THE COMPLETE
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400 MHz CATV SYSTEM PERFORMANCE STUDIES

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ABSTRACT

Composite triple beat measurements of various trunk cascade lengths operating to 400 MHz with fifty-two channel loading are compared to various trunk cascade lengths operating to 300 MHz with thirty-five channel loading. The performance of distribution amplifiers is similarly compared. A system model from which these measurements were obtained is described and the calculated performance based on specifications is compared to actual performance. The improvement to subjective picture quality when using phase lock techniques is discussed. Cross-Modulation and Second Order Beat distortions are not addressed by this article.

INTRODUCTION

The primary objective of this paper is to give the end user of 400 MHz active system components some insight into the actual performance degradation when expanding from 35 to 52 channel loading. It seems meaningful that this subject be addressed due to the skepticism that has been expressed with regard to expanded channel operation. As more 400 MHz data becomes available to the industry, an improved confidence level will be shared. Toward this end, the distortion characteristic of Composite Triple Beat will be treated herein. To facilitate the study of composite triple beat behavior, a system model was designed and constructed.

SYSTEM MODEL

The system configuration for the evaluation, based on performance specifications, was divided into three segments, such that equal distortion contribution would result from: 16 trunk amplifiers; one bridger amplifier; and two line extenders operating at 300 MHz or 400 MHz.

Figure 1 summarizes the resulting operating levels that were chosen, and the distortions that would result in a 300 MHz system with 35-channel loading.

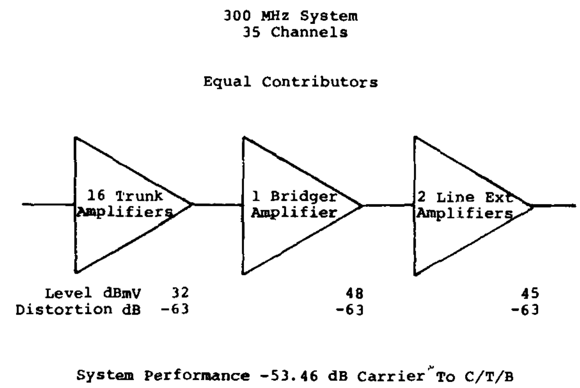

Figure 1

The relative distortion level of -53 dB, which is the recommended minimum level as indicated in the NCTA standard of "Good Engineering Practices for Measurements on Cable TV Systems", was chosen as a reference.

Figure 2 indicates the relative distortion level that would result based on specifications when seventeen channels are added to the system model as introduced in the previous figure.

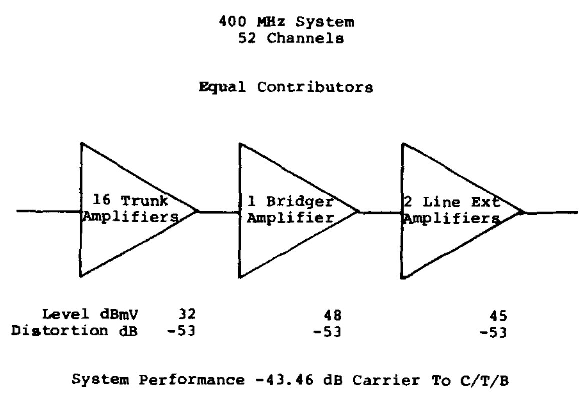

Figure 2

The barely perceptible point for composite triple beat distortion has been established at a relative distortion level of -51 dB. Therefore, the resultant relative distortion level of -43 dB would be unacceptable in terms of subjective picture quality unless a technique such as coherent carriers is utilized.

DATA FORMAT

Two of the 35 channels were characterized to represent thirty-five channel performance. Channel 11, because mathematically it has the maximum number of beats that fall around the carrier and channel 35 which represents worst case performance based on previously accumulated data. Similarly, channel 28 and channel 50 were selected to represent 52 channel performance. NOTE: 43 channel data is also included on all graphs.

In order to provide a logical progression, it was decided to initially treat the trunk cascade, the bridger amplifier and the line extender cascade as separate units, and then finally to evaluate the three components together as a transportation and a distribution system.

TRUNK CASCADE ANALYSIS

Data accumulated during the system study confirmed that composite triple beat distortion increases as a function of frequency and is graphically illustrated in Figure 3.

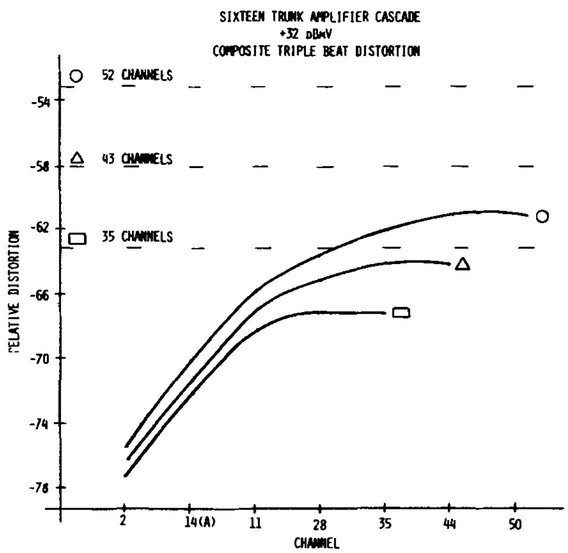

Figure 3

The horizontal lines that are contained in this graph and subsequent graphs indicate the present Jerrold specification limits. They are included for reference purposes only.

The data contained in Figure 4 provides a basis for numerical comparison of a trunk cascade performance using the worst case channel for each of the loading conditions indicated. It should be kept in mind while making comparisons that no attempt was made to select amplifiers with equal distortion contributions as individual units. However, due to the fact that both channel loads were applied to the same cascade, the true value of this information can be realized by comparing the distortion degradation that resulted as a function of channel load. By comparing thirty-five channel data from the cascade locations listed, it can be determined that a 20 LOG N degradation applies (ie: 20 log 16 = 24 dB). Making the same comparison for 52-channel loading suggests a cascade degradation of less than 20 LOG N.

TRUNK AMPLIFIER BEHAVIOR

OUTPUT LEVEL +dBmV	35 CHANNEL CASCADE 1	4	16	52 CHANNEL CASCADE 1	4	16
32			67.0 (63)			61.0 (53)
34			62.5			56.0
36		69.0	58.0		59.5	52.5
38		65.0	54.0		55.5	48.0
40	74.5	60.0	50.0	64.0	52.0	43.5
42	69.0	56.0	46.5	59.5	48.5	39.0
44	65.5	52.0		55.0	45.0	
46	61.5			51.5		
48	57.0			47.5		
	(Spec 47dBmV for -57dB)			(Spec 47dBmV for -47dB)		

Figure 4

BRIDGER AMPLIFIER ANALYSIS

The performance of a bridger amplifier operating as a single unit with various channel loads can be determined by referring to Figure 5.

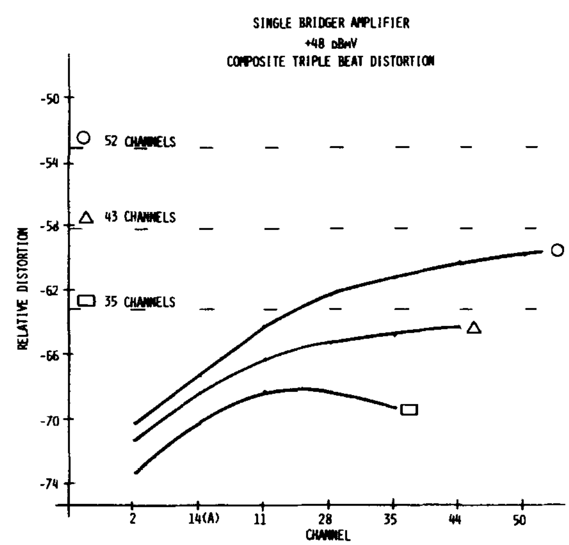

Figure 5

The bridger amplifier was operated with 6 and 8 dB slope for 35 and 52 channel loading respectively. Sloped operation is utilized to maximize the output capability of distribution amplifiers and to minimize tap level variation across the frequency spectrum. It is significant to note that the margin of distortion remains relatively constant regardless of channel loading.

The tabular data in Figure 6, as well as the graph in Figure 5, indicate the distortion degradation that occurs when seventeen additional channels are added.

BRIDGER AMPLIFIER BEHAVIOR

OUTPUT LEVEL +dBmV	35 CHS 6 dB SLOPE CH 11	CH 35	52 CHS 8 dB SLOPE CH 28	CH 50
46	72.0	73.5	67.0	65.0
48	68.0	69.0 (63)	62.0	59.5 (53)
50	63.0	65.0	57.0	53.5
52	59.0	61.5	52.0	48.0
	(Spec 51 dBmV for -57 dB)		(Spec 51 dBmV for -47 dB)	

Figure 6

LINE EXTENDER CASCADE ANALYSIS

Line extender performance with added channel loading tends to resemble that of the bridger amplifier. Refer to Figures 7 and 8. Note that when comparing the tabular data contained in Figure 8, that channel 28 was the worst case channel for thirty-five channel loading as indicated in Figure 7.

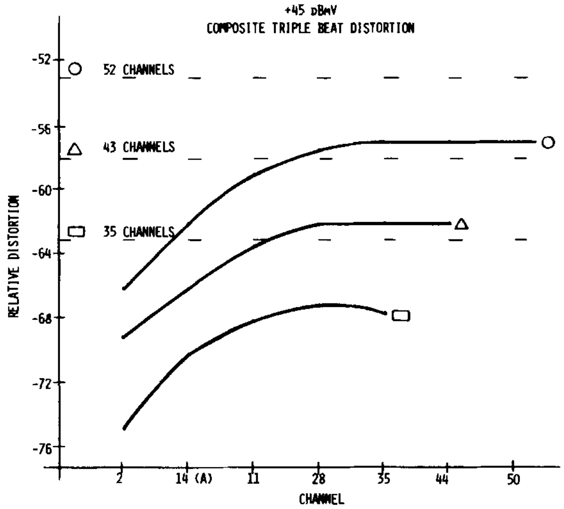

Figure 7

COMPLETE SYSTEM ANALYSIS

The cumulative distortion that was measured after the component parts were connected together to form a typical system is contained in Figure 9.

TWO LINE EXTENDERS IN CASCADE

MEASURED BEHAVIOR

OUTPUT LEVEL +dBmV	35 CHS 6 dB SLOPE CH 11	CH 35	52 CHS 8 dB SLOPE CH 28	CH 50
43	71.0	71.5	61.0	60.0
45	68.0	67.5 (63)	57.5	57.0 (53)
47	63.0	63.5	53.0	52.5
49	59.0	59.0	49.5	48.0
51	54.5	54.5	44.0	45.0
	(Spec 48dBmV for -57dB)		(Spec 48dBmV for -47dB)	

Figure 8

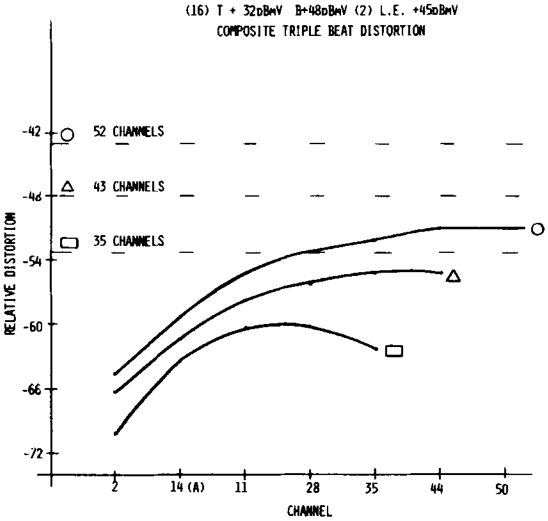

Figure 9

Upon inspection of the distortion data accumulated for each of the elements of the system model on a per amplifier basis at specification level, one can conclude that the degradation in composite triple beat performance by expanding from 35 to 52 channel loading was 10, 9.5 and 10.5 dB for trunk, bridger and line extenders respectively, or approximately 10 dB. This degradation is a result of additional beat accumulation associated with 52 channel operation and loss of amplifier performance as a function of frequency. The data also reveals that the trunk as a cascade of amplifiers only degraded by 6 dB under 52 channel loading at +32 dBmV, instead of the anticipated 10 dB. The bridger and line extender cascade degraded as expected.

In order to investigate the contribution of the trunk distortion to the overall system distortion, it was decided to increase the trunk operating level in two dB increments while maintaining the bridger and line extender output levels constant.

The results of this experiment are tabulated in Figure 10. It is worthwhile to realize that as the trunk level was increased, the thirty-five channel system distortion specification was reached with the trunk operating at +36 dBmV. The fifty-two channel system specification was not reached until the trunk was operating at +38 dBmV.

SYSTEM BEHAVIOR

SYSTEM COMPONENT LEVELS +dBmV			300 MHz 35 CHS		400 MHz 52 CHS	
16 TR +	BR +	2 LE	CH 11	CH 35	CH 28	CH 50
32	48	45	60.0	62.0 (53)	53.0	51.0 (43)
34	48	45	56.5	58.0	50.0	48.0
36	48	45	53.5	54.0	48.5	46.5
38	48	45	50.0	50.5	46.0	43.5

Figure 10

ADVANTAGES OF PHASE LOCK

The recommendation that coherent carrier schemes could be used to reduce perceptible distortion, thus, allowing a significant increase in the number of channels to serve the same geographic area formerly limited to thirty-five channel distribution, is viewed as a "gimmick" by some individuals. Coherent carrier schemes are not new and have been used for many years to improve system margin and/or system reach. If coherent carrier schemes are truly a "gimmick" used to improve the subjective picture quality of a television channel, then push-pull amplifiers, which reduce the effect of second order distortion, must also be classified as a "gimmick".

Subjective evaluations of picture quality that resulted from the system model carrying thirty-five and fifty-two channels have been made in the laboratory. Tests were conducted using both the coherent and non-coherent modes. A group of trained observers established the point of barely perceptible distortion on the channel exhibiting the most distortion. Test results indicated that a system of either thirty-five or fifty-two channels can be operated 5 dBmV higher when coherent carrier schemes are applied to a non-coherent system. A fifty-two channel system using coherent carriers has the same or a slightly better "barely perceptible" reference as the identical non-coherent system carrying thirty-five channels.

SUMMARY

A system model was designed and constructed to evaluate composite triple beat behavior in systems operating to 300 and 400 MHz. Comparing earlier 300 MHz system data to this data verified that no degradation in 300 MHz system performance was introduced when utilizing 400 MHz amplifiers over previously available 300 MHz amplifiers. The behavior of a 35 channel 300 MHz system complied with the 20 LOG N degradation formula. The degradation in trunk behavior of a 52 channel 400 MHz system was less than 20 LOG N. The distortion margin of the bridger and the line extenders, when comparing specification vs. measured performance, remains relatively constant regardless of channel loading. The improved performance of the trunk cascade in 52 channel 400 MHz systems could be utilized to improve the carrier to noise ratio of the system. A system of either 35 or 52 channels can be operated 5 dBmV higher when coherent carrier schemes are applied to a non-coherent system. A 52-channel system using coherent carriers has the same, or a slightly better "barely perceptible" reference as the identical non-coherent system carrying 35 channels.

A COMPATABLE STEREO SYSTEM
VIA SATELLITE

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ABSTRACT

In the domestic satellite medium video service generally enjoys the allocation of full transponder bandwidth. Such allocation can provide abundant spectrum space for in band, ancillary services.

Thoughtful use of the available spectrum and efficient modulation loading can yield dynamically increased information transfer with little more than statistical impairment to extant signals.

One such application provides for the enhancement of satellite delivered program audio into compatible non-redundant stereo.

The technique addressed is an adaptation of the sum and difference scheme introduced by Zenith - G.E. in 1961 and applied here to the conventions of satellite transmission into CATV systems.

INTRODUCTION

To efficiently distribute FM stereo signals without loss of fidelity or monophonic compatibility the multiplex scheme of L+R, L-R double sideband suppressed carrier was put into use in the United States.

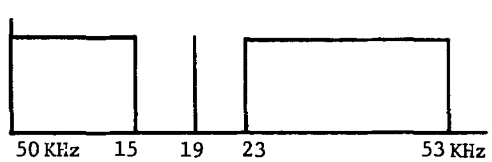


Fig. 1

To the credit of it's developers it has enjoyed widespread acceptance since its inception despite what from a strictly parametric appraisal, was a compromise of virtually all major modulation parameters, in the interest of compatibility. i.e. The FM broadcast band, developed to accommodate a monaural baseband (1 channel audio not exceeding 15KHz) set a peak deviation limit of 75 KHz. As figure 1 indicates to incorporate stereo, a second baseband channel must be multiplexed above the first, extending the baseband excursions to 53KHz. This reduction in FM improvement ratio coupled with the anomolies of de-matrixing the sum and difference signals results in a S/N reduction, in stereophonic reception, of some - 20dB from monophonic reception of the same signal. It is beyond the scope of this paper to discuss further, however, since stereo transmission constitutes the vast majority of all current FM broadcast allocations, it's nearly universal acceptance, despite the inherent degradations, bears testimony to the dynamic subjective appeal of stereophonic sound in the transmission of music.

SATELLITE APPLICATIONS

The application of the sum and difference technique to satellite video transmission however may exploit the scheme to much greater advantage in the absence of the stringent deviation constraits imposed by broadcast regulations.

Two techniques will be discussed:

1. Adhere strictly to NCTA recommendations for main aural subcarrier modulation. The advantage being compatibility in an existing universe.

2. An optimum modulation loading and signal processing technique, emphasizing audio as the prominant signal component.

In both cases, the proposal utilizes generic or public domain techniques. The affiliated participant is not limited to proprietary equipment designs in an as yet undefined equipment universe.

A simple technique for obtaining sum and difference signals is indicated in figure 2.

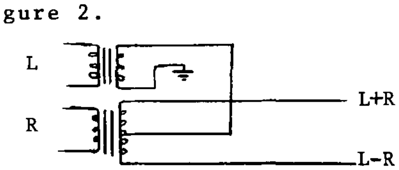


Fig. 2

In the (L+R) output, left and right channel baseband inputs are added to form the monaural signal for use in conventional reception.

In the stereo receiver the (L-R) signal is combined with the (L+R) signal to regain the original left and right channel, stereo relationship as follows:

$$(L+R) + (L-R) = 2\,L$$
$$(L+R) - (L-R) = 2\,R$$

To provide the stereo receiver with proper information to perform the above summation it is necessary to transmit the stereo (L-R) information on separate multiplex subcarrier.

Applied to a Cablenet I transponder, video associated audio may be transmitted in stereo with no redundant signals. Matrixing at the uplink transmitter, the sum (L+R) channel is modulated upon the 6.8mHz subcarrier. A conventional video receiver will detect this as a monaural signal and provide a baseband output. The difference (L-R) channel is modulated upon a separate subcarrier. For discussion let's choose 5.8MHz. Figure 3

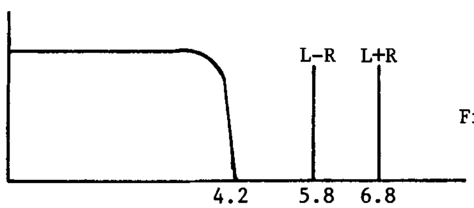


Fig. 3

As per NCTA recommended practices, additional subcarriers may be multiplexed above video, on full transponder (36mHz) services. For the limited subcarrier case, a root sum squared rule applies in determining peak composite deviation and thus occupied bandwidth.

$$F_{comp} = \left[\Delta F_v^{\,2} + \Delta F_e^{\,2} + \sum_{i=1}^{n}\left(\frac{\asymp}{F_{s1}}\,F_{si}\right)^2\right]^{1/2} \qquad (1)$$

where:

F_v = deviation of main carrier by video =10.75mHz

F_e = deviation of main carrier by energy dispersal waveform = 1mHz

$\asymp$ = deviation of main carrier by existing subcarrier = (2mHz)

F_{s1} = frequency of existing subcarrier = (6.8mHz)

F_{si-n} = frequency of additional subcarrier(s)

For the single subcarrier case, assuming conventional subcarrier modulation indices of 1:0.29* and deviation standards (as per NCTA document #________) of 100KHz peak deviation, composite deviation is equal to:

$$\left[\left(10.75^2 + 1^2\right) + \left(\frac{2}{6.8} \times 6.8\right)^2\right]^{1/2} = 10.98\text{mHz}$$

Applying Carson's Rule to determine occupied bandwidth;

$$BW = 2\,(\Delta F + FM)$$

where:

ΔF = peak composite deviation

FM = max instantaneous modulating frequency

Then:

(6.8 + .100)

BW = 2(10.98 + 6.9) = 35.76mHz

This may be rounded to Bandwidth = 36mHz
Thus it may be assumed that in order to add information, in the form of additional subcarrier(s), some reduction in peak deviation of existing service(s) must be accomplished, (1) To avoid overdeviating. Decreasing video deviation to accommodate our difference (L-R) channel subcarrier imposes a minimal penalty, manifest as an imperceptable reduction in video S/N.

Consider, the second subcarrier of 100KHz peak deviation, 1:0.29 modulation index at 5.8mHz. Scaling according to modulation index, yields subcarrier deviations of main carrier.

$$F_{comp} = \left[\Delta F_v + \Delta F_e + (.29 \times 6.8)^2 + (.29 \times 5.8)^2\right]^{1/2} = 11.1\text{mHz} \qquad (2)$$

Statistically, according to Carson's BW rule, this would cause a slight overdeviation. Some parameter (F_v) must be reduced.

SIGNAL/NOISE PERFORMANCE

Video deviation, and subsequent video signal to noise ratio penalty, attributed to the additional subcarrier, is then;

$$\Delta F_v = \left[\left(123.21 - 1^2 - 2^2 - 1.68^2\right)\right]^{1/2} = 10.74\text{mHz}$$

or, approximately a -.01dB reduction in video S/N. A minimal tradeoff to accommodate stereo audio.

Audio signal to noise ratio is identical to one channel operation when modulation indices are maintained.
or;

$$S/N_a = C/N + BW + P + 10\ 3/4\left[\frac{\asymp^2\ \ Fs^2}{F_a^{\,3}\ \ F_s^{\,2}}\right] \qquad (3)$$

where:

BW = bandwidth in decibels = 75 dB

P = Preemphasis improvement (75u) = 13.2

$\asymp$ = deviation of main carrier by subcarrier (1.68mHz)

F_a = top modulating frequency (15KHz)

F_s = subcarrier frequency (5.8mHz)

F_s = subcarrier peak deviation (± 100KHz)

Then assuming a C/N of 12 dB:

$$S/N = 12 + 75 + 13.2 + 10\log 3/4\left[\frac{(1.68 \times 10^6)^2\ (100 \times 10^3)}{(15 \times 10^3)^3\ \ (5.8 \times 10^6)^2}\right]$$

$= 63$ dB

63 dB represents a quite acceptable audio S/N ratio, and should yield excellent quality, at the T.V.R.O., with no apparent effect upon video or monaural audio subcarrier.

Consider however, as mentioned earlier, that prior to carriage over a cable system the conversion to broadcast FM format must be undergone, replete with its - 20 dB signal to noise penalty. This, coupled with average cablesystem noise figures, will yield signal typically 40 dB above the noise floor.

Several methods are available to improve this figure. The most apparent is of course increased subcarrier deviations.

OPTIMIZED TRANSMISSION

In delivery services where audio enjoys a unique prominence, such as Warner - Amex proposed MTV music channel, deviation and processing may be employed which reflects that prominence.

For example, extending deviation peaks to 237 KHz (75KHz + 10 dB headroom) will yield S/N ratios on the order of 70 dB (C/N=12 dB). Again, achieved at minimal penalty to existing services.

The MTV optimized system may utilize subcarriers of 6.6mHz. In the interest of improved threshold performance.

Then, applying the techniques just discussed

$$F_v = \left[\frac{BW^2}{4} - (BW \cdot F_{max}) + F_{max}^2 - F_e^2 - F_1^2 - F_2^2\right]^{\frac{1}{2}}$$

$$= \left[\frac{36^2}{4} - 246.132 + 6.84^2 - 1^2 - 1.98^2 - 1.68^2\right]^{\frac{1}{2}}$$

$F_v = 10.8$mHz; no video S/N penalty to the 36mHz BW receiver.

Audio S/N =

$$S/N_a = C/N + BW + P + 10 \log 3/4 \left[\frac{(\alpha)^2}{(F_a)^3} \frac{(Fs)^2}{(F_s)^2}\right]$$

$$= 12 + 75 + 13.2 + 10 \log 3/4 \left[\frac{(1.98)^2}{(.015)^3} \times \frac{(.237)^2}{(5.8)^2}\right]$$

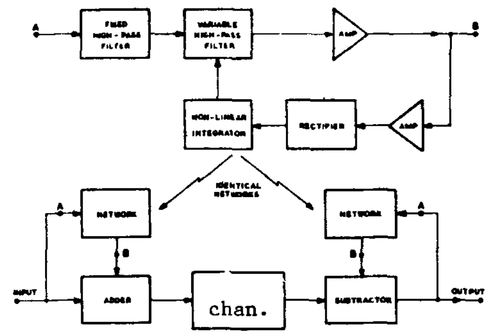
$$S/N_a = 71.8 \text{ dB}$$

a striking improvement, which may be improved further.

NOISE REDUCTION

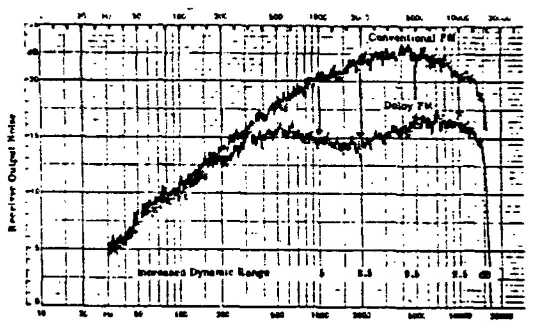
An additional technique, which exploits the freedom of the CATV industry is the addition of a world renouned noise reduction system. B type Dolby encoding.*

The Dolby B system, (fig. 4) boosts high



Block Diagram of B-Type Noise Reduction System.

frequencies by 10 dB. In decode an equal and opposite cut is applied, restoring the signal to its original characteristics. In the process all low level noise introduced between encoder (Uplink) and decoder (T.V.R.O.) is attenuated, as per Fig.5



Overall improvement due to Dolby FM/25 usec system.

MTV, Movie Channel and NICKELODEON transmissions will incorporate "B" type Dolby encoding.

Extensive tests, worldwide have shown the "B" system to be compatable.

The compatable nature of the system permits the CATV operator to allow the encoded signal to pass directly to his subscribers. This accords the noise reduction advantages (Fig.5) of the compander to those equipped with Dolby receivers at no perceptible detriment no non-Dolby or TV receivers.

RECEPTION

Reception of stereo subcarriers may be accomplished by the simple addition of appropriate subcarrier demodulator cards to the satellite video receiver.

Serious caveats apply, and this technique, while enticingly simple, is not recommended at this time.

Consider the following, for good stereo reception it is necessary that the L and R channels remain well separated (that is, audio in one channel shall not appear in the output of the other channel). The FCC requires 29.7 dB separation (which was about the best achievable when the rules were adopted). Exciters soon became available which were capable of better than 35 dB separation.

In order to maintain good separation, it is necessary that the amplitude and phase of the L+R and L-R paths be nearly identical. The channel separation as a function of these three factors is given in the following equation.

$$20 \log \left[\frac{(\cos\theta + \frac{S}{M}\cos\phi)^2 + (\sin\theta)^2}{(\cos\theta - \frac{S}{M}\cos\phi)^2 + (\sin\theta)^2} \right]^{\frac{1}{2}}$$

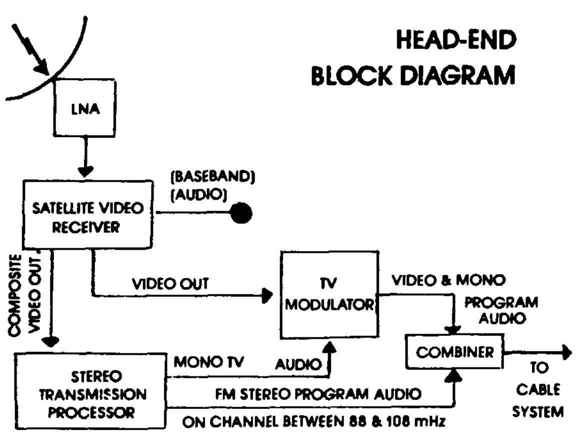
where:

- M is the gain of the main L+R path
- S is the gain of the stereo L-R path
- ϕ is phase error of reinserted 38 kHz subcarrier
- θ is difference in phase between L+R and L-R paths.

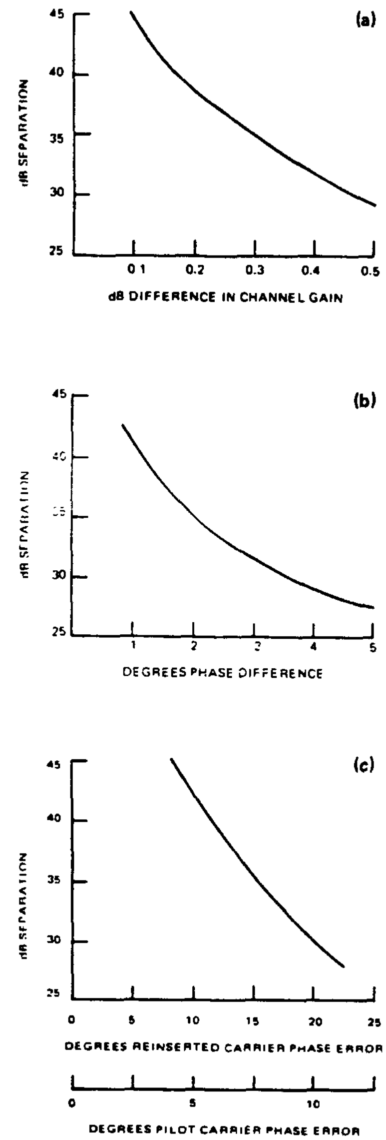
The effect of each alone upon the separation is shown in Fig. . In practice, loss of separation is due to some of each. Therefore, to achieve 35 dB separation, the amplitudes must match to about 1 percent and the phase to about 1° over the entire audio range from 50 Hz to 15 kHz. These are very stringent requirements. For this reason, designers keep the amount of circuitry in the separate L+R and L-R paths to a minimum.

Propagation delay deltas, long term component degradations and manufacturing differences make independent subcarrier demodulator cards impractical as stereo receivers, at this time.

A number of efficiencies are inherent in a reception scheme like that of Fig.6, not the least of which is the preservation of stereo separation in the long term.



Additionally, wide deviations may be implemented in the absence of receiver imposed roofing limitations, thus yielding the benefits of optimized transmission.



SUMMARY

All WARNER AMEX SATELLITE ENTERTAINMENT COMPANY services (MTV, Movie Channel, NICKELODEON) emanating from the new NETWORK OPERATIONS CENTER will incorporate compatible stereophonic audio.

In accordance with NCTA recommended practice THE MOVIE CHANNEL and NICKELODEON will adhere to deviation standards set forth therein.

MTV, as accords with it's format, will employ the optimized transmission technique discussed here, in the interest of superior audio.

Both stereo systems, as well as conventional reception of all WARNER AMEX SATELLITE ENTERTAINMENT COMPANY programming will enjoy the advantages of Dolby noise reduction encoding.

I wish to thank the people of Dolby Laboratories, Leaming Industries and Wegener Communication for their dedicated participation in this project.

CONCLUSION

We have striven to develop a system uniquely suited to the needs of the CATV industry.

A wholly non-proprietary design will allow competition to stabilize costs.

A modern companding technique will allow efficient use of transponder space at no detriment to non-companded receivers and authority compromise to the generic nature of the system.

And, finally as a business person who must mediate between a diverse group of claimants, the CATV operator is well aware of the not insignificant marketing advantages the term "DOLBY" conveys to subscribers.

A NEW PERSPECTIVE ON SMALLER CATV OPERATIONS

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INTRODUCTION

Both technically and economically the smaller CATV system bears little resemblance to its' urban counterpart. Yet, it is interesting to note that identical approaches in system designs are generally employed. It is as though this same approach was effective in both cases though they may be substantially different in nature.

One good example of this is in system design philosophy. The familiar trunk plus feeder technique is universally applied for 1,000 or 20,000 subscriber applications and even the amplifier gain and operating transmission levels are widely accepted without question to be optimum for both cases.

Now there's nothing sacred about these levels and gains and only a moment's review of transmission principles suggests some modifications might not only be technically acceptable, but might be significantly cost beneficial.

But for some reason the question has not been raised.

Perhaps, if we could clearly identify some requirements or problems of the small system operator we might more effectively employ today's technology in addressing those requirements and possibly produce more satisfactory solutions.

This paper reviews some smaller operation problems and proposes some alternative approaches. Some of these alternatives may be as yet unproven. Our purpose is simply to question existing methods and perhaps gain something by the discussion.

IDENTIFYING SMALL SYSTEM PROBLEMS

In the final analysis all the problems of a smaller CATV operation find root in the limited revenue base on which the operation must exist. At REA we have particularly addressed the rural applications where the density of homes per mile of plant become very inhospitable indeed, but even in systems of 1,000 to 2,000 subscribers the economic restriction is ever present.

One example, is the commonly shared costs such as program acquisition or head end. These common costs carry much different weight for a small operation. Take a satellite receiving facility at a cost of say 30 thousand dollars. With 1,000 paying subscribers that pro-rates at 30 dollars each. But with 10,000 subscribers the figure becomes a more benign 3 dollars each. The smaller operation then is under substantial pressures to expand its' subscriber base even at the cost of plant extensions out to less dense surrounding areas.

And with a smaller margin of profit the operation is limited in staff and also in the technical depth of the staff that is affordable. Thus, highly sophisticated maintenance or testing techniques are inhibited and any simplification of long term maintenance or any reduction in logistic spare equipment requirements will have a much larger impact than those same improvements in a larger operation.

SMALL SYSTEM CHARACTERISTICS

But there are some positive advantages in smaller operations also.

For example, most core communities (the central town or population cluster in a rural or small system) are located relatively close to the system point of origin or head end. Thus the length of cable plant required to reach all of this community is distinctly limited. Then the cascade of required amplifiers will also be limited and consequently a transmission engineering approach might be able to take advantage of this condition. Perhaps, cascades of 8 or so conventional trunk amplifiers might be considered typical to serve the core community alone.

In these applications the available off-air signals are usually either limited in number or marginal in quality or both. Thus operations designed for 21 channels may be quite adequate. Indeed in many cases 12 channel operation may be salable thus eliminating or at least postponing the cost plateau of subscriber set converters. In any event the small system need not construct 40 or 50 channel plant, which is no small cost reduction of itself.

The nature of the small community is a factor. Usually the population is more stable and there is less subscriber "churn" than in urban operations. This fact, and the reduced total subscriber count itself, relieves the operator of such complexities as addressable taps, etc. Even billing and accounting processes may be less expensive because of the reduction in scale.

With these facts in mind, how might we best serve the requirements with today's equipment?

INITIAL CONSTRUCTION COST REDUCTION

Obviously any reduction in initial construction cost would be most welcome.

The recent improvements in amplifiers have been very largely influenced and stimulated by CATV's entry into even larger markets. Consider an amplifier which used to produce Y intermodulation distortion at X output levels when loaded with 21 channels. Now perhaps, that unit is capable of carrying 35 or more channels while still producing Y intermod at the same X output levels.

Certainly this increased transmission capacity is presented to the small system designer, but the advantage gained is somewhat academic if that operation cannot demonstrate a need for 40 channels or can not economically support this level of programing.

But that same amplifier improvement might be translated to higher gain, higher output level operation if the channel loading remained at 21 channels. And higher gain translates to longer spacings and reduced system costs.

Let's examine the typical trunk system design as it is almost universally applied today in both the largest and the smallest systems.

Usually operated at + 10 dBmV input and + 32 dBmV output the typical trunk amplifier is spaced 22 dB or so. These levels may be increased by a dB or so for lower channel loading application.

Under these parameters the trunk system would be cascadable to perhaps approximately 25 units and at the end of that cascade could still accommodate an extension through a bridger amplifier and perhaps two line extenders. These feeder amplifiers operate at higher transmission levels to improve subscriber tapping effeciency, but the higher levels impose higher intermodulation distortion contributions also. The higher distortion is tolerable because of the limited cascade of feeder units (2 or 3 typically) and the low distortion trunk contribution due to the low trunk operating levels.

But our smaller system will probably never require anything like a 25 trunk amplifier cascade, at least not to serve the core community itself. Perhaps, we could operate our trunk amplifiers at substantially higher gain and still produce "in spec" end of system performance through the usual 3 amplifier feeder leg.

In effect, if the small system designer simply applies urban trunk parameters, the end result will be better than necessary transmission quality at higher than necessary construction costs.

We examined many small system designs that were examples of this. One, I recall was a total of five amplifiers deep in the head end to system extremity, but the design dutifully (and extravagantly) used 3/4 inch trunk cable and 22 dB spaced trunk amplifiers.

Quite obviously this was designed by rote, not reasoning.

If the rationale is that some long rural extensions may be required later and thus trunk quality must be preserved at the initial extremities of the system, that is a different thing entirely and should be addressed separately.

RURAL SYSTEMS AND SYSTEM EXTENSIONS

The demographics of a rural system or an "out of town" extension of the smaller system are not particularly suitable for trunk plus feeder designs.

Usually the cable route is quite long, and the nominal subscriber tap load is distributed along this entire length. At the same time, side lead or lateral cable runs may be of quite significant length in themselves.

If we apply conventional trunk plus feeder designs we will find a majority of the feeder simply paralleling the trunk cable for tapping purposes. This is not particularly cost effective. We might consider eliminating the second cable and its associated second level of bridger and line extender amplifiers. Perhaps, we could simply insert all required taps into the main cable itself.

If we consider the side lead runs as pure feeder cable, we will find that often the length of such runs will require AGC or thermal compensation anyway and may require a cascade of so many high distortion feeder amplifiers imposing out of specification distortion at the end of the side lead cable runs.

The conventional feeder system technique is simply not compatible with long, lightly loaded cable runs, particularly if little of the feeder plant is located "off" the main trunk cable route.

In the rural extensions we do not anticipate any cluster or group tap loads or a large number of service points at the end of the extension. Rather than apply the trunk and feeder philosophy, which allocates some limited intermodulation distortion to the trunk system and reserves some substantial intermodulation distortion for the feeder sub-system, we might redistribute distortion along the entire length of a single cable system.

We could then accept higher intermod from each individual amplifier, since we expect no subsequent large distortion contribution from feeders. If we can accept higher distortion from each unit, we are free to operate them at higher output levels with higher amplifier gain. This translates to longer amplifier spacing which may be usefully employed in overcoming the tap insertion losses or in using lower cost, higher loss cable or a combination of both.

In any event, the effect can significantly reduce construction costs.

There is no "free lunch", and the effects of many taps inserted into a single cable may have limitations or present problems. Obviously, just introducing a larger number of cable connectors is undesirable, but careful workmanship and a short "debugging" period should make this acceptable.

Such devices will introduce echoes and reflections, of course. Ultimately, these may become limiting, but despite some extensive study we have not, as yet, been able to positively determine the point at which this becomes totally inhibiting. We have a field project under construction which will produce some useful data and, of course, there is the experience of long urban feeders. In many cases, three line extenders have been cascaded and certainly as many as 30 or 40 taps have been included and in this respect the urban feeder is essentially like the rural single cable design.

Of course, several techniques for "shedding" tap loads are available, particularly for clusters or groupings of taps. For example, back feed or forward feed cables, even with some cost penalty for limited parallel cable runs, offer some relief.

Improving the return loss of the inserted devices themselves, either by redesign or simply by production selection, would substantially reduce the potential problem.

In any event, we do not see the limitation as unmanageable. The single cable technique can reduce the amount of larger, more expensive cable required, and reduce or eliminate much of the inefficient parallel cable placement. It could completely eliminate a second level of amplifiers such as bridgers or extenders.

We believe a 36 dB gain amplifier, operated at + 8 dBmV input and + 40 dBmV output with 32 dB transmission loss spacing for 21 channel applications, compromises between cost and system "reach" for rural extensions. Using ½ inch size cable only, and including the typical tap loads along the route, this amplifier can provide rural extensions on the order of 17 to 18 miles depending on the tap and splitting loads.

That is pretty good area coverage if you include side lead and lateral cable runs and at a substantial reduction in cost, anywhere from 30 to 40 percent less than conventional trunk plus feeder designs as shown by our studies.

How might this design be incorporated into the core community design comfortably?

A COMPOSITE DESIGN FOR SMALL SYSTEMS

In our earlier examination of trunk plus feeder designs for core commuities, we raised the question of conventional trunk amplifier gain and operating levels as being less cost effective than we would like. But we had not presented any specific alternatives.

In our rural extension discussion we have introduced higher gain and higher operating level figures. Quite obviously, we might consider these figures when applied to the core community design. In effect, we may have optimized a trunk design for the core community which is completely compatible with the long rural extensions and presents initial construction economies in both applications.

This sounds great, but what of the higher intermodulation distortion introduced by these amplifiers when they are in the trunk portion of the core community system? In this case, our intention is to follow this cascade with a conventional 3 amplifier feeder leg, which contributes a substantial amount of distortion itself.

But, you will recall that our demographic profile of the core community showed a relatively limited distance from head end to core community extremities, thus the cascade of the rural amplifiers to the point of feeder system connection would be distinctly limited. Our studies show that a cascade of 8 or 10 amplifiers operating at + 40 dBmV output (the rural extension optimum) can be followed by a bridger plus two line extenders operating at standard levels and still produce - 52 dB of Cross Modulation at the last service point or better. That would seem quite acceptable.

Let us review what we have:

We have a single, low cost, small size cable, equipped with high gain amplifiers and operating at transmission levels somewhat above the inefficient, conservative, urban trunk levels, but somewhat below the high distortion, high transmission level urban feeder system.

Throughout this single cable, amplifiers are working with + 8 dBmV input and + 40 dBmV output with 32 dB transmission loss spacing for 21 channel operation.

In the "in town" portion of the system this single cable is not tapped for service drop feeds, but is split and tapped by directional couplers to feed conventional feeder type line extenders or bridger amplifiers.

In the rural sections of the system this single cable is directly tapped for service drop feeds and extensions out to 17 miles or so using ½ inch cable. The ultimate extension length will reflect the end of system performance specifications, of course. One might relax the specifications somewhat, since only a small number of subscribers is actually fed at the ends of these extensions.

The identical amplifier is used throughout this single cable and all output levels are identical at all stations. This significantly reduces logistic support and maintenance problems. And any or all amplifiers are capable of AGC (closed loop) thermal regulation as required.

The amplifier we have reference to is not a new design or development. In fact, it is not a unique product of any specific supplier. This unit, or an equivalent, is available off-shelf from several sources. All we are doing is configuring the equipment differently in the system and operating it at different transmission levels.

So far, we have confined our discussion to cost reduction, but earlier we had identified some other unique problems of small system operations. Can we respond to these more effectively through system design or operation?

AN ALTERNATIVE DESIGN FOR SMALLER SYSTEMS

Perhaps we might consider system designs from the standpoint of long term system operation.

Let us suppose that every amplifier in a system, no matter if it were in the trunk or in the feeder sub-system, were identical. That is, the housing and gain module, would in every respect be identical.

What might the long term advantages be in such a case?

Obviously, the logistics of spare amplifiers for maintenance would be much simpler and perhaps a lower level of staff would be able to handle the entire system.

Test and maintenance procedures might be significantly reduced.

For example, suppose instead of designing closed loop AGC into a system as periodic, lumped increments of correction, we were able to incorporate some AGC into every amplifier. The required range of the AGC would reduce, of course, but the cost per unit would not be much improved by this. Then we would expect, from a construction cost only point of view, that total AGC could be somewhat more expensive and perhaps unnecessarily so.

But from a long term operations point of view some cost penalty might be quite acceptable.

In effect, we would have a system with a very high level of self-regulation, and, consequently, a much lower vulnerability, not only to thermal variations, but to maladjustments of the system by low level personnel.

Carried a bit further this might make possible the use of non-adjustable or fixed gain amplifier modules.

The maintenance process might be reduced to the level of, "Go-No Go" indicators simply to isolate the service interruption of failed unit. Restoration of service might be the straight, plug-in substitution of a replacement with no measurements or adjustments.

Perhaps, this is a bit too much to hope for at the moment, but if practical, such a technique might even find application in feeder plant maintenance in the very largest, major market systems eventually. These systems are becoming more and more difficult to staff and maintain and since the majority of the plant involved is limited length feeder legs, the impact on operating costs of reduced maintenance complexity in feeders might be very attractive.

From this blue sky point of view we might look to the small system and its' rural extensions again.

Perhaps the basic amplifier which we have suggested might be equally cost-effective in the single cable extensions and in the core community trunk itself, could also be usefully employed in the core community feeder sub-system. It is already operating well above conventional trunk amplifier levels and might actually be operated at line extender or bridger output levels also.

But, we are feeding this core community feeder plant from some limited, but higher distortion trunk plant, so actually going up to typical line extender outputs may not be possible. But, we are free to operate somewhat higher and this would improve the cost effectiveness of this unit when compared to a conventional bridger or bridger plus line extender combination.

We were operating the basic amplifier at + 40 dBmV output in 21 channel systems. By increasing the input and output by only 5 dB, this unit starts to compare quite favorably in system layouts using the typical line extender. A study we did at REA indicates a cascade of 8 amplifiers, operating at + 40 dBmV output (as trunk units), can be followed by a cascade of 3 amplifiers operating at + 45 dBmV output (as feeder units) and still deliver a - 52 dB Cross Modulation distortion or better.

It is not necessary that every unit in the feeder plant be fully AGC equipped, but the option is available. Thus unusually long feeder legs could be accommodated by operating the first two or three units at the lower + 40 dBmV level and the last two units perhaps at + 45 dBmV.

An ACG could be provided in this feeder leg as required by simply inserting the appropriate additional AGC modules. The field trial previously mentioned includes some plant constructed in this manner and we will be reporting the results and system costs to the industry at large as soon as possible.

SUMMARY

Much of what we have discussed here is yet to be proven to have practical merit, but much of it surely needs no proof. For example, raising operating levels in a limited cascade of a small system trunk and using higher gain amplifiers in that trunk is neither radical nor innovative. Unquestionably it would be economically beneficial and it certainly would appear technically sound.

Yet we continue to find 22 dB spacings and high cost 3/4 inch trunk cables in systems that are designed only ten amplifiers deep and less.

Technology changes-inevitably and inexorably--and it is incumbent upon engineers to not only stay abreast of these changes but to effectively apply them in practice when advantageous to do so.

That's what good engineering is all about, isn't it?

A RURAL INSTALLATION OF FIBER OPTICS

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GENERAL:

Construction of the outside plant of Commonwealth Telephon Company's T3 digital fiber optic system which began on October 26, 1978 was recently completed. The cable installation took place over an 8 week period. This project is one of two similar commercial fiber optic field trials currently taking place in Pennsylvania to test two different approaches in the design of fiber cables. The Commonwealth system, which is the more ambitious of the two lengthwise, spans a distance of 22 km utilizing four intermediate repeaters between the north central Pennsylvania communities of Wellsboro and Mansfield. The system, which was purchased from ITT Telecommunications Division in Raleigh, N.C., is being installed in conjunction with the REA. It serves as the first commercial field trial of fiber optics in an operating company environment for all three parties. When the entire system is completed in early 1979, it will carry toll connecting, intertoll, operator and special service traffic. With the installation of cable, associated splicing and repeater housings completed, this report will deal primarily with specific techniques used during the installation.

The optical cable was installed using four methods of construction: direct buried (plowed), underground (duct), aerial lashed to existing cable, and aerial lashed to a new messenger. The following list shows the approximate length of the four types of construction.

Direct Buried	10.0 km
Underground	1.0 km
Lashed to Existing Cable	3.0 km
Lashed to 6M Strand	8.0 km

Two types of cable construction were used. For the aerial portion a totally dielectric cable rated at 6db/km was used consisting of five graded index fibers individually coated with a colored Hytrel polyester buffer laid up with Kevlar strength members and impregnated with a filing compound to form a central core. The core, jacketed with polyurethan jacket. Polyurethane was chosen over polyethylene for this application because of the added resistance to tear and abrasion, crush resistance, and the flexibility it imparts to the fiber cable. The outside diameter of this cable is .265 inches.

The aerial cable was adapted for direct burial by adding a 12 mil coated aluminum tape longitudinally applied and an extruded jacket of low density polyethylene. This type of protective sheathing meets existing REA specifications for conventional telephone (copper) cables. The outside diameter of this cable is .370 inches. Both types of cable construction utilized sequential markings on the outer jacket. These markings were recorded at various pole locations, splice points, manholes, repeater housing locations, etc. This information will prove invaluable in quickly locating cable damage using a TDR test set.

DIRECT BURIED INSTALLATION

Because of the impending weather conditions, the buried portion was installed first. Installation started near the Wellsboro exchange in an open field. The cable was plowed to a depth of approximately one meter using an International Harvester TD15B identical to that used by Commonwealth Telephone Company in installation of conventional copper cables. The plowing operation varied from very easy to difficult due to varying weather, geological and topographical conditions along the 13.7 mile route. All fiber optic cable installation was performed by Commonwealth construction personnel.

To monitor possible cable damage during plowing, an optical time domain reflectormeter (TDR) was connected to the cable. This instrument consists of an oscilloscope with a special plug-in-module housing for the required TDR electronics. On the first day of construction the test set was damaged by an unregulated A.C. generator. While starting a search, which might have taken days, to obtain a replacement for the failed oscilloscope, a decision was made to start the plowing operation using two alternate techniques to monitor the cable installation.

An ohmmeter was connected between the aluminum cable shield at the starting point of the reel and a ground rod driven nearby. A reading on the meter could indicate a break in the polyethylene jacket, grounding of the shield and possible fiber damage. If a grounded reading was encounted or if the plow stopped for any other reason, each of the five fibers was tested for continuity by shinning a flashlight into the fiber at one end and looking for received light at the other end.

Approximately 460 meters of cable on the first 1km reel was plowed when the ohmmeter jumped. Each of the fibers was tested using the flashlight technique and no loss of fiber continuity was found. The ohmmeter reading turned out to be false. It is interesting to note that the light emitted from the fiber looked red rather than white due to the bandwidth characteristics of the fiber.

The need to communicate between the plow crew and the personnel at the other end of the cable required additional consideration when the radio transceivers being utilized did not operate satisfactorily. A talk path was established using the aluminum shield and ground as a transmission medium.

The first day two 1km reels of cable were buried using these methods of checking for cable damage. However, no damage occurred. Initially, all turns were made with a large radius in comparison to conventional cable installation standards and extreme care was taken to insure the cable was fed smoothly into the shoot of the plow. Based on our experience with the first reels, we found no extra care was required and the cable could be handled the same as conventional cables. By the second day, a replacement oscilloscope was obtained and the TDR was used to confirm that no damage had occurred to the first two reels. For the remainder of the buried portion, fiber continuity and shield ground resistance were measured only after the complete reel had been installed.

Various obstacles were encountered during the plowing operations. A backhoe was used to trench across small streams and drainage ditches. For larger obstacles the cable was installed using an aerial insert. There were a number of road crossings which were accomplished by boring under the road and installing 4 inch PVC conduit or by pushing the cable through existing duct. In one case, about 450 M of cable was pulled back through the conduit to the last splice point. The cable was laid on top of the ground and the plow then buried the cable in from the splice point to the road crossing.

During the plowing operation, an unmarked gas main was cut by the plow. In addition, due to wet ground conditions, the plow got stuck a few times and had to be pulled out using a cable line truck and a backhoe. Through all of this, the cable remained intact with no detectable breaks in either the outer jacket or fibers themselves.

Since installation, the cable was damaged once by a contractor installing buried electric service to a new home. Although the route was well marked, the cable was struck by a shovel while hand digging the trench. Despite the fact the outer jacket and metal sheath were damaged, the fibers were not broken. Repair was accomplished with VM masking tape.

UNDERGROUND INSTALLATION

The underground construction of the cable was confined to the existing manhole entrance systems at each central office. The Wellsboro end was 490 meters long with 6 manholes and two 90 bends. So that the 4 inch duct could also be reused for a larger copper entrance cable and to insure the fiber cable would not be damaged by such an installation, a 1 inch PVC pipe was first installed through the duct system and the fiber cable was then pulled inside.

The Mansfield end was approximately 550 meters in length with six manholes and two 90 bends. The same installation technique applied at Wellsboro was used here. Because of the cable's small diameter, light weight, and tensile strength, a potentionmeter was not used to measure the pulling force on the cable.

AERIAL INSTALLATION

About 500 meters of aerial cable was installed by the manufacturer at a test site in Roanoke, Va. almost a year before the installation in Pennsylvania. In this test, the fiber cable was lashed to a 6M messenger simultaneously with a 12 pair copper cable. A standard General Machine Products lasher was used for both the test and actual cable installations with no special installation techniques or precautions. Expansion loops were not used at any pole locations.

The aerial portion was constructed over a variety of conditions. In the town of Wellsboro, the fiber cable was lashed onto existing cables that varied in diameter from 1 to 2 inches. Overlashing was necessary because not enough space was left on the existing pole line for a new cable run. Once outside the town, the cable was lashed to a new 6M steel messenger. This construction went very quickly and was performed using the standard 3 man line crew that is used to install any small telephone cable. One man climbed the poles to transfer the lashing machine, another pulled the lasher and a third man pulled on the cable to keep it from wrapping around the messenger. No problems were encountered during the aerial construction. Production was at the same rate that is experienced with the installation of any small telephone cable (approximately 2 km/day). Since the fiber optic cable follows an existing aerial cable route, only a fiber cable was installed for the entire 22 km. Copper pairs for power and order wire will be provided from the existing cables.

SPLICING

Fusion splicing was used for this project. Because electric fusion equipment was not available, a flame method was used. We spent about a half day training cable splicers plus additional training on the job under ITT supervision. Within a short time, we were able to complete about one and a half splice points a day. Because of the cold weather, a tent and heater were needed. Most of the splicing time involved stripping the cable and removal of the filling compound from the fibers. In a few cases, this process caused some fiber breakage. Extra care is recommended during this preparation period to eliminate fiber breakage. Actual splicing of two fibers took about 10 minutes.

All splicing was done above ground. The aerial splice housings were pole mounted while in the buried sections, housings were mounted in pedestals. This method allows easy access to fiber conductors in case of trouble. In all cases, slack cable was left at each splice point to allow resplicing or termination of the cable. All splicing was performed by Commonwealth Telephone Company craftsmen.

REPEATER HOUSINGS

Standard ITT T1 span line repeater housings were modified to house the optical transmitters, receivers, fault monitoring unit, physical pair protection and other apparatus associated with the normal and hot standby lines. The housings are pole mounted and come equipped with a copper cable stub for connection of powering and maintenance pairs. Because the unjection laser diode (ILD) sources used in the repeaters are not thermoelectrically cooled, a special sun shield which surrounds the housing was designed to limit high temperatures which are detrimental to laser life. The repeaters themselves are powered by a 140 ma DC constant current loop using standard T1 span line power supplies and current regulators. It should be noted that this current requirement is a standard for T1 systems.

TESTING

The cable testing will be performed in two phases. Initial testing was conducted after completion of all construction and splicing. Tests were performed between repeater locations to determine changes in cable loss due to installation and associated splicing losses. Subsequent testing of the fiber cable for survivability and performance will be conducted on a weekly basis prior to system turn-up. Apparatus used will consist of ITT's OFTS-02 portable loss measuring test sets and the TDR mentioned previously. Loss readings from section to section will be recorded and referenced to the initial acceptance test data. Any significant variations from the reference results will be investigated using the TDR. Based on the results of the ITT test cable at Roanoke, Va., no problems are anticipated.

OTHER SYSTEM CHARACTERISTICS

While this report has dealt primarily with the installation of the outside plant portion, there are other system characteristics which are pertinent to the discussion of this system. The ITT electro-optic equipment will interface existing T1 channel banks and span lines through Farinon M1-3 multiplex terminals equipped with both low and high speed protection. This system has a capacity of 672 channels over one pair of fibers. While the signal between the M1-3 equipment and the ITT terminal equipment is at the standard 45 Mb/s rate, the line rate over the cable is actually 47 Mb/s. The increased bit rate is due to parity bit addition/removal circuitry in the ITT terminal equipment. The additional bits will be used to provide in-service error monitoring and reporting functions at the repeater points, terminal and line looping for test purposes, and hand shake routine between ends to coordinate simultaneous automatic swithcheover and restoral. In addition, a microprocessor controlled alarm reporting system to reduce the possibility of system outage due to component failure and also ease troubleshooting will be provided.

SUMMARY

The conclusions drawn from our experience to date indicate that basically the same construction methods used for conventional cables also apply to fiber obtics. We feel that fiber optics will be the telecommunication medium of the near future. In certain high density applications, fiber optics now proves in economically in comparison with conventional cable and microwave systems. In addition, it offers greatly improved transmission quantities and qualities, ease of installation, reduced maintenance and the capabilities of providing the distributed broadband services of voice, data, and video to our customers. With all of this in mind, the obvious answer to the question, "Why fiber optics?", is WHY NOT!

A UNIFIED APPROACH TO DATA TRANSMISSION OVER CATV NEWORKS

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ABSTRACT

Many feel that data services will compel both rural and urban cable systems to form a national communication network. Concurrance of video and data services can be achieved through establishment of CATV data transmission standards. The characteristics of data transmission, including channel capacity, bandwidth, signal to noise ratio, modulation, error rate, error detection and encoding methods are investigated, a distributed processing complex supporting multiple service offerings is detailed and finally, a full set of quantitative parameters for CATV data transmission is recommended.

INTRODUCTION

Through the 1980's and beyond, the quality of life will be improved in many different ways. A large part of the anticipated enrichment will accrue through progress in communication technology, as it applies to the common man. CATV networks, initially constructed for the purpose of bringing entertainment to rural areas, are now being built in major cities. By the end of this decade, interconnection between individual systems will enable the carriage of information over a national communication network.

The CATV manufacturer stands today, on the threshold of a challenging opportunity. As the emphasis within the network shifts from entertainment toward information, the equipment and techniques offered to support the needs of CATV operators must remain viable. Engineering philosophies now being developed, must be designed to fulfill not only the current requirements, but also the needs of the future. It is, therefore, prudent to establish a set of guidelines for data transmission over CATV networks. The individual characteristics embodied in such a philosophy, are too numerous to explore in detail; however, it is instructive to identify the major technical implications and the resulting benefits of the approach.

INFORMATION TRANSMISSION

All information passed through a communication system is degraded to some extent by distortion and the addition of interfering signals and noise. The degradation results in decoding uncertainty (error rate) whose tolerance is somewhat application dependent and, in general, may be improved by reduction of information rate and/or higher system cost. A suitable philosophy should, therefore, allow for variations in modulation method, bandwidth, error rate and carrier frequency assignments, while providing established guidelines for channel usage, signal levels, interference with other signals and compatability with other equipment and services on the CATV network. Before proposing parameters for CATV networks, it will be helpful to review the general problem of information transmission.

Figure 1 illustrates the data transmission system as it applies to CATV networks. Although a one-way system is shown for simplicity, the concept is the same when extended to two-way.

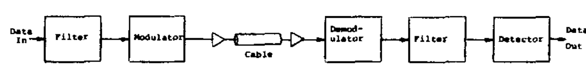


Figure 1
Data Transmission System

The system consists of a modulator, transmission path (CATV cable network) and demodulator. The filters, whether part of the transmission process, or used intentionally, are necessary to assure adequate signal to noise ratio. However, they also reduce the ability to separate the individual transmitted bits, which is called intersymbol interference. The information handling capability of the transmission system, or the maximum rate of transmission of data over the channel, is referred to as the channel capacity. The maximum possible rate of transmission of binary digits over a channel limited to bandwidth W, with mean signal power S and mean noise power N, was found by Shannon[1] to be given by

$$C = w \log_2 (1 + S/N)$$

It should be noted that in order to achieve this rate, the information must be coded in the most efficient manner which will generally involve highly complex circuitry and incur large time delays in transmission. It is evident that for a specified channel capacity, bandwidth and signal power can be exchanged for each other. The modulation method is essentially a means for effecting this exchange, however, the process is highly inefficient since one must increase the power exponentially to effect a corresponding linear decrease in required bandwidth. It should be obvious that in CATV systems, direct transmission of baseband data is not practical due to the amount of bandwidth required. Instead the whole spectrum is shifted to a higher frequency by modulating an RF carrier. This process gives rise to upper and lower sidebands and hence, the required bandwidth is doubled.

