1976 and was completed and accepted by the customer in October of 1976. Careful system and equipment design ensured that installation was quickly accomplished and that a minimum of installation adjustments were required.

Since being installed, the system has provided outstanding performance in all critical parameters such as:

- Transmission response flatness
- Distortion levels
- Signal-to-noise ratio
- Hum modulation
- Stability with temperature variations.

The service record has shown that the system is highly reliable, is easy to maintain, and is stable under extremes of temperature and humidity variations, which have been very severe this year.

The following paragraphs present the basic concepts considered in the design of the hardware and the system. Also covered are the results of post-installation performance tests. The concepts presented will provide useful background information to system designers, field personnel, and system owners.

I. SYSTEM DESIGN CONCEPTS

The refinement of a CATV system is determined primarily by the requirements of picture quality and the need of stable, reliable performance under changing environmental conditions.

Among the major electrical parameters determining picture quality are the level of distortion products in the system, the overall signal-to-noise ratio, flatness of transmission response in a given channel, ghosting due to reflections (mismatches), and group delay.

Part of the Wilson, NC, system is shown in figure 1. The cable network consists of 0.750 in., Parameter 1 cables for the trunk spans and 0.500 in. Parameter 1 cables for the feeders. The RG-59/U cables (foam polethylene) are used for the tap-to-customer spans. Knowing the cable types used, transmission frequencies, and the ambient temperatures, the cable losses are easily determined. Typical cable losses at 68°F are:

Cable Type	Cable Length (ft.)	Loss at 270 MHz (dB)	Loss at 50 MHz (dB)
RG-59/U Foam polyethylene	100	4.15	1.73
0.500 in. Parameter-1	1490	21	8.3
0.750 in. Parameter-1	2120	21	8.2

The loss values vary by approximately 1.1 percent for each 10°F change in ambient temperature.

The cable spans on figure 1 are 21 to 22 dB at 270 MHz; these cable spans take into consideration final achievable performance results with minimum hardware used in the system.

System optimization requires evaluation of noise and distortion parameters; these parameters determine the number and types of amplifiers in the cascade, system cable spans, and optimum operating levels, as shown in the Appendix.

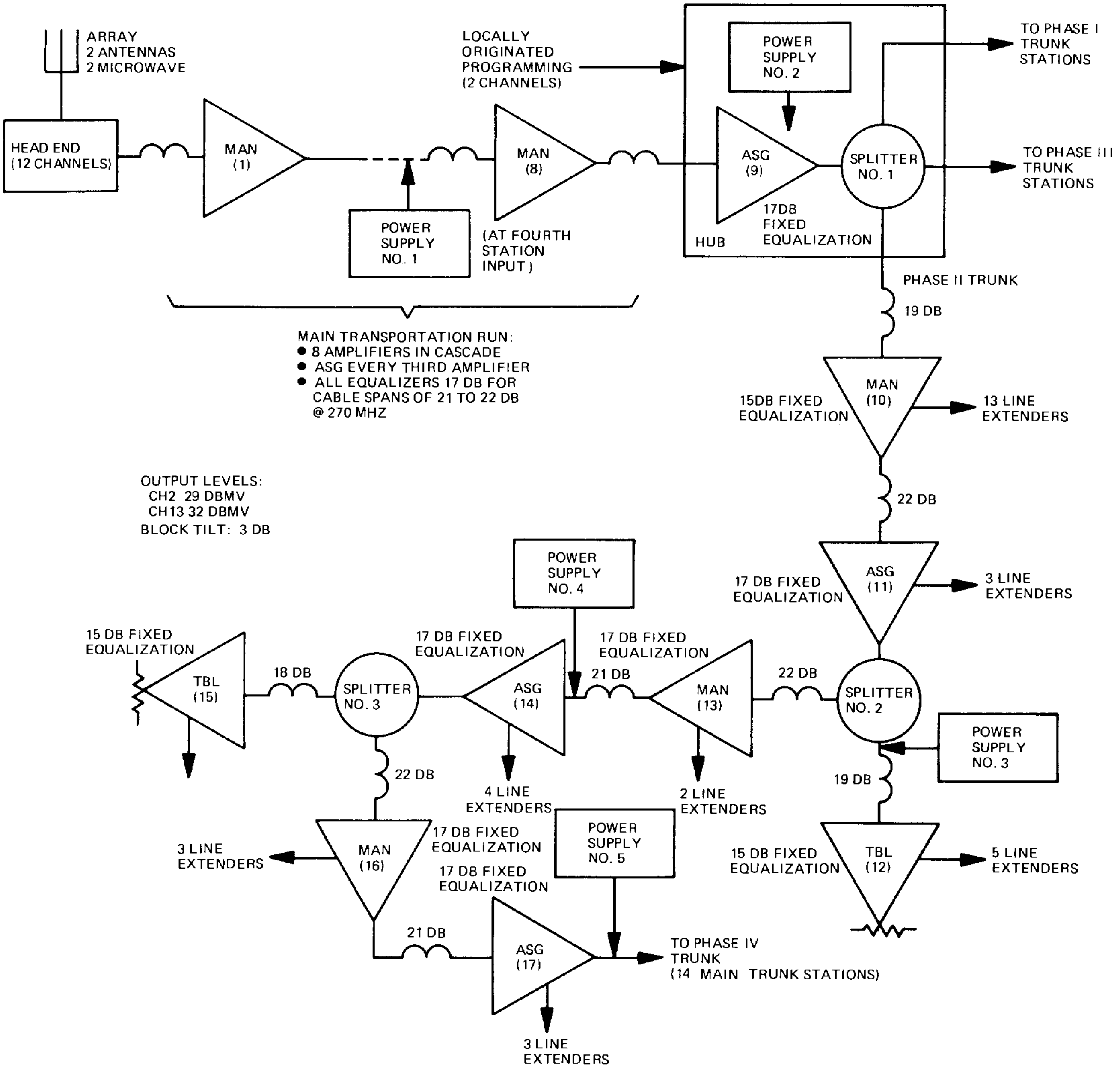


Figure 1. Typical Trunk Section of Wilson, NC System

On the average, a typical TV channel signal delivered to a subscriber in the Wilson, NC, system has the following characteristics: level from 3 to 6 dBmV, depending upon the customer's location in the local distribution system; cross modulation distortion level better than -56 dB; composite intermodulation levels better than -65 dB; flatness variation over a video channel better than 0.06 dB; gain variation to 0.5 dB maximum; slope variation ±0.25 dB. For a TV picture of excellent quality (no perceptible "snow") the signal-to-noise ratio must be at least 45 dB. Tests on the Wilson system have shown the signal-to-noise ratio to be 46 dB. Refer to the Appendix for derivations of the above parameters.

Refer again to figure 1. Twelve-channel air link television signals are received by the antenna array, processed at the head end and sent over the main transportation run to the hub. The main transportation cable runs are 2100 to 2220 ft. in length and represent cable losses of 21 to 22 dB at 270 MHz per run. The signal flow from the hub can be easily traced.

The system design specifications were achieved by employing an ASG (Automatic Slope Gain) station at every third trunk location. This limited use of the ASG stations is achieved by careful design of the automatic control circuitry resulting in a station that tracks cable with extremely good correlation over a wide temperature range as shall be shown in paragraph III. Good temperature compensation ensures stable performance.

The ASG uses Ch 5 and Ch 12 for the control carriers without any appreciable effects caused by sync or other modulation. This is achieved by employing the true peak detector combined with sync filtering in the detector circuits. Temperature stability of the control module is achieved by using temperature-stable capacitors in the tuned circuits. Also, other temperature compensating devices are used in the detectors to stabilize drift due to the diodes and the operational amplifier. The temperature stability of the circuits is ensured through proper compensation techniques. The time constants of the ASG circuits are such that short time variations in the signal do not noticeably affect the gain or slope of the system. Only the long-term variations, such as temperature effects, will cause the ASG circuits to respond; however, the detector design minimizes recovery time from large amplitude transients. The adjacent channel's interference to the control carrier has been minimized by using stable, highly-selective circuits and filters in the control modules.

The function of the ASG module is to compensate for effects of long term temperature variations of cable; it accomplishes this function in conjunction with the gain and slope circuits in the trunk module. The pin diode slope and gain circuits are designed to ensure excellent cable tracking for 10 dB of cable variation. This is accomplished by ensuring that these circuits, as well as all others, maintain at least 18 dB of input and output return loss. As a result, there is a minimum of deterioration in tracking characteristics over the entire adjustment range.

To compensate for cable characteristics each station uses fixed equalization 3 to 5 dB less than the cable being compensated. The additional equalization is provided by the slope control circuits manually or automatically.

To maximize station cascadability, it is essential that the amplifier module have as large a noise and distortion performance window as possible. The Mark IV station trunk module has achieved this by using a pin diode gain control attenuator at the amplifier's input. To accomplish this, two critical performance parameters must be optimized; namely, insertion loss and return loss.

The amount of insertion loss in this circuit is directly additive to the noise figure of the input hybrid in determining the overall noise figure of the module. In recognition of this requirement, the insertion loss of this pin diode circuit has been maintained at 0.5 dB. This slight compromise in noise figure is overshadowed by the improvement in distortion performance when compared to a circuit that would place the pin diodes after the input hybrid wherein, with higher levels present, the diodes would add significantly to the station's distortion.

The attenuator's second design parameter, return loss, is equally important since it directly affects response flatness, cable tracking performance, the characteristics of the station's input diplexing filter, and the return loss of the entire station. Observe that, as a result of locating the pin attenuator at the input, the station exhibits a constant carrier to noise. This simplifies carrier to noise calculations for temperature variations. Even more stringent controls on return loss are established for cascaded building blocks within the station in order to hold the very flat response which will be discussed later.

The AC power is inserted into the cable runs by corresponding AC power supplies as shown in figure 1. Programming of the AC power is accomplished at each station and is also discussed below.

The block diagram of figure 1 demonstrates the manner in which any similar system can be developed by using high-quality versatile stations.

Figure 2 shows local signal distribution in the Wilson system from a typical trunk station to the TV set. Local distribution from the ASG station no. 14 (on figure 1) is typical of the entire system.

Local distribution in this area is accomplished using 0.500 in. Parameter 1 coaxial cable and four AEL

CVT-5E line extender stations. Signal input to the line extenders is 19±2 dBmV; output levels are approximately 42 dBmV for high band signals and 39 dBmV for the low band. Signal taps to the subscribers are represented by the small rectangles. Distribution to the subscribers is accomplished by RG-59/U cable; tap loss for each subscriber circuit is noted in the rectangles. Other aspects of the distribution are marked on figure 2 (equalization, cable spans, etc.).

The CVT-5E extender stations with their low distortion and adequately flat transmission response will permit expansion of the distribution system as system expansion becomes necessary. The low distortion is achieved by using high-quality hybrid devices in the amplifiers.

The packaging approach in the CVT-5E station allows good thermal paths for the active devices in the station. This results in a relatively low temperature rise within the housing and subsequently high reliability.

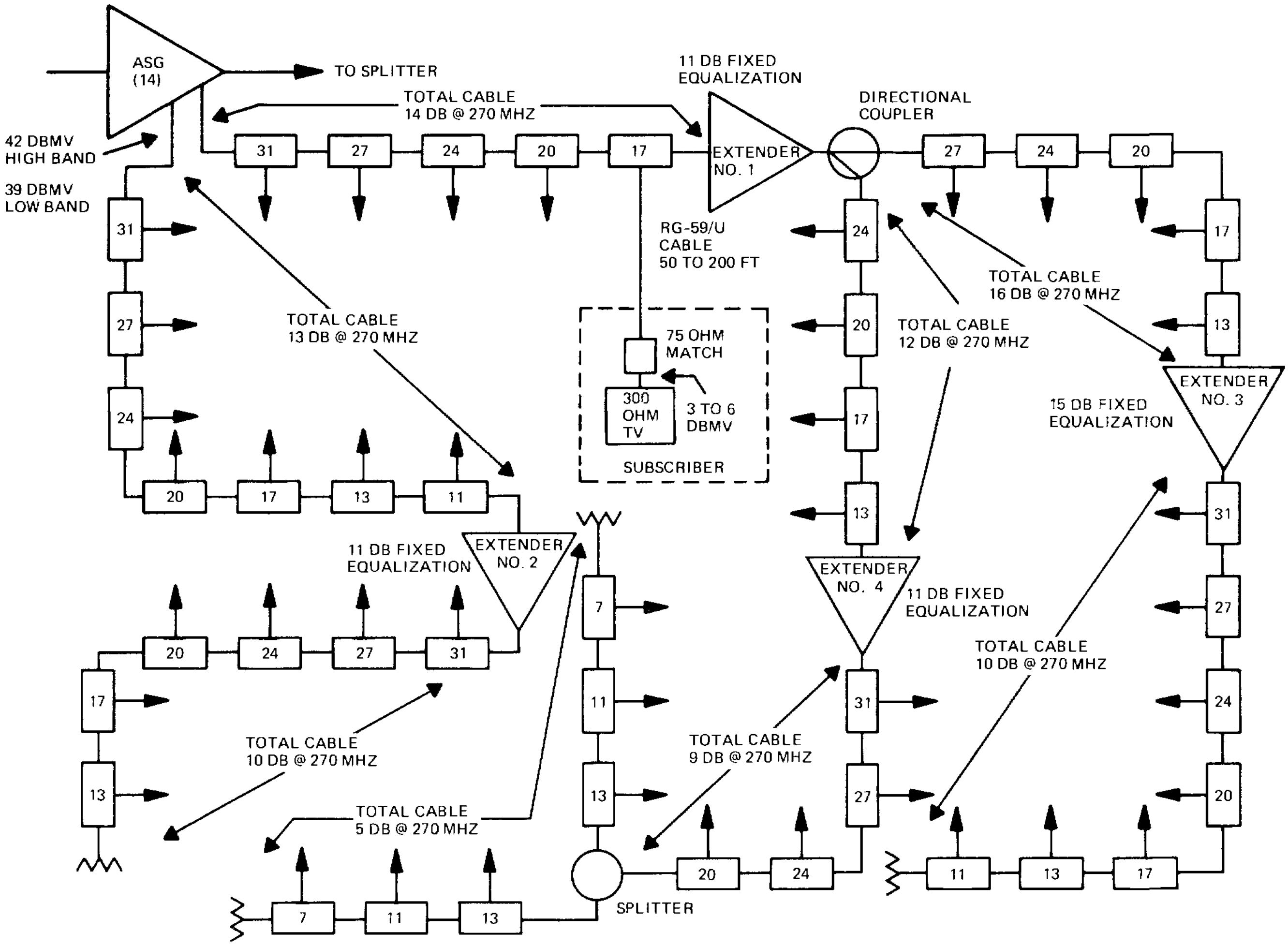


Figure 2. Wilson, NC CATV System (Local Distribution from Trunk Station No. 14)

II. TRUNK STATION DESIGN CONCEPTS

The AEL Mark IV trunk station is the subject of this design evaluation. The station's design features greatly affect the system's performance. To ensure high-quality station performance, the pin diode slope circuit and its control circuitry must precisely track cable slope while maintaining an excellent match to surrounding circuits.

Several aspects of the Mark IV stations design are considered; namely, the rf signal paths, base plate, passive devices, rf modules, power supply, protection circuits, and packaging principles.

The rf signal flow paths are presented in figure 3, "Mark IV Functional Block Diagram," and are self-explanatory: they represent a two-way station with signals from the Trunk Input to the Trunk Output port and also to the feeder cables (54 to 300 MHz); the return path (5 to 32 MHz) is from the Trunk Output port to the Trunk Input port; also from the Feeder Cables to the Trunk Input port. The station may have either Manual or ASG control of gain and slope.

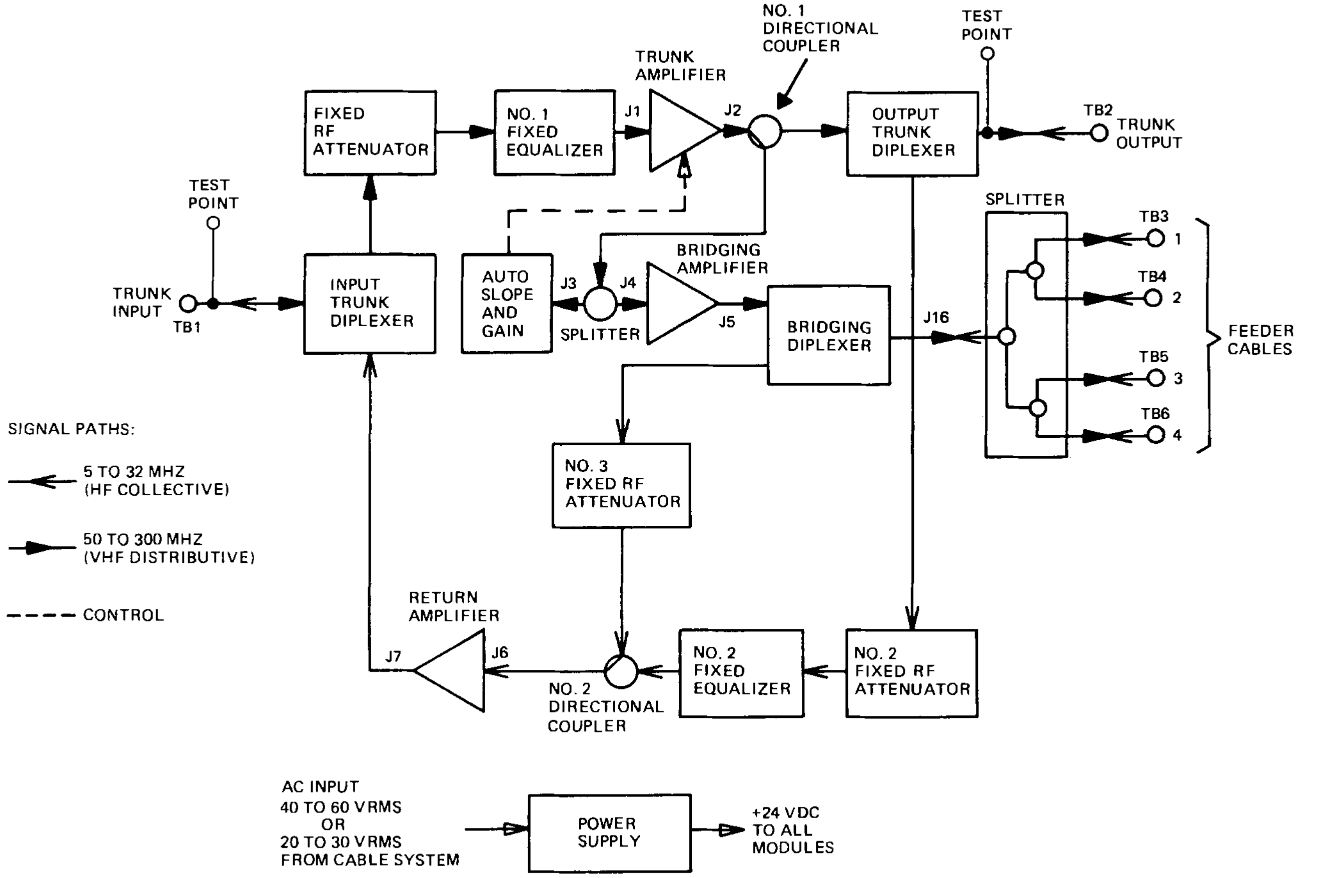


Figure 3. Mark IV Station Block Schematic

In the Wilson, NC, system, the return path of 5 to 32 MHz capability is not used at the present time, but it is an integral part of the installed and tested equipment. Plug-in untuned modules will complete the upstream path with only level setting required.

In addition to wide design margins for electrical parameters, all station modules must be considered in terms of mechanical design criteria. Factors to be considered, in addition to the temperature rise contribution of each module are: ease of handling, ease of adjustment, plus ease and economy of repair.

The temperature rise contribution of each module is minimized by substantial heat sinking of components within the module and by careful attention to the design of the mechanical interface of the module with the station housing. Good mechanical interfaces ensure that heat generated by each module will be rapidly conducted to the station housing and then to the surrounding air. Low temperature gradients within the housing preclude the detrimental effects of local hot spots on electronic components.

The Mark IV station contains the base plate, power supply, and all signal modules within a cast aluminum housing designed to provide a low packaging density environment. This environment ensures that temperature changes within the housing are relatively moderate and provide good electrical stability and freedom from failures related to thermal effects. The hottest area temperature within the housing (heat sinks) is 84°C maximum at 60°C still air ambient test.

All station modules are considered in terms of mechanical design criteria; temperature rise within modules is minimized by adequate heat sinking within the module and from the module to the housing areas from which heat conduction to the surrounding air is good.

The base plate contains all passive devices such as: diplexers for two-way operation, directional couplers, splitters, plug-in fixed attenuators, plug-in fixed equalizers, fusing, surge protection devices, and ports for plug-in modules.

Overall rf signal flow has been carefully planned to guarantee logical signal flow resulting in ease of field installation, structural isolation of the high level bridger output from the trunk input, and structural isolation of all upstream-from-downstream signals.

Feeder maker modules are of such a design that they effectively do nothing to the signal other than split it, which is, in fact, their sole function.

The reliability and efficiency of the station's power supply deserves extensive treatment. The station is not only dependent on the power supply's performance, but also on its location in the cascade; the inability of the power supply to function properly can result in a catastrophic system failure.

The power supply is an area of major concern for the station designer as it contains most of the heavy current circuit elements and, therefore, is the major site of heat generation and the major contributor for circuit element failures related to thermal effects.

Good efficiency combined with low packaging density and adequate heat sinking to the housing surfaces ensure markedly reduced failure probability of all elements comprising the station.

This approach to power supply design suggests the selection of conventional series regulators rather than switching-type regulators. Switching-type regulators provide good efficiency with low dissipation (necessary for high-density packaging designs) for a wide range of ac input voltages in the system. The switching-type regulators, however, are more subject to damage than the series-type when subjected to the transients frequently encountered in operational systems. Transient safeguards for switching-type regulators are very often designed to handle the worst case of a given geographical or local area of installation. The transients that must be considered (for any type of the voltage regulator) include power line turn-on or turn-off induced surges, induction due to adjacent power lines with abrupt load changes, and lightning strikes. The quality of the station's grounding system, both within the housing and at the local site (earth ground return) can not be overstressed. All module grounds must converge into a common station ground. According to regulations, all ground returns from the cable and wire systems on a utility pole (telephone, CATV, power lines of low and high voltage) must have common conductor to ground (earth); this conductor presents a major problem when its impedance is high. Also, the ground impedance from the return conductor to earth may contribute to the common high impedance path; soil type, presence of moisture and the return conductor surface area in soil determine quality of the earth ground. For good reliability, all local grounds should utilize heavy conductors and provide adequate and reliable contact with a good earth ground. The transients mentioned above may also damage any module in the station as well as the power supply.

In most power supply designs, the series-path power transistors and associated components are the first circuit elements to be damaged by heavy transients. The series-path transistors of a switching-type regulator are, however, more susceptible to transient damage. Since switching operation occurs at about 20kHz and the transients apt to cause transistor damage are of millisecond (or less) duration, heavy transients imposed on switching-type regulators during the off period (when input impedance is high) are likely to damage the device. Improvements in the area of transient protection for transistors operating in this manner will be necessary before switching regulators can operate with the same immunity to transients as series pass regulators.

The trapezoidal waveform ac input voltage, of either 40 or 60 Vrms or 20 to 30 Vrms, is taken directly from the cable system. System dc voltage is isolated in the station by an input transformer which has multiple primary winding taps. One of the taps is selected during installation to match the individual station's ac voltage. The six taps provided on the transformer provide an effective and inexpensive way to maintain high efficiency (70 percent). The voltage drop in the series-path transistor of the regulator is kept to a minimum, and the temperature rise within the housing is minimized, assuring higher reliability and stable performance of all modules within the housing.

Standard features of this supply include input and output overvoltage protection as well as short circuit protection. When the power supply senses an overvoltage condition, a crowbar circuit fires thus opening a fuse and thereby protecting the station from damage due to prolonged overvoltages. The short circuit protection is of such a nature as to protect the power supply from damage. Resumption of normal power supply operation occurs after the short has been removed.

Both the chokes and the copper paths of the trunk power passing circuit are capable of carrying the full current output capability of the 60-volt square-wave power supply.

To be able to establish which tap to use at a given cascade station, a conveniently located dc test point is provided in the station's power supply. This test point will show the dc voltage in the voltage regulator before regulation. This voltage value is primarily a function of the ac rms value of the trapezoidal voltage applied to the isolation transformer's primary. A regular dc voltmeter can be used to select the tap for lowest heat dissipation in the series path transistor. The rms value of trapezoidal voltages measured in the field is speculative at best.

Ac power programming flexibility is achieved by the incorporation of an additional fuse circuit; this fuse allows independent powering of the trunk from the distribution ports, or it permits the trunk and distribution lines to be tied together for powering purposes.

Protection from the surge voltages is achieved by using ruggedized, fast-firing surge protectors at each port of the station.

With a primary design objective for the trunk station being the minimization of performance degradation for the broadband, extremely flat, low distortion hybrids, it is necessary that all circuitry in the station be flat, have good return loss, and minimize loss and distortion. As seen earlier in this paper, not only is the design of the circuit important but also the circuit's location is important in determining the station's performance. Maintaining at least an 18 dB return loss not only ensures a minimum deterioration in flatness of the hybrids but also limits the number of controls necessary to optimize that flatness. As a result of all these considerations, the number of "pooch" adjustments in the trunk and bridger modules has been held to two. These two controls take corrective action at the extreme ends of the bandpass only, not in the middle of the band.

