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CHAIRMAN TAYLOR: Thank you very much. Does anyone have any questions?

I have a question regarding the effects of cross-modulation on the weaker carriers in a system. If we take a hypothetical case involving one strong carrier and say 8 or 9 weak ones, does the cross-modulation affect all channels equally or is there a difference?

MR. SIMONS: At this point I believe it is necessary to bring out something that was not stressed in my paper. In this presentation I have been talking about "mathematical" amplifiers. By a "mathematical" amplifier, I mean one which follows exactly the same way at all frequencies. With such an amplifier the cross-modulation from all channels on to any one channel would be identically the same.

The unfortunate thing about this approach is it doesn't work. Real-life amplifiers just don't behave this way. Generally speaking, the cross-modulation which shows up on any one channel in an amplifier is not the same as that showing up on any other channel. These differences are not very great so it is still useful to consider the "mathematical" amplifier as an approximation, but the differences are such that we must measure all combinations of channels if we are to be sure of amplifier performance. Generally speaking, there is no difference between weak channels and strong channels, the difference has more to do with the frequency of the particular channel.

CHAIRMAN TAYLOR: Are there any other questions? Thank you very much, Ken. I think it is quite significant in a matter with which I am quite pleased at this convention that we have several systems operators presenting ideas that they have developed in their systems which can be of use to other operators. This is so in the next paper.

Mr. Robert Scherpenseel is the general manager and microwave technician for the Northwest Video of Kalispell, Montana, a system I know a little about. He was chief engineer with WEVR FM of Troy, New York, chief engineer with KBTK radio, and engineer with KMSO-TV electronics technician at Montana State University in installing and maintaining their television and radio and recording systems. Mr. Scherpenseel is going to talk on "A Low Cost TDR". (Applause)

A LOW COST T.D.R.

By

Robert H. Scherpenseel

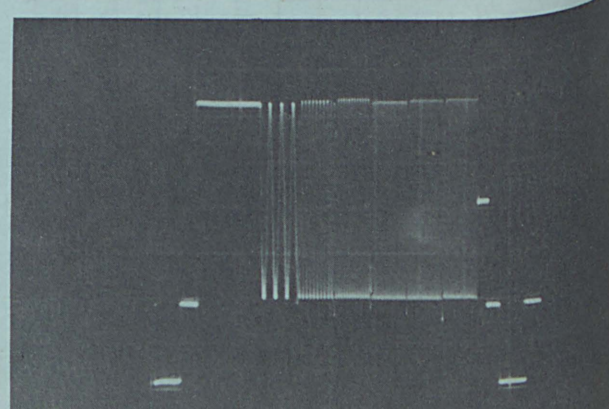
We are probably being a little facetious in calling this instrument a low cost time domain reflectometer. The 1967 catalogue price is $875.00. In a way it is a TDR but with limitations.

Actually, it is a high quality oscilloscope that has a calibrated time base and a vertical amplifier with a band pass of DC to 10 megaHertz. This is a limiting factor because no determination can be made concerning the frequency characteristics of the information displayed beyond 10 megaHertz.

NEXT SLIDE PLEASE (#2)

This is a picture of the scope with the camera mounted in place.

NEXT SLIDE PLEASE (#3)



This unit is primarily used in our work for the -play of video wave forms. This is the familiar lti-burst signal directly from a signal generator.

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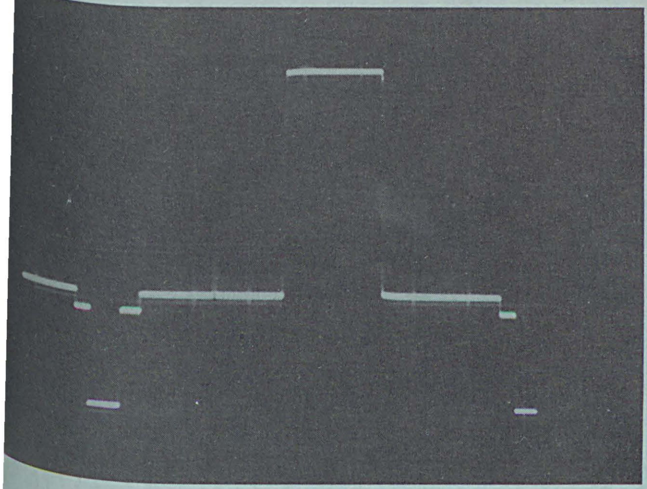

This slide is the sine squared and window signal lso from a generator.

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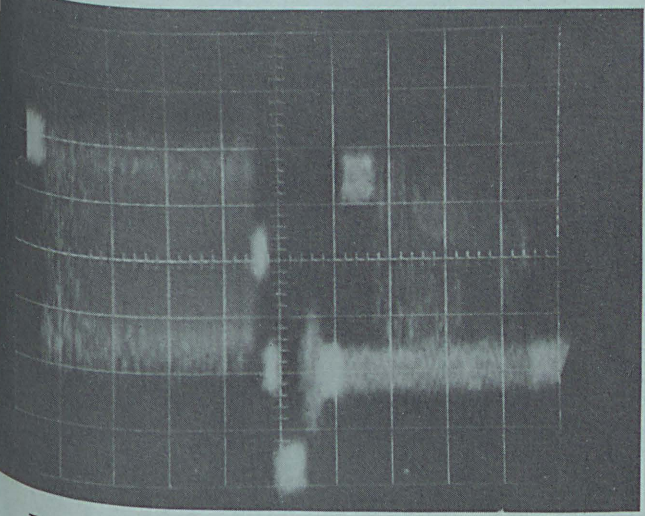

By an adjustment of the trigger control, we can atch a fleeting glimpse of the vertical interval test signals. The multi-burst on the left is from a Riker test signal generator injected at our microwave terminal and the one on the right is one from network received off the air. This is not the best of pictures but it illustrates that VIT's can be observed with this scope.

The time domain reflectometer portion is simply the plus gate output. This positive pulse, which starts at ground and rises to approximately 0 volts, has a start and duration coincident with hat of the sweep portion of the sawtooth. It CANNOT be directly coupled to a cable for testing because the amplitude is too great. If we try to examine the top of the square wave closely to observe the reflection by increasing the scope gain, it is lost from the display area. If we feed this signal through a small capacitor .001 and a resistor 75 ohms it becomes a spike.

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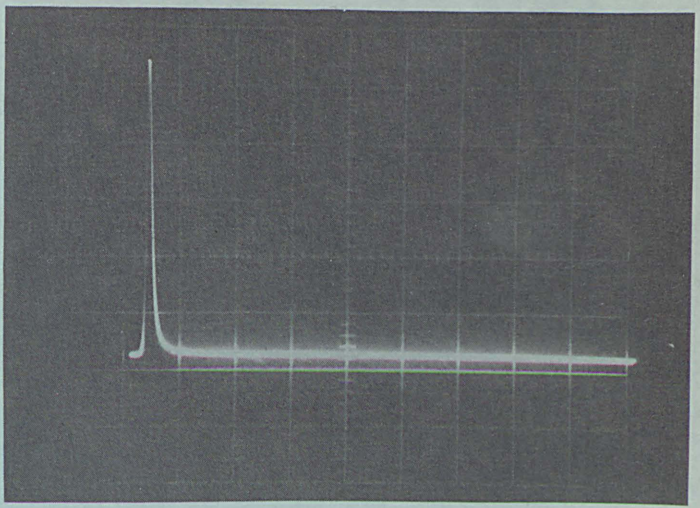

The base line then displays the reflections in the cable under test. Since we know that radio waves travel at the speed of light (186,000 miles per second) and by multiplying this by feet in a mile, we know how far they travel in one second. Our scope time base is calibrated in fractions of a second, we then can determine what each division on the graticule is worth in terms of feet. Using the velocity of propagation of the various types of cable we can then determine how far it is to a discontinuity and back. In foam diaelectric cable using a velocity of propagation .82 times the speed of light, the pulse travels about 800 feet in one microsecond so then one microsecond is equal to about 400 feet of cable because the pulse has to travel to a discontinuity and the reflection returned. If we are using solid polyethylene cable the velocity of propagation is .66 times the speed of light and the pulse only travels about 650 feet in one microsecond. This is equal to half that, or 325 feet of cable. There are some cables with different propagation factors but these two just mentioned are the most common and work quite well for us.

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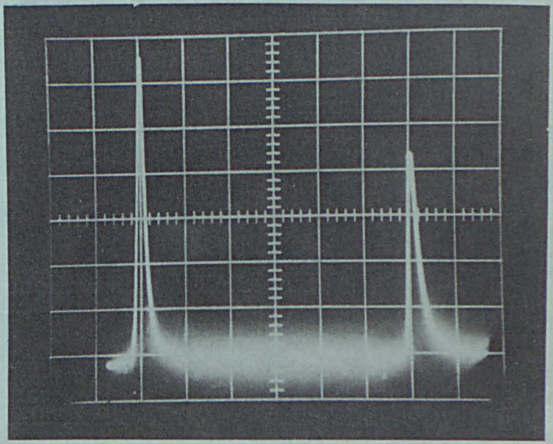

This slide shows about 1200 feet of foam cable with the end open. The scale horizontally is .5 microseconds per division, equal to 200 feet of cable - vertically is .1 volts per division.

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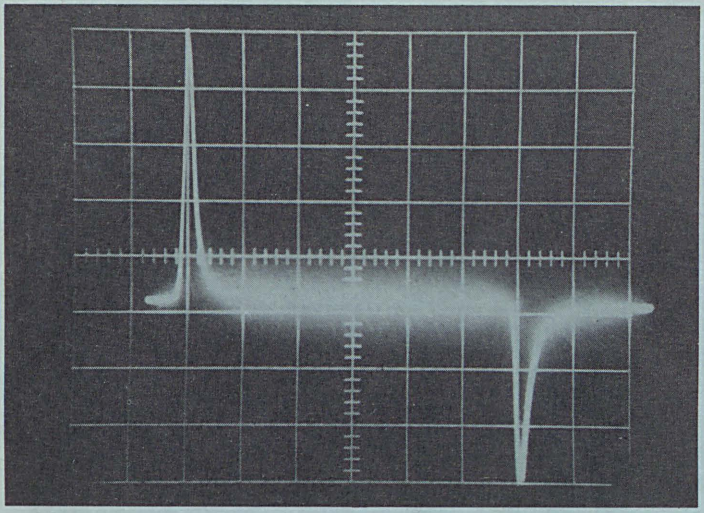

This is the same cable with the ends shortened.

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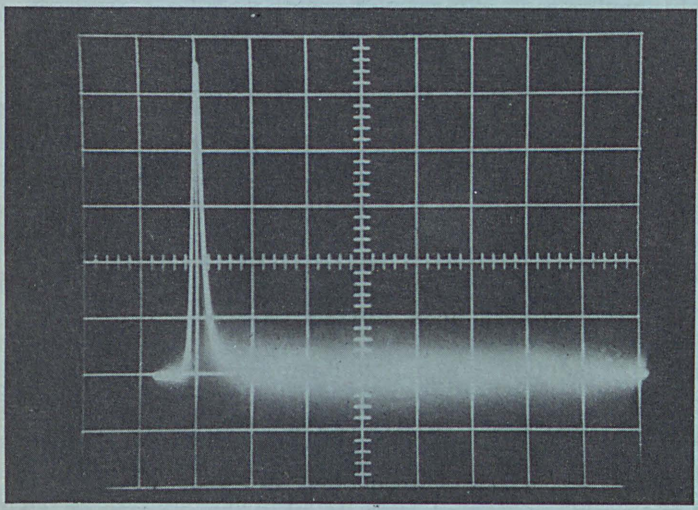

This is the same cable with the end terminated with a 75ohm resistor.

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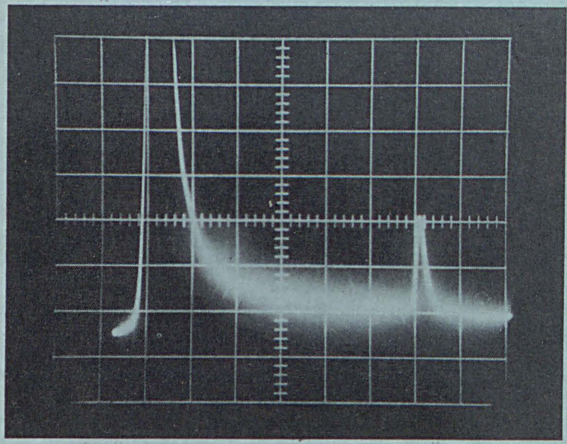

This is the same cable with the end still terminated with the gain of the scope at maximum and we begin to see some of the physical defects in the cable.

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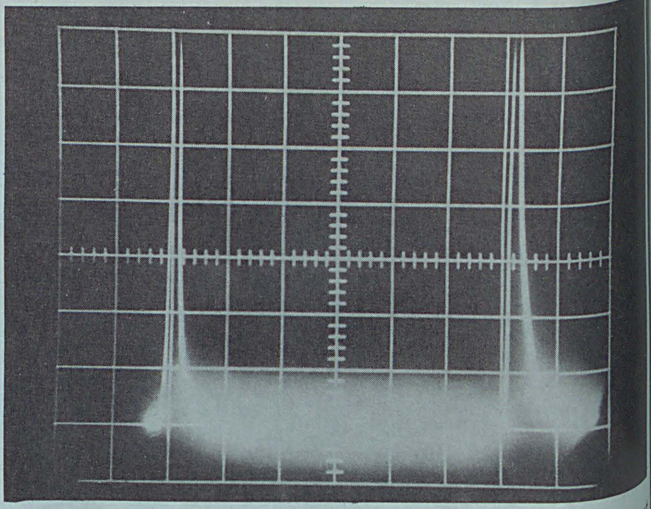

The scale here is 1 microsecond per cm., or about 400 feet per division over 6 divisions equals about 250[0] feet. Here we see about 2500 feet of two types of cable. The first 1400 feet is fairly new cable with a splice at 1100 feet and another splice at 1400 feet. The remain[der] is older cable that has been in the air for a number of years.

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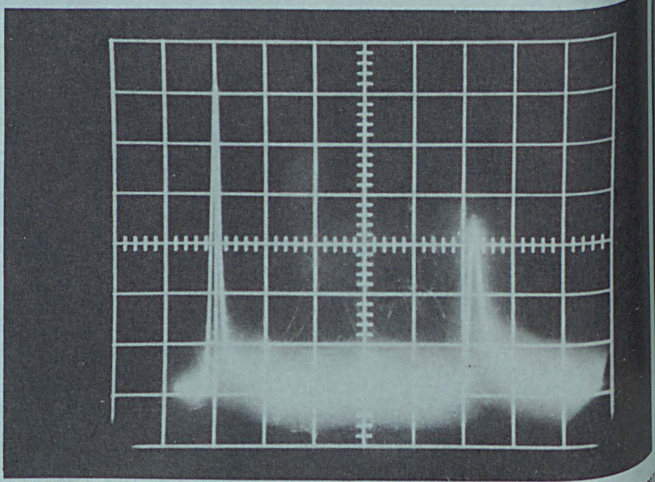

Here the scale is .5 microseconds per cm., or eq[ual] to 200 feet per division. This is about 1050 feet of cab[le] with a pressure tap and ending in a two-way splitter. [...] doesn't mean the splitter isn't good because, as I men[tioned] earlier, we are limited to physical factors because of [the] band width of the scope.

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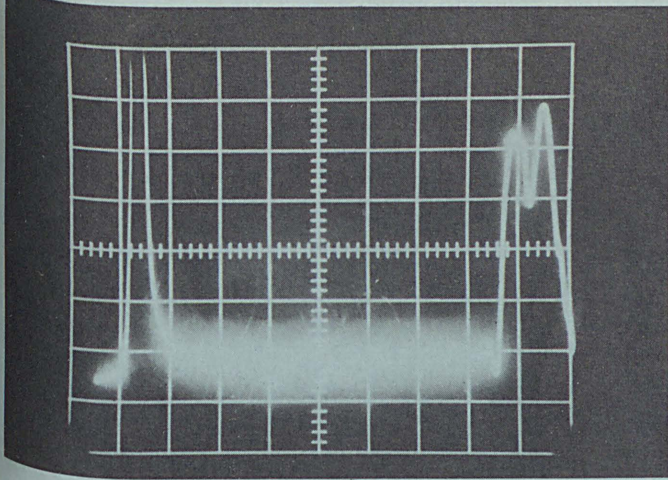

The scale here is .5 microseconds per cm., over 7 divisions or 1500 feet. This is about 1500 feet of cable with taps at 200 feet, 400 feet, 600 feet and another splitter at the end. Probably one or both of the legs of the splitter are not properly terminated.

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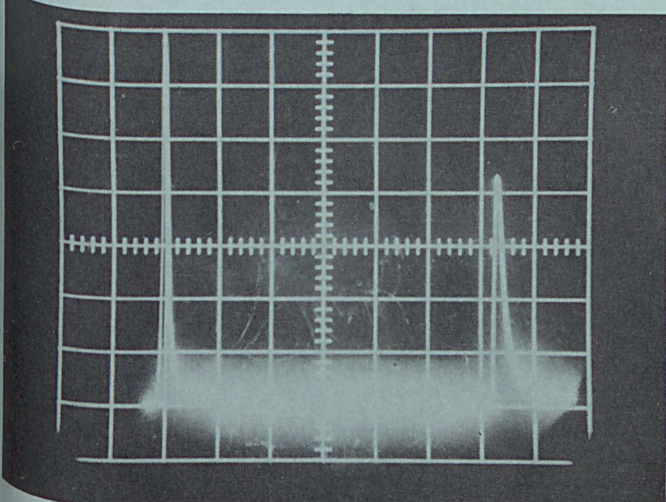

Scale is 1 microsecond per cm., or 400 feet per division. This is about 2500 feet of cable with two pressure taps and an amplifier at the end of this 2400 feet. This end looks open but again we are not making conclusions as to frequency.

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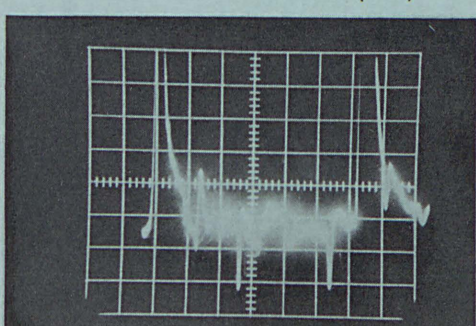

This is the same cable with the scope gain at maximum.

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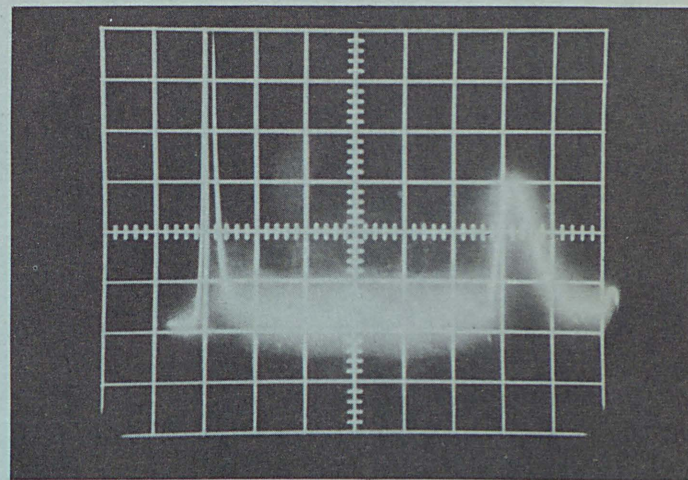

This is .5 microseconds per cm., with 200 feet per division. This is about 1200 feet of cable with two pressure taps and ending in a splitter. The termination of the legs of the splitter appears normal.

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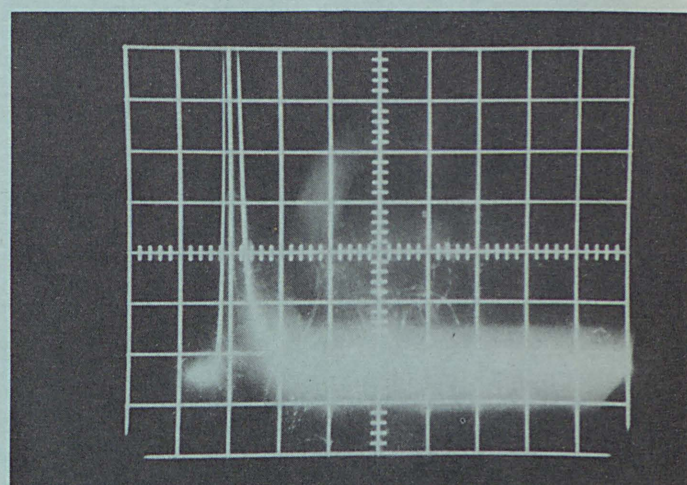

.5 microseconds per cm. Here is about 700 feet of feeder line that is pretty bad. If you were to cut into this piece you would probably find the outer conductor black and drops of water all through the foam.

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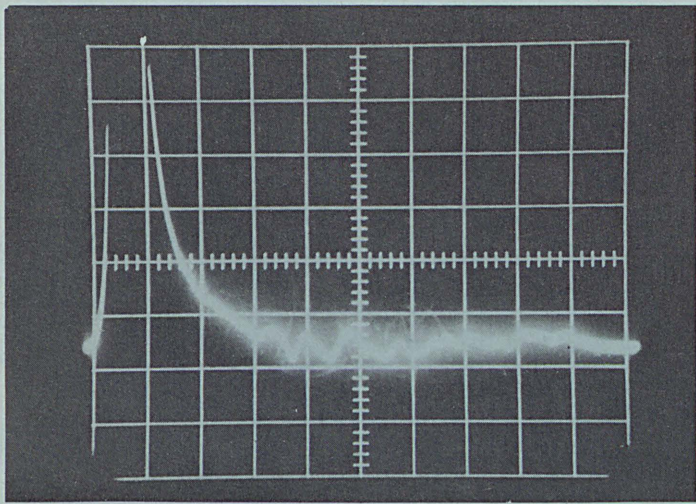


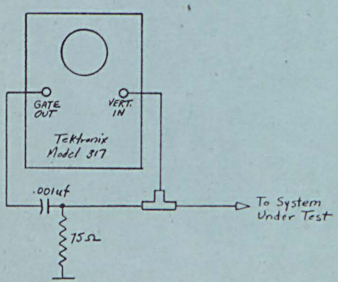
This is the same cable with the time base of the scope changed to .2 microseconds per division and the gain increased to .05 volts per division. At this setting of the scope, each division is worth about 80 feet of cable and you can see it is well riddled with reflections.

You have seen a few examples of what this type of testing can produce and with practice you can evaluate what is seen on the trace. We use this almost daily on our system, if not on the lines - in the shop for measuring partial reels of cable or displaying video wave forms from our microwave terminals.

For those interested in photography, the slides were taken using a 35 mm camera with a set of three portrait lenses attached. The lens opening of F4 and a shutter speed of 1/15 of a second and Ektachrome high speed type B film. We also take Polaroid pictures of wave forms using an old model 95 Polaroid camera and high speed film. Our total investment, including the "custom" mount for the scope is $100.00.

CHAIRMAN TAYLOR: Thank you very much. Are there any questions?

MR. SCHERPENSEEL: Somebody asked me to draw the diagram of the differentiating circuit, and I had better do that.



CHAIRMAN TAYLOR: Are there any other questi

Don't you have a tendency to do a lot of unnecess work of checking equipment when this doesn't check fr quency?

MR. SCHERPENSEEL: No, we are looking for fau This is a fault finder. We know and we check both ends and you can see what is going on in between.

CHAIRMAN TAYLOR: Are there any other questi

This is not a question, but we have a lot of system that cannot afford a TDR or something similar, and th use the same technique on a television set for ghosting conditions. What they do is look at the output of the amplifier with a "T" monitor and by taking a ratio between the ghost and the width of the screen they can determine the location.

CHAIRMAN TAYLOR: Thank you very much. Do y have any other questions or contributions?

From your title it seems to me it is "A Low Cost TDR," but when I look at the picture you have a fairly high priced scope. I wonder where the saving is?

MR. SCHERPENSEEL: It is relative. The TDR is around $3,000. It is all relative.

CHAIRMAN TAYLOR: Are there any other questi If not, we will take a short break for a moment.

(A short recess was taken.)

CHAIRMAN TAYLOR: It is always a pleasure at these functions to have guests from our Sister Country Canada. Our next speaker, I. Switzer, was born and educated in Calgary, Alberta. He received his B.Sc. degree in physics from the University of Alberta in 1949 and spent three additional years in post graduate study in physics.

His professional experience includes a number of years in electronic instrumentation and mathematical problems in petroleum geophysics, several years in applications analysis and programming in the electronic computer field, and association with the CATV field since 1954.

Mr. Switzer was a charter member of the Board of Directors of the Computing and Data Processing Society of Canada. He has been a director of National Communit Television Association of Canada for a number of years. He is a member of I.E.E.E., S.M.P.T.E., and the British Society of Relay Engineers.

Then we tried shooting from both ends, hoping they would twist together. (Laughter) We stood there for close to a week. We had to solve the problem. That was the important thing. We did manage it.

When I talk about an industrial vacuum cleaner I am talking about a device that has a large volume of air. You have got to get the air going through. The air at the manhole we started with was so slight that you had to put your ear against it to even be able to hear any airflow. You could just detect it. I guess we had a religious service the morning before, with all faiths present. It did work.

CHAIRMAN PENWELL: If CATV can continue to innovate like that, we're not dead.

Gentlemen, I want to thank you very much for your time. Perhaps if there are further questions you might try to buttonhole the speakers out in the hall. We have to move along. We are back on schedule now. For the benefit of those who came in late, we didn't have a projector when we started the session, and the second and third presentations require a projector.

Our next speaker, Mr. Pai, has been with CATV and Craftsman Electronics Products for the past three years. Mr. Pai will speak on "Analysis of the Directional Tap in System Design". Mr. Pai.

(Mr. Pai read his paper, marked No. 2.) (Applause)

ANALYSIS OF THE DIRECTIONAL TAP IN SYSTEM DESIGN

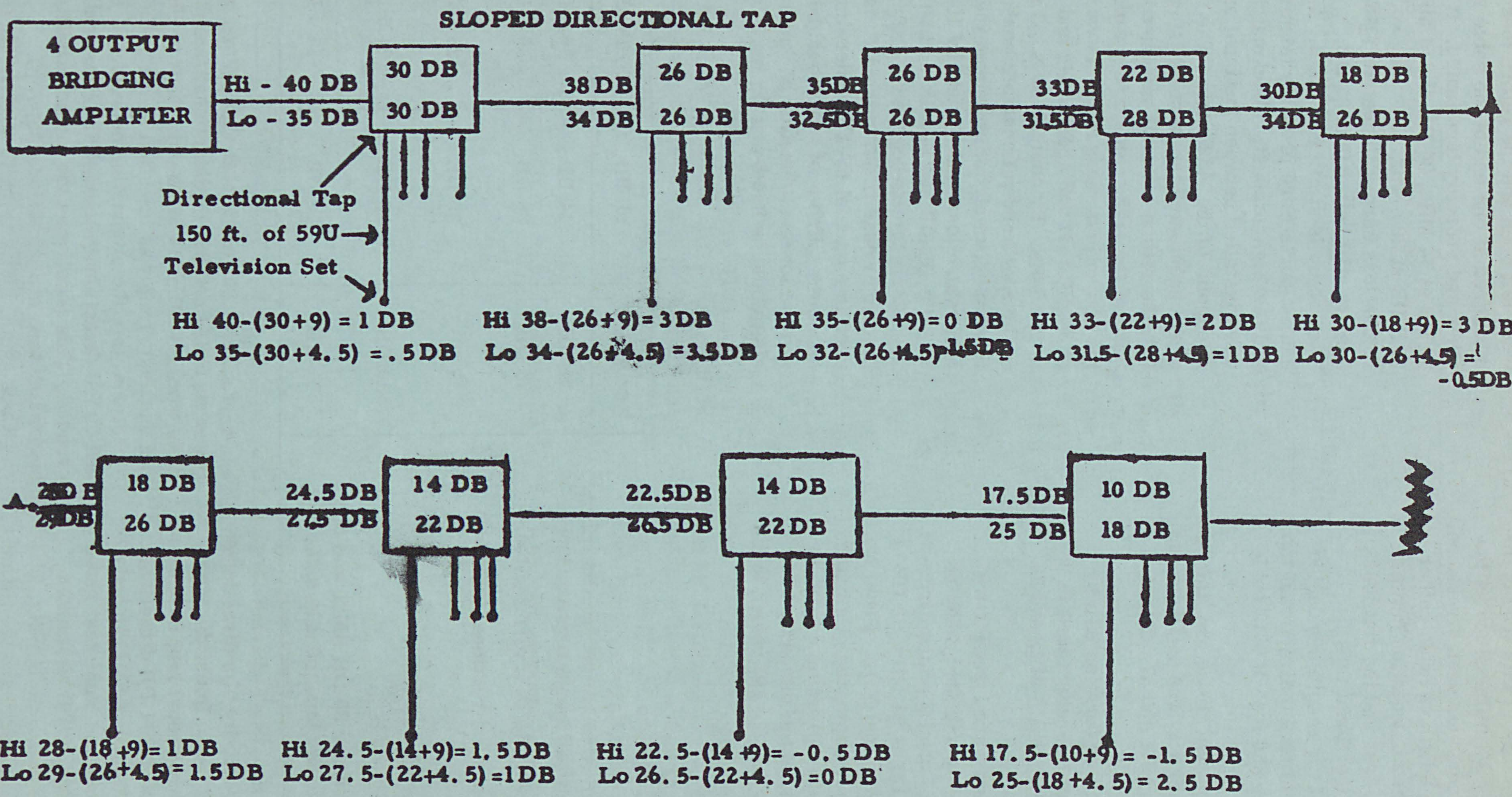
by
S. W. Pai

For years, the technique of tapping off signal from CATV feederline to the customer's set has mainly relied on the pressure tap. Although the design and construction of the pressure tap has been constantly improved -- such as, from capacitive tap to backmatch tap. However, the inherited problem both in the circuit design and mechanical construction of the pressure tap limit its performance in today's sophisticated system, especially since the information carried by the CATV system and the length of the feederline are constantly increasing, coupled with the increased demand for better color signal by the customers. Therefore, a better method of tapping off the feederline must be devised; and the directional tap is the most feasible answer at the present time. The advantage of the directional tap vs. pressure tap is, of course, obvious; and also the characteristics of the directional tap probably are well known by this time in the field of CATV. Unfortunately, even today, the advantages of the directional tap have not been fully utilized by many of the system designers. It is the purpose of this paper to present some of the advantages of the sloped directional tap and the distinct characteristics of the directional tap as a feederline tap off device. Figure 1 is a layout of a typical CATV feederline:

The length of the feederline is approximately 900 feet of .412 aluminum cable with nine directional taps spaced approximately 120 feet apart. The feederline is connected to one of four outputs of the bridging amplifier which provides an output of 40 DB on hi channel and 35 DB on low channel. Let's also assume 150 feet of RG59/U is the average length for the house drop. The DB value in the block designates the in-to-tap attenuation value of each particular directional tap. The top figure is for hi channel and the lower figure is for low channel when the signal is tapped off from the first directional tap through a 150 feet of RG-59/U to the customer's television set. Of course, the signal at the input of the set would be approximately 40 - (30 + 9) = 1 DB for hi channel and 35 - (30 + 4.5) = .5 DB for low channel; the signal for the second set is 3 DB for hi channel and 3.5 DB for low channel; and, the third set is zero (0) DB for hi channel and 1.5 DB for low channel. Because of the difference of the cable attenuation vs. frequency at the input of the forth directional tap, hi channel is 33 DB and the low channel is 31.5 DB. Therefore, in order to provide uniform signal level at the set, a sloped in-to-tap attenuation should be introduced to this particular tap. This would provide 2 DB at the hi channel and 1 DB at the low channel for the television set. When the signal travels further down the feederline, as you can see, the level difference between hi channel and low channel increases. When it reaches the end of the feederline, coupled with the RG-59/U house drop, the difference of the signal level between hi channel and low channel is almost intolerable. Therefore, more slope is needed. At the last directional tap, the in-to-tap attenuation is 10 DB for hi channel and 18 DB for low channel. The level at the television set is 1.5 DB for hi channel and 2.5 for low channel. Now, it is evident if a tap off device does not provide a certain amount of slope, especially when the tap locations are approaching the end of the feederline, a uniform signal level cannot be obtained at the customer's set by economical means with a non-sloped tap. Consequently, this would cause undesirable picture quality and an unsatisfied customer.

From the previous illustration, we can easily say the sloped directional tap has the following advantages:

1. Provides uniform signal level at the input of the television set.
2. More taps can be installed with minimum signal loss.



NOTE:

1.) Directional Tap: All with 4 tap ports.

2.) Directional Tap Spacing: 120 ft. .412 cable.

3.) House Drop: 150 ft. RG 59/U

4.) Attenuation of 120 ft. .412 cable.

54 MHz	1 DB approximately
216 MHz	2 DB approximately

5.) Attenuation of 150 ft. RG-59/U cable.

54 MHz	4.5 DB approximately
216 MHz	9 DB approximately

Figure 1

3. Easier layout for the system designers. Since the through loss of this type of directional tap has a similar slope as the cable, one may consider each directional tap as a certain length of cable rather than a complicated calculation between the sloped cable loss and the flat loss of other types of directional taps.

Now let's look at some of the results conducted by our Engineering Department on the directional tap.

A length of approximately 850 feet of .412 cable was used (Fig. 2)

1. With 75 ohm termination at one end, the return loss at the other end was 44 DB at 54 MHz, 44 DB at 216 MHz and 37.5 DB at 290 MHz.
2. When the same cable is terminated with 50 ohm termination, the return loss is 26 DB at 54 MHz, 38 DB at 216 MHz and 36 DB at 290 MHz.
3. Nine directional taps were installed with one end of the cable terminated. The return loss of the cable and the nine directional taps was 35 DB at 54 MHz, 30 DB at 216 MHz and 25 DB at 290 MHz. From No. 2 and No. 3 it clearly shows the mismatch introduced by the nine directional taps, to be less than the mismatch introduced by the 50 ohm termination (14 DB return loss).
4. The tap ports of all nine directional taps were left open and the return loss was measured at one end of the cable with the other end properly terminated. It was 30 DB at 54 MHz, 26 DB at 216 MHz and 24.5 DB at 290 MHz. By doing so, the return loss across the entire VHF TV band is still better than 25 DB.
5. The set-up is similar to No. 3. All the unused ports were properly terminated, and two high attenuation backmatch taps were installed between the input and the mid-point of the .412 cable. The values of the backmatch tap were 30 DB and 25 DB, the return loss was measured at the input of the .412 cable. The results of the return loss measurements were 25 DB at 54 MHz, 12 DB at 216 MHz and 15 DB at 290 MHz. By comparing No. 3 and No. 5, the additional mismatch introduced by the two backmatch taps caused the system return loss to decrease by 10 DB at 54 MHz, 18 DB at 216 MHz and 10 DB at 290 MHz. Of course, the condition would be much worse if the backmatch tap was used in an actual CATV feeder-line, because the number of taps would be increased and the lower attenuation backmatch taps also would be used.

Figure 2

	$54\ MH_z$	$216\ MH_z$	$290\ MH_z$
1. Return loss of cable with 75 ohm termination.	44 DB	44 DB	37.5 DB
2. Return loss of cable with 50 ohm termination.	26 DB	38 DB	36 DB
3. Return loss of cable and 9 directional taps with 75 ohm termination.	35 DB	30 DB	25 DB
4. Same as No. 3 but open termination on all directional taps' tap ports.	30 DB	26 DB	24.5 DB
5. Same as No. 3 but with one 30 DB BMIT and one 25 DB BMIT close to the input of .412 cable.	25 DB	12 DB	15 DB

Now, let's look at the directivity of a directional tap and backmatch tap (Fig. 1 & 3). Inject the signal to the tap port of the 10 DB directional tap, the measure the level at the tap port of the 14 DB directional tap. The total attenuation is 62 DB at 54 MHz and 67 DB at 290 MHz. Let's duplicate the same test under identical conditions through two 12 DB backmatch taps. The total attenuation is 35 DB at 54 MHz, 51 DB at 290 MHz. Now, you can clearly see the difference in attenuation between directional tap and backmatch tap. The same test was performed between an 18 DB and 22 DB directional tap. The results were 99 DB at 54 MHz and 86 DB at 290 MHz. If a backmatch tap was installed ahead of the 18 DB directional tap, the attenuation between the 18 DB and 20 DB directional tap would be drastically decreased. This illustrates the incompatibility of backmatch taps and directional taps.