As indicated above, virtually error free digital transmission could be achieved (provided channel capacity is not exceeded), by appropriately coding the binary message sequence. Specifically, at a binary transmission rate of R bits/sec., if R<C it may be shown that the probability of error is bounded by

$$Pe \leq 2^{-E(R,C)T} \quad R<C$$

as shown in Figure 2. As the transmission rate R approaches the channel capacity the probability of error approaches 1. The parameter T indicates the time required to transmit the encoded signal. With the transmission rate and channel capacity fixed, the probability of error may be reduced by increasing T.

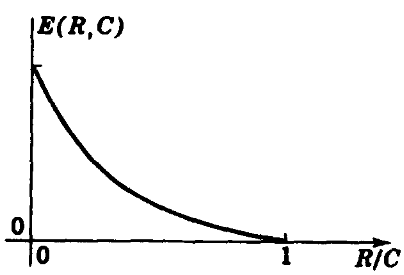


Figure 2
Probability of Error vs. (R,C)

A great deal of research activity is being devoted to the investigation of various modulation and encoding methods. This work froms the basis of communication theory.

MODULATION METHODS

There are essentially three ways of modulating a sine wave carrier: variation of its amplitude, frequency or phase in accordance with the transmitted information. These are commonly known as ASK, FSK and PSK respectively. FSK systems perform better than ASK, while PSK systems perform still better. The major factors affecting the selection of modulation method lie in the demodulation or detection process. The two commonly used detection methods are envelope detection and synchronous detection. ASK may use envelope detection, FSK may use differentiation (to convert frequency variation to amplitude variation) followed by envelope detection, while PSK requires synchronous detection. Synchronous detection requires a locally generated receiver clock of the same frequency and phase synchronized or slaved to the transmitter clock to within much less than a fraction of a cycle. This is difficult and costly to achieve in practice, for example, at a data rate of 3.5 MHz the required accuracy is much less than 60 nanoseconds. The signal to noise ratio of AM versus FM is also important. As indicated previously, widening the transmission bandwidth (as is required for wideband FM) improves the signal to noise ratio. With AM, the signal to noise ratio is linearly dependent on carrier to noise ratio and cannot be improved. In fact, any bandwidth increase beyond what is actually required serves only to increase noise, thereby, lowering the signal to noise ratio. With FM, as illustrated in Figure 3, it becomes obvious that significant improvement in signal to noise ratio is possible by increasing the modulation index at the expense, of course, of increased bandwidth. Notice that the signal to noise ratio beyond the 12 dB carrier to noise point, results in a constant linear improvement of $3\beta^2$, where β is the modulation index - the ratio of FM deviation to modulating frequency.

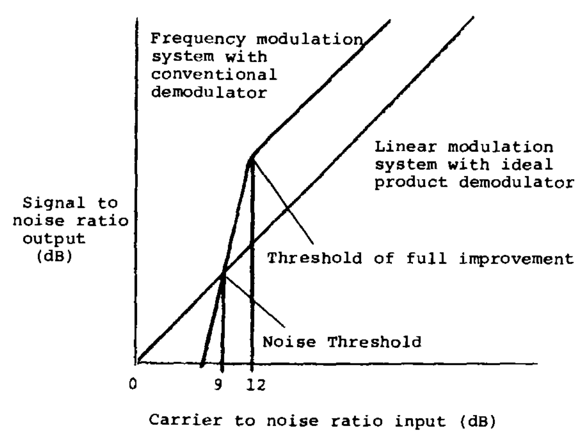


Figure 3

The resulting increase in bandwidth is illustrated in Figure 4. Notice that the AM spectrum consists of only one pair of sidebands per sinusoidal component of the modulation signal and has an effective bandwidth of 2Fm. The FM spectrum has multiple pairs of sidebands, and an effective bandwidth of 2Fm + $2\Delta F$ (where ΔF is the frequency deviation). The noise improvement factor of FM is proportional to the ratio of ΔF to Fm. This improvement corresponds to wide transmission bandwidth ($\beta >> 1$) and better than 10 dB carrier to noise ratio. With narrowband FM ($\beta < 1$) the deviation is constrained to produce a bandwidth of 2Fm (as in AM), therefore, no signal to noise ratio improvement over AM can be obtained.

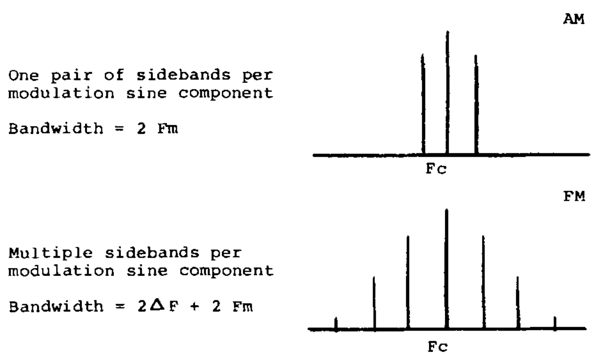


Figure 4

With the previous emphasis on signal to noise ratio, it is important to note that various methods have been devised for coding, modulation, and demodulation of digital signals for the purpose of matching the data integrity with information quality. The selection of technical parameters should, therefore, be tied to the application of the information. For example, in a Teletex application, a decoding error in received data may show up on the screen as a missing letter. The viewer will seldom object to this, because the value of the missing character can usually be implied from the context of remaining text. On the other hand, an error byte in a banking transaction could have drastic implications.

FSM vs. TDM

The two methods of simultaneous transmission of several band limited signals on a channel are frequency and time division multiplexing. In frequency division systems, all of the signals are modulated on different carriers and transmitted continuously. In time division systems, all of the signals are mixed in time and modulated on a single carrier, each signal occupying a distinct time interval. TDM seems to offer a cost advantage, in that, only one carrier need be generated and relatively simple circuits can separate the data intended for each distination. With TDM, the data intended for any individual receiver will occur in bursts as shown in Figure 6, whereas with FDM once the channel is selected, all the data is intended for the individual receiver. Channel capacity, as previously indicated, is a function of channel bandwidth and signal to noise ratio. Consider the 6 MHz bandwidth allowed for a TV signal. With 10 dB signal to noise ratio, the highest usable data rate using ASK is about 3.5M bits/sec. Compared with FSK at $\beta = .6$, the available 6 MHz accomodates 62 channels of 56K bits/sec. which is 3.47M bits/sec., or roughly the same channel capacity. There are numerous "holes" in the cable spectrum as shown in Figure 7, which are too narrow for conventional video services, for example, the FM band. Virtually, every cable system has FM channels which are unassigned, and are essentially wasted bandwidth. Data services in such holes can provide a new revenue source, while not reducing the capacity for carriage of traditional services. Since no two cable systems have the same spectral holes, however, a mechanism is needed to allow the terminals to tune themselves to the desired channel. Recent advances in integrated circuit technology make accurate and inexpensive frequency control systems not only possible, but cost effective as well.

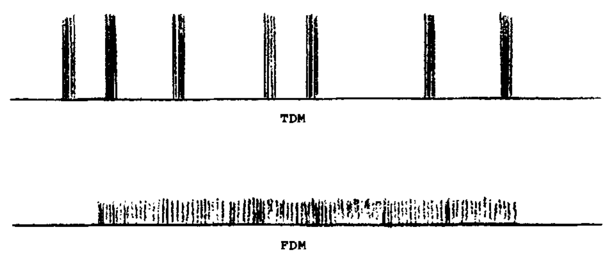


Figure 6
Data Rate Receiver vs. Multiplex Method

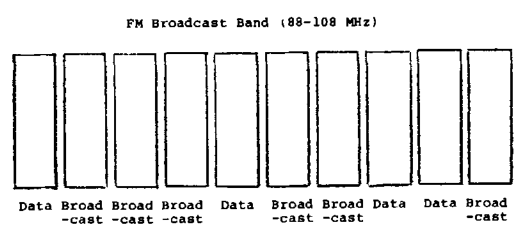


Figure 7

FDM FM is particularly interesting from the viewpoint of interfering carriers. Figure 8 illustrates the allowable interference carrier level versus frequency for an FM transmission with a minimum signal to noise ratio of 10 dB and modulation index of 5. Notice that an interfering carrier within a ± 200 KHz range of the desired carrier need be only 6 dB down to be essentially rejected. In fact, an interfering carrier ± 400 KHz away can be as high as 25 dB above the desired carrier without degrading data reception.

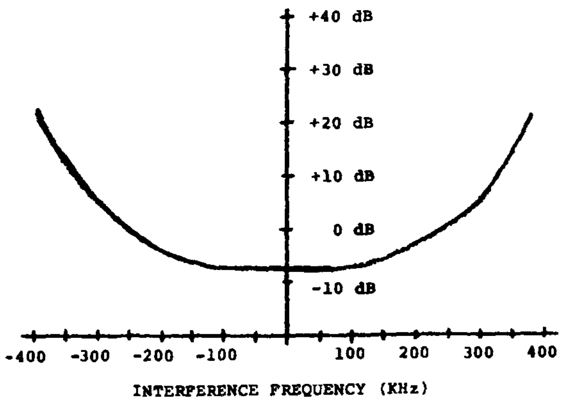


Figure 8
FDM FM Interfering Carrier Rejection

The multiplex method, therefore, should be selected on the basis of cost, available space, and desired error rate.

DATA ENCODING

The maximum baud rate inferred from Shannon's capacity is 2W elements/sec. or 2 bauds/sec. for every hertz of available bandwidth. The signalling rate (or baud rate as it is commonly known) which is defined as the minimum elapsed time interval between successive signal elements, places an upper bound on the achievable data rate. This limit relates to the data encoding scheme in terms of the number of transitions per data cell or baud/bit. Figure 9 shows some commonly used data

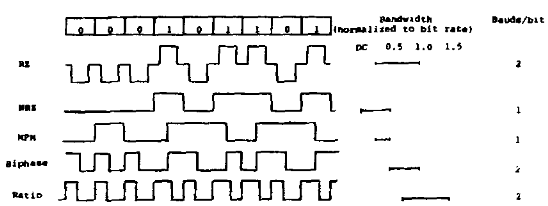


Figure 9

encoding schemes. Three factors are involved in the selection of an encoding scheme:

1) the ratio of maximum to minimum frequency which defines the detector passband filter characteristic

2) the inverse of the minimum time between transitions or baud rate which defines the upper bandwidth limit

3) the presence of a DC component which defines the bandwidth lower limit, precludes the use of AC coupling in the detector, and requires the use of a separate transmission method for the bit clock.

It should be noted that the MFM scheme makes use of previous bit history to reduce the baud rate, with no apparent increase in bandwidth. The advantage of this technique is somewhat negated by the requirement for a preamble to acquire clock synchronization. A preamble is a known bit pattern appended to the front of each message.

ERROR DETECTION

As we have seen above, error probability in digital transmission is a direct function of signal to noise ratio. If, for a given application, the signal to noise ratio is maximized and the error rate is still unacceptably high, then error control coding can provide the solution. Error control coding is simply the calculated use of redundancy, where extra bits or words (or both) are added to the message. They convey no new information themselves, but make it possible for the receiver to detect or even correct errors in the information bits. A multitude of error detecting and correcting codes have been devised to suit various applications. They may be used alone or in combination, for example, a single parity bit on each transmitted word, and a longitudinal checksum on the entire message. For many applications, errors can be rendered harmless if they are simply detected with no attempt at correction. In a two-way communication link, the fact that an error has been detected can be sent back to the transmitter for appropriate action, namely, retransmission.

HEADEND

There are many application similarities regarding data communication when viewed from the data processing end of the CATV network. Figure 10 shows the headend

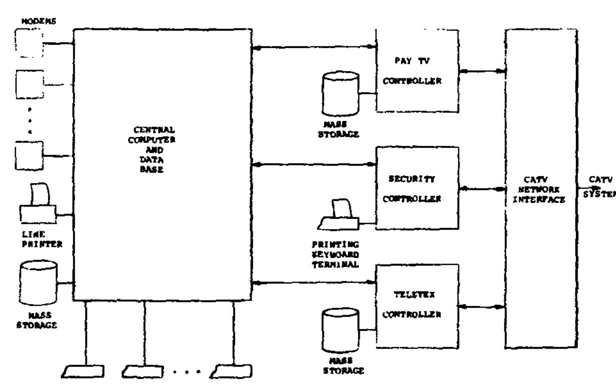


Figure 10

equipment complex for controlling a variety of two-way services. Note that separate controllers are used for each service type, along with the peripheral compliment required by the application. This functional distribution of computing power leads to the following advantages:

1) the controllers can operate standalone because of minimum application requirements (ie: cost), of the central computer is shut down for repair or maintenance.

2) if a controller needs repair, only one service is affected.

3) services may be added through standard interface modules

4) the central computer need not occupy the same physical premises as the controllers

5) one central computer may serve multiple cable systems through the use of more than one controller of the same type

The data path between the central computer and each controller uses a standard communication protocol such as X.25. This allows each controller to use the same type interface hardware and, in a non co-located application, permits the use of standard telco communication links.

Figure 11 shows the recommendations for the central computer and the interface between the central computer and the rest of the system. Figure 12 lists the controller to central computer and controller to digital communication hardware interface recommendations. Note that the signalling speed is either 3.58 MHz or a submultiple of it. This technique permits the use of low cost crystals in subscriber terminals and simplified clock regeneration in coherent detection schemes.

<u>Central Computer</u>

CPU Type:	mini or midi
Word Length:	16 or 32 bit
Mass Storage:	Winchester disk
Capacity:	1K bytes/sub/service
Terminals:	Intelligent
Capacity:	64
Speed:	9600 BPS
Electrical:	RS-232C
Protocol:	X.25

Figure 11

<u>Controller</u>

Central computer	interface
Data link:	Serial line
Capacity:	16
Speed:	Selectable (up to 38.4 KBPS)
Electrical:	RS-424C
Protocol:	X.25
CATV Network Interface	
Data link:	Serial line
Impedance:	75 Ohm co-ax
Voltage:	TTL (0=0.8V, 1=2.0V)
Speed:	Selectable (up to 3.58 MBPS)
Coding:	Manchester biphase

Figure 12

A list of recommended bit rates is shown in Figure 13.

Divide Ratio	Bit Rate
1	3.58M
2	1.79M
4	895K
8	447K
16	224K
32	112K
64	56K
128	28K
256	14K

Figure 13

The CATV network interface consists of the modulators necessary to convert the preformatted digital data to RF sine wave carriers and demodulate the upstream carriers in a two-way system. Figure 14 describes the recommended RF parameters applied to the CATV network, showing the application dependence described above.

APPLICATION	TV GAMES	PAY TV	SECURITY	TELETEX	HOME SHOPPING
DOWNSTREAM					
Multiplex	FDM	-	-	TDM	FDM
Modulation	FSK	PSK	FSK	ASK	FSK
Bandwidth	±200 KHz	±200 KHz	±200 KHz	6 MHz	±100 KHz
Coding	Biphase	Biphase	Biphase	NRZ	Biphase
Error Method	parity + checksum	parity + checksum	parity + checksum	CRC	CRC
Protocol	unique	unique	unique	Prestel	HDLC
Bit Rate	14 KHz	14 KHz	14 KHz	3.58 MHz	28 KHz
UPSTREAM					
Multiplex	N/A	-	FDM	-	FDM
Modulation		PSK	PSK	PSK	FSK
Bandwidth		±200 KHz	±200 KHz	±100 KHz	±100 KHz
Coding		Biphase	Biphase	Biphase	Biphase
Error Method		parity + checksum	parity + checksum	parity + checksum	CRC
Protocol		unique	unique	unique	HDLC
Bit Rate		14 KHz	14 KHz	28 KHz	28 KHz

Figure 14

<u>SUMMARY</u>

With CATV equipment manufacturers rushing to respond to the demand for data services, now is the right time to establish standards for data transmission. The development of guidelines must begin with an understanding of transmission schemes, CATV networks, and the equipment used to provide data services. The parameters of data transmission have been discussed along with some comments and recommendations on channel usage, data rates, encoding techniques and the various tradeoffs involved. The philosophy embodied herein is intended to provide incentive toward the establishment of universally acceptable data transmission standards, designed to achieve harmony between data and video services. Once established, standards will enable CATV manufacturers to produce fully compatible equipment for both current and future systems, while avoiding product rejection or early obsolescence.

1 C.E. Shannon, Communication in the Presence of Noise, Proc. IRE, Vol. 37, pp. 10-21, January 1949

ADDRESSABLE CONTROL

CHARLES O. EISSLER

OAK COMMUNICATIONS, INC.

ABSTRACT

This paper presents a marketing oriented view of addressable control for cable systems. "Addressable control" deals with the ability of a cable system to deliver specific tiers of program material to specific subscribers.

With the spread of premium programming (pay TV) in the cable market, the CATV businessman is confronted with two problems. He must be able to deliver specific kinds of premium programs to subscribers who desire the service. Secondly, he must protect his investment in premium program material from theft. The techniques which will accomplish these two tasks are available today.

A key element in this system is a home terminal that has a unique and unchangeable identity. The terminal responds to commands from the headend. The terminal can be preauthorized to descramble programs that have a tag identity which corresponds to those tiers of programs that the subscriber has ordered.

A small computer stores all information which pertains to the addressable system. The preauthorization data is sent to each terminal during a global address of the system. A program tag identification is sent with the program itself.

Addressable control also allows for future premium service requirements.

INTRODUCTION

This paper describes a system to add headend control to cable television operations. Today, the cable television industry is presented with new opportunities. These opportunities lie in the distribution of multi-tiered premium services to subscribers. In order to deliver these multitiered services, newer techniques in program security, delivery and control must be employed.

Premium entertainment programs are the first of a number of services that the cable system will handle before the end of the decade. Text information services, electronic funds transfer are examples of future services that will also require addressable control.

This paper will consider the problems which confront the CATV operator. Then, the addressable system will be treated in a general descriptive manner. Next, we will consider the hardware, the data requirements and the software. Finally, we will consider some trade-offs involved with addressable control.

THE NEED FOR ADDRESSABLE CONTROL

The cable television industry is experiencing a new business climate. As the product being distributed increases in premium content, greater investment in program material is required. The product increases in value to those who want to view the programs. The CATV operator must be able to deliver specific programs from his multi-tier offerings to the subscribers who desire them. He will also have to protect these programs from theft by those who are unwilling to pay for value received.

As the variety and value of premium programming increases, the problems confronting the cable operator will also increase. He must be able to deal with more than one premium channel of information. Efforts to steal the program often lead to theft of or tampering with the home terminal.

Some older problems intensify as a result of the greater premium content. The operator must be able to collect for services, but with the improved services he will be collecting a larger bill. He must be able to efficiently terminate a delinquent subscriber should it become necessary to do so.

Opportunity also increases as a result of the growth of premium services. You have a greater variety of premium and special event material to sell to your subscribers. But first you must be able to protect the material and deliver it to specific subscribers.

In short as premium content increases, so does the need for headend addressable control.

SYSTEM OVERVIEW

Mature addressability techniques are available and are being applied in the industry today. These techniques were originally developed and applied in STV (over-the-air subscription television). Since any broadcast TV receiver could receive the UHF frequency of the STV station, it was necessary to scramble the premium program prior to transmission. Viewers who wished to subscribe to the premium service were equipped with a decoder. When properly addressed and authorized, the decoder descrambled the picture. These techniques have been utilized in STV for the last four years. Today, they deliver premium STV services to over one-half million subscribers.

These techniques were refined for the cable industry. The ability to offer a number of tiers of service, reflecting the broader capability of cable TV, was added. Today 12 major cable systems are delivering multi-tiered addressable services to their subscribers. More than 120,000 addressable home terminals are in service today.

SECURITY

Addressable control has two dimensions, delivery and denial. One must be able to withhold the premium service from those who are unwilling to pay for it. Since security is one element of addressable control, it is appropriate to review various methods of withholding programs.

Security techniques have been classified by our industry as "soft" or "hard" depending on the degree of difficulty required to defeat them. Soft security usually leaves program material intact but attempts to deny non-subscribers access to it. Hard security, on the other hand, makes the program material unintelligent before it leaves the headend and allows the scrambled picture to come through.

Examples of soft security are negative traps, positive traps, and the use of converters.

Soft security arrangements have provided an adequate degree of premium program protection for some systems in the past. However, for addressability it is necessary to be able to control the security or program accessability from the headend. Soft security arrangements lack the headend "controllability" required for an addressable system.

Hard security arrangements in use today involve encoding or scrambling of the picture so that it cannot be received by a normal television receiver. Two methods in use today are gated sync supression (Figure 1) and sine wave sync supression (Figure 2).

In both cases, the horizontal sync pulse is supressed about 6 dB. The television receiver horizontal phase locked loop then keys on random video peaks and the picture is not started properly. The resultant picture is unwatchable. The function of the decoder is to restore the horizontal sync pulse to its proper relative amplitude. In the sine wave sync supression arrangement, the descrambling signal is a sine wave that is sent through as part of the program material. When properly applied, this cancels the scrambling wave form and the subscriber receives a correct picture.

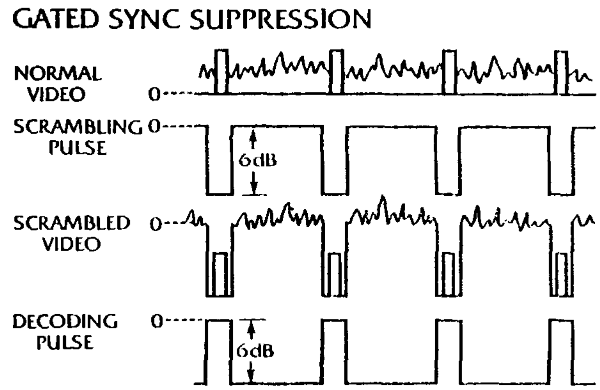


FIGURE 1

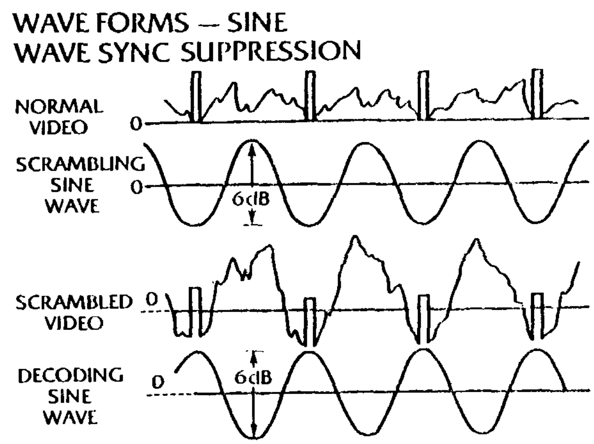


FIGURE 2

Both methods of sync supression scrambling provide effective hard security and can be controlled from the headend. The sine wave type of sync supression is totally "in-channel." It can be used with broadcast transmission and also is applicable through all elements of a cable system.

We have retained the reliable time tested techniques of sync supression scrambling for the addressable system. We have added a time varying element so that home terminals from a previous period cannot descramble an addressable program.

One additional word about program security is in order. One needs to attain a degree of security that is "commercial" rather than perfect. A "commercial" degree of security is one that will support a profitable business. "Perfect" security, if achievable, is expensive.

THE SYSTEM

Now we turn our attention to the addressable system itself. We will describe the general system operation. Consider the hardware required, then the software, and finally the trade-offs for addressable control.

A Key element in the addressable system is a home terminal containing a microprocessor which can respond to orders from the computer at the headend. This home terminal has a unique identity which it was given when it was built. It can be addressed and will react as an individual unit in the system. Control center, headend components and software are elements of this addressable system. The system is one-way and is applicable in existing one-way cable plants. The addressable information can be passed through all elements of the cable plant.

Two kinds of data are involved in the addressable system. They are address data and tag data. The address data is generated by a CRT terminal and is stored in the computer in the control center. The computer periodically cycles through the address information and feeds it to a controller.

When an individual home terminal receives address information, corresponding to its unique address, it does two things. It enables the terminal to operate and it preauthorizes de-scrambling of programs with certain tag identification.

The second kind of data required is the program tag information. The tag identifies the specific program category or channel. When the program being offered contains a tag identification that the decoder is preauthorized to descramble, the viewer will receive the unscrambled picture. The program tag information is conveyed in-channel on the audio RF carrier.

The individual home terminal must receive these two kinds of data before it knows what to do. The address and tag preauthorization must be included in the authorization information from the computer. The program tag is transmitted with the program.

If the subscriber is delinquent or if the box was reported stolen, it is so identified. Authorization is withheld in the "global" address (the periodic address of the entire system) and the terminal does not function.

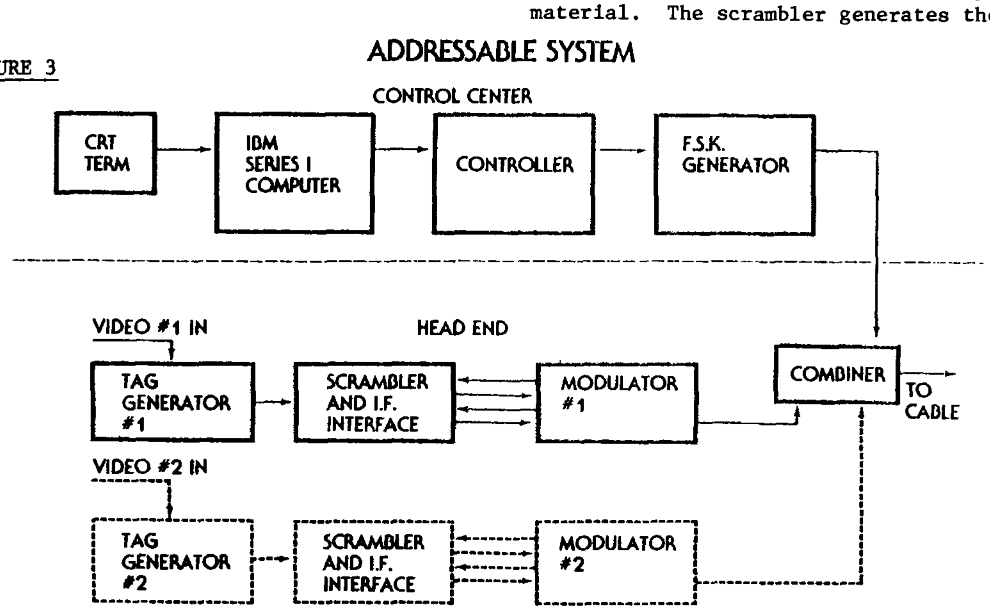
HARDWARE

The hardware required for an addressable system is in three equipment groups. These are: the control center, the headend and the home terminal. The control center and the headend are diagramed in Figure 3. The control center consists of a computer, one or more CRT entry terminals and may include a printer for hard copy. Also, at the control center is a CATV controller and a FSK generator. The computer stores and furnishes the address and tag level preauthorization. It also stores the customer file. The customer file ties individual box, address and serial number to customer name and physical address. The CATV controller converts the data from the computer into pulse width modulated serial data. The FSK generator provides the medium for transmission of this serial data stream over the cable system.

The computer is an IBM Series I. This computer is configured with 64 megabytes of hard disk memory and 128K of volatile memory. The computer allows up to 20 asynchronous I/O ports for CRT operator terminals. Other peripherals may include a line printer and a bar code reader. Our IAS software program provides for handshaking between the addressable system computer and the cable system's host computer.

The second equipment group is the headend, which may be remote to the control center. If remotely located, the headend and control center are linked by coaxial cable. Each scrambled channel has a tag generator, a scrambler, an IF interface and a modulator. The tag generator adds the tag level identification to the program material. The scrambler generates the hard

FIGURE 3



security for premium channel protection. The hard security employed is sine wave sync supression with a time varying element. The IF interface imposes the scrambler signal, the authorization data and the tag information on the carriers for the specific channel. The modulator performs the normal modulation function.

The home terminal is a keyboard controlled unit with infrared wireless remote option. (See Figure 4). The model currently in service is an addressable converter/decoder. It will control 16 tiers of premium programming. The remote transmitter has the same keyboard control as the main unit.

On terminals with keyboard channel selection, the parental keylock option allows up to 10 permitted channels to be locked into the program recall sequence.

The address data itself is a formal 32 bit self-clocking word. The computer sends out each address word twice and moves on. The data rate is 15.7 KHz. Therefore, a total of 12,500 subscribers are addressed each minute. The address data carrier is 104.75 or 112.7 MHz in the FM band. The data bit error rate is 10^{-7}. This means that about one data error may occur per day in a 100,000 subscriber system and it would be corrected with the next data transmission.

FIGURE 4

The home terminal has an on/off function as instructed by the control center. This assures that a floating terminal, such as one that has been stolen, will not function. Publication of this fact, especially at the time of installation, will decrease box theft. Also, the terminal must receive data regularly in order to retain its authorization, if the data stream is interrupted, by disconnecting the input for more than 10 seconds, authorization is lost. If the box has a legal, paid-up status, it is automatically reauthorized by the receipt of authorization data after reconnection.

In the event of a power loss, the unit retains authorization from 3 to 10 minutes. When power is restored or when the unit is plugged in again, the box is reauthorized when its address is included in information sent from the headend. A parental keylock option is operable on program level 8 or can be applied to 2 levels - 7 and 8.

SOFTWARE

A complete software program exists and is illustrated by the menu as follows:

"Enter Boxes" The terminal serial number, address and run number is entered. The cable operator receives this information by means of a diskette packed with the shipment.

"Customer File" Includes a customer name, account number, home address, billing address and authorization level desired.

"Install Customer" Links the customer and the box. This also enables the installer to run an "in-home" test for proper box function.

"Unsuccessful Install" Clears certain records in the event that the box is performing improperly.

"Reauthorize Customer" Sends a single message to an individual box to reauthorize that box.

"Hold/Release" Is used to withhold service when a subscriber is delinquent. Releasing puts the customer back into the currently active status.

"Stolen Box" Suspends service to a box that has been reported stolen. It places the box address in the global file to deauthorize the box.

"Found Box" Reactivates the terminal in the system if certain other conditions are met.

"Disconnect Customer" Cancels the service permanently. It also changes the status of the box from "installed" to "in stock."

"Display/Alter Customer Box" Changes certain customer data but leaves box data unaltered.

"Box Test" Allows either the data entry clerk or the installer in the home to run a test of box functions while checking a customer complaint.

"Assign Channel Authorization" Allows the tagging of certain channels to be done remotely at the headend.

The IAS program with its handshaking capability between the addressable system computer and the host computer provides for interfacing billing and business functions. The capability to control special event programming is also built into the software.

TRADE-OFFS

A thorough financial analysis must be made by the cable operator who is considering an addressable system for premium TV. Comparison should be made between a system with headend addressable control as opposed to just adding security to premium channels. The question to be answered is primitive. "Will I make more money with headend addressable control or without it?"

When compared to a non-addressable system, there are added costs due to the mini computer, added headend components, and the more sophisticated home terminal. However, there are off-setting factors. These include the added revenue from the sale of additional tiers of entertainment which were added as modest incremental system costs. The addressable control also facilitates the sale of special event programming for increased revenue.

Another trade-off is the increased operating efficiency due to improved headend control as opposed to requiring service calls to change subscriber program tiers.

The addition of addressable control will minimize and perhaps prevent some problems associated with premium TV. Program security is improved by the "hard security" scrambling. Box theft is minimized when it is publicized that the stolen and unauthorized terminals do not operate. Tampering and attempts to relocate equipment decline when it is demonstrated that an interruption of data flow deauthorizes the terminal. Accounts receivable become more current once the operator demonstrates the ability to suspend all service from the headend.

On a more positive note, addressable control provides the cable operator with the ability to offer an improved level of service to his customer. He can deliver the selection of program tiers that the specific subscriber wants. He can change the program quickly with little cost. With mail or telephone prearrangement, he can offer special events to his subscriber. Many marketing tools are available to the cable operator. He only needs to apply his own creativity.

When considering an addressable system today, the cable operator is faced with several options. He may choose to extend his bandwidth channel capability and utilize fairly fixed soft security. Or he may choose to add several tiers of hard security that will provide program selection from today's choices. He may intend to include headend addressable control at a later date. But why wait?

The premium entertainment market is developed and available for exploitation now. An adequate number of premium programs exist. The industry is on the threshold of another expansion of these programs. Why install a system that will require a service call to change out a box or to revise a trap when the subscriber wants a new program? It could be done quickly by a data entry clerk who would simply type the information into the CRT entry terminal.

This same addressable capability will allow the cable operator to increase both subscriber satisfaction as well as his own revenue by offering special event programming.

THE FUTURE OF ADDRESSABILITY

The 80's will present many challenges and opportunities to the cable system operator. Headend addressable control is an essential element to help the CATV industry meet these future challenges and exploit resultant opportunities.

ADDRESSABLE CONTROL - A BIG FIRST STEP TOWARD THE MARRIAGE OF COMPUTER, CABLE, AND CONSUMER

LARRY C. BROWN
GENERAL MANAGER PLANNING

PIONEER COMMUNICATIONS OF AMERICA
3518 RIVERSIDE DRIVE, COLUMBUS, OHIO 43221

****

Addressable Control... is it the final step in the evolution of multiple-programming services on cable, or rather a first big step toward a 'new beginning' for the industry? Pioneer believes the latter, and has accordingly developed a System the company believes is 'One Single Solution' to every Cable Operator facing the step up to Addressable Control...and beyond! The key to the approach is a 'Family' of co-existable Subscriber Terminals suitable for virtually every conceivable need envisioned in a one-way or two-way cable system.

****

Addressable Control--"remote control" of a CATV subscriber's channel reception capabilities from a convenient, centralized "HUB" point within the cable system--finally has achieved a solid foothold on our industry. Over the last several decades, the cost of the computer technologies necessary to provide addressable control has plunged. Meanwhile, cable system installer/technician labor costs. ..especially when "fully-loaded" with a vehicle, tools, and an abundant supply of Mad Dog Repellant for those backyard easements ... have soared. At the same time, a multitude of relatively low-cost Premium Programming Packages available by Satellite have evolved, along with a "tiered service" concept for marketing them, creating the most important element of the equation that now makes the addressable control concept so attractive: a crying need. The mobility of the average American is raising the typical cable system's "churn"...the rate of connect/ disconnect of subscribers... to all-time highs. And now we have yet another "turnover" to accomodate...an "intra-tier" churn as subscribers "pick and choose" among the tiers of service made available to them.

"Manual Control" - a physical trip to the subscriber home for every connect, disconnect, or service "tier" change. "Addressable Control" - accomplishing the same thing remotely by simply typing in a command into a keyboard at the cable office. The ultimate payback of Addressable Control is so obvious, it needs no further elaboration. It is not hard to see why some CATV industry experts predict that within the next decade, over 80% of American cable homes will be equipped with "Addressable Control" devices.

But, is the widespread industry acceptance of "Addressable Control" of each subscriber's programming the culimination of years of progress for cable, or might it actually be the first solid sign of a whole new destiny for our industry? Could it be that the computer technology called "Addressable Control" will eventually breed such changes in our industry that some day "cable television" might even be a misnomer for the services we provide?

At Pioneer, we view Addressable Control as not an end, but rather the start of a new beginning for cable. A first big step toward bringing down to earth a lot of the "blue sky" promises we've been hearing for years. A first big step toward the marriage of computer, cable, and the consumer.

At Pioneer we aren't guessing...we're just observing. Closely.

We see the strong government deregulation trend that frees cable of the constraints which have previously hindered its development, but which is also destined to stimulate other competing industries like STV, telephone, broadcast television, and low power TV, to compete with cable for the delivery of the coming 'new services'.

We see an industry bolstered by such consumer acceptance that it can continue to attract heavy capital investment despite a recessionary economy.

We see many Cable Operators like Warner-Amex, ATC, Times-Mirror, Cox, participating in development and field testing of assorted versions of the 'new services': home security, home shopping, home banking, information retrieval.

We see, through companies like HBO, Nickoleodeon, Showtime, ESPN, the impetus that simple 'packaging' of programming into easily-managable satellite-fed channels has given to the pay-TV industry.

We see the growing recognition by Advertising Industry giants like J. Walter Thompson, Ogilvy and Mather, Young and Rubicam, and the nation's largest retailers like Bristol-Myers and General Foods, of Cable Television as a powerful medium for marketing their products to consumers.

We see the soaring interest in cable exhibited by huge publishers like Knight-Ridder and Time, Inc., as they eye the industry for its 'broadband' potentials for 'electronic publishing'.

We see the innovative activity of CompuServe, The Source, CBS Infovision... resources capable of becoming major 'collators', 'packagers', and 'networkers' of new services' for cable.

With all that in mind, its hard for anyone not to believe that "text technology", "2-way", "data communications", "satellite", "home computer", and "information-providers", will eventually shake out into logical packages that can be profitable, ongoing businesses. It won't all come at once, but it will come. Just like "tiered service" and "addressable control" have.

When Will It Come?

Within the next 10 years its highly likely that several radically-new services involving the consumer, "text" technology, 2-way cable communication, and the computer will become viable, established, and truly-accepted industry-wide. Within 15 years its certain. But wait...10 to 15 years? That's the term of a franchise! Ah...there's the rub!

Every franchise being built or rebuilt today is a community where, before long, these coming "new services by cable" will soon be in high demand. So for every cable operator involved in new or rebuild construction the time to start planning for these 'new services' is now.

For the cable operator who is today choosing subscriber "boxes" for "addressable control" is really locking himself into a much bigger picture. For "Addressable Control" marks a giant step up from the traditional "converter". We're no longer talking about a "stand-alone" box that sits in the subscriber home to expand the number of channels he can receive. Addressable Control infers a System. A central computer, a communications path through the cable plant, addressable terminals in subscriber homes are the obvious "system" elements. The not-so-obvious include special support equipment (How do we maintain, test, address these "addressable boxes"?); support services (What if the control computer quits? How do you run a computer, anyway?); computer software, and more. Addressable Control truly means a System itself within the total Cable System.

For any operator considering Addressable Control, Pioneer offers two pieces of advice. First: Stop thinking "box" and start thinking "system". Look at the total system a vendor is offering you for Addressable Control.

*Is The System Simple?

Has it been CONCEIVED AND DESIGNED WITH PERSPECTIVE...designed as a SYSTEM, looking from the APPLICATIONS where the system is ultimately intended to be used, then designing the overall elements of the system so cost/benefit is optimized for you, the Cable Operator?

*Is The System A Solid Foundation To Build On?

Can the One-Way Addressable configuration of the System, used only for remote subscriber reception control, be expanded to Two-Way Interactive configurations employing Security, Text, Transaction and other services?

* Is The System Complete?

Does it provide the necessary "Support Equipment" to make operation and maintenance of the Subscriber Terminals and System more efficient, less time-consuming, thus less expensive?

*Does The System Offer A "TOTAL" Approach To Vertical Services?

Or does the System simply enable "data" exchange between Operator and Subscriber, thus passing the burden of total software development to you, the Operator?

*Is The System CLEARLY Defined?

Does the vendor offer a clear Customer Contract outlining every detail from System Final Planning through Customer Training, including mutual responsibilities of Operator and Vendor to meet a specified Project Timetable?

*Is The System Failsafe?

Do two-way configurations of the system have built-in methods to cope with the real-world problems of undesired signal ingress, an unauthorized subscriber-connected device, or a "locked-on" Subscriber Terminal interfering with communications?

*Is The System Standardized?

Do terminal designs achieve economy of scale through mass manufacturing, yet allow for customization for special requirements, as an option? Are the system's software packages standardized, and designed to reduce the most commonly-employed types of information exchanges between Subscriber and Control Center to their simplest form, making them as easy as possible for both Operator and Subscriber to use?

*Is The System Flexible?

Does it offer not only a terminal for Addressable Control, but A COMPLETE FAMILY OF TOTALLY INTERMIXABLE TERMINALS, all co-existable in the same system, including two-way Interactive, two-way Security, and Video Text designs?

*Can The System CO-EXIST With Conventional Converters?

So you still can offer inexpensive low tiers of service?

*Is The System Truly State-Of-The-Art?

Does it offer the greatest available channel capacity, including dual-cable designs? Is its digital communications fast enough to process large volumes of subscribers in acceptable times?

*Does The System Employ EFFECTIVE Theft-Of-Service Protection?

Will your Premium and other programming have maximum security from subscriber theft?

*Does The System Really Use A Method Of Reliable And Secure Data Communications?

Are schemes of correlation and error detection designed into the Terminals to eliminate "false messages" to and from Subscribers?

*Do Terminals In The System Have A Powerful ANTI-THEFT Design?

Is there a package of electrical and mechanical features inside Terminals to deter Subscriber tampering with or theft of the Terminals.

There are dozens more questions you should ask a vendor before taking the "Addressable" plunge....questions about installation, training, warranty, continuing terminal availability, operations startup, vendor's reputation, many things. But the key is to always be thinking "system"....not just "converter" or "box"... when you ask them.

At Pioneer, we studied all the considerations you've heard mentioned, and reduced them to what we believe is a logical "total system" architecture which can accomodate the "Addressable Control" requirement today, yet grow into a system capable of delivering the "new services" of tomorrow. This one product, the Pioneer VIP System, is intended to satisfy the Subscriber Terminal requirements of every Cable System Operator in every franchising situation, for now and years to come.

THE SYSTEM CONSISTS OF:

1. A CONTROL CENTER

Located at the central hub of the system, Computer hardware, software, and peripherals form a subsystem for one- or two-way data communications with subscribers. Standardized VIP Software Paks exist for the most frequently-requested uses of the system by the Operator (e.g. pay-per-view, one-way control, opinion polling). Primary function of Control Center is to process and store (a) all outbound commands to Subscriber Terminals and (b)all inbound responses from Subscriber Terminals (in two-way configurations).

2. CABLE PLANT ENHANCEMENTS

Located at each Trunk-Bridger Station in the Cable Plant (two-way VIP Systems only), these consist of a Pioneer Bridger Gate Controller (BGC) and a Pioneer-compatible Reverse Bridger Switch (RBS). Primary function is to (a) provide protection against remote upstream plant faults that would otherwise impair data-communications, and (b) provide strategically-located status monitoring capabilities in the plant.

3. SUBSCRIBER TERMINALS

Located in Homes and Businesses throughout the Cable System, these consist of a "family" of terminals, all of which can be intermixed as desired by Cable Operator to provide the services appropriate to each Franchise situation. Besides conventional CATV converter functions, the primary additional function of the terminals is to (a) send informative responses to the Control Center concerning status of the terminal and/or (b) receive and react to commands from the Control Center.

4. SUPPORT EQUIPMENT

Located at various points throughout the Cable System, this Custom-Designed Pioneer equipment has been created for Lab Testing, Field Maintenance, and normal Operation of the terminals. Primary function of the Support Equipment group is (a) protection of the Cable Operator's major investment in Control Center and terminals, and (b) simplification of maintenance and operation of the Pioneer System for better cost-effectiveness.

5. SUPPORT SERVICES

Provided at various appropriate times throughout the development of the entire Cable System, these include materials and planning assistance from pre-franchising, installation services, and training of Cable Operator personnel in proper operation and maintenance of the Pioneer VIP System. Customization assistance for both hardware and software is also available to potential Pioneer customers -- Cable Operators -- from Franchise Proposal through final System Installation and Training.

Our family of "mixable" Subscriber Terminals includes:

A ONE-WAY TERMINAL

Providing simple addressable control of each subscriber's channel reception.

A TWO-WAY TERMINAL

Providing all the one-way terminal capabilities, plus two-way polling and monitoring functions and two-way subscriber transaction capabilities.

A TWO-WAY PLUS TERMINAL

Providing all the two-way terminal functions plus full alphanumeric keyboard and hard copy receipts.

A TWO-WAY SECURITY TERMINAL

Giving subscriber security monitoring capabilities.

A MICRO-COMPUTER ADAPTER

Providing interface capability for most micro-computers to the cable system.

A CONTROL ADAPTER

Suitable for building into other devices, e.g. power relays....to provide "other control" functions via the VIP System.

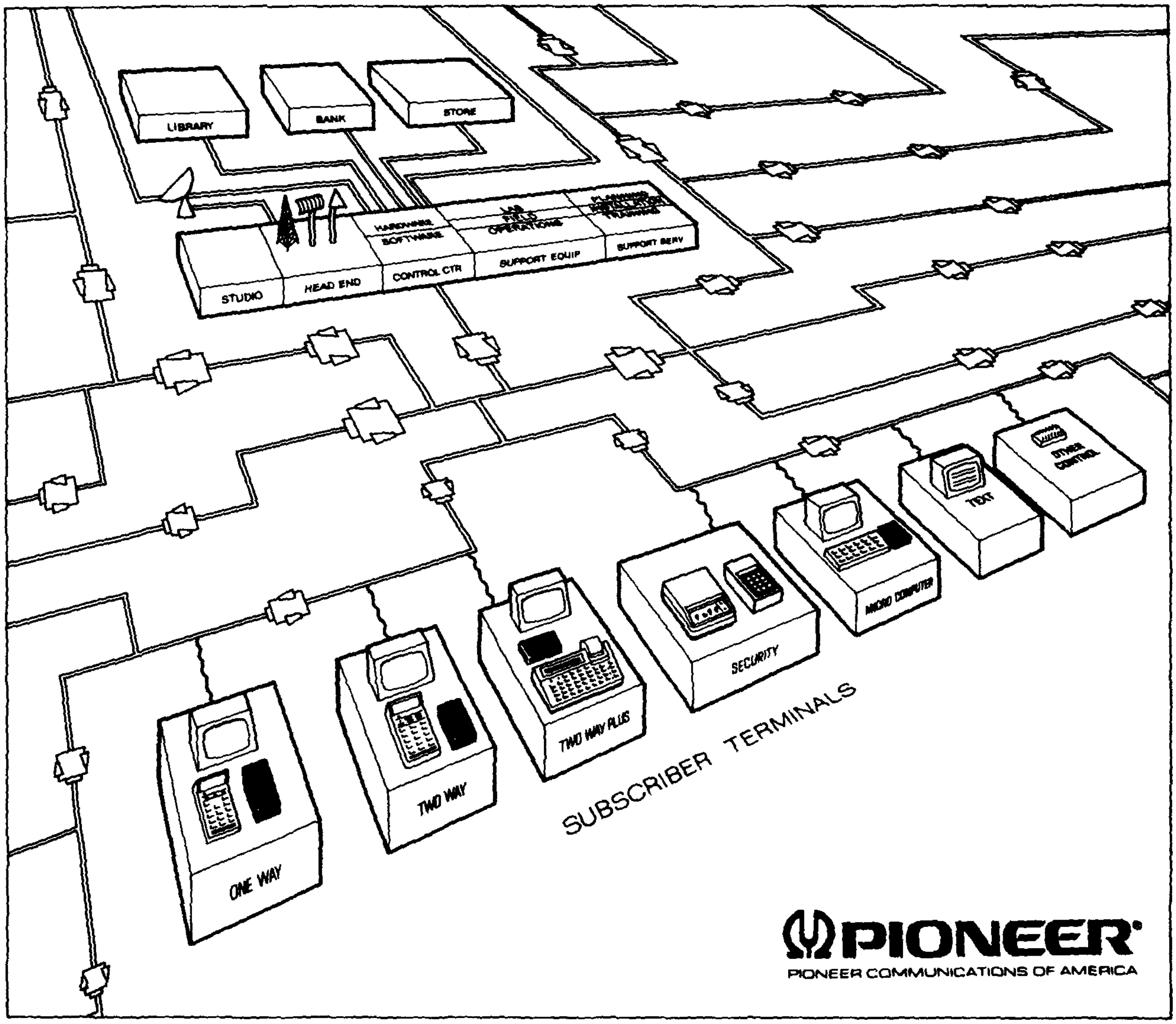
TEXT CAPABILITIES

Making possible subscriber reception of hundreds of text pages on one dedicated channel for both one-way "information services" and two-way enhanced transaction capabilities.

Pioneer's approach to the 'new services' dilemma is not purely a fantasy ideal laid out on paper. The BT-1300 Series Two-Way Terminal, for example, cornerstone of the VIP System, is just now entering mass production, after two years of research and development. And that BT-1300 is a fourth generation interactive terminal from Pioneer. As most of you probably know, only Pioneer has over seven years of research and development experience in interactive two-way cable TV technology, and an installed system with nearly four years of operations already logged....still the world's largest singled interactive two-way cable system, in Columbus, Ohio. Probably the single most influencing factor which has guided the conception of our VIP 'One Single Solution" is the experience we've gained in both addressable control and interactive two-way field operations by virtue of that four years of operating experience. Yes, we had our share of startup pains, and we went through the usual 'new product' learning curve. But it's over now, and the new VIP System is the culmination of our efforts.

Pioneer's VIP System is a result of falling back out of the trees long enough to view the forest again. We think we've developed the one "total system" that can help cable operators meet today's addressability needs, yet also enable them to take advantage of the "new service" opportunties we see coming tomorrow.

All of which leads to our second piece of advice to any Cable Operator considering Addressable Control: (you guessed it)...buy the PIONEER VIP SYSTEM!



THE PIONEER V.I.P. SYSTEM...ONE, SINGLE SOLUTION

ADDRESSABLE TERMINAL CONTROL USING THE VERTICAL INTERVAL

CARL F. SCHOENEBERGER

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ABSTRACT

The concepts of CATV Terminal Control using the Vertical Interval for addressing are explored.

Design objectives of the TOCOM 55 PLUS™ and the advantages of baseband operation with vertical interval addressing are given. Methods used for reliable addressing, channel access control, parental key control, emergency alert, and basic system security, are discussed.

INTRODUCTION

During the past several years, the requirement for a flexible and effective method to control subscriber access to premium television has created the addressable terminal. The principal advantage of an addressable terminal is the ability to change a subscribers service capability rapidly and economically.

A number of techniques are available to transmit the digital information to the terminal for addressing and program control. With the use of a baseband converter, data can be encoded in the standard video format and transmitted in the vertical interval.

The capacity of the vertical interval is sufficient to support a very flexible control algorithm plus a large number of additional services. When appropriate formats are utilized, a highly reliable system is created. Theft of service or addressable terminal security, must be considered as a point of primary concern in the design of the system.

This paper will illustrate the TOCOM 55 PLUS™ system, which is designed to take advantage of the benefits of addressable terminal technology utilizing vertical interval addressing.

Addressable Terminal Design Objectives

The 55 PLUS™ system was developed with foremost consideration given to the following design objectives:

1. High quality RF conversion performance with 400 MHz capability.

Obviously, the primary product delivered to the customer is television pictures, and with performance tradeoffs caused by 400 MHz systems, the performance of the terminal becomes a critical link which can substantially effect plant costs.

2. Flexible control of premium services.

Due to the rapid expansion of premium services and the use of new marketing methods, considerable additional capacity should be provided. The provision for rapid reconfiguration of the system is a necessity to promote additional sales. An individual control mechanism should be provided to permit sales of single and repeated special events such as a single course on an educational channel.

3. A high security, low distortion video scrambling technique.

Using baseband technology, an effective but economical decoding system must be provided.

4. Theft and tamper resistant.

The system design of the addressable terminal must contain various mechanisms to assure that the subscriber can not compromise the enclosure and internal circuits, nor effectively utilize a stolen terminal.

5. Reliable hardware.

The addressable terminal design, and quality of the component parts, must assure long term reliable operation in the environment of a typical consumer's home.

6. Economical pricing.

Although the initial cost per subscriber may be higher with addressable terminal technology, the revenue potential is also much higher. To insure that this occurs, each feature of the addressable terminal should be studied on a cost to provide versus revenue obtained basis.

7. Upward compatability.

The system should be designed to permit substantial upward compatability to fully interactive versions with internal character generators and upstream data transmitters.

8. Wireless remote control.

Provision should be made for an optional wireless remote control which is capable of operating all modes of the terminal including volume and muting. The remote should be economical enough to be replaced at the subscriber's expense when damaged.

9. On-screen display.

The channel number and time should be superimposed on the displayed video, eliminating the need for separate channel number readouts and providing a clock feature for almost no incremental cost.

10. Parental access coding.

The terminal should test the incoming vertical interval data to determine the parental access rating of the video program. If beyond the threshold, it should automatically block the picture and sound while requesting the parental access code. The rating threshold and the access code should be addressable. Although this feature generates little revenue, it is a very powerful franchising tool.

11. Attractive appearance.

The appearance of the set top and remote control should blend well with the typical home television environment.

ADVANTAGES OF BASEBAND CONVERSION AND VERTICAL INTERVAL ADDRESSING

The principle advantages of baseband conversion are as follows:

1. No extra system data carriers.

This feature is particularly important when up to 110 video channels must be controlled and descrambled independently, especially in systems which have virtually all bandwidth occupied.

2. Economical data receiver.

The data receiver is simply a comparator which strips non-return-to-zero data from lines of video. The digital control portion of the terminal determines when actual data is present and disregards other video and noise. It is also possible ble to read data anywhere on the video signal, permitting entire channels to be converted to data use.

3. Internal baseband video input.

This is useful for versions of the product which contain internal character and graphics generators. It also makes on-screen display of channel number and time possible.

4. Control of volume and picture blanking.

This feature permits the remote control to be a true replacement for existing remote controls. The digital control portion of the terminal also utilizes these features to prevent the consumer from seeing or hearing unauthorized programs.

5. Baseband video output.

To prevent unnecessary distortion, an optional baseband video and sound output is available for direct connection to video tape recorders or newer televisions which have baseband video inputs.

BASIC ADDRESSING FORMAT AND RELIABILITY

The addressable terminal must obtain data from the vertical interval at a modestly high data rate, qualify the data as valid, and process the data. Vertical interval data is transmitted on lines 17 and and 18 in place of the broadcaster's VITS (vertical interval test signals). All other signals in the vertical interval are transferred through the system intact, permitting proper operation of VIR (vertical interval reference signal) and other present and future services. The data rate is set at the fastest possible speed which is also a sub-multiple of color burst, in this case 3.579 MHz/4 was selected. This data rate is limited by the speed of the control processor used in the TOCOM 5504A™ and is referred to as the half speed data rate. The TOCOM 5510A™ uses a bit time of 3.579 MHz/2 but can also read and process half speed data. The full speed data permits 92 data bits per line while the half speed data is limited to 46 bits per line. At this speed, the control microprocessor can read data as it arrives, eliminating expensive buffer memories, and process the data during the remainder of the video field. Transmission reliability is assured through the technique of sequenced redundant transmission. All addressing information is sent twice and in sequence, and must be received this way, or it is considered invalid data and ignored. Also, a configuration checksum is transmitted to give a longitudinal check. The specific addressing data is stored in an EEPROM (electrically erasable programmable read only memory) which retains data, even with no power applied. The addressable terminal is actually addressed on only one channel called the home channel. The vertical interval of the other channels are free to be used for text transmission and for the Program Control Word (described later). When the terminal is turned off, it automatically tunes to the home channel and receives any new addressing information as well as a configuration checksum of what the addressable terminal's EEPROM memory should contain. The checksum method is much faster than actually re-addressing each unit. If the checksum does not match, the addressable terminal will disable and show an error code on a blank screen. The error code is useful to the system operator since it will indicate the reason why the addressable terminal has ceased to operate. Except in the case of terminal failure, operation can be restored by re-addressing the unit without a service call.

PROGRAM CONTROL WORD AND THE ADDRESSABLE TERMINAL RESPONSE

Program control is implemented through the use of a digital series of information called the program control word (PCW). This data is sent 3 times per second from the headend and is continuously monitored by all addressable terminals tuned to that channel. The PCW contains the following data:

1. Service Class Identification.

The program may belong to any or all of up to 32 different service classes, each represented by an individual bit.

2. Program Indentification.

An 8 bit number is used to identify the specific program that is being transmitted.

3. Channel Type

A 4 bit value is used to identify the use of the viewable video portion of the channel. In some cases this indicates that full field data is present and the addressable terminal automatically switches to a blank screen. Even channel types are used for A cable, while odd types are used for B cable in an A/B cable system. It is also used for control of the descrambler.

4. Parental Access Control.

A 4 bit value represents the parental control rating of the current program.

The addressable terminal uses the information contained in the PCW to determine if the user is qualified and if so, it releases the video and sound and descrambles the picture for the subscriber.

55 PLUS™ ADDRESSING CAPABILITIES

The addressable terminal must be initialized with its actual address, system number, and home channel, before it accepts commands. This is accomplished by depressing a certain key combination on the terminal while the new address data is loaded. One key combination is utilized for HRC format head ends while another is used for the Standard format. In either case, the terminal listens to the respective channel 3 and accepts the next new terminal initialization sequence. All subsequent commands directed to this address, on the home channel, will be accepted by the terminal. This feature is particularly useful because the actual address can be used to specify a physical location or section of the cable plant with no excess inventory problems or "missing" address codes.

The basic initialization sequence is sent in sequence in 14 transmissions on the home channel. The following information is carried in this sequence:

1. Service class enables.

A 32 bit word is stored in the addressable terminal which defines which service classes it may permit the customer to view.

2. Per-event enables.

Up to 4 different events are stored in the format of a program identification and channel number.

3. Emergency alert group enable.

An 8 bit word is stored which defines any of 8 emergency alert groups to which the addressable terminal belongs.

4. Parental access code and parental control level.

The customer provided control threshold and up to 8 digit access code are stored. These may be set to a null value which removes any requirement for the subsciber to enter the access code.

5. Cable plant configuration information.

Several status bits are loaded to indicate the tuning format HRC, ICC or Standard, Home Channel, A/B cable option, and bit enables to tune the FM band. This information can be changed only when the actual address is loaded.

6. System number.

The system number identifies the original point of programming and is used to prevent theft of service in other systems, and to aid in identification of stolen terminals.

Several other command sequences are recognized by the addressable terminal and are itemized below:

1. Configuration check.

A checksum transmission that is used to verify that the addressable terminal and control system agree on the current configuration.

2. Emergency alert.

An 8 bit word which is compared to the previously stored Emergency Alert Group enable, used to initiate or stop an emergency alert cycle.

3. Addressable terminal individual disable.

This command is sent to deactivate the addressed terminal. It is usually sent to all invalid addresses not accessed by the block disable command.

4. Addressable terminal block disable.

This command disables blocks of 4096 addressable terminals, and is sent to all invalid addresses as a feature to prevent stolen boxes from successful operation.

The Program Authorization Cycle

The process of changing channels is a function of the control microprocessor. When the user selects a new channel, the microprocessor compares the PCW and the subscriber service class enables. If any two corresponding bit pairs are set, then an enable results. If no pairs are found, then a test is made for channel and program identification match to the stored per event enables. If these match, then it is also enabled. When enabled, the terminal then checks the parental control level and requests the access code if necessary. Once this operation is complete, the video and sound are released to the subscriber. The channel tuning and authorization cycle typically takes about one half second if no access code is required.

Service Class Control

Addressable terminal control using service classes provides one of the most flexible methods of premium channel control. The method is best demonstrated by a typical use example as shown in Figure 1A.

In the example, some bits represent a package of channels while others represent a channel during part of a day for a partial service or promotional material reception. A program can belong to any or all service classes simultaneously while the user also can be enabled for any or all service classes. If any corresponding bit pairs are set the subscriber will be enabled. To give a specific example, if subscriber #3 tunes to premium channel #1 during transmission of partial service, bit pair number 7 will be set and the subscriber will be enabled.

Per-Event Control

The per-event enable portion of the addressable terminal is operated by a simple match between the channel numbers and the program identification numbers. A typical use of this type of enable is for the sale of a sporting event, or an educational show such as driver education for a semester. Each channel can be sold with up to 255 special events, and each addressable terminal can store enables for any 4 special events.

Emergency Alert Control

Emergency alert control is operated in the same manner as service classes except that there are only 8 bits or classes instead of 32. The terminals receive the command from the vertical interval and if any bit pair is set, turn the television on if off, tune to the channel specified in the command, and raise the volume to maximum. When the alert is complete, the power will restore to the previous state and the addressable terminal will tune to the home channel. In a typical system each class will represent different groups of people such as: police, fire, auxiliary fire, general population, etc.

TERMINAL SECURITY

An addressable terminal can be circumvented in one of two ways: by compromising the terminal or by directly connecting

Service Class Bit	Typical Channel	Content
1	4,5,8,11,13,21,33,39	Off Air Channels
2	10,14,15,16,17	Economy Premium Package
3	All Premium Channels	Promotional Material
4	50	Premium Channel #1
5	51	Premium Channel #2
6	52	Premium Channel #3
7	50	Partial Service Premium Channel #1

Figure 1A

Channel Control Word Service Class Bits							Channel Use
1	2	3	4	5	6	7	
1	0	0	0	0	0	0	Off air channels
0	1	0	0	0	0	0	Economy premium channel
0	0	0	1	0	0	0	Premium channel #1
0	0	1	1	0	0	0	Premium channel #1 Showing promoted material
0	0	0	1	0	0	1	Premium channel #1 Showing partial service
0	0	0	0	1	0	0	Premium channel #2

Figure 1B

Subscriber Service Class Enable Bits							Subscriber Number	Subscriber Enable Capability
1	2	3	4	5	6	7		
1	0	0	0	0	0	0	1	Enabled only for off air reception
1	1	1	0	0	0	0	2	Off air, economy premium and promotional material
1	0	1	0	1	0	1	3	Off air, promotional material, partial service premium channel #1, premium channel #2

Figure 1C

a "black box" to the plant which descrambles the encoded video.