Some of the station's features which affect the flexibility of the system and its quality are worth restating:

(a) Fixed plug-in cable equalization is of a split type: one plug-in equalizer is at trunk amplifier input, and the second plug-in equalizer is in the interstage area.

(b) The same approach is taken for the fixed plug-in attenuators. These approaches allow the optimization of carrier-to-noise ratio and low distortion for a great variety of cable spans; it accommodates a variety of block tilt and slope combinations required in different system designs.

(c) The diplexer design approach results in an exceptionally flat frequency response and match, low insertion loss, and a cross-over point attenuation and selectivity which eliminate interaction between the forward (trunk) and return paths. The group delay is kept at very low values.

(d) The directional couplers, splitters and rf cabling are of reliable high quality type (low losses, good match and flat overall frequency response).

(e) Match at all ports is extremely flat over the frequency band of interest with monotonic rising characteristics at the band edges. This is achieved by careful rf layout and trimming techniques.

(f) Low density distribution of the rf circuits and passive devices ensures good isolation between the housing ports.

(g) Rf and/or ac test point areas are easily accessible.

(h) The housing construction is solid and of high quality. The temperature rise within the housing is rather small when compared with high density packaging concepts.

To eliminate infant mortality and ensure quality performance, all tested modules are subjected to a burn-in process for at least 48 hours. The station with installed modules is retested for all main specification parameters as a final check.

III. TEST RESULTS

The Wilson system represents 116 miles of operational one-way cable television transmission. The system is capable of operating from 54 to 300 MHz, and from 5 to 32 MHz; the actual operating range is from 54 to 270 MHz.

Test results for the longest cascade (phase III, 19 stations) are as follows:

(a) Transmission Response: see figure 4.

(b) Signal-to-Noise Ratio (system specification, 44 dB):

Ch 2, 47 dB
Ch 7, 47 dB
Ch 13, 46 dB.

(c) Cross Modulation Distortion (system specification, -58 dB):

Ch 2, -62 dB
Ch 13, -60 dB.

(d) Second Order Distortion: -68 dB.

(e) Hum Modulation: less than 1 percent.

(f) Composite Intermodulation Distortion: -60 dB (worse case).

(g) Mark IV Trunk Station Performance Curves: see figures 5 through 14.

(h) Mark IV Trunk Station Group Delay Curves: see figures 15 through 19. These tests were made using the GR 1710 RF Analyzer.

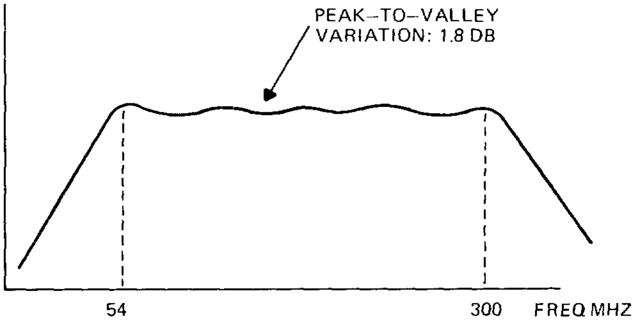


Figure 4. Phase III Simulated Trunk Transmission Response (19 Stations Cascade)

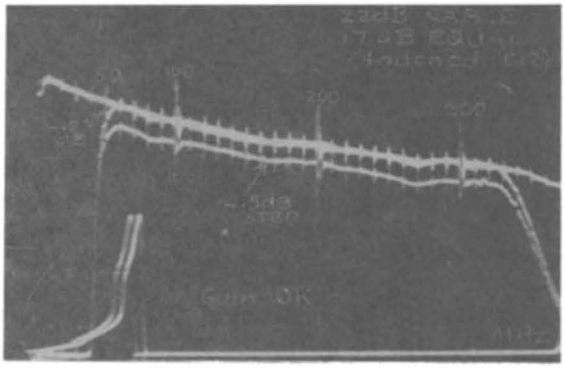


Figure 5. Mark IV Station Frequency Response - Forward Trunk with 22 dB of Cable and 17 dB Plug-in Equalization

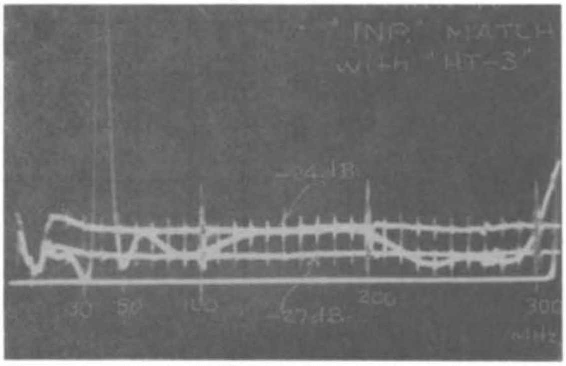


Figure 6. Mark IV Station Return Loss Response at Housing Trunk Input Port

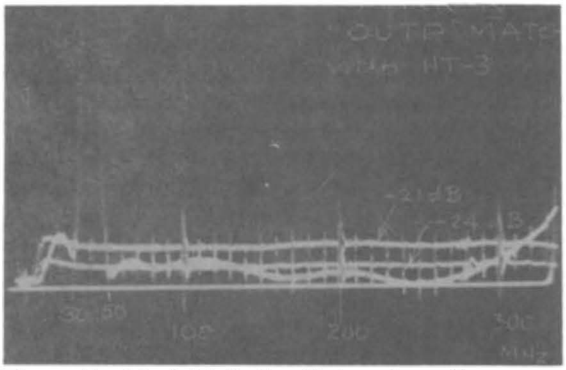


Figure 7. Mark IV Station Return Loss Response at Housing Trunk Output Port

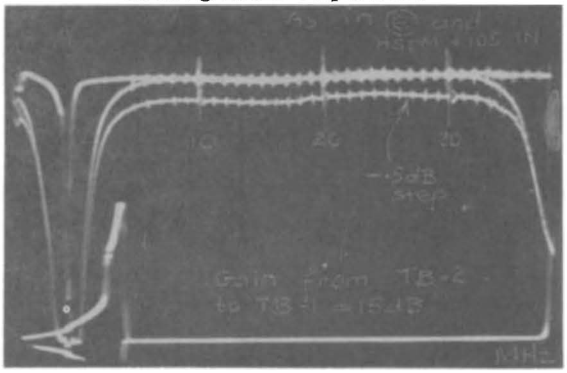


Figure 8. Mark IV Station Sub-band Frequency Response from Housing Output Port to Input Port

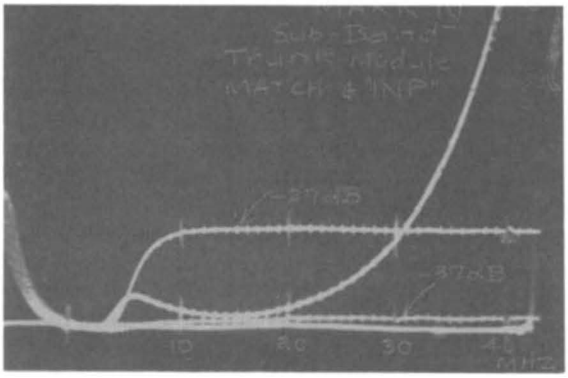


Figure 9. Mark IV Station Return Loss Response at Housing Input Port for Sub-band Frequency Range

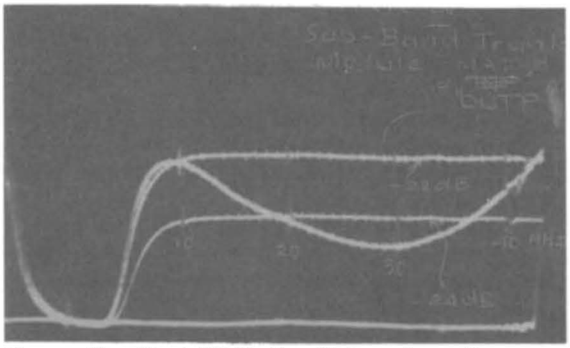


Figure 10. Mark IV Station Return Loss Response at Housing Output Port for Sub-band Frequency Range

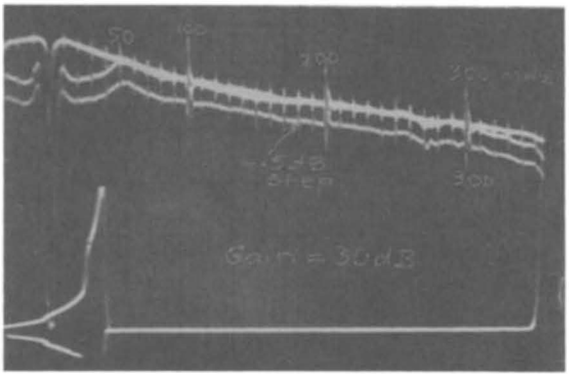


Figure 11. Bridger Amplifier Frequency Response (HB-3)

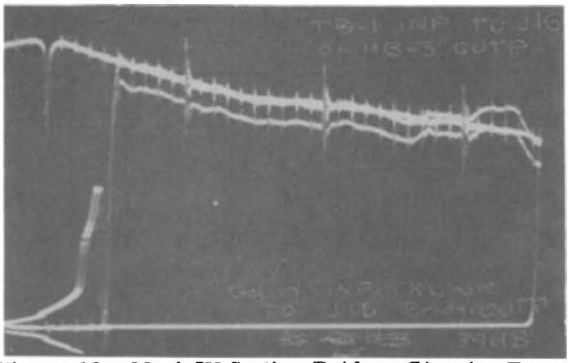


Figure 12. Mark IV Station Bridger Circuits Frequency Response from Housing Input Port to J16 Bridger Output

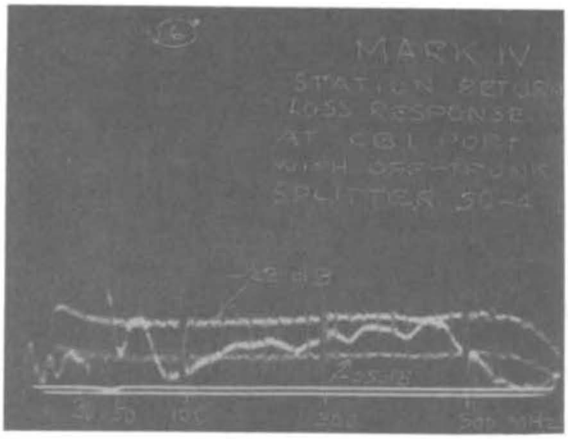


Figure 13. Mark IV Station Return Loss Response at Housing Port CB-1 with SO-4 Off-trunk Splitter

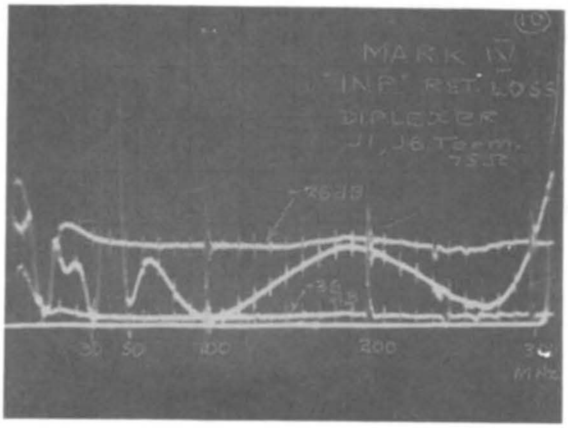


Figure 14. Mark IV Station Input Port Diplexer Return Loss Response with J1 and J6 Terminated

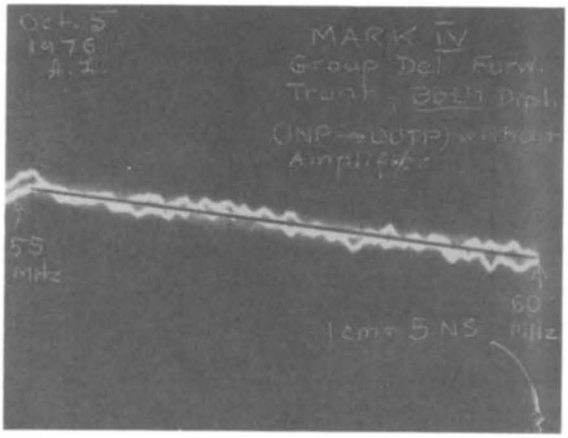


Figure 15. Group Delay from Input to Output (Both Diplexers Combined) from 55 to 60 MHz, 1 cm = 5 ns

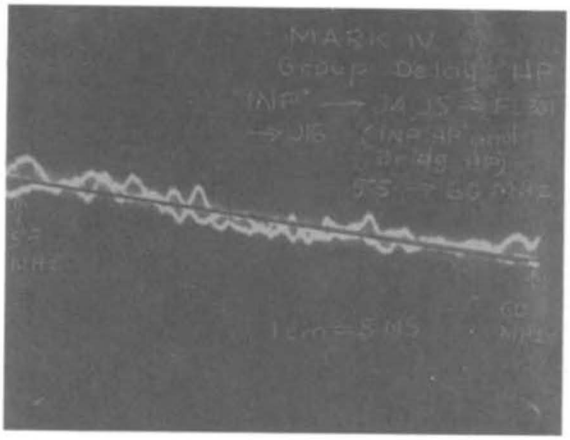


Figure 16. Group Delay from Input to J4, J5 to FL301 J16 (HP Input and HP Bridger Combined) from 55 to 60 MHz, 1 cm = 5 ns

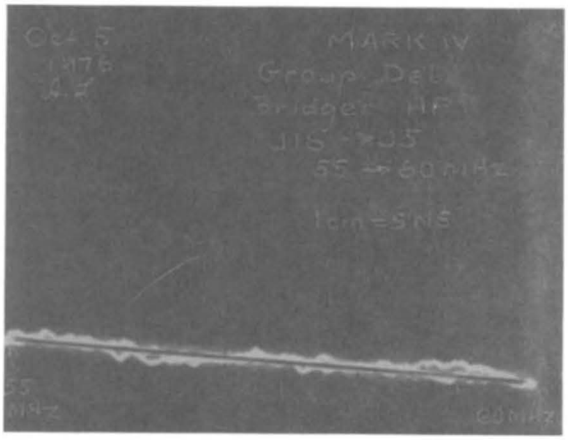


Figure 17. Group Delay for Bridger HP Section (J16 to J5) from 55 to 60 MHz, 1 cm = 5 ns

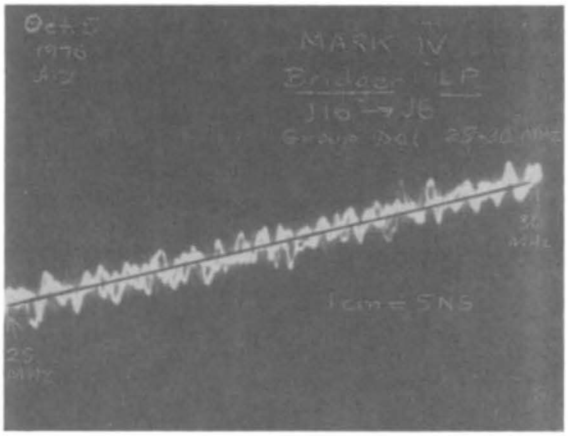


Figure 18. Group Delay for Bridger LP Section (J16 to J6) from 25 to 30 MHz, 1 cm = 5 ns

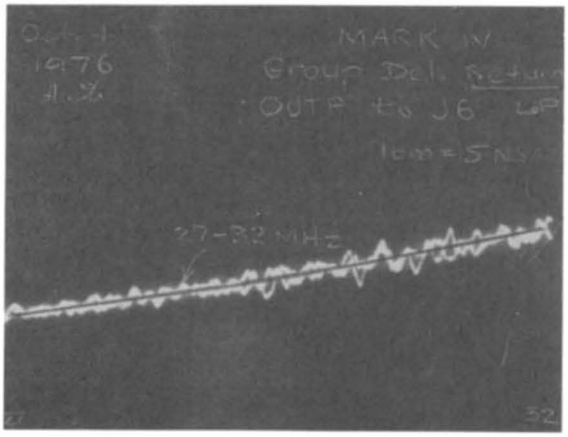


Figure 19. Group Delay for Output Diplexer LP Section (Output to J6) from 27 to 32 MHz, 1 cm = 5 ns

CONCLUSIONS

Reliable design for field installation and test involves a properly designed cable system and reliable equipment which is easy to install and to service.

The CATV system and equipment designs covered in this paper give a basic understanding of "how" and "why" such a system functions.

The Wilson, North Carolina CATV system design aspects were discussed. By using an approach which avoids marginal designs, one can produce a high quality reliable system.

It is important, also, that the equipment design criteria require an absolute minimum of external adjustable controls. This eliminates costly errors and wasted rework time, especially during initial installation and test of the system. With modules having many accessible controls, it is easy to obtain an incorrect combination of the control settings with subsequent deterioration in performance.

The minimization of service and test adjustments also permits the use of persons with limited technical training, thus shortening maintenance efforts and reducing costs.

REFERENCES AND ACKNOWLEDGEMENTS

References

Simons, Ken, "Technical Handbook for CATV Systems," Jerrold Electronics Corporation, Third Edition.

Acknowledgements

The author wishes to acknowledge the contributions to this paper of the following individuals:

1. E. L. Baker of AEL Inc., who performed, during 1976, a major part of the tests and alignments on the Wilson, NC CATV system and supplied data invaluable for the preparation of this paper.

2. A. L. Cavalieri and G. M. Diefes of AEL, Inc. whose valuable advice and encouragement are greatly appreciated.

APPENDIX

CATV CASCADED TRUNK LINE AMPLIFIER SYSTEMS CONCEPTS

For the purpose of this document we will assume that all cascaded amplifiers are identical, have similar performance characteristics, and are separated by identical cable lengths each of which has a loss equal to an amplifier gain. From this, two basic quantities may be obtained: noise and distortion; these characteristics determine the quality of the resultant TV picture and the final length of the system.

a. NOISE RELATIONSHIPS

The noise output of a single amplifier with a terminated input is

$$N_1 = -59 + G_1 + F_1 \text{ (dBmV)} \quad (1)$$

where,

G_1 = operating gain of amplifier in dB

F_1 = noise figure of amplifier corresponding to G_1 gain (in dB).

The lowest allowable signal output is:

$$S_{min(1)} = N_1 + R_{min} = -59 + G_1 + F_1 + R_{min} \text{ (dBmV)} \quad (2)$$

where,

R_{min} = lowest acceptable signal-to-noise ratio (S/N) in dB. See Table 1.

Table 1. Acceptable Signal-to-Noise Ratio (S/N) Levels

TASO Picture Rating	S/N
1. Excellent (no perceptible snow)	45 dB
2. Fine (snow just perceptible)	35 dB
3. Passable (snow definitely perceptible but not objectionable)	29 dB
4. Marginal (snow somewhat objectionable)	25 dB

The system noise figure is determined as:

$$F_m = F_1 + C \text{ (dB)} \quad (3)$$

where,

$C = 10 \log m$ (cascade factor)

m = number of amplifiers in cascade.

The noise output of the last amplifier is:

$$N_m = N_1 + C \quad (4)$$
$$= -59 + G_1 + F_1 + C \text{ (dBmV)}.$$

Therefore, the lowest allowable signal output from the last amplifier is:

$$S_{min(m)} = N_m + R_{min} \quad (5)$$
$$= -59 + G_1 + F_1 + C + R_{min}$$
$$= S_{min(1)} + C$$
$$= S_{min(1)} + 10 \log m \text{ (dBmV)}.$$

b. CROSS MODULATION RELATIONSHIPS

$$XM_m = XM_1 + 2C \quad (6)$$

where,

XM_m = system cross modulation

XM_1 = cross modulation of one amplifier

$C = 10 \log m$ (as shown in equation 3).

To determine the system maximum output, with system cross modulation expressed as XM_{max}, use the relationship:

$$S_{max(m)} = S_{max(1)} - 10 \log m \quad (7)$$
$$= S_{max(1)} - C$$

where,

m = number of amplifiers in cascade

$S_{max(1)}$ = output in dBmV from one amplifier where cross modulation XM_{max} is on the worst channel with the other channels measured at the operating gain.

The system cross modulation $XM_m = XM_1 + 2C = XM_1 + 20 \log m$

c. SYSTEM NOISE AND CROSS MODULATION EFFECT

To relate noise and cross modulation on system length, the term tolerance (T_S) will be used as the allowable variation in level that does not produce objectionable picture degradation. This is expressed as the difference in dB between the lowest permissible output (determined by noise) and the highest permissible level (determined by cross modulation).

For a single amplifier this is expressed as:

$$T_{(1)} = S_{max(1)} - S_{min(1)} \quad (8)$$
$$= S_{max(1)} + 59 - G_1 - F_1 - R_{min} \text{ (dB)}$$

where,

$S_{max(1)}$ as in (7).

For a cascaded system, the system maximum output is expressed as:

$$S_{max} = S_{max(1)} - C; \quad (9a)$$

system minimum output is expressed as:

$$S_{min} = -59 + G_1 + F_1 + C + R_{min}; \quad (9b)$$

and system tolerance is expressed as:

$$T_S = S_{max(m)} - S_{min\ (m)} \quad (9c)$$
$$= S_{max(1)} + 59 - G_1 - F_1 - R_{min} - 2C$$
$$= T_{(1)} - 2C \text{ (dB)}.$$

d. MAXIMUM NUMBER OF AMPLIFIERS

From equations 8 through 9c we may derive the value of tolerance equal to zero as:

$$T_1 = 2C; \; T_1 - 2C = 0 \quad (10)$$

With the value of T_S equal to zero for the maximum number of cascaded amplifiers, the tolerance of a single amplifier approaches the value 2C. During the state of zero tolerance only one operating level is possible.

e. OPTIMUM SYSTEM OPERATING LEVEL

The optimum system operating level is defined as the operating level that is halfway between the maximum and minimum output (i.e., this is the midpoint between the level at which cross modulation becomes objectionable and the level at which noise becomes intolerable).

From equation 7 we have the formula:

$$S_{max(m)} = S_{max\ (1)} - C$$

where,

$$2C = T_{(1)} \text{ for zero tolerance.}$$

Therefore,

$$S_{max(m)} = S_{max(1)} - \frac{T_{(1)}}{2} \qquad (11)$$

In order to find the optimum operating level for each amplifier in a cascaded chain, subtract one half the single amplifier tolerance from the single amplifier maximum output. At zero tolerance:

$$S_{min(m)} = S_{min(1)} + \frac{T_{(1)}}{2} \qquad (12)$$

f. TRIPLE BEAT DISTORTION, SECOND ORDER DISTORTION

The occurrence of composite triple beat distortion is due to the third order distortion in the active devices of the system. The visible threshold level of the triple beat distortion is 46 dB below the peak carrier with 30 channels. However, AEL amplifier performance specifications far exceed these requirements and perform exceptionally well for this criterion.

The second order distortion levels also are very low (-68 dB or better).

RURAL DISTRIBUTION SYSTEMS:
A NEW TECHNIQUE FOR SMALL SYSTEM TRUNKING

John A. Hastings

C-COR Electronics, Inc.

Abstract

There is a requirement for the cable television industry to provide service to areas outside the basic body of the system. In many cases, small systems are actually comprised of many small systems interconnected by what is commonly called supertrunk, express trunk or simply dead trunk runs. This report will not eliminate these situations but will attempt to describe a new technique for providing high performance, low cost cable service to sparsely populated areas.

Introduction

Two of the limiting factors that have prevented cable operators from providing service to remote (rural) sections of their franchise areas have been economics and performance. In many cases, desired performance to these remote areas could be provided, but the cost of doing so is prohibitive. Microwave links could provide the performance desired if there was a subscriber base to warrant the expense. Supertrunks, consisting of large diameter, low loss cable offer land route alternatives to provide pictures of quality to these areas when using sophisticated high quality amplifiers. Unfortunately, in providing a quality product to these remote areas, performance is sometimes more easy to overcome than the prohibitive costs of installing such system extensions. A means to serve remote extensions without compromising performance and being economically feasible should be of interest to many operators and certainly could be considered a new technique.

Discussion

"Mini-trunk" carries the stigma, in the minds of many operators, of something cheap and inferior. This may be the greatest obstacle to generating interest in a mini-trunk amplifier. In this discussion of mini-trunks and their applications, costs should be thought of as inexpensive or reasonable in price, but the system described here is definitely not cheap or inferior.

When C-COR Electronics, Inc., developed their current line of distribution amplifiers, the latest gold bonded trunk hybrids available were used. These gold bonded trunk hybrids produce the highest output now available. The die (transistor) is the output device which largely determines the output capability of the amplifier. This output capability is the most important single electrical characteristic of an amplifier. While one may manipulate the specifications describing output of an amplifier, the facts are that the die (transistor) determines the output. The gold metallization used in these hybrids gives higher reliability than earlier aluminum bonded types, and these newer hybrids were designed for trunk amplifiers.

C-COR utilized different combinations of these gold bonded trunk hybrids in order to provide a line of amplifiers which have 44 dB and 29 dB gain utilizing two hybrids. This use of two trunk hybrids within these amplifiers allows for a definite application for use as mini-trunk amplifiers. The immediate application for such amplifiers is for sparsely populated areas where a full sized trunk station is not economically justifiable but where high performance is still required. The emphasis is not on reduced performance but rather on reduced amplifier expense.