Once again, let us refer to Fig. 1. An off air signal was fed to the input of the .412 cable and the

Figure 3

	54 MH_Z	290 MH_Z
Attenuation of tap ports between 10 DB and 14 DB directional tap.	62 DB	67 DB
Attenuation between two 12 DB BMIT.	35 DB	51 DB
Attenuation of tap ports between 18 DB and 22 DB directional tap.	99 DB	86 DB

150 feet RG-59/U on all tap ports.

television set was connected to the tap port of the 10 DB directional tap. Then we injected 1,000 Hz modulated CW signal (same frequency as the off air signal) into the tap port of the 14 DB directional tap. The CW signal was increased until the 1,000 Hz tone could just be heard on the TV set. At this point the output of the CW generator read approximately 40 DB.

This test was repeated with the CW signal injected into a 12 DB backmatch tap with approximately the same location as the 14 DB directional tap. Again the output signal was increased until the 1,000 Hz tone could be heard on the TV set. The output level of the generator (CW) at this time read approximately 15 DB, which is 25 DB lower than when tested with the 14 DB directional tap.

Let us again measure the return loss, but this time from the opposite end of the .412 cable (Fig. 4).

1. All of the tap ports of the (9) directional taps and the .412 cable were terminated. The return loss of this system was 26 DB at 54 MHz, 23.3 DB at 216 MHz and 23.7 DB at 290 MHz.
2. When the tap ports of all the directional taps were open, the return loss read 25.6 DB at 54 MHz, 23.2 DB at 216 MHz and 24 DB at 290 MHz. As one may see, the return of No. 1 and No. 2 is almost identical. This of course, clearly demonstrates the ability of the directional tap for rejecting the reflections from the tap ports.

All of the aforementioned tests were based on the principal of frequency domain, and the following results were obtained with a TDR.

3. The hookup was identical to No. 1, except a 1 ns. 1 v pulse was fed into the input of the .412 cable. Here (9) discontinuities were evident.
4. This was a TDR test of No. 2 and only (4) smaller discontinuities appeared.

We now have confirmed the advantages of the directional tap by both, frequency domain and time domain methods.

Bear in mind, that the illustrations we used here, are typical and not necessarily an absolute guideline. Generally, the characteristics of the directional tap would still remain the same. In most cases you may still refer to these illustrations in designing a new system layout.

Figure 4

	54 MH_Z	216 MH_Z	290 MH_Z
1. Return loss of cable and 9 directional taps at opposite end with 75 ohm termination on .412" cable.	26 DB	23.3 DB	23.7 DB
2. Same as No. 1 but open terminations on all directional taps' tap ports.	25.6 DB	23.2 DB	24 DB
3. Same as No. 1 but use TDR method p = .02/cm pulse = 1 ns.	9 discontinuity showed		
4. Same as No. 2 but use TDR method.	4 discontinuity showed		

(Mr. Pai read his paper, marked No. 2.)
(Applause)

CHAIRMAN PENWELL: Are there any questions? If not, we will proceed.

Brian Jones, from Fairchild, is still with us. Come up, Brian. Brian is our next speaker. He was born and educated in England, and has worked for the Canadian Defense Research Board on transistor circuits. He has worked for Fairchild Semi-Conductor on high frequency transistor applications, Westinghouse Electric Corporation on integrated circuit design, and has worked for C-Cor Electronics on CATV and high frequency amplifier design. Presently he is with Fairchild in Palo Alto, California.

DISTORTION, VSWR and REVERSE TRANSMISSION IN BROADBAND TRANSISTOR AMPLIFIERS

by

BRIAN L. JONES

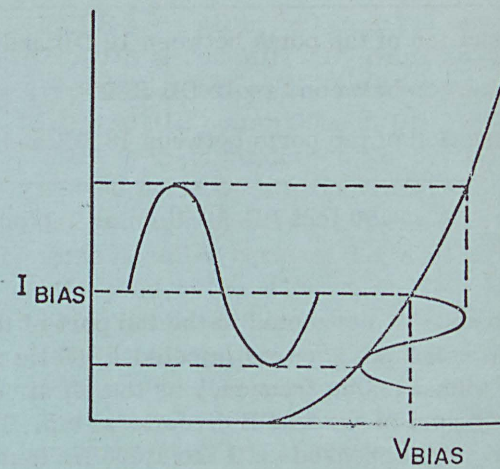
Transistor amplifiers produce distortion. This is a commonplace to everyone who is familiar with the cross-modulation of an overloaded CATV amplifier. Such amplifiers have a certain VSWR when introduced into a 75 Ω system and if this ratio is too high, reflections appear on the picture in the form of "ghosts". If an amplifier is inserted into a system backwards, that is, with the input signal to the output and the output signal to the input, the signal will be attenuated instead of amplified. The ratio of the input power to the output power under such circumstances is known as the reverse transmission. Similarly the gain of the amplifier is the forward transmission.

Now it may not be immediately obvious what connection these quantities may have and the purpose of this talk is to point out the inter-relationship between them. In order to do this I shall start by discussing some of the properties of transistors.

Figure 1 shows a typical curve of the relationship between collector current and base-emitter voltage of a transistor. This characteristic, a nonlinear input voltage/output current relationship is the main source of distortion of transistors. This is illustrated by a sine-wave base emitter voltage which produces the distorted collector-current shown in the slide. It can be shown very easily mathematically that if the input signal voltage consists of two or more amplitude-modulated RF signals, cross-modulation will result. The forward transmission of the transistor is non-linear and shows distortion.

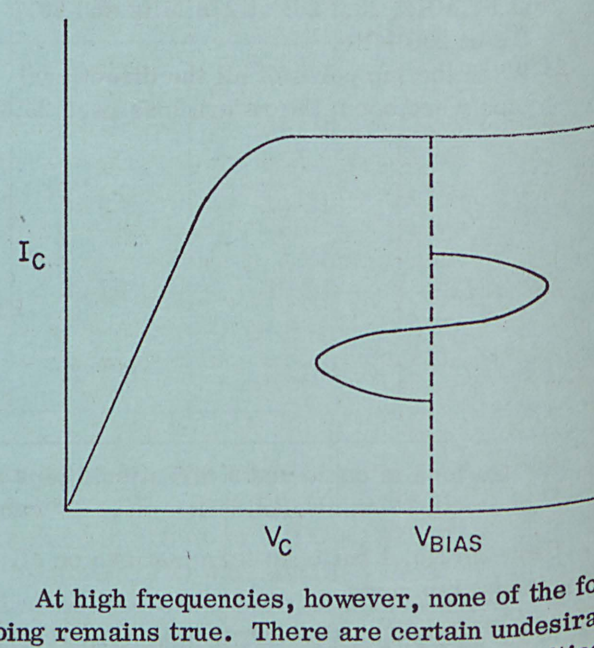
But what about the reverse transmission? If we apply a voltage to the collector of a transistor, will the resulting current show distortion? At first sight,

Figure 1



it would appear not. The low frequency collector characteristics are shown in Figure 2. It would appear that the collector current remains nearly constant regardless of the voltage swing on the collector. The transistor is a good constant current source at low frequencies; that is, it's output current depends only on the base voltage. It is also clear from this figure that what happens at the output has very little effect on the input, i.e., the transistor has a low reverse transmission.

Figure 2



At high frequencies, however, none of the foregoing remains true. There are certain undesirable properties of the transistor, known as parasitics, which give the transistor considerable reverse transmission. Figure 3 shows the two main parasitic resistances: the emitter inductance and the divergent approaches, and they have planned to submit this entire problem to the appropriate E.I.A. committee to work toward some sort of standardization.

We are planning to propose in that particular forum a joint working group of set manufacturers, CATV equipment manufacturers, operators, possibly representatives from the FCC -- if they wish to participate -- to attempt to work toward some overall television industry standardization.

I thought some of you might be interested in this particular point of view because I think the last paper just mentioned that there has been some discussion with TV set manufacturers. I am not sure that any people discussed this with our representatives at Syracuse. They are, however, very much aware of it and very concerned about it.

MR. WYDRO: I have one comment, and the only comment that I can say is, amen.

CHAIRMAN CLEMENTS: Thank you very much.

I know that many of you must have other questions concerning these addresses, and if we have additional time when the panel is completed we will possibly get back to some of the more pertinent points in connection with expanded band use.

Our next speaker is Argyle Bridgett, from Spencer-Kennedy Laboratories, Inc.

He is now Manager of Design Engineering for S-KL. He started with them in 1951.

Without any further introduction, I present Argyle W. Bridgett. (Applause)

MR. ARGYLE W. BRIDGETT (Spencer-Kennedy Laboratories, Inc.): For those of you reading the paper, the first sentence does not sound like anything.

Actually, if you get down to the basics, they are probably two in number, but there are a large number of problems that develop from these.

AUTOMATIC EQUALIZATION AS A FACTOR IN SYSTEM LEVEL CONTROL

BY

ARGYLE W. BRIDGETT

BASIC PROBLEM

The basic problems of CATV are really only two. First is obtaining a sufficient number of high quality TV signals and second is transmitting these signals through coaxial cable without degrading the original quality too much. The cable which is obtainable today does only one undesirable thing to the signal to any major degree. It attenuates the signal. It also causes a delay, but the delay, in general, is not a type which degrades the signal and the amount of delay is small. In a system of 1000 db, of cable attentuation the cable delay will be approximately 100 micro seconds.

The attenuation, however, is enough to completely lose the signal in snow and must be compensated for by providing amplification at close enough intervals to avoid losing the signal. It is in providing this amplification that most of the problems originate, since any amplifier will degrade the signal in several ways. First, if the total response of the amplifiers does not match the loss of the cable fairly well the picture quality will suffer. Second, it will add some noise to the signal. Finally, it will add distortion signals to the desired signals. These last two effects, noise and intermodulation, are usually the factors which limit either picture quality which can be attained or system length.

I believe we are all familiar with the V curves shown in Fig. 1 which show how the amount of noise and intermodulation introduced in a system by the amplifiers depend on signals levels, amplifier gain, and number of amplifiers. The top curve shows the maximum output level at which a given number of amplifiers can be operated with a given amount of cross-modulation. (This will depend on the amplifier, the gain setting and the signal level tilt). The bottom curve shows the minimum input level at which the same number of amplifiers can be operated with a given carrier to noise ratio. The difference between these two curves for one amplifier is what is called by Shekel the "k" factor for the amplifier. The intermediate curve shows the minimum output level at which the amplifiers can be operated without degrading the carrier-to-noise ratio. The distance between these two curves is "system margin" which is the range of output levels at which a system of any number of cascaded amplifiers can be operated without exceeding either limitation. The ideal way to operate a trunk is with all amplifiers operating midway between these limits so that the "system margin" is equally divided between noise and intermodulation.

The important thing to remember about these curves is that the "system margin" obtained from them assumes that all amplifiers are operating at the same levels. In practice this is not always true. There will generally be a difference in levels from amplifier to amplifier due either to measuring equipment errors or variations with temperature.

It would seem at first thought that one could predict results by using the average of the levels throughout the system but this does not turn out to be the case. As an extreme example, suppose that we consider a system of 2 amplifiers and set one at the highest operating level for one amplifier. The amplifier which is at the high level will contribute a very small amount of noise and the amplifier at low level will contribute a small amount of intermodulation. Our system of 2 amplifiers will have exceeded the system limits by a small amount regardless of the "k" factor.

Thus, if we operate alternate amplifiers a few db. above and below the average level we find that we have reduced our system margin. Fig. 2 shows the reduction in "system margin" which would result from this type of operation. Notice that the degradation is very small if we do not deviate a great deal from the central value but becomes very great when the deviations from average are large. This can be very important when the system is long enough to provide very little "system margin".

FREQUENCY EFFECTS

The cable attenuation is not a constant value for all channels but varies almost directly as the square root of requency. The loss at channel 2 is approximately one half of that at channel 13. In a system having a total cable loss of 1,000 db. this requires 500 db. less gain at channel 2.

TEMPERATURE EFFECTS

Probably the most annoying problem in maintaining a system and operating it so as to obtain the best system margin is that the cable losses (and to a lesser degree the amplifier gains) vary with the temperature. If the temperature varies from + 140°F to - 40°F the cable loss will decrease approximately 16%. Thus, if the total high temperature cable loss in a long run is 1000 db. at channel 13 there can be a change in loss of 160 db at channel 13 and a slope change of 80 db. in the system from a summer day to a winter night.

It is obvious that it is impossible to obtain a system margin large enough to accommodate such a wide swing in levels. Therefore, it is necessary either to adjust amplifier gains and slopes every time the temperature changes, or to provide some automatic method of level adjustment. Automatic Level Control Amplifiers by themselves can only correct for one half of the cable variations. It is necessary to provide some method of automatic slope correction.

AUTOMATIC EQUALIZATION METHODS

A. Temperature Operated Equalizers

These are designed and built in the same manner as ordinary fixed equalizers using resistors, capacitors and inductors. However, one or more of the elements uses a temperature sensitive element such as a thermister, selected in such a way that the transmission response varies with temperature in a way as to be complementary to that of cable. Fig. 3 shows the characteristics of a typical equalizer. These are placed in the system at intervals so as to minimize the variations in slope at all amplifiers. Their only disadvantages are:-

1. As with any lumped-constant networks, an exact match to the square root of requency response of cable cannot be obtained. However, the errors in shape can be made very small and once a considerable number have been cascaded, and the errors measured a thermally operated mop-up equalizer can be designed to correct them.

2. The cable is spread out over an area in such a way that some of it is in direct sunlight and some is in the shade. On the other hand each equalizer is in a fixed location. Therefore, an exact match to the cable variations is difficult to achieve. However, if a sufficient number of them are used, and they are suitably located this effect can tend to average out.

3. If exact control of level at every amplifier is to be achieved, each equalizer should be designed to exactly match the span of cable preceding it. This would require that every equalizer be custom designed or that the system be built with spans which exactly match the equalizer. In practice this is usually undesirable for other reasons. As Fig. 2 shows, however, a slight deviation from desired signal levels will not lower the system margin very much and some errors can be tolerated. It is, however, desirable to calculate the location of each thermal equalizer quite accurately using accurate measurement of cable spans. This type of equalizer has been proven to work very well in systems over a period of 6 to 7 years.

B. Compensated gain controls with ALC

Some automatic level control amplifiers have been built with a slope variation designed into the gain control circuit in such a way that the amplifier slope is reduced with the gain. While absolute control of amplifier output level at the operating pilot frequency is obtained, this system also suffers certain disadvantages.

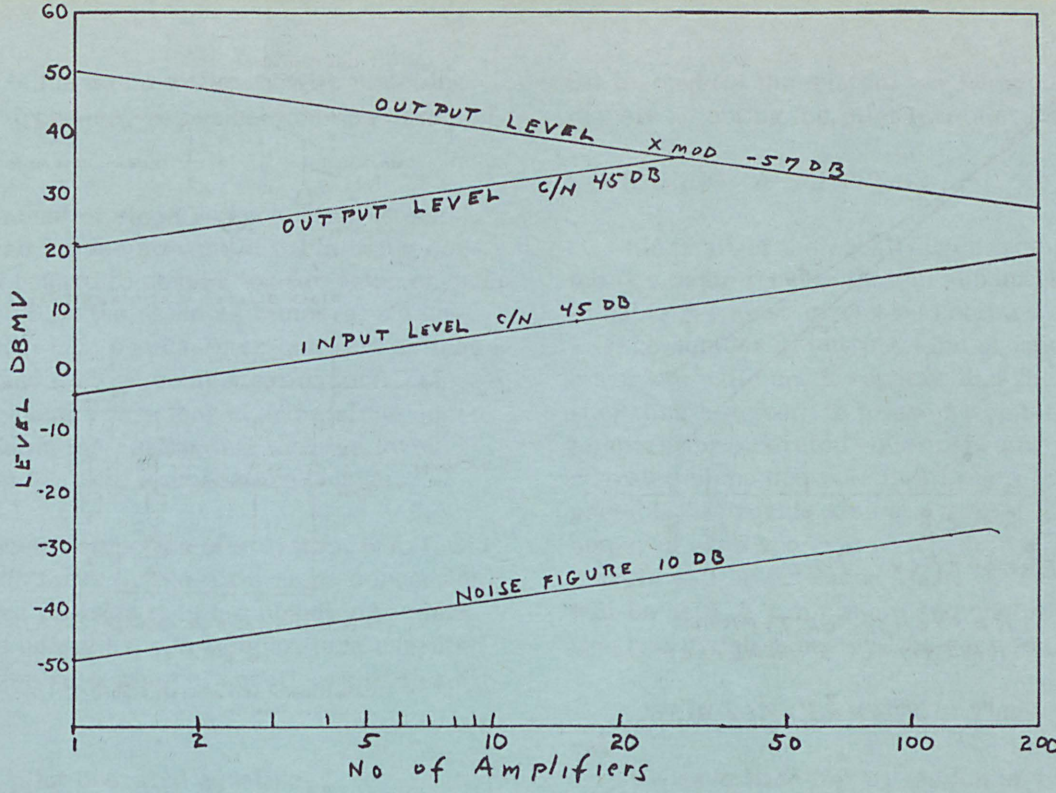
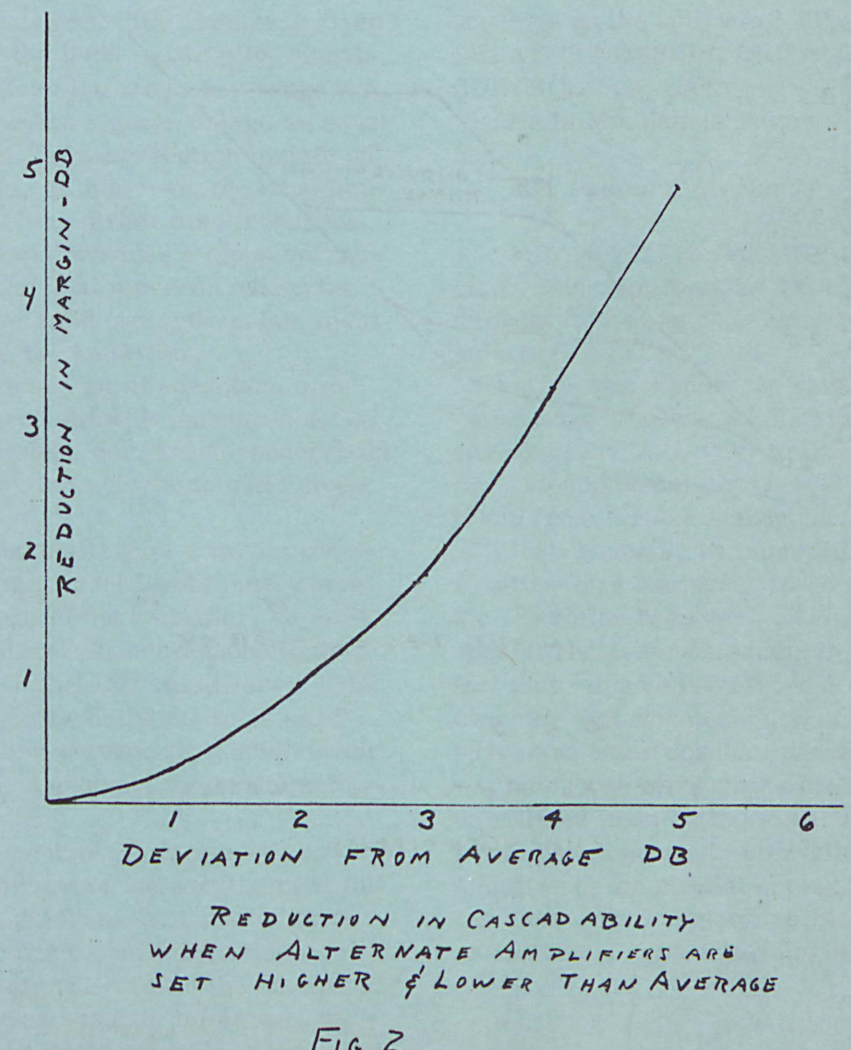
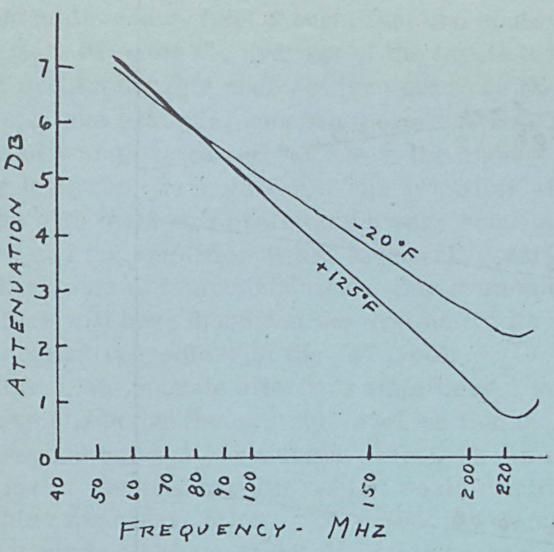


FIG 1



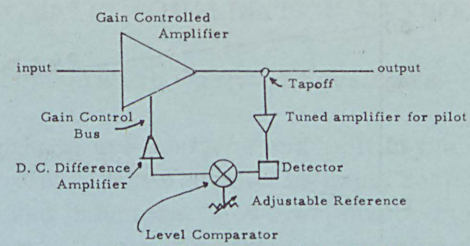
REDUCTION IN CASCADABILITY
WHEN ALTERNATE AMPLIFIERS ARE
SET HIGHER & LOWER THAN AVERAGE

FIG 2

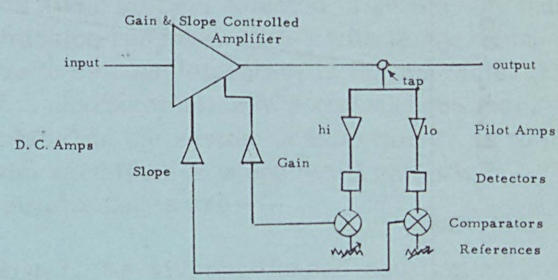


RESPONSE OF TYPICAL THERMAL EQUALIZER

FIG 3



Block Diagram - ALC Amplifier



Block Diagram - ALC/ASC Amplifier

Fig 4.

Comparison of ALC Amplifier & Pilot Controlled Equalizer

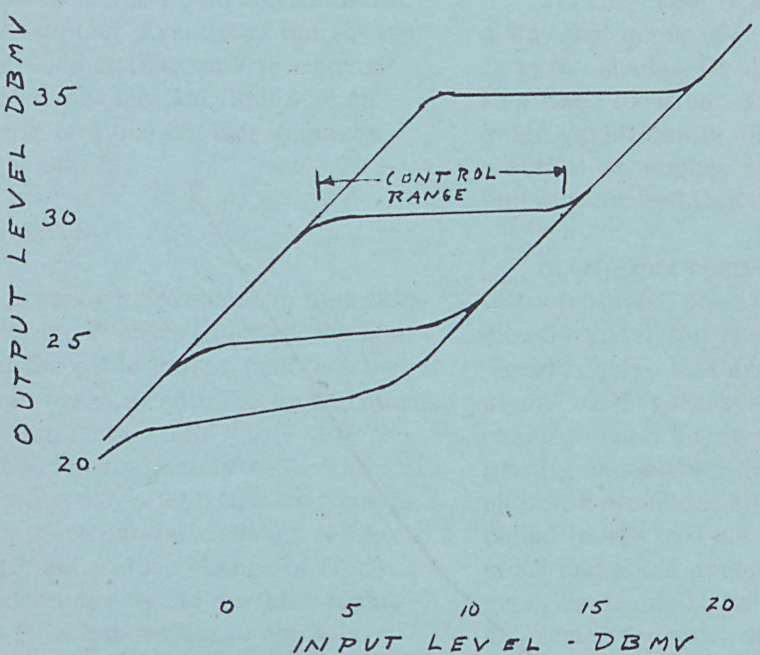


FIG 5

TYPICAL AUTOMATIC CONTROL CHARACTERISTICS

1. There is the same difficulty with matching square root of frequency response common to any of the methods.

2. The amount of slope compensation should be custom designed for the amount of cable being corrected for. In regard to correction for slope changes this method is about the same as temperature operated equalizers. In one case, temperature is measured directly and a slope compensation made. In the other, a level change is measured and a slope compensation made on the assumption that the level change was due to cable temperature change.

3. If, after construction of a system it is found that there is too much or too little slope correction for temperature changes it is not possible to make corrections as easily as with temperature operated equalizers, when relocation of equalizers can easily be made.

C. Automatic pilot operated equalizers

These have been in use in CATV systems since 1957. They operate in somewhat the same way as an ALC station except that the level of two pilot signals located near the two ends of the frequency range are used. If the levels of the two signals change an equal amount, the amplifier makes a correction in gain only to maintain signal levels. If, however, the two pilots do not change equally, the amplifier also measures the difference in levels and provides a slope correction in much the same way that a person observing the slope with a sweep or field strength meter might adjust the tilt control on the amplifier.

This system has the one great advantage over the other two methods that, since it measures actual signal levels, errors in slope correction cannot build up but will be corrected at the next automatic slope control amplifier.

However, just as automatic gain controls require that the range of incoming signal levels must correspond to the control range of the amplifier, so must the range of incoming signal tilt correspond to the slope correction range of the ASC amplifiers. This of course requires that if the units are to be used under normal conditions when preceding cable spans may be different from one another, the initial setup be made carefully.

A knowledge of the control characteristic is very important in planning the use of the equalizers if full advantage is to be obtained from their use. Fig. 5 shows a typical set of control characteristics.

The use of these units will reduce the amount of seasonal adjustments to an absolute minimum. In fact a certain amount of adjustment of both level and tilt throughout the system can be accomplished by merely adjusting the pilot levels at the head end.

COMBINING OF METHODS

Since all of the equalization methods suffer from the one basic trouble that an absolutely exact match to cable response cannot be obtained and cascading a large number of any one kind of unit will allow any errors to build up, it appears that the best way of operating a system is to use a combination of both temperature operated equalizers and automatic pilot operated slope control amplifiers. In this way it is possible to provide almost constant levels at the output of each and every amplifier so that the system margin will be degraded least. Errors in correction will be held to a minimum and cost of both construction and maintenance will be very low.

CHAIRMAN CLEMENTS: Thank you, Mr. Bridgett.

We have time for a question or two.

Apparently there are none at the present time, and we will move to our next speaker, who will address us on the subject of TEMPERATURE, TEMPERATURE DESIGN, AND AUTOMATIC LEVEL CONTROL FOR CATV.

He is Mr. James Palmer, of C-COR Electronics, Inc.

Mr. Palmer. (Applause)

MR. JAMES R. PALMER (C-COR Electronics, Inc.): I do want to make some comments of general interest to the engineering fraternity of the cable industry.

"I am alarmed by the various approaches to the "more than 12 channel" distribution system. They appear to me to be very premature, poorly conceived from an engineering basis and motivated almost entirely from a sales standpoint. Once we exceed the 12 VHF Channels, we must utilize either a special receiver or a converter located in conjunction with the television receiver. Having the converter or the special receiver, we should take advantage of the fact that we have been freed from broadcast frequencies that were established due to spectrum space and other considerations. We should make a very thorough study of the optimum frequencies to be utilized in an optimum system. We should use a total system concept optimizing the frequencies, the amplifiers, the coaxial cable and the converter or receiver. To do otherwise, we are doing ourselves as individual companies and our industry harm."

CATV COAXIAL CABLES
STANDARDIZATION??

by

SIDNEY A. MILLS

The fundamental problem of engineering is the effective production and utilization of the materials and forces of nature. Our complex civilization is dependent upon our increased ability to transport material and energy from the point where it is available to the place where it can be utilized.

The electrical engineer is interested in the production and utilization of the forces of nature, most of which are, both initially and finally, in some form other than electrical. He uses the electrical link because it is one of the most efficient and rapid means available for the transportation of energy. The power engineer may first transform the latent chemical energy of coal or oil into thermal or mechanical energy. After using this mechanical energy to produce electrical energy, he transmits it to some distant point where it again may be transformed into mechanical power by a motor or into radiant energy thru an electric lamp. Similarly, the communication engineer receives acoustical energy for his telephone, mechanical energy for his telegraph, or radiant energy for his television. These forms of energy must be delivered to the receiving end in almost identical form as originated.

The problem of the electrical engineer, therefore, is to pass on energy from one part of a system to another until it is ready for utilization. This usually means passing through a number of devices, each one of which may take its toll by subtracting from or modifying the energy handled.

As the middleman, if not controlled, may alter the amount or quality of produce passing from the farmer to the consumer, so the electrical transporting units containing resistance, capacitance, inductance, etc., may unduly reduce the amount or alter the character of the electrical impulses they receive for delivery to a distant point.

In the CATV industry, insulated electrical cables play a very important role. However, their construction, characteristics and usefulness are not generally immediately perceptible in contrast to the more glamorous components such as amplifiers, modulators, spectrum analyzers, etc., and the inconspicuousness of their contribution to the industry is often the very cause of their being overlooked. Without cable, however, many accomplishments of our industry would not be possible.

It is to the everlasting credit of our industry's pioneers that they were able to adapt or convert available commercial and military cables to perform the miracle of CATV. These great "Imagineers", many of whom are in attendance at this convention, needed, above all, the ability to improvise and innovate. They did not need industry standards and, as a matter of fact, had standards been available, they may well have stifled imagination and inhibited growth of this great industry.

Whether or not the state of the CATV art has advanced to the stage where broad standards covering the many various components are now possible, is beyond the scope of this paper. However, it is the opinion of this writer, that the industry has matured to the point where standards to cover CATV cables are both possible and necessary.

The CATV industry has, like Topsy -- 'just growed'. In its first seven years of existence or by year end 1957, the industry had grown to about 580 operating systems. The average miles per system for these years has been estimated at about 38 miles. During 1966, 258 new CATV systems were built with an estimated 50.5 miles per system. As shown in Table A, the cable footage to be used by the CATV industry is expected to double in volume during the next 5 years to an overall figure in 1971 of 266,000,000 feet.

TABLE A

Year End	Avg. Miles/System	Est. Cable Footage	New Systems	Net Operating Systems
1967	59	131,000,000	350	2300
1968	62	184,000,000	470	2770
1969	64	215,000,000	530	3300
1970	66	242,000,000	580	3880
1971	68	266,000,000	620	4500

We feel that figures such as these make it all the more evident that there is an immediate need for the establishment of meaningful yardsticks by which the mechanical and electrical properties of this highly important system component can be evaluated.

The validity of this premise is a matter for the CATV industry, to whom the cable manufacture plays a supporting role, to decide. This paper, therefore, is not intended to promulgate specific standards but rather to invite the industry's attention to the fact that wide variations in cable constructions for CATV use, do exist. This discussion will also review areas of design, production and testing of aluminum sheathed CATV cables to support our position that meaningful parameters by which the mechanical and electrical properties of cables are evaluated, can now be established.

In an overall CATV system, the final umbilical link between an accumulation of many exotic and expensive pieces of equipment and your customer's TV set is a $2.50 piece of coaxial cable generally referred to in the industry as RG-59/U.

In the initial days of CATV, I am sure that the military RG-59/U coaxial cable was selected because it met the basic requirements of the system, and it was available. Over the years, in order to lower the cost of cables, there have been several changes in construction and, likewise, performance characteristics, without any change in terminology. Such use of deceptive terminology is a gross misapplication of intent.

The terminology for coaxial cables "RG-( )/U" was devised by the military initially in 1944 under their joint Army-Navy Specification JAN-C-17. Basically, their coaxial terminology is derived at as follows:

"R"	-	Means Radio Frequency
"G"	-	Means Government
"(59)"	-	The number assigned to the Government approval.
"/U"	-	Means it is a universal military specification.

If the letters A, B, C, etc. appear before "/", it means a specification modification has been made. Only cables made to the Government specification and meeting the requirements of that specification should be marked with the "RG" legend.

In Table B, we have outlined the basic constructional details for coaxial cable RG-59/U as initially specified under JAN-C-17.

With the change from the "JAN" classification to the "MIL" classification, changes were made in the constructional and electrical requirements for this coaxial cable. The requirements for RG-59B/U coaxial cable are outlined in Table C.

The distinguishing differences between the requirements for RG-59/U and RG-59B/U cables are:

(1) Conductor size changed from 0.0253" to 0.0230".
(2) Conductor conductivity requirements changed from 30% to 40%.
(3) Recognition in the latest issue of high molecular weight polyethylene insulating material.
(4) Change from standard synthetic resin (PVC) jacket material to an improved low temperature non-contaminating Polyvinyl Chloride material.
(5) Change in dimensional tolerances.
(6) Change in electrical properties from a nominal 73 ohm impedance to a 75 ohm nominal impedance.

If there were a precise and definitive understanding that all drop cables were to be either RG-59/U per JAN-C-17 or RG-59B/U per MIL-C-17, then there would be no question in regard to the physical construction of the cable, and the physical and electrical properties would be adequately outlined and understood. However, we do not have this precise and definitive understanding. As such, we can find as many variations in CATV drop cables being used as there are manufacturers.

To illustrate the need for standards, Ameco Cable undertook a field sampling of so-called RG-59/U cables, currently being used as CATV drop cables.

In Table D, we have reviewed the basic constructional details as found in some 19 different coaxial drop cables, listed or referred to as RG-59/U or Type RG-59/U cables. From this analysis, we find these variations in construction to exist:

(1) Conductors are either solid copper or copper-clad steel.
(2) Conductor sizes are 0.226", 0.0253" or 0.032".
(3) The insulating dielectric is either solid polyethylene or expanded (foamed) polyethylene.
(4) The outer conductor is generally composed of No. 34 AWG bare copper but there are cases where No. 36 AWG copper can be found. The number of copper ends per machine carrier varies along with the number of pics per inch. As such, the percent coverage of the outer conductor varies between 78% and 96.3%.
(5) The outer jacket material is either Polyvinyl Chloride (PVC) or Polyethylene.
(6) The overall cable diameters vary between 0.230" and 0.246".

TABLE B

INNER CONDUCTOR: 0.0253" PLAIN 'COPPERWELD'

INSULATION SOLID TYPE A (POLYETHYLENE)
DIAMETER: 0.146" ± .005"

OUTER CONDUCTOR: SINGLE BRAID
TYPE: BARE COPPER
WIRE SIZE: 34 AWG
CARRIERS: 16
ENDS: 7
PICKS / INCH: 8.2 ± 10%

JACKET: TYPE I SYNTHETIC RESIN
DIAMETER: 0.242" ± .008"

ENGINEERING DATA:

NOMINAL IMPEDANCE: 73 ± 3 ohms
NOMINAL CAPACITANCE; 22.3 pf / ft.
ATTENUATION: 55 mc — 2.4 db / 100 ft.
83 mc — 3.0 db / 100 ft
175 mc — 4.6 db / 100 ft.
211 mc — 5.1 db / 100 ft.

In this initial analysis, we have not tried to analyze the properties of the different grades of insulating and jacketing materials that have been used.

A detailed analysis of the various constructions reveals that material costs in the more expensive constructions can exceed the material costs in the least expensive constructions by as much as 46%. The commercial implications of this wide variation are self-evident.

We do not wish to infer that several or, for that matter, any of the constructions are unsuitable for the intended service. We have presented this review only to point-up the fact that the generic expression "RG" is a nebulous designation for a very important component of the CATV industry.

Standards to cover a CATV drop cable are relatively easy to develop, and it is probably that varying operating conditions would require more than a single standard construction. But, until such time as conditions are defined and specific constructions specified, the present conditions, which can best be described as chaotic, will prevail.

While variations in construction of aluminum sheathed cables for trunk and distribution service are not as prevalent as in the common drop cable, constructional differences do exist and, therefore, differences exist in the physical and electrical properties.

For example, from a review of various suppliers' printed data for .412" cable, we find that

TABLE C

INNER CONDUCTOR : 0.0230" COPPER COVERED STEEL

INSULATION : SOLID TYPE A (POLYETHYLENE)
DIAMETER : 0.146" ± .004"

OUTER CONDUCTOR : SINGLE BRAID
TYPE : BARE COPPER
WIRE SIZE : 34 AWG
CARRIERS : 16
ENDS : 7
PICKS / INCH : 8.2 ± 10%

JACKET : TYPE II a (NON-CONTAMINATING PVC)
DIAMETER : 0.242" ± .004"

ENGINEERING DATA :

NOMINAL IMPEDANCE : 75 ± 3 OHMS
NOMINAL CAPACITANCE : 21.1 pf/ft
ATTENUATION : 55 mc - 2.6 db/100 ft.
83 mc - 3.2 db/100 ft.
175 mc - 4.9 db/100 ft.
211 mc - 5.4 db/100 ft.

the nominal inner conductor diameter can vary between 0.075" and 0.081". These figures are shown in Table E.

In the area of polyethylene jacketed aluminum sheathed CATV cables, we again can find a wide variance in the constructional details. The indicated nominal polyethylene jacket walls and finished cable diameters as advertised by several manufacturers, are listed in Table F.

During the next few years, we will see an increasing demand for direct burial installations of aluminum sheathed CATV cables. Considerable concern has already been generated in the CATV industry over this subject and certainly the constructional variations as shown in Table F do not help the situation.