Since a "black box" can always be built, and sold as a kit, the objective is to make it so expensive to sell that the average consumer finds legitimate purchase of premium television much cheaper. The TOCOM 55 PLUS™ encoding technique requires a special demodulation to baseband which raises the cost of "black box" equipment substantially. The actual baseband descrambling process requires line counting circuits, a special sync stripper circuit, automatic gain control timing circuits, and actual video processing circuits. Most of these parts are not extra cost items in the TOCOM 55 PLUS™ since it's basic design is optimized for these features; however, convential "black box" designs will be relatively expensive.

The TOCOM 55 PLUS™ has a number of internal system security features to protect the addressable terminal from compromise. They are itemized below.

1. Tamper switch.

An internal tamper switch detects when the addressable terminal has been opened and disables the terminal. The subscriber will see a blank screen with a special code displayed in place of the channel number. If a correct configuration check is subsequently received the addressable terminal will be restored to normal operation, otherwise it must be re-programmed by the system operator. The tamper switch will operate even if the addressable terminal was not powered at the time of intrusion.

2. Three day configuration check timeout.

This feature may be enabled to deactivate any addressable terminal not receiving a configuration check for three days. This prevents external or internal blocking of the home channel addressing information after ordering premium services. This disable will clear if a valid configuration check is received and also displays a special code in place of the channel number during the disabled period. Note that when the addressable terminal is turned off by the subscriber it automatically tunes to the home channel and receives configuration checks.

3. Checksum verification.

If the internal checksum does not verify with the programmed checksum the addressable terminal will become disabled until the system operator re-programs the terminal. Again a different special code is displayed on a blank screen while the terminal is disabled.

4. No jumper to cut or simple rewiring to enable the descrambler.

The decoding of the addressing information and the source of the real time signals for descrambling, originate in the control microprocessor. Since decisions and real time control come from one part, there are no jumpers to cut. The algorithm of the control microprocessor is not easily extracted and all critical parts including the microprocessor and EEPROM memory are soldered in place. This makes it difficult to develop and install foreign components that would permit the addressable terminal to operate without system control.

5. Individual and block disable.

The disable commands prevent stolen addressable terminals from operation elsewhere in the same system. This feature is also useful for service disconnects since most customer's will not remove the addressable terminal on moving day if it was deactivated when he called in to have the service disconnected.

6. System identification match.

The system identification is compared during a configuration check, and a stolen addressable terminal from another system will be disabled. This will occur even if the address of the stolen terminal is the same as a legitimate customer in the foreign system.

7. Reversing A/B cables.

The TOCOM 55 PLUS™ does not control on a channel basis, but on a program basis. Therefore, switching cables in a dual plant will make no difference. The terminal still decodes the program control word and enables service based on service class or per-event authorization.

8. New terminal initialization done only at the headend control point.

The actual address of the terminal and cable plant parameters are loaded at the headend only, under supervision of the system operator. This prevents identical addresses in which one subscriber pays for all services and the others operate with his address code.

CONCLUSION

The baseband approach to addressable terminal design provides many important advantages over other techniques. Video format data encoding eliminates additional data carriers and is easily expanded to full field data transmission. Valuable product features such as volume control and on-screen displays become part of the basic design. Pay security is enhanced through more secure baseband encoding techniques. The TOCOM 55 PLUS™ product family proves that sophisticated baseband technology can be economically applied to addressable terminals.

AUTOMATIC STATUS MONITORING FOR A CATV PLANT

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ABSTRACT

Many of the customers using the CATV Distribution System for communication require total service and continuity. Premium programming and educational requirements also mandate fast response to plant or system failures. An automatic status monitoring system can substantially improve reaction time and reduce maintenance loads.Such a system has been engineered to meet these service demands.

INTRODUCTION

The present CATV Industry is experiencing a saturation of technology which could be likened to the introduction of rectangular color television sets in the American home. The cable televion industry today is positioning itself as THE mass communication medium which should take us through the turn of the century. CATV's broad influence on American lifestyles will serve to save us energy and provide better educational and entertainment opportunities to our nation and throughout the world.

As the importance of our communication increases, the realibility and the serviceability of this distribution equipment becomes a greater concern to the operators and to the consumers and subscribers themselves. The revenue producing services such as entertainment programming, information exchange, security, and educational and public service functions rely on the quality of the distribution system in their neighborhood.

We should take a moment to consider the justifications of status monitoring. Its implications of improved service, reduced down time, improved technical effectiveness and the ability to pinpoint equipment malfunctions can head up our list of benefits. Additionally an automatic system of data reporting from status monitoring equipment can be preserved for later failure trend analysis which may aid the operator in preventive maintenance service which could reduce down time even further. It has the potential to indicate areas of the plant which may require attention on more frequent basis and presents alternatives to pole climbing and bucket trucks when it becomes necessary to do system checks. The automatic test equipment approach can provide data which has extended usefulness in a plant of any size. So the primary function becomes one of fault locating, and secondary functions enhance its value to the engineering staff responsible for plant performance.

In fact status monitoring is an edict in most new metropolitan franchises. Wide band distribution, larger plants, increased concentrations of subscribers and many physical factors increase the maintenance burden in any operation. Status monitoring has presented some alternatives to the expensive and often sporadic preventive maintenance program. There is no substitute for quality distribution components and conservative plant design. However, a well configured automatic status monitoring system would be an extremely useful service and maintenance tool as well as a trouble shooting aid in times of equipment failure. A broad based economical approach to status monitoring utilizing automatic test equipment techniques will be discussed here.

DESIGN CRITERIA

The exchange of data between remote points and a central location in the cable plant ordinarily would not be a difficult undertaking. However, the expansion of the cable spectrum leaves but few windows where data can be exchanged from points in the system and the head-end which will not complicate normal operation. The exchange of data should occupy as little spectrum room as is practical.

The environmental performance of the automatic test equipment component should exceed that of the distribution component to which it is interfaced. So environmental resistance, immunity to radio frequency interference and transients often encountered in the cable plant is imperative.

Although specifically, size is not a serious concern, a smaller component is usually more easily accommodated into a retro-fit application. Any additional equipment in a cable plant naturally will require powering and implies additional losses which must be minimized so a component which could be considered electrically transparent would be most desirable.

Such a component configuration then begins to appear as any other common CATV component. Efficient, light weight, minimal losses, fast response and circuit integrity all become considerations in the design criteria. Not to be overlooked are the economic factors involved in producing such a device as well as the installed cost or cost per mile to the plant operator. Additionally, we would like to have our status monitoring equipment operate under adverse signal conditions as well.

SYSTEM CONFIGURATION

Let us look at a block diagram of how the system which we have configured performs. Our system components include a computer which serves as a control system, transponders which function as receiver-transmitters and data collectors, an interface or modem and a spectrum monitor which reads cable signal levels shown. In dotted line form you will see the amplifier or other components such as the power supply.

The Computer to be discussed is programmed to continuously scan and read measurements or data from each of the transponders as they are individually addressed from the program which is resident in the computer.

The Modem provides an interface between the microprocessor and the plant RF System. As a Modulator-Demodulator it converts logic levels to RF and Demodulates RF to logic levels.

The Transponder block in our diagram is comprised of an FM receiver, an addressable controller, an A to D Convertor, regulated power supply, an isolation network and an FM Transmitter for returning data to the head-end. The last block shown in our diagram is the remote spectrum monitor which is a specially configured spectrum analyzer designed to withstand the vigors of the cable environment.

SYSTEM COMPONENTS

We are all aware of the significance of the computer in process control applications. We have selected a 6502 microprocessor based computer with 48K of memory as the core of the control system. Dual disc drives, a graphics capable printer, interface cards, a clock-calendar card and a wide-band CRT round out the control system. The operating program of the control system is written in BASIC and machine code and stored on floppy disc.

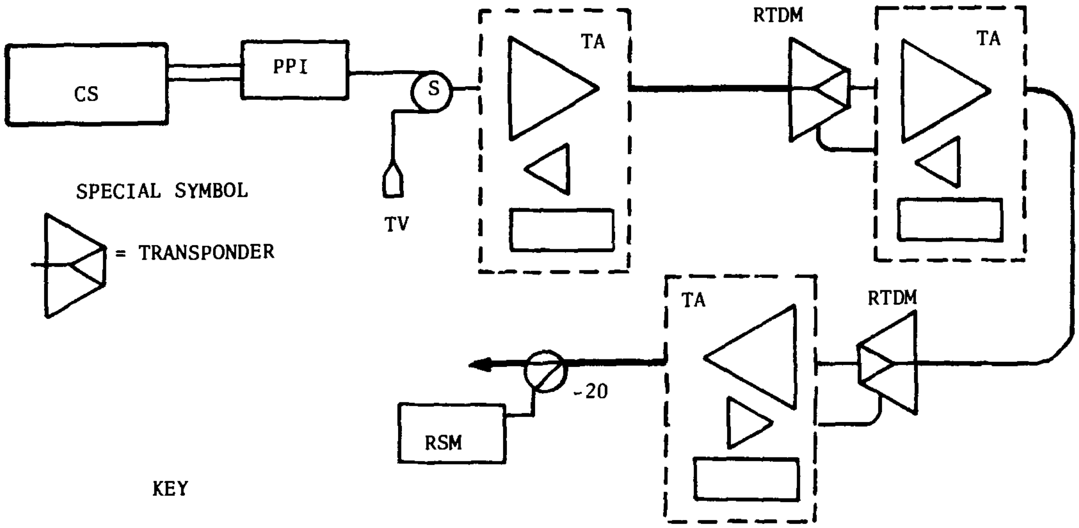
The computer program is designed to analyze the data and compare it to standard data which is entered by the operator when he commissions his plant or installs the transponder. This standard data then becomes the information base within the computer to which all new data is compared. Data errors are double and triple checked by repeated interrogation and if an error persists, alert or fault alarms are generated depending on the magnitude of error. A command is also generated by the computer to print on hard copy the nature of the fault, its address, its location and at the same time all of the remaining parameters at that address are measured and recorded with date and time. These additional parameters may provide both the nature and magnitude of the fault. Besides having an audible and visual alarm presented on the CRT, hard copy print outs provide permanent record of faults as they occur and if desired a paper copy can be provided to the maintenance supervisor.

There are numerous other features of the computer program which enhance the overall system versatility and allow the operator to select specific functions, alter his data base, customize his measurement parameters/formats and do other housekeeping chores including updating files, expansion, and deletion of certain stations which may be undergoing maintenance.

The control system is linked via RS-232 to the modem or interface. The digital data from the computer is sent serially at 4800 Baud (BPS). This serial data is applied as frequency modulation to an oscillator which operates at video carrier levels as a substitute for a normal CW pilot, or as a data carrier alone operating at -15 dBc to -20 dBc. The FSK Data then is summed with the video signals for distribution in the forward trunk. The interface or modem also receives the replies from each of the individual transponders in the reverse trunk.

The above discussed applications, if you will, are well known in the industry. The transponder, however, represents an advance in automatic test equipment techniques as applied to measurements in the CATV Distribution Plant.

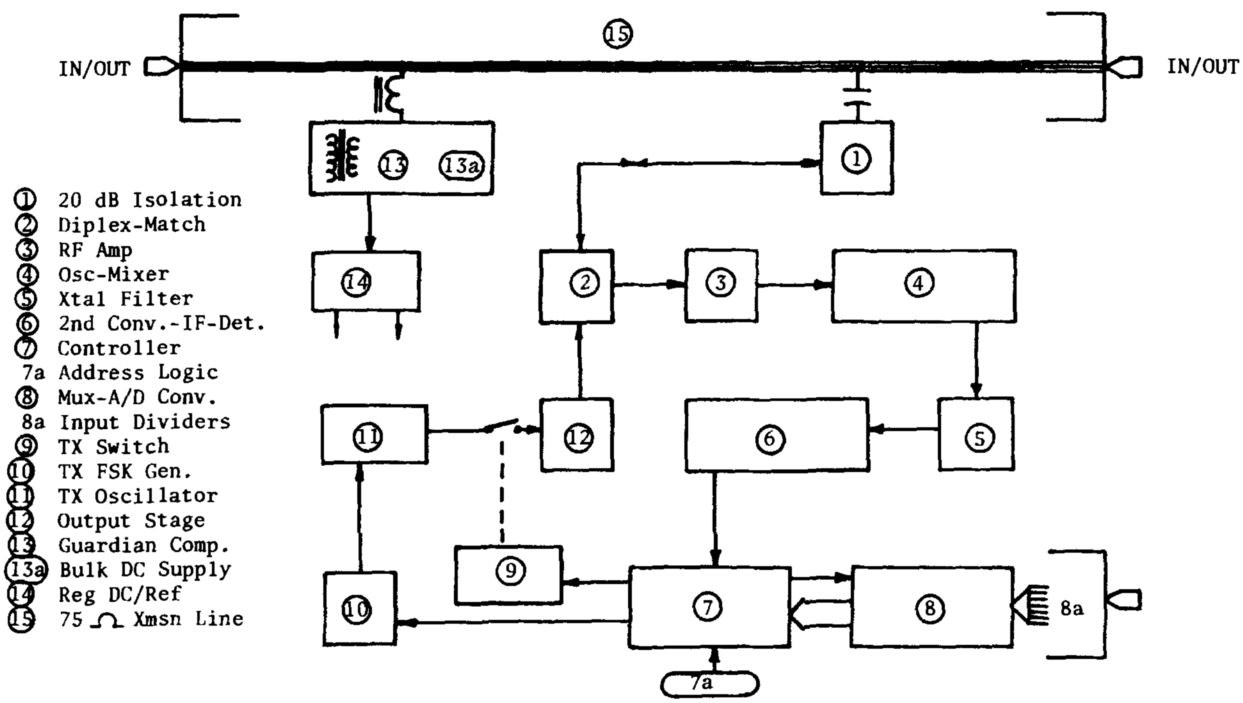
BLOCK DIAGRAM - AUTOMATIC STATUS MONITOR



KEY

CS = uP Control System
PPI - Processor - Plant Interface
RTDM = Remote Transponder Data Module
RSM = Remote Spectrum Monitor
TA - Trunk Amp

BLOCK DIAGRAM - RTDM REMOTE TRANSPONDER DATA MODULE



The Transponder block contains a number of special circuits which will be described briefly. A very narrow band FM Receiver utilizes an adjustable RF gain stage and a very high sensitivity high linearity PLLFM Detector. The detected data or address and command are sent to a controller which interprets the address and command and cycles the A to D converter. Upon completion of the measurement cycle the data is returned to the controller. It again is converted to serial form and applied as FM modulation to a crystal oscillator. Data is keyed through a transmitter circuit and coupled finally to the trunk line through an isolation network. The transponder module is isolated by a minimum of 20 DB from the trunk thereby minimizing loading effects in both forward and reverse directions. The transponder also contains a very stable power supply/reference section and divider networks which adjust scaling of the A to D convertor for full scale values appropriate to the paramters being measured. The selected measurement parameter, after input scaling, is converted to an 8 bit word which is latched into the transmitter portion of the control chip. The control chip then serializes this data, keys the transmitter and FM modulates the oscillator. A one shot multi-vibrator which is keyed upon receipt of a valid address and command, provides fail-safe operation of the transmit output stage.

The accuracy of the data (which is sent to the control system processor for reduction is plus or minus 3%. However, its stability is better than .5% over temp. Since the control system can log data from each transponder individually, the actual accuracy of the measurement is not as important as the stability of repeated measurement over the temperature range. The reference supply has a stability of better than .1% over the temperature range. This is four times better than the resolution of an 8 bit convertor.

A demonstration of the receiver capability is presented in Figure 1 and Figure 2 below. A video carrier spectrum of 330 MHz modulated 100%, and an interfering CW carrier were combined with the data carrier set 30db down. This spectrum was applied to a hybrid amplifier and the overall input level to the hybrid was adjusted to yield Xmod distortion of -40db or worse. The distorted spectrum was attenuated and applied to the cascade @ +28dBmV. See figure (1). Both data carrier and the interfering signal can be seen on the 3rd graticule line from the left in Figure 1. The interfering signal is but 75 KHz higher than the data carrier which is at -30dbc. Figure 2 shows the response of the outbound and return signals during this demonstration. These cascade tests were conducted with staggered reverse amplifiers. In one test case only reverse passives were installed through a 4 amplifier cascade spaced 20db at 270 MHz. The same performance characteristics are retained over the temperature range of -30°C to +85°C.

NOTE: The two carriers of interest appear super-imposed at the arrow due to 200kHz B/W of the spectrum analyzer.

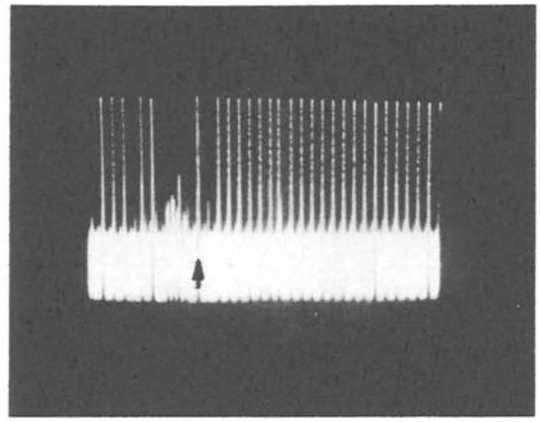


Figure 1

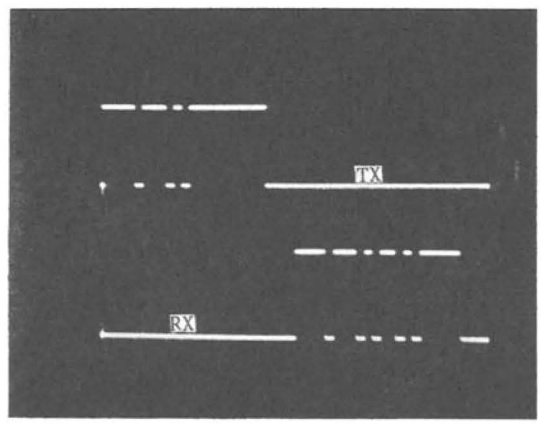


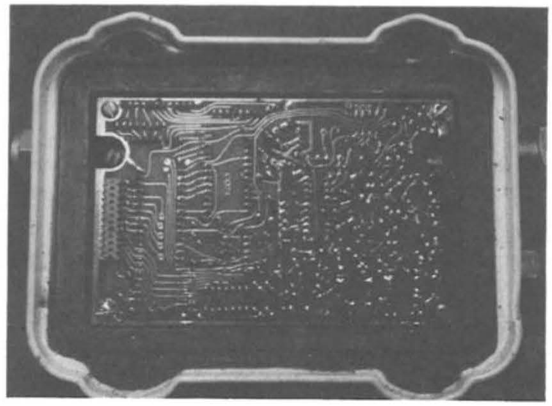
Figure 2

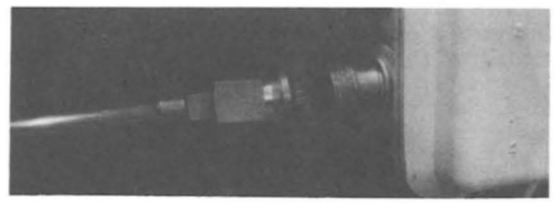
The block diagram shows the integral parts of the transponder module and the interface with the trunk station under test. The transponder/data module is quite small in itself, measuring 5.5x3.5x.75 inches. But most amplifiers if they are fully loaded have little interior room for additional components. So a remote version has been designed which is powered from the cable AC and draws less than one watt.

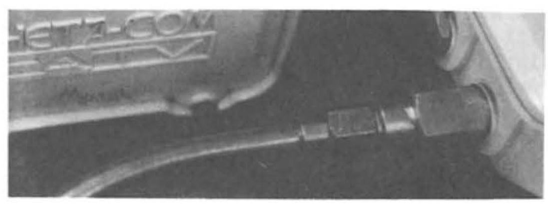
This remote version of the transponder exhibits less than 1db insertion loss from 5 to 450MHz and maintains input and output return losses at better than 20 db. The special power supply within the remote housing includes over voltage protection from a gas-tube surge suppressor as well as a version of the guardian compensator circuit utilized in CATV power supplies. This special circuit pre-regulates the primary voltage applied to the transformer by sensing a rise in the secondary and feeding back an error signal instantly which reduces the applied primary voltage. The circuit is designed to minimize the effects of sheath-current-applied over-voltage. In cascade tests the power supply has successfully operated at extended inputs of greater than 150 volts AC with no measureable effect on the regulated DC supply.

We feel then that the power supply incorporated in the remote transponder/data module may exceed the performance standards of many of the line amplifiers presently installed in the field. This provides a measure of realibility greater than the amplifiers themselves.

A unique umbilical cable assembly links the remote transponder to the amplifier under test. The components of the umbilical include the same pressure-tight fittings used throughout the industry. The umbilical is terminated in a customized adapter harness which isolates RF and taps the measurement points within the amplifier.







CONCLUSION

Two independently operating systems are configured in seperate cascades at the Texscan/Theta-Com facility. These systems are regularly temperature cycled during the course of other engineering work. The reliability of the equipment and data returned thus far exceeds specified BER (Bit Error Rates) margins of <1 ppm. Data verification in the resident program aids in these judgments. We feel that progressive engineers and operators will appreciate these latest and significant advances of CATV Test Equipment; Automatic Status Monitoring, a system management tool.

ACKNOWLEDGMENT

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CABLE AND EARTH STATIONS - A BUSINESS CONNECTION

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Scientific-Atlanta, Inc.

ABSTRACT

In practically every cable franchise being awarded today, the recipient is required to install an "institutional B cable" to serve the communication needs of the business community. Although to date very little use is being made of this non-entertainment cable, industry predictions indicate an explosive growth for business communications over the next ten years. The purpose of this paper is to identify and explain the characteristics of this potentially large business market, and to give an overview of the techniques and equipment requirements for the business/cable and cable/earth station interconnect. It seeks to alert franchise operators that the time to prepare for serving this market is now, when they are applying for franchises and building and rebuilding their cable system.

Introduction

Much has been said about the evolution of the United States from an industrial society to an information society. Just as the number of people working in industry outnumbered the people working in agriculture in the early 1900's, the people working in information occupations now outnumber those working in industrial occupations.

Information and the way it is used will be the key strategic variable in many businesses. For this to happen, effective information transfer can no longer be constrained by a communication system that was designed for voice transmission.

With the advent of the communication satellite, large amounts of information can be sent easily from one city to another. Cable operators need to know that the satellite carriers are well along on their plans and their investment in intercity distribution of information. The bottleneck lies in the local distribution. The cable that is now being laid for distribution of television can be used for a substantial part of this local distribution. The linking of satellite earth stations with cable television distribution systems offers many new opportunities as the information society emerges.

Business Communications Needs

A number of large businesses are essentially information-based. Included are banks, insurance companies, investment companies, and stock exchanges. Their principal business depends on gathering and assimilating large amounts of data. This is currently being done by processing large amounts of paper, but office automation will allow the information to be processed and stored electronically with only summary information being recorded on paper. Communication and transfer of this information will be accomplished by the interconnected cable and satellite systems described in this paper.

Although productivity improvements have occurred in agriculture, manufacturing and service industries, productivity improvement in the office has been slow. Very little has been done to bring spiraling office cost under control. However, office tools are now being put in place to change this situation. These include communicating word processors, facsimile devices, computer-to-computer links, voice messages stored in digital format, integrated voice and data PABX, and intrafacility communication networks. A sophisticated business communication system will allow charts, budgets, last-minute schedules changes, press releases, contracts, and photographs to be transmitted quickly and reliably. Many people will be able to work at home connected by cable to their office. Executives attending out-of-town meetings and salespeople on the road will be able to have immediate and accurate access to information back at the home office. In the future, a person will be able to substitute teleconferencing for some business travel. The possibilities seem unlimited.

With office automation moving ahead, satellite common carriers have recognized business communications as a viable market. These satellite carriers are shaping intercity business communications with their new concept of shared earth stations. Digital satellite carriers offer business customers a capability to transmit vast amounts of data, voice, electronic mail and other business signals from the earth station up to the satellite and back down to another earth station. Cable is a logical choice for a medium to distribute this data from the earth station to the businesses in each city.

Business Communications Services

Satellite and cable systems offer increased communications capabilities for text, facsimile, data transmission, integreated voice and visual aids and video conferencing. In the past, text transmission has been handled principally by telex which is slow and has a rudimentary character set. Telex is being replaced with communicating word processors which allow typewritten material to go from one machine to another at high speed. Much of the transmission and storage is accomplished electronically, thus creating tremendous communications needs. With a satellite/cable communications system, a secretary can type a letter, attach the appropriate electronic "address" and send a copy directly to another terminal at a distant facility.

Graphs, pictures and photographs do not lend themselves to character transmission and are better sent by facsimile. In order to obtain high resolution and transmit at a rate of one page per second, the bit rate needs to be of the order of 256 Kbps. This high data rate is available on the satellite. It creates the need for a high capacity local distribution system such as cable can provide.

The next step beyond communicating by voice and still pictures is conferencing using full-motion video. Point-to-multipoint video conferencing now makes economic sense. Many national sales meetings have been set up with regional salespeople coming to local auditoriums where earth stations are installed or have been temporarily set up. The salespeople view the program material on large television screens and respond to the presentor by phone. Point-to-point teleconferencing is very costly when using full-motion video because of the large bandwidth required. Analog video requires one quarter to one full transponder of satellite. The use of this much capacity for a normal business meeting would be excessively expensive, hence there is a need to digitize the information and reduce the data.

NTSC color video can be digitized at the rate of about 90 Mbps with no visible degradation. Removing redundancy allows a video signal to be sent at 20 Mbps with insignificant loss in video quality. When the motion is limited and the camera is fixed, it is possible to reduce the bit rate to 6 Mbps with limited loss in quality. The challenge is to reduce the bit rate to 1.5 Mbps and maintain reasonable cost in the video source coding equipment. As more devices for video coding are invented and as the cost of travel increases, business teleconferencing will become a common event.

Consider next data transmission. Large computers can manipulate data at rates of one Mbps or faster. Efficient resource sharing, computer back-up, file protection, core diagnosis and other factors make it necessary for distant computers to communicate with each other. Transmission at Mbps rates is required for computer communications in the future.

The office of the future will be integrated electronically. A number of scenarios for linking the equipment and people become evident. One scenario sees the hub of the automated office being an integrated voice and data PABX. The PABX permits users to transmit, switch, and store voice, data and images. Another possibility has local networks connecting office machines, digital telephones, and intelligent terminals or work centers. These terminals process and display data, text, pictures, and graphs. Regardless of the method, there will be a need for rapid communication of information within the office and from office to office.

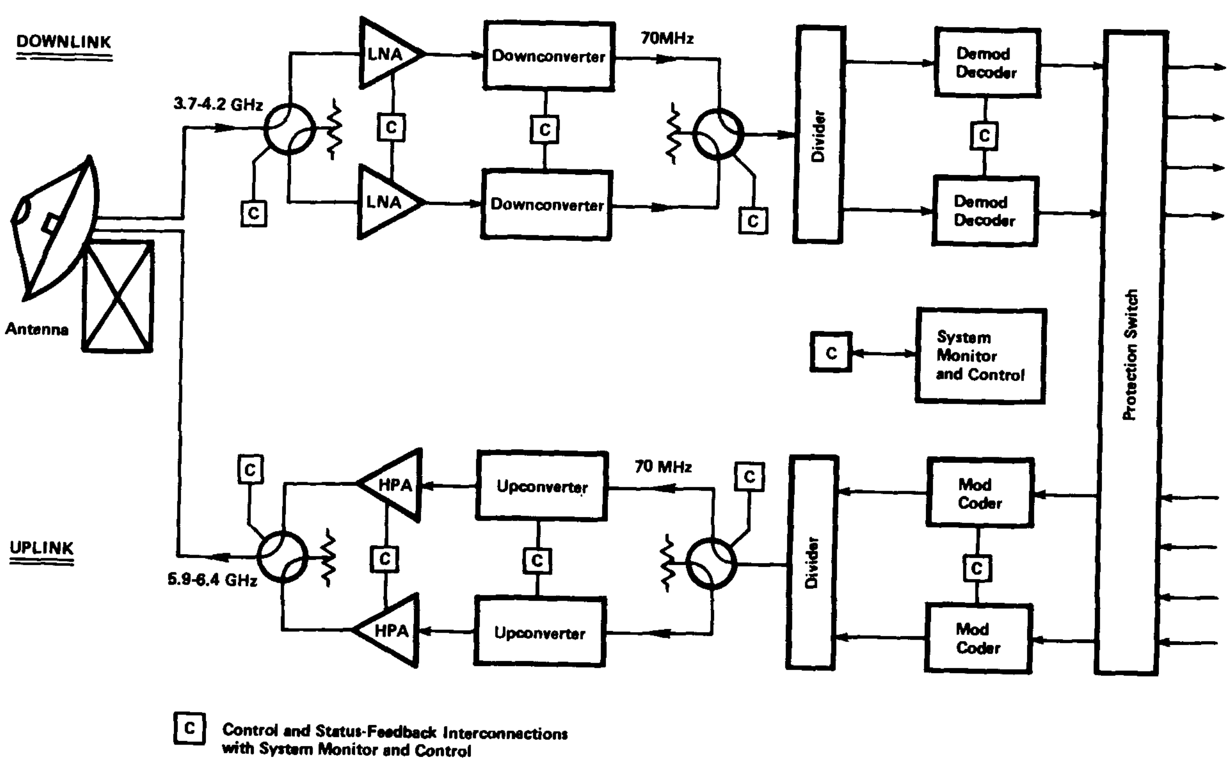
Satellite Business Communications

Satellite business carriers have made great strides in the intercity portion of satellite business communications. Carriers such as RCA, Western Union, and American Satellite Company have provided increasingly sophisticated business communications facilities for their customers. American Satellite through its satellite data exchange (SDX) service has specialized in providing voice and data communications to small earth stations located on end-users premises. American Satellite now has over 50 earth stations operating and another 34 under contract. RCA Communications is providing a data, voice, facsimile, slow scan TV and teleprint service called "56 Plus". Western Union also offers a similar data service to its customers.

A typical customer-premises earth station may have a 5, 7, or 10 meter antenna, redundant GaAs FET low noise amplifiers, redundant 5 watt to 125 watt high power amplifiers, 56 to 1544 Kbps digital modems, and a modem protection switch. Scientific-Atlanta furnishes this equipment and a microprocessor-based monitor and control unit in a complete earth terminal which is calls DET-56. A block diagram of this system is shown in Figure 1. Each 56 Kbps channel can carry a 56 Kbps data circuit or can be multiplexed to carry many data circuits of different speeds. Voice channels can be provided using PCM or CVSD encoding. Data from computers, terminals, and facsimile can also be transmitted over the DET-56. Figure 2 shows the DET-56 earth stations that have been installed to date in the United States.

Communication of business data by satellite offers a number of advantages. The telephone system normally restricts data transmission to speeds of 9.6 Kbps and below. Data rates of one to forty Mbps can be transmitted by satellite. The telephone network can be expected to produce on the average, one error per 100,000 (10^5) bits transmitted. Elaborate error checking and correcting schemes, which reduce efficiency, have been developed to overcome this problem. Error rates of fewer than one error per 10,000,000 (10^7) bits are easily accomplished using satellite communications.

Satellite Business Systems (SBS), a partnership among wholly-owned subsidiaries of Comsat General Corporation, IBM and AETNA Life and Casualty Company, is implementing an extensive digital time division multiple access (TDMA) system for transmitting voice, data, and image. The $7 billion intracompany business communications market is SBS's principal target. The company offers complete voice,



Simplified Block Diagram of Digital Earth Terminal

Figure 1

data, facsimile, and teleconferencing services.

DET-56 Earth Stations for Business Communications

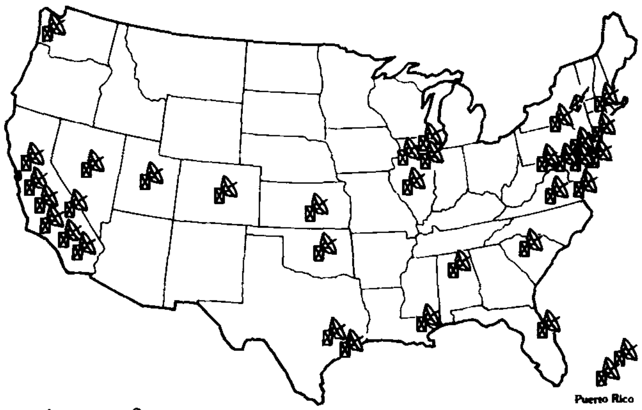


Figure 2

The earth stations, which are shown in Figure 3, operate in the 12/14 GHz frequency band so that they can be located in cities without frequency interference problems. The system offers private networks that are fully switchable and allow capacity expansion on demand. Facilities are provided to enable the companies to dynamically monitor and control the use of their networks. The terminals are small (5.5 meter and 7.7 Meter antennas) and can be located on customer premises or at cable headends. The satellite's capacity is so large that users will be able to send information between locations at rates hundreds of times those used today.

In addition to private networks with dedicated facilities, SBS will offer shared services between two or more users whose traffic volume does not justify customer premises facilities. SBS is also planning an exchange services network between 150 metropolitan areas served by 20 SBS switching centers. A twenty earth station network is to be completed by January 1982. Twenty-five earth stations are to be added by May 1982 and 50 more by January 1983. The shared and exchange services require local data transfer facilities that can be ideally provided by cable.

The need of insurance companies to share data has stimulated the formation of a resale common carrier of SBS service. ISACOMM, a communications subsidiary of Insurance Systems of America, is selling communications services to smaller users, principally in the insurance industry. ISACOMM initiated service through an earth station in Wausau, Wisconsin and one in St. Louis, Missouri in early 1981. ISACOMM is now building earth stations in Baltimore, Atlanta, Houston and Sacramento and anticipates a total network of 40 earth stations by early 1984.

LOCAL DISTRIBUTION BY CABLE

Digital Headend

In several articles which have been published recently reference has been made to the "digital headend". This digital headend will process signals that are somewhat different from video signals and will use modulation methods that may be unfamiliar. Nevertheless, the analogy to the classical cable television headend is apparent.

On the customer's premises, racks of equipment consisting of digital multiplexers and standard bandwidth modems are installed. The output of the modems are frequency multiplexed on a two-way system with the output from other modems. At the earth station, there will be much larger "Digital headends" receiving the modem RF signals and processing them to a format compatible with the satellite equipment. For installations where the digital earth station is not co-located with the cable headend, data translators may be required to allow full access to any location in the system. In many respects this "digital headend" is less complex than some of the very sophisticated cable headend systems which are being installed today.

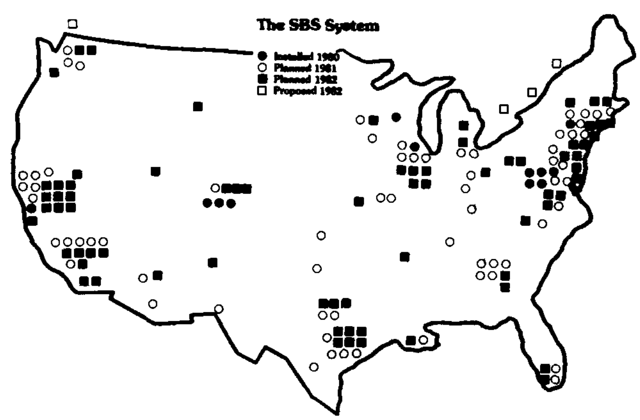


Figure 3

Distribution

The type of distribution systems used to carry the data signals can be any one of several types. In practice, most systems installed primarily to handle data have been of the mid-split type. This equipment is readily available and offers approximately equal bandwidth in either direction. Typical band edges for mid-split amplifiers are 5MHz-108MHz upstream and 174MHz-300MHz downstream. Several manufacturers have recently introduced new amplifiers which take advantage of the 400 MHz technology to extend the data handling capacity beyond that of the mid-split system. This system is referred to as a hi-split system and provides a bandwidth of 10MHz-172MHz in the upstream direction and 234MHz-400MHz downstream. It should be pointed out however that for limited data applications, data signals can co-exist on the same cable with entertainment and other services as long as sufficient spectrum is available. As is well known, the majority of these systems are designed around a sub-split concept (5-30MHz, 54-300/400MHz) with its obvious lack of equality in bi-directional capacity.

Regardless of the type of system, the broadband cable with its inherent high signal to noise ratio and linearity offers an ideal environment for the transmission of data signals.

Multiplexing/Access

The information that is to be sent by cable can be multiplexed using time division multiplexing (TDM) or frequency division multiplexing (FDM). Some combination of time and frequency division access will probably be used for most applications. Consider the data rates which are commonly used in satellite circuits (Table 1). If many low data rate ports are available at one location, the most cost effective method of transmitting the signals is to time division multiplex before modulation. On the other hand, the higher data rate services are usually sent single channel per carrier (SCPC) using frequency divison multiplex on the coax or satellite.

Another item that needs to be mentioned is changing access according to the changing needs of different users (multiple access). Pure time division systems may be made multiple access by allowing different users to occupy different time slots on demand (TDMA). Likewise, freqency division multiplex systems can be extended to demand access (TDMA or DAMA). Another method that is commonly used is called carrier sense multiple access/collison detection (CSMA/CD). Basically, a station wishing to transmit using CSMA/CD listens to the circuit. If the link is idle, it transmits. If two stations should transmit simultaneously (collide), each attempts to transmit again after a random delay.

TABLE 1

Commonly Used Data Rates for Satellite and Terrestrial Services

Multiples of 1.2 Kbps	1.2, 2.4, 4.8, 9.6, 19.2 Kbps
Multiples of 56 Kbps	56, 112, 224, 448 Kbps
T1	1544 Kbps
2T1	3088 Kbps
T1C	3152 Kbps
T2	6312 Kbps

Modulation

In addition to the multiplexing and accessing method, one also has to consider the modulation that is to be used. The basic possibilities are amplitude shift keying (ASK), phase shift keying (PSK), and frequency shift keying (FSK). An attractive method for transmitting on non-linear systems (satellites) is PSK. PSK transmission can take place using any number of phases, e.g., two phases (bi-phase, BPSK), four phases (quad-phase, QPSK), etc. BPSK and QPSK are widely used in satellite SCPC circuits. When transmitting at high data rates on cables, the frequency spectrum must be conserved. Since the cable is relatively linear and the signal-to-noise ratios are high, an attractive modulation method is a combination of amplitude and phase shift keying. The measure of transmission efficiency normally used is called bits/Hz. This is the number of bits per second that can be transmitted in one Hz bandwidth. The number of bits/Hz for BPSK is one, QPSK is two and for a combination of amplitude and phase shift keying, can be 3 or more. For data rates of T1 or larger, a combination of amplitude and phase shift keying should be considered for use on the cable in order to conserve spectrum.

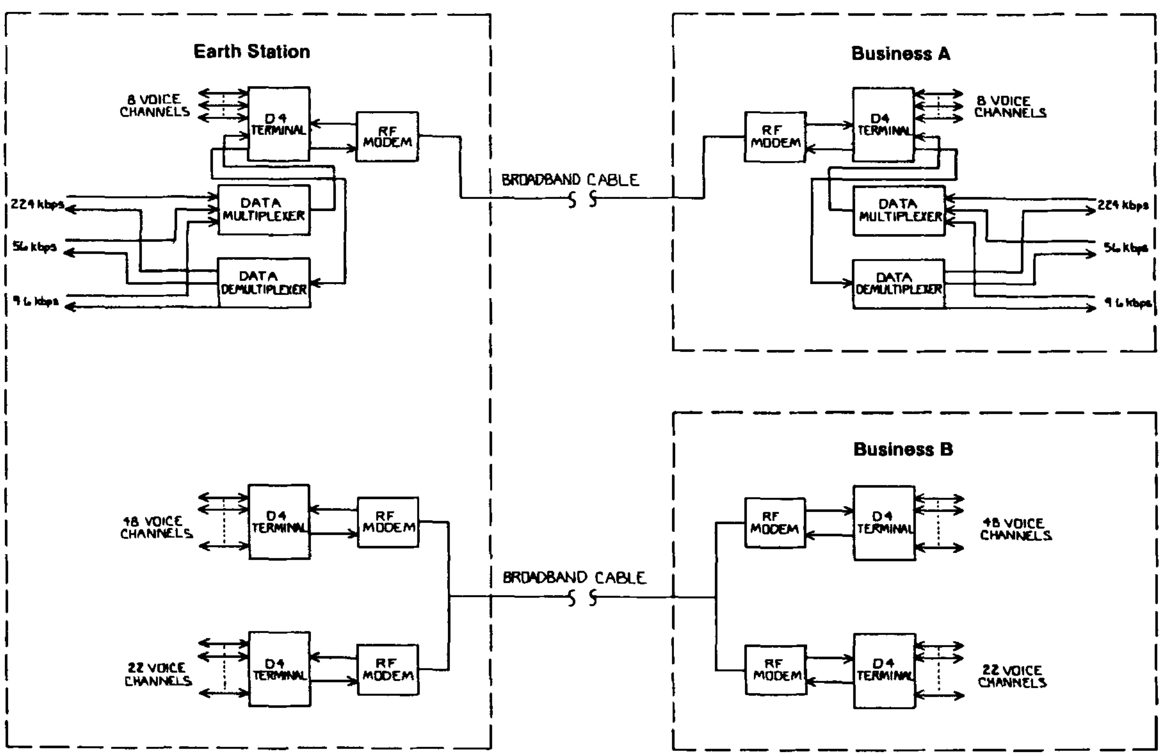
On the other hand, consider the case of a large number of users at different locations, each user having a relatively low data rate, and each user transmitting occasionally. Here a modulation method can be employed that uses spectrum less efficently but yields less costly hardware, e.g. FSK. In addition, the system could employ CSMA/CD, giving all users access to the same channel. In most cases, it is evident which type of modulation method should be employed. For further information on data modems for cable networks see the reference below.

Application for Cable

We have discussed the potentially large market for cable serving as the local distribution facility connecting businesses with satellite common carriers. We have discussed some of the technical methods that are available for implementing this cable distribution system. Now let us consider an example of two current business needs that Scientific-Atlanta is helping address. Business A wants to establish a dedicated communication link to another city with 8 voice channels, one 9.6 Kbps circuit, one 56 Kbps circuit and one 224 Kbps circuit. Business B wishes to communicate with 70 voice channels through the same satellite communications earth station. Forty-eight voice channels can be digitized on a commercially available D4 channel bank and sent on a TIC (3.152 Mbps) circuit. Data multiplexers can be added to one D4 channel bank in order to provide the 8 voice channels and the various data circuits. The TIC output from the D4 channel bank is then fed into a spectrum efficient TIC modem and converted to the appropriate frequencies for transmission on the cable. (Figure 4) It should be noted that Scientific-Atlanta modems can transmit TIC (3.152 Mbps) using slightly more than 1 MHz (1/6 of a video channel). The 70 voice channel requirement for Business B can be satisfied using two D4 channel banks and two TIC modems. Both customer requirements can be satisfied economically using the configuration shown in Figure 4.

CONCLUSION

Cable television systems can play an important part in the intracity distribution of voice, data, electronic mail, and other business communications. In only a few years, cable has gone from an auxiliary system for areas with poor television reception to the most versatile and economical system for mass distribution of many channels of video entertainment. The next step will be equally dramatic. It will involve cable operators finding new business customers for using the cable system to distribute business communications within the city. These customers will be satellite communications carriers, large corporations, financial institutions, municipal agencies, and hospitals and university complexes.



Cable Data Communications Link Equipment Configuration

Figure 4

H.W. Katz, "Status Report on EIA Broadband Modem Standards," NCTA, 1980.

COMMENTS ON AUDIO SERVICES FROM AN MSO VIEWPOINT

Ned L. Mountain

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ABSTRACT

During the past year much has happened to develop the full potential of audio, yet much remains to be done. This paper is an expansion on ideas originally developed in the 1980 NCTA session on Audio Services. Thoughts concerning programming availability, satellite technology, premium signal security, and practical operator implementation will be presented.

INTRODUCTION

There continues to be a flurry of relatively low-level activity with respect to cable audio services. At least two satellite delivered cable TV channels are or will be equipped with full stereo sound, and approximately 7 (I think the number changes daily!) satellite delivered audio only services are on the drawing board. Needless to say, the main push for these services is from potential program suppliers who feel that a genuine unserved market does in fact exist. Since most of these suppliers view cable as their primary delivery vehicle, the MSO is wise to keep an eye on continuing developments.

KEY INGREDIENTS TO "MAKE IT HAPPEN"

There are three key ingredients that must be cultivated and blended to provide the successful implementation of an audio service revenue stream overlay.

1. Economic nationwide availability of unique audio product.
2. Development of acceptable cable delivery schemes for a premium audio signal.
3. Empathy by cable operators that audio should be taken seriously.

There are many interrelated marketing and technical issues of the above three factors that will be a part of the accomplishment of my objective: A quality premium audio service for cable subscribers.

THE PROGRAMMING ISSUES

One of the most common comments I hear when promoting audio services is to the effect that "with over 9000 radio stations in the U.S. what can possibly be left undone - especially in the major markets?" My answer is to use the analogy to television, a medium that until the rebirth of cable provided very limited diversity. The same ideas that are resulting in success (and failure) stories with video alternative programming can be applied to audio. While not all audio alternative programming will be successful, I feel that several key technical ingredients are mandatory to define a minimum acceptable service:

1. Full Stereo - The home audio market is accustomed to it now and will accept nothing less.
2. 15KHZ Bandwidth - The public now associates quality with at least "good cassette deck" frequency response.
3. Low Noise - Stereo S/N ratios on the order of 60 dB should be the objective.
4. Low Distortion - The state of the art today is such that distortion levels of 1% or less are easily obtained.
5. Full Dynamics - The amount and type of audio processing used by radio stations in an attempt to "sound louder than anything on the dial" is just not necessary in the cable audio environment! Contrary to popular opinion, dynamic range is an attribute that is just now being exploited as an important element in all music formats. Even recent rock albums are taking advantage of the increased dynamics offered by digital recording techniques. Cable audio can provide enhanced dynamics without fear of competitive pressures associated with trying to sound loud.

Satellite subcarrier is the most viable method of nationwide bulk distribution of cable audio signals. Unfortunately with few exceptions it has been difficult to justify satellite subcarrier spectrum and inherent video degredation while maintaining "entertainment grade" audio parameters. It is encouraging to see the activity in the area of subcarrier transmission improvements. As cable audio grows it may be possible to justify using a full transponder for audio services.

To summarize this section, the work being done today by several groups and individuals to define and overcome both technical and non-technical obstacles to nationwide distribution of cable audio services is most encouraging. They can't all be wrong!

DELIVERING AUDIO TO SUBSCRIBERS

Assuming that the programming folks get a quality product to our head ends, how do we best get the signal to the subscriber? The most common practice is to feed the composite multiplex FM signals to the plant at aural carrier level (approximately -15dB from video carrier level). Recent experiments in San Angelo show that this results in a delivered stereo S/N ratio of 55.5 dB at the end of a 22 amplifier cascade. (See Figure #1) Note that there is approximately 12.5dB degredation between mono and stereo signals at the subscriber drop. The cable industry is presently delivering marginal stereo signals at this level. Note that if this level is raised 5dB, the resultant stereo S/N ratio measured 59.5dB, which is acceptable. Consequent distortion products as a result of this additional amplifier loading should be insignificant but further analysis needs to be done. In terms of pure power loading, the addition of 50 FM carriers at a channel 6 video -10dB level will require an additional .38dB over and above the load imposed by the same signals 5dB lower in level. (Reference to a Fully Loaded 35 Channel System)

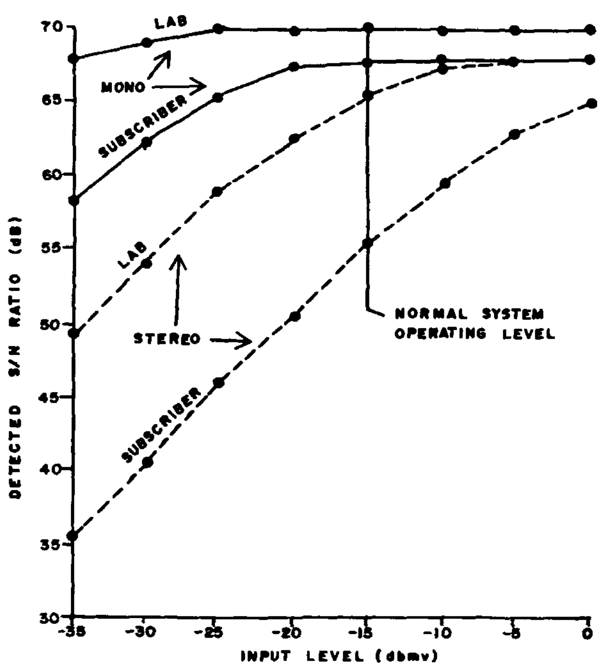

FIGURE 1 - MONO TO STEREO DEGREDATION AS MEASURED AT BOTH LAB AND SUBSCRIBER DROP ON SAN ANGELO, TEXAS CABLE SYSTEM. CASCADE WAS 20 TRUNK, 1 BRIDGER, AND 1 LINE EXTENDER.

For delivery of protected audio services, the operator has several options to consider:

FM Band Trap: Broadband FM traps have been built and are effective at points where the total rejection is greater than about 55dB. Since several areas in a trap stop-band are not attenuated 55dB or greater, care must be exercised when choosing premium audio frequencies. Trapping is probably not economically viable unless FM penetration approaches 40%.

Block Conversion: Simple frequency conversion as a method of "soft" security worked for several years in the early days of Pay TV and the same approach could be taken as an inexpensive vehicle to prove the economic soundness of pay audio. Using this method, premium audio services would be transmitted on the cable at some part of the cable spectrum other than the FM band (say 108-120 MHz) and simply converted back to the FM band by a "stereo-top" adapter. The block converter idea will not work in areas of high FM saturation due to frequency congestion.

Discreet Channel Converter: This device would be analogous to the single channel output CATV set-top converters in use today. FM signals would be transmitted in unused cable spectrum and converted to a single unused space in the FM band. Channel selection would be done from the "stero-top" adapter. A variation of this idea would be to avoid the multiplex format entirely and transmit discreet left and right audio signals as individual low-level FM carriers. This would allow the use of extremely low-level signals (video minus 30dB) to provide high quality audio fed directly to the subscriber's amplifier. (Seems like a good use of 108-120 MHz!)

Digital and other High Security Techniques: It is possible to provide relatively high levels of security to the audio signal by digital or advanced analog techniques and limited research has been done in those areas pending proof of economic soundness of the pay audio concept.

CABLE OPERATOR EMPATHY

The best laid plans of the potential program suppliers will fail unless cable operators take the opportunity seriously! I compare the potential of audio hook-ups to that of second TV set outlet penetration which has shown significant growth as illustrated by figure # 2.

A recent "Business Week" article indicates that even though the U.S. component audio industry is "soft", sales have been in excess of 1 billion dollars annually since 1976.[1] Virtually all of those component units are connectable to cable systems.

A survey by UA-Columbia conducted in Alamogordo, New Mexico indicated that 10% of those responding would be interested in a pay audio service offering 8 commercial free formats for a fee of $3.50 per month.

Warner-Amex, in the process of doing market research for "The Musical Channel," discovered that 96% of those in the 15-30 age group possess an FM stereo receiver in the home and listen to them an average of 19 hours per week.

The UA-Columbia system in San Antonio recently passed the 50,000 subscriber mark with 33% of the subscribers electing to have their FM sets connected to the cable even though nothing more than Broadcast FM is offered.

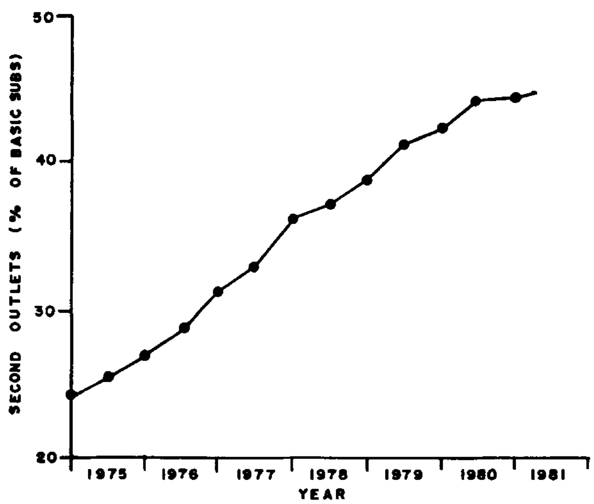

FIGURE 2 - SECOND OUTLET GROWTH HAS BEEN SIGNIFICANT AND RELIABLE OVER THE YEARS IN THE SAN ANGELO, TEXAS SYSTEM. FM OUTLET GROWTH COULD BE EQUALLY AS IMPRESSIVE.

We as an industry do have an obligation, even without mandatory legal requirements, to provide high quality signals as a part of basic service in areas where FM is promoted. Any system promoting FM service should posses a decent quality FM stereo tuner and an empathetic set of ears to judge overall quality of stations carried. Simple monaural tuners will not reveal the majority of problems that can ruin FM stereo multiplex.

Due to lack of measurement techniques for judging on-air FM transmissions without the aid of test signals, I can understand the reluctance of cable engineers to get involved with cable audio quality analysis.

SAN ANGELO FM UPGRADE

As a result of work done for last year's NCTA session on Audio Services, I was encouraged by UA-Columbia management to "upgrade" the FM service in San Angelo, Texas. The objective of the project was to provide a comprehensive high quality audio entertainment service that would be head and shoulders above the off-air market, and monitor subscriber response to the program.

Prior to the implementation of this program, we had a total of 11 FM signals on the San Angelo cable system.

4 Local FM Radio Stations
1 Off-Air Direct Import (90 Mi.)
4 Terrestrial Microwave Subcarrier
2 Local Origination (Christian Radio and Background Music Service)
11

Analysis (subjective, I might add) of our signals indicated that 1 local FM had severe multipath distortion in stereo and all terrestrial microwave stereo signals suffered from significant degredation in the form of beats and noise.

Working closely with both local system and corporate management, a revised FM band plan was designed and the necessary equipment was ordered to implement the service which included 18 sources; a 64% increase over the previous cable FM package. These sources included:

4 Local Off-Air (No Change)
2 Local Origination (No Change)
1 Off-Air Import (No Change)
7 Terrestrial Microwave (3 Additional Stations)
1 Satellite Subcarrier (WFMT-New)
1 Short Wave Channel (New)
1 NOAA Weather Rebroadcast (New)
1 WWV Rebroadcast (New)
18

This package was designed to provide a significant increase in quantity and variety over any off-air or previous cable FM offering.

Technical implementation of the package was mostly straightforward. A new FM omni-directional antenna was purchased and provided excellent stereo pick-up of local signals. It should be noted that all hetrodyne processers were adjusted for peak performance by both eye and ear. In some cases, the most distortion free stereo sound was not at the exact peak when going through the alignment with a spectrum analyzer.

All terrestrial microwave signals are processed with the unique up-converter manufactured by Leaming Industries. The active filter in this unit does a very effective job of removing audible beats from subcarrier derived stereo sources. A wide deviation Leaming unit is used for receiving WFMT via satellite. The NOAA and WWV package were purchased from Catel and do an excellent job.

One of our most innovative channels is our "Ear To The World" short wave broadcast service. Many people do not realize that a significant part of the world relies on short wave news and entertainment. Some very excellent programming is there for the taking! In fact, over 18 million short wave receivers have been sold in the U.S. during the past 10 years. There are currently 34 countries beaming short wave programming of which much is in English.[2] Utilizing a new receiver developed by Sony, we will provide a fully automated

24 hour per day short wave channel that can be programmed to provide the most interesting and beneficial programs to our subscribers. To the best of my knowledge, this will be the first fully automated 24 hour a day SWL cable service in the U.S.

WHAT ARE THE RESULTS?

The FM up-grade was completed on December 20, 1980. (The author really wanted WFMT for Christmas!) The next phase (and still continuing at this time) is to monitor the overall impact of the enhancement to the basic cable service.

Newspaper ads were run beginning in January 1981. Both Catel and United Video provided point of sale material which was distributed to local audio dealers at a luncheon announcing the service. An attractive FM channel guide was printed and made available. It is interesting to note that all of the 5000 guides originally ordered were gone within 10 weeks. One local stereo dealer provided an attractive demo unit for use in the front office of Texas Cablevision to aid in Cable FM demonstrations. This same dealer pays for the subscriber's FM tap installation with each stereo system sold. The most effective form of advertising, word of mouth, is just now getting underway.

I think that the best indication of interest in cable audio can be seen from Figure #3 which plots FM extension sales on a quarterly basis from 1975 to present. The first significant "peak" occurs coincidentally with the addition of a major market rock station (see my 1980 NCTA paper for further details).[3] I have every reason to believe that the record activity level coincidental with the launch of "Musical Theatre Plus" will continue for some time to come.

SOME CONCLUDING REMARKS

I continue to operate on the faith that sooner or later the concept of premium audio will be proven and accepted and predict that within 12 months, at least two new cable oriented audio services will be available. Just like video - once it starts, look out!

A good imaginative and well planned cable FM service should at least be thought of as a natural part of the basic cable package. Good audio is appreciated by a demographically powerful group... the young adults who grew up surrounded by music and continue to enjoy it... all types of it! For example, the 25 to 34 age group is 57% more likely than the average of all adults to regularly listen to classical music.[4]

As Warner's "Music Channel" will prove, the subscriber's thirst for high quality stereo TV product will be unquenchable. The smart cable operator will realize this and capitalize early.

A good analogy to the development of audio services can be found in a recent paper describing the resistance to the development of Texas Instrument's highly successful "Speak & Spell" ™ educational toy.[5] The author states: "After the research is done and the data tabulated, the answers are still the result of the convictions of the designer."

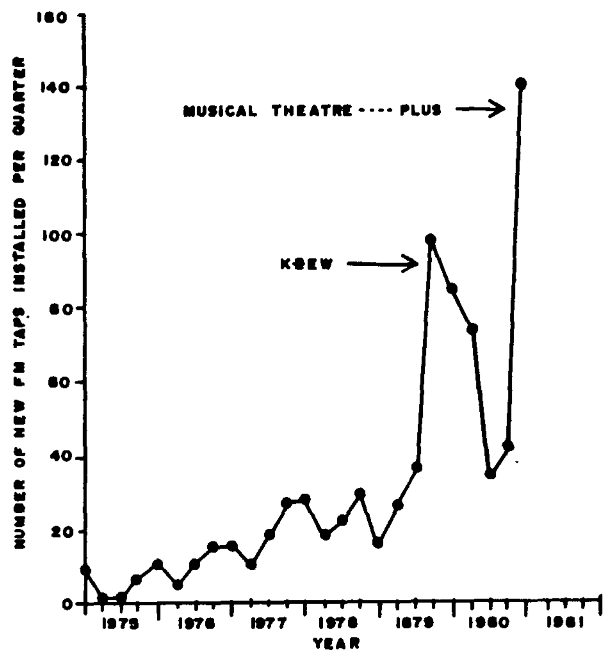

FIGURE 3 - FM TAP ACTIVITY IN SAN ANGELO, TEXAS SYSTEM SHOWS OBVIOUS IMPACT OF KZEW IN 1979 AND "MUSICAL THEATRE----PLUS" IN 1981. THE POTENTIAL IS THERE!

ACKNOWLEDGEMENTS

This document and the work it represents would not have been possible without the extraordinary help of these organizations: Catel, United Video, UA-Columbia Corporate Management, and the Management and Technical Staff of Texas Cablevision in San Angelo.

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COST DESIGN FACTORS FOR RURAL DISTRIBUTION

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ABSTRACT

This paper describes design features for rural CATV systems, using the sub-low technology. The problem, the technology, the solution, and an example are discussed. Also covered are maintenance techniques and ingress detection procedures.

THE PROBLEM/CHALLENGE

The rural designer is typically working in a rugged terrain area which is on the edge of the "B" contour of stations, and with a modest subscriber base.

The system designer then is challenged with a minimum cost design in general, but more specifically, the head end cost is a substantial portion of a small system. This head end cost is composed of substantial monies for new roads, building and utility construction.

The rural community is typically distant from major markets which dictates that the designer is faced with the option of trying to find an optimum high elevation head end site. Oftentimes, the top of a mountain is either not developed or not satisfactory for low level distant signal detection.

Since people typically live on the side of the mountains or in the valley, it is relatively inexpensive to gain access to the side of the hills. With this tenet, often two head end sites can be found facing in different azimuths and sometimes down valleys to pick up the distant receive signal.