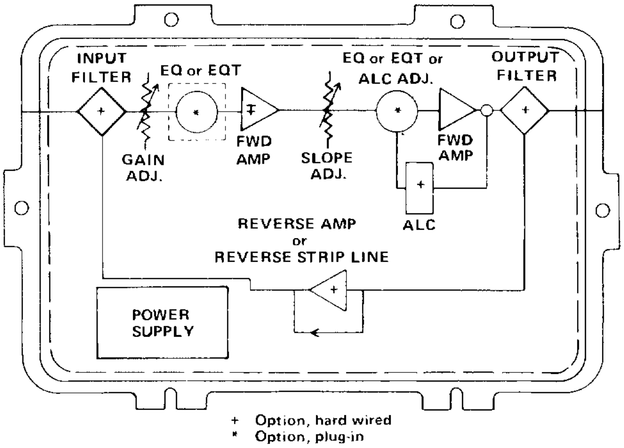
The following provides some typical amplifier list prices for cost comparison of a twenty (20) trunk amplifier cascade.

	List Price
Trunk station w/ALC (22 dB spacing)	$ 885.00
Mini-trunk (D-443) w/thermal level control (22 dB spacing)	339.00
20 amplifier cascade of full sized trunk stations	17,700.00
20 amplifier cascade consisting of 16 mini-trunks and 4 full sized trunk stations	8,964.00

Using list pricing for the amplifier cascade, the utilization of mini-trunks with a full sized trunk station at every fifth (5th) location will result in amplifier costs of approximately 1/2 of the costs resulting from a similar cascade consisting of all full sized trunk stations. Naturally, discounts available and the amount of distribution required along the cascade will result in variations in the total pricing.

Figure 1 illustrates a block diagram of the mini-trunk amplifier. It should be noted that accessibility of the interstage location for equalization and control is a real advantage, especially when coupled with the low noise figure of the amplifiers. The interstage equalizer plug-in position can be used to provide maximum carrier-to-noise ratio when operating with tilted outputs. The use of thermal equalizers, both interstage and at the input of the 28 dB gain mini-trunk, can thermally compensate for 22 dB of cable at the highest frequency. With the 44 dB gain unit, the thermal equalizers at the input and interstage locations will compensate for approximately 34 dB of cable at the highest frequency. The spacing of the mini-trunk is determined by selecting the appropriate equalizers for the desired system bandwidth.

FIGURE 1



Thermal level control for short cascades can be accomplished by seasonal balancing of the amplifier or by interspersing closed loop pilot controlled ALC trunk stations at strategic locations along the cascade. The use of thermal plug-in equalizers within the mini-trunk will compensate for the spacing between amplifiers over the temperature range from 0 to 120° F with better than ± .75 dB flatness from 50 MHz to the highest frequency. If standard closed loop pilot controlled ALC trunk stations are used at, say, every fourth location, an economical trunk cascade with excellent level control can be realized. A typical trunk cascade is illustrated in Figure 2.

FIGURE 2

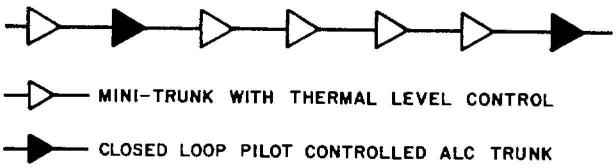


Figure 3 lists the individual specifications for standard type trunk amplifiers. A comparison of the standard type trunk with the mini-trunk shows that the mini-trunk actually has some performance advantages over the standard units, especially with the 22 dB spaced unit. Even with the 34 dB spaced unit, there is substantial improvement over standard units with third order performance.

The 22 dB spaced mini-trunk has system application for extended cascades which have channel loading up to 30 channels. The 34 dB spaced mini-trunk is generally recommended for shorter cascades with 12 to 20 channel loading. The decision on which mini-trunk should be used must ultimately be decided by the individual user as is the case with any amplifier selection process. Bandwidth, channel loading, distance to be traversed and performance desired at the system extremes must be considered. There will be situations in which either of the mini-trunks could be used. Where such a situation exists, many could choose to use the 34 dB spaced unit on the basis that fewer amplifiers increases system reliability. The amplifier selection, however, must be based on realistic requirements, considering both present and anticipated future needs.

Figure 4 lists some typical system performance numbers using cascades of mini-trunk and standard trunk stations. Distribution performance has been included to show system performances. The distribution performance has been calculated on the basis of using the trunk cascade, plus one distribution (Bridger) amplifier and two extenders in cascade. Trunk cascades are included in Figure 4 for comparative performance information. The comparison shows that either standard or mini-trunk stations can be used with negligible differences. By installing closed loop pilot controlled ALC trunk stations at every fourth or fifth trunk station, the resultant trunk run would have excellent level control and excellent performance - plus at a substantial savings over conventional cascades where all full sized trunk stations are not required.

Summary

While the goals for cable systems are fairly rigid in some instances, there is flexibility in the ways to approach those goals. Generally, performance within a system should not be greatly compromised since the object of providing service to remote areas is to gain subscribers and the subscribers will judge for themselves whether cable television is worth paying for. The approaches to getting to the subscriber areas are variable, at least with respect to amplifiers to be utilized and costs involved in purchasing those amplifiers. Every reader of this paper might not agree with the approach discussed here, but we have suggested an approach which is more economical, provides excellent performance and is an option which we believe is worth considering. Other utilization considerations might be to use the mini-trunk within the main body of the system where relatively short secondary trunk runs eminate from the primary trunks. The uses of mini-trunks are as varied as the imaginations of the operators. Perhaps the initial foremost consideration is that it could save cable operators real dollars. In this day, that alone makes the system discussed here well worth considering.

	Mini-Trunk With Interstage EQT	Typical Trunk	Mini-Trunk With Interstage EQT	Typical Trunk	Mini-Trunk With Interstage EQT	Typical Trunk
Full Gain (minimum), dB	25	26	25	26	38	37
Bandpass, MHz	40-220	40-220	40-300	40-300	40-220	50-220
Flatness, ± dB	.3	.2	.3	.2	.3	.25
Output Rating @ -57 dBXM (2) dBmV	+53.5	+50.5	+52.0	+48.5	+53.0	+55.0
Typical Operating Conditions Channels, Number of	21	21	30	30	21	21
Spacing, Operational (1), dB	22 @ 220 MHz	22 @ 220	22 @ 300	22 @ 300	34 @ 220	34 @ 220
Operating Levels (4), dBmV Input	Ch 13/Ch 2 10/15	Ch 13/Ch 2 10/16	Ch W/Ch 2 10/17	Ch W/Ch 2 10/17	Ch 13/Ch 2 6/12	Ch 13/Ch 2 6/12
Output	32/26	32/26	32/26	32/25	40/29	40/29
Distortion Charac. @ Typical Operating Levels (8) Cross Mod, (XM) (5), dB	-100	-94	-97	-90	-83	-87
Second Order (2IM) (6) dB	-88	-86	-88	-86	-72	-84
Third Order (3IM) (7) dB	-114	-111	-117	-114	-98	-90
CW Comp Beat (CB) (8) dB	-99	-95	-93	-92	-82	-77
Noise Figure (3), dB	8	9	8	9	8	8
Factory Alignment Cable Loss, dB	11 @ 220 MHz	11 @ 220	11 @ 300	11 @ 300	18 @ 220	34
Flat Loss, dB	14	12	14	12	20	--
Return Loss, Input and Output, dB	18	16	18	16	18	16
Gain Adjust Range, dB	0-10	0-8	0-10	0-8	0-10	0-8
Slope Adjust Range @ Ch 2, dB (pivot at 200 MHz)	-4.0	-3.5	-4.0	-3.5	-4.0	+4.0

Figure 3. Amplifier Specifications

	CNR at Highest Channel	X-M Linear Tilt	2IM 2 CW Carriers	3IM Triple Beat 3 CW Carriers
22 dB Spacing, 50-220 MHz 21 Channels				
20 Mini-trunk Cascade	+48.0	-74.0	-70.5	-88.0
Distribution	+54.0	-61.0	-69.0	-79.0
System	+47.0	-59.0	-66.5	-76.0
20 Standard Trunk Cascade	+47.0	-68.0	+68.5	-85.0
Distribution	+54.0	-61.0	-69.0	-79.0
System	+46.0	-57.0	-65.5	-75.5
22 dB Spacing, 50-300 MHz 30 Channels				
20 Mini-trunk Cascade	+48.0	-71.0	-70.5	-91.0
Distribution	+54.0	-61.0	-69.0	-79.0
System	+47.0	-58.5	-66.5	-77.0
20 Standard Trunk Cascade	+47.0	-64.0	-68.5	-88.0
Distribution	+54.0	-61.0	-69.0	-79.0
System	+46.0	-56.0	+65.5	-76.5
34 dB Spacing, 50-220 MHz 21 Channels				
10 Mini-trunk Cascade	+47.0	-63.0	-57.5	-78.0
Distribution	+54.0	-61.0	-69.0	-79.0
Systems	+46.0	-59.0	-57.0	-75.0
10 Standard Trunk Cascade	+47.0	-67.0	-69.5	-70.0
Distribution	+54.0	-61.0	-69.0	-79.0
Systems	+46.0	-57.5	-66.0	-67.0

Figure 4. System Performance

SECURITY OF EQUIPMENT AND SERVICES - THE TERMINAL MANUFACTURERS ROLE

Graham S. Stubbs

OAK Industries Inc. - CATV Division
Crystal Lake, Illinois

Theft of equipment and services is of growing concern to CATV system operators, in particular to those using converters and other devices which are installed in the houses of subscribers. Cases of theft of services range from illegal tap connections to attempts to defeat or bypass existing Pay TV security devices. The high rate of loss of terminal equipment appears to be directly related to its inaccessibility once installed in private homes.

To deal with these problems, it is evident that many operators are convinced that terminal equipment must either be installed in such a way as to be difficult to remove illegally, or perhaps, ultimately, installed entirely outside the home.

A simple inexpensive method has been developed for attaching terminal devices to interior walls, requiring the use of a special tool for removal. Ultimately, most of the functional requirements of terminal equipment will be met using an outdoor installation requiring only an inexpensive, replaceable selector to be installed inside the home.

SIGNAL LEAKAGE AND INTERFERENCE WITH OVER-THE-AIR RADIO SERVICES

Robert S. Powers

Cable Television Bureau
Federal Communications Commission

A B S T R A C T

A prime advantage of coaxial cables for telecommunications purposes is that signals carried on such cables will not, in principal, interfere with signals carried over-the-air or on other cables. Thus, the same frequency spectrum may be used many times without the necessity of spectrum coordination. This advantage exists, of course, only to the extent that the space inside cables is in fact electromagnetically separated from free space. To the extent that cable systems do "leak" signals, other measures have to be taken to assure non-interference with over-the-air radio services, particularly those radio services related to safety of life and property.

This paper will address how leaks can occur, what fields can be produced, circumstances under which interference can occur, and how interference can be prevented.

NOTE: Statements in this paper are those of the author alone, and do not necessarily represent the position of the Federal Communications Commission.

A prime advantage of coaxial cables for telecommunications purposes is that signals carried on such cables will not, in principle, interfere with signals carried over-the-air or on other cables. Thus, the same frequency spectrum may be used many times without the necessity of spectrum coordination. This advantage exists, of course, only to the extent that the space inside cables is in fact electromagnetically separated from free space. The extent that cable systems do "leak" signals, other measures have to be taken to assure non-interference with over-the-air radio services, particularly those radio services related to safety of life and property.

It is recognized that there are many factors which should motivate a cable operator to minimize ingress and egress of signals. Among these are loss of signals (particularly pay signals) to non-subscribers, interference to TV and FM radio reception by non-subscribers, ingress of Citizen's Band and other signals or man-made noise which can degrade service to cable subscribers, and physical leakage of water, which can produce additional service calls and perhaps shorten equipment life. But this paper will concentrate on signal leakage as it relates to potential interference with air traffic control radio services. We will examine some possible types of leakage sources, mechanisms by which leakage signals could cause some degree of harmful interference, and some possible techniques for preventing such harmful interference.

History

In February, 1971, the Office of Telecommunications Policy (OTP) addressed a letter to the (Acting) Chief Engineer of the Federal Communications Commission (FCC) expressing concern about possible interference to air traffic control communications during periods of "CATV equipment malfunction." OTP suggested that cable television systems be forbidden to use certain frequency bands. In its Cable Television Report and Order (Ref. 1) the Commission declined to adopt the suggested frequency restrictions, noting that the possibility of interference seemed remote in comparison to other known sources of interference, and recognizing the public benefit to full use of the spectrum within the cable.

The 1972 Cable Television Report and Order (Ref. 1) did adopt restrictions on the allowable signal leakage from cable systems. These restrictions, adopted with some modification from Part 15 of the FCC Rules, are more stringent by some 14 decibels than similar restrictions on radiation from television and FM radio receivers and far more stringent than limits imposed on television broadcast facilities radiating in the air traffic control frequency bands. As we will discuss below, however, the criteria for evaluating interference potential from cable systems may not be the same as those for television and FM receivers or transmitters.

Since 1969, a subcommittee of the Coordinating Committee on Cable Communications Systems, of the Institute of Electrical and Electronics Engineers (IEEE) had been addressing the problems of optimum frequency channelling plans within cable television systems. The Subcommittee recognized that potential interference to over-the-air services could limit the flexibility of frequency channelling plans for cable systems. Thus, a request was forwarded to the Office of Telecommunications, U.S. Department of Commerce (OT), that some specific investigations relating to air traffic control systems should be undertaken. OTP also recognized the need for detailed studies, and made a similar request to the Office of Telecommunications. Studies were undertaken by OT, funded in part by the Federal Aviation Administration (FAA), including the cooperation of personnel of FAA, NCTA, and the IEEE group. Results of these studies were published in 1974 and 1975 as a series of OT Reports (Refs. 2, 3, and 4). These reports give assessments of the susceptibility of certain aircraft navigation receivers to interference from simulated CATV signals, characterize the radiation patterns of a length of aerial cable under several fault conditions, and present results of flight tests which characterize the performance of one type of air navigation receiver under conditions simulating interference from CATV signal leakage.

In April, 1976, interference to an aircraft voice communications system due to CATV signal leakage occurred in Harrisburg, Pennsylvania. The FAA began using the frequency 118.25 MHz for ground/air communications at the Harrisburg airport. This frequency was also being used for pilot carriers by the Harrisburg cable television system. Shortly after initiating use of the frequency for communications, pilots began reporting that an interfering signal was causing communications receivers to "break squelch" (open the quieting circuit of the receiver). Although pilots experienced an undesired audio tone in many locations in the Harrisburg vicinity, the transmitter on the ground was sufficiently powerful to override the interfering signal when the transmitter was on. No significant degradation of actual desired signals seems to have occurred. The interference was investigated by field staffs of the FAA and FCC, with the full cooperation of the cable system operator. It was determined that several factors were involved in the interference.

First of all, the cable system was found to have multiple leakage sources producing fields large compared to those permitted under the FCC's cable television technical standards. A second factor that increased the effectiveness of the interfering signals was that the cable system happened to be using four independent pilot carrier generators in four different portions of the cable system. Although the pilot carrier frequencies were nominally identical, they actually differed by amounts corresponding to audio frequencies. Thus, in addition to opening the squelch on the aircraft receivers the interfering signals beat against each other to produce unpleasant and potentially distracting whistles whenever the ground transmitter was not activated. There was some indication (although no quantitative data were obtained) that at low altitudes the interference effect increased with altitude. This suggested a cumulative effect of large numbers of leaks, radiating signals nearly identical in frequency from an "antenna" consisting of large parts of the cable plant. It would have been necessary to perform extensive testing to adequately characterize both the leakage patterns on the ground and the effects in the air and to fully explain the effects of multiple leaks. This was not done, but it is hoped that future field work can be performed to fully clarify the effects of multiple leaks.

Recognizing its dual responsibilities in promoting the application of communications technologies for the public benefit and at the same time preventing the occurrence of unacceptable harmful interference to radio services, the FCC released in November, 1976, a Notice of Proposed Rule Making, which addressed the broad question of cable interference to air traffic control systems in the context of frequency channelling plans for cable television systems (Ref. 5).

In the remainder of this paper we will address four questions:

- How can leakage occur in cable television systems?
- What magnitudes of electromagnetic fields can be produced from cable leaks?
- Under what circumstances can such leakage fields cause interference to Air Traffic Control (ATC) systems?
- What can be done to prevent such interference?

We shall see that there are indeed circumstances in which harmful interference can occur. We shall also find that there are techniques which look promising for controlling such interference, although not all of the answers are yet known.

How Can Leaks Occur?

We all know that leaks can and do occur at many places within a cable system, from the head end to the subscriber terminal. Let us go through a system from one end to the other end at least crudely assess the likelihood and potential seriousness of various possible leakage sources.

To begin with the receiving antenna, it is clear that local oscillator signals could appear on the antenna, just as they can in the case of an ordinary television receiver. Whether such signals appear or not is determined by the type and arrangement of head end signal processing equipment. Even should they exist, however, these signals are not likely to be a problem. Local oscillator radiation, within the limits established under Part 15 of the FCC Rules, has not been judged a serious enough threat to the Air Traffic Control (ATC) system to warrant further restrictions.

The headend itself is unlikely to produce any leakage signal problem, since equipment is generally adequately shielded and is in a controlled environment. There may now exist some headends which radiate excessively. But the solution is obvious and not expensive.

Trunk and distribution cables, however, can provide an opportunity for signal leakage from outside plant. Trunk and distribution cables are generally of the semi-rigid type, of course, with solid outer conductors. Thus, a nominally non-radiating system is provided. But, as every cable operator can recite, there are numerous causes for leakage in these cables. These include connectors improperly installed or loosened due to thermal expansion and contraction, improperly sealed housings, cracks or splits in the cable itself due to fatigue, partial or complete ruptures due to vandalism or accidents. We note here two significant differences between trunk and distribution cables; (1) trunk cables carry signals at levels typically 10 to 15 decibels lower than those typically carried on distribution cables, and (2) trunk cables have fewer taps, splices, and other connections to provide ingress/egress opportunities. Connectors are of special interest here. Many cable operators are already quite familiar with the fact that older types of cable connectors tended to leak signals after a time, particularly after being tightened a few times. The connectors simply deformed the aluminum sheath of the cable until the sheath no longer offered a firm grip for the connector. Some modern connectors are much more resistant to signal leakage, for reasons to be discussed briefly later. Here we will only note that in a recent test FCC's Field Operations Bureau was unable to locate any leaks in a 100 kilometer section of the trunk and distribution lines of a recently constructed cable system.

Subscriber drops can provide significant leakage signals, even though the signal levels are lower in drop cables than in distribution lines. The drop cables themselves are generally braided, double braided, or covered with foil and braid rather than solid outer conductors. Older types of taps -- pressure taps -- have a history of signal leakage. Finally, the subscriber himself, or his reception equipment, can often find ways to radiate cable signals into free space. It is instructive to note that the same cable system which our Field Operations Bureau found to be non-radiating in the trunk and distribution cables provided nine sources of radiation (beyond the present FCC standards) in subscriber drops.

Preliminary investigation of the causes indicated the following:

1. Six loose "F" connectors on customer drops.
2. One defective 75/300 ohm balun.
3. One radiating customer TV.
4. One customer had connected 300 ohm twin lead to CATV drop.
5. One high level amplifier in apartment house complex.
6. One set of rabbit ears connected to CATV drop.
7. One unknown cause inside house (subscriber not at home).

These add to more than nine because there was frequently more than one cause associated with a given leakage field. Field Operations Bureau measurements indicated some leakage fields in the range 50 to 350 microvolts per meter 10 feet from the cable, whereas the maximum field presently allowable under FCC Rules is 20 microvolts per meter, 10 feet from the cable. These fields were generated in subscriber locations, even though the signal levels in subscriber drops are typically 25 to 50 db lower than the maximum levels occurring in the cable distribution system (+40 to +50 dBmV in the distribution cables, 0 to +15 dBmV in the subscriber drop cables).

In concluding this section, it seems fair to say that with modern equipment, connectors, construction practices, and monitoring techniques it may well be practical for a conscientious cable operator to build trunk and distribution systems that are essentially leak-free, although the dynamics of appearance, detection, and elimination of leaks has yet to be established. It may also be possible to build and maintain those portions of the subscriber drop which are under the operator's control in a leak-free condition, although that has yet to be demonstrated in general practice. Probably the most worrisome points, in a modern system, are those under the subscriber's control -- the TV set, the receiving antenna which can become a transmitting antenna, and the twin-lead or other non-shielded cable which the subscriber may improperly connect to the cable in some fashion.

What magnitude of electromagnetic fields can be produced from cable leaks?

In the previous section we have cited evidence of fields of around 350 microvolts per meter from improperly installed subscriber drops and from improper subscriber actions or equipment. The Harrisburg case reviewed earlier in this paper has provided ample evidence of the ability of cable systems having multiple leakage sources to produce signals high enough to be detected by airborne voice communications receivers. Although no quantitative field measurements were made over Harrisburg, interference was experienced up to altitudes of at least two thousand meters. There are no firm estimates of the number and magnitude of leakage sources in the Harrisburg Cable system. However, the general experience of our Field Operations Bureau personnel in checking older systems for leakage, combined with the facts that the Harrisburg system serves about 35,000 subscribers with about 600 miles of aerial plant and about 95% of the subscriber taps being pressure taps, is roughly consistent with the observed interference.

More quantitative estimates of possible leakage fields are given by Harr and Juroshek (Ref. 3) and by Chwedchuk, Poirier, and Walker in a report from the Canadian Department of Communications (Ref. 6). Further details of the Canadian work are given in a report from the Department of Communications, Telecommunications Engineering Laboratory (Ref. 7).

Harr and Juroshek (Ref. 3) report results of measurement on five possible types of cable leaks. The five types of leaks and the maximum gain (compared to isotropic) observed for each are shown in Table 1.

In the cable section of Type 4, a part of the outer conductor over a two foot section was removed, leaving the center conductor intact but exposed. It was found that in all cases the damaged cable section served as a more or less effective feed point for the outer conductor and the messenger cable, which together constituted an unterminated long wire antenna. The radiation patterm observed show fairly narrow main lobes with 3 dB beamwidths about 10 degrees wide. The direction of the main lobes were generally at an elevation angle of 4.8 to 8 degrees, and at an azimuth of 0 to +12 degrees off of the cable center line. For the tests, the damaged cable sections were installed at the center of a 0.5 in cable suspended 16 ft. above the ground. There were four spans of cable, each 200 ft. in length.

The principal conclusion is that although the 3 dB width of the main beam is narrow (about 10 degrees) it is possible for some types of cable breaks (types 1 and 2) to radiate signals somewhat larger in the main beam direction than would be expected from a matched isotropic antenna. In practice, of course, we should recognize that breaks of Type 1 would be extremely rare in cable systems. Chwedchuk et al (Ref. 6) report that practical laboratory tensile breaks result in a maximum of 3 inches of exposed center conductor. Breaks of Type 2 are quite possible, however. We should also note that if breaks of Types 1, 2, or 3 appeared in trunk or distribution lines, the cable operator would expect to have subscriber complaints within a few minutes. The cable break would cause service to be cut off to downstream subscribers, either because the cable is completely severed or because the direct current circuit would be broken and downstream power supplies would cease to operate.

A closely related type of cable break is the so-called "wedding ring" crack. In this case the shield is broken circumferentially, but electrical connection is still complete at part of the circumference of the cable. Wait and Hill (Ref. 8) suggest that such a crack would be a somewhat less effective feed point than the circumferential slot studied by Harr and Juroshek. With such a cable break, subscriber complaints might not occur, since both RF and direct current connections would still exist.

The Canadian work (Refs. 6 and 7) examined ten types of cable breaks ranging from flush cut open circuits and short circuits (no effective radiation) to yagi and dipole antennas connected directly to house drops. Fields were measured near the ground along the cable, and in the air at 1,000 ft elevations using a dipole suspended from a helicopter.

In the tests with the yagi and the dipole connected to house drops, the signal level at the drop was maintained at 16 dBmV, which is higher by 5 to 10 dB than is usually provided to subscribers in this country, although a higher level may occasionally occur. In the yagi and dipole subscriber drop tests, fields of around 18 dB relative to a microvolt per meter were observed at the 1,000 ft altitudes.

Other Canadian tests involved various lengths of exposed center conductors (like Harr and Juroshek's Type 1 and Type 3 breaks) and a ring incision in the shield, similar to Harr and

Table 1

Types of Cable Leaks

	Test Cable	Max Power Gain (dBi)
(1)	3 ft. (0.91 m) exposed center conductor	+5.0
(2)	3/8 in. (0.95 cm) circumferential slot	+3.0
(3)	3 in. (7.6 cm) exposed center conductor	-6.0
(4)	2 ft. (0.61 m) scrape in outer conductor	-15.0
(5)	1/4 in. (0.64 cm) random holes in outer conductor	-42.5

Juroshek's Type 2 break. These tests were done on distribution cable in an operating cable system with power levels of about 26 dBmV. The maximum levels generally occurring in U.S. cable systems are around 50 dBmV. If the Canadian results are corrected to correspond to a power level of 50 dBmV in the cable, they show field strengths of around 50 dBuV/m (dB relative to one microvolt per meter) at the 1,000 ft elevation.