In regard to the subject matter of direct burial of cables, I would point out that in April 1964, the Institute of Electrical Engineers (IEEE) sponsored a 3 day technical conference on Underground Residential Distribution. This was followed in September 1966 by the 2nd Special Technical Conference on the same subject. Copies of the technical papers presented at these sessions are available thru IEEE.

Also, in the paper "Underground Installation of CATV Cables",[1] presented at the 14th Annual NCTA Convention, the author points out that the direct burial of aluminum-sheathed coaxial cables is not to

TABLE D

	Conductor		Insulation		Outer Conductor						Jacket		
	Mat.	Size	Mat.	O.D.	Mat.	Size	Ends	Picks	% Cov.	O.D.	Mat.	Wall	O.D.
RG-59/U	CS	.0253	P	.146	C	34	7	8.2	95.7	.191*	PVC	.035	.242
Brand A	CS	.0226	P	.146	C	34	7	8.0	95.6	.175	PVC	.035	.242
Brand B	CS	.0253	P	.146	C	34	5	8.0	81.3	.175	PVC	.030	.235
Brand C	CS	.0253	P	.146	C	34	7	8.0	95.6	.175	PVC	.035	.244
Brand D	CS	.0253	P	.146	C	34	5	10.1	84	.175	PVC	.030	.235
Brand E	CS	.0253	P	.146	C	36	6	8.0	78	.165	PVC	.035	.235
Brand F	CS	.0253	P	.146	C	34	7	8.0	95.6	.175	PVC	.035	.245
Brand G	CS	.0253	P	.146	C	34	7	6.0	94.0	.175	PVC	.035	.242
Brand H	CS	.0253	P	.146	C	34	5	10.8	84.0	.175	PVC	.032	.240
Brand I	CS	.0253	FP	.146	C	34	7	8.0	95.6	.175	PVC	.035	.245
Brand J	CS	.032	FP	.146	C	34	7	9.0	96.3	.175	PVC	.030	.240
Brand K	CS	.0253	P	.146	C	34	5	10.8	84.0	.175	PVC	.035	.242
Brand L	CS	.0253	FP	.150	C	34	5	10.8	84.0	.176	P	.030	.240
Brand M	CS	.0253	P	.146	C	34	7	8.0	95.6	.180	PVC	.035	.245
Brand N	CS	.0253	P	.146	C	34	5	12.0	88.0	.180	PVC	.035	.245
Brand O	C	.032	FP	.146	C	34	7	8.0	95.6	.185	P	.025	.230
Brand P	CS	.0253	P	.146	C	34	7	8.0	95.6	.180	PVC	.035	.246
Brand Q	CS	.0253	P	.146	C	34	7	8.0	95.6	.180	P	.035	.242
Brand R	CS	.032	FP	.146	C	34	7	8.0	95.6	.175	P	.035	.242
Brand S	CS	.0253	FP	.146	C	34**	7	8.0	95.6	.175	P	.035	.242

C - Copper
CS - Copper Covered Steel
P - Polyethylene
FP - Foam Polyethylene
PVC - Polyvinyl Chloride

* Max. O.D. Per Spec.
** Braid plus Copper backed Polyester Tape

be feared and can be economically and satisfactorily accomplished provided the cables are designed, manufactured and installed in accordance with established and proven standards and procedures.

Theoretical Considerations

Let us briefly review the general theoretical considerations for CATV cable design and also review briefly a few of the various process variables which can affect cable performance.

Table G outlines the components and general configuration of aluminum sheathed CATV coaxial cables.

d = diameter of the inner conductor
D = diameter over the conductor insulation
t = thickness of the aluminum sheath
O.D. = outside diameter of the cable

TABLE E

Cable Type: .412" Aluminum Sheathed CATV

Manufacturer	Inner Conductor Diameter (Nom.)
A	0.078"
B	0.077"
C	0.078"
D	0.0752"
E	0.075"
F	0.0752"
G	0.081"
H	0.075"
I	0.077"

The electrical design characteristics of such a coaxial cable are defined by the following interrelated equations:

(1) Characteristic Impedance (Z_o) =

$$\frac{138.2}{\sqrt{e}} \log_{10} \frac{D}{d} \text{ ohms}$$

Where e = Dielectric constant of the insulation

(2) Velocity of Propagation (Vp) = $\frac{100}{\sqrt{e}}$ percent

(3) Capacitance (C) = $1016 \frac{\sqrt{e}}{Z_o}$ picofarads/ft.

Attenuation for these types of cables is defined by a more complex equation:

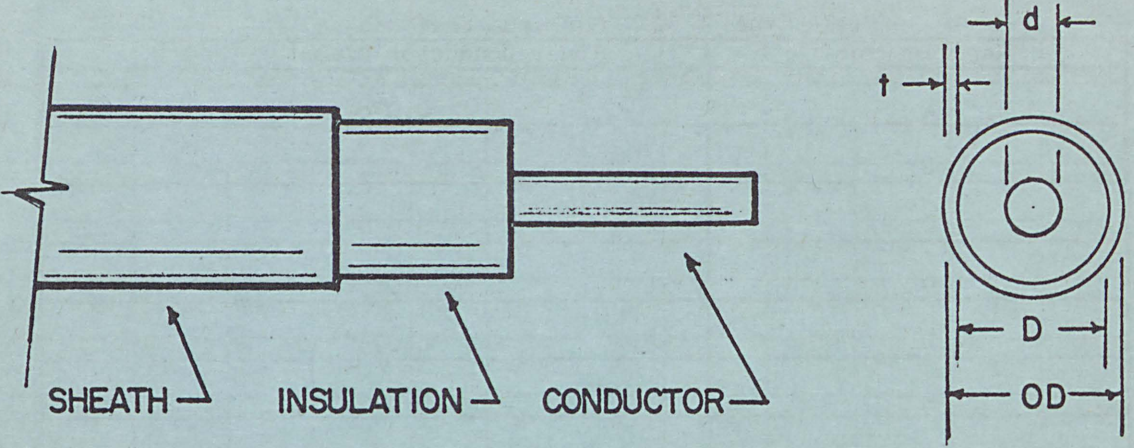
(4) $\alpha = 8.686 \left[\frac{R}{2Z_o} + \frac{GZ_o}{2} \right]$ db/1,000 feet

TABLE F

POLYETHYLENE JACKET WALL THICKNESSES

Manufacturer	.412"		.500"		.750"	
	Wall	O.D.	Wall	O.D.	Wall	O.D.
A	.029"	.470"	.040"	.580"	.037"	.820"
B	.035"	.482"	.040"	.580"	.050"	.845"
C	.034"	.480"	.038"	.575"	.050"	.850"
D	.050"	.512"	.050"	.600"	.050"	.850"
E	.050"	.512"	.050"	.600"	.050"	.850"
F	.034"	.480"	.040"	.580"	.050"	.850"
G	.025"	.480"	.025"	.580"	.036"	.850"
H	.040"	.495"	.050"	.605"	.050"	.855"
I	.029"	.470"	.038"	.575"	.038"	.825"

TABLE G



d — DIAMETER of INNER CONDUCTOR

D — DIAMETER OVER INSULATION

t — THICKNESS of SHEATH

O.D. — OUTSIDE DIAMETER of CABLE

Where R = effective loop resistance in ohms/1,000 ft.

Z_o = characteristic impedance in ohms.

G = leakage conductance of insulation in ohms/1,000 ft.

If the appropriate expressions for R, G and Z are substituted in this equation, we can write the expression for attenuation as:

$$\alpha = \frac{0.02387}{\mathrm{Log}_{10}\, d_o/d_i}\left[\frac{\sqrt{P_i}\;\sqrt{e}\;\sqrt{f}}{d_i}\right] + \frac{0.02387}{\mathrm{Log}_{10}\, d_o/d_i}\left[\frac{\sqrt{P_o}\;\sqrt{e}\;\sqrt{f}}{d_o}\right] + \frac{15.062\ fDe}{\mathrm{Log}_{10}\, d_o/d_i}\ \text{db/1,000 ft.} \tag{5}$$

Where: α = attenuation in db/1,000 ft.

d_i = diameter of inner conductor (inches)

d_o = inside diameter of the outer conductor (inches)

P_o = resistivity of outer conductor (micro ohm - cm)

P_i = resistivity of inner conductor (micro ohm - cm)

e = dielectric constant of insulation (S.I.C.)

f = frequency in megacycles

D = dissipation factor of the insulation

In this expression, the first term represents the loss due to the inner conductor, the second term represents the loss due to the outer conductor and the third term represents the loss due to the insulation.

Process Variables

Basic specifications of the metal industry have established and defined resistivity values for copper and aluminum. For the purpose of this discussion, these values may be considered to be constant.

However, variations in the diameter of the inner conductor will occur during normal manufacturing operations. Wire drawing dies wear and cause diameters to increase. Also, normal handling procedures can cause "stretch" or "draw-down" of the conductor. The final electrical characteristics, particularly the cable impedance, can be quite sensitive to variations in the inner conductor diameter. Changes of 0.001" can change the impedance of .412" cable by as much as 0.6 ohms. In .500" cable such diameter variations can change the impedance by 0.5 ohms and .750" cable by 0.3 ohms. Therefore, the ability to hold close tolerances on the inner conductor dimensions, has an important bearing on the ability to maintain the cable impedance within given limits.

The diameter over the expanded polyethylene insulation is an important variable. When extruded correctly, the dielectric constant of expanded polyethylene is extremely constant. However, in the application of the aluminum sheath, the outer surface of the polyethylene tends to become compressed, thus effecting a change in the effective dielectric constant. The amount of compression is a matter of choice and will vary between manufacturers. In aluminum sheathed, foam polyethylene insulated CATV cables, the dielectric constant usually lies between 1.50 and 1.55. Variations in the dielectric constant of this extent can cause a difference of 1.0 ohm in impedance.

The thickness of the outer aluminum sheath is generally chosen to give the cable suitable mechanical properties. Variations in wall thickness and overall cable diameters can vary differently between manufacturers due to variations in the methods of application. Such variations must also be considered in establishing tolerance limits for both the mechanical and electrical characteristics.

Basically, a CATV cable will contain many minor structural changes in impedance along its length, each of which, by itself, is too minute to have any significant effect on the final electrical characteristics. If these structural changes occur with random spacing along the cable, they are of no special concern since they will tend to cancel out each other. If, however, these changes occur with a periodic spacing, they are of special concern. Under such conditions, there is one frequency at which the effect will be additive and the attenuation will be higher than it should be. Such a cable is said to have periodicity, and the spacing of these periodic irregularities determines the frequency at which their effect is additive.

Control of periodicity requires the meticulous study and analysis of every step of the manufacturing process where the cable or its components may be handled.

Initially, it was common practice to evaluate cable periodicity in terms of a sweep attenuation test. By this method, a sweep signal was introduced at one end of a length of cable and the signal emerging from the other end was displayed on an oscilloscope. Where periodicity occurred, a "hole" or "suck-out" would appear on the display at that frequency. By rough calibrations, the depth of the hole was determined in decibels. There were no established acceptance standards for this test although most spoke of 0.25 db or 0.50 db on the depth of the hole. Later, a percent deviation from the smooth curve theory was introduced. Limits of 2.5% and 5.0% were referenced, but again there were no established acceptance standards.

As cable manufacturing techniques improved, the magnitude of periodicity effects were reduced more and more until the depth of the holes became less than the resolution possible on the oscilloscope display. The best that could be said was -- "no measurable deviation from the smooth curve" -- certainly an imprecise statement to include in a specification.

During the past two years, manufacturers and users of CATV cables have become actively interested in "Return Loss" as a useful parameter for defining the quality of cable.

Return loss testing has been a valuable and highly sensitive test for evaluating electronic equipment for quite a few years. It is a rather sophisticated test, and the equipment and procedures used together with the results obtained required careful interpretation.

Return loss measurements are made by feeding a signal into one end of the cable and comparing the strength of this signal with the signal which is reflected back out of the same end. The ratio between the two, expressed in decibels, is said to be the return loss of the cable under test.

For CATV cables, the ideal condition would be zero reflection, since any signal which is reflected must reduce the strength of the transmitted signal, and it is the strength of the transmitted signal which effects the quality of the television picture carried to your subscriber's TV set. Thus, the higher the ratio between the main signal and the reflected signal, the better the cable.

The return loss test provides essentially the same information as the attenuation sweep test but with much greater sensitivity. It is this high degree of sensitivity that introduces problems in interpretation of the test method. The amplifiers used to achieve the needed sensitivity amplify not only the reflections coming from the cable but also those coming from connectors, terminations, jumpers, etc., and it is difficult to determine from the return loss measured just what part should be attributed to the cable and what part should be attributed to hardware.

When return loss measurements are made using the same equipment, hardware, and test procedures, and when the bridge adjustments and interpretation of results are always made to the same ground rules, this test can be a valuable asset for judging relative quality.

Since we do not have established standards and procedures for this test, it becomes difficult to make true comparative analyses between various cables on the market by simply reading the printed literature. For example, the following statements can be found in any of today's published literature:

(1) 26 db down min. Channels 2 through 13.

(2) 26 db down min. at any frequency 20-220 mcs.

(3) Minimum 26 db structural return loss across all Channels 2-13.

(4) 26 db min. in any TV channel measured by sweep method from 54 to 216 mcs (compared to average characteristic impedance).

(5) 25 db min. return loss at any frequency between 40 mcs to 230 mcs.

(6) Average USWR of 1.05 on all channels.

(7) Average minimum structural return loss at any frequency between 7 and 216 mcs in 32 db.

(8) Return loss - 26 db, 50-220 megahertz.

(9) 30 db return loss (weighted) worst point Channels (2-13).

(10) 25 db min. down at any frequency over the range 20-220 mcs, including sub channel frequencies 20-54 mcs, 88-105 mcs FM band, 105-174 mcs, as well as 12 VHF TV channels.

(11) 30 db loss on TV and FM bands.

(12) 30 db, 20-220 mcs as measured by the balanced bridge method.

Not having established written test procedures, and with such variations in indicated values, variations in test range, encompassed by such wordings as "minimum", "average", "average-minimum" and "weighted", it would be interesting to see how you, the user, would interpret these statements and evaluate each of the manufacturers.

This paper was introduced by stating that the objective was not to solve problems but rather to expose confusion, with the hope that such open discussion would lead to development and support of industry standards. I feel free, therefore, within the latitude of my expressed objective, to point out that vague "advertising copy" is hardly a satisfactory basis for sound engineering decisions.

The CATV system design engineer, on whose judgment millions of dollars are being committed is certainly entitled to more precise data than is commonly found in the advertising sections of trade magazines.

For example, average values without qualifying tolerances are misleading. It must be recognized that some variation is normal in any manufacturing process, and these variations are related directly to the principles of probability. Thus, with any normal processing, under control, as many values will be found above the average as will be found below the average. The actual range or spread of these values from the average will depend upon the degree of control capable of being effected over the process.

Nominal attenuation expressed graphically on fine paper with a broad pen is a poor basis for system design, and the expression "return loss" is just a catchy phrase unless the frequency spectrum and test procedures are precisely defined.

These are shoddy tools for an industry as sophisticated and advanced as CATV and certainly will not support improvement in the state of the art necessary for continued growth.

The wire and cable industry is capable of establishing concise and objective specifications to govern the design, production and testing of CATV cables now in general use. Past experiences in other industries proves that such standards can be devised and adopted without inhibiting progress. On the contrary, they have been the very basis for advanced designs. Such a project, however, can be undertaken only with the cooperation and mutual effort of both the manufacturer and the consumer. Ameco Cable, for one, stands ready to cooperate in establishing such standards which will give the manufacturer assurance that he is furnishing cable to meet the customer's requirements and give the customer confidence that he will receive what he has ordered.

In CATV, as in any area of technology, there must be mutual agreement and widespread use of test methods so that the language we use to describe, and the numbers we wish to measure, are universally understandable.

References:

1. "Underground Installation of CATV Cable," E. Mark Wolf, 14th Annual Convention, NCTA.

(Mr. Mills read his paper, marked No. 4.)
(Applause)

CHAIRMAN PENWELL: That was a very strong message. Archer Taylor told me this morning that yesterday at the NCTA Standards Committee meeting they did indeed appoint a panel of experts from the industry; and these people, during the coming year, will also be working on standards, for presumably cable specification and cable testing.

If anybody wants to stand up and say something, this is the time. We have completed our agenda. We thank you for attending.

(The meeting adjourned at 12:15 p.m.)

such people as Graybar, Westinghouse, and others. The National Electrical Safety Code is available, should any of you wish to order a copy of it, from the Superintendent of Documents, U.S. Government Printing Office, Washington. It is Handbook H-81, and it costs $1.75. It could very well be the cheapest investment you ever made; and I strongly urge that each of you secure a copy of it.

This concludes my remarks, Mr. Chairman. (Applause)

CHAIRMAN SCHATZEL: Thank you very much, Mr. Karnes; and again we say thank you, Mr. Stilwell.

I believe we all appreciate the work these two gentlemen have been doing to further the interests of the CATV industry in connection with these Codes.

Serving with Mr. Stilwell on this Committee is a gentleman who is in our audience, and I note that he wishes to make a comment.

MR. H. J. SCHLAFLY, JR.: Mr. Chairman, I did serve with Mr. Stilwell on this Committee, and I want to emphasize a point that he spoke of, and that is that the draft on the National Electrical Code has not been approved nor adopted by the NEC as yet.

I want to read a word of caution from our current print:

"The above draft has been proposed by the NCTA Standards Committee and delivered to the appropriate NEC panels for their consideration, but there has been no assurance nor indication that the draft will be adopted in this form for the 1968 publication as part of the Code."

So, if it comes out in the end with slightly different flavor than we have been able to report today, please do not be too greatly surprised; but your Standards Committee will endeavor to retain it in its present form if at all possible.

CHAIRMAN SCHATZEL: Before going to the next speaker I would like to present an announcement.

(Announcements)

We are going to change the agenda, moving past the panel which was scheduled to appear next, and going to the last of the morning items which is entitled, COMPARISON OF DEMODULATOR-MODULATOR VERSUS HETERODYNE SIGNAL PROCESSING FOR CATV HEAD ENDS.

The speaker who is going to discuss this subject, I heard a couple of years ago in Denver, when he discussed transmission distortion in CATV. At that time, as I recall it, he was discussing envelope delay distortion, and it was a most interesting paper. What he was talking about was a problem that was facing us in transmitting signals over CATV systems.

It is my hope this morning that perhaps he is going to give us some of the answers to that problem, among others.

Our speaker is Mr. Gaylord Rogeness, who holds Bachelor's and Master's Degrees in Electrical Engineering from the University of Illinois. After several years of experience with various companies in the electronics industry, he joined AMECO, where he is now the Director of Engineering, located in Phoenix.

At AMECO he developed the solid state heterodyne signal processor which AMECO has recently introduced. He has, also contributed to several other items developed by his company.

It is a privilege and a pleasure to introduce Gaylord Rogeness. (Applause)

COMPARISON OF DEMODULATOR-MODULATOR VERSUS HETERODYNE SIGNAL PROCESSING FOR CATV HEAD ENDS

by

Gaylord G. Rogeness

1. Introduction

Two techniques which have been used to receive and process television signals before they are applied to the cable system are the Demodulator-Modulator combination and the Heterodyne converter. The intent of this paper is to compare the two techniques.

With present day microwave relay equipment, at least one demodulatin-modulation is required before the television signal can be applied to the cable system. Hence it is imperative that the demodulator and modulator have characteristics which will minimize distortion of the television signal. However, when the choice between use of a heterodyne converter or a demodulator-modulator pair exists, the heterodyne converter is currently the best choice. Reasons for this choice will be given in the paper.

2. Heterodyne or Converter with IF Amplifier

The VHF converter with IF Amplifier, which will be referred to as heterodyne in the remainder of this paper, must convert any incoming VHF channel to any desired output VHF channel. The signal received from the antenna must not be degraded during the conversion process. Ideally, one requirement of the system is a flat passband from 750 khz below the picture carrier to 4.18 mhz above the picture carrier.

Figure 1 shows a block diagram of the heterodyne. The VHF signal input is amplified by an RF amplifier before it is converted to IF frequencies by the local oscillator in the input mixer. Adjacent channel trapping is accomplished in the IF amplifier. The IF sound carrier is normally separated from the

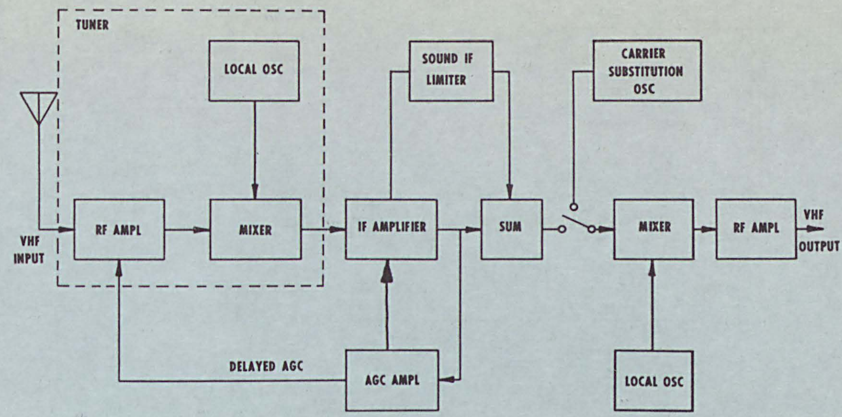


FIGURE 1 HETERODYNE BLOCK DIAGRAM

video IF carrier, amplified and limited, then summed with the output of the IF amplifier. This operation allows independent adjustment of the picture carrier to sound carrier level.

The output of the IF amplifier is held at a constant level by AGC action which controls both the RF amplifier and IF amplifier gain. The RF amplifier is normally allowed to operate at maximum gain until the input signal level reaches a point at which the signal-to-noise ratio will not suffer by a reduction in gain. This is known as delayed AGC. The combined IF output is converted to the desired VHF channel by the output local oscillator in the output mixer. If "on channel" conversion is required, the input local oscillator drives the output mixer and the output local oscillator is disabled. Differential gain and differential phase will be almost non-existant, since mixer conversion is not related to modulation percentage.

Two major advantages of the heterodyne over the demodulator-modulator are excellent low frequency phase linearity and no quadrature distortion. Referring to Figure 2a note that the heterodyne IF amplitude response is flat over the entire video modulation bandwidth. Hence, a linear phase characteristic over this bandwidth is relatively easy to realize. The demodulator IF amplitude response however, is down 6 db at the carrier frequency. A linear phase response is difficult to obtain with this type of amplitude response.

Quadrature distortion, which is discussed in more detail in the next section, is generated when the video signal is detected or demodulated to baseband.

Since the heterodyne does not detect the video signal, but merely translates the frequency of the video modulated RF signal, no quadrature distortion is generated.

3. Demodulator

A block diagram of a demodulator is shown in Figure 3. The demodulator receives the incoming VHF television signal, amplifies it, and converts it to an IF frequency for further amplification and filtering. Up to this point, the demodulator and heterodyne are identical. The IF amplifier provides gain before the video modulation on the IF carrier is detected, and finally amplified at baseband video in the video amplifier. The demodulator also provides the audio output either at audio frequency or on a 4.5 mhz subcarrier (or both).

The demodulator circuits which have the greatest effects on the video signal, in terms of distortion, are the IF amplifier and the detector. A typical IF amplifier response is shown in Figure 2b. The sound carrier must be trapped out to minimize cross modulation distortion in the detector. This filter operation is difficult to accomplish without introducing amplitude and phase distortion to the color subcarrier and sidebands. Note that the edge of the color subcarrier sidebands extends to 41.57 mhz, only 0.320 mhz from the sound carrier.

Filtering of the sound carrier at IF frequencies is also required in the heterodyne IF amplifier. Hence, both the demodulator and heterodyne are challenged to minimize high frequency phase distortion.

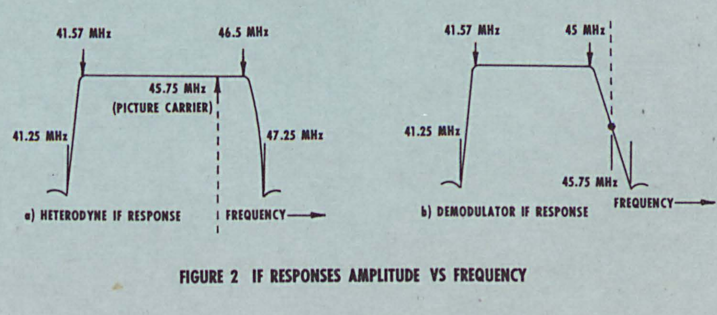


FIGURE 2 IF RESPONSES AMPLITUDE VS FREQUENCY

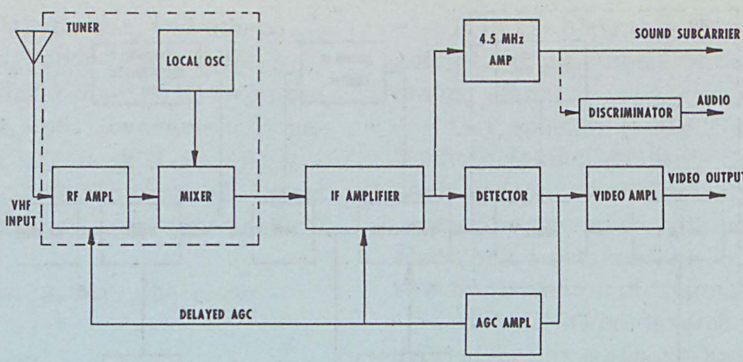


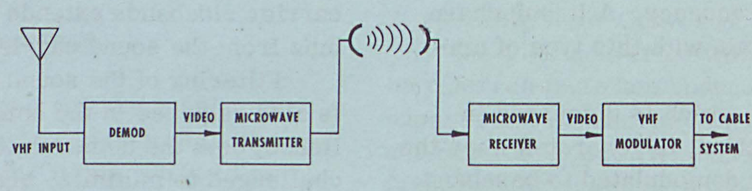
FIGURE 3 DEMODULATOR BLOCK DIAGRAM

The VHF television signal is transmitted as a vestigial sideband signal. As previously mentioned, the IF response required to produce a constant amplitude detected video signal must attenuate the frequencies near the video carrier which are double sideband. The phase response in this region must therefore be linear so that low frequency phase distortion is minimized. Low frequency phase linearity with the required IF amplitude response poses a difficult design problem.

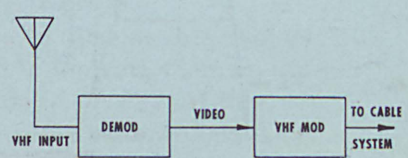
The video detector produces baseband video from the IF amplifier output. An envelope detector is a standard means of demodulating the IF signal. Differential gain and phase, which are a function of modulation percentage, will be introduced in the detector and can only be minimized. The use of an envelope detector is significant, since the signal being detected has a vestigial sideband characteristic. Vestigial sideband meaning one full sideband and a "vestige" or "part" of the other sideband is transmitted. When a vestigial sideband signal is applied to an envelope detector, an effect similar to low frequency phase distortion occurs at low modulation percentages, and quadrature distortion occurs at high modulation percentages. (Ref. 1) Quadrature distortion manifests itself as differential gain and differential phase on color signals. Quadrature distortion also affects the transient response, producing overshoots and streaking. (Ref. 1, 2, 3)

In summary, the demodulator IF amplifier must be carefully designed to minimize both high and low frequency phase and amplitude distortion. Differential gain and phase can be minimized by linearizing the detector. However, quadrature distortion is inherent in a vestigial sideband system utilizing an envelope detector and can only be minimized by utilizing nonstandard complicated video processing equipment.

Two applications of the demodulator are shown in Figure 4. In Figure 4a, the demodulator output, baseband video, is used to frequency modulate the microwave carrier of a microwave relay transmitter. The microwave receiver of the relay link then provides baseband video for the cable system. In Figure 4b, baseband video from the demodulator is applied directly to a VHF modulator which drives the cable system. A VHF modulator is therefore required in conjunction with a microwave receiver and also for direct use with a demodulator. The next section discusses VHF modulators.



a) MICROWAVE RELAY LINK



b) VHF CONVERSION

FIGURE 4 DEMODULATOR-MODULATOR APPLICATIONS

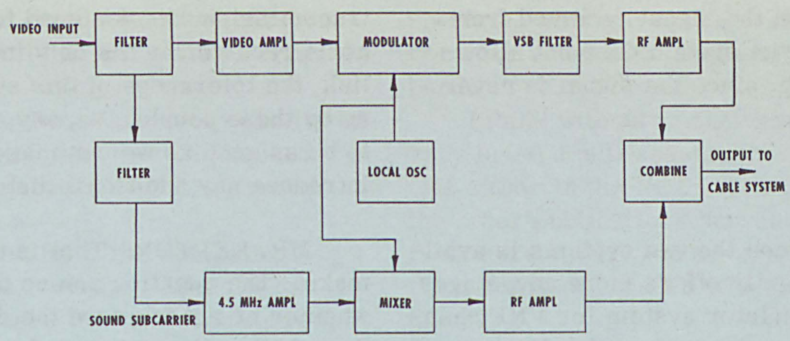


FIGURE 5 VHF MODULATOR BLOCK DIAGRAM

4. Modulator

A VHF modulator block diagram is shown in Figure 5.

Major sources of video signal distortion occur in the heavy outlined blocks in Figure 5. The modulator transfer characteristic depends upon the modulation percentage utilized. To maintain the highest signal to noise ratio, a high modulation percentage is desirable However, at high modulation percentages, differential gain and differential phase occur on the color subcarrier.

For adjacent channel operation, a vestigial sideband (VSB) filter is necessary (reference Figure 6). The VSB filter must be optimized to minimize phase distortion at frequencies near the picture carrier. This is a difficult filter design problem. The phase distortion generated in the VSB filter is usually compensated for in a video phase equalizer.

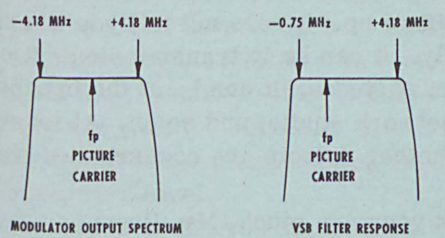


FIGURE 6 MODULATOR CIRCUIT CHARACTERISTICS

5. Comparison of Two Systems

In Table I, the demodulator-modulator system versus heterodyne system is compared on the basis of video distortion which is difficult to avoid. Item 1, phase nonlinearity near the color subcarrier and sidebands, can be minimized in both systems so as to produce a negligible effect on the picture. However, items 2 through 4 require complicated video processing equipment with the demodulator-modulator systems if pictures comparable to the heterodyne system are to be consistently provided.

Since the modulator utilizes down modulation, if the broadcast program goes off the air, a cw carrier signal to the cable system automatically results. The heterodyne system must provide a separate carrier substitution oscillator for this condition.

The heterodyne system offers the advantage of higher reliability because of the greater number of circuits and components required in the demodulator-modulator system. The probability of component failure is reduced since fewer components are required in the heterodyne.

Because of past and present day performance of these two systems, a subtle advantage for the demodulator-modulator system may be overlooked. A properly designed demodulator-modulator pair, used in conjunction with the necessary video processing equipment could conceivably produce an output with

Table I. Sources of Video Distortion

	DISTORTION	DEMODULATOR	MODULATOR	HETERODYNE
1.	Phase nonlinearity near color subcarrier and sidebands	Sound trap in IF amplifier	Video low pass filter	Sound trap in IF amplifier
2.	Low frequency phase distortion (delay distortion)	IF amplifier response	Vestigial sideband filter	
3.	Differential gain and differential phase	Video detector	Modulator	
4.	Quadrature Distortion	Video detection of vestigial sideband signal		

characteristics better than the signal received from the antenna. The heterodyne system does not allow complete video processing, since the signal is never below IF frequencies.

CONCLUSION

When the choice between the two systems is available, the heterodyne presently offers more advantages than the demodulator-modulator system for VHF channel conversion. However, microwave relay links require the use of a demodulator-modulator system. Hence, the problems associated with this system must be minimized in order to service this application.

REFERENCES

1. "Quadrature Distortion Correction for Vestigial Sideband Transmission" by Siegfred Dinsel, presented at SMPTE Technical Conference, November 1-5, 1965.
2. "Transient Response of Detectors in Symmetric and Assymetric Sideband Systems" by T. Murakami and R. W. Sonnenfeldt, RCA Review, December 1955, pp. 580-610.
3. "Improving the Transient Response of Television Receivers" by Avins, Harris and Horvath, Proc. of IRE January 1954, pp. 274-284.

CHAIRMAN SCHATZEL: We have a sufficient time for a question or two.

MR. JOHN MONROE (VUMORE Company): We all appreciate the use of the heterodyne for off-the-air equipment; but when can we expect a better type of hardware for the other use?

MR. ROGENESS: That is a different question to answer.

I would suspect that within the next year there would be equipment available if you are willing to pay the price.

MR. DONALD LEPTON (SWVA): I should like to ask in connection with the demodulator-modulator that you referred to, whether you found a great deal of difference, or whether you found the transmitting stations have this problem and are handling it 100 per cent?

MR. ROGENESS: The transmitting stations do have this problem. I believe that transmitters do use both low and high frequency phase equalization to prevent distortion of the video transmission.

I do not believe, however, they do anything to correct for the quadrature distortions, and since the transmission was designed for the broadcaster and home receiver as the only items in the transmission link, the tolerances of this system are mainly used up by these people. So, any equipment we insert has to be as good as we can make if if we do not want to introduce any additional distortion.

MR. LEPTON: That is the point I wanted you to make. The question comes up, how can we know whether or not for sure the distortion is created by them? Or, do you know of any equipment that will take and monitor an off-the-air signal with absolute credibility?

MR. ROGENESS: I cannot specify any specific equipment; but this is a definite possibility, that with the right equipment available, the CATV operator could monitor the off-the-air signal and determine what the quality of signal is that is being received, so he will know if he is inducing any additional distortion in the transmission system.

CHAIRMAN SCHATZEL: I think the vertical interval test signals, the vertical interval test signals now transmitted by the networks, provide an opportunity to the CATV operator who provides himself with the necessary additional testing equipment. It provides him an opportunity for obtaining some of the information you are talking about now, although not all of it.

It does tell you if there is a transmission defect somewhere between the network studio and where you pick the signal up. It does not tell you where it is, necessarily. It can be in transmission. It can be at the broadcast studio. It can be at the broadcast station, the network studio, and so on. At least it will tell you whether defects are occurring in transmission.

Thank you very much, Mr. Rogeness.

MR. LEPTON: Mr. Chairman, I have a question not relating to this particular schedule. When are you handling the NCTA Standards?

CHAIRMAN SCHATZEL: I am glad you asked that question, because I am about to introduce Archer Taylor, Chairman of the NCTA Standards Committee, who will conduct a brief summarization of the subject indicated on our agenda, THE NCTA STANDARD ON CATV AMPLIFIER DISTORTION.

MR. TAYLOR: About an hour ago it looked as though we had used up all of our "cushion" because of our rather late start. Some of the speakers have, I think, condensed their presentations, so that we still have a little time left.

Unfortunately, however, in the hastily-called conference I believe Jake Shekel has left. Am I correct? Is he in the room?

I am going to introduce the people who were listed on the panel in your brochure, and we will proceed very quickly into allowing questions on this general subject after an introduction.

I believe it would be helpful if the remaining panelists would come to the rostrum. Jake Shekel was to have been on the panel. He was all prepared, and I might say he is a very helpful member of the Committee. Unfortunately, when we were delayed, it was necessary for him to leave, and he is not here at the moment, but perhaps will joint us later.

Mr. Mike Rodriguez, of VIKOA, Inc.; Mr. Ken Simons, of Jerrold; Mr. Earl Hickman, of AMECO; Mr. Heinz Blum, of Entron Company, comprise our group.

I will take a few minutes to briefly describe what the Engineering Subcommittee of the NCTA Standards Committee is, and then throw the discussion open to questions from the floor. If you would like to ask a particular member of the panel a question, designate him by name; otherwise, I will channel the question to someone for reply.

Basically, the standard is a method of specifying and measuring amplifier distortion.

We changed this from the original proposal because we found in practice that it was unworkable, and in several respects meaningless.

The test, briefly, is with 12 channels, and I will oversimplify this somewhat without some of the explanations that are given in the standard itself -- the test is with 12 channels, modulated with a symmetrical square wave. In fact, generally this will be 100 per cent modulated, although the standard allows for a minimum carrier level not more than of one-eighth of the maximum carrier level.

The channel upon which you are making the measurement has modulation removed with the others all modulated synchronously, so the modulation maximum amount occurs at the same time; and the measurement is then made by measuring the sideband voltage which appears on the unmodulated carrier as a result of the modulation on other carriers.

Frequency of the modulating square wave is 15.75 kilocycles, plus or minus 20 per cent, so that a sharply-tuned voltmeter becomes the measuring device to measure the 15.75 kilocycle sideband resulting from cross-modulation.

A second important aspect of the standard is the specification of spurious frequencies. This is defined broadly to cover signals occurring within any of the test channels, at frequencies differing from the frequencies of the test carriers.