THE TECHNOLOGY

Using two lower elevation sites that have limited peripheral access to RF signals is acceptable, if they can be tied together with modest expense.

Using this type of configuration, road costs and utility costs are minimal or non-existant. Typical road costs can run anywhere from $10 to $100 per foot in rough terrain, plus the cost of power line construction and other factors. If the situation present dictates, there can be little or no increase in the cable plant investments and no head end site cost.

The technology tool available to the rural designer is the sub-low configuration. Sub-low configuration of trunk and distribution amplifiers has been known for some time now in the cable industry. However, the application and discussion typically has been in the urban market for either return from the home usage or dedicated channels such as teaching, education, traffic control, and so forth.

With a sub-low return up to four channels can be received at a remote site and trunked back via the sub-low technology to a main head end site where they are reprocessed and distributed.

The radiation sleeve series connectors and the integral ferrule connectors used in the urban markets can be used in the rural area to allow the satisfactory use of channels T7, T8, T9, and T10 in the presence of short wave, ham, and CB bands.

THE SOLUTION

A solution to the head end site selection, then, is <u>not</u> to go for the highest peak with the cost of non-revenue producing trunking, road construction, etc., but rather go for an optimum configuration of two or more sites close to the population pocket and tie these together through the subscriber cables.

An Example

An example of the application and implementation of this type of rural sub-low design is the system our firm recently designed for Giles CATV, Inc., which serves the small community of Narrows, Virginia, located in the New River Valley near the Virginia-West Virginia line. Figure 1 shows a simplified composite of significant terrain features, received signals, and the community served.

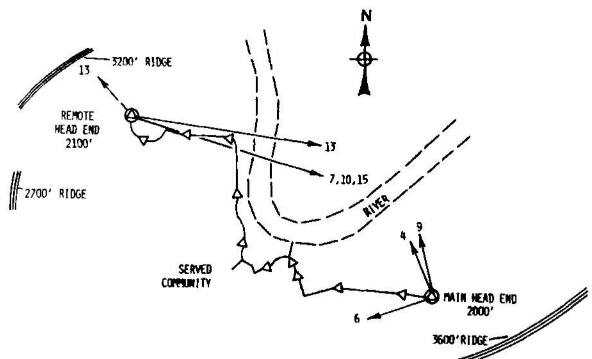

FIG. 1.0 TWO WAY PATH

Two sites were selected (Photo 1 and 2), one on the east side of Stockpin Mountain to the west of the served community, and one on the north side of Angels Rest Mountain to the east of the community, thus eliminating costly road construction.

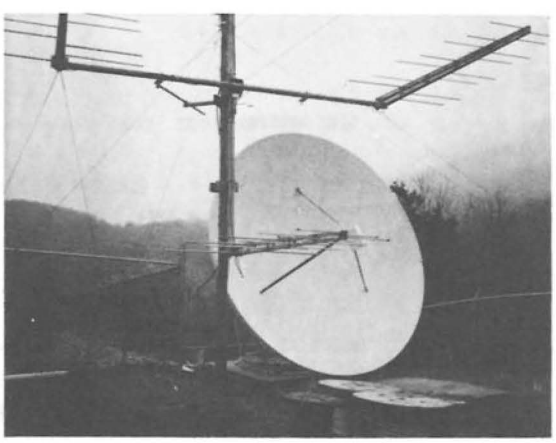

Photo 1.

Photo 2.

These two sites were then connected by ten sub-low return amplifiers. The Stockpin location, which is the remote site on Stockpin Mountain, was not constructed of a building, land, rack, etc., as is typical CATV, but was rather a designed and fabricated pole-mounted facility. The block diagram of this four-channel pole-mounted head end is shown in Figure 2.

The metal enclosure is a catalog purchased item from Acrodyne. This type of enclosure is typically used for television translators (Photo 3.) The box power control panel was removed and four signal processors were mounted inside. This unit comes complete with ventilating fans. The test points for the antennas were mounted on the left rack channel, and the forward and reverse test points were mounted on the right channel racks (Photo 4). It was found that more stable performance was achieved by placing an attenuator in the outgoing path, such that the signal processor operated near their typical head end design levels rather than a substantially reduced level.

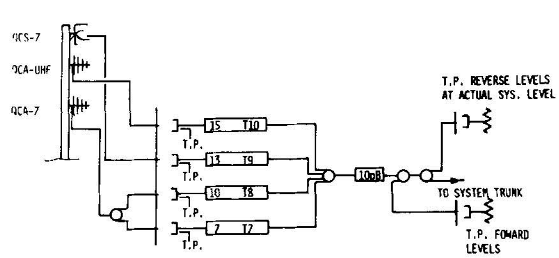

FIG. 2.0 REMOTE HEAD END

Photo 3.

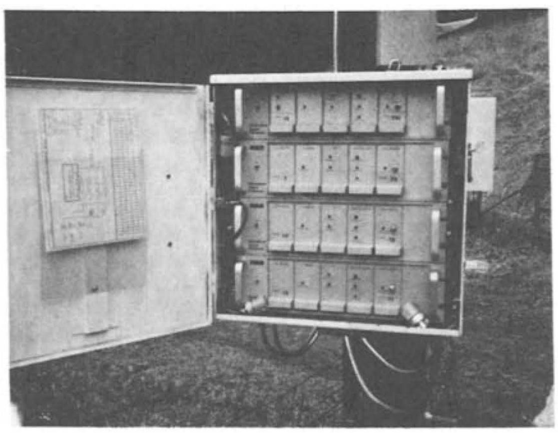

Photo 4.

It is interesting to note that both head end sites have subscribers within the first amplifier span spacing; thus, there was revenue produced almost in the first foot of cable. No non-revenue producing trunking to get to the head end!

The sub-low channels at the remote site were loaded into the system with a 1/2 dB slope T7 to T8 and T8 to T9, with T10 being loaded the same level as T9.

This has proved to be a satisfactory relationship and the ten amplifier cascade was easily aligned and equalized.

MAINTENANCE TECHNIQUES

Several maintenance techniques are helpful in the rural systems where most of the new personnel are not familiar with cable, and where bucket trucks may not be in the initial budget of a small system.

- Pocket cards: Shown on Tables 1, 2 and 3 is the data that has been put on 3 x 5 index cards to be used for a rapid acquaintance of the system.

  Card 1 of 3 is a line card with actual system meter levels given and boxed.

  Card 2 of 3 is an installer's card with instructions reduced to paces on when to use RG-59 or RG-6. For rural areas and long drops, RG-6 is a cost effective application.

  Card 3 of 3 is a cable and component loss card for trouble shooting used with system as-built drawings.

SYSTEM LEVELS / BRIDGER

	TP/Meter	In Put	Out Put	TP/Meter	Bridger Out Put	Bridger TP/Meter
W	-20	10	32	+2	50	+20
13	-16	14	30	0	48	+18
2	-12	18	26	-4	44	+14
T-10	- 3	27	17	-13		
T- 9	- 3	27	17	-13		
T- 8	-3.5	26.5	17.5	-12.5		
T- 7	- 4	26	18	-12		

Card 1 of 3

LINE EXTENDER

	High Gain TP/Meter	High Gain In Put	Standard TP/Meter	Standard In Put		Out Put	TP/Meter
W	-10	20	-6	24	Line Ext.	50	+20
13	- 8	22	-4	26		48	+18
2	- 4	26	0	30		44	+14

Tap +15db min. @ Ch. 13

Subscriber 0db per min all channels

Table 1.

DROP INSTALLATION

Tap +15 Min	1-2 Drop
RG-59 use for up to 60 paces 180'	
RG-6 use for 60 to 100 paces 180' to 300'	

Tap +15 Min	3-4 Drop
RG-59 use for up to 35 paces 105'	
RG-6 use for 35 to 75 paces 105' to 225'	
	Card 2 of 3

DROP EXTENSIONS

"CORRECT RECORD PRINTS AFTER RETURN TO OFFICE"

RG-59 each db Tap decreased

Adds 7 paces 21'

"CORRECT RECORD PRINTS AFTER RETURN TO OFFICE"

RG-6 each db tap decreased

Adds 9 paces 26'

Table 2.

TAP INSERTION LOSS

Tap Value	8	11	14	17	20	23	26	29	30
2 Way	3.8	1.9	0.9	0.6	0.6	0.6	0.5	0.5	0.5
4 Way	-	3.8	1.9	0.9	0.6	0.6	0.6	0.5	0.5
8 Way	-	-	1.9	1.9	0.9	0.6	0.6	0.6	0.5
Label Color	GRY	BRN	YEL.	PUR	BLK	ORN	BLU	WHT	RED

Card 3 of 3

CABLE LOSS db/100'

	300MW3	Ch.13	Ch.2	T10	T7
Trunk 3/4"	.895	.745	.34	.26	.10
Distribution 1/2"	1.32	1.10	.50	.38	.15
RG*6/U	3.8	3.1	1.5	1.2	.45
RG-59/U	4.8	3.8	2.6	1.4	.55

DIRECTIONAL COUPLERS		LINE SPLITTERS	
DC-8	2.3db	SP-2	4.3db
DC-12	1.5db	Sp-3	6.3db
DC-16	1.3db	SP-3U	(2)6.3db (3) 4.3db

Table 3.

° Pole drops: The input, output, and bridger test points are cabled down to the four-foot level for use in trouble shooting and are color coded: green is trunk output; blue, bridger output; and input is unmarked (Photo 5).

° Head end levels: To simplify the output level setting of the head end, scraps of distribution cable were spliced together to be equivilent to 1/2 trunk amplifier spacing and brought back to the head end (Figure 3). This, then, is a flat all-channel test point for meter reading.

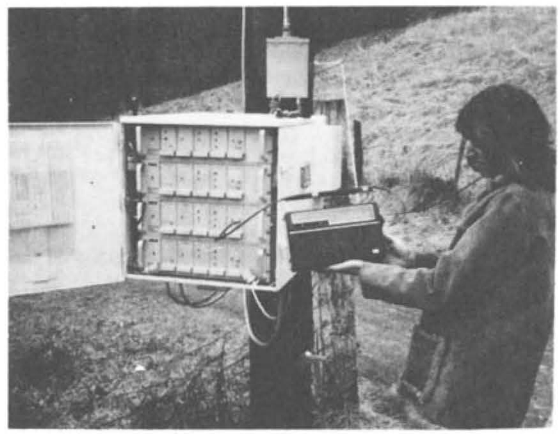

Photo 5.

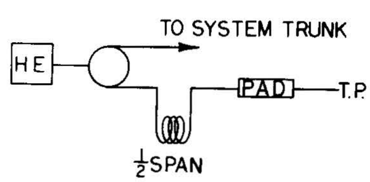

FIG. 3.0 HEAD END ALINGMENT

° Highpass matching transformers: Figure 4 shows the simplified "off" position of a two-way system. The problem is that the all pass matching transformer connected to a TV set acts like an antenna to back feed into the return path. The only isolation up to the first line extender is one switch which terminates the input reverse amplifier. After that you have two in a series --either a trunk and bridger, or a line extender and bridger. As a preventive measure, the first cable span from a bridger has a high pass matching transformer install on all sets to safeguard ingress.

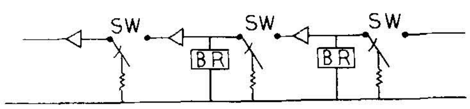

FIG. 4.0 "OFF" REVERSE PATH

- Full tap design: The USDA, REA has proposed a single cable taped trunk design for lightly populated areas. We feel that the introduction of connectors into the trunk add to unreliability; however, if a complete area design is performed and the taps are left out until they are needed, substantial savings can be accomplished by deferring both material and labor costs.

INGRESS

It was found that the higher frequency (mid band) detectors showed a tight system while there was still viewing impairment from short wave broadcast. This was later tracked by the techniques listed below to too-long center conductors which left a sheath vacancy in "not" bottoming of the radiation shield connectors. The short wave signal appears to travel on the surface.

A second level of detection for sub-low integrity was a relatively inexpensive battery powered short wave receiver (in the $50 range). This is used by jacking in at a pole drop and tuning to either carrier and then unplugging to see if there is still an audio signal in the receiver (Photo 6). The banding strap at the end of the lashing cable is a good place to find an area of non shield integrity, then track either way to the egress fault source.

Even with the short wave receiver, there were initial construction defects which were not detected. These were principally improper splices where the sheath was not up inside the connector as a result of the center conductor's being left too long. The ultimate method of detecting these was to mount a mobile test setup as shown in Figure 5, and track the signal from the sub-low source pole by pole comparing visual impairment from input to output. This mobile setup was by far the most sensitive and responsive. It was our experience that each connector needs to have a final visual quality control inspection by taking off the compression nut after installation.

Photo 6.

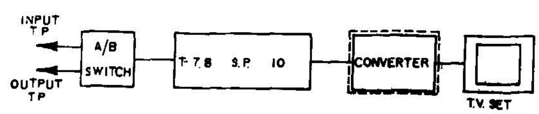

FIG. 5.0 MOBILE TEST SET

CROSS-MODULATION IN HRC SYSTEMS

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Abstract

The nature and origin of AM and PM cross-modulation is discussed. A typical cascode amplifier is examined.

A 400 MHz CATV Hybrid is thoroughly characterized with respect to various forms of third-order distortion. It is shown that phase cross-modulation is a major factor at high frequencies.

Because of the pseudo-single-sideband nature of TV transmission, PM distortion becomes visible. Predictions for the shape and magnitude of visual manifestations are made. A practical experiment is described.

Cross-modulation in 52 channel HRC systems is investigated using a computer model. Significant improvements are predicted.

Cross-modulation in CATV Amplifiers

Historically, cross-modulation is the oldest form of third-order distortion recognized in CATV Systems. The concept was taken from the AM radio field, and was redefined by the NCTA. It causes the typical wind-shield wiper effect, which is easily recognizeable.

As the channel loading increased over the years, another form of third-order distortion became apparent. Soon the horizontal streaks of the composite triple-beat phenomenon dominated.

This led to a situation, where the main linearity criterion was CTB, with good cross-mod performance being taken for granted. Indeed, the cross-modulation of typical amplifiers is much lower than the theoretical predictions made in the early literature(1). This welcome characteristic was described and explained by Meyer et al (2). It is, in principle,due to the fact that phase-shifts in feedback amplifiers tend to convert amplitude cross-modulation to phase cross-modulation. Since X-mod is, by NCTA definition, measured with an AM detecting instrument, substantial improvements were often registered. It is possible for all AM X-mod to vanish, provided the open-loop gain of the amplifier is large and there is a 90^{o} phase difference between the open-loop gain and trasmission angle of the feedback network. In CATV amplifiers, as a first approximation, the transistor gain has an appreciable lagging angle (at high frequencies), whereas the feedback network is essentially resistive and does not turn the phase.

It has been suggested that broadband AM to PM conversion can be achieved by proper circuit design (3). In practice circuit considerations for gain flatness and good match may limit the freedom of the designer.

The Sources of X-Mod

Nearly all CATV amplifiers presently in use employ the push-pull cascode configuration. The push-pull feature has no influence on third-order behavior. The cascode arrangement, a common-emitter stage driving a common-base stage, contains two main sources of cross-modulation.

The base-emitter junction of the C-E stage is the major origin of AM X-mod. The amount of distortion is a function of resistor values in the base and emitter legs, the beta of the transistor, and the emitter current. F_t or other high frequency parameters do not enter significantly. This results in the fact that all amplifiers having like gain and current consumption have about the same X-mod performance on channel 2.

As the frequency rises, the common-emitter stage will exhibit an increasing phase lag, depending upon the cut-off frequency of the device. This phase-shift contributes to the gradual conversion of AM to PM cross-modulation. In 400 MHz amplifiers a 6-10dB reduction in AM X-mod between channel 2 and H14 is not uncommon.

It would be quite wrong, however, to assume that merely a phase shift of the cross-modulation sidebands occurs and that the absolute spurious power remains to be the same.

At high frequencies the non-linear junction capacitors become significant contributors to 3rd order distortion. Of these the output capacitance of the common-base stage has the greatest influence. The junction capacitances are responsible for the increase in triple-beat at high frequencies. Their effect on cross-modulation is the addition of significant phase X-mod in addition to the converted AM portion.

While phase cross-modulation in the past has received little attention, the visibility and possible performance limitations were pointed out by Gumm (4). In order to determine the quantities involved, the following set-up was assembled.

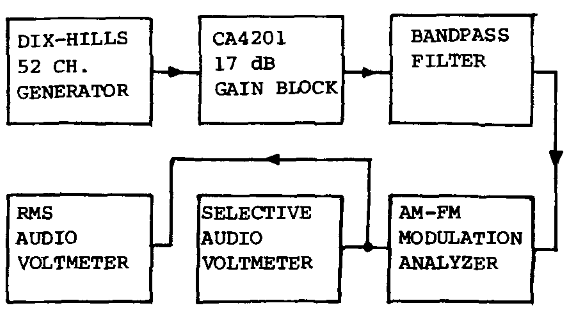

Figure 1. Test Set-up

The amplifier under test was loaded with 52 channels, flat, at 46dBmV. AM cross-modulation sidebands were measured using the AM detector and selective audio voltmeter. PM sidebands were calculated from measured FM deviation(IF bandwidth 400 kHz, audio roll-off 75 kHz). Triple-beat was read on the RMS audio voltmeter (IF bandwidth 20 kHz, audio roll-off 15kC). Figure 2 shows the power in each one of the AM and PM cross-modulation sidebands. To obtain NCTA composite X-mod, subtract 10dB from AM sideband values. It is evident that over much of the frequency range the power in the phase X-mod sidebands dominates. An interpretation of the visual effects will follow.

Plotted on Figure 3 is the RMS triple beat voltage and the effective RMS voltage of the combined cross-modulation sidebands. Both are of similar magnitude and show similar frequency behavior. The

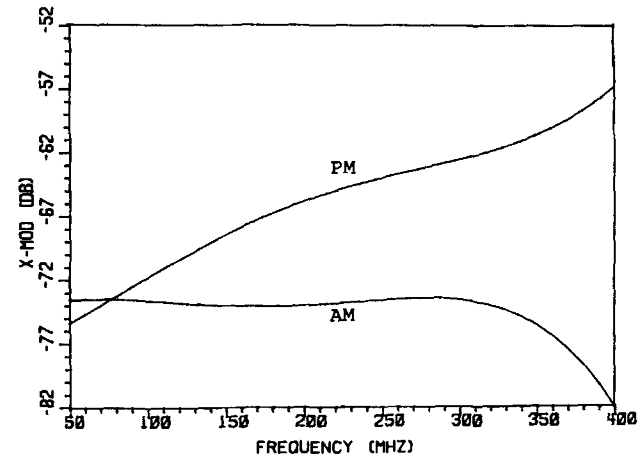

Figure 2. X-mod Sideband Power

triple-beat number shown here is the true RMS value. A spectrum analyzer, used in the logarithmic mode, will indicate a better value. Arnold has shown (5) that the difference between the true RMS value and the spectrum analyzer reading, which is often quoted, is approximately 3dB.

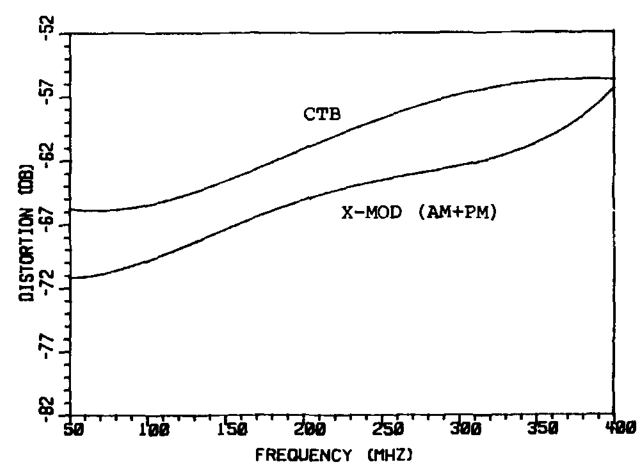

Figure 3. X-mod and CTB

Visual Effects of PM X-Mod

PM cross-modulation becomes visible on a TV screen because TV transmission uses a pseudo single-side band system. Consider Figure 4. The picture carrier is positioned on the halfway point of the Nyquist-slope. Phase modulation of the picture carrier may be expressed in equivalent frequency deviation, which in turn is slope-detected. Thus, PM X-mod sidebands can be expressed as equivalent AM modulation sidebands. For the condition shown in Figure 4 the equivalent AM is

$$AM\ (dB) = PM\ (dB) + 20*\log\left(\frac{f}{600\ kHz}\right) \qquad (1)$$

For f_{mod} = 15.75 kHz, the equivalent AM sidebands will be 31.62 below the PM value.

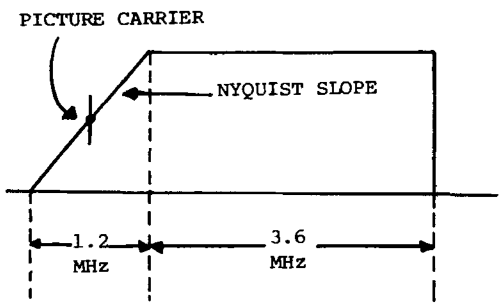

Figure 4. Idealized TV Bandwidth

If the modulation of the interfering carrier(s) is a square wave, a set of PM sidebands will be generated. For a symmetrical modulation envelope, these will be the odd harmonics, decreasing in amplitude inversely proportional to frequency. The equivalent AM sidebands will, however, be all of equal amplitude, because of the term f in Equation 1.

Assume that the modulating square-wave has a rise-time of 140ns between peaks. This is the fastest possible value in a 4.2 MHz video bandwidth system. It can be shown that such a square-wave must contain all odd harmonics up to harmonic number 265. These can be accommodated within the available bandwidth. The first 20 odd sets of phase-sidebands will fall onto the Nyquist slope and contribute equally to the resulting conversion into AM. Of the higher-order sidebands, only the upper ones will contribute. Their influence will be inversely proportional to frequency. Calculation of the total peak equivalent AM modulation is straightforward, but is best done on a computer. For the conditions described (15,750 kHz square-wave modulation, rise-time 140ns), the peak value of the combined equivalent AM sidebands is:
AM peak (dB) = PM (dB) -31.62 + 35.11dB. PM (dB) is the value of one of the first set of PM sidebands. The width of the peak exursion is quite narrow, the "6dB time-width" is 0.212 nsec, that is =0.4% of a horizontal scanning line. For a practical example let us take the measured data from Figure 2. The AM X-mod sidebands at channel M14 were -81.6dB. This translates into -71.6dB NCTA X-mod. The PM sidebands in the same channel were -57.21dB. Using Equation 1 we may calculate a p-p cross-modulation of -41.67dB for this case. The results are illustrated in Figure 5.

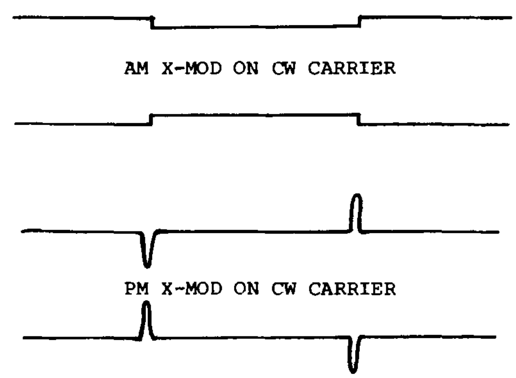

Figure 5. AM and PM X-mod on TV

On the screen we will first see a white, then a black narrow vertical line at the edges of the modulating square-wave.

In practice modulation voltages with longer rise-times than 140 ns will be encountered. If the rise-time is more than 0.833 μs, all associated PM sidebands will fall on the Nyquist slope. In this case the resulting AM cross-modulation is easily calculated:

$$\Delta\omega = \frac{d\phi}{dt}$$

where

$\Delta\omega = \Delta f * 2\pi$ = frequency deviation

$d\phi$ = peak phase deviation

$$= 2 * 10\ \mathrm{Exp}\left(\frac{dB}{20}\right) * \pi/4$$

where

dB = dB value of first set of phase sidebands

dt = rise-time

For example, for PM sidebands of -60dB and a rise-time of 833 ns, the frequency deviation is 300 Hz. The p-p equivalent AM cross-mod is

$$20 * \log\left(\frac{4 * 300}{600\ 000}\right) = 54dB$$

TV Screen Test

In order to observe the visual effects of PM cross-mod the test set-up shown under Figure 6 was assembled.

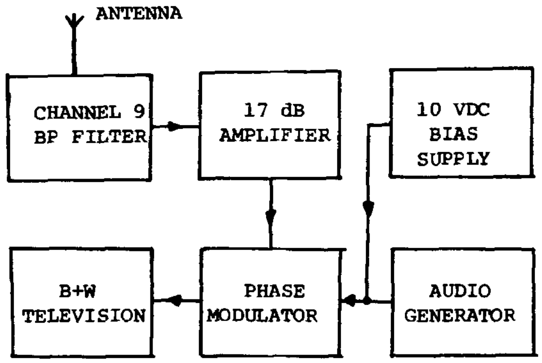

Figure 6. Phase Modulation of TV Signal

The phase modulator was a WB-Engineering RF bridge, the capacitance diode a TRW PC117 (47 pF at 4 volts). When terminated properly, 0.04 radians peak phase deviation were produced at 187.25 MHz by 1 volt RMS audio superimposed on a fixed bias of 10 volts dc. There was no discernible AM. The frequency of 187.25 was chosen because channel 9 was the best channel at the test location. A modulation frequency of 100 kHz was selected. Vertical black and white stripes became visible at a modulation voltage of .25V. These had the same appearance as sinusoidal AM cross-mod. At this point the PM sidebands can be calculated to be:

$$PM\ (dB) = 20 * \log (.25 * 0.04/2) = -46dB$$

The equivalent AM sidebands are:

$$AM\ (dB) = -46+20*\log \left(\frac{100\ kHz}{600\ kHz}\right) = -61.6dB$$

Trained observers are said to be able to detect cross-modulation due to -60dB sidebands. The apparent discrepancy of 1.6dB could easily be caused by a slightly non-standard Nyquist slope of the B&W TV set used or by other minor imperfections of the test set-up. In either case it is shown that phase cross-modulation of the magnitude observed in CATV amplifiers can produce visible distortions.

Cross-Modulation in HRC Systems

The advantages of HRC operation are well known. With few exceptions the industry agrees that the best investment towards better system quality lies in converting to HRC operation. The elimination of all triple-beats has a drastic visual effect. Some of the initial euphoria subsided when it was realized that the triple-beat power did not vanish completely but re-appeared as a form of cross-modulation, albeit at a much reduced level. Under HRC operating conditions the multitude of triple-beat components which otherwise constitute the CTB noise, become a single voltage vector which is added to the picture carrier affected. The magnitude of this vector is determined by the magnitude of all contributing carriers. If their amplitude varies, e.g., if they are modulated, so will the amplitude of the triple-beat vector. The effect is modulation transfer or cross-modulation. Switzer (6) showed early, that by controlling the phase of the contributing carriers, the individual TB components could be made to cancel each other with more or less perfection. Krick (7) described a computer optimization effort for 27 channels. With 52 or more channels now at play, "phase-phiddling" becomes a formidable task. In most HRC head-ends for high capacity systems little or no effort is made to obtain optimum phase conditions.

This situation was investigated by creating the following computer model: A black box with a non-linear transfer characteristic was assigned a first-order coefficient, M_1, of unity and a third-order modulation coefficient, M_3, of 8 E-5. Fifty-two harmonically related carriers of 46dBmV each were summed and passed through the system. A random number generator adjusted the phase of each signal to an arbitrary value. A Fourier analysis was performed on the output which yielded the value of third-order distortion products in each channel. By making many computer runs with different sets of carrier phases and by averaging the results, the probable behavior of the system could be determined. Figure 7 shows the probability with which a certain dB value of AM cross-modulation (in terms of NCTA definition) could be expected. Through mathematical manipulation the "classic" AM X-mod was eliminated so that the results shown are solely X-mod due to triple-beat components.

To put the results in perspective, we may calculate the composite triple-beat for a conventional system as described. 52 carriers on an HRC frequency plan generate 903 beats on 246 MHz. The composite triple-beat (worst channel) is then:

$$CTB = 20 * \log_{10} \quad (A)$$

$$A = 3/2*8E-5 \left(\sqrt{2}*10Exp \left(\frac{46-60}{20}\right)\right)^2 \sqrt{903}$$

CTB = -70.84dB.

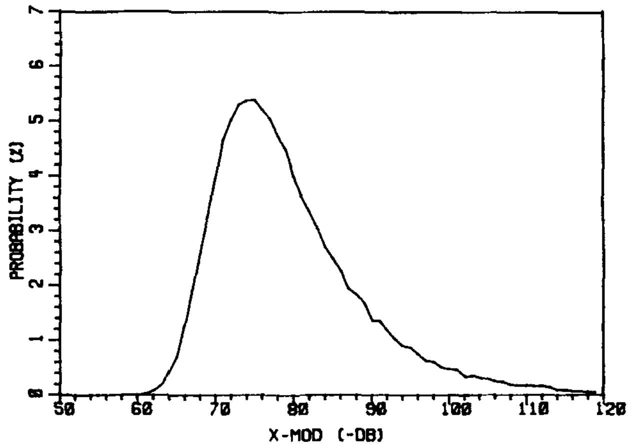

Figure 7. Probability of X-mod

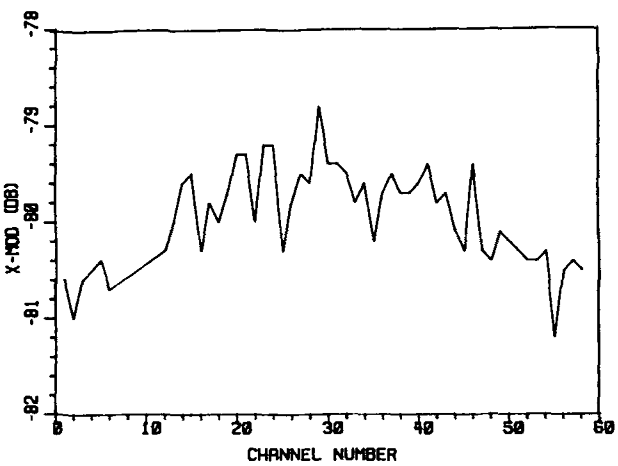

Figure 8. X-mod in TV Channels

Figure 8 shows the probable amount of apparent AM X-mod in each channel. Channel number 1 is 54 MHz, number 58 is 396 MHz. There are no carriers at 72, 90, 102, 108, 114, and 402 MHz. (Disregard portions pertaining to these frequencies on Figure 2, 3, 7, and 9). The typical X-mod is -79.5dB. One may conclude that in HRC systems CTB is converted to AM X-mod at a level 8.66dB below the CTB value. It may be mentioned at this point that the computer model also predicts phase cross-modulation with exactly the same distribution and sideband power as the AM components. This seems plausible because of the completely random nature of the signal phases.

The results shown are simple averages of 1000 computer runs. To demonstrate values obtained from individual runs, 3 sets of predictions are plotted in Figure 9. As seen here, there is always the chance of obtaining "bad" channels. In this case some phase correction may alleviate the problem or move it to a less critical channel.

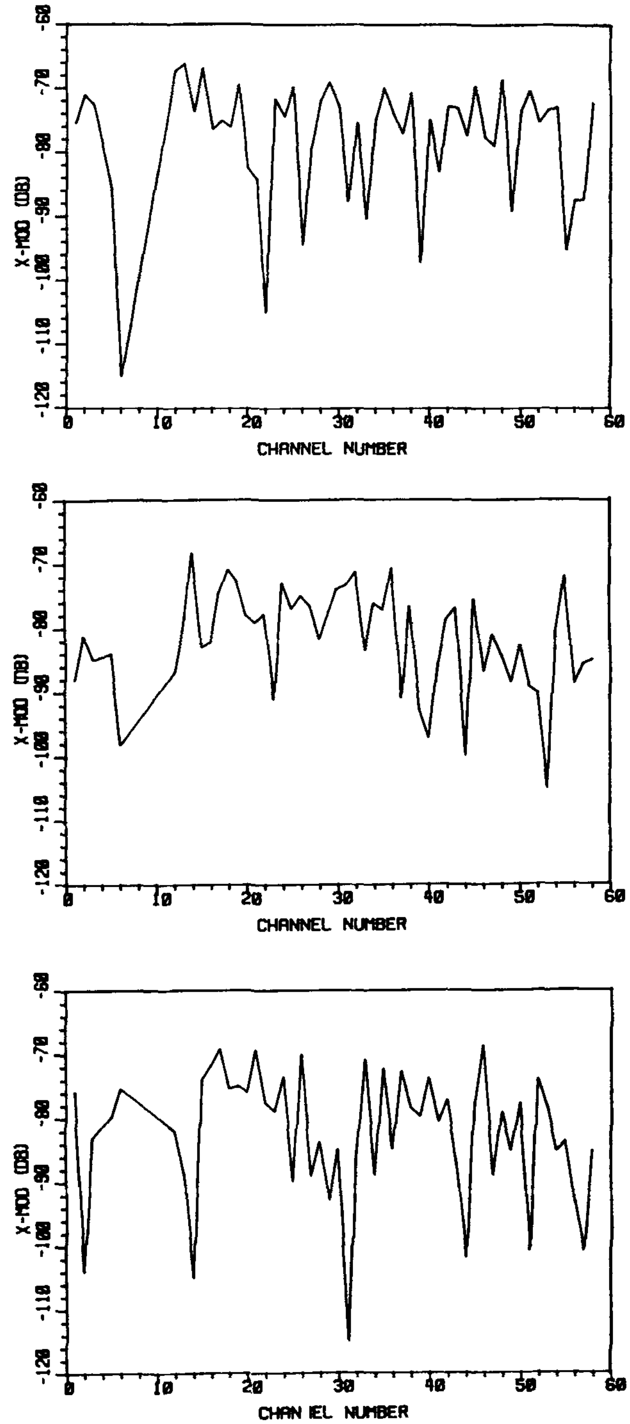

Figure 9. Three Computer Runs

Conclusions

I was shown that HRC operation results in an average AM X-mod 8.66dB below the CTB reading. Since X-mod becomes visible at about -48dB and CTB at -57dB, a total visual distortion reduction of 17.66dB is achieved. This improvement can only be utilized if the "classic" cross-modulation is negligibly small. HRC does not affect this type of distortion in any way. While, due to AM-PM conversion, the AM cross-modulation may indeed be small, the PM components may be so large as to become a limiting factor. More investigation in the light of HRC and 400 MHz operation seems appropriate.

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DESIGN CONSIDERATIONS FOR MECHANICAL PACKAGING OF A CATV TRUNK STATION

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Scientific-Atlanta, Inc.

ABSTRACT

There are many aspects to be considered during the design of the mechanical package of a CATV trunk station. The various alternatives to be considered, and the basis for decisions made during housing design will be presented to help establish comparative guidelines, and to provide a base of information to aid comparison of the various designs on the market.

Attention will be given to housing configuration, selection of materials and parts fabrication processes, compatability of materials and other topics that are considered during the design process. Special attention will be given to analyzing the thermal performance of an amplifier and showing how good thermal performance can be created by housing configuration during design. Component operating temperatures have a primary effect on unit reliability. Additional options that increase total station heat dissipation, the introduction of higher gain block hybrids and the growing popularity of pedestal mounting, make unit thermal performance more and more important.

The general requirements to be considered during the design of a trunk station housing consist of housing size and form factor, product reliability and maintainability, product service life, unit strength and weight, and unit producibility.

This paper will outline the specific requirements of the general considerations listed above and then will show how each of these requirements can be satisfied. To design an integrated, functional producible final housing assembly, consideration must be given to proper housing internal geometry and module placement, proper material selection and parts manufacturing processes, and proper unit thermal performance.

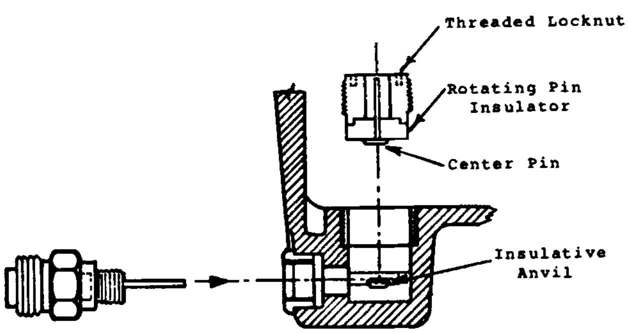
Housing Geometry and Module Placement

Housing geometry and configuration has a primary effect on unit maintainability, reliability, external form factor and producibility.

Module placement is determined by the required interfaces with the external cables, equalization of heat distribution within the housing and module to module interconnections. Trunk and bridger module placement into the housing strand side is dictated by external cable inputs, and the high heat dissipation of the amplication hybrids requires that these modules be mounted directly to an external housing wall to ensure reliable operation. The power supply and reverse amplifier are the remaining high dissipation modules so that their optimum placement is in the opposite housing half. This will provide a uniform heat dissipation input into each housing half to maximize the use of the external housing surfaces for cooling. These modules should also be mounted to an external housing wall to provide adequate cooling for high dissipation components. Power supply placement should be to the hinge side of a standard housing to minimize the torque required to restrain the moving housing half during housing opening. Placement of the Dual Pilot and Status Monitoring/Bridger Switching modules is less critical since module power dissipation is low (dissipation of each module is less than one-half of the bridger hybrid alone). Placement of these modules is therefor governed by module interconnections to provide a simple, producible interconnection system.

Module to external cable center conductor interconnection plays an important role in overall unit performance. The center conductor to module interconnection scheme must meet several requirements. First, the cable seizure mechanism must clamp the center conductors of the external cables while minimizing center conductor deformation and damage. A seizure that minimizes center conductor deformation will reduce center conductor stress concentrations and will make the center conductor less likely to break during the cyclic loading produced during unequal expansion and contraction of the cable outer and inner conductors (copper center conductor and aluminum outer conductor). Next, the seizure should provide a direct interconnection to the modules that is as close to 75 ohms in impedance as possible to minimize system impedance mismatch. Lastly, the seizure itself should be capable of withstanding the center conductor loads.

A cable seizure mechanism as shown in Figure 1 will satisfy all of these requirements. This seizure minimizes center conductor deformation and damage since the rotating pin insulator becomes stationary after contacting the center conductor allowing only compressive forces to be input. This is superior to a seizure that relies on a screw to contact the center conductor since a screw would input both compressive and twisting forces in a drilling action. The cable seizure shown creates an "F" connector when installed into the housing. The modules plug directly into this connector minimizing impedance mismatch.



Cable Seizure Mechanism

Figure 1

Modules should be easily removable from the housing to allow quick replacement of a failed module. Module covers should be easily removable to facilitate module trouble-shooting and to allow the quick interchanging of pads, equalizers, trim networks and feedermakers when these items are mounted within the module.

External housing size and shape should allow pedestal mounting within a TV104 enclosure or smaller and the vertical dimension of a strand mounted unit should allow it to fit within a 12 inch strand to phone line spacing. The external housing should be gasketed to provide both an EMI and water tight enclosure for the electronics. It is preferable to incorporate separate EMI and water gaskets with the water gasket outboard of the metal EMI gasket. Dual purpose gaskets offer reduced performance since they are a compromise of the two functions. In a dual purpose gasket, the presence of the rubber for water sealing increases the electrical contact resistance between the housing and the conductive particles or fibers within the gasket and the presence of the particles or fibers decrease the compressability and resilience of the rubber gasket compromising its sealing ability.

Cable connectors should mate with stainless steel inserts installed into the housing so that if anything is stripped during connector installation, it will be the relatively inexpensive connector and not the housing. Connector port spacing should be a minimum of 1.60 inches to allow the installation of the 1 3/8 inch Hex. bodied connectors used for some one inch cable.

Material Selection

Material selection is the predominant factor that determines unit strength, weight and service life. Proper material selection will also enhance product producibility and reliability.

The properties required of the external housing are good corrosion resistance, pressure tightness and strength, low weight, and good electrical and thermal conductivities. Die cast aluminum meets these requirements and offers the additional advantages of being relatively low in price with the capability of producing complex shapes so that cooling fins, screw bosses and other features may be cast in. The inherent corrosion resistance of aluminum to both marine and industrial environments is good as can be seen from the comparison of metals shown in Table 1. With good casting design, aluminum die castings can typically be cast to be pressure tight to 10 psig. This is adequate for a trunk housing since only a 5 psi pressure decrease would occur inside the housing with an instantaneous internal air temperature change from 160^{o} to -50^{o}F. Of the aluminum die casting alloys, Alloys 13 and 360 provide the best combination of properties with Alloy 360 offering slight advantages over Alloy 13. A comparative table of cast aluminum alloys is presented as Table 2.

Table 1

Average Atmospheric Corrosion Rates of Various Metals for 10- and 20- Year Exposure Times*

mils (in.x10^{-3})/Yr.

	Atmosphere					
	N.Y. City (industrial)		La Jolla,CA (marine)		St.College,PA (rural)	
	Years					
	10	20	10	20	10	20
Aluminum	0.032	0.029	0.028	0.025	0.001	0.003
Copper	0.047	0.054	0.052	0.050	0.023	0.017
Lead	0.017	0.015	0.016	0.021	0.019	0.013
Tin	0.047	0.052	0.091	0.112	0.018	-
Nickel	0.128	0.144	0.004	0.006	0.006	0.009
65% Ni, 32% Cu, 2% Fe, 1% Mn (Monel)	0.053	0.062	0.007	0.006	0.005	0.007
Zinc (99.9%)	0.202	0.226	0.063	0.069	0.034	0.014
Zinc (99.0%)	0.193	0.218	0.069	0.068	0.012	0.013
0.2% C Steel (0.02 P, 0.05 S, 0.05 Cu, 0.02 Ni, 0.02 Cr)	0.48					
Low-alloy Steel (0.1 C, 0.2 P, 0.04 S, 0.03 Ni, 1.1 Cr, 0.4 Cu	0.09					

*Reference 5

Table 2

COMPARATIVE TABLE for COMMON ALUMINUM DIE CAST ALLOYS

	Alloy*			
	380	13	360	384
Corrosion Resistance	4	2	2	3.5
Pressure Tightness	2	2	1	2
Castability**	2	1	1	1
Iridite Protection	5	3	3	4
Thermal Conductivity	0.24	0.29	0.27	0.23
Surface Appearance	3	2	1	N/A
Machinability	3	4	3	3
Electrical Resistivity	6.90	5.56	6.16	7.50
Density	0.098	0.096	0.095	0.098

Excellent = 1 Poor = 5

*Data from references 2, 3 and 4
**Castability is considered to be a combination of fluidity and resistance to hot cracking.

The properties required of the module housings are similar to those of the external housing except that pressure tightness is not a factor. Again, aluminum alloys are the natural choice, but since pressure tightness is not a requirement, a module made from formed sheet and plate can utilize the increased thermal conductivities (approximately double) of the wrought alloys to decrease the temperature rises within the module.

The materials for clamps, hinges and other external hardware should provide adequate strength and corrosion resistance to perform their functions during the service life of the amplifier and should be galvanically compatible with the cast housing. A chart showing the galvanic compatability of metals is shown as Figure 2. Since there are many factors involved in the overall compatability of metals other than the metals themselves, the chart should be used only as a guideline. One important factor is the area ratio of the anodic and cathodic materials. When combined, an anodic metal will sacrifice itself to protect the cathodic metal, so that very large areas of anodic metals in contact with a small area of cathodic material is not as bad as a joint with the area ratios reversed. Aluminum and stainless steel are not galvanically compatible, for example, but an aluminum housing joined by stainless steel bolts would be acceptable where a stainless steel housing joined with aluminum bolts would not. Due to the complexity of the galvanic process and the number of metals in contact in a typical trunk housing, accelerated corrosion testing for any new product should be performed with new product performance compared to the performance of a satisfactory previous product.

Thermal Design and Performance

The reliability of the amplification hybrids and other electrical components within a trunk station is directly related to the average component operating temperatures. With the growing list of trunk options available, increasing numbers of reverse systems, the introduction of high gain block hybrids and the growing popularity of pedestal mounting thermal performance grows in importance.

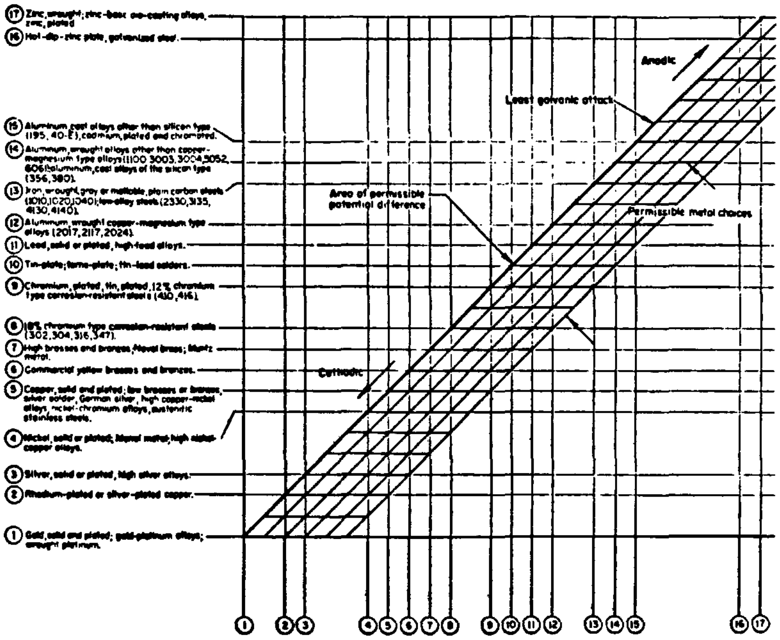
A thermal analysis of the finned Scientific-Atlanta trunk housing with outside dimensions of 9 1/2"x8 3/8"x19" is presented. To give meaning to the calculated temperatures, a curve of hybrid failure rate multipliers versus mounting surface temperature is shown as Figure 3. The analysis is segmented with the temperature rise associated with each discrete thermal resistance, as shown in Figure 4, presented separately.

The calculations presented are for a housing aerially mounted in 50°C (122°F) environment with the sun shining directly on the finned strand side external housing surface. The calculations show a hybrid mounting sink temperature of 76.34°C.

If the same calculations were performed for a housing painted white for added corrosion protection, an addition benefit of the white paint would be shown.

Figure 2

Galvanic Compatability of Metals



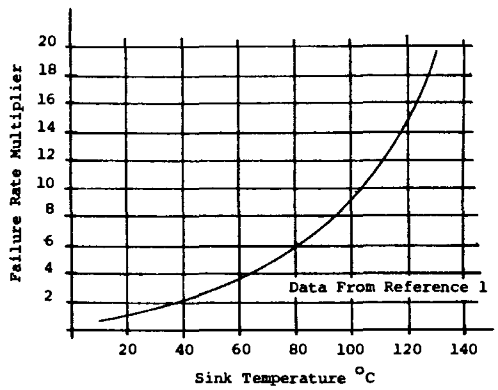
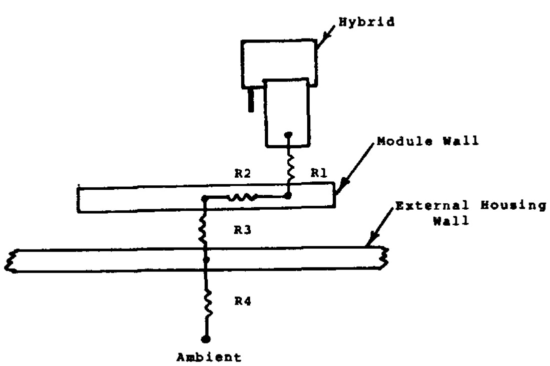


Figure 3



Thermal Resistances From A Hybrid To The Outside Environment

Figure 4

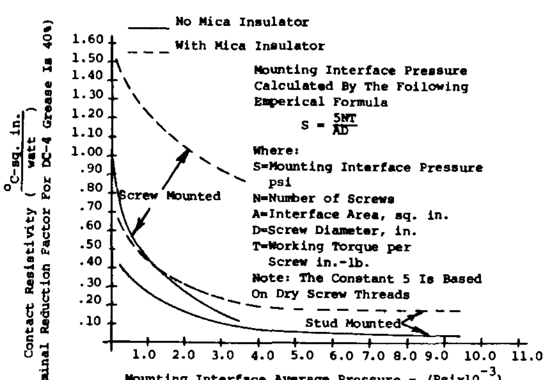


Figure 5

The temperature rise from the housing to the ambient would be reduced significantly due to the reduced solar absorptivity and increased radiative emissivity of the white paint. For a white housing, the reduced temperature rise from the housing to the ambient can be shown to lower the hybrid temperature by 8.5°C.

Pedestal mounting will cause housing temperatures to rise by placing a thermal barrier between the housing and ambient. Pedestal mounting in a TV104 will cause amplifier internal temperatures to rise approximately 20.3°C for an unpainted housing and 11.3°C for a painted housing.

The calculated temperatures presented and the operating temperature differences between the trunk amplifiers on the market take on more meaning when compared to the maximum recommended hybrid mounting temperatures and the hybrid failure rate curve shown in Figure 3. Typical maximum recommended hybrid mounting temperatures are 90°C or 100°C depending on device type; and hybrid failure rates can increase by a factor of 67% with only a 20°C increase in hybrid operating temperature (80°C to 100°C).

The amplifier analyzed has the trunk and bridger modules mounted to the finned wall of the strand-side housing half and the reverse and power supply modules mounted to the other finned outside wall. The Dual Pilot and Status Monitoring/ Bridger Switching modules are mounted to a hinged plate in the center of the housing. The total station dissipation is 52.74 watts with the following power breakdown:

400 MHz Trunk Module - 11.76 watts (two hybrids at 5 watts each)
400 MHz Bridger Module - 8.20 watts (one hybrid at 8.2 watts)
Sub-Split Reverse Module - 7.68 watts
Power Supply - 18.00 watts
Dual Pilot Module - 3.60 watts
Status Monitoring/Bridger - 3.50 watts
Switching Module

The power dissipation within the station is well distributed with 23.81 watts input to the strand side housing half and 28.93 watts input to the other housing half. As may be noted from the power breakdown, the hybrids are the predominate dissipation sources within the modules with the high gain bridger hybrid dissipating 8.2 watts. The analysis will calculate the mounting temperature for this device.

The discrete thermal resistance steps from the hybrid to the outside surroundings for an aerially mounted trunk consist of the resistance from the hybrid body to the module bottom, the resistance within the module bottom as the heat spreads, the resistance from the module bottom to the external housing wall, and the resistance from the external housing to the surrounding environment. These thermal resistances are shown in Figure 4 as R_1, R_2, R_3, and R_4 respectively.

Even though the analysis presented is of a particular amplifier design and configuration, the same resistance steps occur in all trunk stations with the resistance values varying with housing design and configuration. Therefore, after calculation of each discrete resistance and temperature rise, the critical parameters determining the resistance will be listed to aid qualitative comparison of units.

R_1 (Hybrid To Module Wall Resistance)

There is a thermal resistance associated with the contact interface of any joint through which heat must pass. The resistance and temperature gradient are given by:

$R = rc/A$ and

$\Delta T = R \times q$ where:

R = Thermal resistance (°C/watt)

rc = Contact resistivity $\left(\frac{°C\text{-sq. in.}}{\text{watt}}\right)$

A = Contact area (sq. in.)

ΔT = Temperature rise across resistance (°C)

q = Heat traveling across resistance (watts)

Joint interface pressure and contact resistivity may be determined from Figure 5 for a hybrid mounted to a sink with two No. 4 screws torqued to 5.5 in.-lbs. with thermal grease applied to the interface.

$$S = 5(2)(5.5)/1.75(.3)(.112) = 935.4 \text{ psi}$$

$$rc = .50(.40) = .20\ °C\text{-sq.in.}/\text{watt}$$

$$R = .2/1.75(.30) = .38\ °C/\text{watt}$$

$$\Delta T = .38(8.2) = 3.1°C$$

As can be seen from the calculations, the important parameters are contact pressure, contact area and the presence of the thermal grease.

R_2 (Spread Resistance Within The Module Wall)

Once the heat flows from the hybrid to the module wall, it will spread prior to transfer to the external housing. There is a thermal resistance associated with the spread which results in a hot spot underneath the hybrid. The resistance is given by:

$R = {}^{L}/_{kA_c}$ where

L = Length of heat path = 1.00 in.

k = Thermal conductivity (6061 Alum. Alloy) = $5.1 \frac{\text{watt}}{^{\circ}\text{C in.}}$

A_c = Crossectional area of heat path = 2.55(.19) sq. in.

$R = {}^{1.00}/_{5.1(2.55)(.19)} = .40^{\circ}\text{C/watt}$

$\Delta T = R(q) = .40(8.2) = 3.3^{\circ}\text{C}$

In this case, the critical parameters are the heat path length and crossectional area and the module material. For a cast module, the thermal conductivity would be approximately halved doubling the temperature rise. The long narrow heat path from the hybrid to the contact area between the module and the external housing found in some amplifier designs would cause temperature gradients to increase significantly.

R_3 (Module Wall to External Housing Resistance)

To get from the module to the external housing, the heat must again cross a contact resistance, but this time without the aid of the thermal grease. Joint interface pressure and contact resistivity may again be determined from Figure 5 for a 2.55 in. by 2.00 in. area clamped by a No. 8 screw torqued to 8.0 in.-lbs.

$S = {}^{5(1)(8.0)}/_{2.55\ (2.00)(.164)} =$ 47.82 psi

$rc = 1.00\ {}^{\circ}\text{C-sq. in.}/_{\text{watt}}$

$R = {}^{1.00}/_{2.55\ (2.00)} = .20^{\circ}\text{C/watt}$

$\Delta T = R(q) = .20(8.2) = 1.64^{\circ}\text{C}$

The important parameters are contact pressure and contact area. The joint resistance and temperatures rise are directly proportional to contact area and are a strong function of clamping pressure. Clamping pressure is determined by the size and number of screws mounting the module into the housing.

R_4 (Resistance From Housing to Environment)

So far, only the dissipation of the bridger module hybrid (8.2 watts) has been used to calculate the temperature rises associated with the heat path resistances. Now, to find the temperature rise from the external housing to the ambient, the total heat input to the housing half must be used. Solar load must be added to the internal dissipation of 23.81 watts to determine the total heat input to the housing half. Heat input due to sunshine is:

$q = \alpha\ A_p\ S$ where

q = Heat input (watts)

α = Solar Absorptivity (.35 - Bare Alum., .15 - White Paint)

S = Solar constant (.73 $^{\text{Watts}}/_{\text{sq. in.}}$)

A_p = Projected area illuminated by sun (sq. in.)

For a condition where the sun shines directly on an unpainted finned housing bottom

A_p = 17.27 (6.96) sq. in. and,

$q = .35(6.95)(17.27)(.73) = 30.7$ watts

So, the total heat input into painted and unpainted housing halves would be 36.91 and 54.50 watts respectively.

During calculations of the heat path from the hybrid to the housing, only conduction heat transfer has been considered. Calculation of the heat paths from the housing to the ambient will consider conduction to spread the heat from the sink area to the other housing areas and then will consider parallel heat paths to the ambient of convection to the air and radiation to the surroundings. The external housing will be considered to consist of two discrete temperature zones. Zone one will be the housing area that directly contacts the modules and will be a housing hot spot. Zone two will consist of the remaining housing half except the input and output housing ends that will be ignored since they are remote from the sink area. Therefore, R_4 will consist of the series resistors of R_s and R_{z2} in parallel with resistor R_{z1}, where the resistance designators are defined as follows:

R_s - Resistance associated with the heat spreading from Zone 1 to Zone 2.

R_{z1} - Resistance associated with the convection and radiation paths from Zone 1 to the surroundings.

R_{z2} - Resistance associated with the convection and radiation paths from Zone 2 to the surroundings.

The total resistance R_4 can be calculated by combining the series and parallel resistances in the following way:

$$R_4 = 1/\left[\frac{1}{R_{z1}} + \frac{1}{R_s+R_{z2}}\right]$$

Calculations to determine R_s, R_{z1} and R_{z2} will now be presented.

R_s (Spread Resistance)

This resistance may be calculated by determining the conduction shape factor of the surface shown in Figure 6 that represents an external housing half with the side walls folded down. The cross-hatched area represents the sink area or Zone 1. The other areas are the unit side walls and the remaining areas of the housing bottom or Zone 2.

The conduction shape factor is defined by the equation

$R = {}^{1}/kC$ where

R = Thermal resistance (^{o}C/watt)

k = Thermal conductivity (360 Alum. Alloy) = 2.9 $^{watt}/^{o}$C-in.

C = Conduction Shape Factor (in.)

Methods for determining the conduction shape factor for surfaces similar to the one shown are defined in Section 3-4 of Reference 1. The shape factor for the housing geometry shown is 1.84 in. Therefore,

$$R_s = {}^{1}/2.9(1.84) = .19^{o}\text{C/watt}$$

R_{z1} (Resistance From Zone 1 to Ambient)

The thermal resistance associated with convection to the ambient air and radiation to the surroundings from a finned surface to its environment is:

$R = {}^{1}/(hcA\eta_f + hr\,A\eta)$ where

R = Thermal Resistance (^{o}C/watt)

hc = Convection coefficient ($^{watts}/^{o}$C-sq. in.)

A = Surface Area (sq. in.)

η_f = Fin efficiency for convection

hr = Radiation coefficient ($^{watts}/^{o}$C-sq. in.)

η = Fin efficiency for radiation

A value of hc equal to .007 $^{watts}/^{o}$C-sq. in. is given in Reference 6 for a smooth surface in a 2.0 mph breeze. The value for hr is given by the equation

$hr = \varepsilon\sigma\,(T_1{}^2+T_2{}^2)(T_1+T_2)$ that can be approximated for small temperature differences by:

$hr = 4\varepsilon\sigma\,T_2{}^3$ where

ε = Surface emissivity (.15 - Bare Alum., .90-White Paint)

σ = Stefan-Boltzmann constant = $3.66\text{x}10^{-11}$ ($^{watt}/$sq.-in.$^{o}K^4$)

T_1 = Radiating surface temperature (^{o}K)

T_2 = Surroundings temperature (^{o}K)

The surface area of Zone 1 consists of the 6.95x7.25 inch finned housing area to which the module sinks are mounted. There are four fins that are .72 inches high and eight fins that are .97 inches high. Therefore,

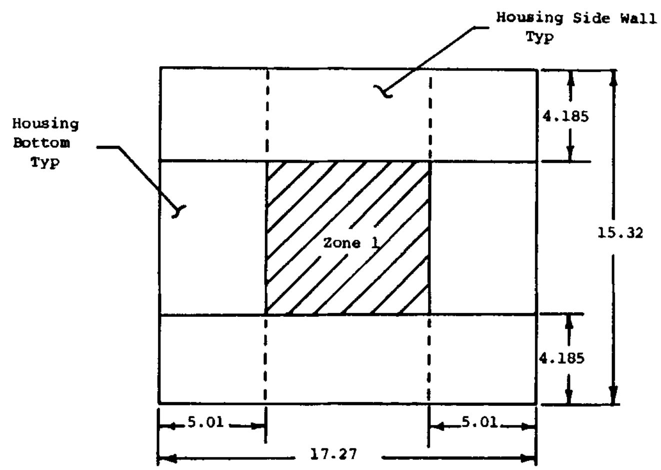
$$A = 6.95(7.25)-12(6.95)(.16) + 4(2)(.72)\left(\frac{1}{\cos 2^{o}}\right)(6.95) = +8(2)(.97)\left(\frac{1}{\cos 2^{o}}\right)(6.95) = 185.03 \text{ sq. in.}$$

Since all fins do not transfer heat with the same effectiveness, a convective fin efficiency must be defined. Convective fin efficiencies versus fin parameters are shown in Figure 7. Fins on trunk housings are typically quite efficient since a housing with extremely long and thin fins would be difficult to die cast. The fin efficiency for the housing being analyzed is

$$\eta_f = .998$$

The radiative efficiency of the finned area may be determined from Figure 8 and is

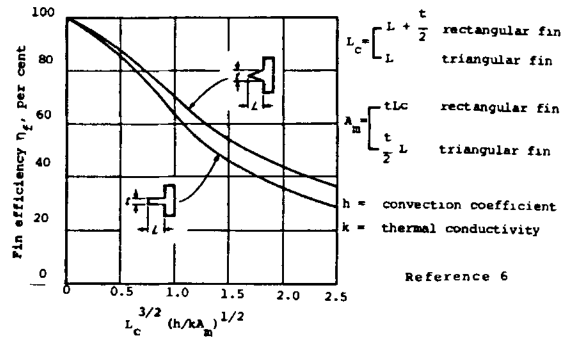
$$\eta = .475$$



External Housing Surface

Figure 6

Figure 7



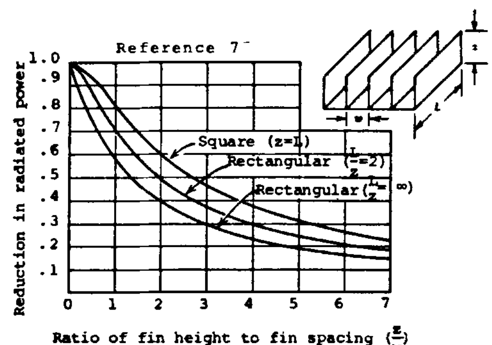


Figure 8

The analysis will be performed for a unit operating in a 50°C (122°F) environment so that

$$hr = .15(3.66\times10^{-11})(4)(323)^3 = 7.40\times10^{-4}\ \text{watts}/^{o}\text{C-sq.in.}$$

$$R_{z1} = 1/\left[(.007)(185.03)(.998) + (7.4\times10^{-4})(185.03)(.475)\right]$$

$$R_{z1} = .74^{o}\text{C/watt}$$

R_{z2} (Resistance From Zone 2 to Ambient)

The thermal resistance associated with convection to the air and radiation to the surroundings from the Zone 2 area can be determined in the same way as it was for the Zone 1 area except that not all of Zone 2 is finned. The calculations are shown below

$$A\eta_f = .998\ 6.95(5.59) + 8(2)(.97)\left(\frac{1}{\cos 2^{o}}\right)(6.95) - 8(.16)(6.95) + 2(17.27)(4.185) + 6.95(4.43) = 312.94\ \text{sq. in.}$$

$$A\eta = .475(6.95)(5.59) + 8(2)(.97)\left(\frac{1}{\cos 2^{o}}\right)(6.95) - 8(.16)(6.95) + 2(17.27)(4.185) + 6.95(4.43) = 240.43\ \text{sq. in.}$$

$$R_{z2} = 1/\left[(.007)(312.94) + (7.4\times10^{-4})(240.43)\right] = .42^{o}\text{C/watt}$$

Substituting into the equation to combine the series and parallel resistances

$$R_4 = 1/\left[\frac{1}{.74} + \frac{1}{.19+.42}\right] = .33^{o}\text{C/watt}$$

$$\Delta T = R(q) = .33(54.5) = 18.3\ ^{o}\text{C}$$

The important parameters determining the resistance and temperature rise from the housing to the ambient are the external housing area, and the length and crossectional area of the path used to spread the heat through the housing.