Reference 6 also indicates that radiation from TV sets connected to rooftop antennas can reach levels of around 12 dBuV/m at the 1,000 ft elevation. Chwedchuk et al conclude that if allowance is made for the usual 6 dBmV level at house drops rather than the 16 dBmV level used in their tests, interference to aircraft receivers from a TV local oscillator can be about the same level as that due to a single cable house drop connected to a roof-top antenna. It has been pointed out, however, that there is a practical difference between the two cases. TV set radiation is somewhat random in frequency, and depends upon the channel to which the set is tuned. In the case of cable, however, radiation may occur from multiple leaks, and is present constantly at whatever frequencies the cable system is using. Furthermore, all leakage sources fed from the same headend will be on the same frequency. The practical significance of this difference depends upon how many subscribers' antennas might be improperly connected to the cable at any one time, and their location relative to each other and the aircraft.

Under what circumstances can such leakage fields cause interference to Air Traffic Control (ATC) systems?

This question must be addressed in two parts. The mechanisms for interference to Instrument Landing Systems (ILS) and VHF Omni-Range (VOR) systems are similar, but the nature of interference to voice communication systems is somewhat different. Both U.S. and Canadian studies conclude that ILS and VOR systems are most susceptible to interference only in a very narrow frequency range. But voice communications receivers are susceptible to interference over a wider bandwidth.

Our primary concern is the power radiated at the visual carrier frequency. Aural carriers are carried 13 to 17 dB lower, the color subcarrier is 30 dB down, the closest (and highest) 15 kHz sync pulse peak is 20 dB down, and the 60 Hz sync pulse peaks are 35 dB down (Ref. 2). These ratios change somewhat if average power rather than peak power at the visual carrier frequency is considered. But the susceptibility analysis can be done on the basis of a CW signal at the peak level.

Both VOR and ILS systems are most susceptible to interference at certain precise sideband frequencies. In the case of VOR these frequencies are 30 Hz and 9,960 Hz removed from the VOR carrier frequency. It has been suggested that VOR systems are also sensitive to interference at a frequency 19,920 Hz (twice 9,960) from the carrier as well, but quantitative data are not yet available. ILS systems are most susceptible to interference 90 Hz and 150 Hz removed from the carrier frequency. This is true both for the localizer systems operating in the band 108-112 MHz and the glide slope systems operating at 328.6 - 335.4 MHz. The OT study (Ref. 2) found that the carrier of the interfering TV signal and the VOR/ILS sideband frequency must be zero beat with each other to a precision of 2 or 3 Hz in order for maximum interference effect to occur Since neither the ATC systems nor cable television systems exhibit that order of stability, special stabilization techniques were necessary in order to observe and quantify the interference produced. The susceptibility results reported in Reference 2 are summarized here in Table 2. The ILS and VOR receivers under test exhibited unacceptable degradation in performance when both the frequency and the desired-to-undesired signal ratio criteria were met. A television test signal was used to produce

Table 2

Conditions for degraded ILS/VOR performance

System	Frequency difference (Hz) between system carrier and visual carrier of TV test signal (± 3 Hz)	Desired to undesired signal ratio (S/S') (dB)
ILS Localizer	0	4
	90	49
	150	24
ILS Glide Slope	0	21
	90	16
	150	21
VOR	0	9
	30	34
	9960	9

the interference. Power was measured with an average-reading power meter.

The critical signal-to-interference ratios given in Table 2 are not sufficient to describe the degree of threat posed to operating ATC systems from operating cable systems. One needs to know the radiation patterns possible from leaking cables. The propagation path losses from the cable break to the aircraft and from the ATC transmitter to the aircraft must also be known in order to estimate desired-to-undesired signal ratios at the aircraft. Finally, we should know something about the expected number and geographical distribution of cable breaks in order to estimate any cumulative effects due to multiple breaks. Harr et al (Ref. 2) proceed to estimate, for a single break, the distance from the ATC transmitter at which cable leakage could cause unacceptable ATC system degradation, as a function of distance from the cable break. These estimates were based on assumed worst case cable leakage, including the assumption that the frequencies were superposed in the worst case fashion to a precision of 2 or 3 Hz.

In the later pair of reports already mentioned (Refs. 3, 4) Harr and Juroshek characterized a selected set of cable breaks and calculated the critical break-to-aircraft and VOR-to-aircraft distances the basis of actual flight tests. For the flight tests a ring-type cable break (Type 2, as described previously in this paper) was used to represent the broken cable. Figure 12 of Reference 4, reproduced here, shows the summary of their flight testing.

The OT reports did not address the susceptibility of ILS and VOR receivers to undesired signals at frequencies other than the most critical frequencies. The Canadian work, however (Ref. 6), indicates that for modulated interfering signals, VOR receivers may be about 29 dB less susceptible to "worst case" undesired signals other than those zero beat with the critical frequencies. At a frequency 20 kHz removed from the VOR carrier, the VOR receiver is indicated to be about 35 dB less susceptible than at 30 Hz from the VOR carrier. Worst case interference to ILS receivers occurs with unmodulated interfering signals. In that case, ILS receivers are indicated to be about 40 dB less sensitive to interference at non-critical frequencies than to interference at 90 or 150 Hz.

The interference susceptibility of communications receivers, designed to receive amplitude modulated voice transmission, is not such a sharp function of frequency, although Chwedchuk et al (Ref. 6) show that interference susceptibility may be down by about 30 dB at a frequency 25 kHz removed from the desired frequency, at least for the particular receiver they examined. One practical criterion by which to judge the degree of interference of unwanted cable TV signals is whether or not the cable signals are sufficiently strong to open the squelch on the aircraft receiver. The interference caused by the cable system at Harrisburg was of this sort. Radiating pilot generator signals opened the receiver squelch and caused whistles because of audio beats with other unwanted pilot carrier signals. Although communication with the ground control tower was not interrupted due to this interference, the unwanted cockpit noises could be a distraction to the pilot in some circumstances, and must be avoided.

Assume an aircraft 1,000 ft directly over a cable leak, with a receiving antenna of unity gain, a receiver input impedance of 50 ohms, and a squelch set for 5 microvolts. Assume a peak power level in the cable of 50 dBmV, which, for average picture conditions we may take as an average power level of about 45 dBmV (Ref. 2). Also assume that the cable leak is well matched to an isotropic antenna. Under these conditions the receiver would experience an average input potential of over 100 microvolts due to the cable leak. Obviously, such leaks would cause unacceptable interference.

Based on experience of FCC's Field Operations Bureau, as well as the result of some Canadian surveys of cable systems (Ref. 6), this author would suggest that it may be possible to reduce the probability of large leaks in the high-level portions of a well maintained cable plant of modern construction to very nearly zero. But this possibility has yet to be convincingly demonstrated with significant plant mileage over a significant time period. Many older systems do have large numbers of major leaks, although perhaps not radiating at such high levels as in this "worst case" example. Less well controlled are potential leakage sources in subscriber drops, particularly where the subscriber himself may connect twin-lead or even a roof-top antenna to the drop cable. However, the level of a single leak of this type will generally be much lower than the maximum possible leak in the high level distribution lines. The signal level in subscriber drops is generally at least 40 dB lower than the 50 dBmV level used in the above estimate.

The Canadian Department of Communications (Refs. 6, 7) examined the potential magnitude of radiation from subscriber drops by feeding a matched dipole and matched yagi antenna with a television signal of 16 dBmV level. As, mentioned previously, they suspended dipole 100 feet below a helicopter, 1000 feet above the radiating dipole or yagi. In both cases they observed fields of 18 dB relative to 1 microvolt per meter, at the 1000 ft height. At 100 MHz, assuming an isotropic receiving antenna, such a field would produce a signal level of 5.6 microvolts at the 50 ohm receiver input. This is about the level required to open the receiver squelch, depending on the squelch setting.

If one is to argue that leaks of the "worst case" variety described above can be prevented or controlled adequately to prevent interference due to single leaks, one still must address the question of multiple leaks. At this writing there is still some controversy over whether it is possible for a significant number of leaks to add "in phase", so that the effective received field due to leaks each producing field E at the aircraft is equal to nE, as compared to an effective received field of $n^{1/2}E$, as would be expected if the fields at the receiving antenna were random in phase. It has been suggested that very large numbers of tiny leaks could combine in phase to yield significant total fields at the aircraft. However, it would seem that if the usual statistics of large numbers is any guide in this case such accidental coherence of large number of small signals is quite unlikely, and becomes more unlikely the larger the number of small leakage sources. On should further note in this regard that the peak signal level in the composite television signal -- the synchronizing pulse -- is at least 13 dB higher than the next highest component of the composite television signal. Furthermore, it is of short duration. The sync pulses are about 5 microseconds in length, repeated at 63.5 microsecond intervals. The arrival time of a sync pulse from any one leakage source at the aircraft is determined by the delay time in the cable and the delay time in the propagation path. If the relative delay between signals arriving via two different paths is between 5 and 58.5 microseconds, the two sync pulses will not overlap at the aircraft, and therefore cannot combine "in phase". Both signals will still contribute to interference, of course, but only through their average powers, and there can be no "in-phase addition of the peak amplitudes."

Since a 5 microsecond delay corresponds to a path difference of about 5000 ft (in free space), it is easy to see that in a cable system with many miles of plant, spread over many square miles of the earth's surface, only about 10% of any large collection of leakage sources will be contributing sync pulses at the aircraft position at any given instant.

This discussion suggests why it might be that the only documented incidence of interference to air navigation systems by a cable television system involved pilot carriers and not television signals. The pilot carriers are, after all, CW signals. Thus, peak power is the same as average power, and whatever addition of signals takes place at the aircraft receiver will involve peak powers at all times. This suggests that pilot carriers should perhaps be maintained at levels considerably lower than peak levels of television signals, or perhaps should be excluded entirely from frequency bands where interference with over-the-air radio services is even remotely possible.

<u>What can be done to prevent cable interference to air navigation systems?</u>

Once again, we must recognize the difference between the instrumented air navigation systems (ILS and VOR) and the voice communications systems. The above discussions have perhaps suggested a few measures which might be taken, and those measures are not always the same for both the voice and the instrument systems. We will discuss here a few such possibilities. The list we will discuss does not purport to be a complete list of even the presently known possibilities. Still further suggestions may arise in the current proceeding before the FCC (Ref. 5) or as a result of future investigations.

Perhaps it is not necessary to say that the <u>sine qua non</u> of interference prevention is a far better job of leak prevention and monitoring than is now common in the cable television industry. It has been suggested that few, if any, existing cable television systems could dependably pass a thorough inspection against the FCC's existing signal leakage standards. This statement does not suggest, in this author's view, <u>either</u> that the industry has been entirely irresponsible in the past <u>or</u> that FCC's existing standards are too strict and should be relaxed. Until the last few years, the cable industry has lacked the tools to really do a dependable job of meeting FCC leakage standards.

One of the major cable plant problems has been due to the lack of cable connectors which could be installed leak-free and remain leak-free through years of buffeting by the weather. Older connectors were simply tightened down on the aluminum outer conductor of the cable. The aluminum eventually would flow under the pressure. If not re-tightened, the joint would then radiate. After repeated tightening it eventually became impossible to make an adequate seal between connector and cable. Now, however, connectors having built-in steel sleeves are available. These sleeves fit under the aluminum outer conductor. Thus, the relatively soft aluminum is supported both inside and outside, and cannot so readily flow to relieve the connector's pressure.

Another cable plant problem has been the taps for subscriber drops. The older pressure taps are reported to be unreliable, as to signal leakage. Modern multiport taps are better constructed in this regard.

Equally importance to the availability of leak free cable plant equipment is availability of effective tools and techniques for monitoring for signal leakage. Until very recently, the only available monitoring and measuring techniques were slow and clumsy, and required expensive equipment and a rather high degree of technical competence. Because most equipment used was wideband, manmade noise was often a limiting factor in the sensitivity of measurements. Now, however, there is available equipment which is relatively inexpensive, easy to use with little technical skill, can be used essentially continuously while traveling along the cable plant, sensitive, and quite narrow band. Such equipment is available at least for monitoring purposes, it not for quantitative measurements.

Clearly, contemporary plant equipment and contemporary measurement and monitoring techniques will be most useful in preventing signal leakage. Indeed, it may prove to be simply impossible for some older plant to utilize frequency bands in which the consequences of signal leakage could provide significant threat to life and property.

It is also clear that no monitoring system can ever be absolutely perfect. Signal leakage, to some degree, will inevitably occur. Only experience will show how reliable monitoring and repair systems can be, in practice, at keeping radiation levels low enough that no interference could occur.

Let us briefly examine additional techniques for preventing interference in the event signal leakage does occur.

The previous discussion of interference conditions and mechanisms for the ILS and VOR systems suggests a simple offset in frequency between the video carrier and those critical sideband frequencies at which ILS and VOR systems are found to be sensitive. If the video carrier frequency is removed by 25 kHz or more from the ILS and VOR carrier frequency, all of these critical sideband frequencies are avoided, including the frequency 19,920 Hz from the VOR carrier, the sensitivity of which has yet to be established. Under current operating conditions, this frequency offset generally exists already. ILS and VOR carriers presently exist only at 100 kHz intervals, from 108 to 118 MHz. The traditional carrier frequencies for the bands A-1 and A-2 are 109.25 and 115.25. These fall 50 kHz from the nearest possible ILS/VOR frequency. Frequency tolerances of 5 kHz or less are adequate to maintain sufficient frequency separation, reliably. This situation could change, of course, if an when the Federal Aviation Administration implements a plan to make VOR/ILS assignments at 50 kHz intervals. The same frequency offset principle would be valid, but cable frequencies would have to be modified in some instances, and frequency tolerances might also have to be tightened.

The situation in the voice communications case is not so simple. Frequency assignments in the communication bands are now made at 50 kHz and 25 kHz intervals in some cases, producing potential conflicts at the video carrier frequencies of the traditional cable channels, A, B, and C. These are 121.25, 127.25, and 133.25 MHz, respectively. Since the communications receivers are designed to receive AM voice signals, there is no set of critical frequencies which, if avoided by only a few hertz, decreases the interference susceptibility dramatically, as is the case with ILS and VOR systems. Thus, the choices seem to be four: (1) establish that cable systems can indeed be maintained adequately tight to avoid interference, (2) avoid the three frequencies 121.25, 127.25 and 133.25 (and perhaps the adjacent frequencies as well) for air navigation communication purposes until such time as it is established that cable systems can be maintained adequately leak-free, (3) avoid channels A, B, and C for cable TV use, or (4) for cable TV purposes, avoid frequencies which are used for air navigation purposes in the vicinity of the cable TV system.

The first option may be feasible in the very near future, at least for the trunk and distribution lines that are under control of the cable operator. In the case of subscriber-accessible portions of the plant, it is more doubtful that leakage can be prevented, even though levels are lower. In that case, however, if every subscriber were provided either with a set-top converter having output only in the VHF television band, or a trap was installed at the tap so the subscriber would have no access to midband frequencies, then at least it should be much less likely that even relatively low levels of interference would occur.

The second option may seem simple enough, in view of the superficiallly large number of frequencies available for ATC communications between 118 and 136 MHz. However, the air navigation system is sufficiently pressed for frequency spectrum that this approach would certainly not be welcomed by those responsible for that system. Furthermore, such an approach would tend to negate one of the primary advantages claimed for cable communications systems -- namely, that because the systems are "closed" over-the-air spectrum is conserved.

The third option has obvious disadvantages complementary to those of option 2. This option would require use of the so-called superband above channel 13 to provide even 19 channel CATV service. If it true that interference problems in the government bands between 225 and 400 MHz are similar to those discussed here in the midband, then avoiding A, B, and C completely would also imply avoidance of all but one of the superband channels, limiting cable to only 19 channels, including the 12 broadcast channel frequencies.

The fourth option would probably be viable in many locations, where no airports or en route transmitters are nearby. But the major problem is not in those locations. The problems are more likely to exist in and around metropolitan areas, where the demand for ATC services and multi-channel cable services co-exist. Even in those locations, frequencies used by ATC systems could be avoided on an ad hoc basis. But since the ATC systems must be free to modify frequency assignments at any time -- and this is done quite frequently -- the cable system would be subject to unplanned frequency changes at any time. In many cases this might be accomodated by small frequency changes not noticeable by subscribers. But when adjacent channels are used, the flexibility for changing the frequency of any one channel is limited. The alternative of modifying the cable system's channel carriage assignments on short notice because of changes in the ATC system is not likely to be welcomed by cable operators or subscribers.

Finally, we should note that all the actions mentioned in this section have assumed that cable television systems will continue to operate more or less as they do today, using VHF frequencies on coaxial cables. Longer term solutions include, of course, use of optical fibers for television signal transmission. If optical transmission all the way to the subscriber's premises should ever prove practical, signal leakage problems would recede into dim memory. Another alternative is the use of UHF frequencies for delivery to subscribers, if not for trunking as well. Even if trunks and distribution lines were to remain at VHF, UHF delivery to the subscriber would prevent the possibility of the troublesome subscriber-caused signal leakage. With modern improved UHF tuners and continually improving solid state amplifiers, UHF distribution and delivery may not be nearly as "far-out" a suggestion as it seemed only a few years ago.

Conclusion

The author has attempted to give some overview of the technical problems and opportunities for preventing interference between cable TV systems and air navigation and safety systems. It is clear that some actions will have to be taken to prevent the recurrence of such interference. Hopefully, the restrictions which may be imposed will be at the same time effective and not unnecessarily burdensome for cable operators, although it seems possible that some older systems may be quite restricted in their use of air navigation and safety frequencies. We note that two major areas, of particular interest to the FCC, have not been addressed at all in this paper. Those are the problems of (1) determining whether an individual cable TV system is indeed technically prepared to maintain signal leakage at a sufficiently low level, and (2) how to monitor and enforce, or otherwise assure that whatever restrictions and rules are judged necessary are actually implemented by every cable TV system using navigation and safety frequencies.

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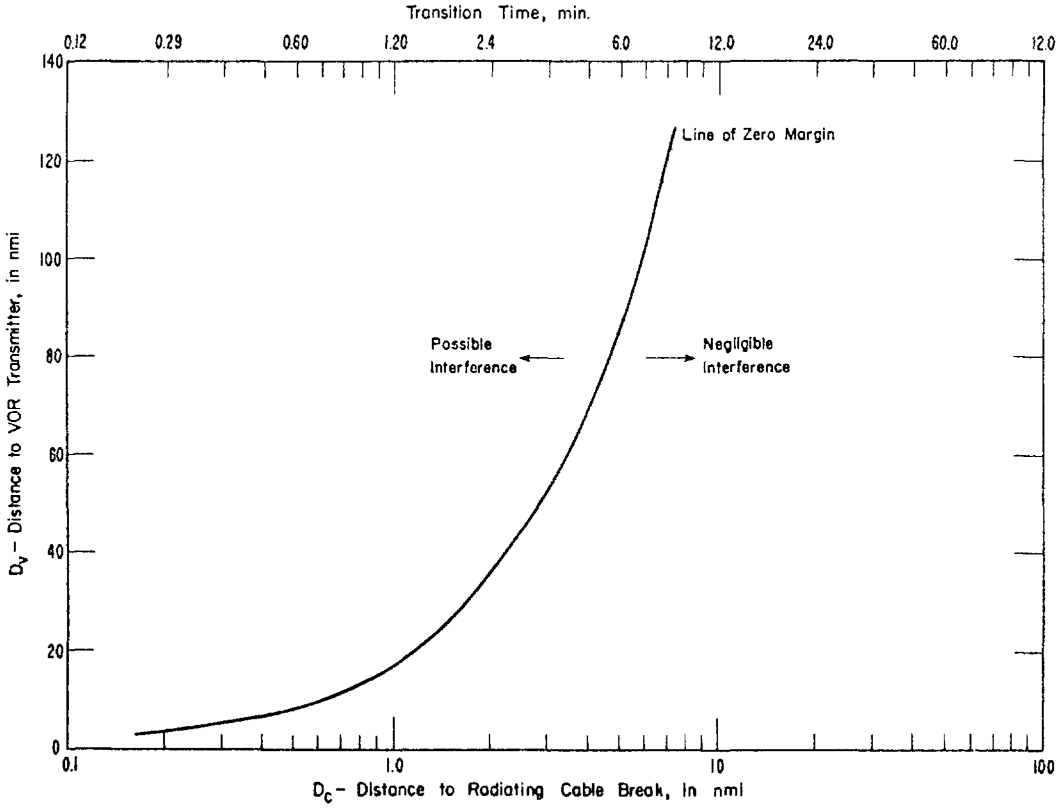


Figure 12. Expected performance of an operational VOR in similar interference tests. Transition time is the time required to fly a straight line distance of $2D_c$ assuming a ground speed of 185 km/hr (100 nmi/hour).

SOURCE: Juroshek and Harr (1975), OTR 75-75 (Ref. 4)

SYSTEMS ANALYSIS AND DESIGN FOR AN OPTICAL FIBER SYSTEM FOR CATV APPLICATIONS

Dr. F.W. Dabby - Dr. R.B. Chesler
John Arbuthnott

Times Fiber Communications, Co.

ABSTRACT

The arrival of fiber optical cable upon the communications scene is recognized as a practical reality. The advantages of optical fiber cables for CATV Trunk application are weighed against conventional coaxial cables for transporting multiple Television Channels.

Available optical fiber constructions are discussed. Their use in CATV Trunk application is described and the advantages are outlined.

Availability of terminal devices to produce a "live" working trunk line is considered and the economic impact of the "in-place" working system is noted.

INTRODUCTION

This paper examines the use of optical fiber technology as applied to CATV trunk-lines. Candidate practical systems using lasers, graded-index fibers and PIN diode detectors are examined. System performance is predicted and handling of the equipment is described. Amplifier spacing, bandwidth capability and unique characteristics of optical fiber technology are also discussed.

FIBER OPTIC CABLE

Fiber optic cable is currently available in single or multifiber construction. These cables, ranging in size from 0.150 to 0.250 inches in overall diameter, have the ability to transmitt RF signals of as much as 300 MHz Bandwidth on an optical carrier with as little 12 db per mile loss.

Three types of fiber can be used, their application being dictated by the bandwidth requirement. Step index fiber can be manufactured having very low loss but bandwidth is sacrificed. Semigraded and graded index fiber are applicable to wider bandwidths. The glass fibers now manufactured are capable of developing tensile strength in excess of 300,000 PSI and as a consequence can be subjected to the exacting environmental requirements of CATV use.

AMPLIFIER TECHNOLOGY

Technological break throughs in laser configuration now make it possible to discuss Fiber Optic analog TV signal transportation systems with at least 12 Channel capacitites.

These lasers operating, at an output of approximately 3 MW, Optical Power at room temperature, have mean time to failure ratings of 100,000 hours. Future development is expected to yield devices with mean life expectancies of 1,000,000 Hours. Solid state thermoelectric devices capable of controlling laser temperature within $\pm 2^{\circ}$ C are in existence today and are compatible with overall amplifier designs.

The electronic techniques for modulation, linearization of the laser output and the detection of low level light signals are a reality.

Therefore it seems pertinent that one should consider a fiber CATV system.

SYSTEM THEORY

The quality of a communications system is determined by the degradation of its signal-to-noise ratio from the system input to the system output. The signal-to-noise ratio is given by:

$$S/N = \frac{P}{N_q + N_t}$$

Where P = Detector Output Power
N_q = Quantum Noise Power
N_t = Thermal Noise Power

These quantities can be calculated as follows:

$$P = a^2 P_s^2 G^2 M^2$$

$$N_q = 2eBG^2 R (aPs + I)$$

$$N_t = 4 FKTB$$

Where A = Detector responsivity in amps/watt (typically 0.55)

P_s = Required power at the receiver in watts

R = Load resistance in OHMS
G = Gain
e = Electron charge in Coulombs
B = Bandwidth in Hertz
I = Effective dark current in Amps
F = Noise figure of the preamplifier
K = Boltzman's constant in Joules/^oK
T = Temperature in ^oK
m = Ratio of lumininance to composite video = 0.7

For a conventional coaxial cable system the Thermal noise (N_t) limits the maximum achievable signal to noise level. In an optical fiber link, the quantum noise (N_q) primarily limits the maximum achievable signal to noise level. Since the Quantum noise is usually mor significant than the thermal noise, the S/N equation reduces to:

$$S/N = \frac{a^2 P_s^2 m^2}{2e\,B\,(aP_s = I)}$$

As a first order approximation, the dark current is negligible and the signal to noise ratio is proportional to the received power divided by the bandwidth of the system. This ratio is multiplied by a constant which includes detector responsivity.

In order that many channels of Television be carried through a single optical fiber, it is necessary that the fiber, the light source, and the detector have sufficient bandwidth and signal strength.

The optimum optical fiber CATV Trunk Line system is judged to be the best balanced compromise between repeater spacing and number of channels per fiber for the required signal to noise ratio.

OPTICAL FIBER CATV SYSTEM

A CATV supertrunk-line or transportation link should deliver a signal to noise ratio of typically 53 db peak to peak luminance to RMS noise. A ten mile optical trunk system having thirty channels can be handled by a single multi-fiber cable. Available LED's can provide for five channels per fiber using semi-graded index fiber. Solid state lasers, currently in development can demonstrate twelve channel capability on a single graded index fiber. Continuing laser development promises devices capable of transporting as many as 30 channels over a single fiber. In both the LED and laser cases the detecting diode can be a P.I.N. type.