This measurement is made in a number of different ways, the most practical method being with a spectrum analyzer actually exploring the video spectrum for undesired frequencies within the video path band.

I think without further explanation, and this is very brief, I will assume that many of you have read this either in the NCTA BULLETIN, or in some of the other publications that have reprinted it. I think from here I will open the discussion to questions from the floor, and we will see where we go from there.

MR. CAMPBELL: What kind of delay do you propose between your bulk so this 15 resembles a faint pulse?

MR. TAYLOR: Do one of you want to answer that? Ken, do you want to speak to that?

MR. KEN SIMONS: I think one of the question parts of the standard that has aroused more comment than any other part had to do with the wave form of the modulation on the undesired interfering characters; and in my opinion, which I believe can be substantiated by measurement, it is that the wave form is relatively unimportant provided that it is within the vicinity of 15 kilocycles, and provides a suitable correction factor is applied to take care of whatever duty is given it by the particular modulation wave form.

There is much to be said about a pulse modulation. It would allow you to look on a receiver and see what was being created, and it would simulate real life, so to speak; but the Committee felt that a square wave is the simplest form of modulation to generate, to determine that a square wave does in fact have a 50 per cent duty factor, so that you merely have to measure the DC level. The DC level is 50 per cent of the peak; it has a 50 per cent difficulty factor.

Also, the oscillators, if you turn them off and on half the time at a 50 per cent kilocycle rate, you do not have to go through any difficult modulation standard.

We want this test to be as easy and as economical as possible so that people can do it. You can elaborate on it as much as you desire. You can take the test signal and say that the test signal should be modulated with television signals derived from the IA standard generator; but this adds cost to the test, and there is some question as to whether this is justified.

The only question is as to what the wave form on the undesired carrier should be, and has to do with the question, is there a correlation between various wave forms?

It was the consensus of the Committee that at the time we settled on this standard there was such correlation and we could use such a square wave.

If there are those who disagree with this, I think it is up to them to show there is not correlation, and it can be considered and modified.

This standard, as you understand, is a proposed standard and open to discussion, and is certainly ready to be modified in any way where this modification can be shown to be desirable.

I would again say the object of the game here is to get a simple test, as simple as possible, in a complex situation; a simple test which will correlate, in fact, with observed pictures.

Does that answer your question?

MR. CAMPBELL: Thank you; that is fine.

MR. TAYLOR: I would like to make one correction, Ken, if you do not mind.

The Board of Directors of NCTA has actually agreed with the Standards Committee's recommendation that this is a NCTA standard. I think it was proposed a year ago, and it has been subject to considerable comment and major revision. As of now, this is a standard of the NCTA industry, although any standard can, of course, be modified upon the proper showing of the need for modification.

Are there further questions?

I would like to point out that in the meantime Jake Shekel has joined us. He is with the SKL Company.

Thank you, Jake.

Does anyone have a question?

MR. BERNIE EVANS: I am curious as to whether these are a group of astrometrical 15 kilocycle oscillators, or whether all of them are on and off alike? I am a little bit unfamiliar with the detail of the standard, and perhaps my question is premature.

MR. TAYLOR: The intent is for all carriers to be on simultaneously and all off simultaneously, as precisely as possible at the same time. Then the carrier on which the measurement is to be made has the modulation removed so it is unmodulated CW, with the other modulators as described.

Does that answer your question?

MR. EVANS: Yes, thank you.

MR. TAYLOR: Are there further questions?

Go ahead --

MR. CAMPBELL: I suppose I should direct this inquiry to Mr. Simons because we sell him a number of products, as do many others, and I assume we can use that CW oscillator and other heterodyne systems for the clear channel.

My question is: Is there any way to get that 15.4, or whatever it is, over to the other commanders that want to do it that way at once, without too much expense?

MR. SIMONS: I think the question is primarily one of where we are talking about the equipment being available, or being made available for making this test, and it seems to me rather evident that with an NCTA standard amplifier distortion, a standard on amplifier distortion, there are certainly people in the world who are interested in making money from selling test equipment, and I am sure that will generate the necessary enthusiasm.

To be more specific, however, if you have some form of heterodyne converter, as Mr. Rogeness has been describing, all you really need is an incorporating signal. We in the laboratory use a 608, which is rather expensive, but it does not have to be that type of signal. You can use any small oscillator and key it on and off at 15 kilocycle rate.

The circuitry involved is not very elaborate, and I hope my Instrument Division representatives are not present to hear me say it, but it should not be very expensive because it is quite simple, technically speaking.

We have purposely written the standard with that in mind. We simply need an indication. Unless we are mistaken, the exact specifications on the undesired signal are rather unimportant. It has to create a strong change at 15 kilocycles from zero to off. It could be silently modulated. It could be bulk-modulated. It could be square-wave modulated with due regulation in the final reading subtracting or adding db; and the measurement could be made on the standard set.

What you need is an IF signal. It should not be difficult.

There are, however, two areas where it is required, and with the signal you get on the desired channel, this must be very clear if you are attempting to measure 60 modulation plus. This puts it on the mixing network where the various channels are concerned, and you must have it clear so you do not have interaction between the various ones.

There is one other point, if I may just comment on it, Mr. Taylor --

MR. TAYLOR: Proceed --

MR. SIMONS: This is the specification, the proposed -- it isn't proposed any more --

MR. TAYLOR: Not proposed any more --

MR. SIMONS: The NCTA standard calls for a measurement at operating conditions, and this sounds very innocent and very essential, but the implication is not quite so simple, because the operating condition is for a line amplifier in the CATV system at levels which are 10 or 15 db below where we have been specifying, and at those levels typically plus 30 to 35 dBnV, the distortion is incredibly small. It has to be so after you cascade many amplifiers, for you do not get a reasonably sizable distortion. It is so incredibly small that it is difficult to measure. This is measuring at minus 85 to 90 db cross-mount.

It is not the intention of the standard to measure at that level. It is the intention, and it was attempted to be written so that the manufacturer guarantees that the amplifier will work at that level and will produce at that distortion.

He may arrive at that distortion by cascading 20 amplifiers and measuring the total distortion, if he is unable to measure at the operating level. There have, however, been advances in the cross-modulation technique, and I am sure the testing people will be stimulated to make the measurement at the operating level. I believe this serves the interest of the system operator because he is buying an operator the manufacturer is saying in effect that when you connect 20 of these, each will produce less than X db distortion, and the result will be good. This is more important.

We purchase sugar on a pound basis, where your pound and my pound are the same pound; and to try to end the confusion when someone says, "My amplifier will put out X dBnV under certain circumstances", this was written.

MR. TAYLOR: Are there further questions?

MR. SWITZER (Toronto): Mr. Simons, you made the statement that you were making the standard apply to a system a small degree higher than it would be if you had a stack of commanders. The simplest way to put a synchronous signal on them all is just to tune all 11 of them to the desired one good, clear, signal, and put the substitution carrier on the one you are checking, and this would be as close to home in your measurement on the distortion that you would want to come; and the instrument problem is not really at the head end. It turns on at the source to meet the standard, or come close to it.

The instrumentation, however, at the other end represents a problem in terms of money and measurement, and so on.

MR. TAYLOR: I would like to raise a question about the measurement of spurious frequencies, and something on that issue. I would like to have some comment made on spurious frequency measurement.

MR. MIKE RODRIGUEZ: One of the problems we have found VIKOA is that although we have the instrumentation, with the proper dynamic range, in order to measure cross-modulation, and incidentally, this dynamic range is somewhere in the order of about 100 db, with that we achieve in utilizing the video output which we put into a recording ray analyzer, a general radio instrument, what this really results in is a receiver with a three-cycle band width.

You can see where you would naturally achieve tremendous sensitivity. The problem, however, is that this recording regulator analyzer is designed for the audio spectrum, and it has a total AC bandwidth a 50 kilocycle measurement. On that basis, of course, if you are searching the spectrum for spuriae you will find you have a really tremendous chore because at 50 kilocycle stems it takes quite a while to check a frequency band between 50 and 220.

Our technique is based on a spectrum analyzer; a cascaded analyzer search, so that spuriae are at least within the capabilities of the spectrum analyzer.

Once we have identified the spectrum frequency within the display of the frequency spectrum analyzer, we use a 608 in connection with a controlling device similar to a synchronizer which gives crystal stability, and the purpose of this is to bring the signal or the signal generator within or close to the spuriae which we have identified.

Then what we do is we take this signal generator; use it as a local oscillator; put it into a mixing device, and then beat the spurious frequency into the 50 kilocycle range of the wave analyzer. At this point, then, of course, it is possible to make a quantitative measurement regardless of how low the spurious response may be.

MR. SWITZER: Looking at the availability of wave analyzers to cover the whole band of interest from the low to the high, and noting that it will take a whole stack of them because you get an audio from 20 to 220 megahertz, and then perhaps something up to 20 as well, there will be a spectrum analyzer that will analyze a single display, 10 megaherta to 20 megahertz, and will spot any spuriae there that should not be there.

It will simplify the search for the spurious.

We have done it by scanning the IF out of a receiver as a free collector, because most spectrum analyzers need a free collector of some kind to look for these things; and the problem that I have found in working with these is that often the best will cause the most trouble, and the one you are most accessible to is of the third order, the product from any three channels. Any two will fall back and the third will fall back as an almost co-channel. On the third one, it will either be above or below. This is a low-level spurious, and it is very close to the carrier, and in a spectrum analyzer display that has a carrier in that spurious, it will often be hiding right under the skirt.

We find it preferable to scan the video; that is, to scan the base panel in effect where the carrier is in the setup.

MR. RODRIGUEZ: This triple beat you mentioned is interesting, because we recently conducted a computer program in order to identify and get an idea of the magnitude of these various spurious responses that do occur, and how many of them there are that are involved.

Just on the basis of 24 carried, we eliminated 12 video and 12 town. The computer identified a total of 63,000 spurious responses, 40,000 of which were of the triple beat variety.

MR. SWITZER: As a practical circumstance, that triple beat that I speak of probably exists in more systems than people realize. We begin to feel that what we call a kind of "waterfall" effect, with some of our pictures, and often what looks like a co-channel, when we know really there is no reason for a co-channel, may be just that third order IM beat from three adjacent channels.

MR. TAYLOR: Other questions come to mind, I am sure, that you would like to ask, and we still have a few minutes remaining.

I would like to have some of these people who have developed test instruments to comment. Do you want to make some comment about the testing procedures?

MR. EARL HICKMAN: I was afraid you would never ask. (Laughter)

If you would like to see an integral test unit that is built following the NCTA standard, if you will drop by our booth I will be glad to demonstrate it.

MR. TAYLOR: I think there are probably some other devices, actually, and I wonder if you would like to say something about yours?

DR. JACOB SHEKEL: I believe all I can do is repeat what Mr. Hickman has said. There is one in the booth, and I will be glad to demonstrate it there.

MR. TAYLOR: Mr. Earl Hickman is with AMECO. Are there any questions? Are there any further comments that you would like to add for the good of the order?

MR. HEINZ BLUM: Just the same comment that my friend, Jake Shekel, made.

MR. TAYLOR: I have not been through the Exhibit Hall so I am not sure what is to be seen there.

MR. SIMONS: We, too, set up a computer program, and we are amazed with the result. It reminded me of an event that happened in my family when my boy, who is now bigger than I, was about 10 years old. We fell a victim to a salesman and bought a set of the ENCYCLOPEDIA BRITANNICA. When the books first came we were looking through them, and under "anatomy" there are a number of beautifully colored charts.

This has to do with the 63,000 beats, and how the CATV survived with all of these beats. There were these beautifully colored charts. You pick them up, and you can work them from the inside out, and cover the entire body. You see the intestines, the spleen, the liver, and the heart, and so on.

Our young son looked at this and he said, "You mean that is inside me, all those things? You mean all of that red thing, all that curlicue?"

We replied, "Yes."

He said, "I think I'll go lie down." (Laughter)

MR. TAYLOR: Unless there are further questions, I would like to close this by reading the information that the Committee has published on how an amplifier should be specified with regard to distortion, and it is our hope that customers will not have to have their own elaborate testing facilities; that manufacturers will specify in this form, which we hope and believe will prove to be meaningful, the necessary data.

(Mr. Taylor presented Specifications on Distortion.)

I will ask once more, are there further questions?

MR. RAY ROHRER (Kalispell, Montana): It is the intent of the Subcommittee of the Standards Committee to check on manufacturers that use this standard?

MR. TAYLOR: You ask a difficult question to answer.

The policing of this will be subject to the Board of Directors of NCTA, and on recommendation of its Standards Committee.

I might say that we have copyrighted, for example, the Able Cable Symbol, and therefore refusal of permission to use that symbol has been ordered by the Board of Directors.

I presume the Board of Directors would take such action as might be recommended by the Standards Committee in the case of abuse or misuse of the NCTA standard.

Are there other questions?

MR. ROBERT HOWARD (AMECO): I am still a little unclear as to how to correlate the new standard to a practical systems case, because of one hand you are not prepared to give me an answer for a situation which generates the worst case numberwise, but does not particularly relate to the practical case, because as was discussed yesterday by William Rheinfelder, the case of the random modulation is much more visibly detectable than the case of the synchronous modulation. Therefore, I am a little confused.

I would like an expression from the group up there as to what kind of a correction to make to the number that I now have to relate it more correctly to my system application?

MR. TAYLOR: I would comment, first, on this that there is a great need for some subjective correlations between what we are generally calling cross-modulation and subjective evaluation of picture quality. This has not been done in any extensive manner, and as you have indicated, and as Mr. Rheinfelder indicated, the parameters are complex and numerous.

The first step, however, in that process comes to the matter of how do you define the distortion that you want to correlate with subject evaluation? This is only a first step.

The next step now will be to provide the correlation with actual picture degradation.

I think that the effort of the Committee was to adopt a worst-case situation, namely, with all of the modulation in phase; how you allow it to go below that is at this moment indeterminate.

Does anybody else care to comment on that question? Apparently everyone has something to say on it.

MR. BLUM: The Standards Committee, of course, wanted to establish a standard measuring technique. It did not intend to set up a standard for the performance of an amplifier, nor for the performance of a system.

In this connection, I would like to acquaint everybody with the capability of computing systems performance in a very simple manner. The cross modulation ratio for each amplifier has been given according to the language we have set forth in the standard, and if you just total the figures for all amplifiers in cascade ahead of the location to be examined, you can determine the cross-modulation at every or any point on the system regardless of whether it is in the trunk line at the output of a bridging amplifier, or at the end of a distribution line. This added advantage is one of the fringe benefits of the particular standard.

Even though we do not attempt to say that we must have a certain minimum distortion line value, is so represented.

Some of the systems operators, as well as manufactures and turnkey constructors, have set certain standards for themselves. These vary.

A very large systems operator uses a standard of 52 db. This is nothing we have to adhere to; we can use other figures if our experience dictates otherwise.

MR. TAYLOR: I will recognize Mr. Rodriguez.

MR. RODRIGUEZ: Just as Bob indicated, Bob Howard, we VIKOA are also very much concerned about making some subjective comparisons in terms of actual performance versus the measurements.

I had intended to wait until this afternoon at which time the Engineering Subcommittee and Standards Committee are going to have a meeting. Is this correct, at two o'clock?

MR. TAYLOR: This is right.

MR. RODRIGUEZ: What we would like to do is volunteer a 60 amplifier system which we actually have working at our facility. We use it merely as an experimental system. Using this system perhaps we could organize a time at which we could actually sit down and make these measurements and make the subjective measurements and attempt to correlate these with the actual distortion measurements that one gets on the instrument.

MR. HICKMAN: I think if we get too deeply involved in this we could get caught in our own trap. I think it all goes back to the system specification.

If a system is to be built using only one amplifier, obviously that amplifier does not have as low a cross-modulation product as the system which would require a considerably larger number than one amplifier.

So, I think we should restate that the intent, as I see it, of this Committee, is merely to come up with a basis for comparison, a clarification of what we mean when we speak of cross-modulation and attach a number thereto, so that we do not have to go into a long dissertation each time we say that our cross-modulation products are down 60 db or 50 db, or whatever the figure; that it will be immediately known what we mean by such a quotation.

That is the principal purpose behind using synchronous modulation on the carriers as the test prescribes.

If we did not use synchronous modulation, we could use any other form of random modulation and it would be very difficult to describe, and we might have trouble finding the common denominator.

DR. SHEKEL: I just want to make clear what the standard does not set or specify, so there will not be any doubt about it.

The standard does not set a level of distortion which is desirable for a single amplifier. It does not say how the distortion accumulates along the line. It does not say what the picture quality should be at the end of the line. We all have our personal opinions, as well as company specs; but it is not included in the standard.

The only thing implied by the standard is a standard way of specifying individual amplifiers, so that a customer can read the specifications of different amplifiers, compare them, and draw his own conclusions.

We believe that if two amplifiers, A and B, that -- measured under the same conditions -- if amplifier A has a lower distortion than amplifier B, and if then two identical systems are built using these two types of amplifiers, then the system with amplifiers of type A will have less distortion than the system with amplifiers of type B. This is the only correlation that we do imply between the specifications of a single amplifier and the picture quality in a system. The standard does not imply any precise numerical relations between amplifier specs and systems performance.

If anyone can prove that this general assumption is not true, that means if the rating of those two amplifiers A and B, does not lead to the same rating of systems, I think we would like to hear about it, and we may then modify our standard. I think, however, that the standard does, what it was supposed to do, and I would not like anyone to assume that it does anything more.

MR. SIMONS: I just want to say that if you look behind these words "subjective testing", you will find it means people looking at pictures and deciding whether they are any good, or not. In your systems you have people. You have television receivers. If you had an amplifier that had a known rating, you could do your own testing. You can look at the pictures and determine whether they are any good. You do not have to wait for us to carry out tests.

We should, of course, do it in a scientific way. You can do it on your own if you have an amplifier.

MR. TAYLOR: Our time has been exhausted, and our panel has concluded.

I will turn the meeting back to our Chairman, Mr. Schatzel.

CHAIRMAN SCHATZEL: We have completed our agenda for the morning, and I think we can say thank you to our speakers for a very capably performance.

We likewise extend our appreciation to the audience for its attention.

This Technical Session is adjourned.

(The Technical Session adjourned at one o'clock.)

DISTORTION MEASUREMENT TECHNIQUES FOR CATV

By W. A. Rheinfelder
R & D Anaconda-Astrodata Co.

In this discussion, distortion will be limited to the effect called "windshield wiper" distortion. Harmonic distortion, spurious frequencies, noise, hum and other forms of distortion will not be considered here.

I Windshield Wiper Effect and Rf-Distortion

In multi-channel TV systems the maximum practical signal level or overload level is usually determined by the onset of windshield wiper distortion. In windshield wiper effect, the sync pulses of one or more undesired TV signals appear as superimposed modulation upon the modulation of the desired carrier. Since sync pulses of different TV stations are of very closely the same frequency, but are not synchronized, vertical or diagonal bars appear which seem to drift from side to side at a low audio rate determined by the difference frequency of the respective sync pulses.

Modulation of an undesired carrier being impressed upon the desired signal is by definition cross modulation. Unfortunately, windshield wiper distortion is a much more complicated effect and can only under special circumstances be directly related to measured cross modulation. To get a better understanding of windshield wiper distortion, we consider first standard cross and intermodulation distortion[1].

Distortion causing nonlinearities can generally be expressed by a power series of the form

$$e_o = a_o + a_1 e_i + a_2 e_i^2 + a_3 e_i^3 + \ldots \qquad (1)$$

where e_o = output voltage
e_i = input voltage
a_n = coefficient of power term n

We substitute for the input voltage the sum of the modulated desired signal and a modulated undesired signal, or

$$e_i = e_d \cos \omega_d t \ (1 + m_d \cos p_d t) + e_u \cos \omega_u t \ (1 + m_u \cos p_u t) \qquad (2)$$

where e = peak voltage of carrier
ω = frequency of carrier in radians
m = modulation index of carrier
p = modulation frequency of carrier in radians
d = desired (subscript)
u = undesired (subscript)

After short calculation, we find that modulation of the desired carrier by the undesired carrier can be produced only by third or higher order distortion. To obtain cross modulation distortion, term a_3 in equ. (1) must exist. The cross modulation factor is then found as

$$k_c = 3\, a_3\, m_u\, e_u^{\,2} / a_1\, m_d\,, \qquad (3)$$

with the parameters as defined above.

Second order distortion, expressed by the term with coefficient a_2 in (1), does not produce cross modulation, but does result in first and second order sum and difference frequencies, which are called intermodulation products and are the cause of what is termed spurious frequencies. Generally, inter-modulation frequencies are defined by

$$f = nf_1 \pm mf_2 \qquad (4)$$

where f = intermodulation frequency
f_1 , f_2 = interfering frequencies
n , m = integer numbers

By substituting expression (2) into (1), intermodulation factor is found as

$$k_i = a_2\, e_u / a_1 \qquad (\omega_d \pm \omega_u) \qquad (5)$$

and for second order products

$$k_i' = 3\, a_3\, e_d\, e_u \,/\, 4a_1 \qquad (2\,\omega_d \pm \omega_u\,;\, 2\,\omega_u \pm \omega_d) \qquad (5a)$$

The theory of active devices shows that by certain circuit design techniques the term a_3 in (1) may be nulled, while term a_2 can normally only be minimized. Tests were already conducted in 1960 to obtain a correlation between observed windshield wiper distortion and cross modulation. All results were negative. Selected transistors, as well as specially designed semiconductors with cross modulation products reduced by 30 db as compared to normal samples, showed no improvement in windshield wiper distortion and in some cases resulted in even increased windshield wiper effect. A correlation to intermodulation was attempted, also with poor results. Windshield wiper distortion, therefore, represents a far more complex effect than simple cross modulation or intermodulation.

Specialized test equipment was then designed[2] to shed further light on the exact mechanism of windshield wiper distortion. Such equipment is necessary if we consider the normal test procedure for windshield wiper effect and its inherent sources of error which preclude any research effort. Before proceeding any further, it is necessary to re-examine this direct test method in detail.

II The Direct Method and Its Error Sources

In normal windshield wiper testing of CATV amplifiers[3], twelve TV signals are applied to the input of an amplifier and the level is increased until windshield wiping is noticed as monitored on a TV set connected to the output of the amplifier. This level is often termed the overload level of the amplifier. While this test procedure is awkward and loaded with errors, it is by no means obsolete. It must still be referred to as the ultimate performance criterion until a better and repeatable distortion measurement technique has become available and a distortion percentage number has been agreed upon by correlation to a certain picture degradation in the normal test procedure. This is analogous to a visual test as the ultimate criterion for signal to noise ratio until the time that a number could be agreed upon, such as 40 db video signal to noise ratio for a studio quality picture. There is then a two-fold problem in developing any standard test method:

1) The development of a repeatable and accurate test technique which directly correlates to an actual observed effect.
2) The agreement upon a number to correlate to a certain acceptable quality level.

Point 2 reaches very much into subjective factors and again cannot be undertaken until a repeatable test technique exists (point 1). Until both points are fully covered, the direct test method must still be considered the ultimate performance criterion.

With this in mind, let us consider the various error sources of the direct method and their elimination. As mentioned above, in the direct method, TV signals are applied to the amplifier under test and windshield wiper distortion is directly observed in the output on a TV screen. This test method does, of course, closely resemble the actual conditions encountered in a CATV system; however, the error sources for testing amplifiers are numerous:

1) Errors due to conversion and sync correlation

In order to obtain twelve-channel signals, all local signals are usually used directly for testing and any empty channels are filled by frequency conversion of the same local signals. This process in itself leads to a different signal quality for the converted signal and a possibility of errors. For example, in the conversion process sync pulses might be compressed, which then results in a lower reading of distortion than is actually present.

The derivation and assignment of the signals for the empty TV channels is even more important. No windshield wiping is possible if all test signals are derived from a common sync, that is one TV signal. Since the number of local stations is usually limited, it will be necessary to use the same off-the-air signal several times. It is important to avoid a conversion scheme where adjacent channels result with correlated sync pulses. For example, if Channels 11 and 13 are available off-the-air, these signals should not be used to produce by conversion a Channel 12 signal, since then adjacent channels use the same sync pulses and windshield wiping is not possible. A lower reading than the actual distortion will be obtained.

2) Errors due to live signals

Modulation levels of live signals are inconsistent. Sync pulses are often poorly shaped and transmitted as such over the air; occasionally inverted sync pulses dipping into the video signal are obtained. Carrier levels often fluctuate several dB. All of these cases lead to proportional measurement errors leading to poor repeatability. Also, the video signal itself tends to mask some forms of distortion.

3) Spurious responses

Interference beats of a variable nature often occur when using live signals. Such beats mask windshield wiper effect. Since their intensity often varies with time, they introduce a measurement error due to a change in distortion visibility.

4) Level errors

The signals applied to the amplifier under test must have the specified levels. Also, output level must be read accurately. Any level errors due to rf-voltmeter inaccuracy or other instrumentation problems appear directly in the reading. This includes level errors of those field strength meters which are affected by varying modulation depths of a TV signal.

5) Errors in TV screen read-out

Normal TV-receivers are not designed for adjacent channel reception. Most sets show windshield wiping at a level of about +10 dbmv. By adjusting the fine tuning, adjacent channel windshield wiping can be improved; however, this results in a misadjustment of the receiver. Consequently, the level to the TV set must be kept always at a safe input level by a separate attenuator; preferably the input level to the TV set is kept constant regardless of the level applied to the amplifier under test. As was mentioned, fine tuning does drastically change the visibility of windshield wiper distortion, as does the setting of contrast and brightness controls. Contrast and brightness should be set for good whites and blacks visible simultaneously, fine tuning to the point of diappearance of sound bars. All of these sources of errors again add several dB to the total inaccuracy. Lastly, the subjective factor of the observer must be considered. As has been demonstrated, there is another margin of several dB between what may be visible to one person as compared to another individual.

There are several other error sources which relate more to the practical aspects (discussed below). However crude the direct method is, it must still be resorted to as the final criterion in case of doubt until another measurement method has been developed whose direct correlation to windshield wiper effect has been fully established.

As an improvement to the basic direct method, a reference amplifier is often used which has a known distortion level. This amplifier is measured before each distortion test and a correction is then made to all readings accordingly. In this fashion, errors due to a varying off-the-air condition, drifts in instruments, errors in adjustments of the TV set, etc., may be largely eliminated and much more consistent and repeatable readings are obtained, although the absolute level of distortion is still in doubt.

III Problems in Correlating Observed Windshield Wiper Effect to Measured Data

As was mentioned in Section I, measurements have proven conclusively that there is no direct relationship of observable windshield wiper effect to either cross or intermodulation. For a deeper understanding of the exact mechanism we must consider the results of a more detailed study of windshield wiper effect which was performed using specially designed test equipment. If windshield wiping were caused by pure cross modulation (3rd order nonlinearities only) black bars should appear since sync pulses are in the infra-black region. These black bars are indeed observable with special test equipment and they can be measured and behave very much like standard cross modulation. Unfortunately, they do not represent windshield wiper effect to the average viewer since they remain generally invisible. As level is increased, distortion increases, however, with a gradual phase reversal. Black bars change gradually from black to gray and then to white. As the shading changes, the bars become invisible since they blend with the background intensity of the screen. We have here a case where visible distortion decreases, although measured distortion increases. Finally, with a further increase in level the bars become white and we have the condition normally understood as windshield wiper effect. At this point distortion increases rapidly and becomes noticeable and objectionable to the subscriber in a CATV system. The difference between the onset of windshield wiping visible to a critical, trained observer and being objectionable to the average subscriber is usually not more than 4 db. The change in visibility of distortion is depicted in Figure 1. The peak visibility level in "black wipe" is typically 15 to 20 dB below the level for the onset of windshield wiping and its magnitude is normally too low to be visible except with special test set-ups. Only in some rare cases of drastically incorrect circuit design, can "black wipe" actually be the cause of objectionable windshield wiper effect and can be distinguished as such by an experienced observer. The generation of "black wipe" is well understood and follows expression (3), Section I. "White wipe," which is the distortion of main interest in CATV, is generated by a different mechanism and is not explained by the direct action of cross or intermodulation or higher order nonlinearities (see Appendix I).

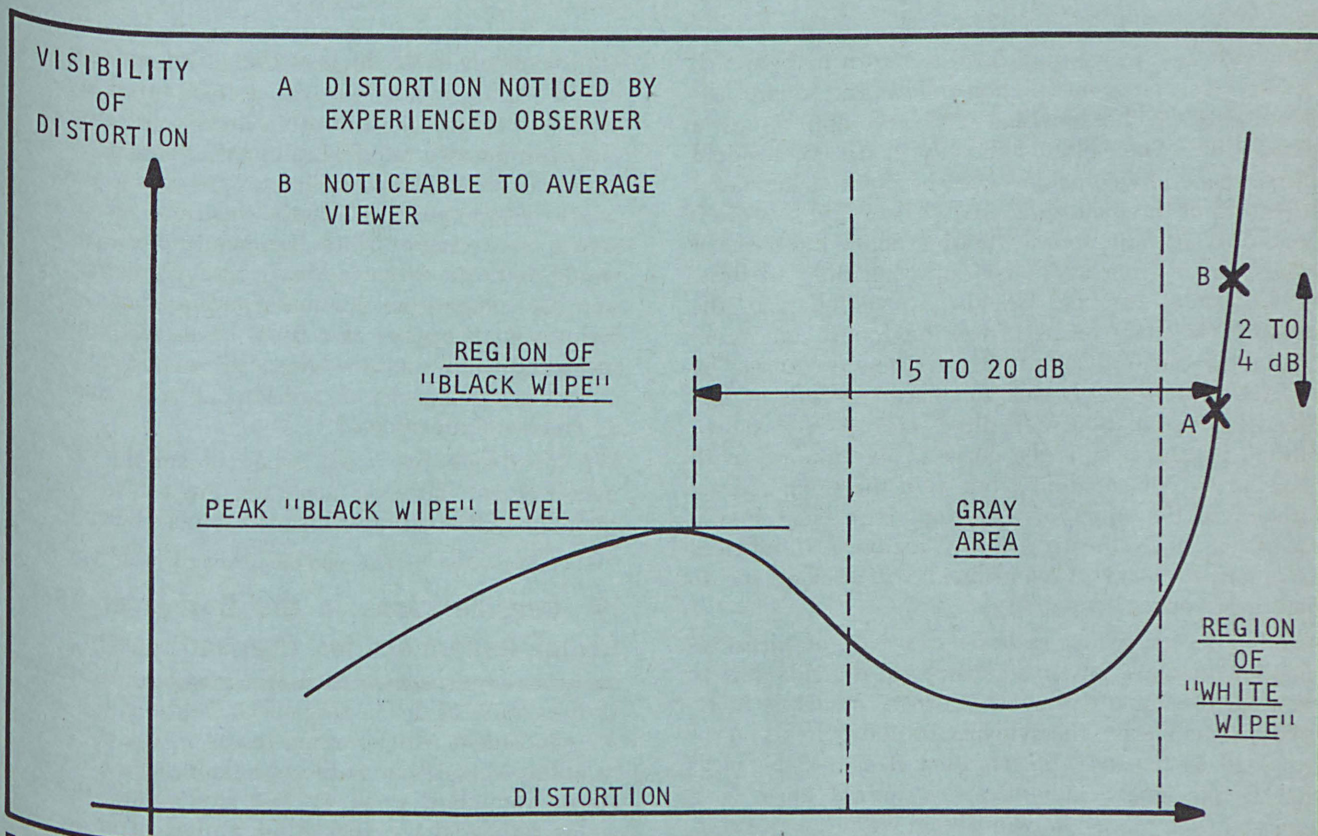


FIGURE 1 VISIBILITY OF WINDSHIELD WIPER EFFECT

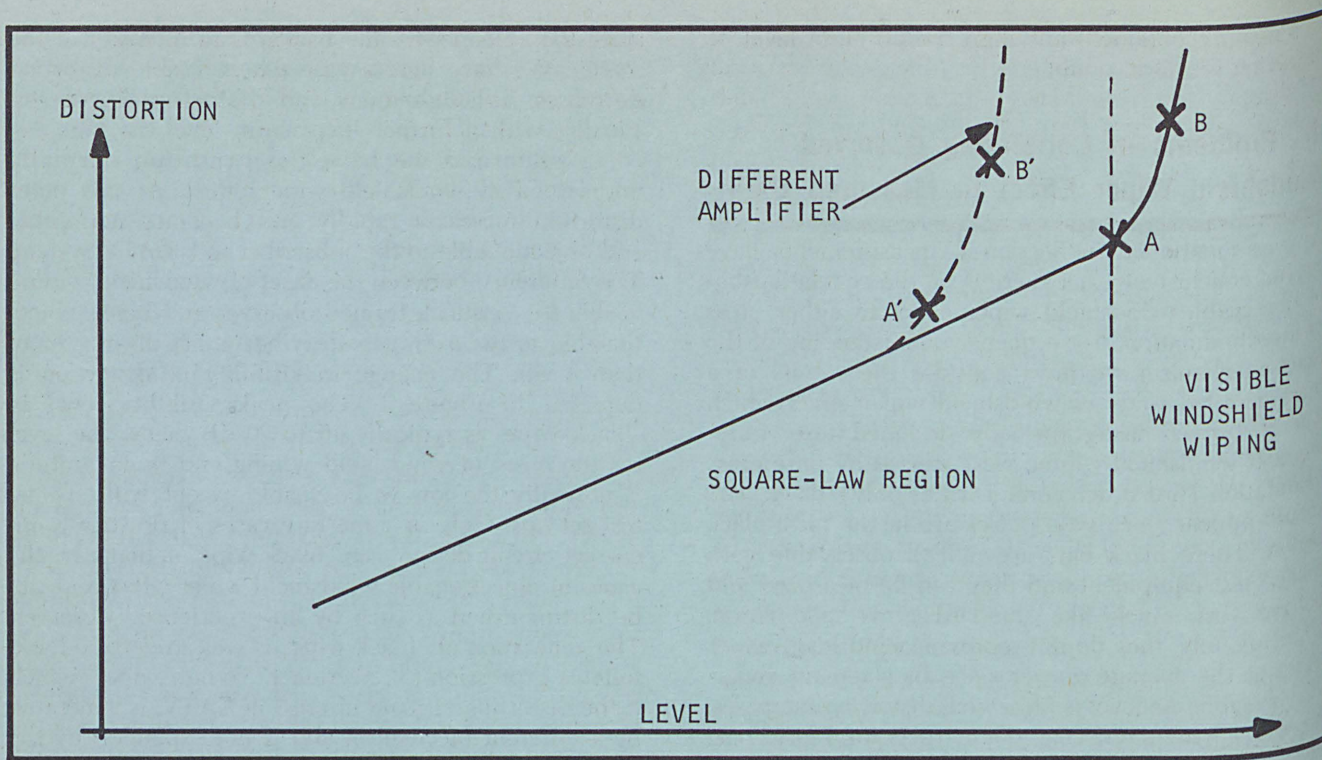


FIGURE 2 TYPICAL DISTORTION VS LEVEL

Distortion as a function of level is shown in Figure 2. At low levels cross modulation follows the square law characteristics of expression (3) and appears as a straight line when plotted directly in dB. Windshield wiping generally coincides with the point of increased curvature of the distortion curve. Therefore, it is often possible to use square law derating below the onset of windshield wiping as a first approximation. In drastically wrong amplifier design a deviation from the square law characteristics may be found, but more commonly such a measured deviation is caused by instrumentation errors due to phase reversals at low levels in combination with direct pickup. Also shown dashed in Figure 2, is the curve of an amplifier with reduced output capability, but with the same characteristics in the square law region. It is clear that a measurement in the square law region is insufficient as a measurement of windshield wiper effect, or to determine output capability.

Another factor which makes correlation of measurements to actually observed distortion difficult, has to do with the timing of sync pulses. If multiple interfering signals exist, the synchronization of sync pulses can lead to peculiar effects. First it should be clear that if all signals, including the desired ones, have common sync pulses, no windshield wiping is possible. The overload level would then be determined by cross modulation of the video signal which occurs at an approximately 8 dB higher level. Although no windshield wiping is possible with synchronized signals, a measurement would indicate a higher distortion level. Next assume two interfering signals which are in sync. In actual distortion visibility tests, two superimposed white bars appear in exactly the same way on the screen as a single white bar, while a measurement would indicate direct addition and increased distortion. By comparison, random sync pulses of two interfering signals appear as a 3 dB lower reading* when measured on a meter while a screen test makes the distortion effect twice as objectionable, because twice as much area is affected.

We have here two cases where a simple distortion measurement, however accurate, gives a reading unrelated to observable windshield wiper effect.

*When read on an oscilloscope the reading is 6 dB lower.

IV Considerations in the Design of Test Signal Generators for Overload Testing

In the course of developing specialized test equipment for windshield wiper testing, research was carried out to obtain correlation to the observable effect on a TV screen. Standard cross or intermodulation test procedures showed no correlation. Only in the normally invisible "black wipe" region does a correlation to third order measured distortion exist.