The hybrid sink temperature is the sum of the temperature rises plus the ambient temperature so that the hybrid sink temperature

$$T_{hybrid} = 50+18.3+1.64+3.3+3.1 = 76.34^{o}\text{C}$$

During comparison of trunk amplifier housings, the presence of some of the desired design features can be determined after a quick inspection. Unfortunately, many features that play important roles in unit service life and reliability are not easily determined. A total evaluation of expected unit performance cannot be obtained without consideration of the less obvious aspects like unit thermal design and material selections and combinations.

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DROP CABLE RF LEAKAGE THROUGHOUT 20 YEARS OF SERVICE

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ABSTRACT

A recent publication in the Multichannel News (1), "Signal Leakage Threatens to Cripple Cable Industry," emphasizes the importance of addressing CATV system signal leakage. Excessive egressive signal leakage could lead to fines by the FCC, ban of CATV use of aviation, navigation and communications frequencies. Excessive ingressive interferences signals lead to loss of customers due to poor reception. This paper evaluates drop cable "aging", an important characteristic which has not previously been evaluated on an experimental basis. Cables were removed from systems and evaluated to determine degradation. The cables measured had been in use for various periods of time, up to 23 years. The most significant "aging" observed was a decrease in shielding (increase in rf leakage). This information is correlated with laboratory "aging" tests to allow predictions of long term performance of relatively new drop cables. The test results show that the different drop cable types in use have varying degradation, a maximum of 18 dB compared to the best cable with only 7 dB degradation in 20 years of service. This quad shield cable, adhesive foil-60% braid-foil-40%-braid, which has the lowest degradation also has the lowest rf leakage at any point in time. (14 dB to 18 dB lower leakage than the second best).

INTRODUCTION

In the late 50's, two copper, 96% coverage braids were used for cable shields. This improved the shielding by 34 dB (a 99% reduction in rf leakage from the standard RG-59/U). However, this increased the cost by 70%. Cigarette-wrapped tapes and braids were introduced in the early 60's. Two basic types of aluminum-polyproplene-aluminum foil tape and aluminum braided shield cables are in use today, one with an adhesive tape and one without. The construction without adhesive adheres the foil tape to the dielectric, has approximately the same leakage as the two copper 96% braids and approximately 1/3 the cost. In the 70's, the adhesive foils were introduced to eliminate the connector installation problem and decrease the degradation of shielding resulting from cable flexure. A new shielding concept was also introduced in the 70's to achieve a significant improvement in shielding, i.e., "trapping" a tape between two braids, which further increases cost by approximately 50%. This cable, with an adhesive foil-braid-foil-braid shield, has a 99.96% reduction in rf leakage (55 dB improvement) over the original RG-59/U. Usually improvements in cable shielding result in an increase in cost but this drop cable is less expensive than the original RG-59/U.

Many factors require a shielding performance which is much higher than has been acceptable in the past, such as possible interference with aeronautical transmissions, advent of citizen band transceivers (CB's) with illegal linear amps and advance in technology of CATV systems, i.e., CATV frequency spectrum has been expanded to 5 to 400 MHz due to the advent of 2-way and 54 channel systems.

Increasing the frequency spectrum to 400 MHz results in higher leakage since the shielding decreases as the frequency is increased above 300 MHz. The 2-way system uses the 5 to 50 MHz band, which also results in higher leakage since the shielding, of the common types of drop cable in use, degrades as the frequency decreases below 50 MHz. The optimum shielding for these cables typically occurs from 50 to 150 MHz.

Many experts have evaluated drop cable performance (4, 5, 6, 7) before installation. The purpose of this paper is to evaluate drop cable degradation on an experimental basis where drops were removed from systems and measured. This "field data" is correlated to the results obtained from laboratory "aging tests". The results show that one can predict the drop performance at any point in time using a special flexure test. The lab "aging" tests are needed since many drop cable types are relatively new and it is important to know their performance after 10 to 20 years in service.

Fifty drop cables were removed from cable systems and approximately 230 tests were performed on the samples. Cables were selected to confirm that the cable performance reported is typical for the same type manufactured in general by industry and to obtain performance for varying years in service. The attenuation of the drop was measured, then samples were taken for shielding measurements and a visual and mechanical analysis.

The shielding was measured using a Radiometer and the results plotted versus years in service to show drop cable degradation and performance at varying points in time.

The degradation in service, "aging", is thought to be predominantly a result of aeolian (wind) flexure; this deduction is based on a visual observation of cable. "Galloping" is commonly observed if the wind is preceded by wet snow build-up on the cable. Accordingly, laboratory flexure tests simulating the aeolian flexure are used to "age" the cable, allowing prediction of performance for varying years of service. The results of the "field data" are correlated with the lab flexure test results, showing that the laboratory evaluation of drop cable allows prediction of performance at any point in time after installation.

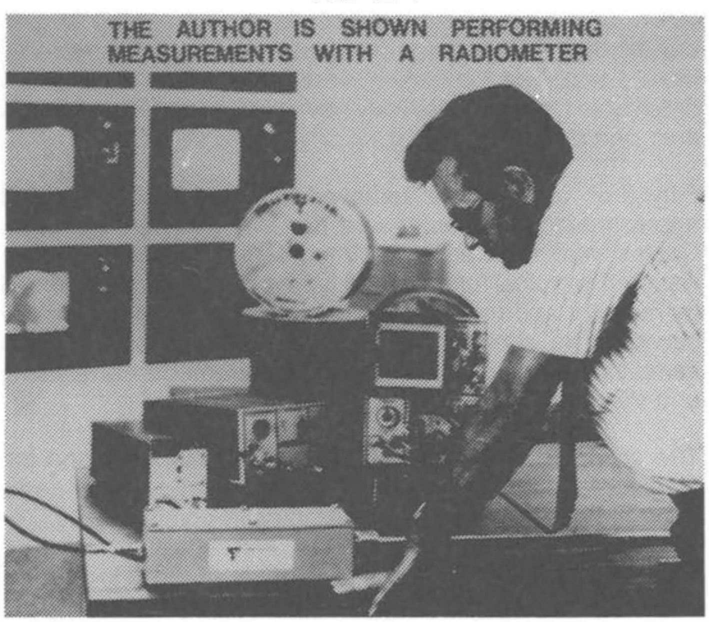
MEASUREMENTS

Drop cable was removed from systems in Wallingford, Danbury, New Milford, Meriden, Seymour and New Haven, Connecticut, South Yarmouth, Massachusetts, Kingston and Vestal, New York.

The attenuation of the drops was measured and was within +10% to −20% of the theoretical nominal for the cable except for a few exceptions which were unusually high. These exceptions were cables with corroded shields throughout a large portion of the length. Usually the corrosion, if it exists, is limited to a short length near the connector and does not have an appreciable effect. The maximum measured deviation was 75% above nominal for a copper braid which had been in service for 8 years. The attenuation of this 100-foot drop was only 3.2 dB above the nominal. The maximum measured deviation for aluminum shield constructions was 30% above nominal after 3 years in service. The unusually low attenuation values measured were probably caused by the measurement accuracy for short lengths of cable.

The shielding was evaluated using a Radiometer (See Fig. 1.) which measures the transfer impedance and capacitive coupling impedance of the coaxial shield (5).

FIGURE 1

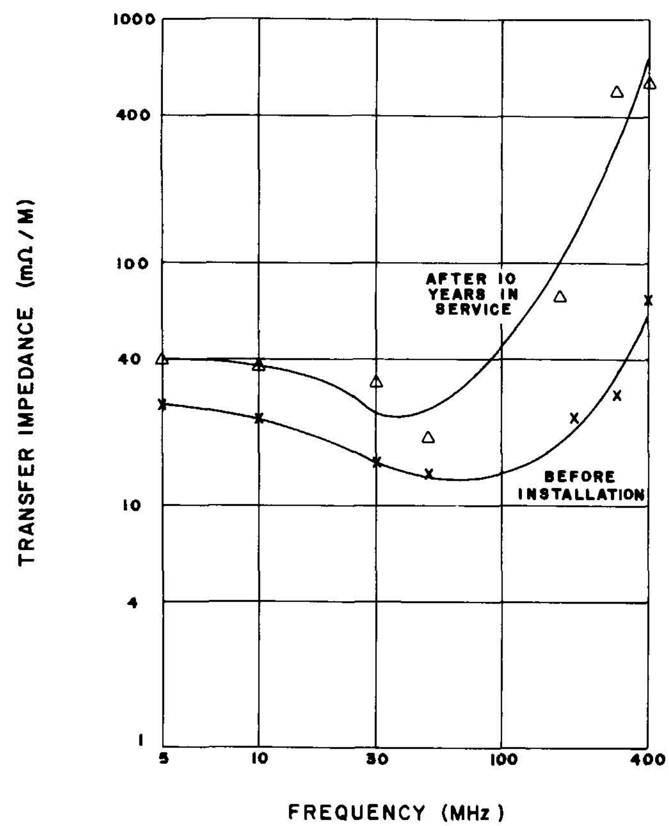


Transfer impedance is a measure of the voltage in the disturbed circuit caused by a current in an interfering circuit. It is a result of current diffusing through the metal in the shield (skin depth phenomena) and coupling of the magnetic field through openings in the shield. Capactive coupling impedance is a measure of the voltage in the disturbed circuit as a result of electric field coupling through openings in the shield. Accordingly, these parameters control the shielding. The egressive leakage concern is excessive radiation causing violation of the FCC rules; these impedances control the external field strength caused by the CATV signal transmitted within the cable. The ingressive leakage concern is RFI; these impedances control the interference signal within the cable caused by a disturbing external field.

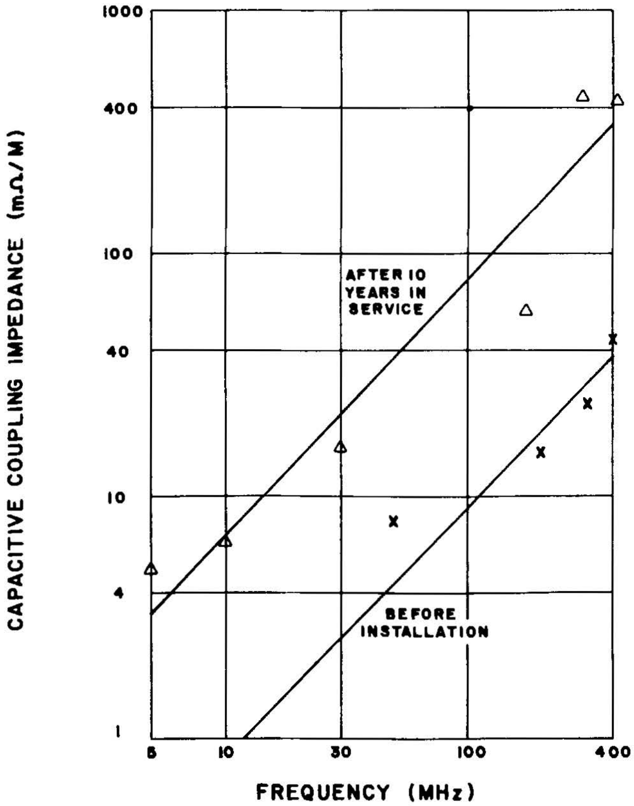
Radiometer test samples were taken from mid span, connection to the feeder line and connection to the house. The mid span tests were eliminated after evaluating the first 16 drops since this section had the lowest leakage in 81% of the cases. The street and house ends were essentially the same for 28% of all drops evaluated; the street end had the highest leakage in 44% of the samples.

The typical transfer impedance and capacitive coupling impedance of drop cable with an aluminum foil and braided shield is shown in Figures 2 and 3 respectively. Two curves are presented, before installation in a system and after 10

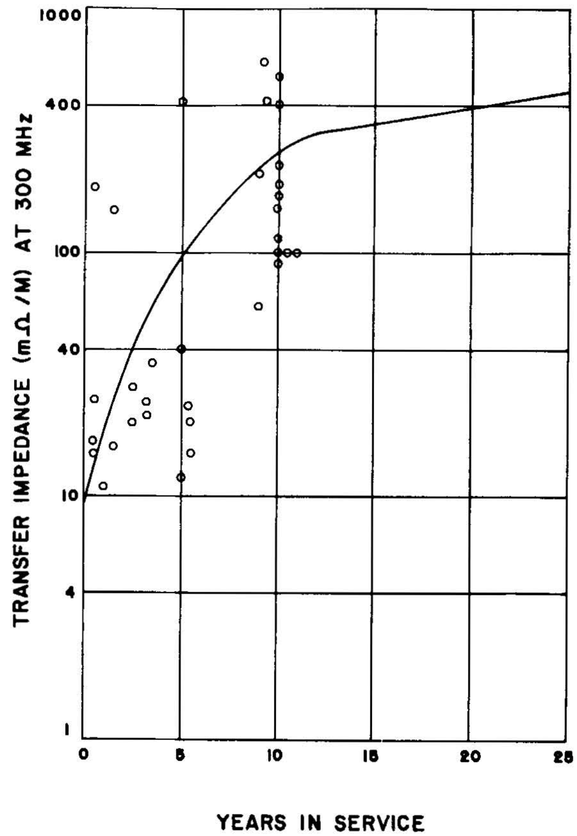
ALUMINUM FOIL-BRAID TRANSFER IMPEDANCE VERSUS FREQUENCY FIGURE 2



ALUMINUM FOIL-BRAID
CAPACITIVE COUPLING
IMPEDANCE VERSUS FREQUENCY



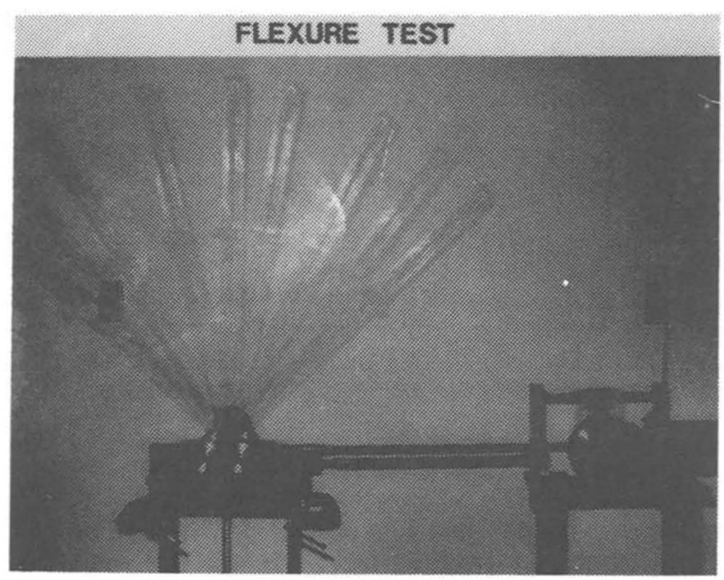
ALUMINUM FOIL-BRAID
TRANSFER IMPEDANCE
VERSUS YEARS IN SERVICE
FIGURE 4



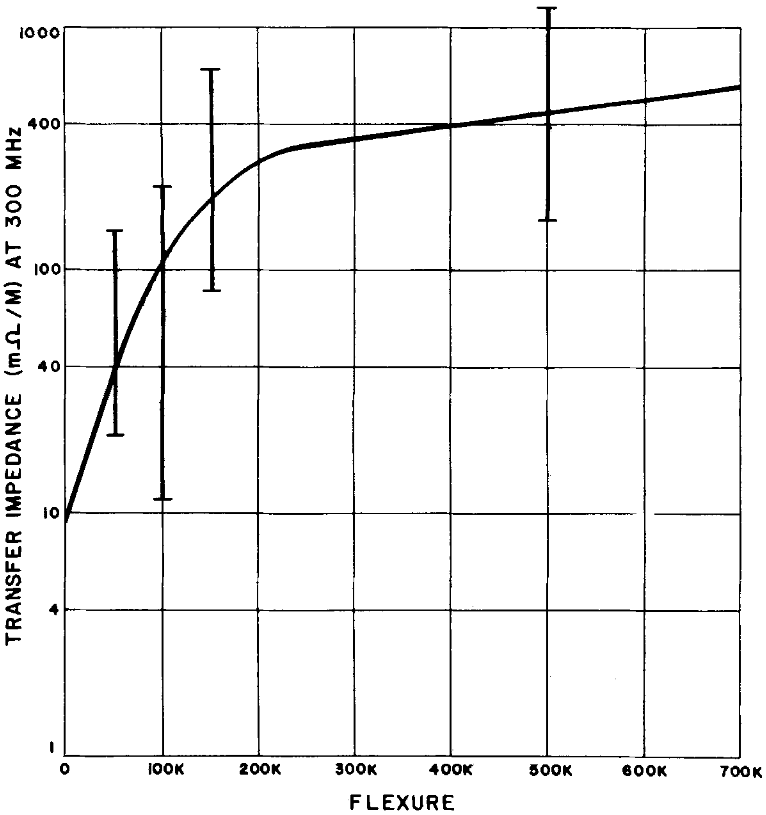
years in service. The maximum transfer impedance and maximum degradation occurs at the highest frequency. The degradation of the cable will be shown by plotting the 300 MHz transfer impedance versus years in service.

The degradation of drops whose shields are aluminum-poly-aluminum laminate foil tapes without an adhesive and an aluminum braid is shown in Figure 4. The points plotted are actual measured performance and the solid curve, which is a reasonable average of these data points, is the average performance obtained from laboratory flexure (aging) tests using a correlation of 15,000 flexure cycles per year in service. This correlation is used for all "aging" tests. The flexure test is shown in Figure 5. The cables are flexed at a rate of 40 cycles per minute. One flexure cycle is plus and minus 8 degrees travel. The results of the flexure test are shown in Figures 5 and 6. The vertical bars are the range of test results obtained on a number of samples from different cable manufacturers. This test simulates the drop cable flexure caused by the wind. The severity of flexure degradation could change with temperature; therefore, the degradation versus time could vary in geographical areas where the prevailing wind and/or temperature is substantially different from the areas evaluated.

FIGURE 5



ALUMINUM FOIL-BRAID TRANSFER IMPEDANCE VERSUS FLEXURE FIGURE 6



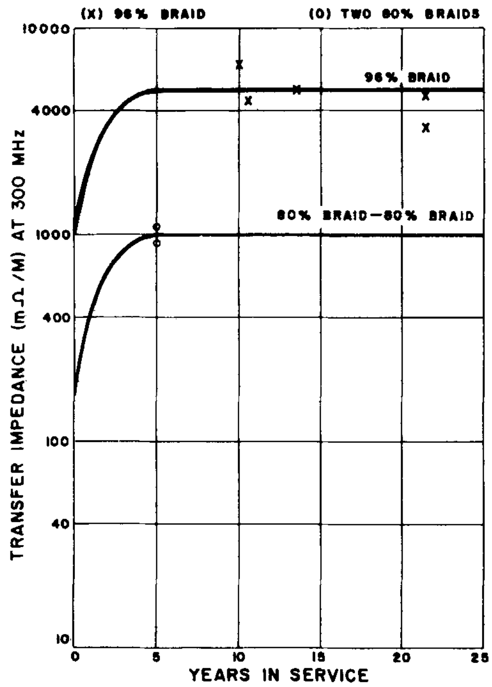
The degradation of copper braid drop cable shields is shown in Figure 7. The points plotted are actual measured performance. There is an initial increase, probably due to corrosion, that does not appear in an "aging" test performed at room temperature. The solid curves are the average flexure performance, no degradation, with an initial increase allowing for corrosion.

Limited evaluation is obtainable for the other constructions, since they have only been in service for a relatively short period of time. The two types evaluated suggest that the flexure test is a valid "aging" test allowing laboratory evaluation of cable performance after any given length of time in service.

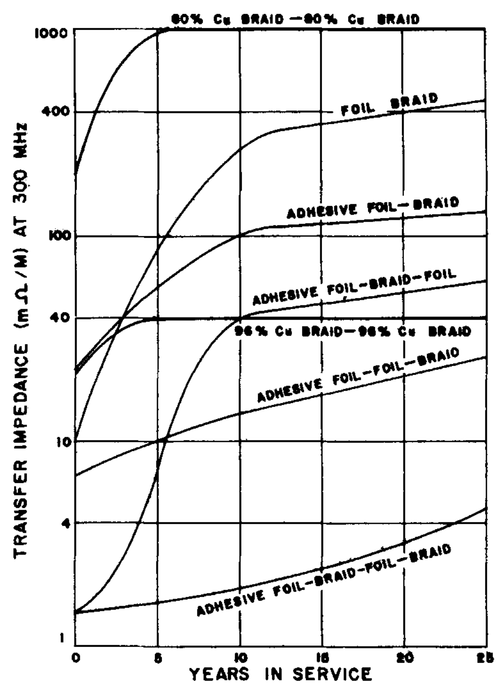
The typical 300 MHz performance of the different types of drop cable which are in use is shown in Figure 8. The curves are based on the average of a number of flexure test samples obtained from a number of cable manufacturers and the results of the "field data".

The typical transfer impedance from 5 to 400 MHz, before installation and after 10 years in service, is shown in Figures 2, 9, 11, 13, and 15. The capacitive coupling impedance for the different drop cables versus frequency for these cables is shown in Figures 3, 10, 12, 14, and 16.

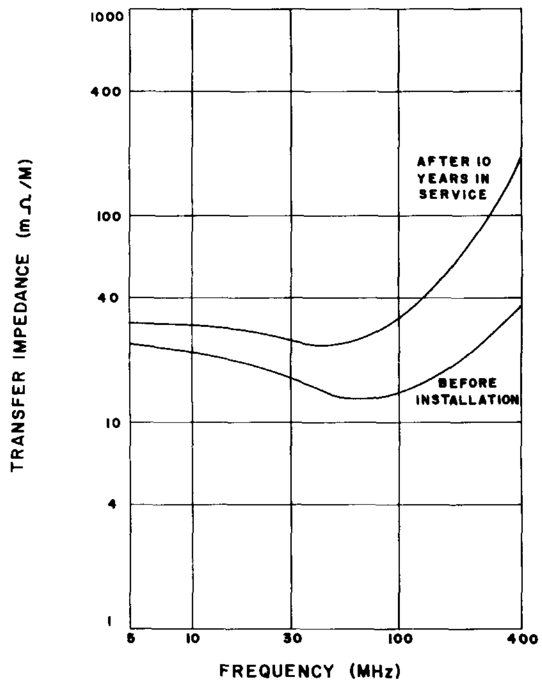
COPPER BRAID TRANSFER IMPEDANCE VERSUS YEARS IN SERVICE FIGURE 7



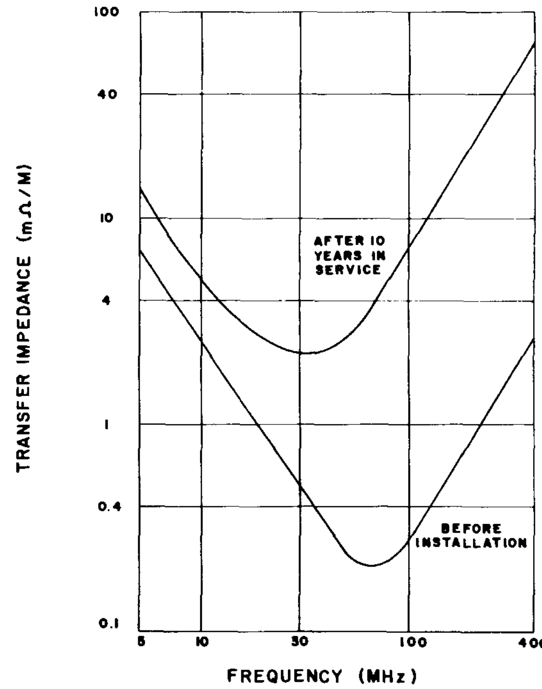
DROP CABLE PREDICTED TRANSFER IMPEDANCE VERSUS YEARS IN SERVICE FIGURE 8



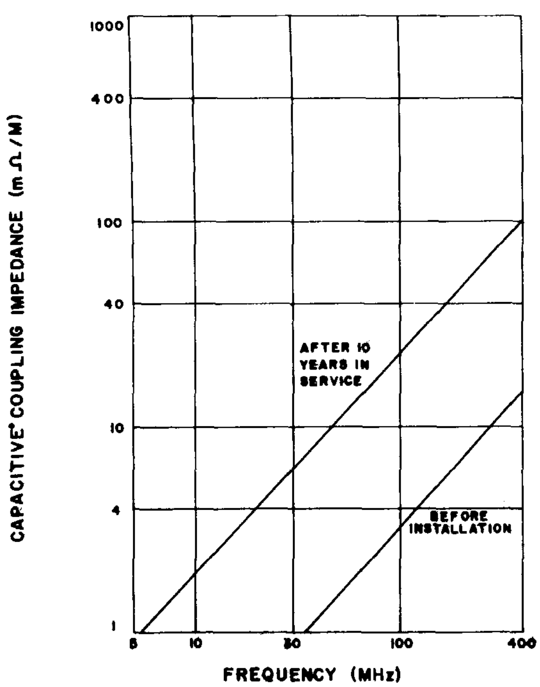
ADHESIVE FOIL-BRAID
TRANSFER IMPEDANCE
VERSUS FREQUENCY
FIGURE 9



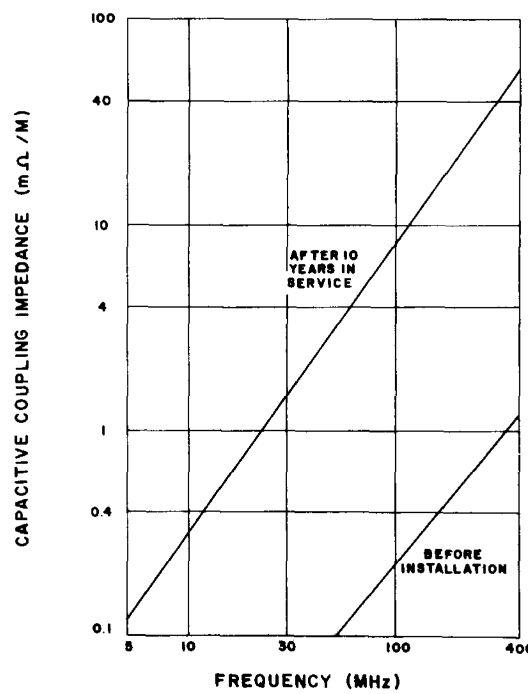
ADHESIVE FOIL-BRAID-FOIL
PREDICTED TRANSFER IMPEDANCE
VERSUS FREQUENCY
FIGURE 11



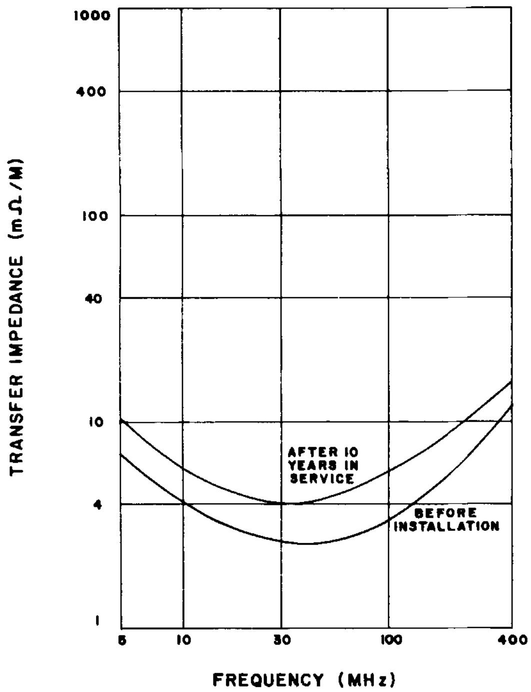
ADHESIVE FOIL-BRAID
PREDICTED CAPACITIVE COUPLING
IMPEDANCE VERSUS FREQUENCY
FIGURE 10



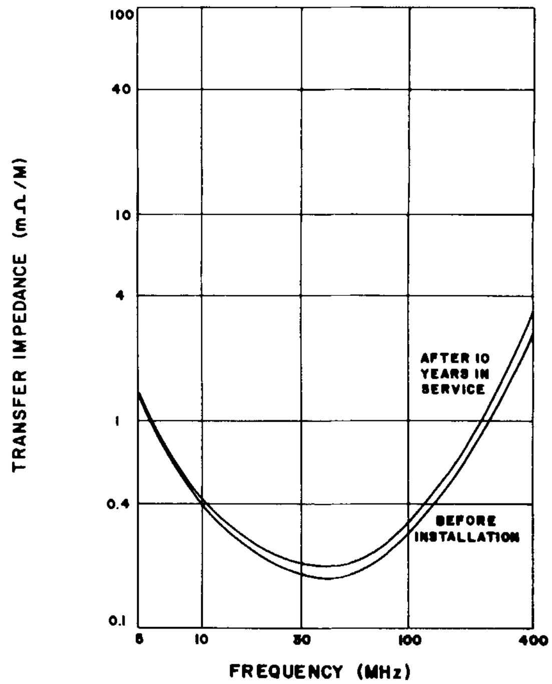
ADHESIVE FOIL-BRAID-FOIL
PREDICTED CAPACITIVE COUPLING
IMPEDANCE VERSUS FREQUENCY
FIGURE 12



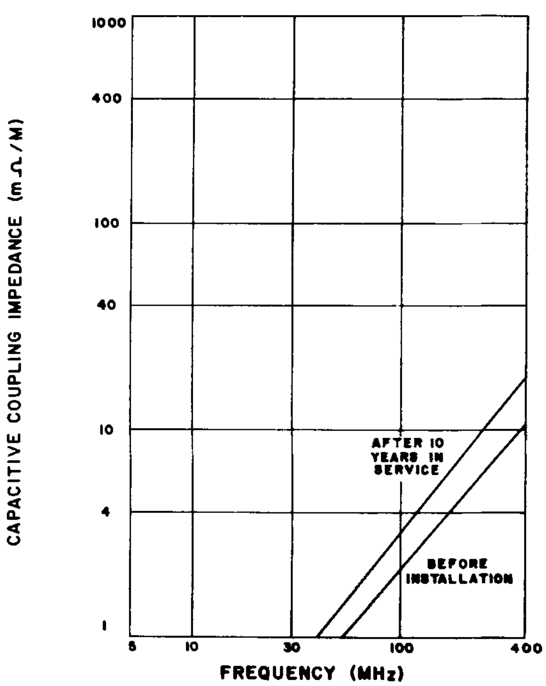
ADHESIVE FOIL-FOIL-BRAID PREDICTED TRANSFER IMPEDANCE VERSUS FREQUENCY FIGURE 13



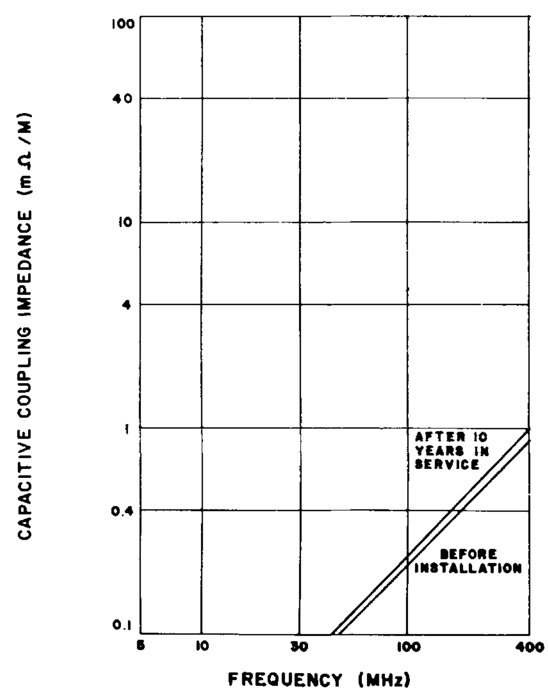
ADHESIVE FOIL-BRAID-FOIL-BRAID PREDICTED TRANSFER IMPEDANCE VERSUS FREQUENCY FIGURE 15



ADHESIVE FOIL-FOIL-BRAID PREDICTED CAPACITIVE COUPLING IMPEDANCE VERSUS FREQUENCY FIGURE 14



ADHESIVE FOIL-BRAID-FOIL-BRAID PREDICTED CAPACITIVE COUPLING IMPEDANCE VERSUS FREQUENCY FIGURE 16



DISCUSSION OF RESULTS

Considerable effort has gone into the solutions of the theoretical transfer impedances, capacitive coupling impedance, ingressive and egressive leakage signals but they will not be discussed in this paper. This discussion will be limited to a brief review of the test results.

There are essentially three types of drop cable shields in use, i.e., (1) braids, (2) laminate foil tapes with a braid adjacent to one side of the tape and in metallic contact and (3) a laminate foil tape with a metallic sheath adjacent to both sides of the tape and in metallic contact.

The 96% optical coverage copper braid cable was replaced with a cable which had two 96% copper braids to significantly improve the shielding. These braided shields have less degradation than the constructions using foil-braid shields. The excessive cost of two 96% copper braids resulted in the advent of laminate foil tape-braid shields. The constructions with one foil and one braid have significantly lower cost with low braid coverage and initial performance similar to two 96% copper braids, but they have higher degradation in service resulting in poorer shielding. The use of adhesive foil decreases the degradation. Similar foil constructions using up to 95% braid coverages are used, but the slight improvement in performance does not warrant the increased cost. Adding a second laminate foil tape over the braid significantly improves the performance before installation in a system; however, this cable has very high degradation in service. Therefore, the net result is a small improvement.

The third drop cable type was introduced to significantly improve the shielding without a substantial increase in cost. The concept employed to improve the shielding and minimize the degradation in service is "trapping" a laminate foil tape between two braids. The two round wire braids electrically short circuit any openings in the tape, thereby eliminating or minimizing the electromagnetic coupling through the opening. This significantly decreases the transfer impedance, improving the shielding (a significant decrease in rf leakage). The drop cable which has two laminate foil tapes under a braid falls into this category, i.e., "trapping" a tape between two metallic sheaths. However, the metallic tape does not short circuit the openings as well as the round wire braid. This cable is considered the second best drop evaluated.

The relative performance of the drop cable types can be expressed in decibles (dB) by the following equation:

$$\text{Relative performance} = 8.686 \ln \frac{Z_{ta}}{Z_{tb}} \text{ dB}$$

where
ln = natural or Napierian Logarithm
Z_{ta} = Transfer impedance of one cable type
Z_{tb} = transfer impedance of a second cable type

Example: The second best drop has a transfer impedance of 10 mΩ/m after ten years in service and the best drop has 1.7 mΩ/m.

$$\text{Relative performance} = 8.68 \ln \frac{10}{1.7} = 15\text{dB}$$

The best cable has 15 dB lower RF leakage than the second best after ten years of service.

CONCLUSIONS

Severe corrosion throughout a large portion of the drop cable length causes an appreciable increase in attenuation and seems to affect copper shields more than aluminum.

Drop cable shielding degrades in service as a result of corrosion and aeolian flexure. The drop cable with maximum degradation had 20x increase in leakage (poorer shielding) after 10 years in service, whereas the increase for the best cable is less than 2x. The various types of drop cable in use results in a large variation in shielding, rf leakage, at any point in time. The best drop available, adhesive foil-braid-foil-braid, has a 99.96% reduction in rf leakage over the original RG-59/U and is less expensive. This cable offers a substantial improvement (14 dB to 18 dB) over the second best at any point in time. Considering the importance of rf leakage, can the second best be afforded?

ACKNOWLEDGMENT

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Kent MacMown, Cape Cod Cablevision
Thomas O'Keefe, Kingston Cablevision
John Palmero, TWC
Jim Petro, Rollins Cablevision
Francis Scott, Empire/Pioneer Cablevision
James Strevey, Empire/Pioneer Cablevision
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FINANCING, MODELING, AND DESIGNING CATV
FOR
THE REA MARKET

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INTRODUCTION

REA developed an interest in television and other video services for rural areas as an outgrowth of its work in bringing improved telecommunications service to people living in rural areas. One of the earliest attempts to develop this capacity was a paper distributed in 1962 by Claude Buster, Chief of the Transmission Branch at REA, to the communications industry.

In this paper Claude recognized the tremendous potential capacity of coaxial cable and explored the idea of a total integrated communications facility that could deliver voice, video and data services using analog transmission techniques to the home. This idea was slowly nurtured and by 1977 the 3M Company was actively developing its analog CS^2 system which would provide a total integrated communications system over coaxial cable to the home. Also, in May 1977 the Office of Telecommunications Policy, now part of the National Telecommunications and Information Agency (NTIA), formed an interagency task force on Rural Communications to which REA was invited to participate. This task force in its report recommended that in order to improve rural communications that REA finance rural cable systems and that the cross-ownership ban on Telco ownership of cable systems be modified by the FCC. Up to that time REA had only financed a portion of the educational statewide television network in South Carolina.

Since that time the 3M Company has abandoned its CS^2 development as too costly. Another company has picked up the idea and is developing other equipment designs using digital transmission techniques to provide voice and data services directly to homes on coaxial cable facilities. The REA, while prohibited from directly financing commercial CATV systems under the RE (Rural Electrification) Act, did receive delegated authority from the Secretary of Agriculture to administer a loan program for CATV systems utilizing funding under the Consolidated Farm and Rural Development (CFRD) Act. Under the RE Act, REA can only finance educational television systems. The FCC in Docket 78-219 in 1978 eased the cross-ownership waiver requirements on Telco ownership of CATV systems and granted a rebuttable presumption of infeasibility for any system with an average density of 30 homes per route mile or less.

FINANCING RURAL CATV

The authority to administer CATV loans was delegated to REA on May 25, 1979. The funds were a portion of the amount budgeted for rural improvements under the Consolidated Farm and Rural Development Act. The CFRD Act provides two categories of financing. One category, Section 306, Community Facilities, provides funds for public bodies, qualified Indian tribes and not-for-profit organizations at a legislatively prescribed interest rate of five (5) percent. These same organizations and for-profit oriented organizations are eligible for financing under a second category of the CFRD Act, Section 310b, Business and Industrial Loans, with the interest rate based on the cost of money to the Government.

Previous to the transfer of authority, only one Section 306 loan was made by FmHA for a CATV system. This loan was to the Western Wisconsin Communications Cooperative to finance construction of a countywide educational TV system. Several CATV loans were made by FmHA using Section 310b authority. Similarly, REA had made only one direct TV loan in 1962 and that was to finance the portion of the statewide educational TV system in South Carolina furnished by the REA telephone borrowers. Since the transfer of authority and in the remainder of the fiscal year ending September 30, 1979, REA administered loans totaling $6 million. In fiscal year 1980, $34 million in loans and loan guarantees were made. For fiscal year 1981, $34 million in loan authority is authorized. However, the Administration has proposed that this loan authority be reduced to $18.0 million. Also, the Administration has proposed that no further funding be authorized under the CFRD Act. Should this happen, the direct financing of commercial CATV systems by the Department of Agriculture would cease as of September 30, 1981.

Financing for rural CATV systems would not stop but would be slowed down and become more expensive. REA could still finance educational TV systems which admittedly would probably be rare. Rural telephone systems would have to apply for funds from the commercial financing market. Similar financing opportunities are available to new entrepreneurs or existing CATV organizations.

The Rural CATV Market

REA has known for some time that a market existed for rural CATV systems from the interest expressed by the rural telephone industry. Until the availability of financing was announced in 1979, we did not know the size of the market. By the end of fiscal year 1979 we had received applications totaling almost $100 million for rural CATV systems. These applications came not just from our current telephone borrowers, but a significant portion came from independent cable operators as well as from electric cooperatives. The CATV loan applications on hand at that time were as listed below in Table 1. Table 2 lists the loans made in fiscal 1980. An examination of Table 2 shows that the loans went to a mixture of cooperative and commercial organizations both cable operators and telephone systems.

TABLE 1

CATV Loan Applications on Hand End of Fiscal Year 1979

Area	Current Borrowers	New Applicant	Total
North Central	$ 6,978,926 30%	$16,000,000 70%	$22,978,926
North East	975,000 54%	830,000 46%	1,805,000
South East	35,517,000 62%	21,484,000 38%	57,469,000
Western	1,781,000 69%	800,000 31%	2,581,000
South West	6,630,000 47%	7,573,500 53%	14,203,500
National	$51,881,926 52%	$46,687,500 48%	$99,037,426

TABLE 2

CATV Loans Approved Fiscal 1980

Co-Op Loans

Oldtown Community Systems, Inc. Oldtown, Maryland	$ 1,095,000
Canby Telephone Association Canby, Oregon	3,100,000
Rural Missouri Cable TV, Inc. Branson, Missouri	1,667,000
Western Wisconsin Communications Cooperative Independence, Wisconsin	4,138,000
Total	$10,000,000

Table 2 Continued

Commercial Guarantees

Franklin Cablevision, Inc. Louisburg, North Carolina	$ 135,000
Tipton CATV, Inc. Tipton, Indiana	342,000
Omniview, Inc. Blair, Nebraska	2,875,500
Hurst Systems, Inc. Osage City, Kansas	1,267,200
BRY-C.A.T., Inc. Durant, Oklahoma	672,300
Atra Cable Vision, Inc Chouteau, Oklahoma	810,000
Pine Rural Television Cable Co. Broken Bow, Oklahoma	1,425,600
Verona Cable Company, Inc. Madison, Wisconsin	267,300
Concord Cable Communications Company Concord, Tennessee	1,953,720
Millington CATV, Inc. Millington, Tennessee	3,969,000
Franklin Telephone Company, Inc. Meadville, Mississippi	459,000
T.V. Services, Inc. Hindman, Kentucky	2,421,000
Tel-Com, Inc. Harold, Kentucky	3,159,000
Jefferson Cable Television Corporation Wrens, Georgia	226,800
VI-TEL, Inc. Beggs, Oklahoma	810,000
Big Bend Communications, Inc. Alpine, Texas	675,000
Atlas Cable Television, Inc. Big Cabin, Oklahoma	1,836,000
Magic Window Cable Television, Inc. McLoud, Oklahoma	664,200
Total	$23,968,620

The present backlog of loan applications on hand has reached approximately $200 million despite the fact that REA has made loans with a cumulative total of over $50 million. Because the loan applications were growing faster than available funds and now with the proposed cutoff of budgetary funding, REA is recommending no new loan applications be submitted at this time.

MODELING RURAL CATV

The REA technical approach to rural CATV systems has been similar to our approach to rural telephone systems. Our goal was to provide good quality CATV service to as wide a rural area as economically feasible at the lowest possible cost. The REA staff has produced technical standards for transmission and construction for rural telephone systems for the past 30 years. Our approach was to determine what a typical rural CATV model would look like in the market that REA might be called upon to finance. Once a model was established, engineering design goals could be set and different design approaches tested until the lowest cost design is determined.

System Model

In creating a system model, use was made of available REA statistics on current rural telephone borrowers adjusted for the estimated effect of cable operators. The first question to be answered was how big is the potential market to be financed and constructed. If all 919 rural telephone related entities decided to ultimately construct a CATV system to serve their present subscribers, over 3/4 of a million route miles of plant would be required. If the percentage of new applicants remained at approximately 50 percent as noted in Table 1 then a potential rural CATV model with a total of 1.5 million route miles of plant is possible.

Next of interest in the modeling process is how big would each individual system be and what subscriber densities could be expected. We had no way to estimate what the answers to these questions would be for cable operators except to assume they would be similar to what could be determined for the present telephone borrowers. Figures 1 and 2 were determined from our published telephone statistical data. Figure 1 shows that a large amount of cable would be required per company to provide total area coverage. The average company would use 839 route miles of coaxial cable. This gives us a rough perspective on the size of an individual construction project. Figure 2 presents the distribution of subscribers per route mile currently served by REA Telco borrowers. As can be noted almost all borrowers have system densities considerably lower than 30 subscribers per route mile. The average density per company is 5.1 subscribers per route mile. With the FCC standard of normal commercial feasibility being 30 homes per route mile or greater and the average REA telephone borrower density of 5.1 subscribers per route mile, the analysis of Figure 2 showed that REA technical standards were going to have to emphasize lower cost consturction to serve the rural areas.

Route Model

Finally, a model of a typical route was needed on which to base technical standards and compare alternate designs. REA has in the past made sampling surveys of its plant facilities to determine what is out there and where the subscribers are. For CATV modeling purposes we are not interested in the makeup of the existing voice facilities, but we do care where the subscribers are located as they would be the same subscribers in the rural CATV system model. Our statistical data determined that an average system would have 740 subscribers and that 98 percent of them are within 100,000 feet of the central hub distribution point. This established one of our technical goals that any CATV design concept must be capable of being implemented on a route as long as 20 miles. Our experience in system layout gave us the knowledge that the total number of subscribers are usually distributed over either two main routes if the system is a linear model or over four main routes if the system is an area model. We now have a general model of how many subscribers would be expected on a rural route and how long that route could be. The last item in the modeling picture is a concept of how these subscribers are distributed along the route. Our sampling data indicates the subscribers are distributed as noted in Table 3.

FIGURE 1

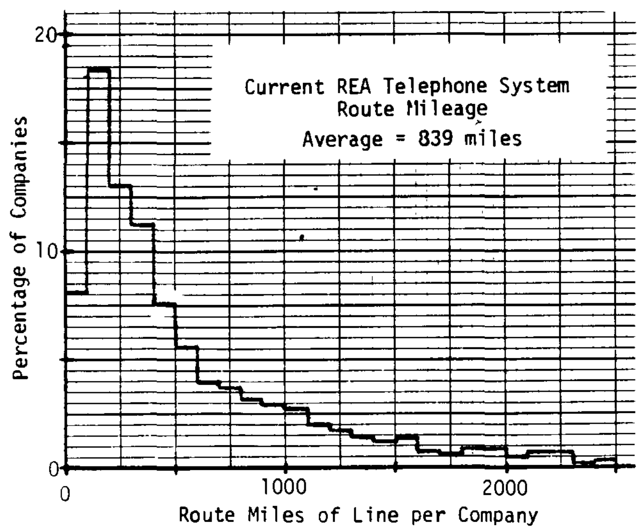

FIGURE 2

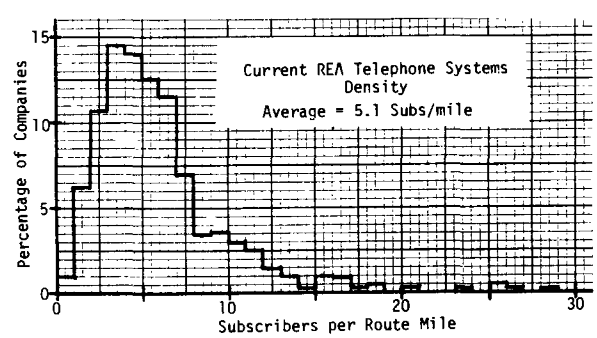

TABLE 3

Rural Subscriber Route Distribution

Distance from Hub (Kf)	Percent Subscribers Remaining
0	100.0
10	54.5
20	37.5
30	27.2
40	18.8
50	12.2
60	7.6
70	4.8
80	2.9
90	2.2
100	1.4

Design Objectives

After determining a rural CATV model, REA was able to create reasonable Engieering Design Objectives for all potential system designs. These objectives are as follows.

A. Twenty mile route capability.
B. Achieve minimum REA transmission standards.
C. Low cost construction.
D. Low cost maintenance.
E. Environmentally compatible plant.
F. Full VHF channel capability.
G. Two-way transmission capability.
H. Widest economical area coverage.

These objectives are listed in descending order of importance in our opinion with our goal to meet all of them in time. Our view is that at least the first three goals are necessary in today's designs so that future design developments can be incorporated to upgrade, expand, or extend the systems.

DESIGNING RURAL CATV

At the time that REA began researching the system design fundamentals for CATV and looking for ways to utilize, modify or adapt current urban design techniques for rural areas, we were fortunate to have Bill Grant join REA as a member of our Telecommunications Engineering and Standards Division. Bill has over 20 years experience in CATV design and operation with Jerrold Electronics and as Chief Engineer for several large CATV operators. With his experience and our engineering objectives he was able to quickly outline a low cost practical design concept for rural areas using directly tapped single coaxial cable outside plant. This concept has been refined and polished over the past 2 years and no basic discrepancy has been found in it. REA recognized that the major cost of a CATV system is the coaxial cable itself and that cost needed to be minimized in rural designs. An urban design with a grid type street layout could afford to pay more for a trunk so that the feeder cable can be less expensive. When trunk to feeder ratios were four to one or better, this created an economical design. However, in rural areas we have a large amount of linear routes with little opportunity for short side feeder legs. In these cases the trunk to feeder ratio could be close to one to one which raised the construction costs considerably. Because of the economic pressures the single coaxial cable design developed. This design, like all other potential designs, must meet our transmission and construction standards. Some of the problems and questions that were raised are answered in a companion paper Bill is presenting at this convention. All of the problems have been resolved in a series of papers Bill has written since being with REA. Copies of these papers are available upon request to REA.

Fundamental Design Techniques

It was found that in order to meet the Engineering Design Objectives the proper choice of alternative design techniques could result in a more acceptable proposed design. Some of the alternatives chosen are as follows.

1. No excess C/N, X-Mod or CTB at end of route. With our goal of a 20 mile capability, it is important that no excess dB margin be allowed at the end of the route so as to keep construction costs as low as possible.

2. Maximum economical use of AGC. In long route systems there is more exposure to temperature created variations and we see the need for an AGC to manual amplifier ratio of no more than 1 to 2 and if economical, we prefer to have AGC capability in as many amplifiers as possible.

3. Minimum use of line extenders. These amplifiers have higher X-Mod than trunk type amplifiers and in a single cable design a lower X-Mod value is required so that C/N and X-Mod both meet transmission specifications at approximately the 20 mile design point.

4. Maximum use of mini-trunk amplifiers. The C/N and X-Mod values for these types of amplifiers are balanced such that, at the operating levels and channel loading we are designing for, the transmission specifications on both factors are met at the approximate 20 mile design point.

5. C/N ratio of 40dB and X-Mod ratio of 50dB are the REA minimum transmission standards. These standards were chosen by REA to give acceptable picture quality to the worst case rural subscriber at the lowest cost.

6. Maximize 1/2" and minimize 3/4" coaxial cable. Our economic studies show this results in the lowest cost system.

7. High gain amplifier output. This minimizes the number of amplifiers required and maximizes the subscriber tapping reach.

8. Preferred top design frequency of 220MHz. This maximizes channel carrying capability at the lowest possible cost. Higher top design frequencies are allowed only if the increased revenues would offset the increased costs.

9. Minimize use of set top convertors. This reduces capitalization and maintenance costs.

10. Maximum use of buried plant. This type of construction in rural areas results in much lower maintenance costs.

11. Minimize amplifier type, quantity, and operating levels. This reduces system maintenance costs.

12. Armored cable for buried cable in gopher areas. This prevents gopher damage and reduces system maintenance.

13. Pay TV capability. The increased investment results in a considerable increase in system revenues.

14. Phased construction. The design is capable of eventually serving the entire area, but system economics require that selected portions of the total area be constructed in a phased sequence.

Engineering and Construction Practices

Historically, REA has provided total engineering support to the rural telephone borrowers through its series of Engineering and Construction Practices, Equipment and Material Specifications, and List of Acceptable Materials. We intend to provide the same support for rural CATV borrowers. Many practices and specifications have been written in draft form and are available from REA for your guidance. At this time only one item is on the list of acceptable materials and that is Generation I coaxial cable. Two suppliers, Comm-Scope and Times Wire, have qualified to supply Generation I cable to REA borrowers. Generation III cable will probably be the next item to be on the list of materials. We are just beginning to work with the active equipment suppliers.

The practices and specifications when in draft form are subject to revision, but are expected to be used by rural CATV borrowers as guidelines in preparing their system designs for a loan application. Specifications when officially published are mandatory and practices when published in final form become the recommended standard design. Some of the more important CATV publications are as follows.

TE&CM 2205 - Final. This practice outlines the technical information required to be submitted to REA in a CATV loan application. Examples are given on how to present the information so as to ease the loan processing.

TE&CM 2206 - Draft. This practice presents guidelines for estimating the size of the potential CATV market.

TE&CM 2207 - Draft. This practice provides forms for the loan fund analysis.

TE&CM 2208 - Draft. This practice is a how-to-do-it tool to create a single cable rural CATV design.

TE&CM 2209 - Draft. This practice shows a method and examples of how to estimate standard unit costs for rural CATV construction. These unit costs can then be used to estimate the total project costs.

TE&CM 2210 - Draft. This practice provides a detailed design lay out process for a rural single cable design. The practice is written for a small operator who may want to manually lay out and design his own system. The process could easily be adapted to computerized techniques.

TE&CM 2211 - Draft. This practice details a method of providing ac power to the field located amplifiers.

Outside Plant Construction Packet #1 - Draft. This packet provides specifications for trunk and drop coaxial cables, construction and installation techniques, electrical protection, and unitized construction bidding.

Any or all of these publications are available upon request to the following address.

Director, TESD
Rural Electrification Administration
Washington, D. C. 20250

SUMMARY

Rural CATV is a service that is unfulfilled as demonstrated by the backlog of demand that quickly built up when the availability of financing to be administered through REA was announced. The fact that REA may not be furnishing future rural CATV financing does not mean that the demand will go away or be unserved. The effect will be a slowdown and an increase in cost to provide this service.

REA in a very short time has provided valuable technical support to the rural CATV industry with its identification and modeling of the market and its series of draft practices and specifications. We have pioneered and promoted updated lower cost design techniques for rural areas. These techniques are being used in systems in construction and we are confident the experience gained from operation of these systems will provide knowledge and economic benefits to the entire CATV industry in the years to come.

HIGH SPEED PCM DATA TRANSMISSION ON CATV SYSTEMS

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CATEL-Division of United Scientific Corporation

ABSTRACT:

An opportunity for the CATV industry to participate in the fast growing data transmission area is examined. The established multiplexing hierarchy for high speed PCM data is reviewed, and practical applications on CATV systems are illustrated. Performance results for PCM data streams on coax links are given.

BACKGROUND

a) The Opportunity

The rapid proliferation of data transmission, world-wide, has created two major types of data networks:

- The satellite high speed data networks (e.g. SBS). These networks have ultra high speed transmission capabilities and can span literally thousands of miles.

- The local high speed data networks (e.g. Hyperbus, Ethernet, etc.), confined within a plant or building. These networks are typically baseband time division multiplex systems, using highly sophisticated software to control protocol.

These two types of networks have comparable transmission speeds, and often need to be linked together. In many cases, they may be linked by telephone lines with limited capacities, a costly process which reduces the overall transmission efficiency.

Microwave transmission can be an alternative where channels and paths are available, but in most cases, an existing CATV plant provides a unique opportunity for the transmission of high speed data between the satellite entry point, and the end user.

b) The PCM Transmission Standards:

In the telecommunications industry, PCM coding is commonly used as a method of handling audio and data signals. The most commonly used format is known as a T1 Carrier, created when 300 to 3400Hz bandwidth voice channels are digitized with an 8 bit code at an 8 kHz sampling rate, and 24 such channels are time division multiplexed into a single serial bit stream. This data stream is known as a T1 Carrier, and represents a data rate of 1.544 MB/s.

When defined in terms of interface characteristics the T1 Carrier becomes known as a DS-1 signal.

Further multiplexing produces the following hierarchy.

24 voice channels = one DS-1 channel (1.544 MB/s, T1 rate)

96 voice channels, or 4 DS-1 signals = one DS-2 signal (6.3 MB/s, T2 rate)

672 voice channels, or 7 DS-2 signals = one DS-3 signal (44.736 MB/s, T3 rate)

c) Actual Uses of PCM Coding:

PCM coding is not limited to voice channels. The most obvious spinoff from voice channel coding is the inclusion of serial data streams. In the basic T1 carrier format, any one voice channel represents a 64 kB/s data stream, and can therefore be replaced by pure data at a rate of up to 64 kB/s. In practical applications, rates up to 56 kB/s are used in place of one voice channel.

Several manufacturers offer multiplex equipmer to condense data signals, or mixed data and voice into the T1 format. (Figure 1.)

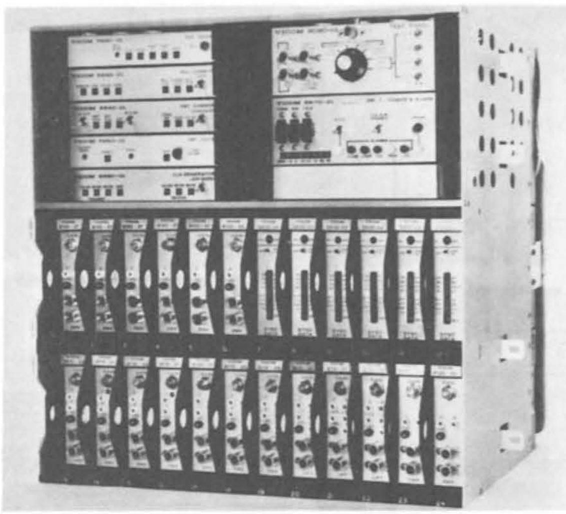

Figure 1. Typical data/voice to T1 rate Multiplexer.

(Photo Courtesy of TRW-Vidar)

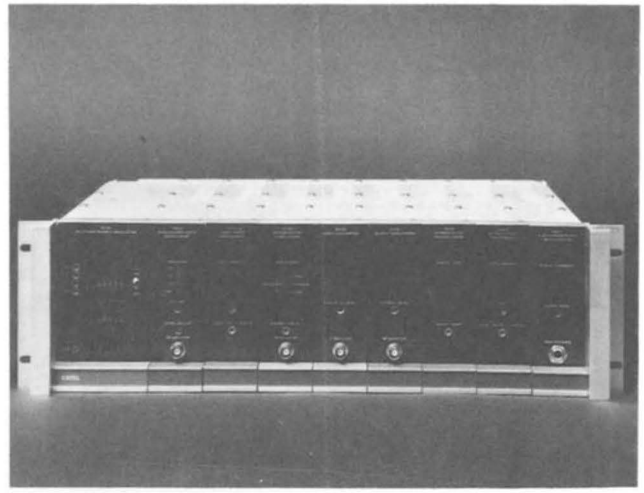

Figure 2. Typical Broadband FM Modem

Digital coding of video signals has created considerable interest, and current efforts are focusing on bandwidth compression techniques to carry broadcast quality video at T3 rate (44.7 MB/s). One manufacturer is currently offering teleconferencing quality (real time) video transmission at T2 rate (6.3 MB/s) and work is even being done on teleconferencing video at T1 rate.

Digital audio has become the choice format for master recordings, and is currently used on the PBS network as one method of very high quality transmission.

Although there is no industry standard for stereo transmission on PCM data streams, a quick calculation will show that two premium quality audio channels could easily be multiplexed into a T1 carrier.