Using lasers to handle a 54-216 MHz conventional VHF Spectrum of twelve channels on a single fiber, some 12 repeaters would be required for a 10 mile run to maintain a 53 db peak-peak luminance to weighted noise. A three fiber cable could thus provide 30 channels.

The repeaters consist of P.I.N. diode receivers coupled to laser transmitters. Sufficient circuit gain is provided by the receiver to modulate the laser at the proper output power level.

For purposes of comparison, three hypothetical 10 mile systems can be laid out as follows:

Conventional	12 Ch. laser	30 Ch. laser
3/4" cable	3 Fiber 1/4" cable	1 fiber 0.15" cable
30 Amplifiers	12 repeater sets	12 repeaters
30 Channels	36 Channels	30 Channels

Each optical repeater occupies less than 5.0 cubic inches. A set of three repeaters will fit in a space dimensioned approximately 2.0" x 3.0" x 5.0". Repeater power requirements are less than 3 watts at 12 volt level, it is expected that power supplies can be provided on-site if pole line electricity is available.

It is anticipated that, because of the small size and light weight of both cable and amplifiers, system construction will be easier. Splicing will be accomplished by use of small, easy to install low loss connectors.

One should bear in mind that the fiber optic system, by its very nature, using a non conductor as a transmission medium, is, for all intents and purposes, immune to RF 1, EMl, lightning surges and ground loops. Additionally the system will not radiate RF energy.

Fiber optic cable has, for all intents and purposes, flat loss and its attenuation does not vary with ambient temperature variations. Sensitive AGC and equalization circuits are not necessary.

In summary, the technology is here. A competitively priced trunk system having significant overall advantages in performance and operating cost is now a reality.

TESTING VIDEO SIGNAL TO NOISE RATIO USING A MODIFIED STAIRCASE WAVEFORM

Robert C. Tenten

Home Box Office
New York, New York

ABSTRACT

Video noise measurements usually require specialized test equipment to obtain accurate results. A method is presented which uses a modified staircase test signal generator at the transmit end and requires only an oscilloscope and low pass and weighting filters at the measurement location. The measurement is direct reading in dB, requires no calibration of equipment, and is fast and simple.

I. INTRODUCTION

While there are several measurement techniques that are used for measuring video signal to noise ratio, they generally require specialized test equipment. Broadband RMS voltmeters have been used to measure the noise level of a system in the absence of a test signal. Rhode and Schwarz produces an excellent video noise meter that measures the noise on a flat field waveform but it is not common in the CATV field. Tektronix has an instrument which strips the noise from part of a line of video (Fig. 1); calibrated noise from this instrument is then inserted by the operator until the noise inserted appears on an oscilloscope to be equal to the noise on the signal (Figs. 2 and 3). Lenco manu-

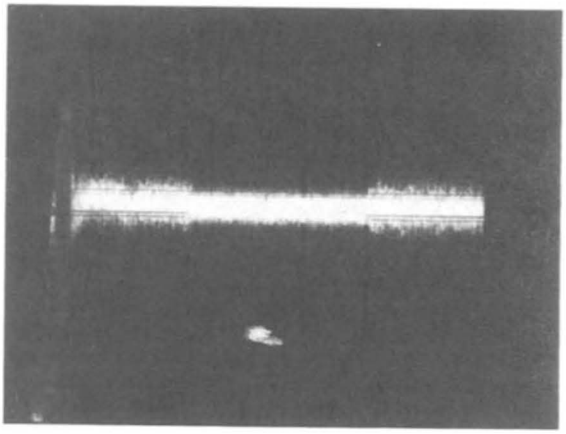


Fig. 2

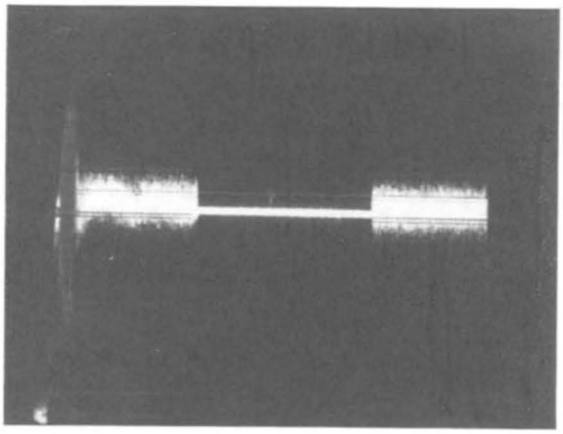


Fig. 1

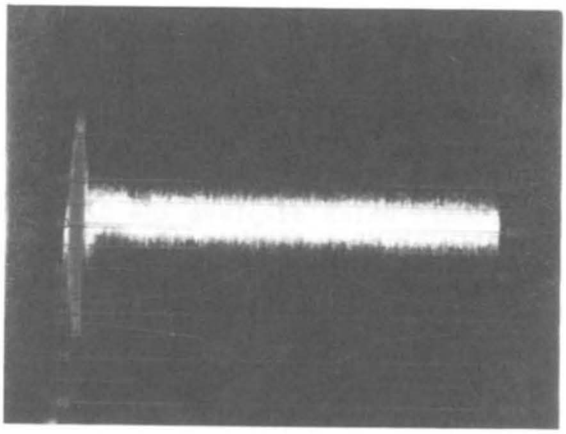


Fig. 3

factures a device which uses a tangential noise measurement technique. This measurement is made by displacing the waveform vertically by a variable voltage; the traces are then brought together until the dark band observed between the two waveforms disappears (Figs. 4 and 5). The

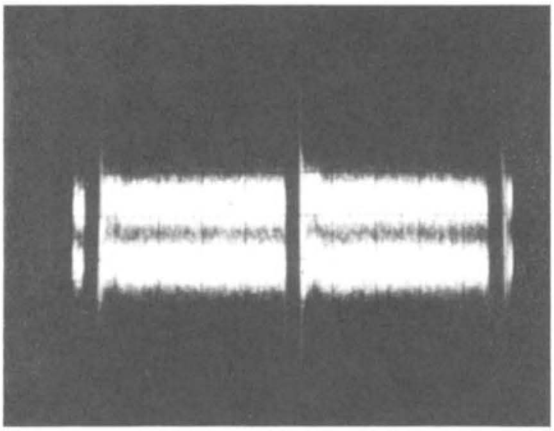


Fig. 4

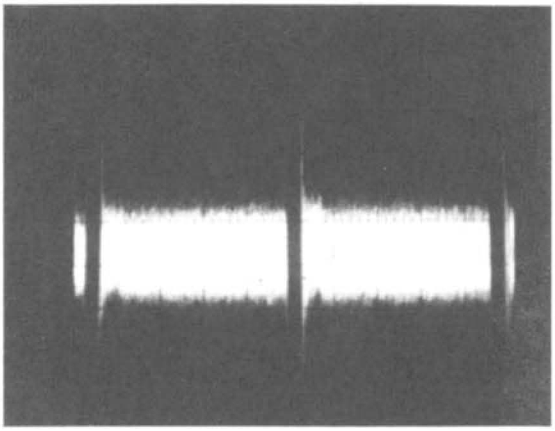


Fig. 5

displacement voltage which is directly related to S/N ratio, is measured by a logarithmic digital voltmeter in the instrument which displays the S/N ratio directly in dB. Another approach (described in the NTC Report Number 7) uses an oscilloscope and low pass and weighting filters. The technique requires estimation of the quasi-peak-to-peak amplitude of the noise at blanking level; quasi-peak-to-peak being defined as "the average level [of the noise] ignoring large occasional spikes of noise." The measured voltage is converted to the video S/N ratio by referring to a graph.

II. OTHER APPROACHES

It would be quite helpful to develop a measurement technique which would eliminate the cost of specialized test equipment and would be simpler and more accurate than the NTC-7 approximation method.

Methods which require only a TV set would be ideal, but at this time there does not appear to be an accurate way to do this, although several approaches were investigated. The next approach was to rely on a wideband (10 MHz) general purpose oscilloscope with low pass and weighting filters.

III. PROPOSED METHOD

If a full field 10 step staircase test signal is viewed on an oscilloscope such that a full field is displayed, the trace appears as 10 horizontal lines of equal spacing. If noise is added to the waveform as in a transmission system, the space between the horizontal lines will be filled in just as in the tangential method. Of course,the steps in the standard 10 step staircase are too widely separated for the S/N ratios which are generally encountered. The generator can be modified to produce steps with closer spacing, but a staircase with equally spaced steps would be useful to measure only one specific S/N ratio. If however the spacing between steps is changed every 1.4 msec across a video field (Figs. 6 and 7),

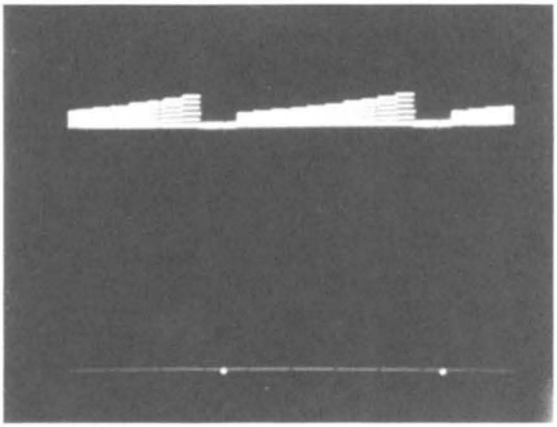


Fig. 6

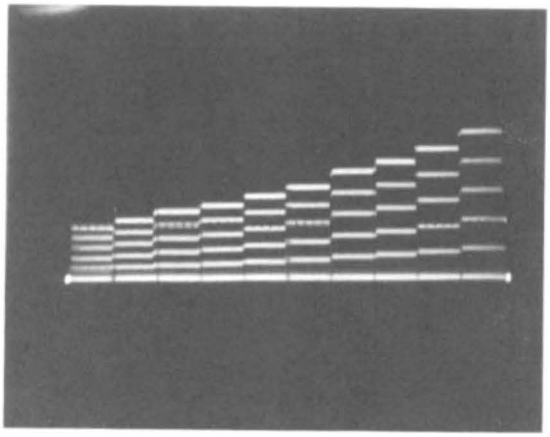


Fig. 7

then 10 S/N ratios could be measured. In this case 1dB increments were chosen and adjusted to cover the range of 47dB to 56dB S/N ratio.

IV. MEASUREMENT TECHNIQUE

In order to make a satisfactory S/N measurement a low pass filter is required to remove noise energy which may be present above the desired video bandwidth. In addition, A CCIR Weighting Filter is used to "shape" the noise over the frequency band to correspond to the response of the human eye. It should be noted that all S/N measuring techniques use these filters to obtain a weighted S/N ratio. The oscilloscope used in the measurement should have a bandwidth which is flat in the area of interest which means that it should have about a 5 MHz to 10 MHz bandwidth. Sensitivity should be about 20mv/division minimum, and DC coupling is desirable although not necessary.

The S/N ratio measurement is made by setting the horizontal sweep to display one field of the test waveform. If the scope sweep has a vernier control the display can be adjusted to have each of the 10 groups of steps fill one horizontal division; therefore each horizontal division will correspond to a specific S/N ratio. The S/N of the system corresponds to the last step which is completely filled by noise of uniform brightness.

The next step(s) which corresponds to a lower S/N ratio(s) will have a dark space (or "banding") between them. If banding appears between all steps the S/N ratio is 57dB or better; if the spaces between first steps are filled with noise the S/N ratio is 56dB. If the first and second steps are filled, then the S/N ratio is 55dB and so on down to the last step. If the tenth step is filled, then the S/N ratio is 47dB or worse.

Figs. 8 through 11 show S/N ratios

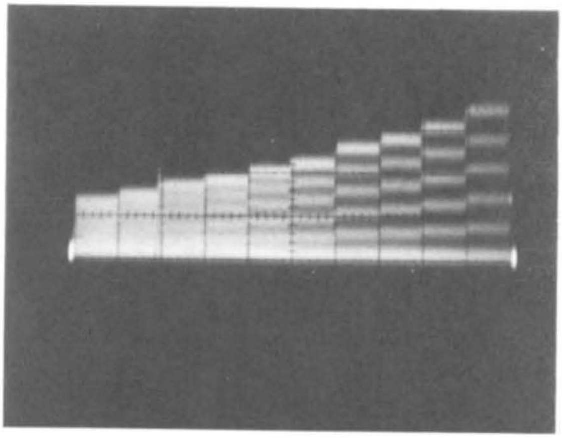


Fig. 8

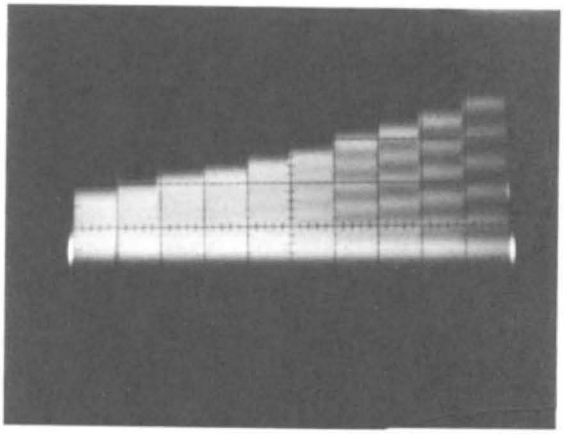


Fig. 9

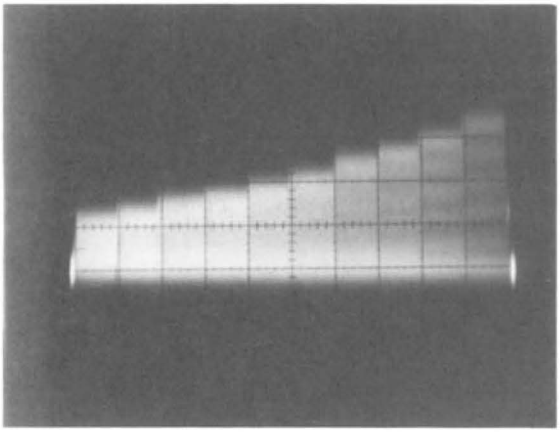


Fig. 10

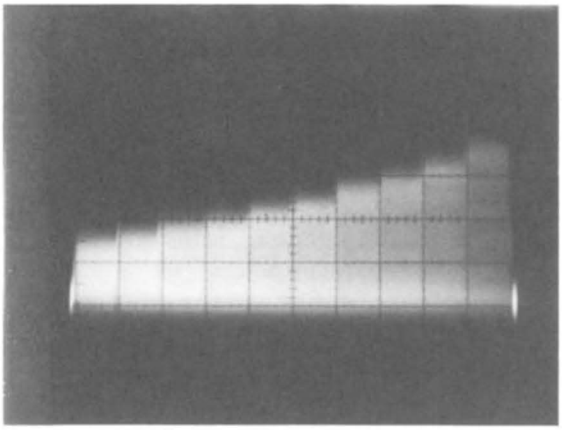


Fig. 11

corresponding to 55dB, 52dB, 49dB, and 48dB respectively. The oscilloscope should be set up for "normal" brightness and focus although the measurement is not very sensitive to these variables.

V. ACCURACY AND RESOLUTION

The accuracy of the technique is dependent on the accuracy of the level of the test signal going into the system to be tested as well as the accuracy of the level between the steps. Resolution appears to be about 1dB. The measurement accuracy does not depend on the accuracy of levels at the receive end nor does it require a calibrated oscilloscope.

VI. FIELD TESTS

While this technique has been tested in a lab environment, further tests will be conducted to determine whether any difficulties occur in a field environment.

VII. APPLICATIONS

The primary application for which the S/N measurement technique was developed is satellite earth stations. Other applications include microwave transmission systems or possibly the cable system itself. The test signal could also be recorded at the beginning of a video tape so that the overall record-playback S/N ratio can be monitored. The test waveform can be set up to accommodate whatever range of S/N ratios that might be required for a given application.

VIII. ACKNOWLEDGMENT

A special note of thanks is due to Jim Demetrius for his invaluable assistance in the construction, testing and criticisms of this technique.

THE EFFECTS OF INTERFERENCE ON TV PICTURE AND SOUND

Jack Golin and Michael Kolcun

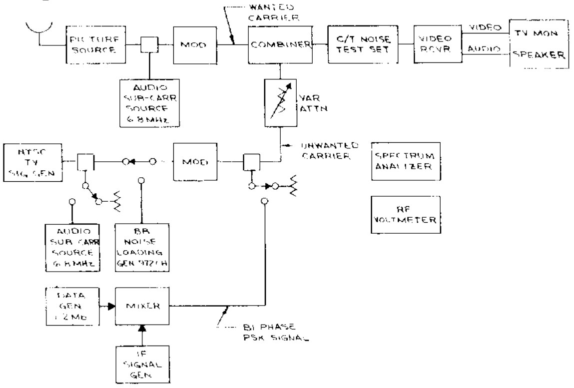
ITT Space Communications Inc.
Ramsey, New Jersey

Abstract

A subjective analysis of the effects of different types of interfering carriers on TV picture and sound was conducted. Interference from TV, High Speed Data, and FM/FDM Carriers was evaluated to determine the level at which each interference is first observed, which type produced the worst distortion, and the level at which each type of interference becomes unacceptable. The results indicated that interference from another TV carrier has the worst effect. TV interference was first noticed on the picture at a carrier to interference ratio of 18 dB. A subjective average showed that the picture becomes unacceptable at a carrier to interference ratio of 14 dB. It can be concluded that an earth station operating in an environment where the C/I is greater than 18 dB should have acceptable TV reception.

Subjective Test Evaluation of Interference Model

The effects of different types of interfering carriers on the TV picture and sound were evaluated by subjective testing. An actual TV carrier was processed through a receiver, and the output signal observed and heard on video and sound monitors. Interference from other TV, high speed data, and FM/FDM carriers was simulated and introduced. A group of observers evaluated the effects of different levels of the interfering carriers. The test setup is shown in the figure.



The TV signal was received and reprocessed to have all of the modulation characteristics outlined in the calculations. The carrier to noise (C/N) operating condition was established by an ITT NTS 7040 noise test set, and the TV carrier was fed into an ITT TV receiver. The output video and audio signals were then displayed on a Sony TV picture and sound monitor. A spectrum analyzer was used to set the reference of the wanted carrier to the interfering carriers at 0 frequency separation and 0 dB in the attenuator. Attenuation was added to set the interference 30 dB below the wanted TV carrier. Switches and combiners were used to introduce the different interfering carriers and carrier combinations. Several C/Ns were used in the tests. A standard ITT TV receiver (C/N = 10 dB at threshold) was employed for C/N = 12 dB and 16 dB; an ITT threshold improvement receiver (C/N = 7 dB at threshold) was used for C/N = 9 dB.

A group of subjects was individually asked to observe the monitor and say when the picture became objectionable as attenuation was removed in 1 dB steps. This test was repeated for the various types of interference at different receiver C/Ns. The results were averaged, and the mean at which the carrier to interference (C/I) became unacceptable was recorded. A color bar TV signal replaced the TV picture signal as the wanted carrier, and all tests were repeated. The C/I at which interference was first noted was recorded for all cases.

The results of the subjective tests are shown in the tables. They indicate that TV interference has a worse effect on the received TV signal than either high speed data or FM/FDM interference. TV interference appears as wavy horizontal lines, whereas high speed data appears as random impulses, and FM/FDM shows up as thermal snow.

For any case, it is evident that the general viewer, on a subjective basis, will accept approximately 3 to 4 dB lower C/Is than the ratio measured when interference is first perceived on the picture. No major changes in the quality of the sound were observed, but for C/Is of 12 dB and lower, a notable increase in background noise is heard. It should also be noted that the C/I measured for the condition when interference

TV Signal Interfering with TV Signal

(0 Frequency Separation)

C/N in 36 MHz for wanted TV carrier	C/I for unacceptable picture (subjective average)	C/I for clearly noticeable color bar distortion	C/I when interference first appears on picture
9	14	16	18
12	14	16	18
16	13	16	18

High Speed Data (1.2 Mb) Interfering with TV Signal

(0 Frequency Separation)

C/N in 36 MHz for wanted TV carrier	C/I for unacceptable picture (subjective coverage)	C/I for clearly noticeable color bar distortion	C/I when interference first appears on picture
9	12	15	17
12	12	15	17
16	12	15	17

972 Channels
FM/FDM Signal Interfering with TV Signal

(0 Frequency Separation)

C/N in 36 MHz for wanted TV carrier	C/I for unacceptable picture (subjective average)	C/I for clearly noticeable color bar distortion	C/I when interference first appears on picture
9	12	14	15
12	13	14	15
16	11	13	15

High Speed Data (1.2 Mb) plus TV Signal Interfering with TV Signal

(0 Frequency Separation)

C/N in 36 MHz for wanted TV carrier	C/I for unacceptable picture (subjective coverage)	C/I for clearly noticeable color bar distortion	C/I when interference first appears on picture
9	14	16	18
12	14	16	18
16	14	16	18

Note: All ratios in dB

is first noted on the picture appears to be independent of operating C/N. This indicates that regardless of how much additional operating C/N margin may be added to the station design, the interference will still start to degrade the picture at approximately the same C/I as for a station with a 2 dB operating margin over threshold. However, in the case of TV and FM/FDM interferences, the subjective acceptance C/I tends to improve at high C/N margins since the subjects see less thermal impulse noise. High speed data interference does not seem to share this improvement since it appears as impulse distortion on the picture.

Conclusions

The subjective tests indicate that a TV receiving earth station, operating with a 2 dB C/N margin above fm threshold, in an area where the C/I is greater than 18 dB should have acceptable TV reception.

It should be noted that the testing was conducted in a laboratory environment where the specific effects of only one or two combined interfering carriers could be evaluated. In the field, many interfering carriers at relatively low levels enter the receiving system and add to the overall link noise. This raises the total noise base and thus lowers the system operating C/N. Therefore, for a good earth station design, proper system C/N margin should be included to compensate for the effects of interference at each location.

Reference:

Multiple Satellite Interference Analysis for 4.5 Meter TVRO Earth Station

Dated 30 July 1976

By Jack Golin and Michael Kolcun

THE FUTURE OF CAPTIONED RADIO

JOHN HUMPHREYS

NATIONAL CABLE BROADCASTING NETWORK, RESTON, VIRGINIA

PUSHING THE LIMITS OF DIGITAL TYPOGRAPHY ... AND A ROMANCE WITH SOUND.

CABLE RADIO - WITH WORD IMAGES - SHOWS IT CAN COMMUNICATE AND SELL!

INTRODUCTION

Captioned radio is a simple but effective technique employing an audio program and character generator, operating in a synchronous and organized manner for television viewership, with distribution on cable TV systems.

This technique reverses the delivery priority of the television presentation; i.e., the audio bears more importance on the communication than does the video. The television receiver acts as a radio with associated printed data displayed on the TV screen.

The primary advantage of this concept is to provide a long-play, automatic, low-cost program delivery system that is acceptable in format by both the cable operator and the TV viewer.

SYSTEM DESIGN

The delivery system consists of an integrated hardware and software package, using available "off shelf" equipment and technology, further cutting costs in technical research and development.

The basic program storage vehicle is economical audio magnetic recording tape. The audio tape format supplies high capacity program storage in the order of 5 to 12 hours per program unit. In addition, high speed audio tape duplication is used, giving a high copy depth of multiple programs at reasonable cost for field distribution.

The field program equipment package consists of an audio tape playback mechanism married to a character generator. Full television sync and color generation are added to the package as well as video-audio monitoring and operating controls. All equipment is housed in a standard 19" rack cabinet. The signal output, audio and composite color video, is fed into a television modulator for trunk line distribution.

The audio tape deck is of professional caliber employing a standard quarter-inch tape width and a four-track interlaced bidirectional format. Full sized 14-inch reeling is used to provide the high capacity program storage. Normally, tape speed of 7.5 ips is used for the advantages of increased fidelity, better signal to noise ratio, reduced flutter and wow components and reduced tape dropouts. However, some program material may merit the use of 3.75 ips tape speed to give optional increased program storage capacity.

The audio program is recorded in monural form on two of the four tracks of the tape (one track in forward mode, one track in reverse mode). The bidirectional feature allows for the program to perform on a "closed loop" basis for the length of the program, and repeat automatically at the end of the five to seven-hour presentation.

The remaining two audio tracks on the tape hold the control data to drive the character generator, and are parallel and in unison with the audio program tracks. The character generator data signal is audio and uses a frequency range of 1200 to 2200 Hz.

Automatic reversing of the bidirectional tape drive is accomplished by audio control tone logic recorded on the tape and/or foil contact sensing.

Minimum field maintenance of the tape drive is expected because of the ruggedness of the deck chosen. Normal, routine cleaning, lubrication and head degaussing procedure is followed. Tape heads are expected to be replaced every two years. The program tape is changed once a week.

The character generator is a self-contained unit with local keyboard input in addition to the audio tape interface input. It holds a four-page internal memory that can be controlled and refreshed from the audio tape.

The page format is 10 rows of characters by 24 characters per row. Two character sizes are used: a larger upper case, 28-scan line high character and a smaller upper case, 20-scan line high character. The generator produces high-resolution quality characters and the clean font design that results in a large, easy to read display.

A companion rack mounted EIA sync and page colorizing generator drives the character generator and provides a choice of seven screen background colors for display with control logic stored on the audio tape.