Since standard test methods failed to show correlation, it was thought that the waveform effect was of significance. Square wave modulated signals were tried and some form of correlation to the visually observed effect was obtained. This correlation was good for some circuits under test and not for others. The problem was traced to the use of square waves for the modulated signal.

Next, pulse modulation was used with pulses 10 μsec wide, spaced at 63.5 μsec. With these signals good visual correlation was obtained regardless of the circuit under test. A test performed with sync pulses having standard "front porch" and "back porch" showed identical results, probably because of the relatively minor waveform change and the inaccuracy of transmitted TV signals which were used for comparison by the direct method.

As a further method of improving correlation, modulation of the desired signal was kept on at all times with the sync pulses of the interfering signal detuned to 10 kHz. The cross modulation components were then separated in a wave analyzer. The test showed no change in readings as long as the peak level of the desired signal was kept constant. This test result greatly simplifies the design and accuracy of a test signal generator since modulation of the desired signal is then not required during the read-out of the distortion products. This would eliminate the need for active filter circuits which introduce another source of inaccuracy.

It appears, therefore, that the simplest test signal, which allows a direct correlation to observable windshield wiper effect, uses pulse modulation similar to standard TV signals without "front" or "back porch." A square wave or sine wave is unsuitable and makes correlation impossible due to time constant effects of different circuits. Standard TV sync pulses may be used but do not seem to offer any correlation advantages while they introduce an accuracy degradation due to higher complexity of generating circuits.

All TV generators should be switchable from CW to modulation without any change in the peak level. Sync pulses should be available both in random and synchronized mode. Modulation depths must be fully adjustable and switchable. All levels must be fully stabilized with respect to temperature and voltage, and frequency should be crystal controlled.*

It is now necessary to discuss the choice of background level used for testing and measurement. Originally, it was thought that 100% modulation would be best (infra-white level) because it might exaggerate the effect, thereby leading to easier measurement. However, it was found, on the contrary, that distortion was less. This is easy to see when we consider that both the desired and the undesired carrier are needed to create this type of distortion. With 100% modulation no carrier exists during the off-periods. The other problem is that since windshield wiper effect is produced by white bars, these become invisible with a white background. With a black background (25% down modulation) the magnitude of the distortion is at the highest possible level both as far as measurement and observation on the screen is concerned, because the desired signal level is maximum in the period between sync pulses and because white bars are most visible against a black background. The desired carrier should therefore be modulated with a black background (25% down) for a worst case effect.

The only difficulty with this level is as a research tool when phenomena such as "black wipe" are to be investigated which become invisible on a black background. There would also be merit in using an average background level (gray at 56.25% down modulation**) because it resembles more closely the actual field condition.

The discussion on background level above relates to the desired carrier, which is the signal under observation or measurement. What about the background level of the undesired or interfering signals? Clearly, distortion is increased as modulation depth is increased. For a worst case condition, the undesired channels should therefore be modulated with a white background level (87.5% down). The determination of the background level to be used as a standard also ties in with considerations in establishing a precise absolute distortion reading rather than some relative figure of merit. For a worst case visual test the undesired signals should be modulated without common sync in random fashion. Common sync is valuable as a research tool and for special applications.

*Test signals meeting the requirements set forth above have become available recently by using equipment such as TV Carrier Generator, Model 916, by Anaconda Astrodata Co.

**For standardization purposes a gray background level at 50% of sync amplitude might be preferable. This will slightly emphasize the more serious white wipe and de-emphasize the less important black wipe in a visual test.

V The Determination of Absolute Distortion Levels

Many of the foregoing discussions relate to visual observation and an improvement in repeatability and accuracy by the substitution of precise test signals. It is now necessary to examine methods of analyzing and measuring the distortion products so generated in order to arrive at consistent readings.

As was already mentioned, no change in reading was observed with or without modulation of the desired carrier. This test was performed in a rather sophisticated setup with frequency separation of the distortion products from the desired modulation by means of a wave analyzer. For measurement purposes it appears therefore possible to use a CW signal for the desired signal. It is, however, necessary to establish a reference level to which the distortion products are related to, or in other words the 100% or 0 dB reference must be established first. When we read numbers such as distortion is 50 dB down, the question must be immediately asked, "down from what"? As a matter of fact, a good deal of the confusion in windshield wiper distortion measurements is related to the lack of a well defined reference. The following have been used as a reference in the past:

a) The dc-voltage out of the video detector of a field strength meter with and without CW signal applied
b) The dc and ac-voltage of the video detector of a field strength meter with signal applied
c) The peak level of the sync pulses of a modulated signal and the peak level of the modulation of the desired signal
d) The peak level of the modulation signal of the desired signal to the peak level of the undesired modulation with the desired signal unmodulated

Before we examine the various calibration references we should first consider a related number which has been reasonably well accepted. It is generally agreed that 40 dB signal to noise or distortion ratio represents a flawless, studio type picture. This number can be corroborated by considerable published material[4] from different observers under varied conditions. When all the material is sifted and brought upon a common denominator because of different references used, this number is commonly found and it refers to video signal to noise or distortion ratio. Since any disturbance 40 dB down is invisible on the screen, the question must be asked why distortion readings of 55 dB or more down should result at the onset of visible windshield wiper effect. On tracing this behavior further, it is found that unusually low distortion readings are obtained by choice of an incorrect or undefined reference level and incorrect test methods. Actual distortion readings, as we shall see, are much worse than some of the commonly used test methods make us believe.

Going back to the display on the TV screen, full modulation is determined by black and white levels. This might be considered the ultimate reference to which everything must be related.

In terms of level, white and black are standardized at 12.5 and 75% respective amplitude of the sync level. If the top of the sync pulse were used as a reference, which might be convenient for measurement purposes, distortion readings obtained will be lower by a constant factor. Simple calculation shows this constant to be 4.1 dB, thus an "actual" reading of 40 dB will appear to be 44.1 dB down when referred to the top of the sync pulse. The difference of average picture level to top of sync pulse is found as 7.2 dB, hence a reading of 47.2 dB down from the sync pulse level is obtained when the primary reference is average picture modulation.

In any type of modulation distortion testing, it is essential to calibrate not only the rf-carrier, but also its modulation level (see expression (3), Section I). This is common engineering practice and is for example, called out in the IEEE standards on distortion testing[5]. By modulating the desired carrier first, a precise 100% reference is established. If the waveform used for calibration is identical to that used for modulation of the undesired carriers, waveform errors drop out regardless of the meter used in the final readout. By this method, errors due to detector nonlinearities and rectification efficiency changes with level are greatly reduced.

Considering the references given above, we find that in a) the references are unrelated to the signal, but rather to the detector dc-efficiency at high level to the residual dc voltage; for example, the static charge of a vacuum tube diode varies with tube life and circuit from 0 to about −2 volts. In b) we are comparing a dc voltage determined by diode linearity to the rectified audio signal which includes diode efficiency and waveform distortion. Method c) uses sync pulse tips as reference when the undesired modulation has a different waveform. Detector nonlinearity directly affects the reading. Method d) is the accepted engineering method which avoids nonlinearity and waveform errors. It is used for all types of communications equipment in tests for cross and intermodulation and applies as well to CATV equipment where high accuracy is required.

A comparison test of method a), using a popular field strength meter, with method d) showed that method a) produced an incorrect, 6 dB lower distortion reading for a given amplifier. The more correct method b) was off 4 dB for this particular case.

It is clear from this discussion that for calibration the desired signal will have to be modulated first with the waveform and background level as discussed above. Calibration voltage is the detected peak to peak voltage. The undesired signals are then modulated with the same waveform and distortion may be read. Even with this basically correct method several possibilities must be distinguished:

1) If the desired signal is kept modulated at all times during the test, detector nonlinearities and changes of detection efficiency drop out. However, it will be necessary to modulate the desired and undesired signals at a slightly different frequency to be able to separate the distortion products from the desired signal. This can lead to waveform errors plus time constant errors of the circuit under test. Also, the added complexity of equipment adds a greater uncertainty factor; however, this method allows probably the most accurate absolute distortion measurement. Also, visual observation and correlation is readily possible.
2) With the desired carrier modulated on calibration only, no waveform error is introduced if the same waveform is used to modulate the undesired carriers. The change in waveform of the desired carrier may result in a different dc-level of the demodulator which in turn can affect detection efficiency and produce a certain error in absolute reading. This error may be made small by careful detector design and choice of signal levels. The great advantage of this approach is relatively simple test equipment and repeatable, precise relative readings.
3) There are a number of ways of obtaining meaningful distortion readings which, however, are only relative. It is possible to increase the reading by simulating a worst case condition. Such methods may lead to increased relative accuracy by avoiding problems with noise, hum, etc. Typically, CW or black background is used for the desired carrier and 100% or white modulation for the undesired signals. This approach combines advantages of method 1) with 2). There is a possibility of waveform error which is avoided by an oscilloscope (peak to peak) readout. However, in a metered reading a correction must be made.

It is immaterial in all these cases if the reference used is the black to white level, the black to zero level, or the sync to zero level since all are related by a constant and a reading is readily converted to a different reference, such as the absolute reference of black to white level, which is the basic video reference.

VI Practical Considerations in Testing CATV Amplifiers

Even with well founded test procedures and accurate instrumentation, there are additional precautions which must be taken with CATV amplifiers due to their particular characteristics. Generally, a CATV amplifier must be operated near its optimum gain setting in a CATV system in order to achieve highest system dynamic range[6]. This optimum gain setting, or spacing ranges between 18 and 28 dB for well designed transistorized amplifiers. Optimum spacing can be directly measured on an individual amplifier and exact values are available from manufacturers. It is clear that all measurements to be meaningful should be taken under the identical amplifier settings as used in the system; this includes in particular:

a) Gain and equalization; for extra accuracy, verify frequency and cable temperature of specifications. Frequencies range from 211.25, 213, 216 to 220 MHz. Temperatures may be system median, room temperature at 68, 75°F or others. Amplifiers are designed to equalize cable of a length determined by the gain. All-band amplifiers will provide correction from 50 to 220 MHz. The flatness of equalization is important and its accuracy enters into the distortion reading. Before any testing, the amplifier should therefore be precision-aligned with the correct length of cable. Equalizers and other switches and controls should be set as they would be in system usage.

   NOTE: For comparative tests of amplifiers of different types and makes, it is necessary to test all amplifiers under identical conditions, that is aligned for the same length of cable (gain and equalization). It will not do to compare one amplifier at a high gain setting and another at a low gain setting since then dynamic range and system derating vary, thereby leading to fallacious interpretations. Alternately, the proper mathematical correction may be applied to readings taken of different amplifiers at different gain settings.

b) System tilt. This is not an amplifier adjustment — they were already completed under a) above — but rather refers to the proper levels of the test signals. If an amplifier is operated in a system under Half-Tilt, measurements should be also performed under Half-Tilt. A test with flat input signals (test signals of equal amplitude), results in Full-Tilt operation and a meaningful number is obtained only if this amplifier is also used in this tilt mode in the system. For Half-Tilt operation, it will be necessary to connect cable of one half the normal spacing between the flat test signals and the amplifier under test. Alternately, the test signals may be preset, but this method is less accurate.
c) Broadband effects. Modern CATV amplifiers are designed to operate without jumpers in the CATV system. Unavoidable mismatches cause flatness errors with jumper cables. To avoid these in overload testing, coaxial attenuators without jumpers should be connected directly

to the amplifier where a problem might exist. Lead lengths in excess of 1 inch are to be avoided. An alternate is to use the correct length of system cable directly. A typical error of 3 dB has been demonstrated when a jumper cable was used in overload testing even with precision test equipment.

d) Powering. Ideally all equipment should be powered for testing in the same way as in the system, that is, via AC cable powering. For convenience purposes, direct DC powering is often used; however, this technique must be verified for each type of amplifier for accuracy in order to avoid misleading readings.

e) AGC-amplifiers. Various AGC principles are used in CATV AGC-amplifiers. Those using open-loop thermal circuits normally do not require special precautions. In closed-loop systems overload of the output stage is not directly measurable due to AGC action which limits overload to the early stages. A more meaningful test results by opening the AGC loop of such an amplifier. Measurements are then taken with a fixed dc-bias applied to the AGC circuit. The correct bias for the spacing under test must be determined on the alignment bench. Logically, tests should be extended to cover the whole specified gain range of the AGC amplifier by varying the applied dc-voltage. In closed-loop testing of AGC-amplifiers it is important to apply the correct input signal levels with the proportionate change at all channels as in the system. This is also true for pilot carriers if used. Overload readings are then expressed in terms of input overload level at Channel 13 rather than the usual output overload reading.

f) Multichannel operation. Amplifiers designed for all band operation must be tested with 12 test signals. Extrapolation from fewer signals has proven unsatisfactory because the relationship varies with type of amplifier and system mode.

In addition to the rules given above, when a metered reading is used it should be checked for hum and noise. With an oscilloscope a reasonable accuracy is still possible even when hum or noise are present. However, a meter in conjunction with a wave analyzer or active audio filter leads to a more accurate and direct reading than an oscilloscope.

Testing may be performed at levels below overload, but readings so obtained are generally not related to windshield wiping, because they are caused by a totally different mechanism. Hence, measurements taken at the normal derated system level have meaning only when performed for the total maximum cascade[7] of amplifiers. Such a test is practical only in a working system and is normally done routinely to establish system safety margins. For individual amplifiers, overload level is synonymous with the onset of windshield wiper distortion, while testing at lower levels may be useful to investigate other types of distortion. For the same reason, does a low level measurement in no way give an indication of the actual output capability of an amplifier.

APPENDIX I

MATHEMATICAL ANALYSIS OF WINDSHIELD WIPER EFFECT

We express amplifier nonlinearities by the power series.

$$e_o = a_o + a_1 e_i + a_2 e_i^2 + a_3 e_i^3 + \ldots \qquad (1a)$$

and apply as input signal the sum of two modulated rf-signals

$$e_i = E_d \cos \omega_d t + E_u \cos \omega_u t \qquad (2a)$$

where $E_d = e_d (1 + m_d \cos p_d t)$
and $E_u = e_u (1 + m_u \cos p_u t)$
with e = peak voltage
m = modulation index
ω = rf-frequency in radians
p = modulation frequency in radians
subscript d = desired signal
subscript u = undesired signal

Expansion of (1a) and separation of the distortion products leads to the following terms:

a) a low frequency and dc-component:

$$a_o + a_2 (E_d^2 + E_u^2)/2 + \text{term with } a_4 + \ldots \qquad (3a)$$

b) a modulation term of the desired carrier:

$$a_1 E_d \cos \omega_d t \left[1 + 3 a_3 E_d^2 / 4 a_1 + 3a_3 E_u^2/2a_1 + \ldots \right] \qquad (4a)$$

c) a modulation term of the undesired carrier

d) second and higher order harmonics of the desired and undesired carriers

e) intermodulation products of desired and undesired carriers

By substitution of the expressions for E_d and E_u in (2a), we see that cross modulation is caused only by the last term in (4a). None of the other terms can produce modulation distortion of the desired carrier. Expansion to higher orders of (1a), leads to additional terms in (4a); however, it is easy to show that no higher order products nor any combination thereof can lead to a distortion product of the form $a_1 E_d \cos \omega_d t (1 - k m_u \cos p_u t)$ where k is a constant, which is required to explain observable windshield wiper effect. It is clear now, that the generation of distortion based on any single nonlinear effect of any order does not produce windshield wiper effect although it explains all other types of rf-distortion such as intermodulation products of all orders, as well as all types of cross modulation, mixing, frequency conversion, multiplication and the generation of harmonics. Since even higher order nonlinearities cannot explain windshield wiper effect, we must now look for a different mechanism and it will be sufficient to limit our investigation to the terms up to the third order of the power series as given in expression (1a). We must include the third order term because it is required to produce observed black wipe (simple first order cross modulation).

We consider now a two-stage process and examine in particular the base band products. Let us assume that at some high level point additional distortion is generated by a different high level nonlinearity expressed by

$$e_o = b_o + b_1 e_i + b_2 e_i^2 + b_3 e_i^3 + \ldots \quad (5a)$$

Substituting terms (2a), we obtain base band frequencies as in (3a) above, which contain a term $b_2 E_u^2/2$ and this in turn can be expanded into a dc-component and a term $b_2 e_u^2 m_u \cos p_u t$ (and a second harmonic term), that is demodulation or rectification has taken place. The term b_3 does not contribute to the demodulated signal. Alternately, we can assume detection in the input circuit of the amplifier at high signal levels. This will also lead to a dc-term and the demodulated signal $\eta\, e_u m_u \cos p_u t$, where η is the detection efficiency. This demodulated signal together with the signals of expression (2a) are now applied together to a new* power series of nonlinear amplification (6a).

$$e_o = c_o + c_1 e_i + c_2 e_i^2 + c_3 e_i^3 + \ldots \quad (6a)$$

where c = coefficients of high level nonlinearities

The modulation polarity of the added demodulated signal is negative with respect to the phase of the modulation envelope of the carrier of (2a). This is so because an increased signal level into any active element (tube or transistor) produces a base band output upon rectification which is in the direction to turn the device off.

The new input signals are now

$$e_i = E_d \cos \omega_d t + E_u \cos \omega_u t - E_b \quad (7a)$$

where $E_b = b_o + b_2 (E_d^2 + E_u^2)/2$ based on (5a)

Quite generally E_b contains a dc component which is of no interest, and the demodulated undesired signal which we may write as $E_b = E_o + k m_u \cos p_u t$

Substitution into (6a) and expansion leads now to the following modulation product of the desired carrier:

$$c_1 E_d \cos \omega_d t \,(1 - 2c_2 E_b/c_1 + \ldots) \quad (8a)$$

The second term in brackets is the countermodulation term. Other, higher order terms are unrelated to windshield wiper effect. Expanding (8a) and adding the original cross modulation term of (4a) we find for the desired carrier, modulated by the undesired modulation

*because of the changed dc-component

$$\text{DC-COMPONENT} \quad -2 c_2 b_2 e_u^2 m_u \cos p_u t + $$
$$+3 a_3 e_u^2 m_u \cos p_u t =$$
$$= \text{DC-COMPONENT} \quad + e_u^2 m_u \cos p_u t\,(-2 c_2 b_2 + 3 a_3) \quad (9a)$$

For term $b_2 = 0$ (no demodulation), modulation of the desired carrier by the undesired signal is possible only through term a_3 which produces in phase cross modulation (black wipe). At some, much higher signal level rectification begins, expressed by term b_2. The demodulated signal is in turn modulated on the desired carrier by a following second order nonlinearity, expressed by c_2, and produces a countermodulated signal which gradually cancels the cross modulated signal and eventually with increased level leads to visible windshield wiper effect.

The sum total of windshield wiper effect is therefore explained by three uncorrelated distortion producing mechanisms, which are functions of the applied signal level as follows:

1) At low levels certain nonlinearities (coefficients a) produce standard cross modulation. For this distortion to occur third order distortion is necessary (terms with a_3).
2) As signal level increases, a new independent mechanism (expressed by coefficient b) produces rectification (demodulation) ahead of the actual amplification. This process produces also an input dc current and results in new nonlinearities of the amplifier (coefficients c).
3) Baseband frequencies together with second order distortion c_2 of the amplifier result in countermodulation which cancels the original cross modulation and produces what is known as windshield wiper effect (white wipe).

In summary, we can say that windshield wiper effect is produced by countermodulation, which can only be produced by demodulation and subsequent modulation. Demodulation can be produced by normal rectification (diode action of grid-cathode or base-emitter) or any second order nonlinearity (square law detection). Modulation is then produced by following second order nonlinearities. The process of countermodulation is a high level effect, not present at lower levels.

Normal cross modulation tends to decrease windshield wiper effect because it is out of phase. Cross modulation is caused by third order nonlinearities.

The mechanism of the generation of windshield wiper distortion might then be represented by an active nonlinear amplifier having a linear input impedance, where this linear input impedance becomes nonlinear at some high signal level (overdriven input).

The mathematical analysis shows that windshield wiper effect is not related to cross or intermodulation. However, there exists a loose indirect relationship to high-level intermodulation because both it and countermodulation contain a common second order term (c_2).

APPENDIX II

TEST DATA FOR WINDSHIELD WIPER DISTORTION

Amplifier Type:________ Model:________ Manufacturer:________ Serial:________

Amplifier equalized for________dB of cable at________ MHz and________°F

Flatness ± ________ dB from________ MHz to________MHz

Number of test signals________ Frequencies ________

Modulation of undesired signal: TV Signals: ________ Random Sync:________ Common Sync:________

Modulation depth of
undesired signal: TV Signal:________ White:________ Gray:________ Black:________

Modulation of
desired signal: TV Signal:________ Blank Carrier________ Sync Modulated:________

Modulation depth of
desired signal: TV Signal:________ Black:________ Gray:________ White:________

Width of sync pulses:________μsec Repetition Rate:________μsec

Modulation of desired
signal for measurement: CW Signal:________ Changed Reptition Rate:________μsec

Overload level determined as: ________ dB below onset of visible windshield wiping

________ dB below modulation of desired carrier

Channel of Observation or Measurement	Overload Level Read on Channel	Output Overload Level in dBmV	Input Overload Level in dBmV
13			
12			
11			
10			
9			
8			
7			
6			
5			
4			
3			
2			

Tilt of output signals: Half-Tilt:________ Full Tilt:________ Other:________

Tilt of input signals: Half-Tilt:________ Flat Inputs:________ Other:________

Powering Direct dc:________ Direct ac:________ Cable Powered ac:________

AGC-Test: Open Loop:________ Closed Loop:________

Residual Reading: Hum:________ Noise:________ Other:________

APPENDIX III

REFERENCES

1) "Design of Low-Noise Transistors Input Circuits" (book), Hayden 1964, pg. 43 ff.

2) "Test Simulates TV Windshield-Wiper Effect," *Electrical Design News*, Sept. 1963

3) CATV System Engineering, Tab Books, 2nd edition 1967

4) See Reference 3, Literature 1-6 and 9-17.

5) IEEE Standard, 48 IRE 17 SI

6) See Reference 3, Chapters 4 and 7.

7) "Calculating Overload Threshold for Cascade Amplifiers," *Electronic Equipment Engineering*, July 1964

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CHAIRMAN TAYLOR: Thank you very much. (Applause) Do we have questions?

Can we make amplifier tests without knowing the exact distortion producing mechanism?

MR. RHEINFELDER: Yes. The important point is, however, that all tests should in some way relate to performance in the CATV system in order to be meaningful. As has been explained in my paper, there are three types of distortion which, singly or in conjunction, may produce overload distortion in CATV systems. These types of distortion, all familiar from communications theory, are cross modulation, intermodulation and countermodulation. Since windshield wiper effect is caused by countermodulation, tests for cross or intermodulation are of minor importance for CATV. Even if you test two amplifiers under the same conditions, if the test does not relate to observed performance in the field, such a test would be meaningless. Instead, a test for countermodulation should be performed.

If you were trying to correlate a measured distortion number to a visual field test, what would be the accuracy of measurement?

MR. RHEINFELDER: The accuracy of the visual test by itself is not very high. This is in more detail discussed in the printed copy of my paper which is available at the booth. As discussed in this paper, one way to increase the accuracy of the live signal test is to use a reference amplifier which is then kept as a standard, and everything is referred to it. If you use this method and make the necessary corrections, you eliminate the subjective effects and eliminate errors in the TV set adjustments, and then you achieve an accuracy of about plus minus one db. From an evaluation standpoint you can live with it, but as a research tool you cannot.

Can windshield wiper effect be caused by cross modulation?

MR. RHEINFELDER: In my own experience and that of all my associates in CATV, overload in CATV systems is evidenced by the onset of white bars. These cannot be caused by cross or intermodulation; that is, simple second or higher order effects, but are caused by countermodulation which is a two-stage second order effect.

Can third order distortion produce white windshield wiping?

MR. RHEINFELDER: The answer is no. Third order distortion does not produce a phase reversal which is the prerequisite for the appearance of white bars.

CHAIRMAN TAYLOR: Are there any other questions? If not, I want to thank the members of the panel for their participation this afternoon, and thank you all for your attention.

(The session adjourned at five-fifty o'clock p.m.)

(Mr. Pai read his paper, marked No. 2.)
(Applause)

CHAIRMAN PENWELL: Are there any questions? If not, we will proceed.

Brian Jones, from Fairchild, is still with us. Come up, Brian. Brian is our next speaker. He was born and educated in England, and has worked for the Canadian Defense Research Board on transistor circuits. He has worked for Fairchild Semi-Conductor on high frequency transistor applications, Westinghouse Electric Corporation on integrated circuit design, and has worked for C-Cor Electronics on CATV and high frequency amplifier design. Presently he is with Fairchild in Palo Alto, California.

DISTORTION, VSWR and REVERSE TRANSMISSION IN BROADBAND TRANSISTOR AMPLIFIERS

by

BRIAN L. JONES

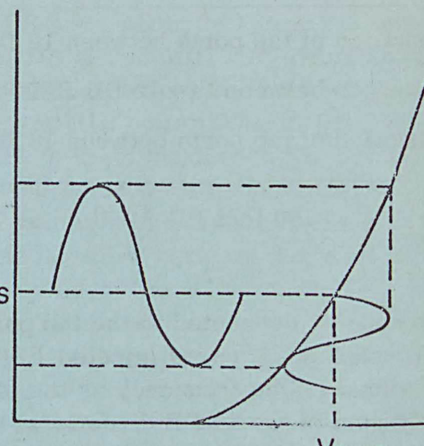
Transistor amplifiers produce distortion. This is a commonplace to everyone who is familiar with the cross-modulation of an overloaded CATV amplifier. Such amplifiers have a certain VSWR when introduced into a 75 Ω system and if this ratio is too high, reflections appear on the picture in the form of "ghosts". If an amplifier is inserted into a system backwards, that is, with the input signal to the output and the output signal to the input, the signal will be attenuated instead of amplified. The ratio of the input power to the output power under such circumstances is known as the reverse transmission. Similarly the gain of the amplifier is the forward transmission.

Now it may not be immediately obvious what connection these quantities may have and the purpose of this talk is to point out the inter-relationship between them. In order to do this I shall start by discussing some of the properties of transistors.

Figure 1 shows a typical curve of the relationship between collector current and base-emitter voltage of a transistor. This characteristic, a non-linear input voltage/output current relationship is the main source of distortion of transistors. This is illustrated by a sine-wave base emitter voltage which produces the distorted collector-current shown in the slide. It can be shown very easily mathematically that if the input signal voltage consists of two or more amplitude-modulated RF signals, cross-modulation will result. The forward transmission of the transistor is non-linear and shows distortion.

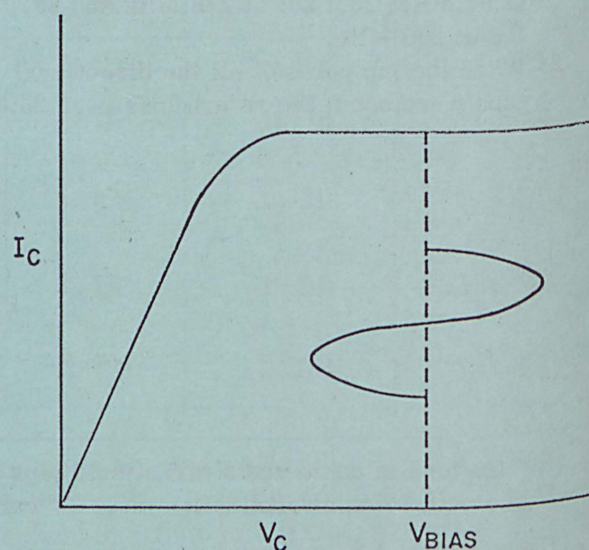
But what about the reverse transmission? If we apply a voltage to the collector of a transistor, will the resulting current show distortion? At first sight,

Figure 1



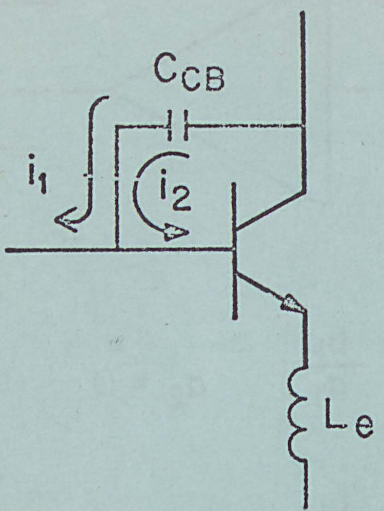
it would appear not. The low frequency collector characteristics are shown in Figure 2. It would appear that the collector current remains nearly constant regardless of the voltage swing on the collector. The transistor is a good constant current source at low frequencies; that is, it's output current depends only on the base voltage. It is also clear from this figure that what happens at the output has very little effect on the input, i.e., the transistor has a low reverse transmission.

Figure 2



At high frequencies, however, none of the foregoing remains true. There are certain undesirable properties of the transistor, known as parasitics, which give the transistor considerable reverse transmission. Figure 3 shows the two main parasitic resistances: the emitter inductance and the

Figure 3



collector base capacitance. The emitter inductance increases the reverse transmission because it is common to input and output circuits. The collector-base capacitance provides a direct path from output to input. Although the emitter inductance can be quite important in some transistors, I will only consider the collector base capacitance which is usually dominant.

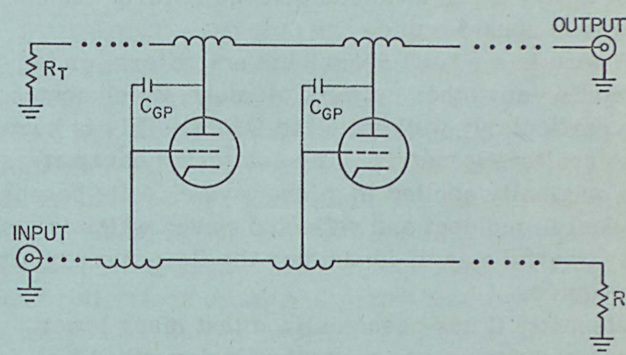
This capacitance is rather peculiar, inasmuch as it's value varies with voltage -- it is non-linear; thus the reverse transmission of the transistor is non-linear. This means that if a signal voltage is applied to the collector there will be a distorted current flowing out of the base. Part of this current will flow into the external circuitry, but part of it will flow back into the transistor base where it will be amplified, causing a distorted collector current to flow. The new result of all this is that the output impedance appears non-linear and contributes cross-modulation and other distortion to the amplifier characteristics.

Let us now suppose that the transistor is driven from a high impedance source. If this is the case i_1 will be zero and the whole of the feedback current will flow back into the transistor. The distortion will thus be greatest in this case and will be less if the transistor is fed from some finite impedance.

The important point is that the distortion resulting from a signal at the output is dependent on the conditions in the input. Everyone who has worked with transistors at high frequencies knows that what is done at the output affects the input and this is also true of distortion.

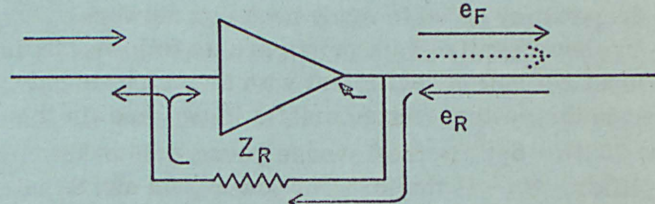
Let us leave transistor amplifiers for a moment and consider an old fashioned tube amplifier of the distributed type. Part of a typical circuit is shown in Figure 4. Two differences from the transistor amplifier are immediately noticeable. These are (1) the output impedance is matched to the 75 Ω cable by a resistor, not by the output impedance of the tube and (2) the tube amplifier also has feedback capacitance but it does not vary with the output voltage. It is a constant capacity determined only by the tube electrode geometry and it is included in the artificial transmission line; thus reflected waves are terminated in R_T the terminating resistor and do not modulate the tube characteristic significantly.

Figure 4



The importance of this point can be seen in Figure 5. The amplifier in this diagram is assumed to be perfect, that is, it has no reverse transmission. All real amplifiers have some reverse transmission however and this is simulated by the green resistor. We can see that if there are reflections on the output cable, the effect of these reflections will be felt at the amplifier input and amplified, resulting in a change at the output.

Figure 5



Now consider the case where the reverse impedance Z_R is non-linear, which is the case in transistor amplifiers. The reflected wave will be distorted as it travels back through the amplifier and the resulting amplified wave will show cross-modulation and other forms of distortion. If we look into the output impedance of the amplifier it appears non-linear.

The other important point to make here is that the output impedance and VSWR depends on the source impedance connected to the input of the amplifier. Usually amplifiers have their input and output VSWR specified when the other part is well matched. Sometimes, however, this is not the case in practice. If the output part is connected to a short length of cable which is terminated in a component of poor VSWR then not only will there be reflections at the output if the reverse transmission of the amplifier is considerable, there will be reflections at the input also.

This is a simple test of the reverse transmission of an amplifier. If the VSWR at the input is different, depending on whether the output is terminated in 75 Ω or not then you can conclude that the reverse transmission is considerable.

There is a way of describing amplifiers, or for that matter any other network element, which seems to be particularly well suited to CATV. This is known as the scattering matrix. The scattering parameters were originally applied in microwave circuits because they deal in incident and reflected waves which is the most powerful way of describing the flow of energy in a waveguide.

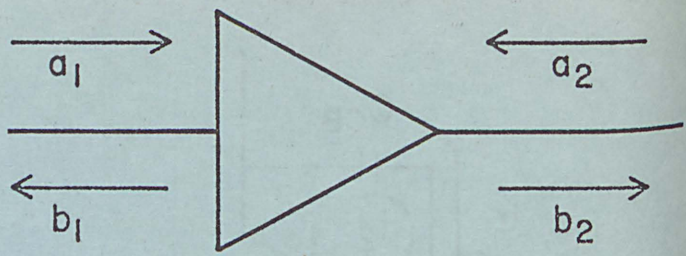
Recently it has been realized that many lower frequency systems are conveniently described by scattering parameters. CATV systems being coaxial throughout are usually considered as having incident and reflected waves and the scattering parameters include a measure of the forward and reverse transmission.

In Figure 6 the scattering parameters are defined. The waves a_1, b_1, a_2, and b_2 differ from voltage waves in that they have the dimensions of the square-root of power. That is, if you square them you will get power. They are also normalized to some impedance level, which is usually 1 Ω. In the present case it would be more useful to normalize to 75 Ω.

There is not time for a full discussion of scattering parameters and anyone who is interested in delving deeper may do so in many books on network theory; however the main points are as follows: S_1 is the input reflection coefficient with the output terminated in the system characteristic impedance (in this case 75 Ω). $|S_r|^2$ is the reverse power gain of the amplifier, $|S_f|^2$ is the forward power gain and S_o is the reflection coefficient of the output with the input terminated properly.

It can be seen that these four scattering parameters give all the information necessary to evaluate the performance of an amplifier, with the exception of distortion. In particular, a knowledge of S_r enables one to calculate the input VSWR when the output is terminated on a non-ideal load. The calculation is shown in Figure 7.

Figure 6



$$S_{11} = \frac{b_1}{a_1} \qquad a_2 = 0$$

$$S_{12} = \frac{b_1}{a_2} \qquad a_1 = 0$$

$$S_{21} = \frac{b_2}{a_1} \qquad a_2 = 0$$

$$S_{22} = \frac{b_2}{a_2} \qquad a_1 = 0$$

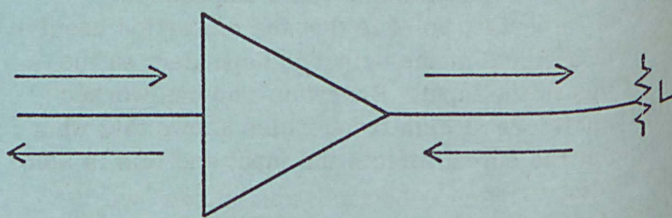
This equation:

$$\rho_{in} = S_i + \frac{S_r S_f \rho_o}{1 - S_{22}\rho_o}$$

is easy to solve if the scattering parameters are given.