IMPLEMENTING PCM DATA TRANSMISSION ON CATV SYSTEMS

a) Data Stream Density and Bandwidth Requirements:

Manufacturers of PCM multiplexers offer various configurations, such as 2 port, 4 port, 8 port, and 12 port multiplexers where each port handles one T1 line. All use multiple level (and/or phase) coding methods to reduce the occupied bandwidth of the PCM baseband signal.

Our work at Catel has focused on the use of 4, 8, and 12 port multiplexers in conjunction with broadband FM modems. (Figure 2)

The coding efficiencies of the multiplexers are offset by the relative inefficiency of FM transmission. Past attempts at the use of VSB-AM transmission to reduce bandwidth have given disappointing results. The FM/PCM combination is a good compromise which allows highly reliable transmission with "off-the-shelf" components, while retaining an overall transmission efficiency which ranges from 0.5 to 1.2 bit/hertz. Figures 3, 4, and 5.)

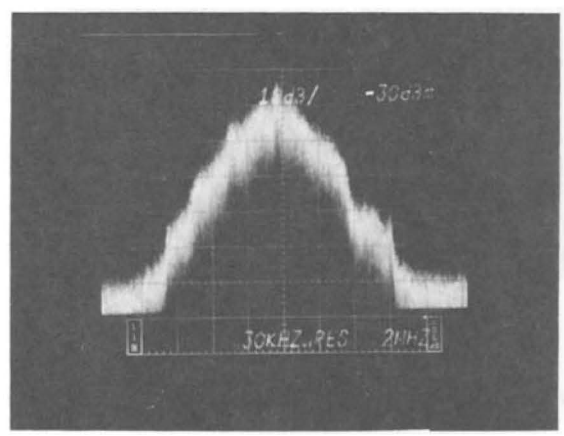

Figure 3. 4 Port Multiplexer, FM Modulated Spectrum.

(96 Voice/Data Channels, 6.3 MB/s)

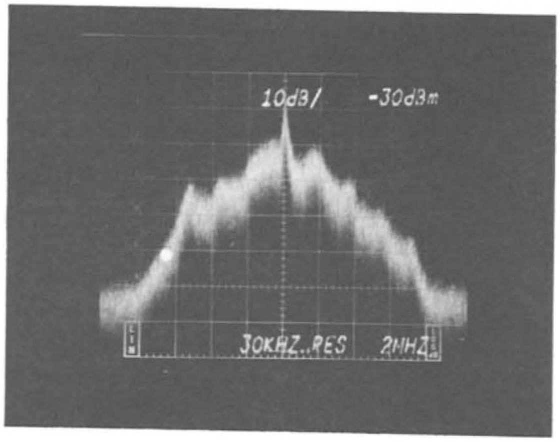

Figure 4.

8 Port Multiplexer, FM Modulated Spectrum.

(192 Voice/Data Channels, 12.6 MB/s)

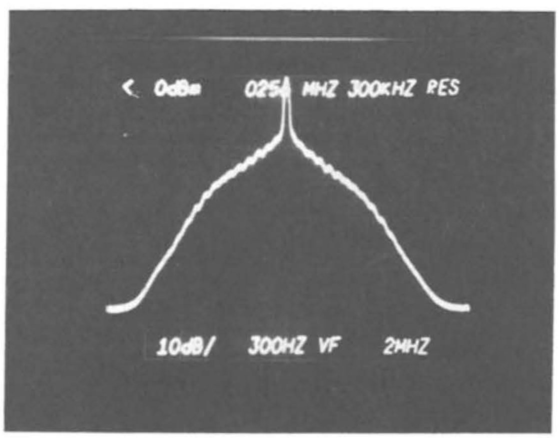

Figure 5.

12 Port Multiplexer, FM Modulated Spectrum.

(288 Voice/Data Channels, 19.2 MB/s)

b) Interfacing PCM and RF Equipment:

PCM multiplexers are available with 75 Ohm BNC Transmit/Receive Ports. The data amplitude at these ports is 1 Volt P.P., which makes interfacing quite straightforward. RF interfacing follows standard CATV procedures, and the complete interconnect is illustrated on Figure 6.

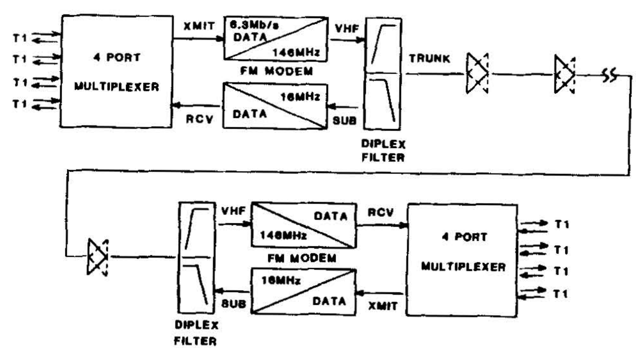

FIG.6 PCM MULTIPLEXER TO CATV SYSTEM INTERFACE

Figure 6. PCM Multiplexer to CATV System Interface.

c) Performance Results:

The performance data presented here was obtained with an amplifier cascade of 8 line extenders, equipped with diplex filters.

Tracking input/output attenuators were used to create a variable carrier to noise ratio in the 25 to 35 dB range, which is considered to be a realistic range of "actual life" performance. Carrier to noise was measured on a Tektronix 7L13 spectrum analyzer following the manufacturer's recommended methods.

A qualitative evaluation of transmission performance was made by observing the eye pattern of data, which is created when all possible combinations of ones and zeros of the data are displayed on an oscilloscope locked to transmit clock. Results for 4, 8, and 12 port data streams are presented in Figures 7, 8, and 9 respectively.

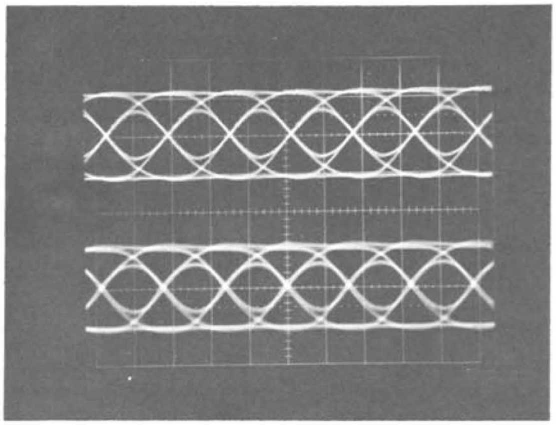

Figure 7. 4 Port Multiplexer Eye Pattern (6.3 MB/s Data)

Upper Trace: Transmitted
Lower Trace: Received

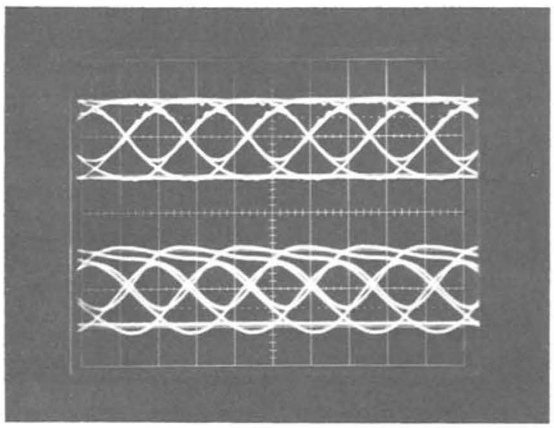

Figure 8. 8 Port Multiplexer Eye Pattern (12.6 MB/s Data)

Upper Trace: Transmitted
Lower Trace: Received

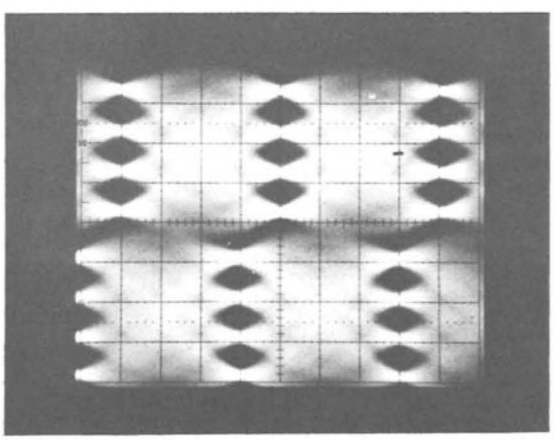

Figure 9. 12 Port Multiplexer Eye Pattern (19.7 MB/s)

Upper Trace: Transmitted
Lower Trace: Received

A quantitative evaluation was made by performing a bit error rate test.

In figure 10, bit error rate was plotted as a function of carrier to noise ratio for a 4 port multiplexer.

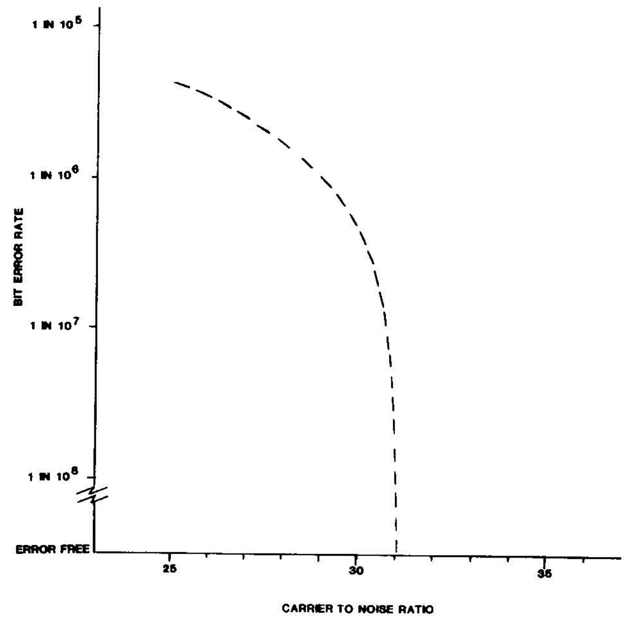

FIG. 10
BIT ERROR RATE VERSUS CARRIER TO NOISE RATIO.

The effect of intermod products was simulated by sweeping an interfering tone through the modulated PCM data spectrum. The level of the interfering carrier was varied to produce a fixed error rate of 1 in 10^6 bits, considered to be the minimum acceptable for quality PCM transmission. Figure 11 illustrates the experimental curve derived, as well as a practical protection curve.

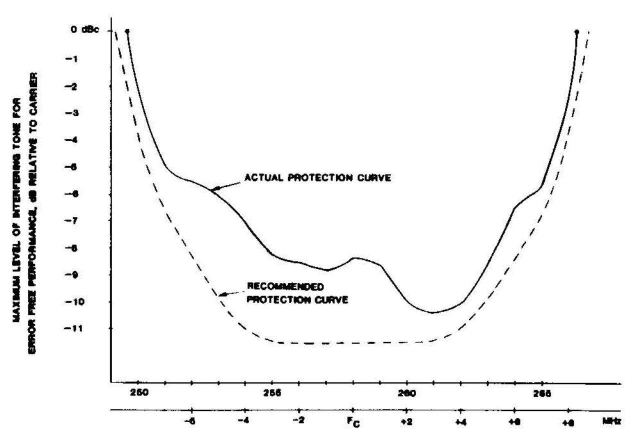

FIG. 11
PROTECTION CURVE FOR ERROR FREE PCM OPERATION
IN THE PRESENCE OF INTERFERING TONES.

CONCLUSION

The T1 PCM carrier and associated multiplexers offer a versatile and accepted format for data, voice, and even video transmission.

Interfacing T carriers to CATV systems is a straightforward procedure, and the performance results are excellent.

The inherent bandwidth capabilities of a coax network give the CATV operator a unique opportunity to transport T carrier signals, and participate in the current communication explosion.

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Installation and Performance of
An 18-Channel Fiber Optics TVRO Link

by
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ABSTRACT

This paper reports on the design, construction and performance of a 32-channel Earth Station downlink installed by Times Fiber Communications and Falcon Cable TV in Monterey Park, California.

INTRODUCTION

Falcon Cable TV has built a master headend with 54-channel capacity at Monterey Park which will interconnect subsystems in Montebello, Temple City, Alhambra, Norwalk, Huntington Park and La Canada, California. The satellite antenna site is approximately 4 km (13.125 ft.) from the headend. A total capacity of 32 channels from the headend to the antenna site was required with a minimum degradation of signal quality so that the largest possible geographic area could be serviced with acceptable quality signals. (Eighteen channels were to be activated during startup with the remainder for future expansion.)

Fiber Link Design

The earth station downlink design used at Falcon has been successful in several other installations. At Falcon, Scientific Atlanta satellite receivers were utilized, while Microdyne receivers have also been used in other installations such as United Cable's installation in Plainville, Connecticut. Any satellite receiver having 70 MHz IF output and input ports can be utilized in this method. The receiver is purchased as a split site type; that is, one complete receiver is divided between two housings. The down-converter and 70 MHz IF circuits are installed at the antenna site and the FM demodulator, video and audio circuits are located at the headend site.

The fiber link "up converters" receive up to four 70 MHz IF receiver outputs. One remains at 70 MHz and the other three are converted to higher frequencies. The four frequencies are then frequency division multiplexed and fed to the laser transmitter. The laser transmitter converts the RF signals by intensity modulation of the laser to light signals and transmits them down the fiber.

At the receiver end of the link, an avalanche photodiode (APD) converts the optical power back to RF signals which is split and down-converted to four 70 MHz IF signals. These are then fed to the split site receiver demodulators which give us baseband video and audio out.

Figure 1. System Block Diagram

In the Falcon system, two (4-fiber) fiber optic cables were lashed to a strand along with coaxial cables from the headend. The fiber used was Times Fiber Communications, Inc. graded index fiber with an average bandwidth of 800 MHz/km and 5.0 dB/km loss at 840 nm. Five fibers are presently activated with four channels on four fibers and two channels on the fifth fiber for a total of 18 channels. The system capacity is four channels on eight fibers or 32 channels. The upconverters convert three of the four 70 MHz IF signals to 110, 160, and 250 MHz. 70, 110, 160, and 250 MHz signals are transported on each fiber.

Design Calculations

SNR

In a four channel earth station downlink of this configuration, the signal-to-noise ratio is dependent upon:

1. CNR of the laser output (typically 45 dB).
2. Noise factor of the APD receiver (NR_X = 9 dB).
3. Cascade factor 10 log N (N = No. of repeaters plus receiver.
4. Receiver input level Vin (typically 5 dBmV).

Since this system does not exceed 4 km in length, optical attenuation and bandwidth are not a problem so a repeater is not required.

System CNR = CNR Laser - NR_X + Vin -10 log N

CNR = 45 - 9 + 5 - 10 log 1

CNR = 41 dB

The FM improvement in signal-to-noise over carrier-to-noise for this wide deviation FM link is 39 dB.

SNR = CNR + improvement

SNR = 41 + 39

SNR = 80 dB

This SNR indicates that the fiber link will be transparent. By transparent we mean that no signal parameter will change within the accuracy of the test equipment utilized. See actual measured performance section.

Link Loss

In selecting the optical fiber loss required for the system, the following have to be considered:

1. Minimum received optical power.
2. Laser transmitter output.
3. Connector losses.
4. Splice losses.
5. Operating margin.

$$\text{Fiber Loss} = \frac{\text{Max link loss + connector loss}}{\text{length}} + \frac{\text{splice loss + margin}}{\text{length}}$$

$$\text{Allowable link loss} = 10 \log \frac{\text{received power}}{\text{transmitter output}}$$

$$= 10 \log \frac{1\ \text{uw}}{1000\ \text{uw}}$$

$$= -30\ \text{dB}$$

Connector loss = 2 x 1.5 dB /connector = 3 dB

Splice loss = 3 x .3 dB /splice = .9 dB

$$\text{Fiber loss} = \frac{30 + 3 + .9 + 6}{4\ \text{km}}$$

$$= \frac{20.1}{4}$$

$$= 5\ \text{dB/km}$$

AM Coaxial Cable

An AM coaxial system would be possible and we could calculate its SNR as follows:

- o Assume 1" coaxial cable with 0.85 dB/100' at 400 MHz
- o Amplifier spacing 20 dB
- o Amplifier noise of 9 dB
- o Assume input level (Vin.) of 10 dBmV

$$\text{No. of Amp} = \frac{\text{Dist.} \div 100 \times \text{Loss (dB/100)}}{\text{Amp Spacing (dB)}}$$

$$= 13{,}120 \div 100 \times 0.85 \div 20$$

$$= 5.58 \text{ or } 6 \text{ amplifiers}$$

$CNR = +59 - N.F. + Vin - 10 \log N$
$CNR = +59 - 9 + 10 - 10 \log 6$
$CNR = 52.2$ dB
$SNR = CNR - 4$dB
$SNR = +48.2$ dB

<u>FM Coaxial Cable</u>

Using conventional FM over coaxial cable would be an alternative method; however, cost of such a system would be greater than a fiber link with considerably more electronics including strand mounted electronics in the system. One could also use the same up/down conversion method used over fiber. This would mean eight times as many outdoor electronics locations since eight coaxial cables would be required. (See cost comparisons.) FM in either configuration would produce a transparent link. The SNR calculations are as follows:

$CNR = +59 - N.F + Vin - 10 \log N$
$CNR = +59 - 9 + 10 - 7.8$
$CNR = +52.2$ dB

The FM improvement for conventional FM links would be 6 to 9 dB or a SNR = 58.2 to 60 dB and the conversion technique gives us a 39 dB improvement which makes both methods transparent.

In summary, we can readily see that if we had a satellite channel at the antenna site of 54 dB weighted SNR, we would obtain, at the headend, in the case of the fiber link or FM link, a SNR of 53.96 dB by combining the two signals on a power basis. In the case of the AM link we would have a 54 dB input signal on a 48.2 dB system with a resultant SNR = 47.19 dB. Transporting the satellite signals at 70 MHz IF and 10.75 MHz deviation gives us an advantage over an AM system of 6.75 dB in SNR. This means that when we use this fiber link, we can extend our system by the number of amplifiers that it replaced, which in this case is six amplifiers.

<u>System Planning</u>

With aerial construction, fiber optic cable splicing must be performed from a bucket truck. Therefore, all splice points must be accessible from a bucket truck. Much of the Falcon installation was along backyard easements which prohibited the use of a bucket truck except at street crossings and short distances along streets as can be seen in the route map below.

Figure 2. Route Map

Because of this, the cable lengths had to be selected carefully so as to have the splice points come out at accessible places with a minimum of excess cable. Once the cables were selected and the splice points located, construction began.

<u>System Installation</u>

The installation of the Falcon cables was accomplished by a contracted cable installation company under the supervision of Times Fiber personnel. Construction was started at the headend working toward the earth station. Because the system was a new installation, coaxial cables were being installed at the same time, all lashed to strand. The first length of cable to be installed was 1.3 km (4200 ft.). This length had seven 90° corners, (three vertical, four horizontal) and three 45° bends. No special equipment or techniques were required beyond good coaxial cable installation practices. Hanging and lashing of the fiber and coaxial cables was accomplished in approximately three weeks without any problems.

Fiber Cable Splicing

After the cable installation was complete, Times' splicing crew proceeded to splice the cables. Fiber splicing is accomplished using a fusion splicer which melts the ends of the glass fiber together. One person makes the actual splices while a second person advises him of the quality of the splice by observing using an optical TDR.

The 24 splices required for this system were completed in three days with an average splice loss of less than 0.3 dB.

System Interconnection

The optical components (transmitters and receivers) are then hooked up and received power measurements made. Actual received power measurements and meas- ured system attenuation was very close to the predicted values. See actual system measurements.

After the optical power measurements are made, the remaining equipment is hooked up and system performance is measured. System performance attests to the fact that this fiber optic satellite downlink is truly a transparent system.

Actual System Measurements

All 18 active channels were measured, and the signal-to-noise figures are given below. The HBO channel was examined in detail as the photos below show. In all cases, the Fig.(n)A is the antenna site and Fig. (n)B is at the headend. HBO transmits, during the vertical interval, a composite combination test signal, modulated stairstep, and a field square wave which were utilized.

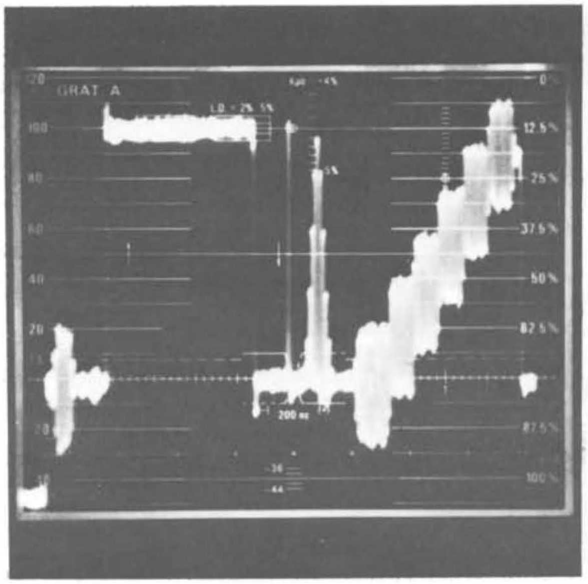
The following table is a comparison of the predicted system loss to the measured loss. For the five lines in use:

Predicted loss = Cable loss + Connector loss + Splice loss:

	I	II	III	IV	V
Cable loss-dB	20.3	19.2	20.2	19.7	19.6
Connector loss-dB	3.0	3.0	3.0	3.0	3.0
Splice loss-dB	0.9	0.9	0.9	0.9	0.9
Total - dB	24.2	23.1	24.1	23.6	23.5

$$\text{Actual Loss} - 10 \log \frac{\text{Transmitter output}}{\text{Receiver input}}$$

	I	II	III	IV	V
Transmitter Output-μW	1000	1000	1050	995	1075
Receiver Input-μW	6.1	4.7	5.5	4.65	4.2
Actual Loss-dB	22.1	23.5	22.8	23.3	24.1



Earth Station
Fig. 3A

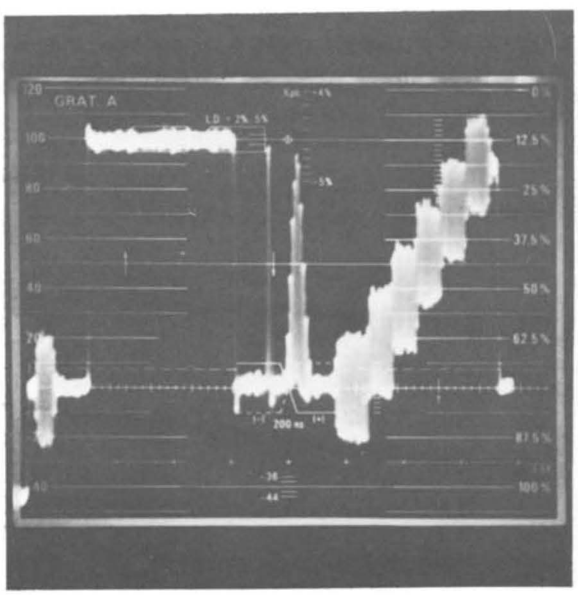


Fig. 3B
Headend

The above composite signal shows insertion gain is zero, and line time distortion is zero.

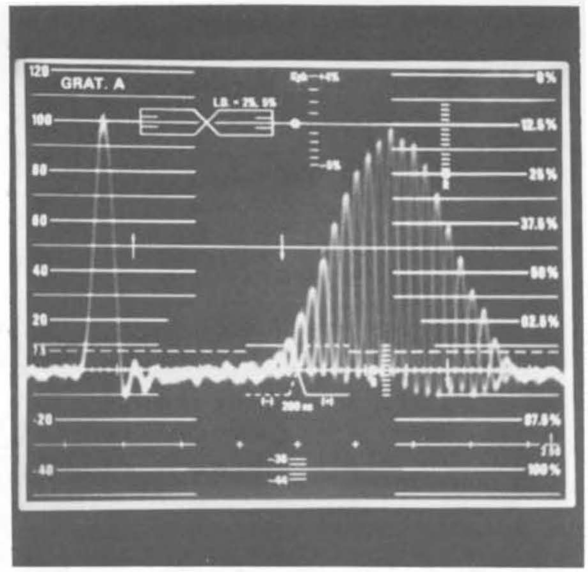


Fig. 4A
Earth Station

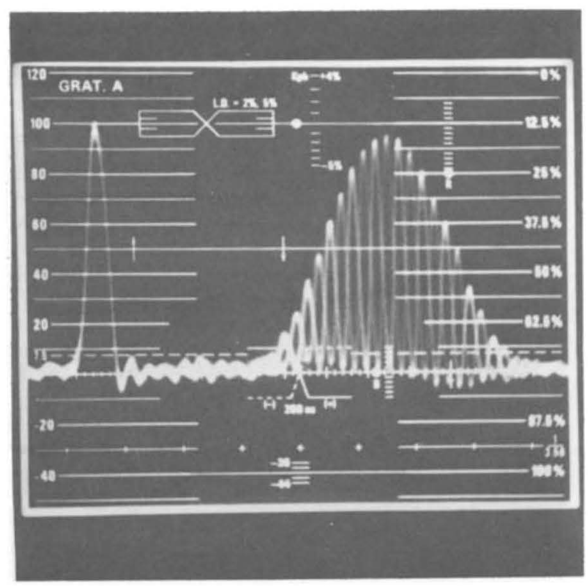


Fig. 4B
Headend

The above expanded view of the 2T and 12.5T pulses show some short time distortion and chrominance-luminance given inequality and some chrominance-luminance delay inequality, however, they are virtually the same at the earth station and the headend.

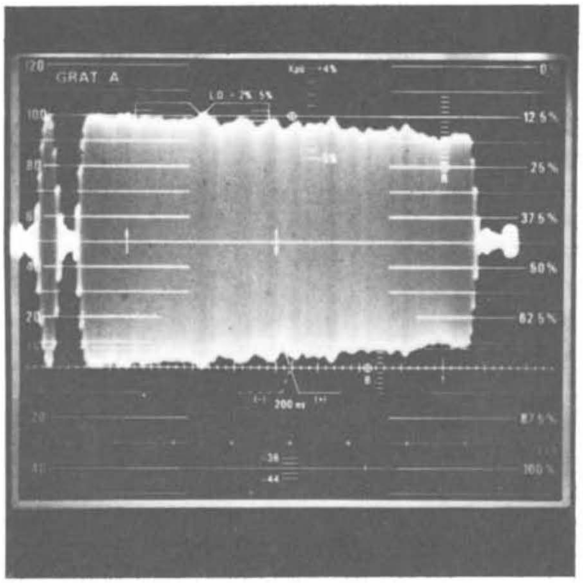


Fig. 5A
Earth Station

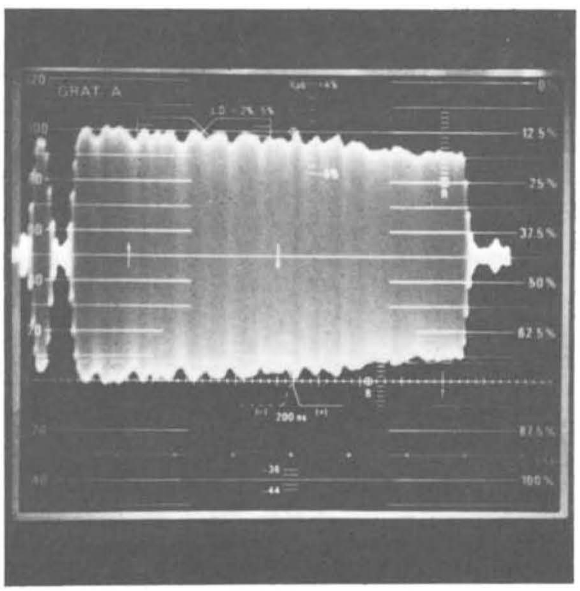


Fig. 5B
Headend

The above pictures of the 5 step staircase passed through a high pass filter show some differential gain, however, it is the same from Earth Station to Headend.

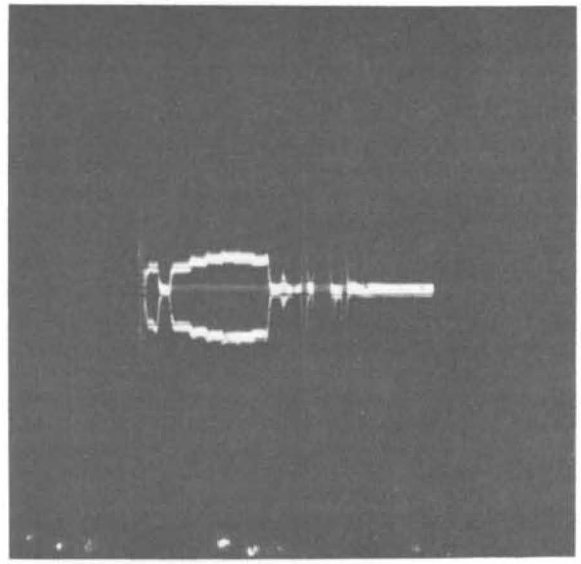


Fig. 6A
Earth Station

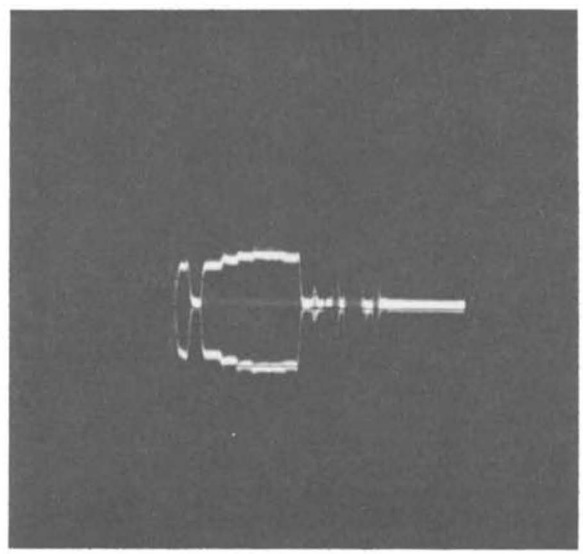


Fig. 6B
Headend

The above pictures show some differential phase distortion, however, it is the same at both ends of the fiber link.

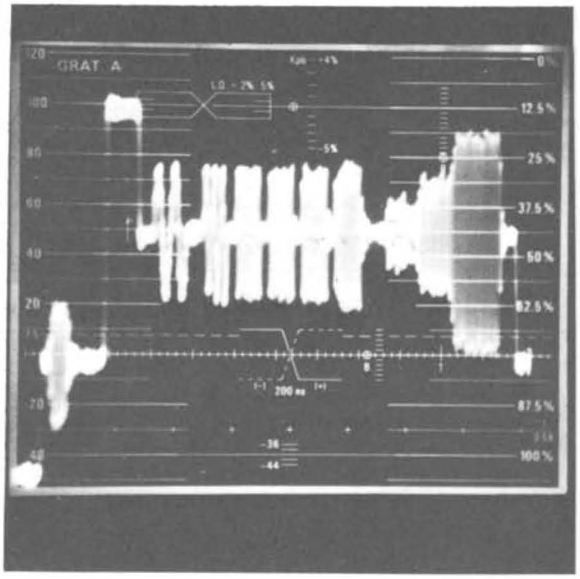


Fig. 7A
Earth Station

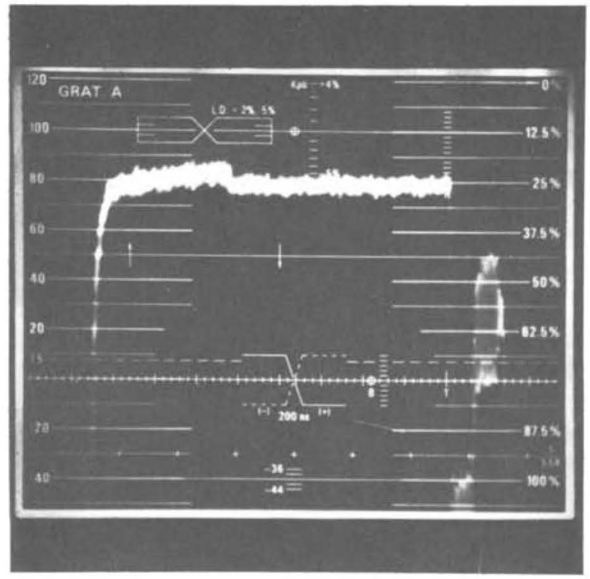


Fig. 8A
Earth Station

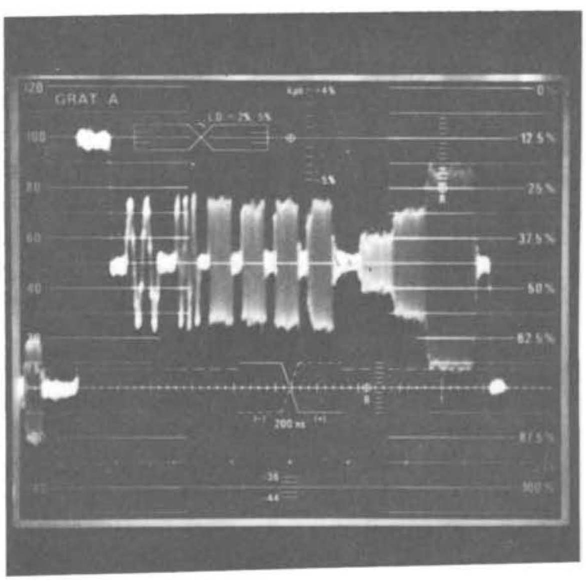


Fig. 7B
Headend

The above pictures show that gain/frequency distortion is zero at both ends of the link.

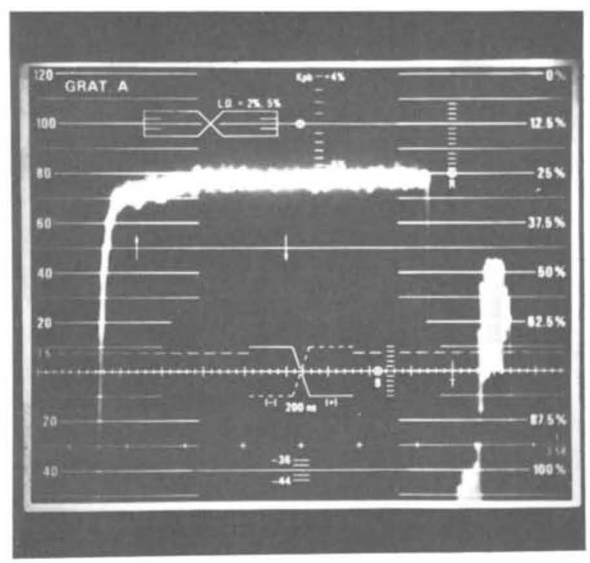


Fig. 8B
Headend

The above pictures are of the line bar of the composite waveform with noise inserted. The weighted signal-to-noise measurement of both ends of the system indicate 52 dB signal-to-noise.

The actual EIA weighted SNR measurements at the Earth station site and after the fiber link at the headend were measured. It should be noted that a time interval of several hours elapsed between the measurements at either end and some change in transmission or reception quality can enter into the measurements, consequently one should not consider a difference of 1 dB significant. In the following table under station, a statement such as ------blank (HBO) means there was no signal on the assigned frequency so an agile receiver was used to put up another signal (in this case, HBO) to make the fiber system measurements.

Fbr. #	Rx #	Station	S/N Anten.	S/N Hdend
1	1	WGN	53 dB	52 dB
	2	ESPN	52 dB	52 dB
	3	USA	52 dB	51 dB
	4	Ncklodeon	52 dB	52 dB
2	5	WOR	51 dB	50 dB
	6	Blnk (ESPN)	52 dB	52 dB
	7	Cinemax	52 dB	52 dB
	8	Movie Chan	52 dB	51 dB
3	9	CBN	52 dB	52 dB
	10	CNN	51 dB	51 dB
	11	ACSN	50 dB	51 dB
	12	Gala-vision	51 dB	50 dB
4	13	HBO	52 dB	51 dB
	14	WTBS	51 dB	50 dB
	15	BRAVO	49 dB	48 dB
	16	Blnk (Gala)	51 dB	50 dB
5	17	Blank (HBO)	52 dB	51 dB
	18	Blnk (WTBS)	51 dB	50 dB

Cost Comparison

32-Channel-8-fiber Earth Station Link

8 ea. Transmitters and Receivers (Optical)	$ 31,500
8 ea. Up/down Converter Sets	38,224
8 fiber optic cable 13,125'	31,500
Total System Price	$101,224

Note: This price includes all connectors, hardware, etc., except racks for the electronics.

32-Channel FM Coaxial Link

For cost effectiveness 1/2" coaxial cable was used with 9 amplifiers in this calculation. Two cables required with 16 channels/cable.

32 ea. FM Modems @ 3,000/modem	$ 96,000
18 ea. Trunk Amp. @ 900/amp	16,200
26,250' 1/2" cable @ 210/1000'	5,538
Total Cost	$117,738

Note: This price is for the electronics and cable only. No interconnections, connectors for the coaxial cable or rack mounts for electronics are included.

SUMMARY

The fiber optic system installed by Falcon and Times at the Monterey Park facility is transparent, has no electronics on the strand outdoors, and is the least costly method of transporting quality signals to the headend. There is no question but that they can now extend their trunk lines by at least the number of amplifiers saved over the AM method with the same SNR that would have provided. This ability to extend their trunks another 6 amplifiers deep means a great increase in geographic area covered.

LOW COST RURAL CATV SYSTEMS

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ABSTRACT

Substantial economies may be achieved in the electronics of trunk and distribution systems by the use of high gain line extender amplifiers. Additional savings may be found in the head end design, reduction of dual trunk/distribution cabling, and labor saving construction.

INTRODUCTION

Many system operators have towns within 20 miles or so of their system, and/or small communities or groups of homes within a few miles of their cable. However, when the system designer has made an estimate of the cost of cabling these areas, it is just not economically possible using conventional construction techniques. What alternatives do we have that will allow us to profitably cable these outlying areas?

ELECTRONICS

First, the high cost of trunk amplifiers can be substantially reduced by utilizing line extender amplifiers as trunk amplifiers. This "mini trunk" approach may bring to mind cheap and inferior construction to some operators. This is just not so. There is a wide selection of high quality line extender amplifiers, using the same quality components found in the best trunk amplifiers. Table I provides price comparison for the twelve amplifier cascade illustrated in Figure I.

	UNIT COST	NO. IN CASCADE	COST	COST OF 12 AMP CASCADE
Trunk Station (Manual) 2000/152	$1000	9	$9000	
Trunk Station (Automatic) 2000/152	$1150	3	$3450	$12,450
Mini Trunk (Manual) 3000/152	$ 482	9	$4338	
Mini-Trunk (Automatic) 1000/152	$ 766	3	$2298	$ 6,636

TABLE I

Using list pricing for the amplifier cascade, the "mini-trunk" approach results in amplifier costs approximately one-half the cost of full sized trunk stations with no degradation in capability.

Now, remember that we are dealing with small communities which translates to short amplifier chains. Conventional trunk amplifiers have gains around 25 dB and are designed for maximum cascadability. Modern high quality line extender amplifiers are available with performance characteristics as shown in Table II.

With short cascades we can operate the amplifiers with 0 to + 3dBmV input, which corresponds to about a + 40dBmV output. In a well-behaved amplifier, the cross modulation/composite triple beat expressed in dB will increase 2 dB for each dB increase in the output level. Applying this principle to the data in Table II, results in the data in Table III.

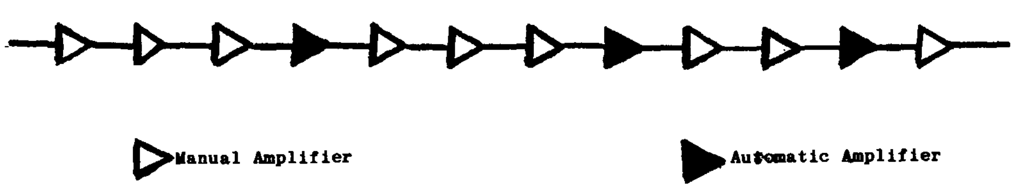

FIGURE I

MODEL	NOISE FIGURE	GAIN	OUTPUT LEVEL	CROSS MOD TRIPLE BEAT	CHANNEL CAPACITY
231	8 dB	31-38 dB	33 dBmV	-89 dB	30 (270 MHZ)
	7.5 dB	31-38 dB	34 dBmV	-91 dB	21 (220 MHZ)
	8 dB	38-43 dB	33 dBmV	-89 dB	30 (220 MHZ)
241	7.5 dB	38-43 dB	34 dBmV	-91 dB	21 (220 MHZ)

TABLE II

MODEL	NOISE FIGURE	GAIN	OUTPUT LEVEL	CROSS MOD TRIPLE BEAT	CHANNEL CAPACITY
	8 dB	31-38 dB	40 dBmV	-75 dB	30 (220 MHZ)
231	7.5 dB	31-38 dB	40 dBmV	-77 dB	21 (220 MHZ)
	8 db	38-43 dB	40 dBmV	-75 dB	30 (270 MHZ)
241	7.5 dB	38-43 dB	40 dBmV	-77 dB	21 (220 MHZ)

TABLE III

Again, keep in mind that we are dealing with small rural communities and super channel capacity is not required, and is probably cost prohibitive. Typically, we are dealing with 21 channel 220 MHZ or 30 channel 270 MHZ systems. Now, where does all this lead us? Table IV shows that with 40dB spacing and limiting our system to 21 channels, amplifier spacings a mile apart are possible. This reduces the number of amplifiers by one-half.

TRUNK CABLE AMPLIFIER SPACING (.750 CABLE)

	22 dB	40 dB
21 ch (220 MHZ)	1900 ft.	5300 ft.
30 ch (270 MHZ)	2500 ft.	4700 ft.
36 ch (300 MHZ)	2400 ft.	4500 ft.

TABLE IV

Now our electronic's cost has been reduced to one-quarter of a conventional system. But what about performance? The cross modulation at the output of a cascade of identical amplifiers increases 6 dB each time the number of amplifiers is doubled. This rule can be applied to a cascade of any number of amplifiers by using Table V as follows:

> To find system cross-mod, add the value from the column (20LOGm) opposite the number of amplifiers in the cascade to the cross-mod for one amplifier.

Using the data in Tables III and V, we can calculate the cross-modulation at the end of our 12 amplifier cascade and find it to be -56 dB. This is approximately the industry system design standard of -57 dB and well below the -46 dB for perceptible interference.

It should be noted that good thermal equalization is essential for proper operation. The use of thermal equalization will compensate for the variable cable loss between two amplifiers over the temperature range from -20^{o} to 120^{o} F with approximately $\pm$ 1dB flatness from 50 MHZ to the highest frequency used in the sys-

10 LOGm NOISE	NO. OF AMPS IN CASCADE	20 LOGm CROSS MOD	10	NO. OF AMPS IN CASCADE	20	10	NO. OF AMPS IN CASCADE	20	10	NO. OF AMPS IN CASCADE	20	10	NO. OF AMPS IN CASCADE	20
0	1	0	10.41	11	20.82	13.22	21	26.44	14.91	31	29.82	16.13	41	32.26
3.01	2	6.02	10.79	12	21.58	13.42	22	26.84	15.05	32	30.10	16.23	42	32.46
4.77	3	9.54	11.14	13	22.28	13.62	23	27.24	15.18	33	30.36	16.33	43	32.66
6.02	4	12.04	11.43	14	22.86	13.80	24	27.60	15.31	34	30.62	16.43	44	32.86
7.00	5	14.00	11.76	15	23.52	13.98	25	27.96	15.44	35	30.88	16.53	45	33.06
7.78	6	15.56	12.04	16	24.08	14.15	26	28.30	15.56	36	31.12	16.63	46	33.26
8.45	7	16.90	12.30	17	24.60	14.31	27	28.62	15.68	37	31.36	16.72	47	33.44
9.03	8	18.06	12.55	18	25.10	14.47	28	28.94	15.80	38	31.60	16.81	48	33.62
9.54	9	19.09	12.79	19	25.58	14.62	29	29.24	15.91	39	31.82	16.90	49	33.80
10.00	10	20.00	13.01	20	26.02	14.77	30	29.54	16.02	40	32.04	17.00	50	34.00

TABLE V

tem. If an automatic gain/slope amplifier is used at every fourth amplifier location, an economical trunk cascade with excellent level control can be achieved.

Another area of savings is the use of long distribution cascades. The tradeoffs of this approach are as follows:

Advantages

1. Elimination of double (trunk/ distribution) cabling.

2. Reduce the number of bridger amplifiers.

3. Allows the extensive use of integrated messenger (figure 8) cable.

Disadvantages

1. Possible disruption of service for a large portion of the system if a tap fails.

2. Degradation due to an unterminated drop or feedback from a TV receiver.

3. Tap discontinuities.

4. Degration from amplifier cascade.

5. Powering problems.

The key to reducing the disadvantages to a level that will result in reliable service, is the modern quality tap. Using today's high quality directional taps, with seized center conductors, provides high reliability and isolation coupled with 5 to 6 amps through current at low hum-modulation levels. Figure II shows a typical directional tap. Note that it has one important distinquishing feature, reverse path isolation.

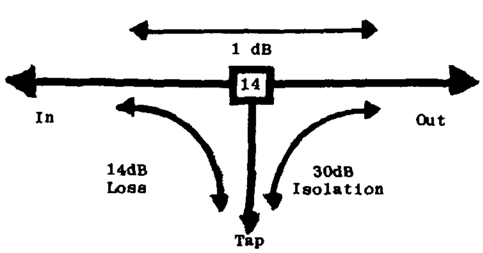

FIGURE II

This isolation helps us in two important ways. First, it reduces signals coming back down the distribution cable (reflected ghost, etc.) from getting into the subscribers drop; and secondly, keeps subscriber generated signals from feeding back into the downstream direction.

A directional tap can cause hum modulation. The power passing AC coil is a very high impedence to RF, the coil may have a ferrite, powdered iron, or air core. At some point, as current is drawn through this coil, the field will collapse. When the field collapses the coil no longer presents a high impedence to the RF. Now the power passing coil field does not just collapse and remain collapsed. As the AC current passes back through the zero point, it re-establishes itself, and then recollapses, as the current increases again. All this at a rate of 60 cycles per second. This 60 cycle rate is, in effect, a form of modulation and will appear in the RF signal. Directional taps are current rated and it is important not to exceed that rating, not because the tap will fail but because of the collapsing field and the resultant hum modulation. Keep in mind, that if a core is defective, hum modulation may begin at very low currents. Hence, there are some advantages to using directional taps with air core coils.

Figure III is a typical rural town distribution line with 150 foot spacing of 4-way taps on .500 inch cable. In the distribution system, the signal level must be maintained high enough to feed the last tap; thus, the block loss will not be as great as in our trunk example, and an amplifier gain of about 35 dB is required. Amplifier spacing of about 2000 feet is practical with these parameters.

How far can we go using this technique? Going back to Table V, we can calculate that at 40 dBmV out, we can go a maximum of 12 amplifier cascades. Remember, that this is the maximum cascade chain. In a real situation, we are not running a single straight line, but more like a grid design or possibly using a hub type distribution. Thus, the total number of amplifiers could be many times the twelve amplifier maximum cascade, and cover substantial areas. Conversely in some small communities, the maximum cascade may be less than twelve and we could operate at even higher output levels.

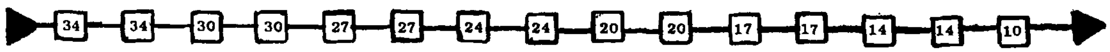

FIGURE III

INTEGRATION

How can we integrate these techniques into an existing or area-wide rural system? First, we may extend a short trunk, to a cluster of homes, or small community, or just distribution from an existing system using low cost techniques to serve an area that would not otherwise be economical.

A rural area is normally made up of a number of small communities, clusters of homes, and scattered individual homes, farms, etc. While it may not be practical to provide service to everyone, it may be feasible to design a system consisting of a large number of small "low cost systems," as we have described, interconnected by a super trunk. The super trunk may be 1.00 inch cable, and, may use a conventional or "mini trunk" technique, depending upon the overall complexity of the system.

The cross modulation of two dissimilar systems may be calculated using Table VI as follows:

1. Determine the cross-mod level for each system.

2. Compare these levels to obtain their difference.

3. Using this difference, find the derate value in the chart.

4. Derate the worst cross-mod level by this factor to obtain the combined cross-mod level.

DIFF. IN dB	CROSS MODULATION COMBINING DERATE: FOR DISSIMILAR AMPLIFIERS						
0.0	6.02	Diff.		Diff.		Diff.	
1.0	5.53	11.0	2.16	21.0	0.74	31.0	0.24
2.0	5.08	12.0	1.95	22.0	0.66	32.0	0.22
3.0	4.65	13.0	1.75	23.0	0.59	33.0	0.19
4.0	4.25	14.0	1.58	24.0	0.53	34.0	0.17
5.0	3.88	15.0	1.42	25.0	0.48	35.0	0.15
6.0	3.53	16.0	1.28	26.0	0.42	36.0	0.14
7.0	3.21	17.0	1.15	27.0	0.38	37.0	0.12
8.0	2.91	18.0	1.03	28.0	0.34	38.0	0.11
9.0	2.64	19.0	0.92	29.0	0.30	39.0	0.10
10.0	2.39	20.0	0.83	30.0	0.27	40.0	0.09

TABLE VI

CONSTRUCTION

Once the decision is made to utilize long distribution cascades (up to 8-10 amplifiers), a sizable portion of our cable plant is now single cable. Integrated messenger (figure 8) cable, with its associated hardware, and, installation labor savings, may be used for a sizable portion of the system. About a 30% reduction in the cost of cable and labor will be achieved by the reduction of dual trunk/feeder, and the use of figure 8 cable.

HEAD END

For the system that must stand alone, the head end represents considerable cost for the system planner. Signal processors for off-air channels, and modulators are available from at least one manufacturer (Triple Crown) in an economy version at one-third the cost of more conventional equipment. While not having all the fancy options, and not quite as good specifications, they will provide satisfactory performance in most cases.

Antenna and pre-amplifier economies may be achieved where several signals are received from the same direction. Heavy duty all-channel antennas (Jerrold J283-X); or hi/lo band logs, combined with a low noise broad band (customed to a specific bandwidth) pre-amplifier (Q-Bit Corp.) may be used to receive a number of channels at the cost of one antenna and one pre-amplifier. Of course, this technique will not work in all cases, depending upon the severity of the reception problems, so a careful analysis should be made for each situation.

CONCLUSION

The classic cable system with which we are all familiar, is designed for maximum cascadeability; which is all right providing we are cabling New York City, but for Centerville USA, do we need that? The techniques presented here to provide service to subscribers in rural areas at a reasonable cost, hopefully will start you thinking about how you can save money without sacrificing service quality. While not everyone will agree with the approach presented, I believe it is worth considering.

MULTICHANNEL VIDEO TRANSMISSION
THROUGH LASER DIODE BASED FIBER OPTIC SYSTEMS

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Valtec

ABSTRACT

This paper details some of the practical design considerations in employing injection laser diodes and avalanch photodiodes in the transmission of video signals through fiber optic cable. Specific attention is given to the noise properties associated with these devices (including laser noise, modal noise and noise due to coupling effects) and how it relates to system performance. The effect of laser diode non-linearities on noise and bandwidth is also discussed.

A three channel FDM-FM prototype system is presented and its measured performance is related to the optical devices employed.

INTRODUCTION

Throughout the summer and fall of last year we explored requirements necessary to implement a wideband analogue transmission link employing laser diodes. The primary emphasis was on a multichannel video system. Of the possible modulation techniques, FM was chosen and developed because of the possible noise bandwidth tradeoff. To this end, a prototype transmitter and receiver were designed and tested together with a Catel VFMS-2000 FM modulation system.

GENERAL CONSIDERATIONS

In the implementation of a wideband (>200 MHz) analogue system, 50μm core graded index fiber was selected as the best choice fiber. Fibers of this type will soon become readily available with bandwidths beyond 500 MHz-Km and attenuations less than 3db/Km and 1db/Km at wavelengths of 850 and 1300nm respectively. In the future even broader bandwidths will become available. Long wavelength sources and detectors presently are not as readily available as short wavelength devices. Furthermore, they do not perform as well. Primarily for this reason, only short wavelength devices are considered in this paper.

Of the three optical elements in the transmission system, the laser and laser fiber interaction present the most difficulty. LED sources are limited by material dispersion; therefore, they cannot be used in this application.

Both singlemode and multimode lasers were investigated. In the singlemode devices, the resultant modal noise caused noise floor variations as great as 15db. We felt this was unacceptable. Microwave modulation was attempted and the noise floor exhibited comparable stability to the multimode devices tested. Under this condition, the minimum noise initially observed was significantly below the level observed with u-wave modulation. Therefore, the program tended toward securing a multimode laser system.

LASER NOISE

It is now necessary to briefly describe the several noise processes.[1] The most fundamental is intensity fluctuations caused by the spontaneous and stimulated emission processes. These fluctuations are increased by reflection back into the laser cavity from the laser-fiber and fiber-fiber interfaces. While it is desirable to achieve tight coupling, this interference may decrease the carrier to noise (C/N) ratio sufficiently to limit the system S/N ratio even at moderate received power levels. Figure 1 shows the signal to noise ratio of our system with two different laser sources. For both lasers employed, the S/N flattens at high power levels. Theoretically, it should increase with the square root of the power (which it does for LED sources).

Figure 1.
System Signal To Noise Ratios

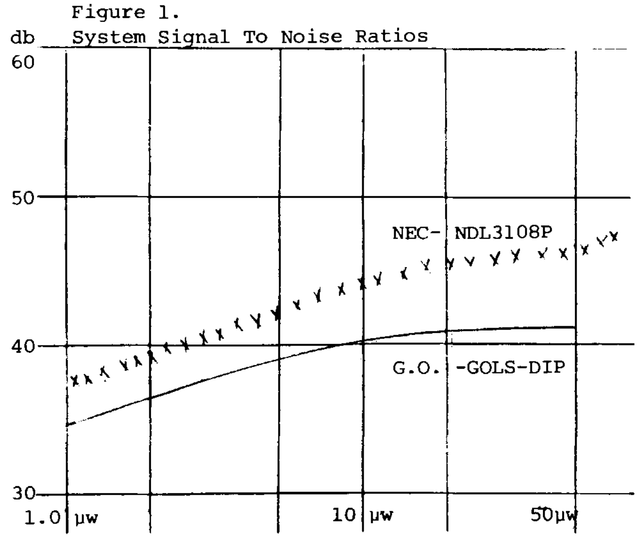
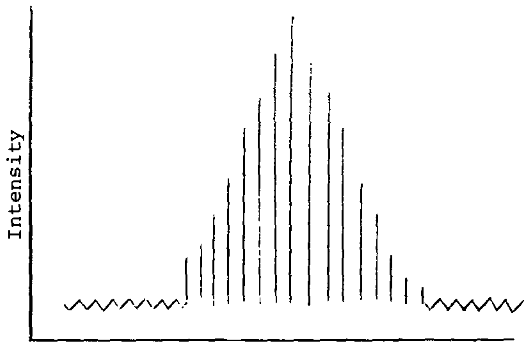


Figure 2 shows the spectral output of a typical multimode laser. It has been found by Ito[1,4] and others that individual modes can vary as much as 50db above the ensemble average. If all modes are passed evenly to the detector, little noise will appear. However, the fiber and connector form a mode selective network. As a consequence, the detected output voice floor will shift because of the uneven delay and attenuation characteristics in the fiber. This noise, therefore, is initiated by either fiber refractive index changes (e.g., an aerially suspended cable in wind) or thermal instabilities in the laser.

Figure 2



In summary every attempt should be made to align all connectors as accurately as possible, to insure good thermal stabilization of the laser, and to minimize reflections back into the laser cavity. This however will not totally eliminate modal noise. The resultant low C/N ratio makes wide deviation FM equipment necessary for multichannel applications.

COUPLING

One of our major objectives was efficient optical coupling. The small emitting area and large beam divergence in the direction perpendicular to the heterojunction produce 8 to 10db coupling loss for a cleaved fiber. The use of tapered fibers with hemispherical lenses formed on the end have been used by us with good results. Employing this technique, we have been able to achieve greater than 1mw output power consistently from a 5 - 8mw laser, coupling efficiencies of >30%.

A second objective was to minimize reflections back into the laser cavity. The smaller curvature of the lens after tapering, and the wider separation from the laser cavity, made possible by this technique, helps meet this objective.

DETECTORS AND SOURCES

Currently two kinds of detectors are employed in fiberoptic receivers. They are PIN diodes and avalanch photodiodes. Even for FM transmission good video will require sufficient received power to make leakage currents insignificant.

Of the two types of detectors, the APD has a significant advantage in wideband systems. The avalanch gain allows the detector shot noise to dominate the receiver noise at most received power levels. Furthermore, the APD can be used as a gain control element. The PIN diode may be employed in shorter distances and reduced channel capacity systems. Generally, they do not require the temperature compensation and large reverse bias supply of an APD.

In our prototype, the APD chosen was the RCA C30908E with integral light pipe. This device was chosen primarily because of its low excess noise.

Multimode lasers from LDL, NEC and G.O. were evaluated with the following results. The G.O. GOLS-DIP laser provided the most linear operation. Furthermore, the noise floor was the most stable, less than 1db. It was felt that this offset the increased average noise. Table 1 shows the measured signal to noise ratios for the NEC 3108P vs the G.O. GOLS/6687-DIP. The LDL SCW 10 produced the same noise characteristics as the NEC device. Linearity of the devices was measured using a two tone test method. The modulation index for the two tones was .3 each at 10 MHz and 17 MHz respectively. The NEC 3108 and LDL SCW-20 lasers measured at -33db 2nd harmonic distortion. General Optronics specifies their device at -40db 2nd and -50db 3rd.

Table 1
Output S/N NEC-3108P, GOLS 1/6687-DIP

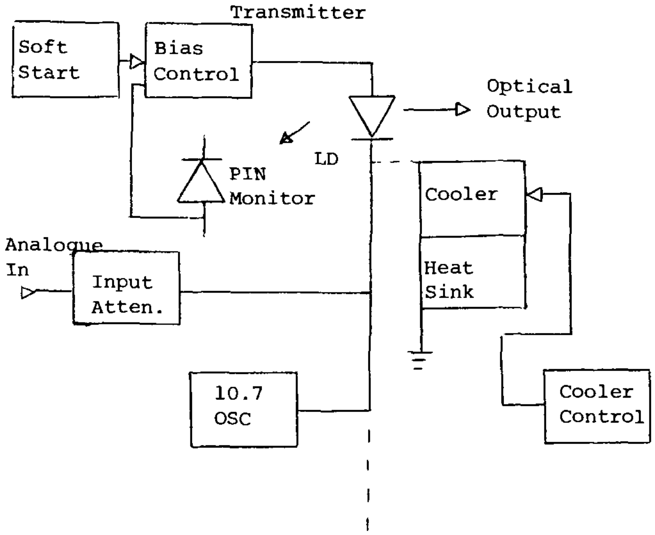
Laser Transmitter

	NEC		GOLS	
PIN	S/N_U	S/N_W	S/N_U	S/N_W
1	37.3	48.4	34.5	44.5
2	41	52.0	36.5	46.5
5	43.7	54.4	40.5	50.5
10	44.1	55.1	41.5	51.5
20	47.5	56.5	42	52.0
35	47.2	58.1	42	52.0
50	46.7	57.1	43	53.0

OPTICAL TRANSMITTER

Figure 3 shows a block diagram of the analogue transmitter. A 10.7 MHz oscillator is provided for AGC purposes. 10.7 MHz was chosen because relatively inexpensive ceramic filters could be purchased at that frequency. A PIN diode monitors the output power at the rear facet. The operating point is controlled within 1db.

Figure 3
Transmitter



THE OPTICAL RECEIVER

Figure 4 shows the preamplifier detector circuits. The APD can be used as a linear gain control element. To this end two separate bias control networks are provided. The first bias control allows the gain to vary from 100 to 20 as power is increased. The second circuit fixes the gain at 20 for all increased power levels. The preamplifier is of the transimpedance type with a transimpedance of about 1K.