Programming for the captioned radio concept is produced at a central studio. A variety of program formats and information may be presented. Normal low-cost radio production techniques are used to build the program. The master tape is recorded on a professional four-track, half-inch audio tape recorder. The associated caption copy is stored in sequence using digital computer data entry techniques; and, through FSK conversion, it is dubbed on the master audio tape.

The final program is checked for errors and corrections are made, if needed. The completed master tape is then placed on a high speed tape duplicator to reproduce the required field copy depth.

FIELD TEST

In 1976, a full year of field testing was conducted using the captioned radio concept. A cable radio format was established and the system was operated under a multitude of channel program requirements. A total of six CATV systems joined in the test. (See Addendum)

The test mix included a variety of: market size, subscriber base, geographic location, and demographic differences.

A commercial entertainment program was structured to prove the viability for an advertising base support. Substantial viewership was accomplished and audience reaction was effective. Pilot national advertising contracts were sold and performed with measurable results. The program was seven hours in length; produced weekly and repeated 24 times per week in all markets to reach the accumulated audience.

There were several interesting audience reaction points realized from the project test:

(1) Higher viewer reaction was noted with the use of intensive "screen dance" (a term denoting active screen display movement). When a static screen was displayed for sustained periods, audience reaction dropped to about 20% of normal.

(2) It is felt that the "expectance" level" of the TV audience watching a captioned radio program is less for non-commercial information material ("expectance level" -- the factor of a viewer's response to accept a nontelevision presentation).

FUTURE SERVICES

The future of captioned radio lies with the usage of cable TV distribution. The concept is custom built to serve a multitude of CATV systems on a network basis, capable of reaching large viewing numbers -- so essential to tape the advertising base. The use of captioned radio in the noncommerical-information program areas also needs the viewing numbers that CATV systems offer, to solidify and justify active participation.

Sub-networks, using lighter equipment, can be added -- giving a smaller, but selective, audience. These nets would include: hotels/motels, hospitals, MATV in large complexes, campus distribution and MDS service.

By using part-time, receive-only aural service from satellite transmission, current live program presentations using the captioned radio format would augment the basic taped programs.

CONCLUSION

Captioned radio service -- is a reality. It has audience appeal and is cost effective. The technology is simple and equipment for operation is available. Programming for captioned radio is produced on a central studio basis, supplying cable systems a network service for both commercial and non-commercial programs.

ADDENDUM

Cable TV systems joining the test project - 1976. The cable radio network reached 148,000 viewing homes.

New York, N.Y. -- TelePrompter Manhattan CATV Corp.
Reston, Va. -- Warner Cable of Reston (Radio Reston)
Madison, Wisc. -- Complete Channel TV, Inc.
Kansas City, Kans. -- TeleCable of Overland Park, Inc.
Rock Springs, Wyo. -- Sweetwater TV Co., Inc.
Los Angeles, Calif. -- Theta Cable of California

THE IDEAL MODULATOR/DEMODULATOR

Carl T. Johnson

Jerrold Electronics Corporation

The first step in evaluating the baseband performance of a head-end modulator is to obtain an "ideal" demodulator. Otherwise, shortcomings of the test equipment and those of the device under test will be difficult to separate. A similar requirement plagues the evaluation of the head-end demodulator. In this case the "perfect" modulator is needed. But what is "perfect"? How are the "perfect" instruments tested? This paper answers these questions.

Introduction

Cable television today is an exact science. Providing quality signals to the customer requires not only reliable and sophisticated plant equipment but also the best instruments available for testing and maintaining that equipment. The job of quality assurance is made easier by modern test equipment. However, in some cases the equipment under test is of higher quality than the test equipment. This is not a problem for the system operator. He does not need a precise characterization of his plant equipment. But for the design engineer the situation is different.

For the sake of illustration, assume that an engineer is developing a new head-end modulator. Consider some of the questions that he must face.

Does a demodulator exist which is good enough for testing this modulator? If so, what kind of detector does it have? Does it have a differential gain less than one percent? If it has excessive differential gain, how does it vary with luminance level? Will it cost more than $8000? Can I find a substitute? If so, can I get away with $100 in materials?

It is true; the best philosophy for testing a modulator is to find the perfect demodulator. Conversely, the perfect modulator is needed to test a demodulator. However, it is more practical to search for the virtual perfect demodulator and modulator. That is, make it appear as though the perfect test instruments were used. A simple example is to subtract the distortion of a test device alone from the composite distortion of the piece under test and the test device operating together. This assumes, of course, that the distortion of the test device is accurately known.

Therefore, the question now is not how or where to find the perfect modulator or demodulator, but, rather how to simulate them. As a first step in answering this question, it is important to realize that the technique or device which brings about the simulation does not come in a single clearly defined embodiment. Rather, for each test performed, the technique, the lash-up, indeed the entire concept may be different.

The Perfect Demodulator

Returning now to the head-end modulator, which is to be tested for differential gain, one's first reaction is to look for the best demodulator available, a vectorscope and a video waveform generator. However, a careful analysis of this test will result in less expensive equipment. Furthermore, accuracy will be as good or better.

What is differential gain? It is a measure of the change in color subcarrier amplitude over the luminance dynamic range. Luminance and color are supposed to be independent. If they are not, then differential gain is present. A common method of measuring it is to add a steady subcarrier to the normal video portion of a stair-step waveform, apply the result to the modulator under test, recover the video in a precision demodulator, discard the luminance by passing the recovered video through a filter, rectify the remaining 3.58 MHz subcarrier, and display the resulting D.C. as a function of luminance on an oscilloscope.

As a matter of fact, the chief advantage of this test approach is convenience. Accuracy is excellent when synchronous detection is used in the demodulator but commercially available units using this technique are expensive.

There is another method which yields high accuracy and low cost. The RF produced by the modulator contains the color subcarrier in the form of a sideband component 3.58 MHz above the picture carrier. If the modulator exhibits differential gain, it will not be confined to this component only. However, since differential gain pertains to color only, it is customary to measure it at the color subcarrier frequency. Nevertheless, the frequency does not have to be precise. The only item of interest is amplitude variations, not frequency variations. For the sake of illustration, assume the subcarrier sideband component to be in TV channel 2. It falls, therfore, at about 58.83 MHz. Any amplitude variations of this component will cause a corresponding variation in the 3.58 MHz output of the video detector. But most video detectors will create additional differential gain which is difficult to separate. However, since this additional distortion is caused by the luminance portion of the signal, why not remove it? Doing so results in the added advantage of not needing a third detector to convert the 3.58 MHz to D.C. The desired D.C. can be obtained directly from the 58.83 MHz component. In this illustration, the entire test set-up requires a video waveform, a narrow bandpass filter tuned to 58.83 MHz, a diode detector, and an oscilloscope. A very convenient form of tunable bandpass filter and diode detector is available in the signal level meter. They are are available with adequate selectivity and with a video output port.

The companion test, differential phase, is more difficult because it requires comparing two signals of practically identical frequency. Again, the frequency need not be precise, but the frequency of the first must be precisely equal to that of the second. This test is similar to differential gain; only phase change rather than amplitude change is under scrutiny. Differential phase is the change in phase of the color subcarrier over the dynamic range of luminance. There should be complete independence between luminance and color subcarrier phase. If there is not, then differential phase is present.

The customary test set-up requires a video waveform generator which delivers a ramp or stairstep with steady subcarrier during the luminance interval. This generator drives the modulator under test, which then feeds a precision demodulator. The color subcarrier is separated from the the demodulator output and is applied to a phase detector, the output of which is displayed versus luminance level on an oscilloscope.

The measurement of differential phase is further complicated because of the relationship between baseband subcarrier and picture carrier. Furthermore, this relationship is strongly affected by the type of detector used to recover the subcarrier. If an envelope detector is used, the phase of the baseband subcarrier is determined by the instantaneous phase difference between the picture carrier and the RF color subcarrier. If a synchronous detector is used, the phase of the baseband subcarrier is determined by the instantaneous phase difference between the RF subcarrier and the local oscillator signal, which drives the synchronous detector.

If the modulator generates an RF subcarrier phase jitter, then the picture carrier most likely has a similar phase jitter. Because the phase difference between the two signals is unchanged, the phase of the baseband subcarrier output of an envelope detector will remain unchanged. In certain practical applications, this can be a distinct advantage. However, more often the inherent distortion of the envelope detector will offset this advantage. However, in a synchronous detector, the local oscillator signal does not change phase in exactly the same manner as the picture carrier; therefore, the subcarrier output of a synchronous detector will show a phase distortion.

The proper characterization of a modulator should be independent of the demodulator with which it is used and conversely, of course. Therefore, determining the behavior of a modulator as it pertains to differential phase requires that all parameters be measured which might affect differential phase. Those parameters are RF (or IF) color subcarrier phase and picture carrier phase. The former can be readily measured by making use of a sample of both the modulator IF local oscillator signal and the baseband color subcarrier. The local oscillator sample will be independent of the modulated version. Therefore, if it is mixed with the IF color subcarrier after it has been extracted from the composite signal by means of a narrow bandpass filter, the resultant 3.58 MHz signal will exhibit a phase variation which is dependent only on the phase of the IF subcarrier. This signal can be applied to a phase detector which is driven by the baseband subcarrier sample from the video generator. The output of the phase detector can then be displayed versus luminance on an oscilloscope.

Measuring the phase variation of the picture carrier is difficult because of the interfering luminance components. They are too close in frequency to be filtered out. One method is to detect the luminance quadrature component of the picture carrier. That component is the part of the modulated picture carrier which is ninety degrees out of phase with the unmodulated picture carrier. Wherever the output of the quadrature phase detector is different from zero, the angle of phase change is equal to the change in the setting of a calibrated phase shifter required to restore zero output from the phase detector. If the video luminance waveform is applied to the horizontal input of an oscilloscope, and the quadrature output to the vertical terminals, the phase shifter can be used as a comparator scale and the oscilloscope as a null indicator.

Another example of simulating the ideal demodulator can be found in the measurement of modulator flatness. Before examining this in detail, it is important to interpret the meaning of flatness as it pertains to modulators. Naturally, any demodulator should produce a video output which is an exact replica of the video at the input of the modulator. This ideal condition can be called one of zero flatness, that is, zero amplitude variation versus baseband frequency from video input to video output. Any deviation from the ideal would be called a flatness of some percentage of full amplitude, or more commonly, a flatness of some dB.

It is desirable to express this quantity as if the ideal demodulator were used. This admits that any deviation from the ideal is caused by the modulator. An alternative is to give flatness in terms of the RF output only. Regardless of whether the demodulator is ideal or practical, the video obtained from it can be predicted only by knowing the RF characteristics of the modulator.

One method of obtaining this is to apply the output of the modulator to a broadband diode detector. The modulator input is a sinewave of adjustable video frequency. Depth of modulation should be light so that the nonlinear properties of the diode are not evident. This is permissible since frequency response is not affected by modulation depth.

The output of most head-end modulators is vestigial sideband. Over part of the video frequency range, a double sideband is produced, but over the remainder, only a single sideband is produced. When a broadband envelope detector is used for this signal, the output for a given modulation depth is twice as large for video components producing a double sideband as it is for those producing a single sideband. Consequently, the output of a wideband envelope detector is intentionally non-flat. A good method of determining the "flatness" of a modulator is to measure deviation from this intentional non-flat characteristic.

More examples of measurements on a modulator could be given. They all will have one quality in common. They all will be designed to simulate the perfect demodulator, that is, they will produce data which allows the determination of the nature of the signal which would be delivered by a perfect demodulator if it were driven by the modulator being measured.

Similar techniques are used when evaluating a demodulator. The test data which characterize a demodulator should presuppose the use of a perfect modulator in making the tests. Attention is now directed to the question of how to bring about this simulation.

The Perfect Modulator

Although the philosophy is the same, corresponding tests will show surprising differences. For the sake of comparison, consider the requirements for measuring the flatness of a demodulator.

As for the practical modulator, the RF characteristics of the practical demodulator must be known before one can predict how it behaves with any modulator, perfect or otherwise. Also, the demodulator RF characteristic is purposely non-flat in order to compensate for the vestigial sideband non-flatness. Therefore, as with the modulator, the best way to measure the "flatness" of a demodulator is to measure the deviation from its ideal non-flat RF characteristic.

One common approach is to take advantage of the Nyquist slope, which has two virtues. First, it compensates for the double sideband portion of the input signal thus causing it to appear as a single sideband signal. Secondly, it rejects components in that part of the lower sideband which are supposed to be rejected by the modulator. Therefore, if the input signal is double sideband, the demodulator response will be the same as for a vestigial sideband signal. The double sideband signal is easy to produce, hence the desirability of this test. However, it has the disadvantage of not revealing the true shape of the Nyquist region. A second test, namely to sweep the Nyquist filter, can remove any doubt, and should always accompany the double sideband test.

Another approach to the measurement of demodulator flatness is to provide two input signals, both unmodulated sinewaves. The first signal is set to the picture carrier frequency. The second signal has an adjustable amplitude and frequency, which is variable between 4.5 MHz above and 1.25 MHz below the picture carrier. As the second signal is moved across the band, a calibrated attenuator is adjusted to maintain constant detector output. The attenuator readings versus frequency give a plot of the RF characteristic including, of course, the Nyquist region.

Assuming an instrument is linear, its behavior can be fully described by specifying both amplitude response and phase response. A plot of phase versus frequency provides the necessary information. However, that data will be translated into the more common form known as group delay, which is the slope of the phase versus frequency curve. This quantity is a more sensitive measure of system performance. The following example will show how group delay is measured.

In keeping with the previous philosophy concerning the measurement of amplitude response, the measurement of demodulator group delay is performed in a manner which simulates the use of a perfect modulator. Also it is desirable once again to characterize the demodulator in terms of RF response. Furthermore, because of difficulties in measuring group delay at very low video frequencies, say from 200 KHz down, RF measurements are necessary. By making use of both RF group-delay and RF amplitude data, the baseband group delay can be calculated all the way to zero frequency. This technique accomplishes more than the simulation of an ideal modulator, it also simulates an ideal group-delay measuring device, in the sense that it is practically impossible to make the measurement at baseband.

How is this test implemented? A double-sideband modulator can be the source, but precautions the same as those for amplitude response must be taken. The Nyquist filter response must assure that no contribution is made to group delay from the region below the Nyquist slope. The method is valid over the entire video band except for the lower end from about 200 KHz down. The wideband modulator is driven by a video group delay source and the group delay detector is driven by the video from the demodulator under test.

For the region from 200 KHz down, a single-signal technique must be used. One approach is to apply to the RF input of the demodulator a signal directly from the group-delay source having a carrier frequency covering the range from 200 KHz above to 200 KHz below the picture carrier frequency. The resulting group delay data along with amplitude response will allow the calculating of the equivalent baseband delay from 200 KHz down to zero frequency.

What is Perfect?

Several examples have been cited of methods of simulating a perfect test instrument. Unfortunately even the simulation is not perfect. But whenever this approach is taken, the notion of specialization is suggested. That is, there is not any single instrument which can perform or aid in performing a plurality of functions in an optimum manner. When video enters a modulator, it is only natural to consider that a process has begun, the end of which is the delivery of that same video at the output of a demodulator. However, within that process are many sub-processes which can give greater insight into the final product than the final product itself. When it comes to testing a mod-demod system or any part of it, the notion of perfection is ever present. But somehow the desire for perfection is accompanied by an equal desire for simplicity. An attempt at simplicity was made in formulating each of the tests described. Furthermore, each test is designed to be the most accurate and straightforward for the parameter being examined.

Conclusion

It should be obvious that no attempt has been made to convey much detail about precision testing of head-end modulators and demodulators. One objective was to expose an engineering dilemma concerning accuracy both in the laboratory and on published product specifications. The dilemma was an obstacle to precision testing, namely the ideal modulator/demodulator. A second objective was to show that this dilemma was removed by recognizing that another course had to be taken. There is an ideal modulator/demodulator but not in the form normally expected. And if they ever do take the more familiar form, it will only be because the virtual instruments were used so skillfully.

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THE WORTH OF SECURITY

Dan Pike

United Cable Television Corporation
Tulsa, Oklahoma

ABSTRACT

Security is worth considerably more in a system with subscription Pay Television because more areas of potential loss, both in materials and service, are presented. This paper discusses the worth of security before and after implementation of subscription Pay Television. Treated are losses due to unauthorized connections to the cable system and losses to inadequate performance of the hardware protecting the pay service.

Decisions to pursue rigorous system security against unauthorized connections through the use of tags, locking terminators, audits, and closely controlled office procedures and supervision have previously been made using reduced theft of basic cable service alone as the benefit to be weighed against the cost. With the introduction of pay cable these considerations expand to many other areas which may very well establish the worth of security to be far above its cost.

Perhaps the most significant costs readily determined are the material costs that are lost to an illegal, or more correctly an unauthorized drop. Assuming a trapped system using a popular technique in which 100% trapping is conducted before the implementation of the pay service and subsequently the traps are removed from the drops of the pay cable subscribers, it follows that a trap will be installed on every illegal drop in the system and the direct material cost of that trap and the cost of its installation is a direct dollar outlay that will never be recovered. While the exact number of unauthorized drops in any given system is quite a debatable figure, it is generally established as a percentage of paying customers and may be ranged conservatively between five and forty percent. Documented examples show that a major market system where locking terminators and drop identification tags were used from the beginning phases of the system may have 10% unauthorized connections quite easily, and further work has shown that two separate independent sample audits performed on a major market system not using locking terminators revealed a 25 to 30% unauthorized rate there. Certainly existing traditional 12-channel systems having the accumulated unauthorized drops of several years that occur without the use of locking terminators or tags and other security measures may well approach 25%. Some factors contributing to the unauthorized drops, to be distinguished from illegal drops, may be office error, disconnects not performed, and errors of that nature rather than the deliberate and illegal connection by a subscriber to the cable system. Estimates in the number of unauthorized connections as a percentage of the total of unauthorized and illegal drops approach 95%.

For the purpose of examining the worth of security, a 10% unauthorized rate will be assumed. In addition to the cost of the material that would not be lost if adequate security were practiced, the reasonably recoverable revenue must be considered that will be gained from the use of security measures. Reasonably recoverable revenue is also quite a debatable figure and different audits have turned up many different percentages of recovered subscribers, but since audits are seldom measured for efficiency and marketing conversion procedures are very seldom performed in a consistent and well-defined manner a given figure cannot be derived. There is, however, reasonable documentation to support a 25% recovery of illegals and a 25% recovery of that number to the pay service and the revenue accrued from those percentages based on the given service rates for both basic and pay will be assumed to be the reasonably recoverable revenue that can be attributed to the worth of security.

To graphically depict these conditions the following assumptions will be made: 10% of basic subscribers are unauthorized or illegal; 25% of those are recovered to basic service; 25% of that number is recovered to the pay service; traps cost $5; their installation costs $1.50; basic service price if $7 per month and basic pay service costs $10 per month. The costs of audit will be assumed to be $.40 per home passed. In order to get a reasonable cross section of data, this material is drawn from four systems and the experiences enjoyed during the implementation of pay television in them. Two were major market systems built within the last three years and two were traditional 12 channel systems. Their locations vary between the central U.S. and each coast. Example I depicts these conditions and establishes that the basic plus pay reasonably recoverable revenue would be equal to the cost of the audit in a little less than four months. A line with that slope is added to the loss of material expected with a 10% unauthorized rate and yields about a one-month recovery against the cost of the audit. Included in example one for reference purpose are the losses incurred in material for the previous case which shows that material losses alone based on the past experience in those four systems, which can be construed as a reasonable cross section of the industry, may well exceed the cost of the audit.

From Example 1 it may be concluded that revenue realized from recovered unauthorized connections added to material otherwise lost revenue is significantly greater, even in the short term, than the costs of security hardware and technique.

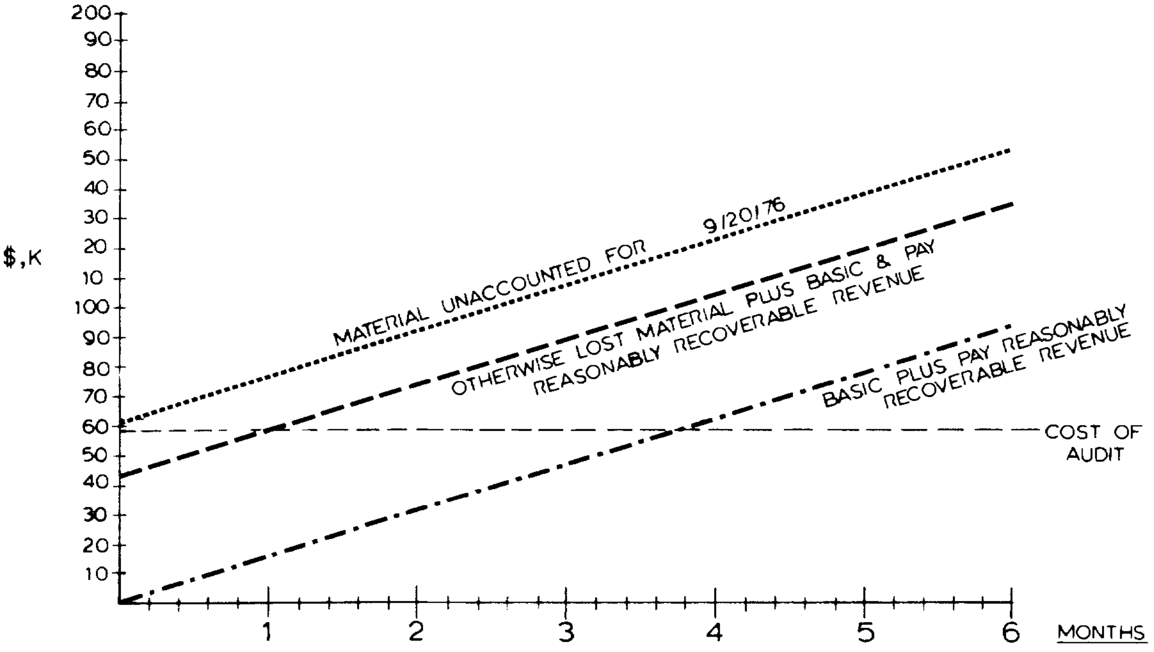
There are other areas of consideration that are somewhat less tangible that should be appraised in the worth of security. Consider the case of a remarket campaign where certain fees are waived or other concessions are made in an effort to gain subscribers. Certainly the amount of customers are known in a particular system and if the amount of illegals are estimated based on this number of known customers, then the number of customers, plus the number of illegals must be subtracted from the potential in order to know the number of homes that are potentially marketable. It stands to reason that existing cable customers and existing unauthorized connections will not be interested by any type of remarketing effort. Example 2 shows the percent of available customers for remarket plotted against percent saturation for three given unauthorized rates. These percentages are of potential to weigh out the various saturations of many different systems. The important point to realize is that traditional 12 channel systems which fall in the highly saturated areas have a great deal to gain in terms of the percentage of their potential customers who are interested in any kind of a remarket effort if they first reduce their unauthorized percentage rates to get on a more linear portion of these curves.

Further enforcing the worth of security is the intangible but quite logical line of reason that a subscriber converted from an unauthorized condition is much more likely to remain on the system since the service was appealing enough to steal or more probably was appealing enough that when given to him by office error or employee error he did not see fit to report it to the cable office. His propensity to stay on the cable is a great deal higher than the subscriber who is enticed to get on the cable by some concessions in fees or other sales approaches whose propensity to remain on the system decays rapidly when those run out. A quick comparison of dollars per subscriber made after a 90 day wait so that fluctuations caused by embarrassed unauthorized or illegal subscribers and those who are after something for nothing could die down could very well show that the recovered subscriber is worth more money in the long run than the remarketed subscriber and could very well cost less to recover.

Inadequate performance of the hardware selected to protect the pay service can also find its way into the worth of security if security is envisioned to include the maintenance of those devices, as it well should be, since very stringent efforts on security can never recover a basic cable subscriber that receives the pay service because of a faulty trap. There have been several efforts to define the minimum limits of these devices in order to secure a pay system against voluntary or unvoluntary theft of the service. A program should be established to accurately determine that the performance of those devices remains acceptable through their entire life. Recently it was documented that a subjective opinion by technically qualified people that would indicate 98% effectiveness of the units could occur at the same time that an analytical testing would show 15% effectiveness of those same units and it serves to show that subjective opinions by trained service technical people are based on the entirely different reference of a quality picture where subscriber acceptance and analytical testing are based on "something for nothing" or a given set of parameters, and the two have little or no correlation. Customer attitude would support the analytical opinion in the previously mentioned documentation. Very strict interpretations must be made if subjective evaluations are used to determine compliance with system parameters and effectiveness of the devices in the protection of the pay signal. The revenue from the estimated number of subscribers, yet undocumented, that would otherwise subscribe to the premium service that do not because of marginal or faulty hardware must be included to determine the worth of security.