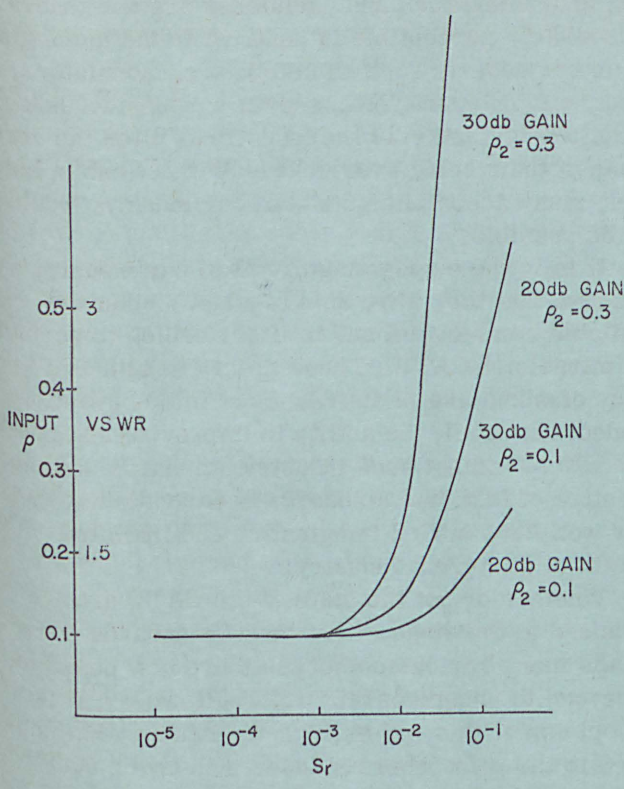
Figure 8 shows the variation of input reflection coefficient versus reverse transmission. Notice the importance of forward gain. As the gain of an amplifier is increased the reverse loss must be

Figure 7



$$\rho_{IN} = S_i + \frac{S_r \; S_f \; \rho_L}{1 - S_o \, \rho_L}$$

Figure 8



correspondingly increased, otherwise the input will become too sensitive to output reflections.

The ordinate of this graph is plotted as S_r and since $|S_r|^2$ is the reverse power transmission we can simply take

$$20 \log \left| \frac{1}{S_r} \right|$$

if we wish to know the reverse loss in dB. Thus if S_r is 0.1 the reverse loss is 20 dB. You can see from the curve that the amount of S_r that be tolerated depends on the forward gain or S_f. 40 dB reverse loss would be a good figure for an amplifier with 20 dB gain but if the amplifier gain is raised to 30 dB the reverse loss must be raised to 50 dB to give the same isolation of input from output.

These transistor characteristics impose a heavy burden on the amplifier designer. At Fairchild we are trying to improve the devices used for linear broadband amplifiers and one of the most important things is to reduce the reverse transmission. The preliminary results of this work indicate that considerable improvement is possible over currently available devices. The improvement can be expected to be passed on to the amplifier designers in the near future.

In some transistors there is a distortion cancellation effect which arises because the phase of the S_r distortion. When the load VSWR is poor, the distortion may be disturbed and there is a dramatic increase of cross-modulation. If the reverse transmission of the amplifier is reduced the cross-modulation becomes nearly independent of the load.

(Mr. Jones read his paper, marked No. 3.) (Applause)

CHAIRMAN PENWELL: Are there any questions?

MR. BERNARD EVANS (Malibu): I am curious about whether this reverse transfer characteristic is feeding back through an amplifier. I can see where this would be quite a factor on, say, a one-transistor extender, where you had virtually no isolation; but on a practical amplifier, say three or four devices, is this not quite minimized by the time it gets back through all these four stages, or do your reflections occur within the coupling of the last stage and the second before the last stage?

MR. JONES: In a well-designed amplifier I think you are right. If the forward gain were 20 db and the reverse loss were 60 db, for example, you probably would be quite well off. But, as you say, there are reflections which occur at the input to the last stage.

MR. EVANS: This is the most troublesome spot, then, I presume?

MR. JONES: Yes.

CHAIRMAN PENWELL: Thank you, Brian. I have learned a new parameter today, reverse gain. Maybe we will see that on the spec sheets some day.

During the course of this convention a lot of interest and activity has developed over the mounting chaos in standards of the CATV business. People in the business session have their own brand of chaos. We have wrestled with some of our problems. Archer Taylor, who is Chairman of the Engineering Subcommittee of the NCTA Standards Committee, has asked that we present Mr. Sidney A. Mills at this time, to talk about the problem of cable standardization.

Sid is Vice President of Production and Engineering of Ameco Cable, Inc., Phoenix, Arizona. He graduated in 1949 from Syracuse with his EE. He was in the U.S. Signal Corps following graduation for two years, and from 1952 to 1966 he was Senior Product Engineer for Rohn Cable. Presently he is with Ameco. Sid Mills.

expanded band capability. There is still a great deal of information needed before a real decision can and should be made, and we would like to introduce some of our thoughts into the discussions that are going on today.

EXPANDED BAND CATV CAPABILITIES

By

Dr. Leon Riebman and Mr. Walter Wydro

Of all the conventions that AEL participates in throughout the year, certainly the NCTA CONVENTION is by far the most dynamic and exciting. CATV is still in its infancy. New ideas for applications and a rapidly changing technology are the order of the day. The buildup for the Convention starts many months ahead with whispered rumors as to magical, new equipment and new system approaches that are being prepared for the Convention by all CATV manufacturers. The pressure of these rumors cause the engineering departments of all the major manufacturers of CATV equipment to put in many extra nervous hours in order to bring to the show advanced equipments ahead of schedule. Of all the fields of endeavor that AEL's 250 professional scientists and engineers are engaged in, certainly CATV is the most exciting and rapidly moving, technologically speaking.

CATV is our Number One commercial effort today! It is presenting a tremendous challenge to every technical discipline within our organization.

The CATV Industry today is in the painful throes of changing from an art to more of a science. When a field of endeavor is an art, decisions are based on emotions and judgments. In a true science, decisions are based on experiments and physical laws.

CATV will always be a mixture of art and science. The art will be the visualizing of future possibilities for applications of this new means of signal transportation. At the present time, the applications appear to be unlimited and the requirements on the system should be primarily the users' responsibility. The system owner should provide the specifications, in qualitative terms, for the requirements and the purpose of the system that he wants to build. Once the decision is made as to the ultimate purpose of the system, it becomes possible for systems designers and manufacturers to scientifically optimize design and cost for the most effective system based on existing state-of-the-art equipment.

The topic of our paper today is, "Expanded Band CATV Capabilities."

In the beginning, the first systems were only one or two channels. Then, low channels only came into being followed by a combination of low and sub-channel systems. Many of these original systems are still in existence.

More recently, interest developed in all-band or twelve channel systems. As a result of this requirement, broadband tube amplifiers were developed and the modern CATV industry took shape and began to grow.

Incidentally, during the first fifteen years of the CATV Industry much was done by intuition or cut and try. It was mainly art -- very little science. During 1964, 1965, and 1966, many very capable engineers working independently and building on the work of others worked out the ingredients of a theory for a fully integrated CATV System. This was the first time that various design parameters could be related and optimized for a particular system requirement. The theory is now being extended and perfected and will greatly accelerate the pace of developments and open new opportunities for new applications of CATV systems.

During January of 1966 AEL first discussed with a CATV user the possibility of building an Extended Bandwidth System (extended to 270 MHz). In October of 1966 a detailed proposal was written and equipment development started.

At this, the 1967 NCTA Show, AEL is offering a trunk extender amplifier and remote bridger amplifier with 270 MHz bandwidth -- a minimum of twenty channel system capacity.

In some geographical areas such as the corridor between Boston, New York, Washington, and Philadelphia or the corridor between San Francisco and Los Angeles, viewers can now receive twelve channels off the air. Thus, the need for more channels in CATV.

Let us review the various approaches to a system of more than twelve channels. Essentially five methods are being explored as feasible transportation systems.

1. The Sub-channel method -- this approach places twelve channels between the frequencies 5 MHz and 95 MHz.

2. The Mid-Band Method -- this method uses the spectrum between Channel 6 and 7. In particular, the frequency spectrum between 108 MHz and 174 MHz.

3. The Dual Coaxial Cable Method -- this method uses two coaxial cables each carrying twelve channels.

4. The Octave Band Method -- this method places 20 channels between 120 and 240 megacycles.

5. The use of the spectrum above Channel 13 -- this method - The AEL Method-uses the frequency band between 220 - 270 for extra channels.

Let us examine each of these signal transportation methods and explore strengths and weaknesses.

The sub-channel Method does not lend itself to more than twelve channels and has the usual difficulties of a multi-octave system. Such systems, historically, present tremendous design difficulty in the building of the required amplifier with sufficiently low and acceptable harmonic distortion. There are some of these systems in use today which have beats and harmonics that usually interfere severely. To minimize the harmonic problem, low signal levels are utilized or balanced but very expensive amplifiers can be designed to correct the problems and permit operation at higher signal levels.

There is much discussion today about the Mid-Band approach, using the spectrum between Channel 6 and 7. The NCTA Engineering Subcommittee is studying the many unanswered questions about this band. For example, must the FM band 88 - 108 MHz be excluded? But the more important problem is, can allocations be designed to avoid the danger of direct pickup interference from air navigation or air communication services between 108 - 136 MHz, or from space tracking services at 136 - 138 MHz, or from various mobile, space, and amateur services between 138 - 174 MHz. Also, there are the usual harmonic problems because of the multi-octave nature of this approach.

I have permission to quote from an unpublished paper by Isaac S. Blonder, Board Chairman of Blonder-Tongue Laboratories, Inc. as follows: "The region between 108 - 136 MHz should be avoided since radiation from a system into the aircraft communication and guidance frequencies will be impossible to completely control. The CATV operator may believe he can monitor the cable systems to prevent radiation but the same cannot be said of the home environment." We agree with Mr. Blonder's statement.

The Dual Coaxial Cable Approach has both economic and technical problems. The installation costs are virtually double but of greater concern is the problem of cross-talk between cables. It will require tremendous care and tight shielding to keep cross-talk in any extended system to a reasonable level. Tests made with reasonably short systems may not be sufficiently accurate to predict the effect of extended mileage systems.

The Octave Band Approach from 120 - 240 MHz is a hybrid mid-band approach and has disadvantages and problems similar to the mid-band method.

AEL is recommending the approach utilizing the spectrum above Channel 13. Based upon available transistors and other considerations, we feel that 270 MHz should be the next logical spectrum plateau for system designers. The spectrum from 54 - 108 MHz would cover Channels 2 to 6 and the FM band. The spectrum between 174 - 216 MHz would cover Channels 7 to 13 as is now the case for twelve channels. Additional synthetic channels would be created between 216 - 270 MHz. The spectrum between 108 - 174 MHz could be used in the future for special services not requiring high-level modulation signals; perhaps facsimile, delivery of telegrams, transmission of computer data, control of traffic signals, or local interest FM cablecasts. The type of modulation at the level of the modulation would be controlled so that low channel harmonics would not interfere with the signals to be transmitted nor would the signals themselves generate significant higher harmonics to interfere with the higher band signals.

Some of the advantages of the spectrum above Channel 13 are as follows:

1. The system can be laid out with conventional twelve-channel techniques.

2. Proper planning and attention to detail at time of initial construction will permit conversion to expanded band at any time by installing repeater amplifiers utilizing the modular concept. The initial cost involved in preparing your system for expanded bandwidth can be very minimal; e.g., cable manufacturers are now sweeping cables to 300 MHz. We urge you to specify 300 MHz swept cable now for any new installations. The very small hardware such as directional couplers reflectometers, splitters, tap-offs, etc., are either available or present no technical difficulties.

AEL has introduced at this 1967 NCTA Convention a trunk extender amplifier and intermediate bridging amplifier meeting all specifications expected of the highest quality 220 MHz equipment, yet including extended bandwidth of 270 MHz.

We are actively proceeding to round out the line of 270 MHz equipment by improving the current 220 MHz colorvue modularized trunk line amplifier to handle the 270 MHz bandwidth. Also, under active development, are compatible headend equipment and the necessary test equipment needed to install and maintain the 270 MHz system.

Incidentally, engineering models of new trunk line amplifiers are easily achieving +52 dbmv for -57 db cross modulation when used in a twelve channel configuration; therefore, we can expect to meet the usual twelve-channel cross modulation specification at 48 dbmv but with twenty channels in operation. In effect, we have gained some system performance with added bandwidth.

There is one problem in the proposed system and that is the requirement of a top of the set converter, which converts the synthetic channels above Channel 13 into channels that the TV set can utilize. Such converters are available from several manufacturers today and this field is actively being pursued.

One interesting solution to the problem is to put complete conversion directly into the TV receiver; manufacture a TV set especially for CATV. AEL has discussed this possibility with several set manufacturers and they are very receptive.

There is a tremendous need at the present time for standardization within the TV industry. Standardization will bring with it many benefits to the CATV owner. The equipment costs will go down and the dangers of obsolescence will be greatly reduced. We strongly urge that NCTA take the lead in recommending which approach to a twenty-channel system should be recommended to CATV owners. Once one system has been accepted, the manufacturers will be able to plan ahead and modularize compatible equipment that can at minimum cost be expandable in the future.

Another problem area in the proposed system as it is in every wide-band CATV system is the effect of temperatures on system performance. Thermal equalizers are not a satisfactory solution for reasons all too familiar to you. AEL is currently developing a system called Auto-Tilt that will automatically compensate for temperature in a frequency selective manner. It involves, sensing, pilot carrier signals at both ends of the spectrum and adjusting the tilt. The key to success of this system is a frequency flat AGC system. AEL's current AGC amplifiers use a novel pin-diode attenuator (the diode is manufactured by AEL) that is frequency flat considerably higher than the 270 MHz required and, in addition, is voltage controlled. Auto-Tilt should be available from AEL within the next six months.

Thus, all the equipment for an extended band 270 MHz system is either available or under development to provide you with upwards of twenty-channel capability within the next twelve months. Today, we equipment manufacturers need and solicit your ideas and suggestions as to what you want future CATV systems to be capable of doing. Don't worry about whether, or how, what you want will be accomplished -- that is our job! Knowing what you want, we will stretch our imagination, achieve and push the state-of-the-art, and surprisingly -- in most cases -- come very close to what you originally might have considered impractical. It does not take much foresight or risk or courage for us to predict a very rapidly changing technology in the CATV industry during the next few years. We, at AEL, are proud to be participating with you during this pioneering period. We find it very exhilerating, very challenging, and very satisfying. In addition, let's all hope we will all reap the rewards that pioneers who take risks well deserve.

Thank you!

Thank you very much. (Applause)

CHAIRMAN CLEMENTS: Thank you, Dr. Riebman.

I am glad that someone else is working with the equipment manufacturers and the television receiver manufacturers to try and get them to become cognizant of our needs for multi-channel use beyond the present 12-channel system we are now utilizing.

I must agree with him, personally, because equipment manufacturers have been telling me for 15 years that if we tell them what we want and can make up our minds as to what we desire, they will come up with the product. I believe we are seeing this come true.

We have perhaps three or four minutes for questions, and I will ask now if anyone has a question?

MR. MIKE RODRIGUEZ: I think my question is of a rather general nature.

We have heard many comments about using various portions of the spectrum for banded channel use, but one thing that does not really get mentioned too prominently is, if we do utilize the upper portion of the spectrum, what about the systems that are being constructed now? Will it be required that they be re-spaced?

What sort of problems do the system owners who are presently constructing systems face in this regard?

Is this going to be a slow transition?

This is one of the questions I have in mind; and another is, what use is the modular concept in the housing where you have taken the outer space? It is not just that simple, replacing the module. If you have to take the housing and change the system layout, this is another consideration. I wonder if you have any feelings about that?

DR. RIEBMAN: Let me ask my colleague to give you the answer. He is much more familiar with this phase of the situation.

MR. WALTER WYDRO (American Electronics Laboratories, Inc.): Mr. Rodriguez, as we have looked over the situation, and the way the hardware was developed, the current hardware, as we have introduced it here, does go to 270; but it is utilizing a system, as you now use it, through a 220 or 216 megacycle amplifier. If you were to design for a 22 db spacing, it would have, again, at 216 and something higher than 22 db, at 270, something taking care of the rise in tilt.

The result is you design the system with 220 megacycle concept, totally; in fact, with the current amplifiers, if you put those in, you have automatically a system properly spaced and properly equalized.

Now let us assume the condition where you are designing a 270, but you want to run 220 temporarily through it. By the same token, we are preparing on the amplifiers a dual specification. These are paper specifications. You cannot change the gain of the amplifier. The amplifier has a certain gain and a certain equalization. This is true. Whatever the frequency cutoff is, this is a fixed value. It has nothing to do beyond the fixed content of the amplifier.

If you take the amplifier and write a set of specifications at 220, based on its tilt values, write a duplicate based on the 270, allowing for the cost of difference in the gain, you can now design a system with current technology; install it; and your spacing is automatically handled.

We are not advocating changing spacing to a 270. What we are saying, however, is design for 220; current practice; and install the amplifier, and automatically it has the spacing to offset the cable drop.

DR. RIEBMAN: As Fred Schulz was presenting his fine address, you noted the compatibility problem between the MATV system and the CATV system, and again to re-emphasize, the sooner that CATV standardizes, the quicker you are going to have to stop worrying about changing equipment in the future.

As far as the manufacturers are concerned, they will sell more equipment the longer it takes you to settle that problem. There will have to be changes made.

We are doing our best, however, to build compatibility into the system that we are producing today. So, again I say, it is up to you to standardize.

MR. DON SHIELD (Vancouver): I do not know whether I fully understood your discussion concerning the use of some of the areas in the mid-band. I believe you said the use of low-level modulation carriers could possibly be effected in this area.

What I am concerned about is that the harmonics in the low-band television signals in the 54 to 108 level will probably wipe out the use of this mid-band.

The facsimile or data processing character, because of the obscurity and the harmonics, rather than the fact that the mid-band signals are not usable because of what they may do to the television in the low or high band areas, would represent still another consideration.

MR. WYDRO: I do not think this is quite the case, and here is why: First of all, we are indicating that the mid-band should be delegated or relegated, and this I should not say, to service low-level modulation, but those that require low signal noise and ratios, not as high as television requires.

Secondly, most of the pulse-type signals that we are referring to, and I say "pulse", or the use of low-level FM modulation, for example, will render complete immunity to amplitude interference caused by the harmonics of the low band.

The use of sub-carriers or FM modulation would entirely take care of it. Also, the fact that you are occupying the low band is no worse than you now have in a 12-channel system where Channel 6, for example, in the FM band, will reflect that harmonics do appear in Channels 10 and 11.

MR. SHIELD: My final question I wanted to ask concerns something similar in the area above 200, where you are proposing to put selectors/ carriers. I would presume you have a similar problem with octaves. If you continue to use the standard television band between 54 and 108, and you have a computer program giving you some clear channels in this region, would this not be true?

MR. WYDRO: Yes; but they do not have to be clear by the very statement I made previously.

There are 12 channel systems today; 88 megacycles appears right in the middle of Channel 10, and this is not causing any major problem in the current 12-channel-system practice.

Yes, I know a number of systems that require Channel 5 and Channel 6 and the FM band downgraded inband by a few db. In most systems, however, the harmonic problems in most of these channels are relatively minor.

By putting the rest of the channels above Channel 13, we have eliminated the need for harmonics falling within the band. They are not there, and they are not falling within the bands not occupied.

The suggestion for the non-occupied band is to use it for service that can be handled by a form of modulation such as FM that can be made interference-free.

CHAIRMAN CLEMENTS: Thank you very much. We have time for one additional question.

MR. WILLIAM HENCHE (General Electric Cablevision Corporation): We have been watching this development of the extra channel concept here with considerable interest, and a little concern. I have been in frequent consultation with our television receiver people, our Television Receiver Department, on this same subject; and I can tell you that they are very much concerned about the divergent approaches to the extra channel concept.

They have had CATV in mind for some time. I think most of you are aware that General Electric does make a standard line of television sets with 75 ohm inputs. I repeat, they are concerned about these divergent approaches, and they have planned to submit this entire problem to the appropriate E.I.A. committee to work toward some sort of standardization.

We are planning to propose in that particular forum a joint working group of set manufacturers, CATV equipment manufacturers, operators, possibly representatives from the FCC -- if they wish to participate -- to attempt to work toward some overall television industry standardization.

I thought some of you might be interested in this particular point of view because I think the last paper just mentioned that there has been some discussion with TV set manufacturers. I am not sure that any people discussed this with our representatives at Syracuse. They are, however, very much aware of it and very concerned about it.

MR. WYDRO: I have one comment, and the only comment that I can say is, amen.

CHAIRMAN CLEMENTS: Thank you very much.

I know that many of you must have other questions concerning these addresses, and if we have additional time when the panel is completed we will possibly get back to some of the more pertinent points in connection with expanded band use.

Our next speaker is Argyle Bridgett, from Spencer-Kennedy Laboratories, Inc.

He is now Manager of Design Engineering for S-KL. He started with them in 1951.

Without any further introduction, I present Argyle W. Bridgett. (Applause)

MR. ARGYLE W. BRIDGETT (Spencer-Kennedy Laboratories, Inc.): For those of you reading the paper, the first sentence does not sound like anything.

Actually, if you get down to the basics, they are probably two in number, but there are a large number of problems that develop from these.

AUTOMATIC EQUALIZATION AS A FACTOR IN SYSTEM LEVEL CONTROL

BY

ARGYLE W. BRIDGETT

BASIC PROBLEM

The basic problems of CATV are really only two. First is obtaining a sufficient number of high quality TV signals and second is transmitting these signals through coaxial cable without degrading the original quality too much. The cable which is obtainable today does only one undesirable thing to the signal to any major degree. It attenuates the signal. It also causes a delay, but the delay, in general, is not a type which degrades the signal and the amount of delay is small. In a system of 1000 db, of cable attentuation the cable delay will be approximately 100 micro seconds.

The attenuation, however, is enough to completely lose the signal in snow and must be compensated for by providing amplification at close enough intervals to avoid losing the signal. It is in providing this amplification that most of the problems originate, since any amplifier will degrade the signal in several ways. First, if the total response of the amplifiers does not match the loss of the cable fairly well the picture quality will suffer. Second, it will add some noise to the signal. Finally, it will add distortion signals to the desired signals. These last two effects, noise and intermodulation, are usually the factors which limit either picture quality which can be attained or system length.

I believe we are all familiar with the V curves shown in Fig. 1 which show how the amount of noise and intermodulation introduced in a system by the amplifiers depend on signals levels, amplifier gain, and number of amplifiers. The top curve shows the maximum output level at which a given number of amplifiers can be operated with a given amount of cross-modulation. (This will depend on the amplifier, the gain setting and the signal level tilt). The bottom curve shows the minimum input level at which the same number of amplifiers can be operated with a given carrier to noise ratio. The difference between these two curves for one amplifier is what is called by Shekel the "k" factor for the amplifier. The intermediate curve shows the minimum output level at which the amplifiers can be operated without degrading the carrier-to-noise ratio. The distance between these two curves is "system margin" which is the range of output levels at which a system of any number of cascaded amplifiers can be operated without exceeding either limitation. The ideal way to operate a trunk is with all amplifiers operating midway between these limits so that the "system margin" is equally divided between noise and intermodulation.

The important thing to remember about these curves is that the "system margin" obtained from them assumes that all amplifiers are operating at the same levels. In practice this is not always true. There will generally be a difference in levels from amplifier to amplifier due either to measuring equipment errors or variations with temperature.

June 28, 1967

The session convened in the Monroe Room at 9:15 a.m., Mr. John R. Penwell presiding.

CHAIRMAN PENWELL: Gentlemen, we will start the ball rolling. Welcome to the final technical session of this 16th Annual Convention. I think we have had an excellent group of technical papers and presentations to date, and today's session certainly promises to be most interesting, rigorous and deep.

Listening to some of the other papers in the past two days, I recalled an experience at Philco in Palo Alto. There was an unseen but pretty well-known prophet named Murphy. He had written some laws which the designers encountered. The first law was that you design an amplifer and it oscillates. The second law was that you design an oscillator and it amplifies. When the poor guy was really in trouble he discovered the third law, which was that things hate people. I think we also find problems of that type.

Todays panelists may or may not come to the podium, at their option. There is plenty of room up here.

The first paper this morning is "How to Evaluate Coaxial Cable for Maximum Ulitization and Longevity". Allen Kushner is Manager of Engineering Services for Times Wire and Cable Company, Division of International Silver Company. He works out of Wallingford, Connecticut. He has a Bachelors Degree in Mechanical Engineering and a Master's in Electrical Engineering. In his nine years with the company he has been responsible for the design, development and evaluation of many of the cable products. Allen Kushner.

HOW TO EVALUATE COAXIAL CABLE FOR MAXIMUM UTILIZATION AND LONGEVITY

ALLEN M. KUSHNER: As technical men, you now have or will have the problem of determining what coaxial cable will give you maximum system revenue. As a cable designer, our company has the same problem. Because of this, over the years we have been constantly pursuing the design which was both economical and would give us longest life. We applied polyethylene jackets to give you longer jacket life. We use foam polyethylene to give you longer distances between amplifiers. We have improved our manufacturing techniques to raise the return loss to 30db to prevent signal loss and ghosting. As we continue in our efforts to improve our design, our material and our method of manufacture, we have developed certain guidelines to aid ourselves in determining the worth of possible improvements. I present these guidelines here because I feel that they can be of value to you in evaluating cable for your systems. Once the factors critical to cable usefulness are understood, cable evaluation is quite simplified.

FACTORS LIMITING CABLE USEFULNESS

There are two primary factors which limit the usefulness of the coaxial cable.

1. Stability of electrical characteristics-when the electrical characteristics of the cable have degraded system performance beyond an acceptable limit.

2. Functional obsolescence-when the electrical characteristics will not allow the system to economically perform a functional different from that for which it was selected.

STABILITY OF ELECTRICAL CHARACTERISTICS

The electrical characteristics which are vital to the system are:

1. Attenuation
2. Shielding
3. Return loss

A sufficient number of papers have been written concerning the effect of moisture on the attenuation in a foam dielectric cable, so that as an industry we appreciate the necessity of preventing moisture from entering. We also seem to agree that a metallic barrier is the only economical method of preventing moisture entry. At the present time all plastics, with the exception of the Teflon family, will allow vapor to enter. Some are better than others, but they all do pass vapor at some rate.

ATTENUATION

Almost all of the trunk and feeder cable used today incorporates foam polyethylene as the dielectric material. The foam consists of tiny, individual air spaces which are formed by a gas which is liberated by the heat of extrusion. Another by-product of the extrusion operation is water vapor which collects in the individual air spaces. Directly off of the extrusion line, attenuation of our foam cores are quite high. When we dry out the moisture, the attenuation drops to the level which is guaranteed. However, it is necessary for us to insure that the cable does not again absorb moisture prior to our placing it in the metallic sheath.

To completely keep moisture from the foam core, the metallic barriers should be complete. However, experience has shown that this is not practical. We know that connectors improperly-installed will leak, and we also know from REA experience that aerial cable will develop at least one hole in the sheath per 1000 feet due to many causes.

The construction must therefore be such that moisture will not propagate thru the cable from the ends or from holes generated in the metallic barrier along its length. There are three paths moisture could take:

1. Between the center conductor and the foam polyethylene.

2. Between the foam polyethylene and the metallic barrier.

3. Through the foam polyethylene.

Moisture can be prevented from traveling along the center conductor, if the foam polyethylene adheres to it tightly. Moisture can be prevented from traveling between the foam polyethylene and outer barriers by tightly compressing the surface of the dielectric. Thus moisture entering from the ends or at holes along its length will not be able to rapidly travel through the cable.

The question then arises, as to how fast the moisture will travel through the foam polyethylene. Actually it travels quite slowly. While it might travel radially through the cable from outer conductor to inner in a matter of months, along the length of the cable this is an insignificant distance. We can easily tolerate one foot of cable with an attenuation twice as high as normal as long as the remaining 2500 feet did not change.

How do you verify that a cable design is moisture tight? The test is simple. Apply 15 psi of Freon pressure into the end of the cable and search along its length, and at the opposite end with a freon detector. Ten feet of a well-designed cable should be sufficient to prevent vapor travel from end to end.

We have also learned that a by-product of a cable which is made pressure tight, as we have described above, will reduce the effects of different coefficients of expansion in the inner and outer conductors.

It is interesting to note that we have had other foam materials with which we could achieve lower losses, increase our output and achieve better return loss figures. However, we are unable to bond this material to the center conductor, and as a result have been unable to make use of it. Another interesting by-product of a cable which will not pass vapor longitudinally is the fact that it reduces dielectric shrinkback should the cable be stretched substantially on installation.

We have considered above the design and manufacture of a cable which would maintain a constant attenuation over a long period of time. We must also be certain that large sections of the tubular outer conductor is not removed by corrosion. This subject will be discussed further on in the paper. The factors which I have stated above appear to have been borne out quite well by field results and laboratory tests. It is our conclusion that a cable from which longitudinal travel of moisture can be prevented, will be able to maintain a constant attenuation for an extended time.

SHIELDING EFFICIENCY

This is a factor which is sometimes overlooked, because of the inherent, excellent shielding offered by our tubluar, outer conductor. This efficiency will be lost if the outer conductor were to open in any way, either from design deficiency, improper manufacture or installation or corrosion. A break in the cable, or improperly-installed connectors, will allow signals to escape or unwanted signals to enter. As we move out of the "on frequency" channels, we should remember we are being exposed to massive interference.

If we move down in frequency toward the AM frequencies we should also remember that the shielding efficiency is a function of shield thickness. We should also not forget that the voltage developed along the outer conductor and between the outer and inner conductors if lightning should strike, are a function of the resistance of the outer conductor.

In situations where a jacket is required to protect the outer conductor, whether it be aerial or underground, we must remember that the jacket becomes as vital as the tubular metal outer conductor. The following must be considered:

a. Jacket thickness.
b. Number of pinholes.
c. Tightness of jacket on tubular outer conductor.
d. Life of jacketing materials.
e. Protection of the jacketing material.
f. Type of metallic outer conductor used.

While the requirement for sufficient jacket thickness is obvious, the requirement for no pinholes is overlooked. Extruded jackets will have pinholes. These must be searched out by application of a high voltage in sensitive testers and removed. We must be certain that the jacketing material will have the proper life expectancy. Let us not forget the work done 15 years ago which determined that only specific polyethylenes, without contaminants but with an optimum percentage of carbon black particles of a stated size and properly dispersed, will protect the jacket from the cracking effects of sunlight and certain chemicals.

UNDERGROUND BURIAL

I think it pertinent at this time to discuss the suitability of jacketed cables for underground burial. This is an area where the technology of our industry is lagging. It is known that if the jacket is damaged during installation or removed by rodents and then exposed to the moist earth, then corrosion of an aluminum outer conductor will proceed at a rapid rate. It is logical to expect that more new systems will be buried to improve the appearance of our expanding towns and cities. We must give serious consideration to the protection of cables from installation damage, damage due to subsequent excavation and damage from rodents and borers.

It appears that a steel tape or strip armor with an outer polyethylene jacket may have to be applied for the worst conditions. Another design approach would be to seal the outer jacket to the tubular outer conductor with a flexible sealing compound. We may have to consider copper as the outer conductor to inhibit corrosion.

RETURN LOSS

The return loss of the cable is not affected by moisture. It could be affected by physical damage during installation or during its life, or by severe corrosion of the outer conductor. In metropolitan areas, we see perhaps, the requirement for making splices at each manhole. At higher frequencies, a nominal cable impedance, different than that of the splice impedance, could build up to a substantial figure. While non-uniform spacing will reduce the problem, a tightly controlled nominal impedance is desirable.

FUNCTIONAL OBSOLESCENCE

As previously stated the economical life of the cable is determined by the stability of the electrical characteristics and by functional obsolescence-when the original electrical characteristics are no longer suitable for the changing function.

INCREASING NEED FOR CHANNELS OR BANDWIDTH

It appears that the most obvious change in function will be the offering of more services. 12 channels for many are already being superseded by 20. This is, of course, a dynamic example of how quickly functional obsolescence can occur, when we consider that in essence 12 channel systems installed one or two years ago may for certain areas be obsolete.

It is easy to appreciate why this is happening. You are making available to each subscriber a total communications media — you can supply sound, video or data. In reasearching ideas for this presentation, I was impressed by the thinking of the system designers. I would like to list some of the possibilities:

1. T.V. between schools and class rooms due to shortage of teachers.
2. The teaching of various types of skills — different channels for different skills required in that area.
3. The teaching of languages.
4. Data transmission in business such as inventory records and work loading.
5. Stock market reports.
6. Civic affairs, congressman direct to constituent — perhaps as far as registering a vote.
7. Automatic reading of water, power and gas meters.
8. Burglar alarms.
9. Fire alarms.
10. Medical electronics.
11. Shopping, ordering and billing.
12. Surveillance.

What this means in terms of cable is that we must assure that the widest possible bandwidth is available to cover such expansion. It appears that it would be economically feasible to expand systems in the foreseeable future to as high as 300 MH_Z.

The return loss is the parameter with which we must concern ourselves when considering broad bandwidths. As you most likely know, the return loss is a function of how the cable is manufactured and how it is handled during shipment. To manufacture a cable which has a good return loss at channels 2 thru 13, may be substantially different from achieving the same return loss from 8 to 300 MH_Z. It has been our experience that this could cause a redesign of the basic manufacturing equipment.

The state of the art is such today that good return loss can be guaranteed over 8 to 300 MH_Z. In addition, though data is not available to definitely prove this, there appears to be an indication that a cable exhibiting a good return loss figure to 300 MH_Z will also be good to above 500 MH_Z.

CONCLUSION

The utilization and longevity of a cable depends on how long it will economically perform the desired function of the system. This depends primarily on how long it can retain its attenuation without significant increase; how long it retains its shielding efficiency; and the bandwidth over which a good return loss is available.

If the criteria of development is correct, the state of the art offers the maximum insurance that the longest economical cable life will be achieved. It is suggested that you use the following criteria to evaluate cable for its life expectancy:

a. Is the cable moisture tight — apply pressure to one end and determine if there is any leakage through the cable.

b. Is the outer conductor susceptible to splitting — flex the cable to determine if it will sustain bending.

c. Lightning protection — check the D.C. resistance of the outer conductor.

d. Corrosion resistance — apply pressure beneath the cable jacket and determine if there are any leaks.

e. Return loss — what is the highest return loss and broadest bandwidth obtainable.

CHAIRMAN PENWELL: Are there any questions?

FROM THE FLOOR: You said something about teflon. Have you used the family name?

MR. KUSHNER: The family name is fluorocarbon. Teflon is the trademark of the DuPont Corporation for the generic family.

FROM THE FLOOR: You said that you have designed cable that you can't get moisture into, and then you build it, and the first thing you do is to take the moisture out of it. I am a little confused.

MR. KUSHNER: When we make our cables, regardless of which way the industry makes it, we take a center conductor and extrude a dielectric over the center conductor. Then we apply some outer conductor around it. There are different outer conductors. In foam polyethylene, when we extruce it, moisture is right inside of it. Fortunately we can drive the moisture out. If we could not, we could not use this material.

FROM THE FLOOR: You drive the moisture out after you put the outer conductor on?

MR. KUSHNER: No; before. Before we put the outer conductor on we drive the moisture out.

FROM THE FLOOR: I can't remember that your 201 cable didn't stick to the outer conductor — did it?

MR. KUSHNER: Hopefully, the 201 did.

FROM THE FLOOR: But not because you were afraid of moisture? The paper you wrote came some time after that.

MR. KUSHNER: The 201 cable stuck to the center conductor. In that cable we had it sticking there for an entirely different reason. We were sticking it to the center conductor to maintain stability of the dielectric. Foams have a characteristic also of shrinking. By adhering it to the center conductor we give the foam dimensional stability. A problem with most plastics is that they will shrink or expand, but if you obtain a bond to some metallic member you give it inherent stability.

MR. DONALD LEVENSON (Wheeling, West Virginia): I have been using the Freon technique for about four years, and I think you might point out that you can also use this technique for finding pinholes in the outer sheath of a cable by putting the entire reel of cable in a polyethylene bag.

If I might make an observation, I have never found a roll of cable yet that you can't get freon through, not ten feet but 2,000 feet. I may be wrong, and there may be some newer cables that are better, but I have always been concerned with this problem. Sometimes from the inner conductor to the polythylene you can separate this. You can find out where it is coming and how it is going through, or between the outer conductor and the polyethylene, and then of course you put the whole thing in a bag and you will find you have holes in the aluminum. Maybe they are microscopic and may not cause trouble.

MR. KUSHNER: My compliments! I wasn't aware that people in the field were using this. We use freon mainly because in our business we make a multitude of cables for Underwater use — a very good technique. I would like to talk to you more about that later.

I would like to say, as another technique, that to find out exactly where we are having problems along the length we use a gas collector which we build to go around the cable, and we run our cables through it. When you come to a leak with our electronic detectors it will sound a horn, so you can stop and investigate and analyze where the problem is and what it costs.

FROM THE FLOOR: You take some freon and blow it and see what you get on the other end. There is nothing more esoteric than that.

MR. KUSHNER: It works on the basis that moisture will propagate because of the pressure difference.

MR. NADEAU (Alcoa): I would like to have you elaborate a little more. You mentioned the steel jacket and the changing of the shield to a different type of metal, or what-have-you. Would you care to elaborate on this?

MR. KUSHNER: Actually, there is not really too much elaboration that I can give you at the moment. I could say as a cable manufacturer that we have seen cases where cables have been installed in the ground and it looks as if the jacket has been damaged either on installation or by subsequent burial. Anybody who has worked with the corrosion characteristics of aluminum I am sure has been the characteristic that the aluminum is corroded extermely rapidly.

It is our conclusion, therefore, that for areas that are going to be subjected to this abuse, we of the industry should recognize this characteristic and do something to protect our cables; and quite honestly, at Times Wire and Cable Compnay we have our thoughts, and we are developing a product.