Figure 4
Preamplifier

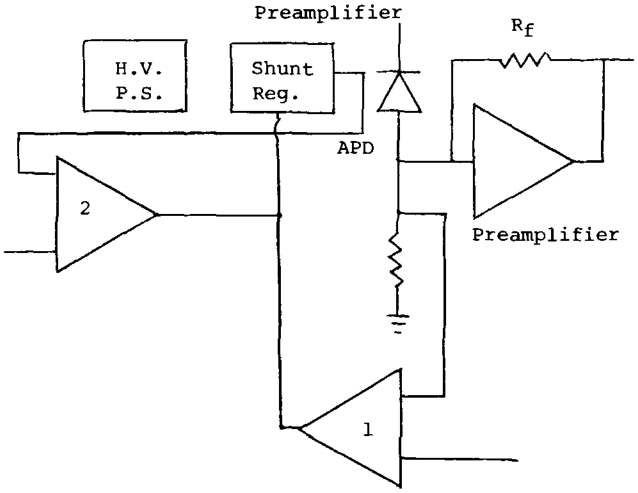
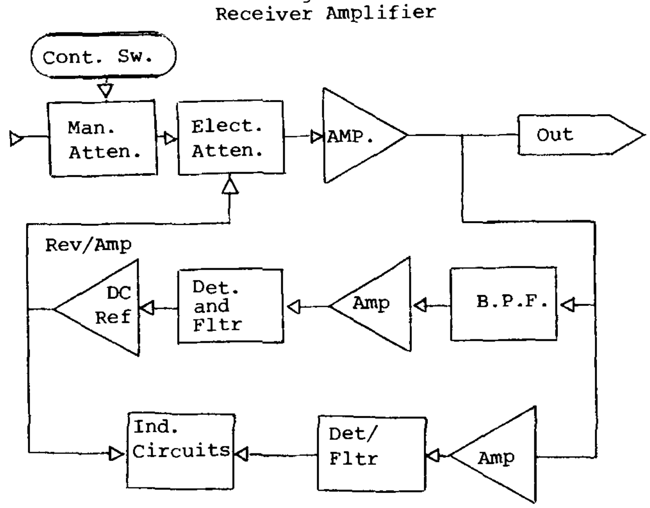


Figure 5 shows the rest of the amplifier. This circuitry employs a FET attenuation network and a manual gain switch. The output is sampled and fed through a 10.7 MHz band pass filter which detects the pilot tone used to control the AGC elements. A high frequency modulation detector is also provided. The receiver bandwidth is about 200 MHz. Harmonic distortion for this receiver is typically at -50db second, and -55db third. The dynamic range of the receiver is about 20db optical.

Figure 5
Receiver Amplifier



SUMMARY OF TEST RESULTS

The initial objective was to produce a wideband system capable of supporting at least 3 FM video channels with better than 50db S/N ratio. If the maximum modulation depth (m) is restricted to, say, .2 per channel and the system is shot noise limited at the detector, approx. 3μw received power would be required for 50db S/N ratio (CCIR weighted).

The output signal to noise ratio of our system employing the Catel FM modulators is shown in Table 1. Note that the 50db S/N ratio was achieved only for the NEC laser. Its noise floor was subject however to 3 to 4db variations, making the exact S/N difficult to establish. The G.O. laser was stable and produced noise 6db greater than anticipated.

Interference susceptibility against a gray screen was found to be imperceptible at -40db in most cases, -50db in all cases. It is felt that if the number of channels were small, 3 or 4, a channel plan could be found which would allow minimum interference possibilities and allow increased modulation depths, say a 70 MHz, 90 MHz, 130 MHz plan. The FM enhancement is about 4db with standard Catel modulators. The CCIR weighting network improves the S/N additionally 10 to 11db. This corresponds well to the 16db measured total improvement. It is extremely advantageous to increase the modulation index (β) of the FM modulators even further.

ACKNOWLEDGEMENTS

I wish to thank Bill Toohey of Valtec for his excellent cooperation during this project and in writing this paper.

CONCLUSIONS

1. Increased source noise make wide deviation FM equipment necessary.

2. Laser noise produced results which indicated system noise limited by source C/N ratio.

3. Multimode lasers are preferred as they limit modal noise.

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NEW SERVICES VS. THE FAA: A PROBLEM IN NEED OF A SOLUTION

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ABSTRACT

Recent technological advances in amplifier design may make it possible to deliver new broadband communications services in step with the public demand for these services. However, burdensome government regulations threaten to impede full development of new services, and an unfavorable political climate may postpone the needed relief. The author proposes an interim solution which may effectively eliminate many of the restrictions faced by operators wishing to provide new communications services to subscribers.

INTRODUCTION

The extension of cable amplifier channel capacity is one of the most promising developments to occur in recent years. It comes at a time when the public demand for entertainment and informational services is increasing at a rapid pace.

Extended bandwidth cable systems with capacities from 40 to 52 channels, utilize precise interval frequency plans such as HRC, to reduce the effects of distortion caused by the increased channel loading. FCC Rules and Regulations, Part 76.610 require that all cable system carriers in the 108-136 MHz and 225-400 MHz bands, with power in excess of 10^{-5} watts be offset from aeronautical radio service carriers operating within 110 kilometers of the cable system. But, offsets or deviations from constant interval frequency plans are not practical. What technological gains promise to provide, current regulations threaten in part, to take away.

BRIEF HISTORY

During the twenty-five year period preceding 1976, no incidences of cable interference to aeronautical communications had been recorded. However, as a result of tests conducted by the Department of Commerce, Office of Telecommunications in 1974, the FAA became concerned with the potential of cable interference to aeronautical communications. The results of the aforementioned tests, published in 1974 and 1975, showed that under certain extreme conditions, interference could occur.

In April 1976, pilots flying over the cable system in Harrisburg, Pennsylvania heard whistling noises on voice frequency 118.250 MHz, in the absence of a desired signal. A subsequent investigation by the FCC determined that signals leaked from the cable on the nominal frequency of 118.250 MHz caused the interference. It is important to note that the 118.250 MHz signal was transmitted in the cable system at essentially the same level as visual carriers, and that the system was found to have a large number of leaks with levels significantly in excess of FCC Rules, Part 76.605.

What followed in December 1976 was an FCC Notice of Proposed Rulemaking, Docket 21006, addressing the issue of cable use of aeronautical frequencies. Comments were filed by a number of interested parties. In July 1977, the FCC issued a Report and Order requiring cable systems which used frequencies in the 108-136 MHz and 225-400 MHz bands to coordinate usage of these frequencies with any aeronautical assignments located within 110 km of the cable system. Coordination generally entailed offsetting of cable carrier frequencies from aeronautical assignments where the power level of those cable carriers exceeded 10^{-5} watts in the system.

The Rules were admittedly stringent. To paraphrase the FCC Report and Order, the offset requirements were adopted "out of an abundance of caution, until research can fill the gaps of our knowledge."

The FCC then fostered the formation of the Advisory Committee on Cable Signal Leakage, composed of representatives from the FCC, the FAA and the cable industry. Members of the Committee performed both aerial and ground based leakage measurements on a variety of cable systems, and in November 1979, published the results in the Final Report of the Advisory Committee on Cable Signal Leakage. From the results of the Report a number of interesting conclusions were drawn:

(1) Airborne and ground based leakage measurements correlated; therefore, a thorough leakage monitoring and prevention program could prevent interference in the airspace above a cable system.

(2) Signal power from multiple leaks increases by power summation; the FAA's hypothesized phased array effect was not observed to occur.

(3) Cable systems with reasonable RF integrity did not produce interference in the airspace; cable systems with many gross leaks could cause detectable levels of interference in the airspace above them.

Based on the findings of the Committee, the FCC adopted in March 1980, a Further Notice of Proposed Rulemaking which proposed relief from the burdensome regulations. Then in August 1980, a case of cable interference to aeronautical communications was reported over a cable system in Flint, Michigan.

As of this time, a total of five cases of cable-related interference to aeronautical communications have been documented. Information on the cases is tabulated below.

Location	Aeronautical Frequency MHz	Cable Carrier Frequency MHz	Power Level Watts
Harrisburg, Pennsylvania	118.250	118.250	$>10^{-4}$
Oxnard, California	135.500	135.500	$>10^{-4}$
Hagerstown, Maryland	118.250	118.250	$>10^{-4}$
Wilmington, N. Carolina	Degree and cause of interference uncertain.		
Flint, Michigan	133.250	133.250	$>10^{-4}$

Because the Wilmington case contains apparent inconsistencies, I have attempted to draw no conclusions from it. The remaining four cases had several factors in common: carrier power levels exceeded 10^{-4} watts by a significant amount, carriers were not offset from aeronautical frequency assignments, and the systems had no leakage monitoring and prevention programs in place.

To put things in perspective, during the nearly thirty years that cable systems have been in operation, four cases of cable interference to aeronautical frequencies have been proven to have occurred. To responsible cable engineers, four cases are four too many. However, during this same period, hundreds of cases of interference to aeronautical communications were caused by over the air transmitters.

TELECABLE CORPORATION'S EXPERIENCE WITH PRIOR COORDINATION

During the period from 1977 to 1981, TeleCable performed prior frequency coordination for 168 television and data channels in the 108-136 MHz and 225-400 MHz bands in 13 cable systems. By present FCC Rules, Part 76.610, we discovered 44 potential conflicts with aeronautical assignments, a rate of approximately 25%. The conflicts were avoided either by offsetting the carrier frequencies or by simply not using the carriers in question.

We then reexamined all 168 cases under the hypothetical conditions that carriers whose maximum system power levels fell below 10^{-4} watts need not be offset, and that carrier frequency offsets from non-emergency aeronautical frequencies of 10 KHz + /T/ were sufficient. (1)

By contrast, only five conflicts remained out of the 168 channels which were examined. One of the five channels was a pilot carrier whose frequency could easily have been offset to clear the problem. The remaining four conflicts were all associated with one system. The system is located in a major metropolitan market and utilizes an HRC channelization plan.

COGENT POINTS FROM THE FCC NOTICE AND THE FINAL REPORT OF THE ADVISORY COMMITTEE

Based on data gathered during the extensive measurements conducted under its auspices, the Advisory Committee recommended that "the threshold cable system power level at which leakage integrity and frequency offset rules become applicable, should be changed from the present 10^{-5} watts to 10^{-4} watts." As can be seen from the computations presented in the Addendum, the adoption of this recommendation would allow most aural carriers and frequency modulated data carriers to operate without offset.

The FCC in its July 1977 Report and Order acknowledged that "the Radio Technical Commission for Aeronautics (RCTA)

(1) /T/ = absolute value of cable headend equipment frequency tolerance.

standards for aeronautical communications receivers specify that the response of receivers should be down by 40 dB at ±10 KHz, relative to the desired carrier."

PROPOSAL

I propose that the following interim regulatory measures be adopted:

- All cable system operators who desire to use frequencies in the 108-136 MHz frequency bands shall initiate a complete filing as required by FCC Rules, Part 76.610; users of these frequencies shall be bound by the leakage monitoring provisions of the present Rules.

- Carrier frequency offsets from non-emergency aeronautical frequencies should be reduced to 10 KHz + /T/.

- Carriers with maximum peak envelope power levels below 10^{-4} watts need not be offset in frequency.

- NCTA and the FCC jointly develop a simplified waiver process for systems desiring to use frequencies in the 108-136 MHz and 225-400 MHz bands, but unable to offset carrier frequencies. The key criteria that a cable system must satisfy should be demonstration of a suitable leakage monitoring program and the measurement of system leakage to satisfy any of the following criteria:

    (1) $10 \log I_{3000} < -7$

    (2) $10 \log I_{\infty} < 64$

    (3) leakage levels at 450 meters < 10uv/meter

CONCLUSION

Significant relief from current FCC Rules Part 76.610 could be granted without posing any additional risk of interference to aeronautical communications. Relief of the form I have proposed would eliminate the vast majority of conflicts and provide a method of resolving those which remain.

REFERENCES

(1) Final Report of the Advisory Committee on Cable Signal Leakage, November 1, 1979.

(2) FCC Rules and Regulations, 76.610.

(3) "FCC Report and Order", Docket 21006, July 27, 1977.

(4) "Further Reply Comments of the National Cable Television Association," Re: Docket 21006, July 31, 1980.

ADDENDUM

Assume that the maximum specified rms level at the modulation envelope peak for any visual carrier on a particular cable system is + 48.75 dBmV. Adding 3 dB to allow for system level variations and subtracting 13 dB to allow for the minimum permitted visual to aural carrier level difference, the maximum aural carrier level on the system would be + 38.75 dBmV or 86.6 millivolts.

$$P = E^2/R$$

Where, P = power in watts

E = voltage in volts

R = 75 ohms, characteristic impedance of cable system elements

$$P = (86.6 \times 10^{-3})^2/75$$

$$P = 1 \times 10^{-4} \text{ watts}$$

PERFORMANCE OF A 400 MHz, 54 CHANNEL, CABLE TELEVISION DISTRIBUTION SYSTEM

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ABSTRACT

A summary of extensive tests of a 400 MHz, two-way sub-split distribution network is given. Data includes noise performance, frequency response, and distortion measurements. Subjective evaluations of the television picture quality are also given.

The distribution system consists of a 20 amplifier trunk cascade and a bridger, taps and line extender. Each station was fitted with standard equipment and accessories as would be encountered in a typical field installation. The entire distribution system was installed in an environmental chamber and tests were performed from -40°F to 140°F.

A complete TV headend system with 54 forward and four reverse channels fed the distribution network. Television signals were obtained off the air, from satellite video receivers and test generators. Tests were conducted for standard and harmonically-related-carrier (HRC) frequency assignments. Of particular interest is the comparison of performance when phase locked and non-phase locked.

INTRODUCTION

At Scientific-Atlanta, a 400 MHz headend and distribution system was constructed for engineering tests, evaluation, and customer demonstration. With this complex, tests can be conducted under controlled conditions and a variety of experiments can be performed that would be inconvenient or impractical in a field installation even before commissioning the system. A summary of the more important tests that were made is the subject of this paper. Tests of the headend are not addressed since it consists of standard equipment (except for hyper-band LO units) that have been operational at 300 MHz for a number of years. Likewise, performance of the 5-30 MHz sub-split reverse system is the same as for 300 MHz reverse systems and is not discussed herein. All 400 MHz distribution equipment employed for these tests was assembled with standard production run Scientific-Atlanta products.

System Description

Before discussing the performance of the distribution system, a brief description of the system complex is in order. In the headend, television programming originates from an earth station with 16 video channels and off the air with four VHF and four UHF channels. Each of these video channels is processed by two modulators to provide 48 TV channels. These are supplemented with teletext and test patterns for a total of 50 channels in the harmonically-related-carrier (HRC) frequency plan. Phase locked and non-phase locked operation is employed. In addition, a 54 channel Matrix Electronics Multiple Frequency Signal Generator (in the standard frequency plan) supplied carriers for CW distortion tests.

The trunk cascade consists of 20 trunk stations, each interconnected by 0.5 inch gas injected dielectric cable with 22dB loss at 400 MHz. Each trunk station includes a dual-pilot control and a sub-split reverse amplifier. The feeder, which consists of 8 taps (each separated by 1dB of cable), an in-line equalizer, and one line extender is driven from the bridger in the last trunk station. The entire trunk cascade and feeder system operates in an environmental chamber with capability of operation from -40°F to over 140°F.

The trunk amplifier is a conventional two-hybrid design. All fixed cable equalization (plug-in equalizers and pads) is at the input to the first hybrid. Automatic-gain-control (AGC) and automatic-slope-control (ASC) circuits are included in the interstage network between hybrid amplifiers. Provisions are included for plug-in interstage trim networks which may be used to make small corrections to the cascade response. Gain of the trunk amplifier is 22dB in the normal operating configuration. Normal operating level is 33dBmV at the high channel with 3dB cable-equivalent tilt.

The bridger and line extender operate at a level of 46dBmV at the high channel with 7dB tilt. The line extender includes a thermally-compensated slope and gain control designed to compensate for 10dB of cable loss and 8 taps, or an equivalent mixture of cable and tap loss.

AMPLIFIER SPECIFICATIONS

	Trunk Station	Trunk with Bridging Station	Line Extender
Typical Operating Gain	22dB	35dB	29dB (max.)
Noise Figure	11dB	14dB	12.5dB
Output Level	33dBmV 3dB Tilt	46dBmV 7dB Tilt	46dBmV 7dB Tilt
Composite Triple Beat (54 Channel)	-82dB	-59dB	-61dB
Cross Modulation (54 Channel)	-85dB	-61dB	-64dB
Second Order	-83dB	-64dB	-73dB

Amplifier Specifications

Abbreviated specifications for the trunk amplifier, bridger, and line extender are given below. These specifications apply for all equipment in its normal operating configuration at 68°F.

Trunk tilt was chosen to provide constant carrier-to-noise ratio. Since all fixed equalization precedes the first hybrid amplifier (the trunk amplifier response is essentially flat with no equalization added), a tilt of 3dB is required to overcome the higher noise figure and circuit loss at 400 MHz. The bridger and line extender operate with 7 dB tilt to overcome feeder cable and tap losses.

Calculated Performance

From the above unit specifications, performance of the distribution system can be calculated by noise-power addition of uncorrelated components and voltage addition of distortion components which maintain the same phase relationship in each amplifier. Since the preponderance of third-order distortion terms (Fa+Fb-Fc, and 2Fa-Fb) add in phase in a linear-phase cascade,[1] composite-triple-beat and cross-modulation components are added on a voltage basis. Second-order distortion is accumulated on a power basis. With these assumptions, the computed system performance is given below.

TABLE 1

CALCULATED SYSTEM PERFORMANCE

	TRUNK CASCADE ONLY				TRUNK CASCADE + BRIDGER STATION				TRUNK CASC + BRIDGER + 1 LINE-X CASCADE			
CSC	C/N	X/M	2ND	CT/B	C/N	X/M	2ND	CT/B	C/N	X/M	2ND	CT/B
1	59.0	-85.0	-83.0	-82.0	56.0	-61.0	-64.0	-59.0	53.2	-56.4	-63.5	-53.9
2	56.0	-79.0	-80.0	-76.0	54.2	-60.5	-63.9	-58.4	52.2	-56.0	-63.4	-53.6
3	54.2	-75.5	-78.2	-72.5	53.0	-60.0	-63.9	-57.8	51.4	-55.7	-63.4	-53.3
4	53.0	-73.0	-77.0	-70.0	52.0	-59.5	-63.8	-57.3	50.7	-55.4	-63.3	-53.0
5	52.0	-71.0	-76.0	-68.0	51.2	-59.0	-63.8	-56.8	50.1	-55.2	-63.3	-52.6
6	51.2	-69.4	-75.2	-66.4	50.6	-58.6	-63.7	-56.4	49.6	-54.9	-63.2	-52.4
7	50.5	-68.1	-74.5	-65.1	50.0	-58.2	-63.7	-55.9	49.1	-54.6	-63.2	-52.1
8	50.0	-66.9	-74.0	-63.9	49.5	-57.8	-63.6	-55.5	48.7	-54.4	-63.2	-51.8
9	49.5	-65.9	-73.5	-62.9	49.0	-57.5	-63.6	-55.1	48.3	-54.1	-63.1	-51.5
10	49.0	-65.0	-73.0	-62.0	48.6	-57.1	-63.5	-54.7	47.9	-53.9	-63.1	-51.3
11	48.6	-64.2	-72.6	-61.2	48.2	-56.8	-63.5	-54.4	47.6	-53.6	-63.0	-51.0
12	48.2	-63.4	-72.2	-60.4	47.9	-56.4	-63.4	-54.0	47.3	-53.4	-63.0	-50.8
13	47.9	-62.7	-71.9	-59.7	47.5	-56.1	-63.4	-53.7	47.0	-53.2	-62.9	-50.6
14	47.5	-62.1	-71.5	-59.1	47.2	-55.8	-63.3	-53.3	46.8	-52.9	-62.9	-50.3
15	47.2	-61.5	-71.2	-58.5	47.0	-55.5	-63.3	-53.0	46.5	-52.7	-62.9	-50.1
16	47.0	-60.9	-71.0	-57.9	46.7	-55.2	-63.2	-52.7	46.3	-52.5	-62.8	-49.9
17	46.7	-60.4	-70.7	-57.4	46.4	-54.9	-63.2	-52.4	46.0	-52.3	-62.8	-49.7
18	46.4	-59.9	-70.4	-56.9	46.2	-54.7	-63.2	-52.1	45.8	-52.1	-62.7	-49.5
19	46.2	-59.4	-70.2	-56.4	46.0	-54.4	-63.1	-51.9	45.6	-51.9	-62.7	-49.3
20	46.0	-59.0	-70.0	-56.0	45.8	-54.2	-63.1	-51.6	45.4	-51.7	-62.6	-49.1

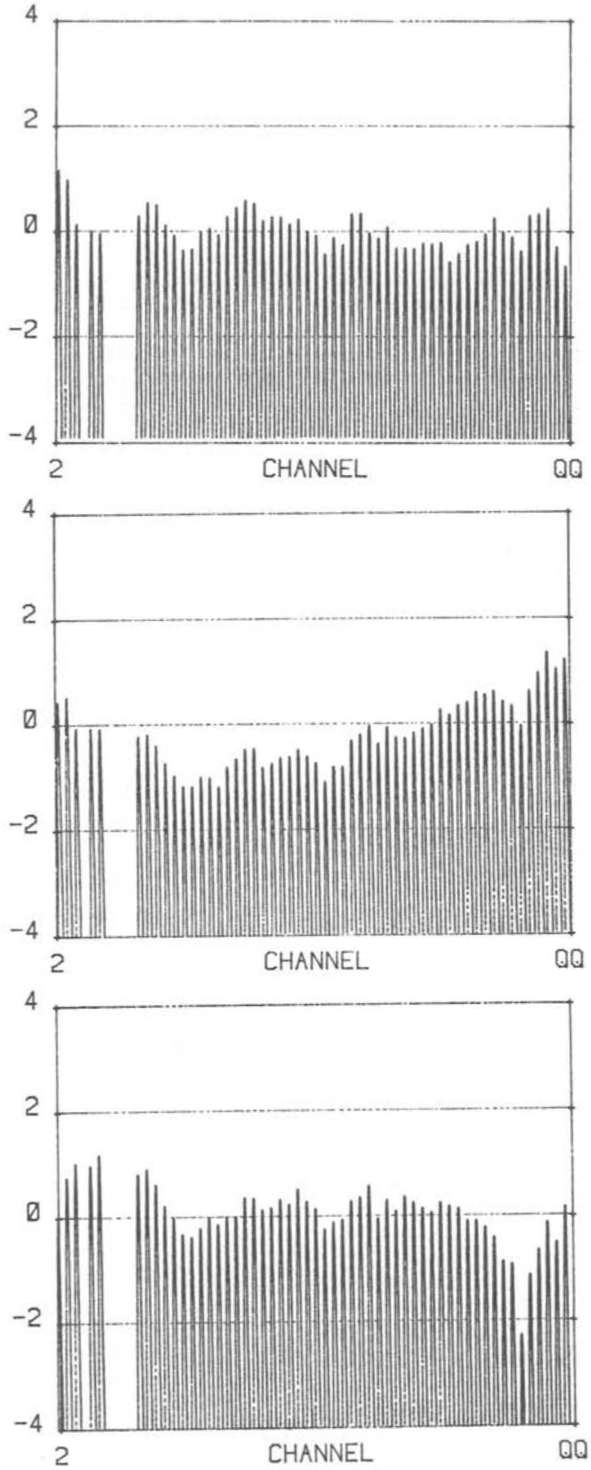

Figure 1. Trunk Response
Top: 140°F
Center: 68°F
Bottom: -40°F

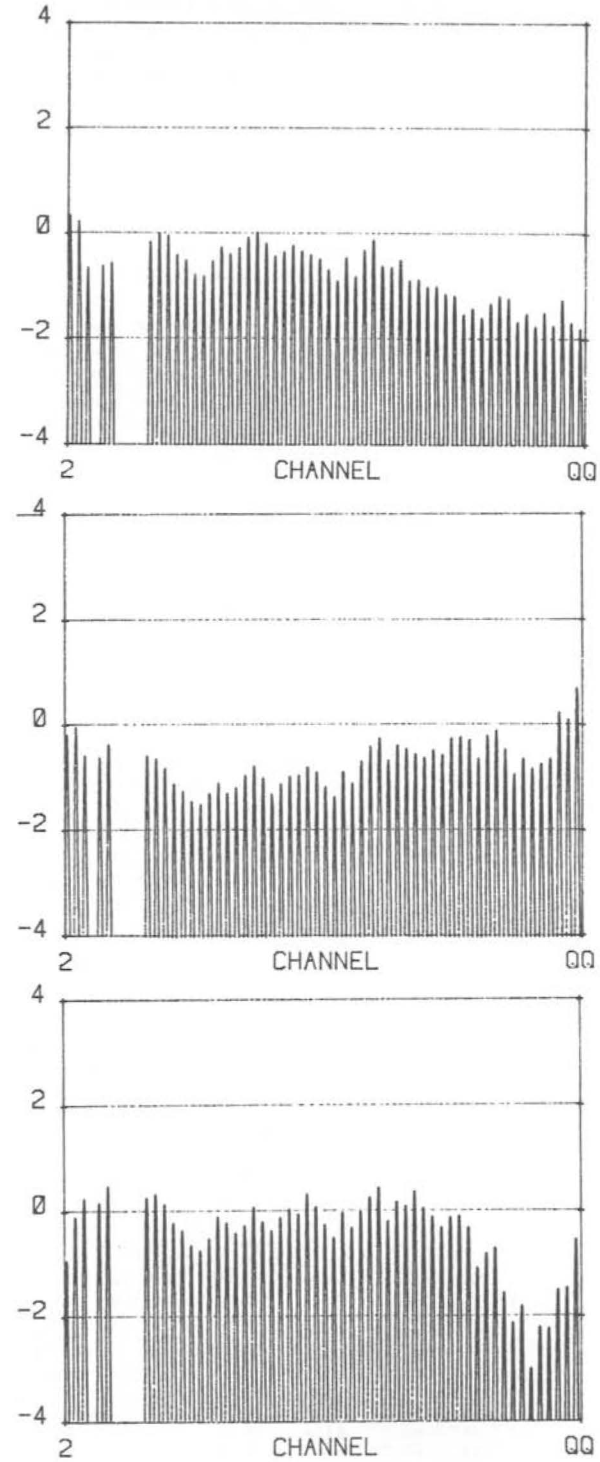

Figure 2. Bridger Response
Top: 140°F
Center: 68°F
Bottom: -40°F

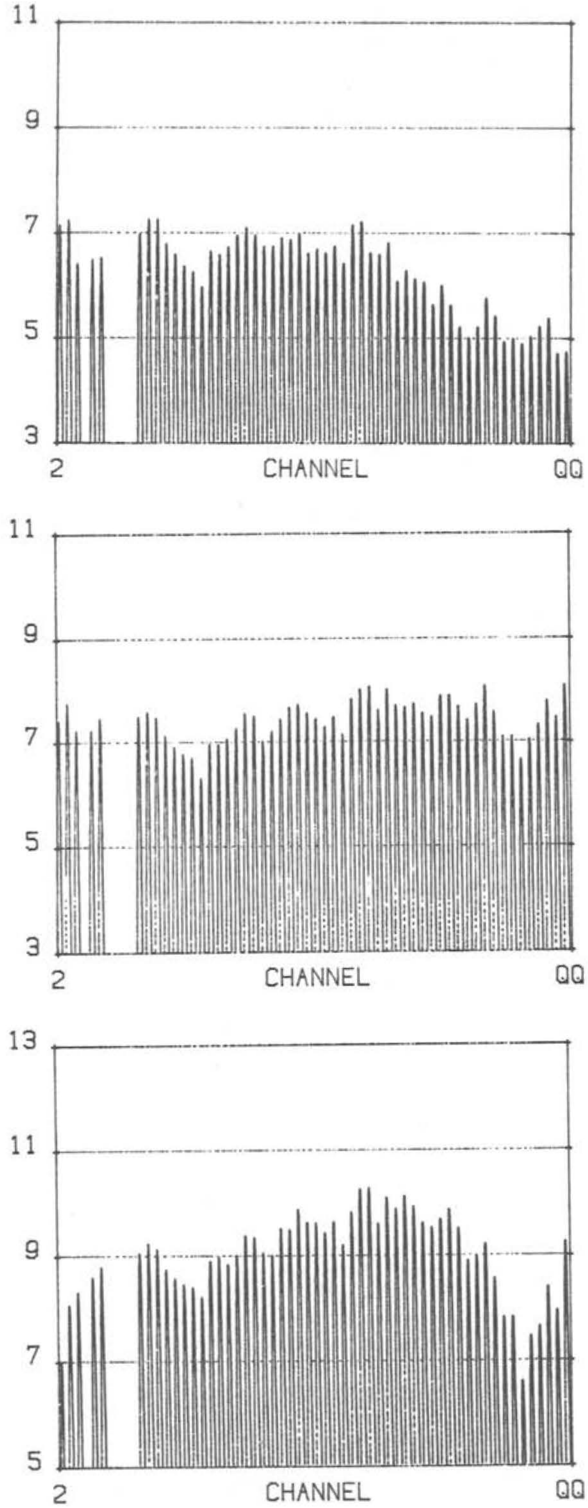

Figure 3. Tap Response
Top: 140°F Center: 68°F
Bottom: -40°F

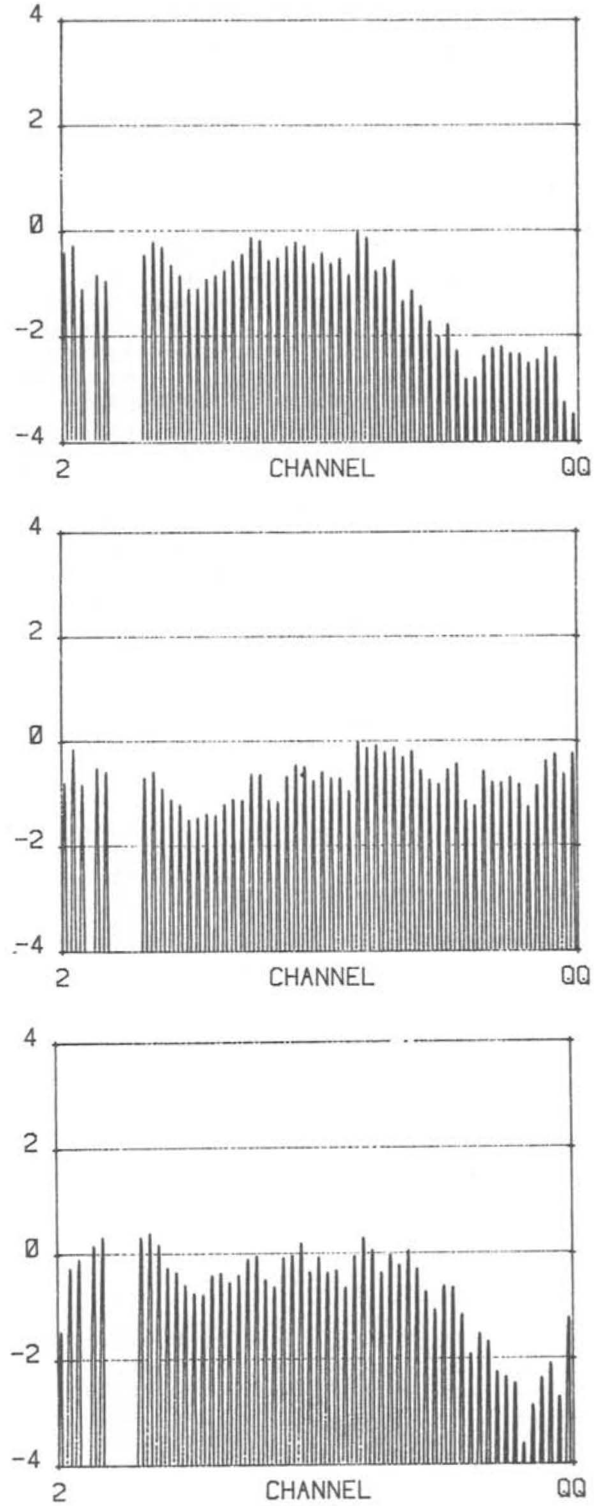

Figure 4. Line Extender Response
Top: 140°F Center: 68°F
Bottom: -40°F

MEASURED PERFORMANCE

Frequency Response

Plots of the trunk, bridger, tap and line extender are given in Figures 1-4 for temperatures of -40°F, 68°F and 140°F. These responses were recorded through a tilt correction network to remove the nominal system tilt. The 0dB reference on each scale represents the nominal signal level. The scale for the tap output is the tap level in dBmV. Response of the trunk cascade within ± 1dB was achieved with five interstage trim networks, four of which are low-frequency peak networks that compensate primarily for diplex-filter cross-over loss, and one broad-band "dish" network (a mid-band dip with peaks at low and high ends). As seen in Figure 1, the response of the trunk cascade remains nearly constant from -40°F to 140°F. The line extender contains a thermal gain and slope network to compensate for approximately 4dB total change in high-frequency loss of the feeder network over the temperature range. The response of the total cascade to the line extender output is within 4dB peak-to-valley over the temperature range.

Carrier-to-Noise Ratio

Carrier-to-noise ratio is plotted in Figure 5. The results agree well with the predicted performance - approximately 1.5dB better than calculated at 68°F, and constant to within 1.5dB. The carrier-to-noise ratio decreases as temperature increases due to the increased cable loss and increase in noise temperature of the cable and lossy circuit elements. However, the main source of output noise are the hybrid amplifiers, and those devices operate at elevated temperature. The separation of the high-temperature and low-temperature curves of Figure 5 follows that expected from noise temperature calculations.

Composite-Triple-Beat

Composite-triple-beat is measured as the ratio of the average power of all beats at the carrier frequency to the carrier power with all carriers unmodulated. These triple-beat measurements were made in the standard frequency assignments (carriers not phase locked) and, therefore, do not include second-order beats. Plots of the composite-triple-beat are given in Figure 6. The cascade performance is well behaved and 2-3dB better than predicted by the amplifier specificatios. The plots also show very little change with temperature. Although the maximum number of beats occur on channel 0, that is not necessarily the worst channel. Hybrid "high-frequency effects"[2] produce a weighting factor that is higher at the higher frequencies.

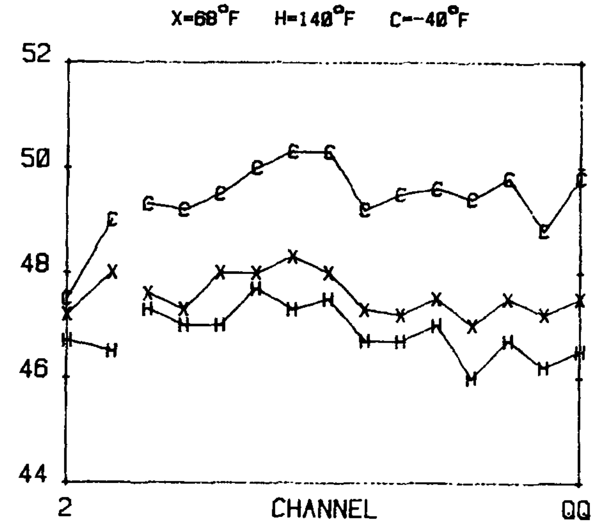

Figure 5. Carrier-To-Noise Ratio (dB)

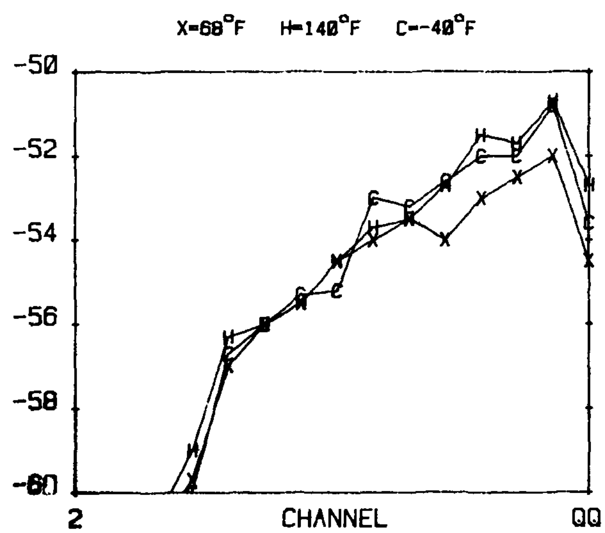

Figure 6. Composite Triple Beat (dB)

Cross-Modulation-Ratio

Cross-modulation-ratio is measured as the ratio of the modulation detected from an unmodulated carrier to the modulation detected in a 100% modulated carrier with all carriers modulated except the one in the channel being measured. Modulation of the triple-beat components also produces modulation noise on the carrier being measured, but when not phase locked, that noise was rejected by the narrow-band selective level meter employed for the test. Plots of the measured cross modulation are given in Figure 7.

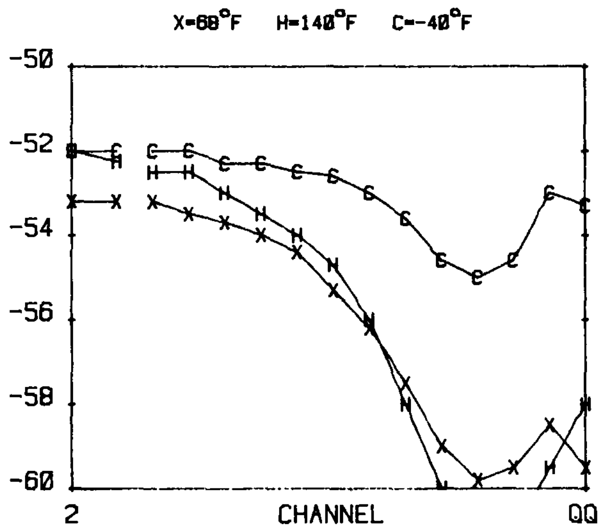

Figure 7. Cross-Modulation Ratio (dB)

Second-Order-Distortion

Second-order distortion causes the sum frequency of two carrier beats to fall 1.25 MHz above another carrier and the difference frequency to fall 1.25 MHz below a carrier in the standard frequency plan. The second-order single beats measured were quite low as seen from the data in the table below. Beats falling on channel QQ were -70dB or lower. In addition to single-beat measurements, composite second-order beat was measured with all carriers on, and this level also was low. The actual power in the channel 2 beat is somewhat higher than measured since the spectrum of the beats is spread and high analyzer resolution had to be used to resolve the beats from noise.

SECOND ORDER DISTORTION

Channel Measured	Carriers On	Second-Order Distortion (dB) -40°F	68°F	140°F
2	HH, QQ	< -69	-66.5	-67
2	All	-69	-66	-65
QQ	2, HH	< -70	< -70	
QQ	10, 12	< -70	< -70	< -70
QQ	All	-62.5	-63	-60

VISUAL TESTS

Visual tests were performed to assess the quality of the TV picture for home viewing and to determine the upper margin of signal level in the trunk system at which distortion becomes perceptible. The set-top terminal and receiver could be switched between the headend output and output of the distribution system for direct comparison. Both television programming and test patterns were observed on a Sony Trinitron. At normal signal levels and under close scrutiny, the author found no significant degradation in picture quality due to distortion with the headend either phase locked or not. Some noise could be seen in the background under close scrutiny. No estimation of noise impairment was made since it was felt that the carrier-to-noise data reported previously would best measure the effect of noise.

Experiments were performed in which the signal level at the input to the trunk was elevated and correlated with the threshold of perception of impairments in the TV picture. Here, the judgment of perception was made by another trained observer. Results of this experiment are plotted in Figure 8. When non-phase locked, interference was first observed as what appeared to be composite triple beat, or dark horizontal streaking in the picture. The threshold level of Figure 8 has the general shape of the composite-triple-beat curve of Figure 6. The shapes of the curves are very similar as they should be for a composite-triple-beat limited system.

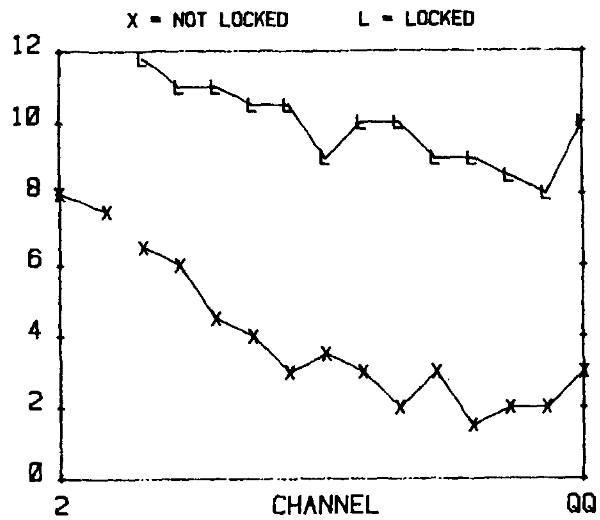

Figure 8. Elevated Level for CTB Threshold of Perception

For the phase locked mode, the signal level could be elevated considerably before distortion could be seen in the test pattern. Distortion first appeared as a hint of frames or sync bars slipping in the background, and occasionally a faint image could be seen. At about the same level, or slightly higher, horizontal streaking similar to triple-beat streaking in the non-phase locked mode could be seen. The threshold for which distortion of either type first appeared is plotted in Figure 8. The improvement by phase locking is clearly evident. The threshold date for Figure 8 was taken on a color bar test pattern.

REMARKS

The tests reported in this paper are evidence to the technical accomplishment of 400 MHz Cable TV. Now a number of similar systems are in operation in major cities and similar results are being experienced. The first 400 MHz system became operational June 30, 1980 in Orland Park, Illinois, and performance of the distribution system as reported to this author has been very good; results are comparable to data presented in this paper. Details on the performance of that system are given in a paper by Gerald Bahr[3] to be presented at the 1981 30th Annual National Cable Television Association Convention.

REFERENCES

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2. Luettgenau, G. et al, "400 MHz - A Challenge For The Hybrid Manufacturer," 29th Annual NCTA Convention Technical Papers, 1980, pp. 5-8.

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SATELLITE SERVICE PROTECTION

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INTRODUCTION

Satellite common carriers face a special problem -- their basic communications facility cannot be repaired once in orbit. If a single transponder or a complete satellite fails, it is gone forever. But most customers have a need for continuity of service. Fulfillment of this need by satellite carriers requires that they provide backup facilities or "protection."

Satellite carriers have responded to this requirement in various ways. The purpose of this article is to describe RCA Americom's plan for service protection, to discuss the relative need for protection by various classes of customers, and to describe an alternate plan which might be adopted.

SATELLITE RELIABILITY

The best form of protection is to minimize the need for it. Current communications satellites have been more reliable than expected, and future developments should make them even more so.

A whole series of evolutionary improvements is being made in battery systems, solar arrays, component and circuit designs, and operating practices. In addition, beginning with the launch of SATCOM V in October 1982, all RCA Americom satellites will employ solid-state transponders; these will eliminate the system component with the greatest potential for unreliability -- the travelling wave tube and its high voltage power supply. The cumulative effect will be a further improvement in reliability. Communications satellites launched in the 1980's should be highly reliable, indeed.

Nevertheless, the consequences of loss of service are so severe for most customers, that the risk of loss is unacceptable, even though small. These customers should demand protected service, and their carriers should plan their systems to provide it.

PROTECTION FOR INDIVIDUAL TRANSPONDER FAILURE

RCA Americom is planning a "belt and suspenders" system for protection against individual transponder failure. This is illustrated in Figure 1.

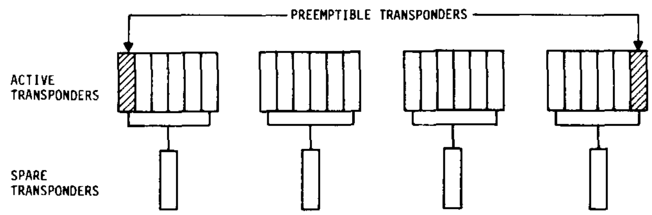

Figure 1

TRANSPONDER PROTECTION PLAN

Each bank of six transponders is provided with a spare which can be placed in service to replace any one of the six in the event of a failure. If two transponders in a single bank fail, traffic is restored on one of the preemptible transponders. This requires, of course, that any traffic on the preemptible transponder be bumped.

With this arrangement, and given the inherent reliability of second generation satellites, the probability that the carrier can offer protected service on 22 transponders during the entire life of the satellite is extremely high.

PROTECTION FOR SATELLITE FAILURE

Protection for satellite failure requires that sufficient preemptible transponders be provided in the system so that traffic on all of the protected transponders on any failed satellite can be restored. These can be grouped on a single satellite or distributed among the satellites in the system.

A superficial perception might indicate that the grouped configuration is inefficient in its use of orbital slots. It portrays the image of an "in-orbit spare" floating empty in space occupying a valuable orbital slot. But an examination of these two configurations in Table 1 shows that the difference in the total number of preemptible transponders in a five-satellite system is small -- 25 vs 30. Furthermore, as will be seen later, there is a market need for preemptible service, and it is expected that the in-orbit spare will receive considerable utilization.

Table 1

GROUPED PROTECTION CONFIGURATION

Preemptibles Distributed

Satellite	A	B	C	D	E	Total
No. of Transponders						
Protected	19	19	19	19	19	95
Preemptible	5	5	5	5	5	25
						120

Preemptibles Grouped

Satellite	A	B	C	D	E	Total
No. of Tranponders						
Protected	22	22	22	22	2	90
Preemptible	2	2	2	2	22	30
						120

RCA Americom has chosen the grouped configuration because customers in two of its markets, Alascom and the cable TV program suppliers, require that all protected transponders be restored on the same satellite. In each case there is a large number of earth stations, all communicating through transponders from a single satellite, which must continue to communicate with a single satellite after traffic is restored.

In the event of a satellite failure, service will not be protected from a second failure until another satellite is launched and in orbit. In order to minimize this time interval, RCA Americom plans to construct a ground spare which will be kept in readiness for launch. In an emergency situation, it is expected that NASA would make every effort to expedite an unscheduled launch. The expected time for this would be six months from the date of the failure.

GRADES OF SERVICE

RCA Americom offers three grades of service for transponder lease: protected, unprotected and preemptible.

Protected service is restored in the event of either satellite or transponder failure.

Unprotected service is not restored but cannot be preempted to protect other services.

Preemptible service is not only not restored but, as its name implies, is subject to preemption by protected service.

TARIFFED RATES

The rates for these services reflect their grade with protected service having the highest rate and preemptible the lowest. From the carrier's standpoint, the cost of providing unprotected service in a multi-satellite system is nearly as high as the cost of protected service. Hence the difference in Americom's tariffs for protected and unprotected service is small.

The rate for a protected transponder is equal to the basic cost for that transponder plus a proportionate share of the net cost of the preemptible transponders in the system (the gross cost of these transponders less any preemptible revenue received). An examination of Table 1 discloses that the cost of protection will diminish as the number of satellites in the system increases. In the five-satellite system shown with preemptible transponders grouped, 30 preemptible transponders provide protection to 90 protected transponders, or a ratio of 1:3. Thus, each protected transponder need bear only one-third the net cost of a preemptible transponder. In a two-satellite system, on the other hand, this ratio would be approximately 1:1 and each protected transponder would have to bear the total net cost of a preemptible transponder.

SATELLITE SERVICE PROTECTION -- WHO NEEDS IT?

Having described the means and the cost of satellite service protection, the key question, "Who needs it?" can be considered.

A preliminary answer would be, "Everybody!" One could make a case that communications is so vital a function that no one can afford a significant risk of service interruption. And for most applications and customers this is true. There are, however, important exceptions -- situations where the use of a preemptible service is reasonable and prudent. These include the following:

- Alternate transmission routes are available.

  A customer might lease preemptible service from two carriers -- or from a single carrier on separate satellites. The risk that both services would be interrupted would be small.

  Or, terrestrial routes might be available and the only penalty would be higher costs.

- Non-real time communication.

  Communications which are not on real time, i.e., batch data transmission on TV commercial distribution could, in an emergency, be handled by mail or other means.

- Cost of service is critical.

  There are applications where cost is so critical to their economic justification that the lower rates of preemptible transponders makes them attractive even with the added risk. Examples are teleconferencing or the start-up period for an entrepreneurial TV program service.

In summary, protected service is basic and will be required by most customers. Nevertheless, there are few specific situations in which the lower costs of preemptible service make it an attractive and reasonable alternative.

ALTERNATE PROTECTION CONFIGURATION

The FCC on December 3, 1980 issued a satellite decision in which it authorized the construction of 25 satellites and the launch of 20. Launch of the remaining satellites would be authorized when need was demonstrated. Closely related to the demonstration of need was the question, should a valuable orbital slot be devoted to an in-orbit spare? The Commission stated that further study of this was required and established an inquiry for this purpose.

As noted above, the total number of preemptible transponders required in a satellite system is nearly the same, whether they are grouped on an in-orbit spare or distributed throughout the system. The real issue, then, is not whether orbital slots should be devoted to in-orbit spares but whether preemptible transponders should be permitted anywhere in the system -- whether grouped or distributed.

There is an alternative configuration that could be adopted which would permit most of the transponders in a system to be designated as "protected." In this configuration the in-orbit spare would be inactive and would be co-located in the same orbital slot with an active operating satellite. If any of the satellites in the system failed, the spare would be moved to the location of the failed satellite where it would be put into operation. The time required for this could vary from a few days to a few weeks, depending on the distance and the amount of fuel consumed in the movement. This configuration is given in Table 2.

Table 2

ALTERNATE PROTECTION PLAN

Satellite	A	B	C	D & E (spare)	Total
No. of Transponders					
Protected	22	22	22	22	88
Preemptible	2	2	2	2	8
					96

This configuration reduced the amount of orbital capacity devoted to preemptible service, but has serious disadvantages:

- There would be an interruption of service for customers utilizing a failed satellite while the spare was being moved into position.
- Protected service would be more costly because there would be no revenue available from the spare to offset a portion of its cost.
- The supply of preemptible transponders available for lease would be limited, probably below the level of demand.

In view of these disadvantages, it is not believed that this configuration offers the most effective and efficient use of the orbital arc.

SUMMARY

RCA Americom's plan for satellite service protection has been developed as the result of six years experience in providing satellite service to a variety of customers with a wide range of service requirements. It has important advantages which make it near optimum both with respect to customer service and efficiency in the use of the orbital arc:

- For the majority of customers who require a high degree of service protection, it provides total restoration capability for both transponder and satellite failure.

- For customers requiring a lower degree of service protection, it provides preemptible service at reduced rates.

- Protection is provided at a reasonable cost, since the cost of the preemptible transponders is shared by all of the protected transponders in a five-satellite system.

- The use of a five-satellite system also increases the efficiency of the use of the orbital arc because of the sharing of the preemptible transponders.

THE DESIGN, CONSTRUCTION, COST AND PERFORMANCE THE FIRST 400 MHz CABLE TELEVISION SYSTEM

GERALD BAHR, JEFF BLOWERS, ED DICE, DAN DOORN

COX CABLE COMMUNICATIONS, INC.

Orland Park, Illinois was the first 400 MHz system to be designed, built and operated with a full compliment of 51 phase-locked, harmonically related coherent carrier television channels. When completed, the system will have a total of 100 miles of CATV plant, with a maximum cascade of 18 main line amplifiers, one bridger amplifier and two line extenders.

The main line was designed for a spacing of 22 dB at 400 MHz using 3/4" cable for trunk and ½" cable for feeder. This design resulted in a feeder-to-trunk ratio of 3:1 with 5.5 actives per mile. The plant design was maximized to withstand the temperature extremes the system will experience and because of the then many unanswered questions concerning the performance of a 400 MHz system, every main line amplifier position was designed for AGC and ASC operation.

After completing the design, we found the cost for electronics increased approximately 34%, due primarily to the higher usage rate per mile. The cable increased approximately 20% because of the feeder-to-trunk ratio change from 4:1 at 300 MHz to 3:1 for 400 MHz design. All other costs have remained virtually the same, when inflation is accounted for, resulting in a net increase of 13%.

INTRODUCTION

Over the past year and a half to two years, there has been considerable rhetoric, industry-wide, as to whether 400 MHz cable television systems can be built and operated successfully. First, there was the issue of the availability of 400 MHz equipment. Then, after equipment deliveries began, the cry went out that it was a whole new design, that it was not proven and would not be reliable. We hope to show: 1) that equipment is readily available; 2) that 400 MHz technology is not a new technology, such as the move to transistor and integrated circuits was, but that it is simply an extension of a proven technology; and 3) that the technology meets or exceeds expectations concerning distortions and that it has proven to be very reliable. The issue of whether or not additional channel capacity is needed will be left for other discussions.

CONSTRUCTION

Construction of the first 400 MHz system began on June 5, 1980. This state-of-the-art system was designed, constructed and is operated by Cox Cable Communications, Inc. When construction began, approximately twenty miles of 400 MHz equipment was in inventory. Commensurate with plant construction, installation of the Master Telecommunications facility with all the towers, TVRO antennas and processing equipment began. Since construction of the office and MTC complex had not commenced, a 10 x 50 foot trailer was brought on sight to house the ten racks of equipment that were required for a system of this size. At present, 100% of the aerial plant is built and approximately one-half of the 60% underground plant is completed. Rather than equipment, as many had predicted, our major obstacle was the age-old problem of make ready and right-of-way clearances.

SYSTEM DESCRIPTION AND DESIGN

On June 30, 1980, the first fully loaded, 400 MHz CATV system was turned on and began serving subscribers in Orland Park, Illinois.

The Master Telecommunications Center (MTC), or headend, design includes two 4.5-meter dual polarized Andrews satellite TVRO antennas - one receiving signals from SATCOM I, the other receiving signals from COMSTAR D-2. Scientific Atlanta 5500 satellite receivers are used on both antennas. The MTC processes 51 channels of television information in a harmonically related coherent (HRC) format using Scientific Atlanta 6350 TV modulators and 6150 TV processors.

The 100-mile cable plant design anticipated and incorporated the capacity for two-way communications. However, the upstream amplifier modules were not installed with the initial construction. The design of the system specified ComScope PIII+ 3/4" trunk cable and ComScope PIII+ 1/2" feeder cable. Scientific Atlanta Model 6500 trunk amplifiers are spaced 22 dB apart with a maximum cascade of eighteen amplifiers, one bridger and two line extenders. With our design philosophy, the 400 MHz system yielded a 3:1 feeder-to-trunk ratio with an active ratio of 5.5 amplifiers per mile.

The system was intentionally overdesigned because of the many unknown and unanswered questions regarding 400 MHz. For instance, we designed the system for AGC and ASC operation at every trunk amplifier. Because of the superior performance experienced to date, we have operated the system with every other amplifier in AGC/ASC mode and find that the system is still performing well beyond expectations, even with the severe temperature variations. The operating levels are: trunk input +11 dBmV, output +33 dBmV; bridger output +45 dBmV; line extender output +43 dBmV. Lectro automatic standby power supplies are provided at every power supply location.

COSTS

The design constraints resulting from the new engineering requirements, with all other factors remaining the same, produced an overall increase in system cost of 13% to build a 400 MHz system versus a 300 MHz system. The design criteria resulted in an increased cost of approximately 34% in electronics. Cable cost increased approximately 20% due to the feeder-to-trunk ratio change, requiring more trunk cable and more loop-back design. In addition to the increase in length, a premium was being charged for 400 MHz cable, at that time. This net cost increase of 13% yields a 48.5% increase in channel capacity, so the cost per channel actually decreases.

PERFORMANCE

On February 16, 1981, Cox Cable Communications, Inc. and Scientific Atlanta performed a proof of performance on the system, one line of which consisted of seventeen trunk amplifiers, one terminating bridger and two line extenders. The following test equipment was used for perform the measurement:

Wavetek Sweep	Gen.	Model 1855	S/N 270346
Wavetek Swepp	Rec.	1865	270347
Dix Hills Signal	Gen. (matrix)	SX16	181
Six Hills Distortion	Anl. (matrix)	RHi2	102
Spectrum	Anl.	8854B	2002A02611
Wavetek Freq. Sig.	Gen.	3001	280261
Wavetek Freq. Sig.	Gen.	3001	319245
Mid State	FSM	SAM-1	5126
SA 7dB true tilt	NET.	T	----
Texscan	BFP	75XX-35	
Texscan	BFP	75XX-37	
Texscan	BFP	75XX-38	
Texscan	BFP	75XX-39	
SA Pre Amp		SA-1	18 dB gain

All tests were performed using accepted NCTA test measurement procedures. Temperature at the time of the tests as +20 degrees Fahrenheit. The following are the results of the tests as compared to the calculated predictions:

Ch.	CTB Pred.	CTB Meas.	C/N Pred.	C/N Meas.	Cross Mod. Pred.	Cross Mod. Meas.	
2	-50.07	-57.5	46.17	47	-52.77	-63.5	dB
E	"	-57	"	47	"	-67.5	dB
12	"	-55	"	49	"	-67	dB
P	"	-56	"	47	"	-61	dB
R	"	-52	"	48	"	-59	dB
W	"	-55	"	47	"	-57.5	dB
QQ	"	-54	"	46	"	*	dB

* QQ cross mod was not measured because, at that time, a receiver was not available for that channel.

With this comparison, it can be readily seen that system performance far exceeds the predicted distortion levels. The overall system response, at the output of the 17th amplifier, had a peak-to-valley of 3.32 dB with an almost Gaussian shape 2dB peak near 210 MHz. Discounting this one peak, the response at the output of this amplifier would easily be within 1.4 dB peak-to-valley. The first line extender output exhibited a peak-to-valley of 4.22 dB with the output of the second line extender yielding a 6.4 dB peak-to-valley. At the output of the first line extender, between 50 MHz and 300 MHz, the response is well within 3 dB peak-to-valley. This response is not as tight as we would like to see, and we are continuing to work with Scientific Atlanta to improve the overall response. The major contributor to the poor response at the end of the second line extender appears to be the accumulative effects of roll-off on feed through loss exhibited by the directional taps between 300 MHz and 400 MHz.

RELIABILITY

With over 2,000 subscribers now being served by this 400 MHz system, and increasing at approximately 40 subscribers per day, it is worthy to note that in the past five months, not one service call has been attributed to the distribution svstem. The system has now successfully performed through summer and winter and has exhibited level stability of $\pm$ 3 dB over wide ambient temperature variations. The only outage experienced thus far occurred when the system was purposely shut down to allow the processing equipment to be moved from its temporary facilities in the trailer to its permanent facilities in the Cox Cable of Orland Park office complex. It is certainly note-worthy that, at this time, there have been no distribution equipment failures of any type. Our people on site report that this is the most stable and reliable system that they have ever worked with.

CONCLUSION

Our experience with 400 MHz systems in Orland Park, Illinois with over 2,000 subscribers and Jacksonville Teach, Florida with over 1,000 subscribers gives us great confidence that 400 MHz systems are not something of the future, but are deliverable, workable and reliable - today. Judging by the noise and distortion figures measured, we see no reason why at least a twenty amplifier cascade could not be designed and operated successfully. Our confidence in 400 MHz cable TV systems utilizing 400 MHz technology is evidenced by our commitment to the following systems, which are either under construction, or in the design phase: Michigan City, Indiana; Cranston, Rhode Island; Great Neck, New York; North Shores, New York; Maywood, Illinois; Park Forest, Illinois; Libertyville, Illinois; Mundelime, Illinois; Wauconda, Illinois; Grayslake, Illinois; Omaha, Nebraska; New Orleans, Louisiana.

THE IMPACT OF 3° SPACING
ON CABLE TELEVISION

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RCA AMERICAN COMMUNICATIONS, INC.

ABSTRACT

This paper discusses the impact of 3° orbital spacing upon satellite distribution of cable television programming. Included are preliminary results of:

- Experiments designed to establish an appropriate protection ratio for cable video transmissions.
- Calculations indicating expected levels of interference at 3° spacing.

The conclusions of these exercises indicate that a 3° orbital spacing for C-band domestic satellites will not have a deleterious impact upon program distribution to existing (4.5 meter) cable earth stations. Recommendations are made concerning appropriate protection ratios, use of 3 meter antennas and optimum spacecraft deployment schemes.

INTRODUCTION

The Federal Communications Commission, in December 1980, dramatically set a course for the domestic satellite business. Its grants of orbital assignments and launch authorities provide a framework encouraging the orderly development of our industry. Among the issues addressed by the Commission's order was the recognition that the geosynchronous orbital arc is a finite resource that must be used efficiently. One approach to satisfying this requirement is reduction of spacing between adjacent C-band satellites from the present 4° to 3°.

This paper examines the impact of such a reduced spacing upon cable television distribution via domestic satellites.

ENGINEERING CONSIDERATIONS

The most important measure of picture quality in a satellite television link is signal-to-noise (S/N) defined as the ratio, in dB, of the peak-to-peak picture (luminance) signal to RMS weighted noise. Expressed in equation form by:

$$S/N = C/N + FMI \qquad (1)$$

where

S/N = signal-to-noise ratio

C/N = carrier-to-thermal noise ratio in the link

FMI = frequency modulation improvement

Typically, cable television systems operating with current United States domestic satellites realize an S/N on the order of 50.0 dB at the earth station. The primary determinants of C/N are the thermal noise contributions of the up and downlinks of the satellite system; however, the video receiver at a cable earth station is also exposed to the interfering effects of undesired signals which may simultaneously occupy the same bandwidth as the desired carrier (see Figure 1).