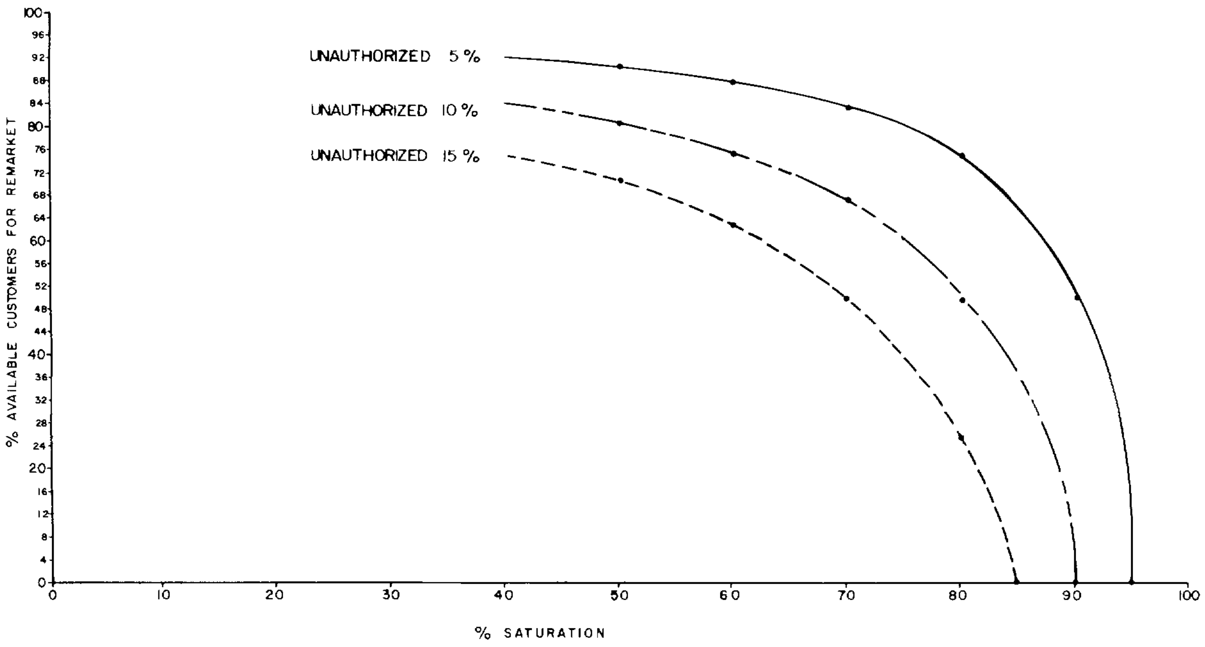
With a so-called positive device used in the home as a vehicle of delivery for the pay channel, be it a descrambler or decoder or converter or combination of those, the primary security effort lies in the recovery of those units from the churn encountered from all various reasons for the churn. Every unit not recovered is a loss in material dollars plus a loss of service dollars for the useful life of the product. With only moderate effort extended towards the recovery of those devices, approximately 75% may be assumed to be the recovery rate, and very strict efforts are required to recover all of the units that are put into the field. In addition, inventories must be very closely controlled and distribution prodecures very carefully monitored. Approximately 25% of the active customers per year may be assumed as a ball-park churn figure and if one out of four of those units are not recovered, the material dollars plus the loss of service dollars can well add up to more than the required cost of a more secure program. Documented churn factors, like documented recovery rates, vary widely and have approached 100% in some areas of certain systems.

The primary objective of this dicussion has been to point out using figures from actual experience and best estimates that security and its benefits must now be considered as they relate to many areas previously left out of the decision, especially with the introduction of pay television into any system with any type distribution scheme. The net result is that the worth of security extends into many, many areas, most of which are intangible in terms of absolute dollars, but certainly the conclusion to be drawn is that the decision for security quite clearly must come out in its favor.



EXAMPLE 1

EXAMPLE 2



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TV PICTURE INTERFERENCE STUDY
PART I - ENGINEERING ASPECTS

Archer S. Taylor

Malarkey, Taylor & Associates

ABSTRACT

A comprehensive study of viewer ratings for certain kinds of television picture interference experienced in cable television was recommended by the Cable TV Technical Advisory Committee (CTAC) Panel 2 and funded by the National Science Foundation. The study encompasses 30-channel intermodulation noise, discrete frequency interference, synchronous cross-modulation, and, for control purposes, random noise. Stimulus pictures were recorded on 2-inch quad video tape, and observed on a studio monitor under controlled conditions by over 700 viewers representative of the population as a whole. Part I describes the methods of simulating interference and recording stimulus pictures, and discusses the significance of the findings.

INTRODUCTION

One of the working panels[1] of the Cable TV Technical Advisory Committee (CTAC) established by the Federal Communications Commission in 1972 was assigned the task of determining "... either by properly controlled subjective testing or by ... analysis of existing literature, the significant relationships between picture quality ratings and ..." certain designated types of signal impairment (Fig. 1). The panel did analyze in detail the extensive and rigorous studies conducted in this area by the Bell Telephone Laboratories,[2][3][4][5][6][7] but additional subjective tests proved to be beyond the scope of the volunteer panel. The present project was undertaken on recommendation of CTAC Panel 2, with funds provided by the National Science Foundation.

The purpose of this project was to determine, by scientific experiment under controlled conditions, (1) the level at which certain kinds of interference can barely be seen, and (2) the level at which the interference is annoying. (Fig. 2) The data obtained from these experiments should prove useful guidelines for the engineering design and evaluation of cable television system performance.

OBSERVERS

Over 700 observers were carefully selected to match the adult population as to age and sex. Although most observers live in St. Louis, they were drawn from all economic and educational levels, including diverse racial and ethnic orgins. Some had good eyesight without glasses, others had poor eyesight and many wore glasses. All were paid a small stipend.

VIEWING CONDITIONS

The stimulus pictures were observed in a small carpeted room with homelike decor, in subdued lighting, 11 lumens/m^2 (1 foot candle) at the face of the picture tube. This is 50 times as bright as the room lighting in the Bell Telephone Laboratory[8] tests, and nearly twice as bright as in the TASO tests.[9] Even so, most of the observers reported that the room in which they normally watch TV is even brighter yet. Picture screen luminance contrast between reference white and black averaged about 92:1 in the center, ranging from 66 to 153 in the corners. Since screen brightness at reference white (about 79 cd/m^2) was somewhat higher than in most of the BTL and TASO tests, the actual scene contrast ratio was of about the same order. Viewing distance was 6 times picture height, as recommended by CCIR.[10] Bell Telephone Laboratory tests were at 4 times; and TASO, at 6-8.5 times.

TYPES OF INTERFERENCE

Three kinds of interference were selected for the tests because of their particular significance in cable television. (Fig. 3) Interference due to thermal noise was included in addition as a control so that the findings might be compared with the earlier findings of other investigators.

One kind of interference tested is intermodulation noise, perhaps better known as the composite triple beat, which has emerged as the principal factor controlling operational carrier levels in conventional cable TV systems. Arnold [11] [12], Pranke [13] and others have published some information in this area, based on somewhat limited investigations.

Discrete frequency interference (beats) was included because of wide discrepancies in the literature. Figure 4 is a composite chart showing four versions of the subjective effect of beats of various frequencies. Jeffers [14] and Schwarz [15] are in close agreement, with regard to the threshold of perceptibility for critical observers. The FCC report [16] gives very little information from which to deduce reasons for the much less critical ratings. No measured data have been published to support the CRTC curve specified in its BP-24 regulations. [17]

Although the industry has long recognized that the very high stability of the scanning rate for color television virtually eliminates "windshield wiper" cross-modulation, no scientific determination has been published upon which to base a new guideline to replace the long familiar 51-52 dB specification. While it is generally true that cross-modulation is no longer important as the limiting factor in conventional 30-channel systems, it is important in phase-locked systems, with either the harmonically related or constant interval channelling plan.

DISPLAY MONITOR

The physical characteristics of a photograph, such as grain size, modulation transfer, and contrast ratio can be measured with instruments directly on the face of the photo, for correlation with the psychological impression of sharpness in the minds of selected viewers in subjective tests. [18] [19] This is not (yet) possible with respect to the television image where the physical characteristics of the picture itself, as it appears on the face of the tube, cannot be analyzed directly. Instead, it is necessary to measure the characteristics of the electrical signal which produces the picture. Ideally, the measurement of signal characteristics should be made at a point in the circuit as close to the CRT screen as possible (See Figure 5). Since there are three signals at the cathode of the picture tube, containing red, green, and blue picture information, with luminance information encoded into all three, the closest test point to the CRT screen lies just ahead of the chrominance separator.

Unfortunately such a point does not exist in many TV receivers. For a variety of reasons, receiver designers frequently depart from the simple block diagram, often using special circuits to compensate for all kinds of signal errors and distortions. They are guided, quite logically, by the quality and cost of the end product, rather than by the convenience of a textbook block diagram.

It is apparent, however, that the portion of the diagram in Figure 5 following the indicated test point is a simplified representation of a video monitor, whose characteristics closely approach the NTSC ideal, are quite stable, and can readily be measured. Therefore, rather than using a particular make and quality TV receiver, the viewing experiments were designed around the latest model professional studio monitor, the Conrac RHB-19.

Thus, the thresholds of perceptibility and acceptability were determined in these experiments in terms of a signal to interference ratio measured at the test point in Figure 5. To translate these findings to the ratios at the RF antenna terminals requires only certain measurements in the laboratory, with appropriate instruments; additional viewing tests should not be necessary.

As an example, the experiments showed that the median observer could see interference at a signal to random noise ratio of 37 dB, peak-to-peak signal without sync relative to weighted rms noise, but did not consider it annoying. Dr. Tom Straus, of Theta Com, has shown [20] that, for an "ideal receiver," with correct Nyquist slope and flat i.f. response to 4.2 MHz, the weighted signal to noise ratio will be 37 dB at the test point when the carrier to noise ratio measured in accordance with the NCTA standard [21] (which incidentally is the same as the FCC Definition in Part 76) is 37.2 dB. However, if video peaking equivalent to, say 10 dB at 1.5 MHz, has been introduced to compensate for loss of luminance resolution, [22] then the NCTA ratio equivalent to 37 dB at the test point would have to be somewhat greater than 37 dB, perhaps 40 dB, depending on peaking frequency and magnitude. This effect can be measured in a laboratory without relying on viewing tests, so long as the CCIR noise weighting curve is valid.

Similarly, the relative amplitude of beats obviously depends on the i.f. selectivity curve, which can be measured in the laboratory. An r.f. beat at 0.5 MHz below the visual carrier frequency would have to be considerably stronger at the antenna terminals than one at 0.5 MHz above the visual carrier, to produce a signal to interference ratio at the test point which the experiment shows would be visible but not annoying.

Use of the video monitor reliably relates interference ratings to known amounts of signal impairment delivered to the receiver display circuitry. These data can then be related to interference ratios at the antenna terminals of any TV receiver by measuring the appropriate transmission characteristic of the receiver. Thus, video monitor data can be universally applied to any receiver, good or bad, and to future design improvements, as well.

STIMULUS PICTURES

A great deal of study and effort went into selection and production of the scenes to be displayed with impairments for the viewing tests. Three scenes were designed, and arrangements were made with Eastman Kodak Co. to produce both slides and movies in their Rochester studios. The slides and 35 mm motion picture film clips were made on negative film, using identical models, settings, lighting, exposures, and processing. The three slides and film clips were first generation positive prints. The Kitchen scene (Fig. 6) was deliberately staged as a very "busy" picture with lots of detail. The Exercise scene (Fig. 7) was deliberately designed to have large unbroken areas of moderately high luminance. The scene with Susan (Fig. 8) was designed to be "typical" of television, with a fairly close shot of head and shoulders, some background detail, and definite focus of attention. All scenes have areas of saturated reds, and all have flesh tones. The vertical stripes on the kitchen door were expected to show strobe effects in the presence of beats. For the special split screen tests, the center portion of two prints was cut and mounted in a split frame format with identical images on the two sides. (Fig. 9, 10, 11) One experiment was designed to compare interference ratings using slides with ratings for motion picture film clips. Ratings at different viewing distances were compared. Ratings by TV station technicians and TV repairmen were compared with ratings by the general public. The results of the experiments based on these slides, properly interpreted, are expected to provide reasonable guides for evaluating or specifying system performance.

VIDEO RECORDING

All of the stimulus pictures were recorded by the Public Broadcasting Service on 2-inch video tape, using Ampex AVR-1 equipment. Programmable attenuators were controlled by a microcomputer to produce preset ratios of signal to interference. Precise 5 and 10 second timing intervals were obtained by accurate cueing marks prerecorded on the tape. It is unlikely that the project could have been completed at all without the tape recorded stimuli. The inevitable human errors in setting attenuation ratios as well as in timing were also completely avoided by this technique. Inherent video tape noise was measured at 55 to 59 dB below 0.714 volt, weighted.

SIMULATION OF SIGNAL IMPAIRMENT

In conducting any scientific experiment, the variables under investigation must be varied in a controlled manner, with all other variables held as nearly constant as possible. To this extent, all scientific experiments are simplified simulations of a sample slice of "real life," in which certain variables are isolated for test purposes.

In these experiments random noise was isolated from all other sources of interference. A signal from an essentially flat noise source was passed through a 4.5 MHz band limiting filter, Fig. 12 and a special filter designed to simulate the effect of incoherence between upper and lower vestigial noise sidebands in the NTSC receiver/demodulator. (Fig. 13) By using the CCIR noise weighting filter [23] [24] [25] for the measurement, (Fig. 14) reasonable allowance was made for the reduced subjective effect of high frequency components of random noise. Figure 15 is a sample of the result, photographed from the monitor. This represents 28 dB S/N ratio.

A discrete frequency beat at approximately 1.25 MHz was selected as a reference on the basis of previous work indicating this to be the most sensitive portion of the video pass band of a TV receiver. Work is still in progress to compare the effect of beats at other frequencies (0.5, 0.75, 2.00, 2.50, 3.25, and 3.50 MHz) with the effect of the 1.25 MHz reference beat. (Fig. 16) For this experiment, observers viewing two monitors side by side will be asked to adjust the signal-to-interference ratio of one of the beats, using a conveniently arranged attenuator, until the interference appears to be equivalent to that of the reference beat.

It can readily be shown that a change of beat frequency of approximately 30 Hz results in a marked change in ability to perceive the beat. This is one of the reasons why beats on an actual TV screen usually seem to dance in and out of the range of perception. In order to isolate and control the variables, therefore, a synthesizer was used to generate the beat frequency with stability well within 0.1 Hz. Both the synthesizer and the sync generator were locked to a rubidium standard. (Fig. 12)

At integral multiples of the horizontal scanning frequency (i.e. even multiples of half the line rate), the beat pattern consists of stationary vertical bars. When the beat frequency differs from an integral multiple of the line scanning rate by an integral multiple of the field rate, the pattern consists of stationary bars, slanting at an angle depending on the ratio of vertical to horizontal multiples. Halfway between each stationary pattern, the visibility of the beat is greatly reduced. Tests are underway to determine how much it is reduced. Informal tests indicate that a frequency shift of only 30 Hz produces reductions of 10-20 dB. Between the stationary and the low visibility pattern, the bars are in motion across the screen.

The resultant reference beat is shown in Figure 17. Signal to interference ratio is 30 dB; frequency is 1,244,813.1 $\pm$0.1 Hz. In the video tape display, the slanting bars moved to the left at approximately 2 inches per second.

For beats in the chrominance band, 3.0-4.2 MHz, the beat frequency must be referenced to the chrominance subcarrier frequency. In addition to the six nominal beat frequencies listed above, one or more beats within $\pm$30 Hz of the reference will be compared in order to measure the improvement due to field and line interlace.

The frequency of beats occurring in a television system is usually controlled by source frequencies which are independently subject to drifting, often much more than 30 Hz. Obviously, therefore, "real life" beats will often tend to drift rapidly from worst case to best case. Furthermore, most beats result from modulated carriers, and are themselves modulated, though not always in a simple manner. The experiments did not include these effects, either of drifting or of modulation, because of the complexity of designing a suitable program for generating and displaying the effects in a systematic fashion without bias.

Intermodulation noise was generated by transmitting 28 unmodulated carriers (30 less Channels 5 and 6) through a wide band trunk amplifier at high enough level to produce a severe effect. (Fig. 18) A carrier approximately in the center of the array (Channel 8) was demodulated, along with its complement of several hundred triple beats. The detected video was then added, through a variable attenuator, to the desired video signal. The carrier frequencies were generated by run-of-production crystals used in the Dix-Hills Model SX-15 multi-carrier generator, and deviated from 5.1 kHz below nominal frequency to 8.4 kHz above. The "desired" Channel 8 carrier frequency was 2.1 kHz below its nominal value. The composite beat before demodulation was measured at 28 dB below the Channel 8 carrier, using the spectrum analyzer at 30 kHz bandwidth, with a 10 Hz video averaging filter. (Fig. 19) The detected composite beat was also measured at 26 dB below 0.714 rms V, using the HP-3400A RMS voltmeter, confirming within 1 dB the spectrum analyzer result, after appropriate adjustment.

Severe intermodulation noise generated by modulated carriers is always accompanied by sideband intermodulation effects which could not effectively be utilized for these experiments. These effects consist of patches of colored beats, phantom images, and moving patterns in a constantly, but slowly changing kaleidoscope which would have to be mentally integrated by each observer over a period of at least several minutes. Figure 20 is a photo showing the appearance of the simulated IM noise at 27 dB signal to interference ratio.

At the threshold of visibility, the use of CW carriers for the intermodulation noise test is reasonably representative of the actual situation, providing an adjustment is made, as suggested by Arnold [12], Pranke [13] and others to account for the shift in rms carrier level under clamped downward modulation. However, it seems more than likely that if an appropriate test could be designed, the threshold of annoyance due to the sideband effects would be at a higher signal-to-interference ratio than was the case with the unmodulated carriers, due to the cross-modulation effects.

One decisive fact demonstrated during the project was that video cross-talk and cross-modulation was definitely not the same. This is because the former is the sum of signal voltages, while the latter results from the multiplication of at least three signal waveforms. Whereas in cross-talk, the waveform of the undesired signal is not subjected to non-linear distortion, it is severely distorted by extreme sync stretch and white compression as a consequence of the cross-modulation process. The visual manifestation of cross-talk, as reported by Fowler and others, is a rapid "windshield wiper" effect whenever there is an appreciable difference between desired and undesired scanning rates. This stabilizes in a strong phantom image when the scanning rates are the same. (Fig. 21) Cross-modulation also produces a rapid "windshield wiper" effect when the scanning rates are unequal. But when they are equal, the extremely stretched sync and blanking predominate, while the phantom picture is so compressed as to be scarcely visible. (Fig. 22)

Interference stimuli due to cross-modulation were generated in a straightforward manner, using two modulators, feeding a trunk amplifier at high level, and a demodulator to detect the desired but impaired channel. (Fig. 23) Separate sync generators were used for each channel, locked to a common frequency standard, but slewed vertically and horizontally so that the undesired blanking bars were visible and stationary. The trouble encountered in this procedure was that the back porch clamps in the video monitor were confused by the undesired vertical sync and blanking, producing abnormal effects which would not occur in TV receivers with dc restoration. Because of this difficulty, it appears that the ratings for cross-modulation interference may be somewhat more severe than they would have been with a TV receiver. On the other hand, a sufficient difference in scanning rates so that the blanking bars moved across the screen at 15 second intervals would probably have been rated more critically.

To the extent that these two anomalies tend to cancel themselves, the results of the experiment may be considered to be reasonably reliable.

RESULTS

The next speaker will describe the psychometric procedures used and will summarize the results of the tests. Following this presentation, an interpretation and evaluation of the results will be presented.

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TV PICTURE INTERFERENCE STUDY
PART II - PSYCHOMETRIC ASPECTS

Robert E. Welch, Jr.

University of Missouri at St. Louis

ABSTRACT

Categorical procedures have been used almost exclusively for rating television pictures. Magnitude estimation, a well know psychometric technique, was employed in this study, perhaps for the first time for evaluating viewer perceptions of various kinds and degrees of interference with television pictures. Under a grant from the National Science Foundation, a comprehensive series of tests has been conducted, using video tape recordings and split-screen techniques, to measure the ability of subjects representing a cross section of the viewing population to detect specific interference, and their degree of annoyance because of interference. During the tests, interference from random noise, single frequency interference, intermodulation noise, and cross-modulation were investigated, separately as well as in combination. Some interesting findings from these studies will be reported.

USE OF LOW-FREQUENCY BI-DIRECTIONAL, DIGITAL TRANSMISSION ON CABLE

Michael L. Ellis
V.P./Director of Operations

ICC, Inc.
San Diego, California

Six years ago a major representative of one of the leading manufacturing companies said these words, "Cable Television of the future will include two-way, answer-back, communications for subscribers who desire it. Shopping, banking, opinion polls--and many other services--will be made available. But these things are tomorrow." -- Gentlemen, welcome to tomorrow!

The cable television industry has long been faced with the dilemma of meeting the social demands placed upon it by it's purported technological capabilities and the real problems of generating adequate income to support these humanitarian goals. Through the use of the Bi-Di-Comm system, we will describe how ICC has analyzed the goals and placed them within the realistic achievements of the cable television industry. We will also demonstrate where and how the additional revenue can be generated to not only make the cable television industry once again the profitable gold mine at the end of the rainbow, but also a valuable asset to the community which it services.

Introduction

Bi-Di-Comm represents a novel application of an old and existing technology, interfaced to the state-of-the-art RF world. The result of this is to accomplish many of the tasks previously referred to as the blue-sky of cable television.

The Bi-Di-Comm system is a bi-directional, digital data communications network generated from an intelligent home terminal unit and transmitted to a central computer location. The method of the transmission of digital information is through the use of pulse-code modulation at the 3 to 300 KHZ range. The use of low-frequency transmission is neither new nor novel when applied to the general communications media. Until recently, however, it has not been considered an acceptable method of transmission by the cable television industry.

When faced with the challenge to supply all the blue-sky, state-of-the-art capabilities, the CATV industry turned its' engineers loose on the 5 to 35 MHZ frequency band. (Unfortunately, this frequency band is not devoid of other transmitters and static generators. Among these generators is included the world's worst -- the citizen's band radio.)

From an engineering standpoint, a typical two-way RF system can be made to function very nicely in a laboratory; however, once subjected to the real-world atmosphere, it becomes a monster waiting to devour the unwary operator's potential profits along with a large portion of his operational capital.

It was for this reason that ICC looked towards an alternate method of transmission. We identified, prior to design, some of the real-world applications which might be used to generate additional revenue for the cable operator.

An examination of the potential markets indicated that there were three areas in which a cable operator could make very effective use of this technology to generate a substantial rate-of-return. They are:

1. Pay television on a pay-per-view basis with remotely programmable control of hardware in the home.
2. Police, fire and medical security surveillance.
3. Energy conservation and load management.

Before delving into the financial impact and applications of these three areas, I would like to discuss briefly the operational and technical considerations that made the Bi-Di-Comm system unique in its' application. The basic system consists of a central polling computer which may be divided into four parts:

1. Microprocessor for management of data processing.
2. Bulk information storage capacity of the central processor which normally uses a disc for rapid access to data files.
3. Dispatcher computer interface, whether it be video display screen, a hard-copy teleprinter, or both.
4. Computer I/O terminal board which is used to decode incoming data and also code the out-going data to be accepted by the subscriber home terminal unit.

Once the data leaves the central computer terminal, it is transmitted through the coaxial cable system; and, at special data reconstruction terminals located at key points along the CATV system, it is regenerated. Typically, such a data regenerator would be located at approximately every fourth CATV line amplifier.

Part I: Bi-Di-Comm Data Format -

Reference Figure 1

Upon entering the home, the signal is passed through an individual home terminal unit capable of data reconstruction prior to processing. The home terminal unit first identifies its' own unique address then receives the computer data word associated to that address. Upon completion of the receiver cycle, the transmitter portion of the home terminal unit responds back to the central computer with its' own set of data information.

Part II: Bi-Di-Comm Home Terminal Block Diagram -

Reference Figure 2

In order to more fully understand the various applications of a system of this nature, it is important first to understand the functional block diagram of the home terminal unit.

The home terminal unit consists of a duplex filter with its' high output fed into the input decoder network. This has as its' nucleus a phase-lock-loop that tracks the central transmitter frequency. When a start bit is received, it is analyzed by the start bit detector. This in turn enables the control logic to begin check-out of the transmitted address. The incoming address is compared with the units internal wired address. If, during the address transmission sequence, the two addresses do not compare, the control logic will be reset. Should all address bits be identified, the following transmitted computer data word will be stored in the receiving data storage register where it is used in controlling peripheral equipment.

Upon completion of the receiver cycle, the control logic enables the transmit portion of the home terminal unit to be activated. The transmitter frequency F 2 is derived from the control logic which is in turn derived from the master input clock located in the input decoder. This output frequency is modulated at a data rate. Data consists of the line-sync and start bit information, the data mode identification, the address code of the particular unit, and the data which has been entered into the transmitter data storage register. If the data has been received from the alarm mode of operation, it will override any serial data which might have been received from the remote control unit. In the normal mode of operation, the remote control unit, which is hard-wired to the main modem box, consists of a keyboard interfaced to a microprocessor which drives a two-digit, seven-segment readout. Data from this microprocessor is stored in a data storage register in the remote unit until such time as either the "C"-channel or the "R"-response key is depressed. This indicates that the user wishes to transmit one or the other back to the central computer.

The control logic from the main modem unit assures that the data are transmitted from the remote unit to the transmitter data storage module at the proper time sequence.

Significant features of this system are:

1. It is a self-reporting system, meaning that every time the computer interrogates an address, it must receive a valid response from that address whether the unit desires any action be taken.