The problem really is that right at the moment there are other industries that have done work in this area, and they do have ways of slowing down, we will say, gophers. We have no way of stopping gophers. We slow them down. They go through steel and lead and steel tapes. So, what we end up doing is that we come to a compromise.

There is a cable construction whose price is reasonable enough so that you can install it, and it will give you sufficient protection for a reasonable life expectancy. I suggest really that our industry take a very good look at these cables that will be installed in areas where they are likely to encounter such damage.

MR. S. W. PAI: I wonder if you have any data on the cross tap problem of two cables. Suppose you have two cables stranded tightly together for many, many miles. Cable A carries from Channel 2 to Channel 13 and cable B also carries another Channel 2 to Channel 13. Do you have any data at this time concerning these problems?

MR. KUSHNER: Yes, we do, except that data on shielding is extremely difficult to give you unless you really relate exactly how you have tested it. We get into ground circuits and the exact setup of the test equipment.

There has been a lot of literature that has been collected on this. Do you have in mind aluminum sheath cable?

MR. PAI: Yes; say 412 or half-inch, and so on.

MR. KUSHNER: And this is at frequencies from 50 MH and on up?

MR. PAI: Yes.

MR. KUSHNER: We don't have data, let's say, on a long length of line stretched parallel or close to another line. We have laboratory tests. Our laboratory tests indicate that if there are no breaks in the aluminum sheath cable, at about 50 MH you need not really concern yourself with the cable. The area of concern is the connectors.

You will find that the leakage from the connectors, depending upon the type of connector, is the area where you are getting your leakage, and that really depends upon the particular connector, because I would say probably no two connectors are within 20 db of each other. So, I think it becomes a question of evaluating the connector, and on that we really have no data.

MR. McCURRY (Cook Electric Company): What kind of design life are you looking into as far as the underground cable of the future is concerned? It it five, ten twenty, forty years?

MR. KUSHNER: Sir, we just look for the longest we can get, really. To put a time limit on it is impossible.

MEMBER: Aren't you just saying it upside down — that the functions he is after are practically skip-continuous and very irregular, in such a way that you can't collect any data? When you say you don't have it for each type of wire, this has been one of my problems. As a matter of fact, we have spoken on the phone about it. You don't have it for almost any wire.

Having it for one wire, given the way it is tied together, for instance, you don't have it for another wire; you don't have it whether they are tied this way or that way. In other words, the function itself. There is no usable function at all. You have to find out for each wire under each situation, given the length of wire also, and of course the discontinuity you mentioned, the connectors. There is nothing you can do in so far as function relationships are concerned, no general statement you can make.

MR. KUSHNER: I think there is probably one statement you could make.

In a flexible cable, where we were perhaps ten years ago, there was a very definite pick-up from the two cables if they were side by side. There were other problems in the system. We probably weren't aware of it, or it was a situation that really didn't hurt us. But going to semi-flexible cables, we have improved our isolation per cable better than 60 db. That is from each cable. So, we are 60 db plus 60 db, and that is 120 db therefore we have a order of magnitude of difference.

MEMBER: Would you touch on something for me that is rather elementary? This matter of periodic discontinuities that are causing your return loss to go down — to be lowered. Is this such a serious problem when compared to the components that we insert in the cable — splices, amplifiers, that have a termininating or output impedance that is considerably inferior to the cable itself?

It seems like your cable is so much better than the equipment, that asking for a return loss of 30 db is rather gilding the lily, so to speak.

MR. KUSHNER: There are three points I would like to make in that connection: No. 1, we have to think of the characteristic of obsolescence. Maybe ten years downstream our system will be so much better that the cable will be the poorest point. That is one thing to consider.

No. 2, the total system performance is equal to the sum of all its parts. Perhaps in all honesty the cable is so much better that what is the difference between 30 db and 26 db? It doesn't add that much to the sum. That may be valid.

No. 3, I think the real question is: What are you going to pay for it? If you have to pay twice as much to go 3 or 4 db return loss, you won't pay it. What really happens today — and I think this is what we apply when we buy any component — is that we buy the best there is if the price is reasonable. There really is no set answer. Right today — two years ago, if you bought the best there was, perhaps you only got two years out of it; but if you hadn't bought the best there was maybe you would have gotten less.

MEMBER: I wonder if this might be related to ghosting, smearing, and things like that.

MR. KUSHNER: Very definitely.

MEMBER: Connectors and periodic connectors every 250 feet, probably would contribute more to that as a problem than just little periodic discontinuities in the cable itself?

MR. KUSHNER: No doubt about it. As a particular component in your system today, the cable, as far as return loss is concerned, is the best you have; but it does add to the total picture. How much it does lose is a question.

There is something else here we should not forget, when we are talking about an individual system. You have to be aware of cascades. If you cascade a system to the limit you can get yourself into a situation, even with 30 db cable, where you might have a problem.

There is a characteristic about cable that we should be aware of. I think the return loss characteristic of cable is something we don't have a really good feel for. In other fields we talk about transfer function. Return loss is something we can measure because it is easy to measure it. We can all buy the equipment for $1,000 or $2,000 to measure return loss. People going into the metropolitan areas are measuring return loss on every piece of cable, and they are really concerned.

What we are really looking for is not the return loss characteristic, but it is something else we can't measure. We are looking for attenuation spikes of less than .1 db. Our equipment is not sensitive enough to measure it. What happens is that in cascaded systems, if you have a spike at the same frequency, you can still end up with 30 db with a noticeable attenuation of signal or noticeable reflection.

If you could get 40 db cable, I would say, get it. The problem is, we also have to be careful that as our components get better we are going to be seeing other things that we never saw before — things we never really expected would hurt us. I must admit that buying the best return loss is a marketing axiom, but I think on an engineering basis it makes sense. If it doesn't cost too much, that is.

MR. FRED SCHMIDT: In the construction of the cable, the dressing of the cable, what is the effect of putting in a right angle bend? We know if it is bent too hard it will give a suck-out. How much will cable deviate by putting these right angle bends that are silos into a cable?

MR. KUSHNER: In general there are recommended bend radii which we list. If you will go with those recommended bend radii you will not see any reflections; in fact, as a sort of rule of thumb, if the cable isn't wrinkled it won't bother you. The reflection at that point is usually less than 1 per cent if it isn't wrinkled.

MEMBER: What about the usual flooding compounds under the jacket for burial for underground cables, and as it is used by Gordon Electric for the Bell Telephone in Canada?

MR. KUSHNER: With regard to the flooding compound, my feeling is that flooding compounds have two purposes. The first purpose is to do away with the air spaces so that you will not get water accumulation. The second purpose is to cover the metallic surfaces so they will not corrode. The flooding compound should be tenacious so that it will truly stick to it. In that case it does a very find job.

I think we should be careful if we think that flooding compounds are going to prevent the passage of vapor. They will not. So, depending upon the purpose for which they are put into the cable, in general they do perform a function. I think there is a very serious question as to whether they perform a function with regard to the passage of vapor.

MEMBER: Measurements were made showing that flexible foam cables exhibited an attenuation increase due to humidity. I had the impression it then tended to level off. Have you found that since you made these measurements this is true, or does the thing keep on going up?

MR. KUSHNER: In general, what appears to happen is that the attenuation of the cable is a function of the relative humidity level to which it is subjected, with one exception: If you allow the foam to come in contact with water it will go so far in some cases as to absorb the water like a sponge.

MEMBER: You mean that foam 59/U could go up worse than RG 59?

MR. KUSHNER: Yes. In the worst case it could. Thank you very much. (Applause)

CHAIRMAN PENWELL: Thank you very much, Allen.

We don't have a projector yet, and S. W. Pai's paper has some slides. Is Brian Jones in the room? Do you have slides with your paper? (Yes) Oh, boy! I think the projector is on its way.

This might be the time to go into the "Underground Construction" program, so if Mark Wolfe, Ted Hughett and Sam Booth will come up, we will introduce this panel. Each of the panel members will bery likely make a short statement about underground, and then we will turn it around.

I understand Vern Collidge could not attend, and Walt Roberts is going to sub for him. He was probably looking forward to coming on a little later. I think we had better proceed with the three panel members.

Ted Hughett, on my left, is with Alarm Corporation, on the Monterey peninsula in California. He attended Monterey Peninsula College. He has been with Alarm Corporation for the past eight years, and he is presently Executive Vice President of the company. He is on the Electronics Advisory Committee for the Monterey Peninsula College.

At my right, Mark Wolfe attended Cornel University and graduated in Electrical Engineering. He is a member of IEEE. He has had 34 years of engineering experience in wire and cable. Presently he is the Chief Engineer, Communications Division, Anaconda Wire & Cable, Sycamore, Illinois.

I am sorry I don't have further information on Sam Booth. He is with Sarasota Cablevision.

After the printed papers there was omitted from the program another paper, on "CATV Coaxial Cables Standardization?" by Sidney A. Mills, from Ameco Cable, Inc., Phoenix, Arixona. This will follow the last of the papers this morning. We are sorry his paper was omitted from the printed program.

At this time we will start with Ted Hughett. Do you have any comments on underground construction? You ought to have a lot of them.

MR. TED HUGHETT: Thank you, John.

Having to put a CATV system underground gives most technicians and engineers a very uneasy feeling both from a maintenance and construction point of view.

Alarm Corporation, over 16 years ago, found there was a need for a CATV system in a unique little town in California called Carmel. Because of the character of the town, the city fathers decided that they system must go underground, much to our dismay. In Carmel there are no sidewalk areas and no accessible utility easements. This left only the blacktop streets to bury the cables in; so we developed methods and equipment to bury cables 6 to 8 inches underground. This was so that we could get back at the cables for tapping and repair purposes. This type of construction I do not recommend unless it is absolutely necessary.

Today's need for ever better pictures and more efficient and economical methods has brought about substantial improvements in both equipment and methods. There are basically two ways of putting cables underground. One is the direct burial method and the other is the ducting or subshielding, as we call it.

Generally speaking, we do not recommend direct burial, per se. It is our opinion that it is too earily damaged or cut and is very costly to repair or replace. In our system, being as shallow as we are, we are cut on the average of once a day, 365 days a year. So, we have gone to a system of, when possible, particularly in new subdivisions, ducting or sub-shielding. We use polyethylene duct because it gives us added protection. We go to depths of 24 to 30 inches, and it gives us permanent raceways. This I feel is the big factor — the permanent raceway system.

If you have problems with cables you at least have a permanent hole in the ground. You don't have to dig up sidewalks, years, tear down fences, and get your customers very angry at you.

The costs of going underground are more than going overhead; but this is offset, I feel, by the nomakeready charge and no pole rental fees. So, generally, underground does have some advantages if done correctly.

You are also not as subject to damage from storms, falling trees, and things of this nature.

In new subdivisions we use methods of joint trenching. This is where the trenching cost is shared or split by anywhere from two to four utilities. Also, in new subdivisions we will put the raceway system in and not commit the cables or the amplifiers at this time because in a great many cases subdivisions will go in and there won't be a house built in there for a year.

We have devised some methods of sealing ducts and cables. We have used shrink tubing; we have used tape; we have used practically everything that comes out. You can't seal them.

The duct sizes that we have standardized on for trunk and distribution combinations — we will use a 2 inch duct. For distribution we will use 1-1/2 inches. This gives us plenty of leeway to get back in and out. We space pull points no farther apart than 250 feet. This facilitates the repair and maintenance, and reduces the time that you may have to have your customers off the air due to a bad or damaged cable. You can pull in pretty quickly 250 feet of cable, and you can isolate your problems down to 250 feet reasonably rapidly. We feel it is much more economical to do it this way.

I think I will leave it at this for the moment, because I know there will probably be a great many questions. Underground varies widely across the country. In California we have some unique situations, and I imagine there are many areas that have as bad, if not worse problems; so I will stop at this point, and say thank you. (Applause)

CHAIRMAN PENWELL: Thank you, Ted, I think we will defer questions until the panelists have all commented. Don't get frightened by Ted's early experience; we might have some more cheering news.

Sam Booth, from Sarasota Cablevision.

MR. SAM BOOTH: Thank you.

Unfortunately, I am not an engineer, and a lot of these problems didn't worry me when we first started in with underground cable. We have about 200 miles of cable buried underground in Sarasota, and it is all direct burial.

We have found recently that General Cable is making an armored cable that has a double shield on it with a floating, flooding compound in it, and in between the double shields are stainless steel spirals; and we are standardizing on that for all of our trunk cable. In areas where we use in-line taps (and they are very few) we are going to use that.

We have taken shovels and axes and abused this cable as best we could, and find it is very difficult to get through to the second — it is not a polyethylene but sort of a coarser material than the normal polyethylene. We feel this flooding compound gets away from the pinholes and other things that you do encounter.

Our decision to go underground is usually based upon one of several factors, one being the unavailability of poles or restrictions of the subdivider, or else the desire to cooperate with Mrs. Johnson's beautification program. Although considerable types of cable have been buried, we still have to use some ingenuity and inventiveness to develop the necessary hardware. This is one of the biggest problems we have found, because, as Ted said, in each area you have problems of a different nature.

We do believe that underground is a superior way to put in a cable system, although you do have a different set of problems, and the fact that so little of it has been done scares almost everybody when they think about it.

You do get away from the annual pole rental, and you don't have the problems of temperature changes. We have made studies and have found that at about 18 inches in Florida we have only a 3 or 4 degree temperature swing in any period of time.

An underground system does create some good public relations systems for you because you are not polluting the air with cables.

We have also found that, in construction of an underground system, labor costs are considerably less because you are not involved in unions, and you don't have people climbing poles, and the high rates you have to pay. We believe in direct burial. There have been mechanized ways of ploughing cable in to speed the mechanization and reduce the cost.

To be perfectly truthful with you, the reason we went underground was because we couldn't get any pole contracts. There were several other franchises outstanding at the time we were trying to build, and it was a matter of us building or somebody else.

When we first started burying we were trenching, and this is going at it the hard way. You go down somebody's lawn in Sarasota, Florida. About 50 per cent of our people are retirees, and most of them have just moved there, into new subdivisions, and have just put $1,000 into a new lawn, and if you take a Caterpillar tractor down their front lawn you will have a problem.

We knew that the ideal way to do it would be to plough it in, but all of the ploughing equipment we had seen was a tractor with a reel on the front of it and the cable going back over it. It meant that every time you came to a street crossing or a driveway you would have to cut the cable and splice it — and of course we all know what splices do.

About the third or fourth day we were underway a representative of the Ditch Witch people came around and showed us how to put the cable in. Set the reel at the point you begin, and pull the cable. They have a vibratory plough and you can go down somebody's yard and they will be hard put to come out and find where you put the cable in because it is just a very thin slice through the lawn, less than 1 inch wide. After a good rain the grass has grown back and there is no complaint.

We have used this method very successfully. Originally we were burying about 30 inches, but we found that was a little too deep; so we standardized at a minimum of 18 inches and a maximum of 24 inches.

We have very little difficulty with out trunk or distribution. House drops are the things we have problems with. We have had cases where the power company set a new pole right in the middle of the trunk; but those cases are few and far between, and we have given all the utilities copies of our "as built" so they at least have a hunting license and know we are somewhere in that vicinity.

We were fortunate that in Naples, Florida, a system down there has been buried for five or six years, and Dick Cox and Quain Fletcher of Gulf

Toast TV of Naples were kind to us and explained many of their problems to us. We were able to take steps to avoid some of the problems they had encountered.

From our point of view, putting in the trunk and the distribution is not a real problem. With these Ditch Witch machines or Davis machine we have had a four-man crew put in a half-mile system or better in a day's time at a cost that we think is comparable to what it would cost us for overhead.

The problems we get into are getting from the cable into the house. This is a problem we share in common with the utilities. I am talking about some of the electric people. General Telephone operates in that area. A large per cent of their system distribution is underground. They have a pole and they have a house drop running there, and it is very unsightly. It seems to me to defeat the purpose of underground. If you are going to go part of the way you might as well go all the way.

We have recently come across a machine, a Pied Piper, that is made by Sod Master of Minneapolis. They have taken what was a sod cutting machine and reversed the vibrator, and you can plough in short lengths of 412 with it. It is ideal for putting in house drops. We have tried various ways of putting in house drops, and we finally standardized on a little machine used for putting in lawn irrigation systems. It cuts a trench about an inch wide and 6 inches deep, but it has been so dry in Florida that the soil would all blow away, and we caught hell because of the trencher running to the house. We are thinking seriously about buying some of these Pied Pipers and putting it right in. It makes no trench at all, and it works out very nicely.

We have fought the dampness problem. That is one of the biggest problems with underground, especially in an area that gets as wet as Florida. The other day we had 10 inches of rain in two hours.

We really didn't have as many problems. We have had sleepless nights thinking we would have problems. We have tried heat-shrinkables, and we have tried Gayco and various other things. The other day we were looking at a reel of Times cable and we noticed some sort of gunk on the end of it. We called Larry and he got us a sample of it. It is an adhesive made by Raybestos-Manhattan. It comes in a solid form. We heat it, and we have started using that entirely for all of our waterproofing. We use it on connectors and splices and all our house drops. We find it is the most satisfactory material we have been able to get for waterproofing. You can apply it. It is hot, and as soon as it comes in contact with the metal it hardens. It does not harden to the point where it cracks. If you want to work on the splice you can take a knife and peel it off. You can throw it back in the pot and heat it again and use it again.

At the time we formulated our plans for the system we made a decision not to go into in-lying taps. We use pressure taps. We use a football type of tap or block that Wiking makes, and the waterproofing of those was a problem. First we started using Gayco and we used rubber tape and put plastic tape on top of it, but the moisture got through to it. Then we tried a butyl type of caulking compound, and it never got hard enough to really work with, although it was very satisfactory. We finally got this adhesive which we are now using, and we are trying to develop some sort of mold that we can use to pour this around the pressure tap and have it all done in one neat little job. We haven't achieved that yet.

The problem is in areas where you have to cross a street, or a state highway, and you are not permitted to cut a ditch into it. In some areas we sought permission to take a concrete saw and cut a half-inch cut through the street about 12 inches deep. We convinced the county this was an expansion joint for their road system, but in some areas we haven't got that message across yet.

We have tried using a hydraulic press to push pipes under roads. We have tried water jetting and air jetting, and the highway departments have stopped this practice because it isn't good for the road system.

We are currently trying to use an auger that hooks onto the side of one of the tractors. Davis actually has a little machine that fits on there. This is one of the big problems.

Basically, from our point of view, underground is not too much more trouble than overhead. We have four systems in Florida; two are underground and two are overhead. We really haven't been in operation long enough to get an honest comparative cost.

Our experience in building in Sarasota underground has taught us a lot of things, and we are improving some of the other systems. We do feel that the manufacturers are recognizing the fact that underground is here to stay and there is going to be more and more of it. I am sure you have noticed in some of the exhibits that instead of having everything for strand mounting they now have right-angle connectors and you can mount them in a vertical instead of a horizontal position; so, this will make life a lot easier for everybody.

I am sure you will have some questions later, and I will be very glad to answer them. (Applause)

CHAIRMAN PENWELL: Thank you, Sam.

E. Mark Wolf, from Anaconda Wire.

MR. E. MARK WOLF: I think we sometimes get into trouble when we talk about underground systems, because we fail to point out in the beginning that each system has got to be engineered. We sound (as I think I may sound in my brief remarks this morning) as though we can make general rules and they apply to everyone's problem.

You have heard from two gentlemen this morning who certainly have problems that don't fit the average case. There are many options available in cable construction and installation techniques. They all have their price. The practical engineer gets into this to determine what is the best choice for you.

Underground installation of cable is not new, and the history and progress of underground power and telephone cables is one of the more interesting chapters in the field of cable engineering. It covers a span of at least forty years, perhaps even more than that. In this time period we have seen costs go down and reliability improve to the point where today there are an increasing number of telephone and power companies that are promoting underground systems on the basis that they are more reliable and more economical.

Seomone asked earlier, what was meant by long life? That certainly is one of the things we are concerned with when we go underground. There is no positive answer to that, as Allen Kushner said; but most of the utility people we talk with -- power companies and telephone companies -- want the time span to be at least twenty years. So, if that helps you put a number on it, there it is.

Our present situation is that underground installation is generally more economical and more reliable. It was not always this way. Both high cost and poor reliability were almost trademarks of underground installations some years back. The learning curve has really been steep, particularly in the past twelve to fifteen years when we have seen very radical changes in both construction of the cable and in installation techniques. There are a few of these that are worth mentioning.

I feel that in the field of cable construction we have developed a truly new technology in the selection and use of non-metallic coverings to protect the cable cores from underground environment. In the last decade or two polyethylene has been a consistent front runner as a covering material for a number of very good reasons; but early applications of polyethylene as a covering gave very disappointing results, and there were many unexplained cable failures in the early days.

Out of this came a long and comprehensive investigation that was participated in by raw material suppliers, cable manufacturers, power companies and telephone companies; this went on over a span of quite a few years. Two really important facts came out of the investigation -- many more, but I will just mention two:

We learned from this experience that the molecular structure of the polyethylene is more important to its proper performance underground. Today we have very sensitive tests for the environmental adequacy of polyethylene. We know we must use a high molecular weight polyethylene in this environment. The old problems of environmental stress cracking are no longer problems; we can almost forget them.

The other factor that emerged from this investigation was that these coverings must be properly applied if they are to act as an impervious barrier between the soil environment and the cable core. Consider cable with a metallic outer conductor or shield, covered by some kind of polyethylene jacket. To prevent the polyethylene jacket from acting as an osmotic membrane and permitting the transmission of moisture vapor, it just has to be in complete and intimate contact with the underlying aluminum or copper. There is more than one way of doing this. One of the best means for achieving this condition is the use of an adhesive bond between the polyethylene and the underlying aluminum shield. Today I feel it is well within our capabilities in industry to manufacture cables which are both economical and trustworthy and which will give long and reliable service when directly buried.

So much on changes in cable construction we have seen.

At the same time this was happening, I believe we have seen equally remarkable advances in the technology of cable installation. Early installations gave a great deal of trouble due to a variety of causes related to installation techniques. Buried plant construction was in those days very costly. Cables quite frequently were damaged by insects, by rodents, by frost heaving, accidental dig-ins, rocks, and rough handling during installation. I am sure you have all heard of these.

Today -- and again I am speaking not of the special conditions that exist but generally what I guess you could call average areas -- if there is such a thing -- these problems have been largely solved by the development of a wide variety of special equipment for underground installation. Most (certainly not all) of these past difficulties from insects and rodents and frost heaving and accidental dig-ins have been overcome by making available equipment to let you get 3 feet below grade with the cable.

Vibrating ploughs are available, and they do a good job of surrounding the cable with rock-free dirt where rocky terrain is a problem. Cable ploughs now are designed to really reduce to a minimum the possibility of damage during installation.

There isn't enough time here, of course, to even attempt to present our collective engineering knowledge in this field; but these highlights perhaps will illustrate that the background and knowledge does exist in cable fields other than CATV. It really doesn't matter whether the cable to be buried is CATV cable, power cable or telephone cable. One basic problem is common to all, and that is to protect the cable core from the underground environment. The means for accomplishing this economically and reliably exist, and I don't feel we should run scared when faced with installing an underground system.

As I mentioned, there are many options available to fit the particular conditions you have. I think the knowledge exists and the background is here, and I think you can find a way to do it to suit your particular situation.

Thank you. (Applause)

CHAIRMAN PENWELL: Our last panelist is Walt Roberts, Director of Research for Superior Cable Corporation. He is substituting for Vern Coolidge, who was on the program.

Walt has over eleven years with Superior, and has been involved in development of high-frequency coaxial cables. He spent three years in the Army during the Korean conflict. He received his Bachelor of Science degree in Mathematics and Chemistry in 1956, and completed work on his masters in Physics in 1958. Walt Roberts.

MR. WALTER ROBERTS: In my remarks, rather than attempt to repeat anything said before, I thought I might take Mr. Wolfe's remarks and pick a few aspects as far as cable itself is concerned, and touch on those very briefly.

As he pointed out, the cable sheath of the coaxial cable, when it is buried, bears the burden of protecting the core. The remainder of the cable, the construction and design, is pretty obvious. It has a function to perform, no different from the aerial cable. Once it is buried it is then susceptible to moisture, water, damage, and so on; so it becomes the burden of the sheath to offer this protection.

I thought I might mention a few susceptibilities that may or may not be unique with buried construction, but some of the various means of losing stability of the cable, and some of the more obvious means for trying to protect against this.

Attenuation stability obviously is the name of the game here. You install a cable with a certain loss (or you are anticipating a certain loss), and if the system is to function properly this loss has to remain constant, within limits.

The two major sources of changes in loss that we know of -- and there may be others that some day will come out -- are: (1) Changes in the dielectric loss; (2) changes in loss contributed by the shield. If major changes in loss occur in the center conductor, this is an indication of a disaster of great proportion, and I think the subject of that particular length of cable comes to a close right there.

Moisture vapor as such can and does affect the dielectric losses of a foam dielectric (one of the two major materials used) and does not require the presence of physical water in the core, meaning liquid water, to do its damage.

Solid polyethylene, used as a dielectric, is not susceptible to moisture vapor as such; and although it is at first glance less economical to use, in some cases it offers a more economical approach in cable design.

The cable obviously has to be larger in order to achieve the same loss as a cable using foam polyethylene as a dielectric. This penalty may or may not be outweighed by the cost or burden of additional protection schemes for foam polyethylene, which obviously has to be protected.

Moisture vapor will certainly permeate nonmetallic sheaths such as polyethylene, and I think polyethylene is probably the material if we are considering plastic materials for a sheath. If no other barriers are present, it will permeate into the core, the losses will go up to some saturated value. Perhaps you could design a system on the basis of this; but then I think you would have to consider the loss of the cable as being that saturated value. Now compare economics with cables such as the solid dielectric, which may have started out a little larger but now you find the relative losses can turn around and actually reverse. So, I don't think this is a way to go about presenting the system. Assuming this, we will have to offer protection.

Mark mentioned the seal required to prevent water movement. This seal also would have, and does have, an influence on the water vapor or moisture vapor that permeates through the core. Picture this cable lying there with the polyethylene sheath, and the polyethylene being the vapor barrier -- a permeable barrier -- moisture can pass through. If you have space between the polyethylene and the shield -- and this is not necessarily a hole you can stick your hand in, but just space -- the moisture then can travel in parallel, you might say, and from this parallel attack can slip around the sheath, and if there is an opening it can surround and attack the core again in parallel.

If you fill this space either by sealing the polyethylene to the tape or by filling it with a flooding material, you accomplish the same purpose. You

confine this space to a simple path that is in near proximity to the overlap, (if it is an overlaped shield). Likewise on the inside if you have it filled or bonded, you can confine the path now to a path emanating or spreading from that entrance point.

Obviously, a welded or swedged aluminum sheath, has no known path. There you are depending on maintaining the integrity of the sheath.

At this point, then, disregarding man-made damage, we have viewed cable construction of two classes: (1) where you have a dielectric that is not susceptible to the presence of moisture. In the case of solid polyethylene you can ignore it and shrug your shoulders. (2) In the case of foam polyethylene you definitely have to maintain integrity by some barrier type or protective means.

I think this has been mentioned in an earlier presentation. Water, as a result of man-made damage, can enter the cable; and even if the core were not susceptible to its effects -- if there is space for it to move, it won't move far before a junction of some sort, a connector or tapoff or something -- it will now become defective because of the water that gained entrance somewhere else and moved along the cable. So, protection from moisture, whichever technique is used to protect the sheath in either case blocks the water from migration along the length of the cable.

These are two separate and distinct problems that can arise. We have found a lot of confusion both on our part and on the part of those trying to interpret problems in the field, as to which was really the culprit; whether it was moisture vapor in the sense we are speaking of it or whether it was simply water.

Physical damage to a sheath, whether it is due to foreign workman damage, rodent damage or perhaps a pinhole puncture of a sheath as a result of a surge of lightning -- all of these obviously now lay the core of the metallic sheath open to corrosion if such can occur.

After spending a few minutes this morning reviewing a book on Underground Corrosion, published by the National Bureau of Standards, it would appear that you are always susceptible to corrosion. I picked up a few numbers, not to try to impress you with numbers but just to indicate the range of corrosion that you might experience depending on locality. This brings out one point: if you are considering buried construction in a particular locality, corrosion in that locality involves a unique set of circumstances and it must be scrutinized and examined from that viewpoint. This book, if it is of interest to anyone, very likely will not have answers for your own problem, but I have found it an excellent reference. It shows maps and distributions of various soil types and areas in the country, and gives you a starting point for considering corrosion in your own locality or in a locality under consideration.

The name of the book is Underground Corrosion, by Melvin Romanoff, NBS Circular 579. It costs $5 or $6, and is at least 200 or 300 pages long. It lists page after page of corrosion data taken at various NBS test sites; there must be 75 or 100 listed in it. They are spotted geographically all over the United States.

Just as an example, one of the listings on copper corrosion in these tables, listed in terms of ounces per square foot per year corrosion rate: There are ranges from one test site in California, a dry loam type soil, of .03 ounces per square foot per year, to another extreme of .13, which was in decomposed peat soil in Wisconsin at a test site. This is no condemnation of Wisconsin but just a particular site that was used.

Here is a ratio of at least 5 to 1 in corrosion rate. Something that is a little easier to picture, an ounce per square foot is equivalent to 1-1/2 mil penetration in copper. We are talking about a ten-year period here, assuming the metal has been exposed to corrosion, of something of the order of .5 mil to 2.5 or 3 mil.

The data in this book are pretty sparse as far as aluminum is concerned. I found one set of data for a ten-year study on commercial aluminum where samples 1/16 inch, in five or six different test sites, all had pitted to a depth of 60 mil or so -- almost completely through. In one case apparently the plates had decomposed or somebody stole them. The range was about a 5 to 1 ratio. As I recall the most severe corrosion on aluminum, occurred in a highly alkaline soil condition.

I mention these numbers just by way of illustration. Regardless of protection scheme of the cable design, corrosion will occur to varying degrees, but can be improved by proper metal selection.

Copper in general, the telephone industry has assumed, would be the most corrosion-resistant material, certainly by comparison with aluminum. Yet I can point out personal cases where we found chemical corrosion by hydrogen sulfide. This does not require a hole in the sheath. It can permeate through the polyethylene like a dose of salts. In the southern part of Florida we have found cases in the telephone construction business of just such examples, where the gas permeated through the sheath with no openings. In the laboratory we duplicated this in a matter of minutes, not months. Naturally the gas will attack the copper as soon as it passes through. Since the free gas attacks it as fast as it gets in, you maintain a partial pressure difference until the copper is reacted.

Again this illustrates that there is no one answer. There is at least one case here where copper will not be suitable and I am sure there are others.

This is a rather rambling dissertation on susceptibilities. I am still pointing to one common cry in design, in that stability of this cable is the criterion around which all design points rotate and toward which they all focus.

We as manufacturers certainly want to be able to offer a cable that will meet your needs, and feel that certainly a mutual exchange here of what we think is a proper design for your needs can only be improved upon through mutual exchange and feedback from your own operating viewpoint.

Rest assured (and I think I speak for all manufacturers) that we are certainly standing by to try to offer you, to the best of our ability, a cable that will perform. As Mark pointed out, we have had long years of experience in other areas, and specifically years in the telephone business, from which we feel we can apply practical design considerations.

Thank you. (Applause)

CHAIRMAN PENWELL: Thank you, Walt.

We have heard some very experienced cable operators, one on the West Coast and one on the East Coast, and we have a formidable array of experts in cable. For perhaps seven or eight minutes we will turn the microphone around and let you shoot questions at our speakers.

MR. ALLEN (Arizona): I would like to ask a question of the entire panel, since apparently it is impossible to keep moisture or water out of the duct. I would like to ask whether it is worthwhile to duct rather than to be prepared to replace the cable as soon as it goes to pot; whether it is necessary to put it in duct; and if you are going to put it in duct, whether it is valuable to have the polyethylene jacketing on the cable, or bare copper. What is the preference?

MR. WOLFE: In answer to your question, the answer inevitably has to involve a certain amount of opinion. I think in using duct installation you would be very foolish not to anticipate the fact that there is going to be water in the duct at some time; and therefore the cable that you put in it has got to be suitable for underground use, suitable for direct burial, with one exception, and that is that the mechanical protection that is often needed for rocky terrain and direct burial is not going to be required.

Other than that, the cable has got to be a cable that will operate under water, because at some time or other, as you said, that duct is going to get wet. Don't fool yourself on that.

MR. JOHN FOOD: I direct this to Ted or any other member. I wonder about the plastic pipe without the cable in it. Do you find that it is possible that due to frost, heaving or snow, it gets kinked?

Another question: Does the plastic pipe snake so that when you pull the cable through it is hard to direct it through?

CHAIRMAN PENWELL: I think you hurt his feelings. He is from Carmel. (Laughter)

MR. HUGHETT: As far as the frosting is concerned, you are way out of my area. I live on the West Coast. The crushing or snaking -- we have buried quite a few different types of conduits, ducts and raceways. We are presently using a coiled type of duct, a duct that comes in a coil, a polyethylene. We have done the majority of our systems in duct trenching where we are laid in with power and telephone. We have not had any great problem in the snaking or looping in the trenches.

When the tranches are joined they are about 12 inches wide and 30 inches deep. When we do it ourselves we use a 4 inch wide trench so that snaking is not a great problem.

Do you mean when the cable goes bad?

MR. HOOD: You mentioned something about subdivisions where you placed this pipe, and you didn't pull the cable until later.

MR. HUGHETT: That is correct. This has been very successful. We use a two-man construction crew in both phases, and it is very fast; in fact, we walk circles around the power and the telephone companies. Our crews have to shift jobs because of this.

The pulling in and out factor, in answer to this other gentleman's question, brought up the factor of why you use duct. As long as you have a permanent hole in the ground, or semi-permanent hole, you are not going to have to disturb the areas of sidewalks, customers' properties, and so on. We also use a 3/4 inch ducting into the house to keep away from this, and the speed with which you can do this means that your reliability factor is much higher and you are not off the air as long.

VOICE: Are you working from a pedestal -- the drop line from the house to the distribution line?

MR. HUGHETT: Correct; a common pedestal or a vault. We have used pedestals, vaults, different methods of surface, housings, practically every type that is made.

VOICE: What about vaults? Do you find they fill up with water? Getting back to frost again, if we had a vault and it was not drained properly there might be a big cake of ice.

MR. HUGHETT: As far as freezing and frost areas are concerned, I don't know, except that we do know that rodents, gophers, backfill these vaults. They literally do. They push dirt into them. Moisture comes up from underneath. The vaults, we use only as pull points. We have used them as tap points but found this not to be too successful. We use them as pull points, and then we will attempt to encapsulate, in one way or another, any device. If it is a connector we will try to sling-tube it or cover it or put it in one type or another. A vault is another form of a permanent hole in the ground.

VOICE: We have 300 miles of dielectric cables in one system, and we do seal it.

VOICE: Is it possible that the difference between your experience and Mr. Sarasota's is that when you went deeper you got out of trouble?

Another thing I am curious about is what percentage of the breaks that you had would have broken conduit. You say you had a great deal of breakage; then you changed to conduits. You also went lower when you changed to conduits. The question is: Would the conduit have been broken by the breaks you had? And of course the other question is, Is it the depth and not the conduit that saved you a lot of trouble?

MR. HUGHETT: I think it was a combination of all these factors. The breaks I am talking about -- well, somehow they seem to hunt for the cables. Anybody who digs in the ground seems to find the cables, but the ducts are stronger than the cables.

VOICE: Not as far as a bulldozer is concerned?

MR. HUGHETT: Bulldozers won't stop it; but again we are primarily cut by plumbers, by the power company, by the telephone company; and they don't use bulldozers in built-up areas as a general rule. True, in new subdivisions we have had systems put in and had them torn out before they were ever activated.

VOICE: You have no percentage?

MR. HUGHETT: No, we don't have a percentage, except that it is just something you have to learn to live with and try to work out on your own local basis. Educate the people as to where you are. Try to educate the people who work in the field to be cognizant of where you are, and to be careful.

MR. BOOTH: With this new type of cable that General has, it is stronger than the conduit because it is a stainless steel jacket. It is double jacketed. It has a flooding compound. I would prefer to see it instead of in the conduit, where you are using a polyethylene or water tubing or something like that.

MR. HUGHETT: It is a duct that is manufactured.

MR. BOOTH: Is it like Hercules makes?

MR. HUGHETT: The corrugated? Both corrugated and smooth wall. We will go as far as to put direct burial cables in ducts.

VOICE: The problem we have had with trunk cutting is that we would have had it if it had been in a transit pipe or any kind of pipe. Somebody digs around, and wham!

CHAIRMAN PENWELL: We will allow one more question and then we will have to move along.

VOICE: Rather than asking a question, we have had a problem at one time that we have solved rather uniquely, and it may be of interest. It was a problem of how to get a cable into somebody else's conduit when you have permission, and the possibility of damage when you have to pull it at one time.