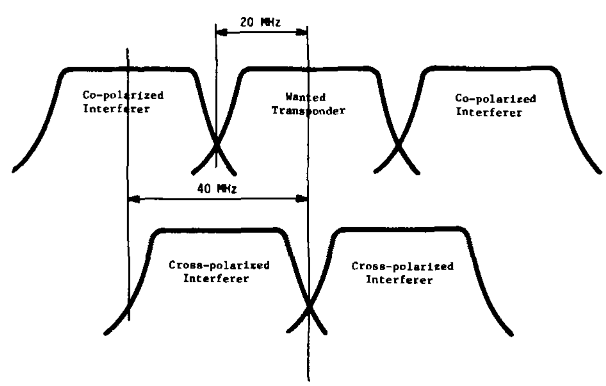

Figure 1

Transponder Frequency and Polarization Plan

These originate from three major sources:

- Internal interference (C/I_{int}) within the satellite caused by noise or signals in adjacent or cross-polarized transponders which penetrate into the desired transponder. The level of this interference is established by the skirt selectivity of the transponder filters and the cross-polarization performance of the earth-satellite link.

- Terrestrial interference (C/I_{terr}) from microwave systems operating in the 4 GHz band.

- Adjacent satellite interference (C/I_{adj}) from co-frequency signals of neighboring satellite systems, the level of which is primarily a function of the receiving antenna's off-axis discrimination.

Total carrier-to-interference (C/I_{tot}), defined as the ratio, in dB, between the power of the wanted signal and the power of all interfering signals as measured at the input to the earth station receiver, is expressed in equation form as:

$$(C/I_{tot}) = C/I_{int} \oplus C/I_{terr} \oplus C/I_{adj} \quad (2)$$

where

C/I_{int} = 26 dB for frequency reuse spacecraft

C/I_{terr} = 25 dB the typical level for which frequency coordination is accomplished

C/I_{adj} = adjacent satellite interference

$\oplus$ = power summation

This paper examines the (C/I_{adj}) ratio with 3^o spacing and its impact upon cable video transmissions.

The next section presents results of subjective testing accomplished at the RCA Laboratories for the purpose of establishing reasonable protection ratios (minimum required C/I_{tot}) for cable video services.

PROTECTION RATIO

An appropriate protection ratio for cable television services can only be determined via extensive subjective testing. The unique nature of the color video signal, and the complex physiological and psychological processes involved in human perception of color images combine to make the effect of an interfering signal on a color television transmission analytically intractable and highly subjective, i.e., viewer dependent.

RCA has ongoing programs investigating the nature and characteristics of video signals. The most recent efforts explored subjective judgments of color video interference effects by groups of viewers. This involved controlled introduction of various types and levels of interfering signals as viewers indicated on data sheets the points associated with:

- Just Perceptible Interference (JPI), defined as that level in which the viewer first notices an anomaly in the picture.

- Just Objectionable Interference (JOI), defined as that level at which the viewers will turn off a program they desire to watch because the picture is intolerable.

A description of the test conditions and results follows. Note that data reduction efforts are still under way and the results presented here are preliminary.

TEST CONDITIONS

Wanted Signals (all with audio sub-carrier and energy dispersal):

(1) Still slide (red flower on green background)

(2) High quality video tape (Rose Bowl Parade)

(3) EIA Standard color bars

Interfering Signals:

Full Transponder:

(1) Full transponder FDM/FM (1872 channels)

(2) EIA Standard magenta field

(3) EIA Standard color bars

(4) Off-air scenes

Narrowband:

(1) 56 kbps BPSK

Transmission parameters used for the wanted signals (all located in the center of the transponder) were:

	Peak Deviation (MHz)	IF BW (MHz)	C/N (dB)
Case I:	10.8*	30	11.9
Case II:	10.8*	30	15.9
Case III:	6.7	17.5	19.2
Case IV:	6.7	17.5	25.2

*Presently used for Satcom video transmissions

Tests were conducted at the RCA Laboratories in a dark room. All signals were displayed on a 25" RCA XL-100 television set. Viewers were seated 4 - 6 feet from the screen.

There were ten participants; five male and five female. Of the total, two were expert and the remainder were inexpert viewers.

Experimental Results (Preliminary)

Full Transponder Interferers:

Average Required C/I (dB)	Cases I	II	III	IV
JPI	14.6	15.9	18.6	17.7
JOI	5.7	3.9	6.3	5.5

Narrowband Interferer:

Average Required C/I (dB)	Cases I	II	III	IV
JPI	19.5	19.3	21.9	21.3
JOI	11.4	7.6	13.1	11.1

PRELIMINARY CONCLUSIONS OF SUBJECTIVE TESTING

- A protection ratio (C/I_{tot}) of approximately 18.0 dB would be satisfactory for cable television service.

- Narrowband signals were found to be the worst interferers requiring, on average, the highest protection ratios. However, the level of narrowband signals in operational systems is considerably below the power which might introduce interference in adjacent satellite transmissions because such signals operate with substantial transponder backoffs.

- Reduction of the peak deviation from 10.8 MHz in Cases I and II to 6.7 MHz in Cases III and IV resulted in a greater susceptibility to interfering signals. Pursuing this, we ran some abbreviated tests using overdeviation techniques (peak deviation 13.7 MHz) and discovered that the required C/I for Just Perceptible Interference was reduced (improved) by 8.0 dB. Changing Satcom video transmission parameters to make the signal more rugged and less susceptible to interference may be appropriate. More experiments are planned on this point.

- Waveform monitors show the effects of interfering signals well before (10 dB) the picture does. Protection ratios predicated upon meeting parametric measurements would need to be considerably higher than the recommended level of 18.0 dB.

ADJACENT SATELLITE INTERFERENCE

Figure 2 illustrates the mechanisms of adjacent satellite interference. There are two contributions:

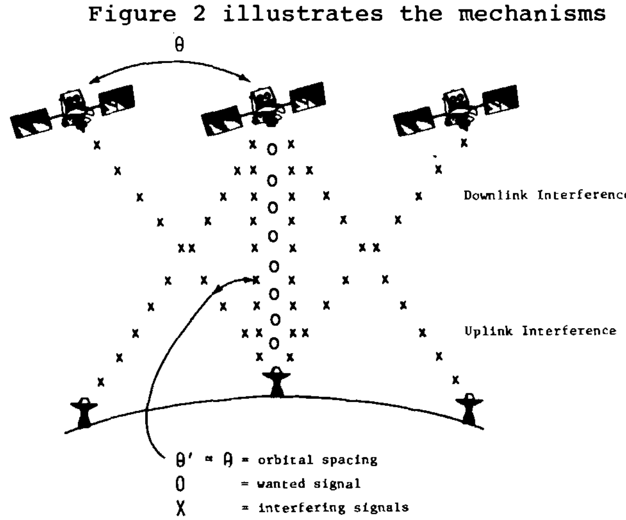

Figure 2

Interference Mechanisms

- Uplink interference occurs by virtue of the finite gain of transmitting antennas in the direction of an adjacent satellite illuminating the receiving system in the wanted spacecraft. This energy is then reradiated into the receiving earth station.

- Downlink interference occurs by virtue of the finite gain of the receiving earth station in the direction of an adjacent satellite.

Clearly, a most critical parameter is the earth station antenna discrimination, the ratio in dB between maximum gain on boresight and gain in the direction of an adjacent spacecraft. Earth station antenna gain decreases monotonically with increasing angle off boresight (the FCC requirement is 32-25 log θ, where θ is the angle off-axis). Thus, greater separation between satellites implies greater discrimination and concomitantly lower interference.

There also exists a cross-polarization advantage of approximately 4 - 6 dB in the off-axis (sidelobe) region of earth station antennas. This compares to 30 - 40 dB cross-polarization discrimination on-axis. An antenna oriented to receive a given transponder from a spacecraft (e.g. horizontal) will attenuate the energy of a co-frequency transponder in an adjacent satellite in accordance with the 32-25 log θ characteristic; however, if the co-frequency transponder is orthogonally polarized (e.g. vertical) it will encounter an additional attenuation of 4 - 6 dB.

Frequency plans of 24-transponder satellites utilize staggered transponder center frequencies to minimize internal interference (see Figure 1).

This ameliorates the interfering effect of frequency interleaved transponders in adjacent satellites as well. Additional improvement for television transmission is realized because the bulk of the energy in a video signal is concentrated near the center of the transponder at the carrier frequency.

EXPECTED INTERFERENCE LEVELS

The expected total C/I ratio for 4.5 meter facilities at 3^o satellite spacing is 17.2 dB (see Table 1). This assumes no advantage due to cross-polarization discrimination (XPD) in the sidelobe region. The subjective testing discussed previously indicates that this would provide satisfactory performance for cable television distribution via satellite. Thus, the impact of 3^o spacing on 4.5 meter cable systems would be a modest reduction in system margins with no perceptible degradation of the video signal.

Off-axis cross-polarization discrimination of cable earth stations offers a means of recovering lost system margin. Optimum placement of satellites at 3^o spacing would call for spacecraft having orthogonal polarizations and frequency interleaved transponders on uplinks and downlinks to be located adjacent to one another, i.e., Transponder 10 on one satellite would be horizontal on the uplink and vertical on the downlink, whereas in the adjacent spacecraft Transponder 10 would be vertical on the uplink and horizontal on the downlink. Table 1 shows total C/I ratios that could be expected as a function of off-axis XPD for 4.5 meter and 3.0 meter antennas and a beam edge EIRP of 33.0 dBW (provided by RCA Satcom III-R at 131^o for all CONUS except southern Texas, Florida and New England). By way of comparison, the predicted C/I_{tot}, assuming no XPD advantage for 4.5 meter earth stations at 4^o spacing, is 19.2 dB.[1] Therefore, while 4.5 meter dishes will provide satisfactory performance at 3^o spacing, margin can be recovered as a function of XPD off-axis and it makes a dramatic impact upon performance with 3 meter antennas.

RCA plans further studies on the subject of interference to and from video signals. Of particular interest is an evaluation of the impact of high-speed (50 Mbps) services on orbital spacing.

Table 1

BEAM EDGE EIRP

33 dBW

3^o Satellite Spacing

Cross Polarization Discrimination (off-axis)	4.5m		3.0m	
	C/I_{adj}	C/I_{tot}	C/I_{adj}	C/I_{tot}
0	18.8	17.2	14.2	13.6
4	22.3	19.4	18.0	16.7
6	23.8	20.1	19.8	17.9

1. Declaratory Ruling and Order, Federal Communications Commission, 15 DEC 1976, Authorization of Receive-Only Small Earth Station Antennas.

CONCLUSIONS

- Spacing domestic C-band spacecraft at 3° will not degrade cable television distribution via satellite to 4.5 meter facilities. System margins will be slightly reduced but overall performance will be satisfactory.

- Cross-polarization discrimination (XPD) in the sidelobe region of earth station antennas offers a means of improving system margins at 3° spacing. Modest levels of XPD provide significant improvement in protection ratios. Optimum orbital deployment for use of this feature calls for adjacent satellites to be completely cross-polarized relative to one another on both up and downlinks and to be homogeneous, i.e., to have approximately the same EIRP.

- Three-meter antennas will not provide satisfactory protection ratios with 3° satellite spacing unless off-axis discrimination of these antennas is superior to the FCC minimum of $32-25 \log \theta$.

- Revising video transmission parameters (overdeviation) offers a means of reducing susceptibility of video signals to interference.

ACKNOWLEDGMENT

Many thanks to R. Dombroski, M. Freeling, K. Lanza, and R. Rosensweig, all of RCA Americom Technical Operations, whose efforts made this study and paper possible.

THE LINK BETWEEN THE COMPUTER AND TELEVISION

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Abstract

Much discussion has been focused recently on "the home of the future. Making the home interactive is a goal of cable television operators to create new markets and increase cable revenues. Recent advances in computerized image processing components make such applications possible.

Teleshopping, Demand Electronic Knowledge, Municipal Image Data Bases, and other applications require the creation, storeage and distribution of a vast quantity of images. They need to be created inexpensively, recalled at random, and distributed easily over currently installed cable systems.

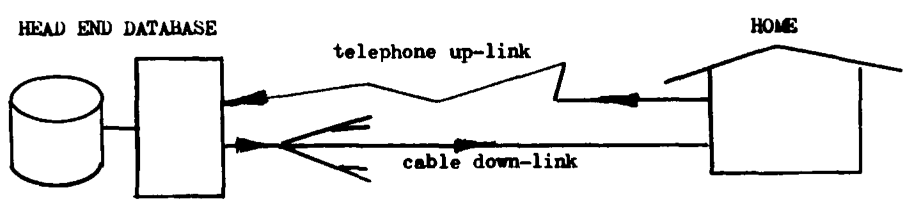
This paper describes new developments in inexpensive image processing components that use standard television and interface directly with inexpensive minicomputers. The author will present a video tape presentation showing the live creation of a Teleshopping catalog data base, and other applications along with a description of a home and municipal distribution system suitable for two-way interaction Demand Electronic Knowledge.

Three applications are demonstrated live:

1 SECURITY
2 IMAGE DATA BASE
3 TELESHOPPING

SECURITY on a real-time monitoring basis uses the future capability of full two-way video cable.

IMAGE DATA BASE and TELESHOPPING are here today with a telephone for inbound transmission and cable TV for outbound transmission. Although telephone lines are widely used for vidoetext services at present, cable TV offers an alternate delivery method. Its advantage is that it is broadband, which allows sophisticated graphics and photographs to be readily transmitted to a terminal screen.



Let's focus on TELESHOPPING.

Retailing is a $1 trillion market in the USA now, and direct marketing (catalog shopping and direct mail) is over a $100 billion market. Yet powerful social, economic and technical trends will significantly reshape the merchandising marketplace in the 1980's leading to shopping over home television...TELESHOPPING:

* over ½ of the women now work and have less time for shopping.
* the rising cost of gasoline will preclude shopping trips while preselling of name brands will make trips a luxury.
* cable operators are rapidly wiring the majority of American homes and doing so with excess channel capacity mandated by local franchise boards anticipating "two-way" services.
* Teletext and Viewdata are already accepted in England and Europe and are already generating significant retailing revenues. These services will explode shortly in America.
* the advent of home computers, television sets designed like friendly appliances, and declining prices of video components will create consumer demand for the home information network.

But two major problems remain...

1 FRAME CREATION
2 FRAME DISTRIBUTION

For TELESHOPPING to truly reach it's potential "information providers" must be able to easily create and edit literally many thousands of frames of information. European experience with Teletext and Viewdata supports the conclusion that plain text frames are not read. They have the problem... "How do you put the Sears Catalog in?"...and do so in the television media.

A second opportunity for TELESHOPPING is image distribution over cable TV. Industry experts agree that cable TV operations offer a significant market advantage to "information providers" with the capability to provide distribution of full images at high bandwidth. This will be 30 frames per second with addressable frame grabbers in the home.

The author shows how inexpensive image processing components and minicomputers are used in the VISIONtec system to address thest two major opportunities by providing frame creation and a frame distribution system.

"Tieing It All Together"

William Down

LRC Electronics, Inc.

How and why of connector usage is reviewed along with some pointers as to the selection of connectors sizes and types. Testing of connectors for return loss and center conductor strength is described, noting some of the pitfalls that can be encountered in this testing. The objective of this report is to enable the reader to "Tie it all Together" and havé a smooth running cable system.

Without connectors a cable system is no more than a lot of Coax Cable and electronics with nothing to do.

There are many things to be considered in the selection and application of aluminum cable connectors, and I will present some thoughts on the various applications of these connectors. These considerations can be divided into two broad classes, mechanical and electrical, and then these can be further subdivided. We will first cover the many mechanical considerations in connector selection.

First and seemingly very simple is the matter of what size connector has to be selected. I say simple, but it must be realized that all aluminum cable of the same size designation (1/2 - 3/4, etc.) is not created equal. To go back and review, the impedance of a coaxial structure is determined by the ratio of the outer diameter of the inner conductor, to the inner diameter of the outer conductor, modified by the dielectric constant of the material in between. Since the different manufactures of cable all have different methods of "creating" a dielectric in the cable, there are almost as many variations of ratios of diameter of cable within any one size designated as there are cable manufacturers.
See fig. 1

$$Z_0 = \frac{138}{\sqrt{\varepsilon_r}} \log_{10} \frac{b}{a} \text{ ohms}$$

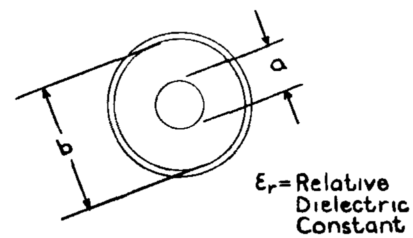


figure 1

Thus, much attention has to be paid to what particular type of cable one is buying connectors for. Going furthur, make sure that you are using the connector the manufacturer recommends for the particular cable you are using.

This selection must be done without the user making any assumptions as to which connector goes on which cable. For example: just because one connector company groups cable connector combinations in a particular way, don't assume that another connector company does the same. This doesn't mean one is right and the other wrong, just that they have chosen their mean dimension of their connectors at a different point. In a practical connector design the center conductor seizure terminal will only reliably close a finite amount from its full open size, therefore, the choice of this starting size will influence the range of center conductor sizes that can be accommodated in any one connector size.

The type of connector to be used is a matter that should be considered early in the design phase of your system build or rebuild. By type I mean pin type, feed through and with some connector companies,which family of connectors you want to use. Each type can have some finite advantage, and disadvantages for the way you may want to use it.

Feed through connectors have a major advantage in that they are cheaper to buy, but some of the cost can be used up in the type needed for a longer center conductor preparation along with the increased difficulty removing equipment (taps, etc.) once they are installed. Feed through connectors generally have better electrical specifications due to their lack of internal parts. This same lack of parts is interpreted by some people to mean a greater reliability, but this point can be argued to great length, since the same basic steps must be followed in installation, the connector is subjected to the same errors as other types. Feed through connectors may be used in conjunction with splice blocks which gives the user some finite advantages with this type of construction. In the older systems and in partial rebuilds, the splice block may be used to join two different types of cable and can even be used to splice two different sizes should the need arise.

Splice blocks have the additional use of allowing maintenance personal access to the center conductor of the cable without interrupting service or opening up a housing simply by removing the access plug on the splice block. Most connector companies also offer a test adaptor that may be screwed into the splice block which then has a test point for both RF and powering brought out in a usable manner. This test adaptor should only be used as a trouble shooting tool and not to set amps or balance the systems. This is due to the error introduced by making a "T" connection in the coax structure instead of going through a transformer as one does in a directional tap. The "T" connection introduces a mismatch of about 10db at the higher frequencies which would introduce about 1db error in the through loss.

Feed through connectors in the larger sizes (3/4) require a reducing pin to be used in many pieces of equipment due to the inability of the center conductor. This reducing pin must be crimped in place with the proper tool in order to achieve the reliability desired. This is important because this crimp is the actual means of holding the center conductor and making good mechanical and electrical connection.

While on the subject of crimping, this is a good time to discuss the use of Nicropress type splices. These fittings have been around for a good many years and probably will be around for a good many more. These fittings are very simple to use and have very good mechanical and electrical specifications, the only disadvantage is that they require the use of individual radiation sleeves and this is distasteful to some.

However, properly installed these fittings will give service that compares very favorably with the so called "State of the Art" fittings.

A second broad classification of connectors generally in use is the Auto seize variety which are sometimes referred to as "seized center conductor" fittings, both in the entry and splice configuation. These connectors are the variety that with some form of internal mechanism close the center terminal around the cable center conductor in a manner that seizes or holds the cable center conductor for good mechanical and electrical performance. See fig. 2

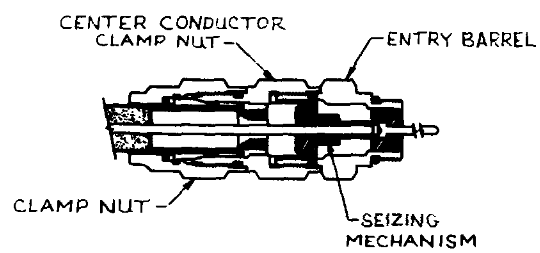


figure 2

The more common configuration of this type of connector is to have a separate closing mechanism for the center conductor and the cable sheath ferrule. These connectors all have radiation sleeves, but have different internal mechanisms from manufacturer to manufacturer. As with any connector it cannot be stressed enough times to read and follow the suppliers instructions for assembly of his connector on to the cable. In preparation of cable for auto seize connectors always pay alot of attention to the center conductor prep length, remembering "more is not better" in the length of the center conductor preparation because too long a center conductor could hold the center terminal open or it will not allow the sheath in thecable to bottom in the ferrule. Not allowing the cable sheath to go all the way into the connector ferrule can produce both mechanical and electrical problems. Mechanically, the ferrule does not have the full gripping surface and the pull strength of the holding nut will be reduced by a fair amount. A mismatch in impedance can be introduced by the radiation sleeve not being all the way in to the cable end and allowing cable with no dielectric around the center conductor for too great a length.

Another style of connector now being offered by some manufacturers combines the action of the center seizing nut with the action of the ferrule seizing nut in the same device, this type of connector is much simpler to use and because of its simplicity is rapidly gaining acceptance in the industry. With these connectors a pusher that surround the plastic center conductor closing mechanism is driven forward by the cable ferrule while it is closing around the coaxial cable sheath, thus gripping the center conductor with the same tightening nut. That closes the ferrule on the cable sheath. See fig. 3

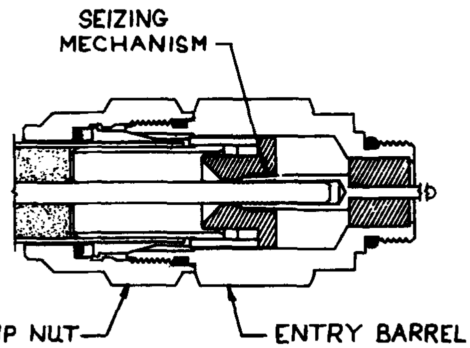


figure 3

With any seized center conductor connector the user should be concerned with the "pull strength" specification of both the center conductor and the sheath gripping mechanism on the type of cable that he is going to use.

In fig. 4 a plot of pull strength vrs. distance is shown as they are run on a typical connector. Notice the straight leading edge that gradually "rounds off" near the maximum pull strength of the connector, then rapidly drops about a third of the pull, and holds at about two-thirds of the maximum pull while the center conductor slides out of the gripping terminal.

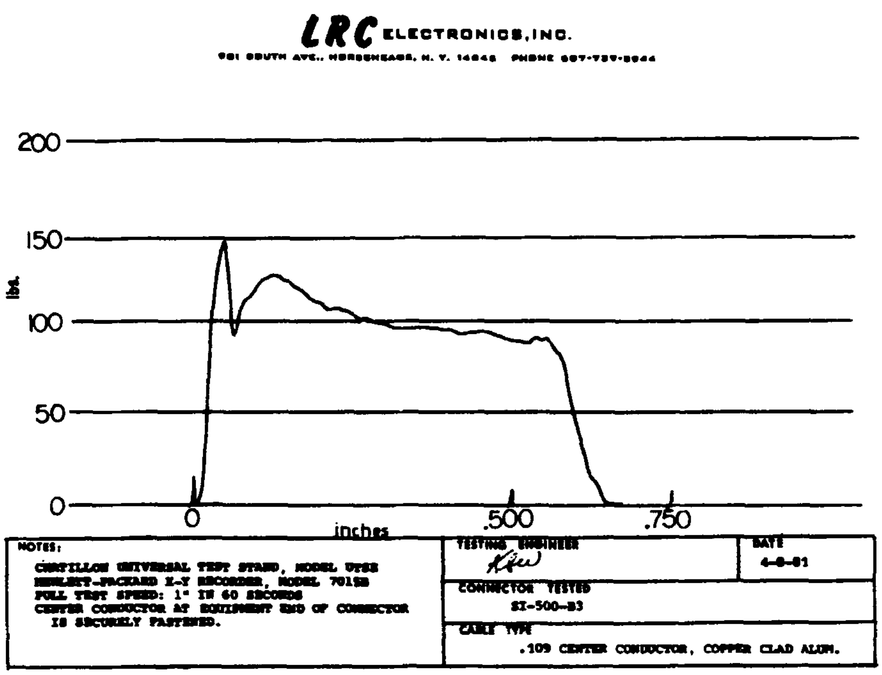


figure 4

It is only necessary to stretch the center conductor of the cable, because as it stretches it slides out of the terminal due to the reduced diameter. The conductor can be gripped harder, but this only results in a stress point on the conductor causing it to break at a lower strength, with the overall effect of a higher likelihood of a catastrophic failure.

Notice in the figure presented that all of the data needed to come to a conclusion is presented on the plot. (i.e.; cable size, type, center conductor seize) not like some of the information circulated in our industry which show a plot but with no accompaning information or description.

As the system requirements are expanded to a greater number of channels and services that must be provided, it becomes necessary to examine the electrical requirements of the connectors used in these systems. These requirements, fall into only two categories that will effect system performance, insertion loss and return loss.

On the surface it would appear that measuring either one of these parameters would be quite simple, however, if one gives these measurements some thought it becomes evident that this can become real problems as to test fixtures methods, etc. "How does one test an entry connector?" "Easy", one answers. "Install it in a housing and run your tests." This sounds easy and is, if the test connectors, cable, housing and terminations are all perfect.

But now lets come back to earth and see what we can do about testing a connector by itself. In order to test a connector for return loss, the cables, test fixtures and termimators must be considerably better than the connector to be tested. To be assured that the test is valid much pretesting needs to be done, and methods developed that will minimize the contributions of the test fixture to the overall result.

Fig. 5 shows one type of test fixture that can be used to run return loss measurements on an entry connector. The fixture is a standard 1/2" Test Connector, Lumafoam III Cable, and a special connector bored out to permit the cable to go all the way thru. The cable adapter has 5/8-24 female threads and allows the terminatied cable to go all the way thru to butt the ends of the cables. Calibration is then made with no connector in place. To test entry connectors the cable must be prepared and the connectors substituted for the bored out entry. The center pin of the connector is cut flush with the 5/8-24 male thread and the special adapter and termination are screwed on to complete the test. To test splice connectors both pieces of cable are prepared and the splice inserted between them, but in all cases it is possible to first run the complete test fixture by itself before adding the connectors to be tested.
See fig. 6

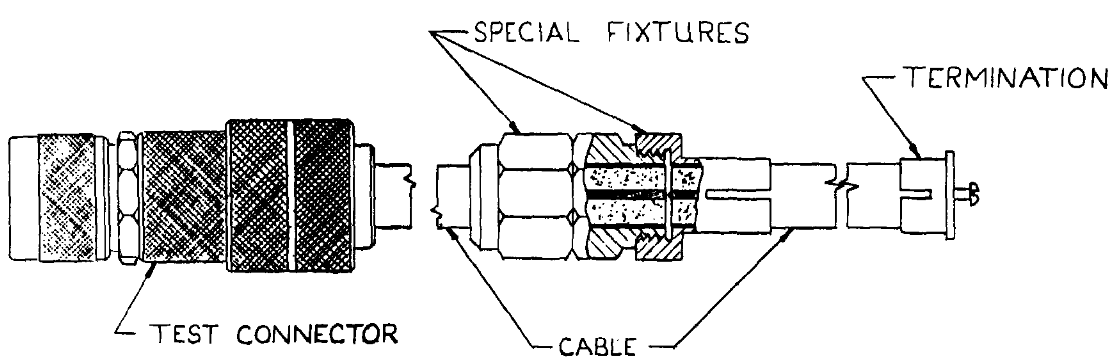


figure 5

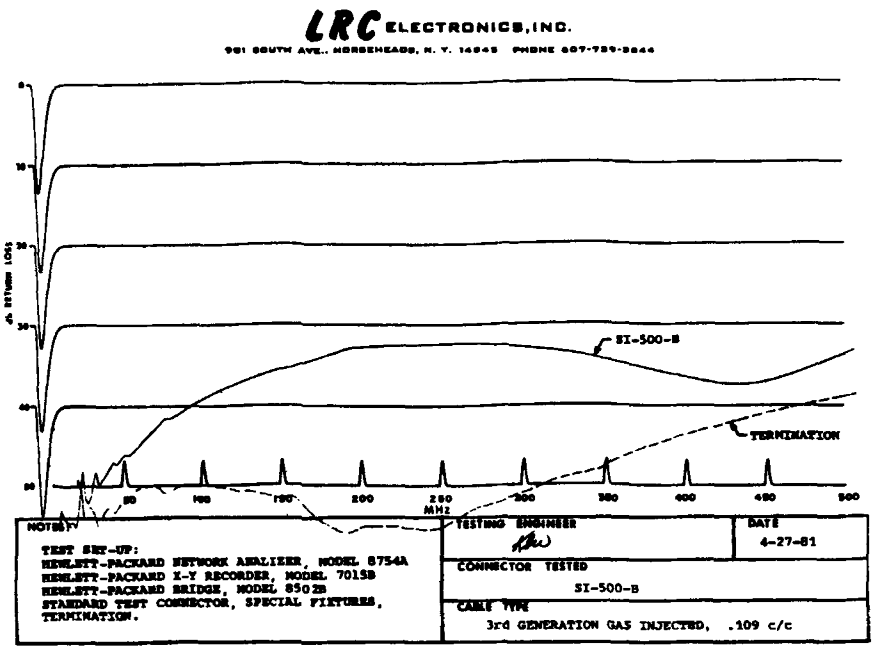


figure 6

After considering the many features of the connectors offered the final step in your selection process should defintely included a "hands on" session with connectors you are considering. With the instruction sheet in hand go through step by step the actual installation of a connector on a sample of the cable you are going to use and pay close attention to any problems that may arise such as cable twisted or difficulty of assembly.

After installation remove the connector from the cable and note the amount of gripping shown on both center conductor and cable sheath.

Much information has circulated in the cable industry as far as the electrical specifications of connectors and associated equipment with little thought given to the overall effect on the system performance. Until the cable industry has some equipment performance standards, it is up to the technical staff of the user to determine practical specifications for the system that is to be built.

UPSTREAM NOISE AND BIT-ERROR RATE ANALYSIS OF AN OPERATIONAL ONE-WAY SYSTEM CONVERTED TO TWO-WAY OPERATION

CLAUDE BAGGETT, PAUL WORKMAN, MICHAEL ELLIS

COX CABLE COMMUNICATIONS, INC.

INTRODUCTION

A. As an industry, we have spent many years perfecting the art of building analog RF wideband communications systems. Although the meaning of the term "wide-band" takes on a new meaning every few years, and the technology of RF circuit design may still be more black art than science, still we have become fairly comfortable with this discipline. Now, however, we have witnessed the marriage or perhaps elopement of digital data processing with our broadband RF analog cable systems. What will be the ultimate issue of this union cannot be fully determined at this time, however, it can be said that it is here to stay. Cox Cable has responded to this stimulus by the development of its Tandem T-16 based INDAX system. INDAX, which is an acronym for INteractive DAta eXchange system, is a versatile, modularly expandable interactive data system for subscriber services and is based upon the multi-processor, fully load-sharing Tandem T-16 system. Communications between this central processor and the user terminals occurs over dedicated bandwidth on the subscriber cable. The basic data transmission rate for all INDAX communications is 28 KBS. This occurs in two different modes. A number of 28 KBS channels are set aside for what is essentially one-way common user communications. In this mode, data items of common interest, such as sport briefs, stock market reports, news and the like are constantly cycled. A subscriber may tap into one of these 28 KBS channels at any time without requiring a unique response from the INDAX processor. The second mode of operation is a two-way interactive process, which once again is implemented over dedicated bandwidth on the cable. This service also operates at 28 KBS, but in a different manner. After extensive investigation Cox has determined that the most efficient implementation for this kind of service is a packetized system utilizing carrier sense multiple access with collision detection, commonly called CSMA-CD protocol. With this technique, all communications occur in standard digital packets in a listen-before-transmit mode. This is the CSMA portion of the protocol. The CD, or collision detection, means that the transmitter listens to see if another transmitter came up at exactly the same time. If so, a random time is delayed before attempting to retransmit. Utilizing this process, the INDAX two-way interactive system achieves a 70% efficiency.

B. Cox has installed and is now operating INDAX in a very large test area in our San Diego system. However, before this occurred, Cox wished to determine two very important things. First, what kind of bit error rate environment would our INDAX system be working into in San Diego and what distribution would those errors take; and second, would the inclusion of digital data and the possible carrier collision in a CSMA-CD type system have any adverse effect on adjacent video channels. From the engineering standpoint, we felt that San Diego was a good choice because the system, although well maintained, is not new and is very typical for systems of its age, size and construction. After an initial examination of the typical spectrum on the plant, we knew that we would never be accused of testing INDAX in a pristine laboratory environment. Not a "worst case" perhaps, but certainly representative.

With this introduction, let me now proceed with a description of the test.

TEST STRUCTURE

A. The portion of the INDAX market area chosen for the test is as shown on this slide. We arbitrarily designated the trunk amplifier at this location as the headend and chose a subscriber point downstream through an eleven amplifier cascade. These sites were primarily chosen for the convenience of the test and observational personnel. The headend for the San Carlos area is located atop Cowles Mountain and requires a 4-wheel drive vehicle to approach. We were not convinced that our rental cars were adequate for the climb, nor that we were up to the attempt. Our choice proved to be good as there was considerable bouncing back and forth between each end of the test sample. The test supervisor was Mr. Claude Baggett, Manager of Advanced Systems Engineering for Cox in Atlanta. The chief test engineer was Mr. Paul Workman, Chief Engineer for Cox's subsidiary in San Diego. Assisting were Mr. Gilles Vrignaud of Catel Corporation, Mr. Mark Dineson of Sytek Corporation, and Messrs. Bob Celuska and Dan Barton, technicians from the San Diego system.

B. This slide shows a block diagram of the test set-up. Note that with frequency translators at both ends of the test sample we were able to vary the amplifier cascade in eleven amplifier increments out to a 44 amp cascade, which we did. We used Sytek, Inc. Tverter frequency translators, the new Catel Prentice FM system FSK modem, and an Amdax Model 740 Bi-Ø modem. Test equipment included the Avantek 2000 Analyzer, H.P. 141 Spectrum Analyzer, Instrument Flight Regul. Receiver Corporation, Model FM/AM-1000A Transceiver, and the Astrocom Corporation AC-1900 data test set.

TEST PROCEDURE

With this equipment, we were able to observe the following test factors:

A. Amplifier Cascade, as previously stated.

B. Data Rate, up to 19.2 KBS.

C. Modulation Scheme.

D. Signal Input Levels from a maximum of 15 dB below video through the error threshold and below (35 dB down from video.)

E. Carrier Collision.

At a data transfer rate of 19.2 KBS, to measure to a 10^{-8} error rate takes a minimum of 1-1/2 hours per test run. Since we wanted to make measurements with two different amplifier cascades, two different modulation schemes at 4 levels, a total of 16 tests were required at 1-1/2 hours each. In fact, as we gained experience with this testing, we found that several of these data points were unnecessary, since the communication scheme was far more robust than first believed. As a result of this, only the threshold areas needed to be investigated for definition. The tendency of the modems were to hang on until the signal passed below sync lockup threshold, then drop out at once. If timing were provided through an alternate source, data transmission would have been possible to a much worst S/N.

Based on findings that the maximum cascade which we were able to achieve exceeded the minimum requirements for threshold operation, we proceeded with the following special tests to get a better feel for operation of data transmission with multiple modem technologies.

The modems previously mentioned incorporated three methods of modulation. They were: FSK, FM and Bi-Phase. The purpose of these special tests were to determine the effect of collisions with other data carriers in the cable TV RF spectrum as well as to determine the impact on the bit error rate during such collisions. This was accomplished by using a CW generator and zero beating it with the data carrier which was transmitted at a level 15 dB down from video signal reference. The amplitude of the injected carrier was varied from a level equal to the transmitter carrier to a level 12 dB below the transmitted data carrier with the following findings:

With the data carrier 12 dB greater than the interfering carrier, there was no change in the BER. As the interfering data carrier level was increased, the bit error rate increased to the point when the interfering carrier was 7 dB below the data carrier level at which point the system totally failed. The results of comparing this with the three different modem modulation techniques indicated that the superior decoding capabilities of the bi-phase was able to hold a higher bit error rate than was the FSK or the FM, however, all three still failed at the 7 dB level.

With regard to spurious signal generation due to the collision of data carriers is precisely controlled, all spurious signals fell within the expected bandpass of the data channel and were greater than 60 dB down in adjacent channel spectrum.

Another question which was quite frequently asked and which we sought an answer to was whether the bit error rate would be proportionate to the data rate on the system. Given the limitations of the modems we had available to use at the time of the test, we varied the data rates from 300 baud to 29 Kbaud, holding other parameters in the system constant and found no measurable difference in bit error rates. While it can be argued that burst noise impacting higher speed data rates can affect a higher instantaneous bit error rate, the statistical average always came out consistent.

Another test which we accomplished was to check the bit error rates on the cable TV system as a function of carrier-to-noise ratio. This was accomplished by reducing the output carrier level of the transmitted modems under test. The findings are shown on this slide. As you will notice, at the time of this test, a consistent knee in the bit error rate showed up between 27 and 30 dB down from peak video carrier on the cable TV system. The sharpness of this knee was dependent on the method of modulation and de-modulation used in the system with bi-phase having the sharpest knee.

Since these tests were initially made, we have proceeded to complete the design of the overall INDAX system in its analog and digital forms and have had additional opportunities to test this newly designed hardware in the San Diego system.

Our initial concerns were that a converted two-way operational system could be kept free of spurious signals in the return path. We have since found that normal good trouble-shooting procedures in keeping equipment aligned and connectors tightened has been sufficient to supply a 44 dB carrier-to-noise ratio for the upstream signal path with approximately 200 miles of plant activated.

The present system in San Diego has not been modified for bridger switching nor have the drop cables been replaced for higher RFI integrity. Based on our earlier tests, our requirements had called for a 10^{-8} bit error rate using a 33 dB carrier-to-noise ratio as a design parameter. It is apparent, based on these tests and later operational findings, that this was a conservative design goal.

Several areas of interest have come out of the testing and development of the RF portion of this design. The method of modulation, modulation index, and pre-modulation requirements that would give a noise-free narrow band data transmission system. It has been shown in our tests that Manchester and bi-phase modulation coding schemes offer superior data recovery capabilities. It is not clear at this time that a data recovery system requires the complex overhead of these modulation schemes in order to work effectively. The use of a pre-modulation filter in FSK and FM modulation allows for the compression of the data in the RF spectrum and is shown to be a very valuable trade-off. It has not been found that wide band FM adds any significant performance to the operation of the data system.

As INDAX and other cable based data transmission schemes move forward in the near future, additional data will be gathered and will help in bringing this technology into reality.

"VIRTEXT & VIRDATA:
ADVENTURES IN VERTICAL INTERVAL SIGNALING"

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There are many videotex tests, trials, experiments, and demonstrations in the U.S. But, to the best of our knowledge, there is only one commercial operation based on teletext technology in the U.S. This enterprise is based on practical, produceable, cost effective hardware. The results have been encouraging. Several important new features have been introduced.

Additionally, a brief discussion of the teletext activities in Chicago will be included.

INTRODUCTION

Text-on-Video activities in the United States are accelerating. This is a many-faceted situation and this paper will concentrate on only a few aspects. The aspects chosen for emphasis are those with which I have closest association. Specifically, I will cover the satellite applications, and some features of the Chicago venture.

It is amusing to note that we see a pattern emerging which allows us to gauge the progress of a new technology. The first people to make money on a new technology are the short-course organizers. Closely following these are the multi-client study people. Conferences and newsletters pop up next. Once the important issues are defined, the lawyers enter to determine the nature of the rights to the technology. Of course, the lawyers make as much money as all the preceding phases. Finally, the hardware and software producers become involved. Their problem, of course, is the classical chicken and egg problem. Hardware sales are hampered by lack of software; software producers are less than enthusiastic in the face of a paucity of hardware. In the case of videotex, one opportunity exists for an amelioration of the chicken and egg problem because the chicken and the egg can be relatively inexpensive. Videotex technology is currently in these last two stages.

VIRTEXT

The first commercial, non-experimental application of teletext in the United States is the Cabletext system by Southern Satellite Systems. This fills a current market need. U.S. cable television systems presently have what are called "Character Generator Channels." Information suppliers provide data signals over telephone lines to cable signal origination points. These signals are converted into synthetic video for modulation onto otherwise blank television channels. The viewer sees scrolling lines of text. The usual information providers are Reuters, United Press International, Associated Press, Dow Jones, and others. This is a current well established practice in the U.S. cable industry. Another well established practice is the use of "super stations." A super station is a formerly local television station which is picked up and distributed nationwide via satellite to Television Receive Only (TVRO) earth stations. The first super station was Channel 17, WTBS-TV of Atlanta, Georgia. Ted Turner was the spark plug behind this concept and Southern Satellite Systems, Inc. (SSS) made the technology work. Now WTBS is received by almost three thousand TVRO stations for use by cable systems. WGN-TV Channel 9, Chicago, is another super station; it is distributed by United Video Inc. to about one thousand cable systems.

SSS conceived of the concept of using teletext to distribute the data via the super station's Vertical Blanking Interval (VBI) to its subscribers. This allows the cable systems to avoid leased telephone line charges. In addition to this benefit, the SSS system facilitates the entry of new, smaller information providers. The equipment used to provide the SSS CableText service is based on British defined format teletext technology in general and the Mullard integrated circuits in particular. An early adaptation of this technology to North American television standards was accomplished. The result is a workable, efficient, and cost effective system. However, it is not precisely the British proposal for teletext in North America. It is a precursor of that standard. It is important to realize that VIRTEXT and VIRDATA seek to build on a technology which has an economic embodiment available, i.e., integrated circuits. However, VIRTEXT and VIRDATA must be incompatible with what might someday be a consumer service because the specific application of VIRTEXT and VIRDATA requires restriction of access to subscribers. Full compatibility would permit theft of service. Specifically, VIRTEXT differs in that the page format is twenty rows of forty characters instead of twenty-four rows, none of the enhancements are formally included, and the method of "gearing" is a preliminary approach.

GEARING

The hallmark of the defined format teletext system is the one-to-one relationship between time in the television signal, location in the page memory, and spacial position on the television screen. By simply knowing where an information bit appears in time in the VBI, its location in memory, and its position on the television screen are unambiguously determined.

This procedure has two very important consequences. First, it is a very rugged signaling scheme because it carefully contains the results of any transmission errors. Errors are simply not allowed to propagate. The decoder takes advantage of the most stable part of a television signal, the horizontal synchronization pulse. The second very important consequence is that the decoder is made less expensive by not requiring the processing of the signal prior to loading it into memory. A microcomputer is not needed for decoding the teletext signal; there is nothing worthwhile for it to do. The data comes pre-addressed, caryying with it its memory location. Thus it goes directly into memory. There it is stored for access by the raster-generating circuits. In essence, the processing of the data has been pre-accomplished once, at the signal origination point. This task is not wastefully repeated in each decoder.

Gearing is the procedure which allows the preservation of a one-to-one relationship between time in the television signal (as measured relative to the horizontal synchronization pulse) and the spacial location of characters on the television screen. Because the British television channel bandwidth is significantly larger than the North American channel bandwidth, a higher signaling bit rate can be supported. Thus, all forty characters which are displayed in one row of the teletext page are transmitted in only one horizontal television line. The North American bandwidth being smaller will not allow this. The gearing procedure provides an ordered method of partitioning the characters between the television lines. SSS employs a 30/10 ratio with 5.5 megabit/second data rate. Thus, the first thirty characters of the first teletext row are transmitted, then the first thirty characters of the second row, then the first thirty characters of the third row. Following this is the three sets of ten characters which are needed to fill in the first three rows. This procedure is repeated until the page is filled. This takes place so quickly that the viewer does not notice the details. The page quickly wipes on to the screen.

The VIRTEXT method of accomplishing gearing is an effective method using special control characters which are Hamming protected. The official proposal for teletext in North America uses an improved method of gearing which is somewhat more rugged and efficient in terms of hardware realization. The two methods work well but are not compatible.

DATA RATE

The data signaling rate of the VIRTEXT unit can be changed by replacing a few components. Among the various possible rates are 4 Mbits/second yielding a 20/20 gearing ratio and a 5.7272 Mbits/sec rate yielding a 32/8 gearing ratio.

The Mullard teletext chip set for the U.K. is employed. Only the timing chip has been modified for 525 scan lines. External chips are added to accomplish gearing.

TWENTY-FOUR ROWS

A twenty row display is exceptionally convenient and suitable for the VIRTEXT application. However, we are advocates of a twenty-four row display for the actual videotex services. We have built several different versions of twenty-four row display and have found twenty-four rows to be very practical and economical, both with decoders built into receivers and with set-top adapters. These techniques have been demonstrated to the Electronic Industries Association (EIA) Teletext Committee. We believe there is no question that twenty-four rows are technically achievable, economically practical and eminently readable when used with character rounding and intelligently designed character fonts.

PAGE SELECTION

The user of the VIRTEXT equipment has several methods of page selection to choose from. This is because the page selection mechanism is interfaced with a four bit microcomputer. The usual wired or wireless remote control key pad is available as well as a set of thumb wheel switches mounted on the panel of the unit. Additionally, the unit can be hard wired to receive only a small number of pages or the microcomputer can be programmed to work its way thru a group of pages. The nonsubscriber can be precluded from accessing pages.

ORIGINATION EQUIPMENT

A small business computer product, the Zenith Data Systems Model ZDS-89, has been programmed to create teletext pages and to organize them into magazines. This unit plus a small rack-mounted box of electronics is all that is required to generate teletext signals. Software packages are available for VIRTEXT as well as the proposed British standard. In fact, this small scale signal source can originate Antiope, Telidon, or any other signal format. The unit is small scale, capable of forty-eight page magazines, and holding seventy pages on a floppy disk. Two computers could be used to double this capacity immediately. Other methods of increasing capacity are under development.

VIRDATA

Because the coding structure and the Mullard chip set has so much inherent flexibility, we have been able to add several exciting extensions to VIRTEXT. And yet, we have hardly begun to exercise its full flexibility.

The VIRDATA system allows for transparent data transmission simultaneously with transmission of teletext. The data can be computer programs, teletypewriter signals, or other teletext formats such as Antiope and Telidon. The header row contains control signals which can be assigned to direct a microcomputer to handle the data sent in the rest of the line. This data can then be formatted for an RS-232 plug on the back panel of the unit.

If one line in the vertical interval is permanently assigned to this function a baud rate of 13,200 can be supported. More lines can support higher data rates. Conversely, if lower baud rates are all that is required the VBI line can be time division multiplexed to simultaneously provide teletext. It is important to note that this powerful adaptation is by no means the most efficient transparent data transmission mode. It's just one method that is particularly convenient for implementation with the integrated circuits as they currently exist. Since it fulfills the requirements of its application with plenty of margin, there is no need to search for the optimum. The "unhook mode" of British teletext is more efficient and does not require a microcomputer. However, as previously mentioned, this application seeks to build on but not be compatible with what might someday be a consumer product.

An important application of VIRDATA is in situations where an elaborate set of type fonts is desired. Here VIRDATA's RS-232 output drives a commercially available character generator to yield the type face of choice.

OTHER EXTENSIONS

A second type of RS-232 output is available. Called page-dump, it allows hard copy printout of what appears on the teletext screen. Of course the result is in monochrome. A detailed record of pages received is possible.

Multipage storage versions allow many pages to be received at a convenient time for subsequent display. Time codes associated with the pages permit them to be called forth and retired at assigned times.

An important feature assigns each decoder its own private address. Thus, electronic mail can be delivered only to the intended decoders. Global messages can, of course, be sent to all decoders.

The teletext page number is just an annoyance to viewers on a cable or master antenna system who do not have a remote control. Thus, an enhanced version suppresses the header row. Borders of selectable color replace the black frame of the original series of decoders.

The fundamental flexibility of digital systems makes it possible to assign control code sequences which can be used to cause relay closures. Thus, a remote control mechanism is established.

TRUE TELETEXT POSSIBLE

Since the SSS teletext signal is carried in the VBI of Channel 17, WTBS, and since no cable system is known to blank out that signal, VIRTEXT and VIRDATA decoders can be carried into the cable system for true teletext performance. That is, the user can be given personal control of which pages appear on his screen rather than having to wait for the page of interest to roll by. This has been tried in several cases with quite encouraging results. Both set top adapters and decoders built into receivers are possible from components already available. Only the details of assembly and interface are required. It is anticipated that this will take place later this year.

THE CHICAGO ACTIVITY

While VIRTEXT and VIRDATA are specifically intended not to be compatible with a broadcast teletext standard, the WFLD-TV, Channel 32 activity is the first complete realization of level one of the British proposal for teletext standards. The WFLD activity comes under a newly formed subsidiary called Field Electronic Publishing (FEP). FEP information comes from the Chicago Sun-Times newspaper via telephone computer link. A unique feature of the FEP activity is the permission to charge advertisers and to lease receivers. The only way to determine willingness to pay is to provide an opportunity to pay. Anything less is mere hypothesis. A second unique feature is that FEP is entirely funded by Field Enterprises. There are no government (foreign or domestic) funds and no foundation grants. This makes for a more rigorous test of the economic viability of the enterprise.

Again, the four Mullard integrated circuits are the kernel of the decoder. But this time the integrated circuits which surround the four implement the official proposal. Twenty-four rows, 5.7272 megabit/second data rate, and the new method of gearing are employed.

Approximately, one hundred and fifty color receivers will be involved. These will be twenty-five inch receivers with the decoder entirely built in. The picture tube's red, green, and blue electron guns will be directly driven (RGB drive) for the sharpest possible images with the most saturated colors. The television's wireless remote control key pad will also control the teletext functions. Since the key pad is interfaced via a microcomputer, several interesting consumer convenience features will be tested. The receiver includes a special linear phase surface wave intermediate frequency amplifier, synchronous detector, and special matching filter for data.

Later, a set-top, antenna terminal decoder is planned. Also, a cable-head end version which will allow character generator-like pages to be placed on blank cable channels will be introduced. This is similar to our VIRTEXT product, except that compatibility is desired and use of the signal is encouraged since the signal is advertiser-supported.

It is intended that after-hours transmission will soon go to full field. Only data will be transmitted permitting four to six hundred pages per second capacity.

As the venture proceeds, levels two thru five of the British proposal will be implemented. Parallel attributes by the more efficient ghost row technique and smoothened mosaics are just some of the enhancements of level two. Level three includes Dynamically Redefineable Character Sets (DRCS) which permit cost effective, high resolution graphics. Level four features alphageometric graphics which can be Telidon compatible and level five boasts alphaphotographic level quality. The unhook mode for transparent data transmission will also be implemented.

WGN-TV Channel 9, the Chicago Tribune-owned VHF station in Chicago, has experimental transmission of teletext using the VIRTEXT equipment. This equipment was chosen for its immediate availability. It is convertible to the official standard proposal. Level one conversion is available now.

CONCLUSION

A very practical and broad system of features have been described which are possible because of the flexibility and extensibility inherent in the defined format teletext system. The Mullard integrated circuit set's implementation of this system is particularly convenient for realizing these potentials. The limits of the system have not yet been found.

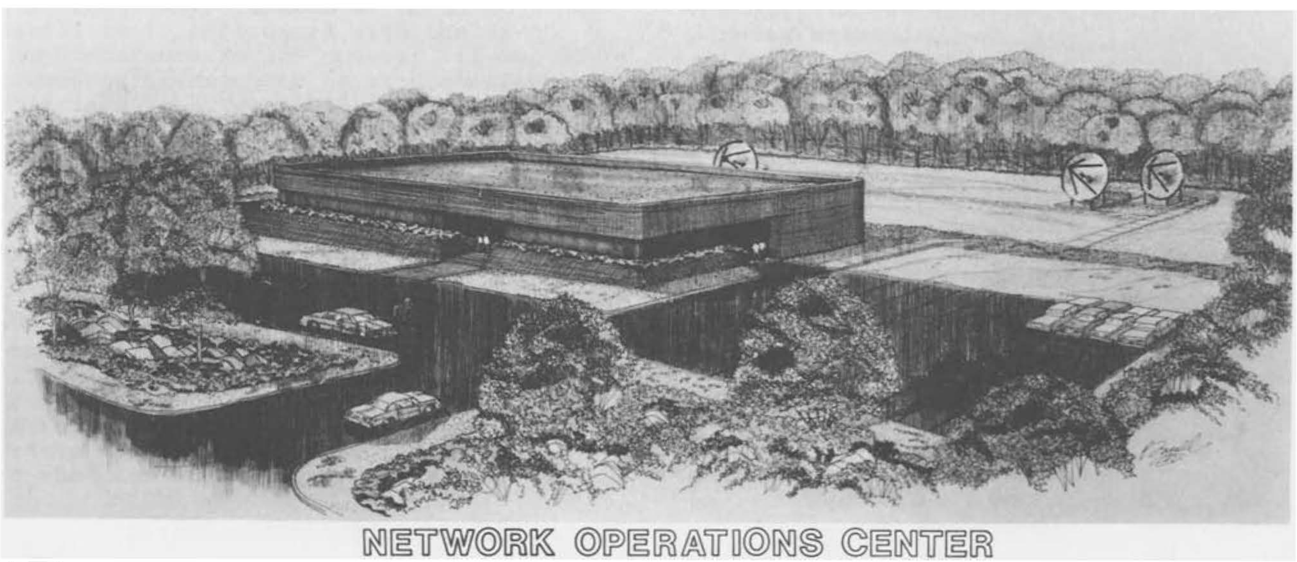
WASEC'S NETWORK OPERATIONS CENTER

ANDY SETOS

WARNER AMEX SATELLITE ENTERTAINMENT COMPANY

ABSTRACT

A year and a half ago the newly formed Warner Amex Satellite Entertainment Company was given a charter by its parents, Warner Communications, Inc. and American Express to develop and operate several national cable television networks. In order to accomplish this goal plans for distribution both on the earth and in space were formulated. We describe operational requirements and the resulting design concepts which led to plans to construct the WASEC Network Operations Center in Smithtown, N. Y. NOC will begin operations 12:01 a.m. 8/1/81 to deliver MTV, Music Television, The Movie Channel, and Nickelodeon.



Warner Amex Satellite Entertainment Co.
Proposed Facility Smithtown, N.Y.

BACKGROUND

Currently WASEC leases space in Buffalo, New York for its videotape and communications equipment. Although operations there are now satisfactory opportunities for long term expansion are poor and its remoteness from headquarters is an intantible but sorely felt factor. In the summer of 1980 we undertook a search for a site that would meet our needs realizing that new program service offerings would be delayed until a new expanded facility was available. A list of site selection parameters was developed while the facility itself was being designed. During the course of this project the PERT system was used to insure tasks would be undertaken at a moment most appropriate to complete the project within a minumum amount of time.

SITE SELECTION

To consider a site we used a scoring system with factors of differing weights. In order of importance these were:

1. frequency coordination
2. community acceptance
3. available work force
4. proximity to headquarters
5. available services

The New York City metropolitan area is a most congested communications environment. Armed with such tools as natural and man-made shielding evaluations were made both with computer and on site RFI measurements. ATT Long Lines was invited to the site during the prior coordination phase so that upon application to the Commission there would be a minimum of objections. Community acceptance was a crucial hurdle. As site selection narrowed community officials were briefed frankly and to the point regarding potential hazards and benefits of such a facility so that we would gain an early sense of disposition to our plans. It was important to have a resident trained workforce to augment those who accepted the staff-wide invitation to relocate from Buffalo, as we would need fifteen to twenty additional operators and technicians at Smithtown. That intangible, proximity to headquarters was constantly directing our focus nearer to transportation facilities and the city itself. We also considered the density of high technology service and supply companies which would make routine and emergency repairs that much easier.

The difficulty of reconciling the first two criteria with the last three was great. But a location in the township of Smithtown, N. Y. within an industrial park met all our specifications. Using natural and man-made shielding and employing a double diffraction model the orbital arc from 50°W to 150°W was cleared for the entire C band. WASEC now holds an FCC Construction Permit for the site. The industrial park has served as a high frequency communications facility for over forty years and recently within the park two 11 meter X band antennas have been erected for an experimental military satellite program. These installations made explaining the nature and implications of our facility to the county officials that much easier. Zoning variances were approved on the eve of the hearings. With respect to available workforce, a ten mile radius encloses two UHF televisions, several large cable systems, and three universities each with elaborate teleproduction centers. The site is located a little over an hour by car from headquarters via two main highway arteries and is serviced by the Long Island Railroad. Also it is five minutes from an airport which can be reached in ten minutes from a Manhattan heliport. Within a five mile radius are several major suppliers of equipment and services needed by such a facility. In fact, the ground communications equipment design is being supported and will be installed by a firm within the industrial park, Satellite Transmission Systems.

DESIGN

Three overall factors quided our design of NOC, all of equal importance.

Capacity

Quality

Reliability

WASEC now operates two networks, The Movie Channel and Nickelodeon. On August 1st, MTV, Music Television will be launched. Several program service offerings are in various stages of development. Our space segment now consists of four 24 hour assingments on RCA Americom's Cable Net 1 and one 24 hour assingment on Cable Net 2. Soon RCA will allocate an additional thirteen 24 hour assingments for activation in January 1982. Taking these factors into consideration we settled on a building able to house ten sets of facilities to service any particular network. Each facility will include highband videotape equipment, a control room, and ground communications equipment. In addition there will be three communications antennas; two of eleven meters and one of seven meters diameter. While these will serve the near term long term capacity of the site will allow the addition of two eleven meter antennas plus tripling the building size. In all we have purchased four acres of land and are constructing a 15,000 sq. ft. building.

The technical quality of our picture and sound is of major importance. In the homes of your subscribers premium, basic, distant signals, and must carry's will all be judged by the same standard. WASEC intends to be unsurpassed in this arena. Every piece of equipment has been selected as an example of state of the art. Every moment of origination will be from either 1" Type C format or 2" quadraplex cartridge machines. There will be a dedicated control room for screening all incoming programs so that picture and sound may be monitored in a darkened and quiet environment. Digitally generated VITS and VIRS will be continuously available on all networks for in-use testing. To protect our videotaped programs from premature wear the atmosphere within the plant is cleaned with filters used in hospital operating rooms and kept to close temperature and humidity specifications.

Sound shall not be the "forgotten child" of WASEC's networks. All equipment, including quadraplex VTR's, backup VTR's, routing switchers, and patch fields have been designed for two channels of sound. The first Dolby A noise reduction equipment designed to be integral to the Ampex VPR-2B's will be employed. The sound transmission system for MTV, Music Television will carry to your subscribers hi-fidelity true stereo sound doing justice to the most discriminating audiofile's component audio system.

High reliability is maintained by a balance between personnel and equipment. Not only must the inevitable equipment failures be taken into consideration but the work load and environment must be analyzed to ensure technicians will not be overly burdened with information or tasks, therefore avoiding potentially error prone situations.

Elements of the equipment backup system include:

1.a. Prime power diesel electric set for the entire plant with a four day fuel supply.

b. Five minute Uninteruptible Power Supply for all technical equipment to carry load while the generator starts up.

c. Dual primary power feed from the electric utility company to avoid outages caused by local power line interuptions.

2. Completely redundant Heating, Ventillating, and Air Conditioning System.

3. Each "VTR" is an ensemble consisting of:

   1" Type C w/TBC
   3/4" w/TBC

   Time Code Synchronizing equipment
   Audio Video switch between the two VTRS

   This ensemble will ensure that programming will not be interupted due to VTR related difficulties.

4. Isolated backup switching equipment in each control room.

5. Two Hot Standy Exciter/HPA's under computer control.

6. Temporary emergency authorization license for transmit on the seven meter antenna in case of an 11 meter antenna failure.

All of these steps have been taken to ensure that a single point failure will not effect operations on any network.

Elements of the personnel workload limiters are:

1. One control room per service - no operator will be asked to operate or monitor more than one network.

2. Distributed computer control for each network using non-keyboard type panels - during the inevitable control system failures operators will have access to program switchers and VTR machine controls, rather than having to remember and type complex commands on a keyboard.

3. One inch reels will be limited to 1 hour in length so that there will be a uniform one to one relationship to backup 3/4" recordings.

4. Sound isolation will be used between VTR and Control Rooms so not to distract operators from the task at hand.

5. Uniformity of equipment by make and model so as to speed repairs by technicians.

FUTURE

This project will not end with the scheduled launch in August. In addition to providing for rapid expansion of capacity to distribute program services which are currently in development at WASEC, NOC will be used as a tool for technology development in transponder loading in order that we maximize the quantity, quality, and type of services we make available to our affiliates using limited transponder resources of domestic satellites.

ACKNOWLEDGEMENTS

Many people, manufacturers, and service firms provided customized and unique solutions to the challenges of this project. So thanks is in order for many. Above all Dom Satsi, Director of Engineering for WASEC has been instrumental in locating, designing and inplementing NOC. Compucon must be congratulated for going back to the computer keyboard repeatedly with new and unconventional models to fully coordinate this site. Finally Abcon Industries as construction manager took on a skeptical zoning board and formidable design task while keeping within a budget and doing so in one half the usual time frame associated with such projects.

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