2. It is a synchronous type system with both the line drivers and the home modem units tracking the frequency of the central transmitter at all times. This greatly reduces the complexity of the system and makes much more cost-effective use of all the internal logic.
3. Noise immunity is greatly enhanced by using a data rate which is less than one-fourth of the carrier frequency. This allows each data pulse to be sampled at the center rather than trying to compare an entire data pulse.
4. Through the use of the phase-lock-loop and the decoder network, the entire transmitted data stream is reconstructed prior to data processing.

Applications and Their Economic Impact

Now that we have had an opportunity to review the technological operations and flexibility of this system, I would like to discuss the applications as we see them in today's market place.

Part I: Energy Management

In our present day and age, it has become increasingly apparent to all concerned that the world is rapidly reaching its' functional limits in the area of available energy resources. As this energy commodity becomes less available, the basic economic system demands a higher cost. This increased scarcity and higher cost warrants the use of some means of improved energy management.

The average power used by the consumer in today's market is not of principal concern. What is of principal importance is controlling the peak energy demand. To this end, many agencies are seriously considering some method of time-of-day rate structure; and, there are several power companies presently reviewing methods of load control.

The bi-directional use of the Bi-Di-Comm system would readily facilitate the interface of a solid state meter. This could easily allow a utility company to do continous monitoring of a community and generate definite guidelines as to their rate structures.

In addition to this, along with rate structure information, the data can also give the power company the necessary information to make more efficient use of available energy.

Also aimed at the same goal of reducing the peak load required by any community, is the system's ability to implement a deferred-useage plan whereby such things as water heaters, air conditioners and space heaters could be interrupted for short periods of time with a minimum of inconvenience to the user and a maximum efficiency to the power company. The most logical means of accomplishing these functions would be over a coaxial wired system since it could be operated at a high frequency that is still well below video frequencies.

Further applications of energy load control using a bi-directional communications network would be in the commercial market, where monthly billing is based on peak load rather than average power consumption. In this case, a computer program would be utilized to direct the termianl controller units as to which items could be cycled on or off to stay within the energy guidelines of the industrial complex.

An example would be an organization with multiple machinery which might be cycled on at the same time. The computer could take over and insure that these units would be started on a sequencial cycle, thus reducing the peak load.

Power consumption information could be continuously fed to the central computer. As the power consumption increased, the computer would have in its' files a list of priority titles to indicate which service could be terminated for short durations to retain the most efficient level of energy consumption. The net result would be reduced energy bills to the commercial user and also reduced peak load capacity from the supplying power company.

An economic example of the applications of this system would be in the use of a commercial hotel complex, where, through a simple data entry at the front desk, the clerk could turn off the AC power to any room in the complex as the guests checked out. A short time prior to the new guests' arrival, the clerk could turn the power back on allowing the room to air out beforehand.

In one actual application, a hotel's monthly energy bill was $330,000. Through the application of this system it was determined that the user could save a minimum of $33,000 a month in energy bills. The approximate cost of installation for this system would be $125,000. Thus recouping the investment after only a few months.

Part II: Security and Public Safety

Through the use of this system, we have the ability to transmit priority data from a home terminal unit to a central dispatcher to help a subscriber in distress.

In a typical operating security system, these sources would be assigned to monitor such things as the power status of the home terminal unit. These could include: smoke detectors, heat sensors, exterior detectors, interior detectors and three separately identifiable panic situations.

Subscriber Information File -

Reference Figure 3A

The subscriber would fill out a data information sheet at the time of installation. This is fed into the computer and then assigned a computer entry code. This code would correspond to the computer address of the subscriber's home terminal unit at the residence.

Subscriber Data Sheet
Figure 3A

```
          Computer Address
Address                     Phone
Name      Age      Blood Type      Sex
Name      Age      Blood Type      Sex
Name      Age      Blood Type      Sex
Name      Age      Blood Type      Sex
     In Case of Emergency Notify:
Name           Phone
Doctor         Phone         Hospital

Special Instructions:
```

Typical Alarm Read-Outs -

Reference Figure 3B

Should any alarm sensor be triggered it would automatically override any other data presently being passed through the home terminal unit and would indicate an alarm message to the central station dispatcher, via both video display and hard-copy print-out. Such a display would indicate the name, address, phone number and any pertinent information pertaining to that type of alarm. The implementation of this system can be extremely complex or as simple as the operator desires.

If a medical alert were to be generated from a home, for example, it could be patched automatically to the local hospital. The hospital computer then could display the complete file history and the hospital would be prepared to receive the patient upon arrival. The same could be true in patching both security and fire alerts to the proper agencies.

Typcial Alarm Read-Outs
Figure 3B

```
  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  X                                 X
  X          Medical Alert          X
  X                                 X
  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Name
Address
             Notification
Name
Phone
          Physician/Hospital
Doctor                  Phone
Hospital                Phone
Special Instructions:

  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  X                                 X
  X            Fire Alert           X
  X Notify Residence/Local Station  X
  X                                 X
  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Name
Address
Phone
Special Instructions:

  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  X                                 X
  X          Security Alert         X
  X Varify and Notify Local Station X
  X                                 X
  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Name
Address
Phone
Special Instructions:
```

In the polling method utilized by the Bi-Di-Comm system, each home terminal unit is interrogated in sequence and must respond and indicate the status of that home terminal unit. In the event of an alarm, the central computer will automatically varify the alarm through consecutive interrogations - each interrogation taking approximately 2.4 milli-seconds. Through the use of the receiver data lines, any sensor, such as a smoke detector, may be reset and retested through the central computer without human intervention. This further reduces the false alarm rate.

There are two alarm functions that could be generated because of interrogation. The first would be a "no-response" alarm which indicates that the home terminal unit has completely failed to respond. The second would be an "incorrect address response" which would indicate that the home terminal unit has attempted to respond but that it's address does not match the one transmitted by the central station. Both of these methods of detection are designed to prevent the possibility of an undetected electronic or mechanical failure in the system or to show up any attempt to subvert the system in its' normal operation.

From an economical standpoint, it has been projected that a typical two-bedroom condominium could be completely wired for security for less than $300. A monthly service rate for monitoring police, fire and medical alerts from such an installation might be in the $15 to $30 range.

There is also a growing market in the public health and safety fields with new legislation being passed daily for high-rise buildings and private residences requiring installation of fire and public safety monitoring systems.

I would like to point out that the cable operator has a unique opportunity to step into the lucrative security field. The justification of this security market lies in the fact that there are 2.6 million burglaries reported annually. This translates into one burglary every eleven seconds! The security market was a five billion dollar annual industry in 1974, and has grown to a seven billion dollar industry today. By 1980, it is projected to be an industry of thirty billion dollars.

Part III: Subscriber Response Capabilities

Through the implementation of a remote terminal device interfaced to the Bi-Di-Comm home terminal unit, a subscriber can generate a two-digit numerical response on a pseudo-random-basis and, through this method, respond to a situation presented on a television channel. The cable television industry can offer the possibilities for pre-school, high school and Educare programs for senior citizens.

The use of the Bi-Di-Comm system capability in the area of subscriber and instructor interaction lends itself to solving many of the educational concerns of home teaching. No longer would the subscriber be tied to the traditional 6 a.m. to 11 p.m. instructional television. Programs could be offered at the viewers' convenience. Students who have been assigned to double sessions at their regular school could utilize a system of this type to derive additional educational benefits and homework assistance.

At the present time, many shut-in students are denied educational opportunties that their healthy counterparts enjoy. Through this system, complete classes can be taught with examinations being taken by the home student. This would allow the instructor to immediately evaulate the level of comprehension of the students.

Through the use of indicator lights on the remote terminal keyboard, the student can immediately tell whether or not his response to the questions asked were correct. The applications of this system become readily apparent when one views the utter chaos in the school systems of the Eastern United States due to poor weather conditions. If a system like this would be implemented, the closing of classrooms would not have such damaging consequences as they presently have.

Other remote response capabilities of this system could be utilized in conjunction with our local political system. An example is a city council meeting where citizens are asked their opinions on matters of issue. Here, several options are presented and the residents are invited to respond with their desired opinion. This means true democracy for the people when they can be heard - here - at the grass roots level.

From an economical standpoint, the cable operator should be interested in educational applications of the cable television system because the typical school system looses seven hundred dollars for each student who drops out. They must then send an instructor out to give home lessons to the student if they wish to retain their federal and state subsidies. Through the use of this system and its' ability to do roll call, testing and complete educational functions, the school system can make much more economical use of their teaching resources. The cable operator would have a desirable and saleable product to school systems in addition to offering an invaluable service to the entire community.

Cable television relies heavily upon its' public relations appeal and its' application of ancillary services to generate new subscribers. In the past, this has always been an area of negative cash flow. Through the use of the Bi-Di-Comm system, the cable industry is offered the ability to supply a multitude of services previously referred to as the blue-sky applications to its' subscribers and, above all, generate a reasonable profit.

Part IV: Premium Television

Traditionally, pay television has been handled through the use of either a specially allocated, although not normally available, channel or by installation of a specially prepared descrambler box placed in the home of the individual wishing to view the pay television program. Some of the disadvantages of a system of this type are that whenever the subscriber desires pay television service, a piece of physical hardware must be installed and when they wish to discontinue this service, that piece of hardware must be removed. Another disadvantage is the fact that the user must subscribe for a minimum period of time and must accept any and all programming that is available during that period of time whether they find it pleasing or not.

The Bi-Di-Comm system incorporates the remote terminal keyboard as a converter control. When a subscriber desires to change channels, the central computer is automatically notified and can implement individual pay television programs.

An example would be if a particular channel were allocated as a pay-television channel, and a resident selected that channel for viewing, the computer would receive notification when the channel was tuned in and could allow the resident to preview that channel for an arbitrary period of time. At the end of that time, the computer would reinsert the scrambling. The viewer would then have the option of recalling the channel or of turning on a non-pay channel. Should the viewer choose to recall the program, the computer would take care of any billing and allow the viewer to continue watching.

The principal advantage of the Bi-Di-Comm system is to allow for a true pay-per-view type system where total control of what the subscriber desires to see and pay for is in their hands. The entire system relies on software computerized control as opposed to hardware implementation. A multitude of such channels might be activated without changing the existing hardware in the user's home.

In addition to the pay television capabilities of controlled channel selection, the cable operator is immediately presented with a totally new capacity of supplying secure channels for special interest groups, such as doctors, teachers, lawyers, etc., whereby only certain home terminal units would be authorized the use of certain channels during specific times of the day. Once again, total control is by the software programming as opposed to any hardware installation.

Because of the data recording system, the cable operator can generate revenue from their ability to supply broadcast stations and advertising agencies with statistical data as to the number of people watching any program or commercial at any given time. This data can be derived from the computer since any individual using it to change channels is automatically recorded by the central computer. Through special programming, this data may be accessed by the cable operator.

Also inherent in the system capacity is the ability to do automated billing and credit reference checking by the computer on each subscriber who uses a premium program.

A typical example would be a client who indicated at the installation of the system that they did not wish to exceed a given amount of premium program or ancillary service charges during a thirty-day period. The computer would take care of billing each time service was required by the subscriber. If the subscriber approached his credit limit, the computer would notify the central dispatcher who in turn could notify the user and ask if he desired an extension on his credit limit.

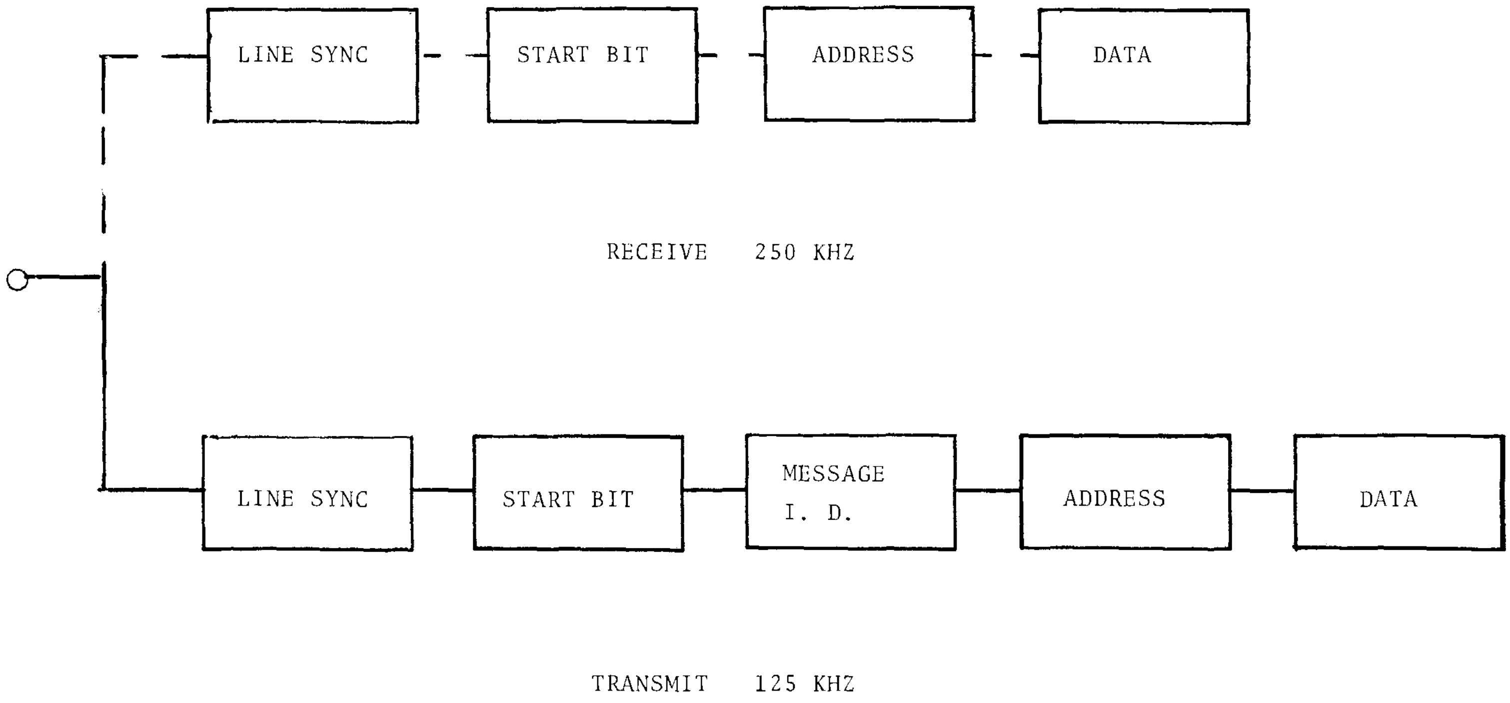
Summary

I would like to reemphasize that th Bi-Di-Comm system allows the cable operator the advantages of two-way data communications over an existing cable television plant with a minimal amount of changes or additions.

Now that you have had the opportunity to review the Bi-Di-Comm system with me and analyze both the technological and financial advantages it offers, I am sure that you will agree that the blue-sky promises of the cable television industry are here today.

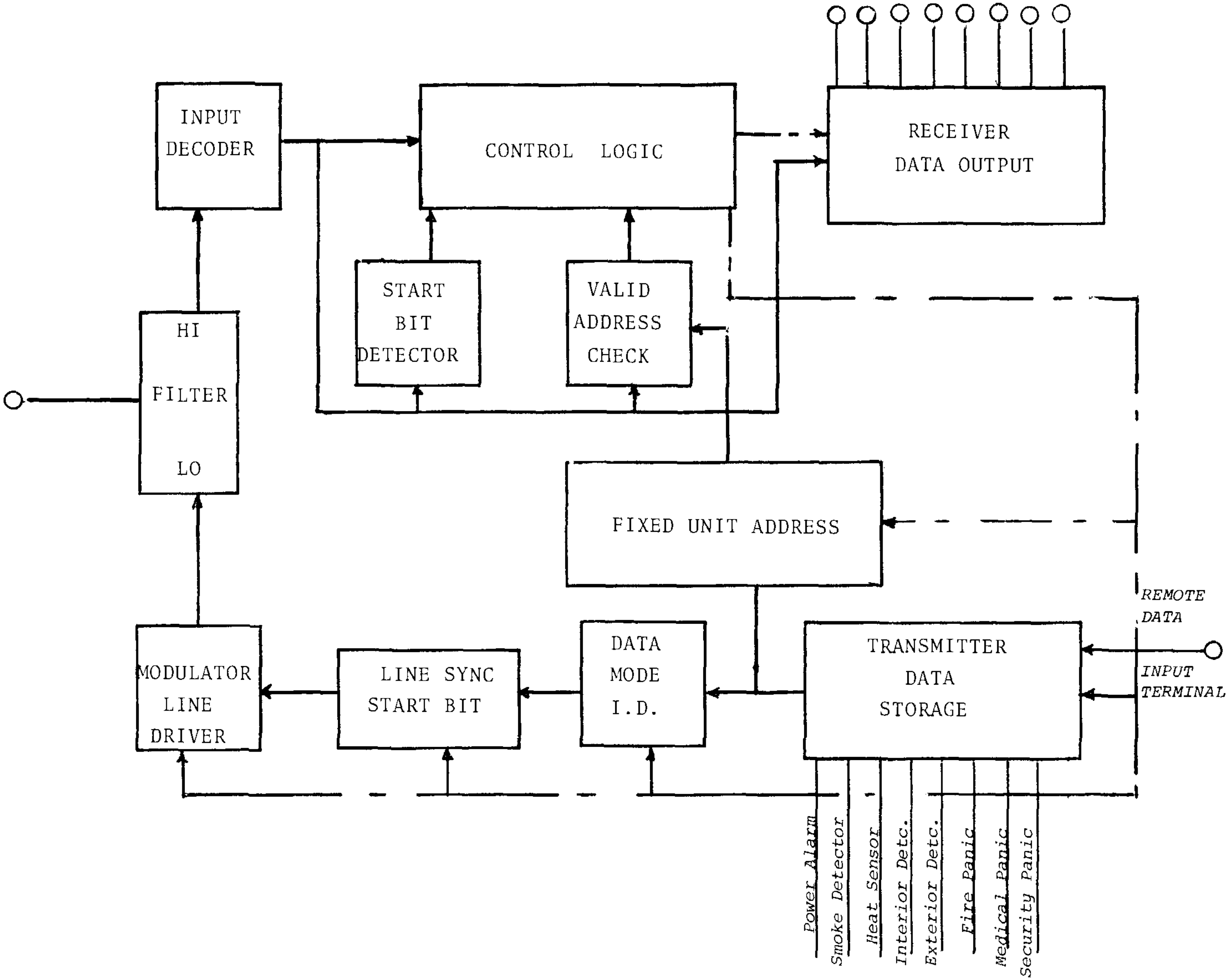
BI-DI-COMM DATA FORMAT

Figure 1



BI-DI-COMM HOME TERMINAL BLOCK DIAGRAM

Figure 2



VIDEO TAPE CASSETTE DUBBING AND OPERATIONAL IMPROVEMENTS

Edward W. Stark

Cox Cable Communications, Inc.

In June 1976 the NCTA formed a 3/4" Video Cassette Subcommittee to study the problems of VTR operations and to make recommendations and write standards. This paper will briefly touch on the VTR's history in CATV and will preview the standard and recommendations expected from the committee.

Video tape recording and playback machines have been in CATV operations in significant numbers only about 10 years. The first ones used were 1/2" reel-to-reel machines made for playback into video monitors. The video response and signal-to-noise performance was poor, the machines stretched and tore the tape, and they typically spent more time on the repair bench than they did in service.

While our early experiences were frustrating, they were also educational, and we soon developed a list of improvements that would have to be made if VTR's were to gain widespread use in cable television. The major improvements on the list were:

1. Improved recording and playback quality, primarily in the area of signal-to-noise performance.
2. Simplified operations and maintenance.
3. Improved quality tapes.
4. Reduced costs of machines and tape.

Manufacturers responded to the problems and continued to improve their products and today we have a simplified 3/4" video cassette machine that provides reliable service and good signal-to-noise performance.

The major problems have now shifted to dubbing quality and operational control.

In June 1976 the NCTA formed a 3/4" Video Cassette Subcommittee to study the problems of VTR operations and to make recommendations and write standards. The committee is staffed by seven experienced engineers chosen from operating CATV companies, program suppliers and tape dubbing companies. The committee has met a number of times and has defined the problems and is busy seeking solutions, and writing standards and recommendations. Since the committee is not yet ready to publish its material the remainder of this paper will explain the quality control and operating procedures now in effect at Cox Cable Communications.

Inventory control of incoming tapes is of utmost importance. Immediately upon receipt the tapes should be delivered to the control room to be stored for a minimum of 24 hours to allow temperature and humidity stabilization in a controlled environment. The tapes should then be played according to an established procedure and compared to an established standard. Any problem found in tape quality should be reported immediately to the dubbing company. Sometimes this report is only to alert them to a quality control problem, but other times it may be necessary to ask for a replacement tape.

Cox Cable has a minimum test analysis using only a waveform monitor and a video monitor. The figure of merit is arrived at on a comparative basis using a Sony video alignment tape as the reference. This checks the operation of the playback unit and provides a measurement of quality available even to the smallest operation.

The most critical factors on any video signal are the proper levels of white peaks, black peaks, sync tips, and burst.

These can be noted by simply viewing the overall signal on the waveform monitor. This leaves the problems of blanking noise and chroma level or color saturation noise. Excessive blanking noise shows up on the video monitor as a form of horizontal, multi-colored, segmented lines which might be referred to as snow or glitches in the pure video picture. Excessive chroma level manifests itself in the amount of color in an object which can be taken to a point where the object loses its contrast and shape and becomes a brightly colored blob.

The chroma and blanking levels can be measured on a waveform monitor, hence we can perform the tests for comparison.

At the start of the test each tape should be run fast forward and then through rewind to release tension on the tape.

Chroma Level: Set the response switch to the chroma position and the sweep switch to the 2H position. Make note of the maximum chroma information reading, that is, the information above the blanking level. Take readings from five different places on the reference tape and obtain an average to be compared with similar readings taken on the tape under test.

Blanking Noise: Set the response switch to the flat position and the sweep switch to the 1U Sec./Div. position. Using the vertical position control, place the lower limits of the blanking line on the blanking line indicator. Take the measurement for the maximum total width of the overall blanking pulse shown in the trace. To determine voltage use the IRE scale on the scope face for amplitude readings and convert to voltage by multiplying the IRE scale number by .00714. This gives a peak-to-peak voltage reading.

After taking the necessary readings, determine the dB merit figure through the formula:

$M = 20 \text{ Log } E_t/E_r$
E_t = Test tape voltage reading.
E_r = Reference tape voltage reading.

A merit figure of 1.5 dB or less is considered good and anything over 2.0 dB is unacceptable.

The results of the above tests performed with only a waveform monitor and a video monitor will aid in explaining problems to the dubbing company. When the results are acceptable they should be recorded and filed. When unacceptable, the reasons must be communicated to the dubbing company and a new dub ordered for immediate shipment.

The best of tapes and the best of equipment will provide quality programming only when proper operating procedures are observed. The following is a brief summary of Cox Cable control room operating procedures.

1. General Rules.
   a. No smoking, drinking, or eating in the control room.
   b. No unauthorized personnel in the control room.
   c. Operation and maintenance of the equipment shall be performed only by those technically qualified and authorized to do so.
   d. The operator shall maintain the general cleanliness of the control room.
2. Equipment.
   a. Only minor maintenance will be performed by the operator. If a major problem arises the operator shall immediately notify the video engineer or other personnel authorized to perform the required maintenance.
   b. The tape heads, guides, and rollers shall be cleaned after each tape is played and before the start of each telecasting day.
3. Video Tape.
   a. All video tapes shall be stored in a lockable cabinet in the control room.
   b. All shipping and receiving of video tapes shall be handled by a designated member of the control room staff.
   c. No video tapes other than those specified for telecast shall be allowed in the control room at any time.
   d. Any prospective outside tapes that are to be previewed for possible telecast must have the approval of management before being brought into the control room for viewing.

4. Operations.

a. All telecasts shall follow a standard format and shall be subject to a written log to be maintained by the operator on duty.

b. Corrections on the log shall be made by the operator on duty. The operator making the corrections shall strike through the original entry, write out the change information and initial and date the entry.

c. A discrepancy report shall be maintained by the operator on duty. This will record any irregularity, whether caused by equipment malfunction or operator error. It shall be written at the time of the discrepancy and shall report the event being telecast, the nature of the irregularity and what was done to correct it. The operator shall then sign and date the entry.

The two final areas of needed improvement go beyond the control of the operator or the dubbing company, all the way back to the film producer.

Until very recently the dubbing companies received from the producer only theatrical prints for transfer to video tape. The contrast ratio of the theatrical print is greater than can be reproduced on video tape. When the light parameters are compressed to meet the limits of video tape, black picture detail is lost. Even with black stretch circuits the black areas of a scene produce black chroma noise on the subscriber's TV screen. Some producers now supply companies with flash prints. The process of flash printing decreases overall film density. The light shift in the transfer of the film from the theatrical print to the flash print enhances black detail while compressing some white detail. This process is usually a single setting correction of the entire film and gives an overexposed look to the lighter scenes. The flash print, even with the overexposed lighter scenes, is a great improvement over the theatrical print.

Many scenes filmed for theatre viewing lose impact or artistic value when cropped for television's 4 to 3 aspect ratio. Film producers and directors need to recognize the differences in the two mediums and stage the scenes for acceptability to both. In rare cases where this is not possible the same scene should be filmed separately for each medium. Finally, credits should be positioned so as not to be lost in cropping or should be filmed separately for the television print.

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