Between 1,000 and 1,100 feet we had to put up a $10,000 cash bond that we would not damage it. We brought specialists in from big cities who are supposedly knowledgeable in this business. They got paid by the day, and after two or three days they took their money and left.

We tried all of the techniques that the industry has. You may be interested in how we finally accomplished the job. Would you like me to tell you? I'll tell you what we did.

We were in Wheeling, West Virginia. We built a pliofilm parachute, and we put an industrial vacuum cleaner at the far end of the conduit. The objective here is that as you get closer to the power source you are pulling more string behind you, and therefore this is the way you want to work it. By the way, this conduit had two turns in it. That is why the device is a rocket to shoot through, and they hit a turn and they expell all their energy.

It was very important that we accomplish it. It was the only way we could serve this one area, by building this pliofilm parachute and nylon thread. We could barely feel the air at the side we were working on. With this big vacuum cleaner at the other end we managed to draw the parachute through more than 1,000 feet. Once we got the little thread through we ended up getting the heavier through.

This was transit duct. It was dirty. Mr. Wolfe will have to tell me the compound they used to use about a generation ago on the outside of the cables, like a fiber material. All these other devices, as soon as they started rubbing against this, would lose their energy. We were thinking of skyrockets. You are familiar with the devices they use -- a carbon dioxide pellet device. They would get 100 to 300 feet maybe, but that was all.

Then we tried shooting from both ends, hoping they would twist together. (Laughter) We stood there for close to a week. We had to solve the problem. That was the important thing. We did manage it.

When I talk about an industrial vacuum cleaner I am talking about a device that has a large volume of air. You have got to get the air going through. The air at the manhole we started with was so slight that you had to put your ear against it to even be able to hear any airflow. You could just detect it. I guess we had a religious service the morning before, with all faiths present. It did work.

CHAIRMAN PENWELL: If CATV can continue to innovate like that, we're not dead.

Gentlemen, I want to thank you very much for your time. Perhaps if there are further questions you might try to buttonhole the speakers out in the hall. We have to move along. We are back on schedule now. For the benefit of those who came in late, we didn't have a projector when we started the session, and the second and third presentations require a projector.

Our next speaker, Mr. Pai, has been with CATV and Craftsman Electronics Products for the past three years. Mr. Pai will speak on "Analysis of the Directional Tap in System Design". Mr. Pai.

(Mr. Pai read his paper, marked No. 2.) (Applause)

ANALYSIS OF THE DIRECTIONAL TAP IN SYSTEM DESIGN

by
S. W. Pai

For years, the technique of tapping off signal from CATV feederline to the customer's set has mainly relied on the pressure tap. Although the design and construction of the pressure tap has been constantly improved -- such as, from capacitive tap to backmatch tap. However, the inherited problem both in the circuit design and mechanical construction of the pressure tap limit its performance in today's sophisticated system, especially since the information carried by the CATV system and the length of the feederline are constantly increasing, coupled with the increased demand for better color signal by the customers. Therefore, a better method of tapping off the feederline must be devised; and the directional tap is the most feasible answer at the present time. The advantage of the directional tap vs. pressure tap is, of course, obvious; and also the characteristics of the directional tap probably are well known by this time in the field of CATV. Unfortunately, even today, the advantages of the directional tap have not been fully utilized by many of the system designers. It is the purpose of this paper to present some of the advantages of the sloped directional tap and the distinct characteristics of the directional tap as a feederline tap off device. Figure 1 is a layout of a typical CATV feederline:

The length of the feederline is approximately 900 feet of .412 aluminum cable with nine directional taps spaced approximately 120 feet apart. The feederline is connected to one of four outputs of the bridging amplifier which provides an output of 40 DB on hi channel and 35 DB on low channel. Let's also assume 150 feet of RG59/U is the average length for the house drop. The DB value in the block designates the in-to-tap attenuation value of each particular directional tap. The top figure is for hi channel and the lower figure is for low channel when the signal is tapped off from the first directional tap through a 150 feet of RG-59/U to the customer's television set. Of course, the signal at the input of the set would be approximately 40 - (30 + 9) = 1 DB for hi channel and 35 - (30 + 4.5) = .5 DB for low channel; the signal for the second set is 3 DB for hi channel and 3.5 DB for low channel; and, the third set is zero (0) DB for hi channel and 1.5 DB for low channel. Because of the difference of the cable attenuation vs. frequency at the input of the forth directional tap, hi channel is 33 DB and the low channel is 31.5 DB. Therefore, in order to provide uniform signal level at the set, a sloped in-to-tap attenuation should be introduced to this particular tap. This would provide 2 DB at the hi channel and 1 DB at the low channel for the television set. When the signal travels further down the feederline, as you can see, the level difference between hi channel and low channel increases. When it reaches the end of the feederline, coupled with the RG-59/U house drop, the difference of the signal level between hi channel and low channel is almost intolerable. Therefore, more slope is needed. At the last directional tap, the in-to-tap attenuation is 10 DB for hi channel and 18 DB for low channel. The level at the television set is 1.5 DB for hi channel and 2.5 for low channel. Now, it is evident if a tap off device does not provide a certain amount of slope, especially when the tap locations are approaching the end of the feederline, a uniform signal level cannot be obtained at the customer's set by economical means with a non-sloped tap. Consequently, this would cause undesirable picture quality and an unsatisfied customer.

From the previous illustration, we can easily say the sloped directional tap has the following advantages:

1. Provides uniform signal level at the input of the television set.
2. More taps can be installed with minimum signal loss.

Technical Session 1, held in the Adams Room of the Palmer House, Chicago, Illinois, convened at nine o'clock, a.m., Mr. Charles Clements, CATV Consultant, Waterville, Washington, presiding.

CHAIRMAN CLEMENTS: The Technical Session will be in order.

We will split into three groups, so that we have six different topics to cover within the next two hours and fifty minutes.

Our first item on the agenda is MATV TECHNIQUES FOR CATV OPERATORS, by Fred Schulz of Blonder-Tongue Laboratories, Inc.

MANUSCRIPT FOR PRINTED RECORD
MATV TECHNIQUES FOR THE CATV OPERATOR

BY:
Fred J. Schulz

CATV operators deliver their signals, in most cases, to individual subscribers, through individual drop lines; however, almost all systems serve hotels, motels, apartment houses and similar multiple dwellings. Today, virtually all new large buildings in metropolitan areas have Master Antenna TV (MATV) systems. It is the purpose of this paper to disseminate the experiences and techniques used in the MATV industry.

An MATV system, as well as a CATV system, consists of three major sections:

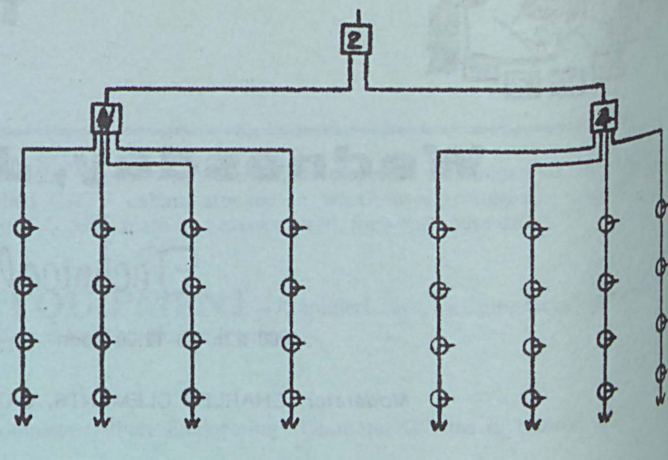
1. Signal pickup (antennas).
2. Signal processing, amplification and mixing (HE gear).
3. Signal distribution.

In our case, all TV signals are delivered to the MATV system already mixed and equalized from a CATV drop and we, therefore, need to concern ourselves only with the distribution system and the necessary amplification.

MATV distribution system are, wherever possible, arranged to avoid use of reamplification within the system.

The usual way signals are distributed is by using so called RISERS or BRANCH lines into which tapoffs are inserted at each TV set location. The risers in turn are connected together with a number of splitters. Such an arrangement looks like the drawing shown.

It is desirable to limit the number of tapoffs per riser to 15 to keep reflections to a low value.



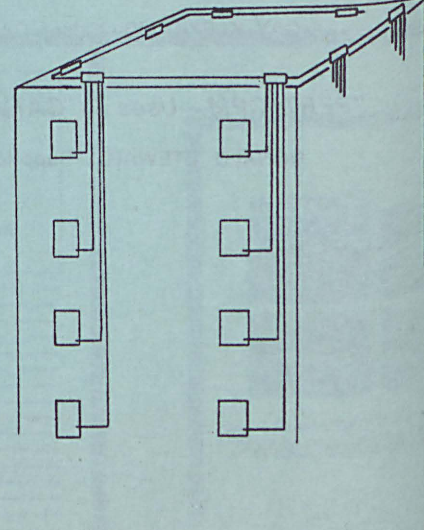
We not must look at the building in which we wish to install a distribution system and decide where we can run the risers most efficiently, as well as for a suitable place for the amplifiers. Two most commonly encountered structures are:

A. Tall buildings, for which vertical risers are most suitable. Risers may, for instance, be run in utility shafts.

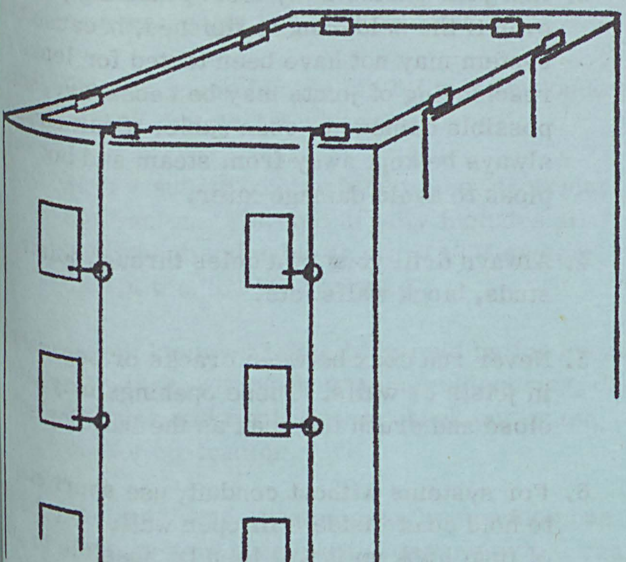
B. Long buildings, such as motels, for which horizontal risers (or branch lines) are most suitable.

A separate TV conduit system should be installed in all new buildings.

In existing structures it is often not possible to use wiring inside the building. A cable run along the top periphery of the building with periodically-inserted multiple tapoffs and individual drop cables to each apartment can be used in such a case. The illustration below makes this clearer.



For existing tall structures one may use a series f 2 or 4-way, or asymmetrical splitters on top of the uilding with drop lines down the outside walls and ressure taps located just outside of each apartment. ee illustration below:



For small installations, it is also possible to run series of splitters with individual lines to each ten-ant's TV set.

There are a great variety of MATV tapoffs avail-ble, such as:

A. Surface mounted types for existing buildings.

B. Flush mounted types (usually fit into GEM boxes).

C. Multiple output types.

D. 75 ohm output types.

E. 300 ohm output types.

F. Pressure taps.

Manufacturer's MATV catalogs are a good source for detailed tapoff information. The key electrical characteristics are, as in CATV taps:

A. Isolation (typically 12, 17, 23dB).

B. Thru loss (typically 0.7 dB for a 17 dB resistive isolation tap).

It should be noted that it is not necessary to terminate unused tapoff outputs; risers however must all be terminated.

ELECTRICAL DESIGN OF THE SYSTEM

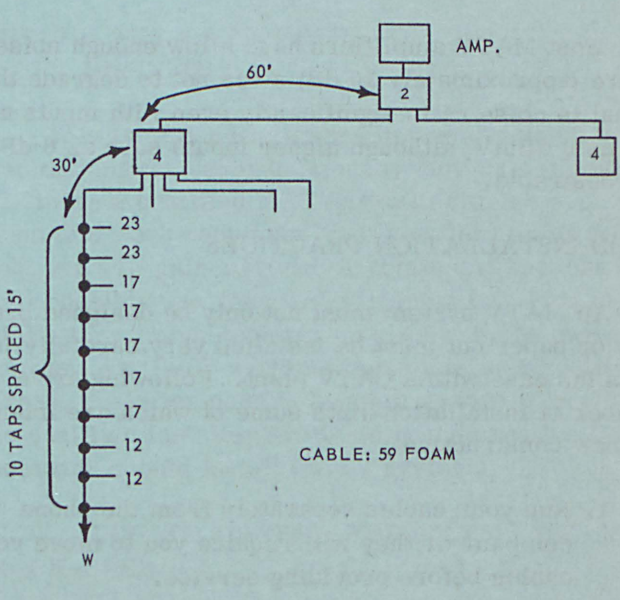
After it is decided on how to run the risers and where to place splitters and amplifiers, one must make a systems loss computation.

Losses should be computed for channel 13 and for the longest riser, with a double check on channel 2 for the shortest one (maximum tolerable signal level to TV set). The losses to be added are (from furthest TV set to amplifier):

1. Matching transformer loss.
2. Tapoff isolation value.
3. Thru loss of all taps on the particular riser.
4. Cable losses.
5. Splitter losses.

It is customary to use graded isolation on the taps just as is done in CATV taps. The last three taps on a riser are usually 12 dB. The next ones (approximately 5) are 17 dB with the remainder 23 dB types. RG-59/U or 59 type foam cables are usually used in MATV systems. If pressure taps are employed one is forced to go to RG-11 type cable because there are no pressure taps for RG-59 type cable available.

Let us look at a sample system and its loss computation:



The losses for the longest riser are:

Matching xformer		0.5 dB
Tapoff isolation		12.0 dB
Thru loss:	three 12 db taps @ 1.2 dB	3.6 dB
	five 17 dB taps @ 0.7 dB	3.5 dB
	two 23 dB taps @ 0.4 dB	0.8 dB
Cable length 9 x 15' + 30' + 60' - 225' @ 4 dB/100'		9.0 dB
One 4-way splitter		6.5 dB
One 2-way splitter		3.5 dB
Total distribution loss		39.4 dB

In case all tapoffs are spaced equally (as was the case in our example), one may use a precomputed riser diagram, as a sample of which is attached.

The required amplifier output is simply - Amplifier output = distribution loss + desired signal level at TV set.

The signal level at the TV set should be the same as is used for individual CATV drops, namely 0 to +6 dBmV (except for areas where local pickup is a problem and move than 6 dBmV may be needed).

The required gain of the amplifier is the difference between the required output level and the level fed into it from the CATV system.

Assuming we decide to supply 0 dBmV to the TV sets and provide +6 dBmV from a CATV drop, our amplifier must have the following characteristics:

Output capability = 39.4 dB (distr. loss) plus 0 dBmV at the last set

= 39.4 dBmV

Gain = 39.4 dBmV minus 6 dBmV input level

= 33.4 dB

Most MATV amplifiers have a low enough noise figure (approximately 10 dB) so as not to degrade the signal to noise ratio significantly even with inputs as low as 0 dBmV, although higher inputs such as 6 dBmV are desirable.

GOOD INSTALLATION PRACTICES

An MATV system must not only be designed properly on paper but must be installed very carefully just as is the case with a CATV plant. Following are a number of installation hints some of which are intended for new construction.

1. Run your cables separately from the phone company or they will require you to move your cables before providing service.

2. Run your cables separately from the electrical wiring because the electrician may damage your coax cable while pulling his heavier cables.

3. Run your cables away from plumbing pipes, even if the soldering is finished, because the system may not have been tested for leaks and resoldering of joints may be necessary, with possible damage to coax cable. Coax should always be kept away from steam and hot water pipes to avoid damage later.

4. Always drill your own holes through joists, studs, block walls, etc.

5. Never run coax between cracks or separations in joists or walls. These openings may later close and crush the coax as the building settles.

6. For systems without conduit, use short staples to hold coax inside still open walls. At the time of final hook up it will then be possible to pull slack as the short staples can be pulled out.

7. Install 2" deep ROMEX GEM boxes wherever tapoffs are required. Set the depth of the boxes from the stud to be slightly less than the thickness of the sheet rock or wet walls. GEM boxes should be mounted 18" on center from finished floor.

8. Local and national electric codes must be followed.

9. Leave approximately 6" to 8" of coax cable at each box for connecting the tapoff. Coil this slack into the GEM box. Gently tighten cable clamp. Tapoffs will be installed after the walls are finished.

10. When installing the tapoffs remove the BX cable clamps to provide more space in the box. Install cover plates after walls are painted.

11. Be careful to terminate each and every riser, (usually explained on the tapoff instruction sheets).

12. Determine easiest and/or shortest way to run coax. Install coax to tapoffs as predetermined in drawings and calculations.

THE MATV INSTALLER AS CONTRACTOR

In new construction, its customary that the MATV system is part of the electrical contract. In this case, the MATV installer is a subcontractor to the electrical contractor. Listed below are a number of points to be aware of:

1. Written specs for the MATV installation are part of the electrical contract.

2. MATV subcontractor bids to the electrical contractor. This bid usually includes all equipment and cable in the MATV system, except the "GEM" boxes.

3. Labor included in the bid would be for hookup, drawings, wiring diagrams, engineering, deliveries and final system check out by the MATV contractor.

4. The MATV contractor usually provides one year system guarantee to the electrical contractor, who in turn guarantees the system to the owner.

5. All correspondence with the architect, electrical engineering firm, or the owner is handled through the electrical contractor.

6. A "submission" consisting of "cuts" (spec sheets) of the equipment to be supplied, and a wiring diagram of the proposed system is submitted to the electrical contractor by the MATV contractor. The electrical contractor in turn submits this, under this cover letter, for approval to the architect.

7. Electrical contractor furnishes all (roughing) labor up to Head-End connections and final check out.

8. MATV sub-contractor must instruct electrical contractor's personnel in the proper method and handling of all associated MATV equipment, (supply equipment-instruction sheets and drawings if necessary).

9. Obtain from electrical contractor a copy of work schedule with equipment delivery dates listed.

10. Final checkout and acceptance of system to be arranged with electrical contractor in accordance with specifications.

In some cases, the MATV installer is the prime contractor to the owner. Here are a few hints for such an arrangement.

1. MATV contractor supplies all equipment, cable and labor directly to owner.

2. Establish in writing with the owner, the method and location of all associated phases of the installation. Verify working hours available. Establish (with the owner) who will furnish electrical power to the headend location. Obtain permission for storage area on job site while installation is in progress.

3. One year guarantee and service contract to commence from date of final checkout and acceptance of system by owner. Prepare a renewal contract in advance.

COST OF MATV INSTALLATIONS

Many people feel that a magic per outlet cost is available to compute the price of an MATV installation, this unfortunately is not so. Nobody knows better than the CATV installer that the cost of running a drop line to a TV set is not at all constant and that it depends a great deal on the local conditions. The old fashioned method of using a cost sheet where individual labor estimates for cable installation, tapoff installation, hook-up time, check out time and material cost are made in an orderly fashion is still the best way to quote an installation at a fair price and profit.

It is particularly important to keep records of actual expenditures so future job quotes can be adjusted accordingly.

SHOULD THE CATV OPERATOR ENTER THE MATV BUSINESS?

This is of course, a very important question and the answer depends on many factors such as: "Is there a qualified MATV installer in the area who does this work regularly"? If yes, let him do the job, you will gain a friend or retain one because he will possibly use your CATV signals in future installations rather than put up a HE with its own antennas. As CATV systems move into metropolitan areas, the latter case is becoming more likely. If no qualified installer available in the area the CATV operator should install MATV systems.

HOW MUCH TO CHARGE FOR MATV SYSTEM HOOK-UPS?

The best arrangement for the CATV operator is to make a deal with the apartment house owner, this will save collection cost and provide a nice lumped sum income. A tennant used to multichannel TV service is also likely to stay your customer should be later buy his own home in the community. People moving into a community for a new job and newlyweds fall into this category.

For motels, a reduced rate of approximately 1/2 the regular home subscription rate is quite common.

Hsopitals, convalescent homes etc. are different from apartment houses. One might find it desirable to donate an installation as a public relations good will gift. At least one operator put a system into a community senior citizen home at cost and charged full rates for a number of outlets donating the service for all others. Renting TV service to hospital patients can bring extra revenue to the CATV operator and the hospital.

Obviously there is not enough time to go into all details of MATV techniques; MATV product manufacturers are however more than happy to furnish additional information.

In conclusion, let me say that MATV installations are a natural extension of CATV service and the CATV operator should make it his business to be familiar with this field.

CHAIRMAN CLEMENTS: Thank you, Fred.

I am sure that many of us are being faced with this situation right now, on the wiring of apartment houses, which is an entirely new phase to me. I am aware that Lennie Cohen in New York has this real problem, and I know that others have, also.

If there are any questions of Fred, he is available to answer them.

DR. LEON RIEBMAN (American Electronics Laboratories, Inc.): I have a question. What is the status of UHF and MATV?

MR. SCHULZ: Equipment is available for UHF distriction in MATV systems. Blonder-Tongue has made this equipment available for a number of years, and so have other manufacturers.

The basic limitations are the higher cable losses of UHF reamplification in large UHF distribution systems may be needed. The equipment is available, and in fact we are recommending that all systems being installed in buildings be UHF-VHF distribution systems, even if UHF channels are not in the area at this moment, or if not all channels will be used on VHF; or, where conversion could be used, because conversions, as a rule, bring problems with them.

"Putting in UFH-VHF distribution systems might become very important for CATV and MATV systems, because once you have 20 channel systems, the additional channels may be moved up to the UHF band.

FROM THE FLOOR: In CATV systems we are somewhat concerned about how much signal level to put on 59/u cables. One of the things we have noticed in these distribution systems is that amplifiers go out at 40 dBmV and are going into single shield coaxial cable, and I believe they do radiate and create problems.

Is there any consideration of this at the moment?

MR. SCHULZ: Many installations in MATV are made with cable of the 59 type. We have found that rather than the radiation problem being one, it is conversely the local pickup, which is the problem and to solve it you may have to go to double-shielded cable. The installation techniques are very important. You do have to provide good grounding of equipment, possibly putting amplifiers in radiation enclosures, with proper feed throughs so there is a minimum of signal going on the outside of the cable.

FROM THE FLOOR: What I was primarily concerned with, the FCC regulations indicate that you should not radiate more than a specified value from a meter on any coaxial cable, and putting the 40 dBmB on the 59 cable would apparently violate the regulations. I have recently been involved with some systems, and my approach is that it seems to me with CATV design system, using the double-shielded cable, using hybrid couplers, et cetera, it becomes very costly as a process for doing it.

I cannot, however, think of another way to do it and still remain within the FCC requirements.

MR. SCHULZ: In many MATV systems you have the conduit system which acts as an additional shield. When you go into existing buildings you might have to go to double-shielded cable for a portion where the signal levels are high until you come to the splitters. You might have to use aluminum cable up to that point if radiation is a problem.

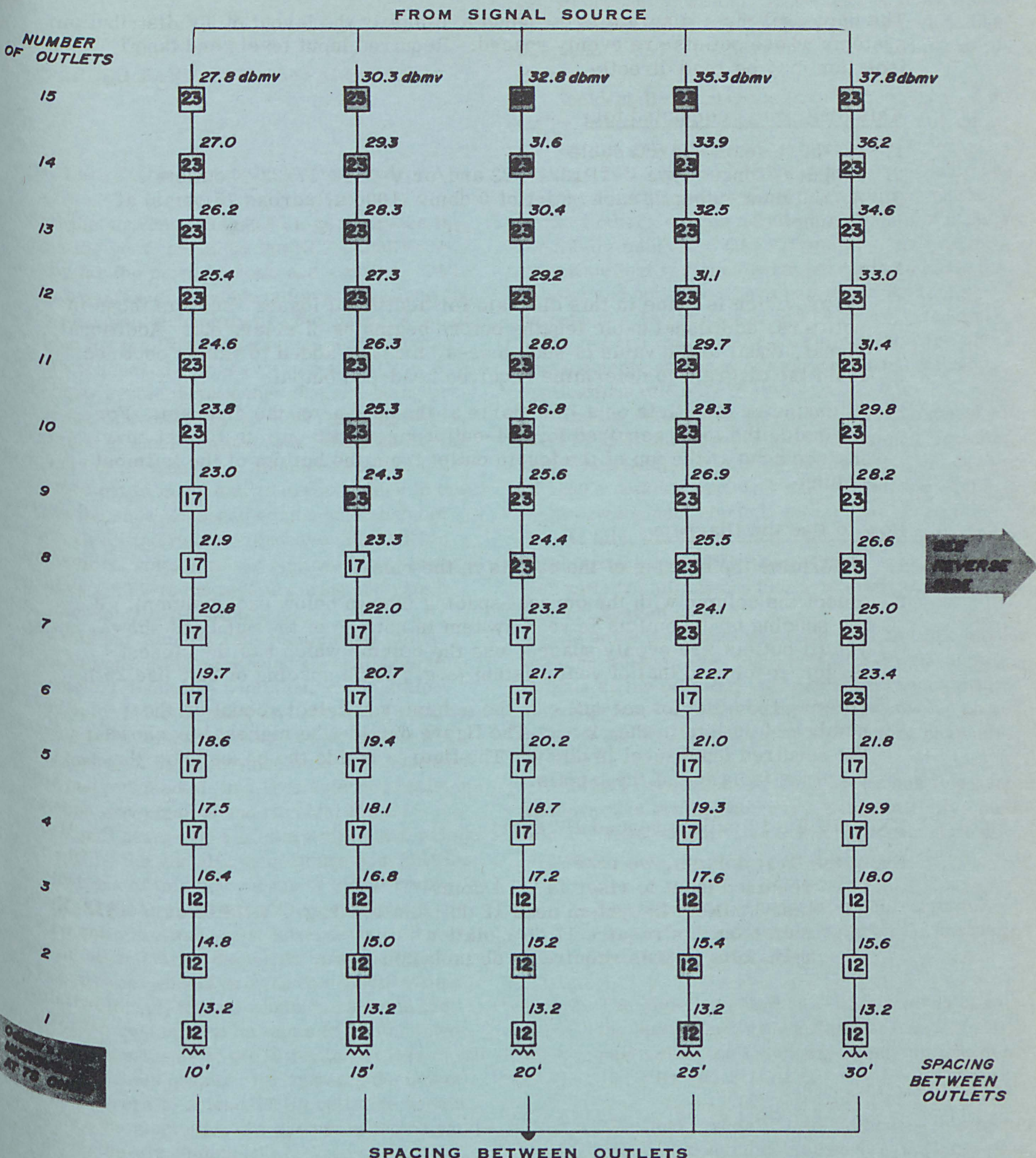
CHAIRMAN CLEMENTS: Are there any other questions of Fred Schulz? As I understand it there are copies of his manuscript in the rear of the room.

We will vary our agenda somewhat at this point, and ask Dr. Leon Riebman, of American Electronics Laboratories, Inc., to address us on the subject of EXPANDED BAND CATV CAPABILITIES.

Dr. Riebman.

DR. REIBMAN: Thank you, Mr. Chairman.

It is a pleasure for me to have the opportunity to present this joint paper prepared by Walter Wydro, my colleague at AEL, and myself, on a subject that is still in a rapidly-changing environment. There is still a great deal of flux going on in the business of


FROM SIGNAL SOURCE
NUMBER OF OUTLETS
15
27.8 dbmv
30.3 dbmv
32.8 dbmv
35.3dbmv
37.8dbmv
14
27.0
29.3
31.6
33.9
36.2
13
26.2
28.3
30.4
32.5
34.6
12
25.4
27.3
29.2
31.1
33.0
11
24.6
26.3
28.0
29.7
31.4
10
23.8
25.3
26.8
28.3
29.8
9
23.0
24.3
25.6
26.9
28.2
8
21.9
23.3
24.4
25.5
26.6
7
20.8
22.0
23.2
24.1
25.0
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19.7
20.7
21.7
22.7
23.4
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18.6
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21.0
21.8
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18.1
18.7
19.3
19.9
3
16.4
16.8
17.2
17.6
18.0
2
14.8
15.0
15.2
15.4
15.6
1
13.2
13.2
13.2
13.2
13.2
10'
15'
20'
25'
30'
SPACING BETWEEN OUTLETS
SPACING BETWEEN OUTLETS

The universal riser diagram is designed to simplify the layout of TV distribution systems whose outlets are evenly spaced. Required input levels and tapoff isolation may be read directly.

This diagram is computed for:

1. RG-59/U foam coaxial cable
2. Blonder-Tongue type V-1P12/17/23 and/or V-1S12/17/23-X outlets
3. A minimum output at each outlet of 0 dbmv (1000 uv across 75 ohms) at Channel 13

Notes

1. No provision is made in this diagram for additional losses, such as those in splitters, additional cable lengths before beginning of riser, etc. Additional signal, equal to the value of such losses, must be added to values obtained from the diagram to determine required head-end output.

2. The number of outlets on a line starts at the bottom of the diagram. For example, the level required for a 4-outlet riser with outlets 10 feet apart may be read at the top of the fourth outlet from the bottom of the leftmost column.

How to Use the Diagram

1. Determine the spacing of the outlets in the riser.

2. Select the column with the correct spacing (shown below each column). If the spacing of the outlets in your system is not one of the numbers shown, yet all outlets are evenly spaced, use the column which has the closest larger spacing to that of your system (e.g., for a spacing of 22', use 25').

3. Starting from the lowest outlet in the column you select, count up the number of outlets in the riser. The figure outside the highest box shows the required input level in dbmv. The figures inside the boxes show the required isolation of the tapoffs.

EXAMPLE: 12 outlets spaced 10' apart

From the first column, we read:

(1) required input to riser is 25.4 dbmv
(2) last 3 outlets in system need 12 db isolation (e.g., V-1P12 or V-1S12-X)
(3) next 6 outlets require 17 db isolation
(4) remaining outlets require 23 db isolation

expanded band capability. There is still a great deal of information needed before a real decision can and should be made, and we would like to introduce some of our thoughts into the discussions that are going on today.

EXPANDED BAND CATV CAPABILITIES

By

Dr. Leon Riebman and Mr. Walter Wydro

Of all the conventions that AEL participates in throughout the year, certainly the NCTA CONVENTION is by far the most dynamic and exciting. CATV is still in its infancy. New ideas for applications and a rapidly changing technology are the order of the day. The buildup for the Convention starts many months ahead with whispered rumors as to magical, new equipment and new system approaches that are being prepared for the Convention by all CATV manufacturers. The pressure of these rumors cause the engineering departments of all the major manufacturers of CATV equipment to put in many extra nervous hours in order to bring to the show advanced equipments ahead of schedule. Of all the fields of endeavor that AEL's 250 professional scientists and engineers are engaged in, certainly CATV is the most exciting and rapidly moving, technologically speaking.

CATV is our Number One commercial effort today! It is presenting a tremendous challenge to every technical discipline within our organization.

The CATV Industry today is in the painful throes of changing from an art to more of a science. When a field of endeavor is an art, decisions are based on emotions and judgments. In a true science, decisions are based on experiments and physical laws.

CATV will always be a mixture of art and science. The art will be the visualizing of future possibilities for applications of this new means of signal transportation. At the present time, the applications appear to be unlimited and the requirements on the system should be primarily the users' responsibility. The system owner should provide the specifications, in qualitative terms, for the requirements and the purpose of the system that he wants to build. Once the decision is made as to the ultimate purpose of the system, it becomes possible for systems designers and manufacturers to scientifically optimize design and cost for the most effective system based on existing state-of-the-art equipment.

The topic of our paper today is, "Expanded Band CATV Capabilities."

In the beginning, the first systems were only one or two channels. Then, low channels only came into being followed by a combination of low and sub-channel systems. Many of these original systems are still in existence.

More recently, interest developed in all-band or twelve channel systems. As a result of this requirement, broadband tube amplifiers were developed and the modern CATV industry took shape and began to grow.

Incidentally, during the first fifteen years of the CATV Industry much was done by intuition or cut and try. It was mainly art -- very little science. During 1964, 1965, and 1966, many very capable engineers working independently and building on the work of others worked out the ingredients of a theory for a fully integrated CATV System. This was the first time that various design parameters could be related and optimized for a particular system requirement. The theory is now being extended and perfected and will greatly accelerate the pace of developments and open new opportunities for new applications of CATV systems.

During January of 1966 AEL first discussed with a CATV user the possibility of building an Extended Bandwidth System (extended to 270 MHz). In October of 1966 a detailed proposal was written and equipment development started.

At this, the 1967 NCTA Show, AEL is offering a trunk extender amplifier and remote bridger amplifier with 270 MHz bandwidth -- a minimum of twenty channel system capacity.

In some geographical areas such as the corridor between Boston, New York, Washington, and Philadelphia or the corridor between San Francisco and Los Angeles, viewers can now receive twelve channels off the air. Thus, the need for more channels in CATV.

Let us review the various approaches to a system of more than twelve channels. Essentially five methods are being explored as feasible transportation systems.

1. The Sub-channel method -- this approach places twelve channels between the frequencies 5 MHz and 95 MHz.

2. The Mid-Band Method -- this method uses the spectrum between Channel 6 and 7. In particular, the frequency spectrum between 108 MHz and 174 MHz.

3. The Dual Coaxial Cable Method -- this method uses two coaxial cables each carrying twelve channels.

4. The Octave Band Method -- this method places 20 channels between 120 and 240 megacycles.

CHAIRMAN CLEMENTS: Thank you, Mr. Palmer.

Does anyone have any questions?

DR. RIEBMAN: Mr. Palmer, I would like to just discuss for a minute or two your extemporaneous remarks that you made before your prepared talk, and particularly your comment that you feel the extended band width may be just an attempt by manufacturers to sell more equipment.

First of all, I did mention in my presentation that our original interest in the extended band width was because a user, a system user, came to us and said, "We would like you to study this problem and recommend to us how you would handle it."

I think he was on his toes, and he is one of the largest users in the metropolitan area in this country, and that he felt the need for the extended band width.

We then proposed the solution to him.

I feel the manufacturer has a responsibility to his customers to look ahead and try to make his equipment compatible with what future needs might be, and several questions came from the floor about the concern of, "Are we going to buy equipment now and then next year have to replace it?"

Our company, AEL, is making an effort, every effort that we humanly can, to protect our customers against obsolescence. In fact, we are trying to make our equipment compatible with future expected needs. We are recommending for the future.

We are indicating that 300 megacycle cable should be utilized now. It costs you nothing. We have made our system modular. I think we have pioneered the modular concept for the very purpose of minimizing the cost in changing the system in the future.

Rather than be criticized I think we should be commended for trying to help the users and save them future expense.

Now I would just like to raise a question to you in these metropolitan areas, which I think are concerned with this problem first, although it is spreading all over the country. What is your answer to the difficulty of how to attract a subscriber who can already get nearly 12 or more than 12 channels off the air; or 12 channels?

MR. PALMER: I agree with you that we ought to install coaxial cable that goes up to 300 megacycles.

For the rest of your comment, all I can say is that I disagree with you for the reasons I have stated. I just, pure and simple, do not agree. I think it is wrong to take the solution to a particular problem for a particular customer, and offer it as an industry solution.

You are in the electronics business, and so are we. We have one amplifier to do thus and so, and we build it for that purpose. But we do not want to establish an industry requirement based on that one particular customer.

I do not think we have taken time yet, as an industry, to give this the thoroughness, the depth in study, and the consideration that is required. I believe once we divorce ourselves from broadcast frequencies that we are making a grave error if we do not take a very thorough view of the whole system, the whole concept.

This is just my opinion; my viewpoint.

CHAIRMAN CLEMENTS: Thank you.

Are there other questions relating to the paper?

There are copies of the paper available in the exhibit area.

Again, thank you, Mr. Palmer.

Our next speaker is Mr. Gay C. Kleycamp, who is going to address us on the subject of MID-BAND USE IN CATV SYSTEMS. (KAISER CATV)

Mr. Kleycamp. (Applause)

MID-BAND USE IN CATV SYSTEMS

BY

GAY C. KLEYKAMP

INTRODUCTION

This is a report on a series of tests and simulated as well as actual CATV system operation with the application of additional TV channels in the 120 to 175 MHz frequency spectrum. This region is generally referred to as the "mid-band". Standard production unmodified Phoenician Series trunk line amplifiers (KAISER Model Nos. KGAA and KGMA) were used with normal 22 dB spacing.

In assigning the frequencies for the various mid-band channels, it was considered practical to use 6 MHz separation between each of the video carriers with the lowest mid-band channel (Channel "A") at 121.25 MHz. No attempt was made to use mid-band frequencies above 157.25 MHz (Channel "G") in order to avoid interference with the 166.5 MHz pilot carrier used in the KAISER equipment. The lower frequency limitation of 121.25 MHz was selected in order to avoid any possibility of interference with aircraft navigational radio devices.

LABORATORY TESTS

All KAISER Phoenician Series amplifiers are tested for a +50 dBmV, 12-channel plus pilot carrier

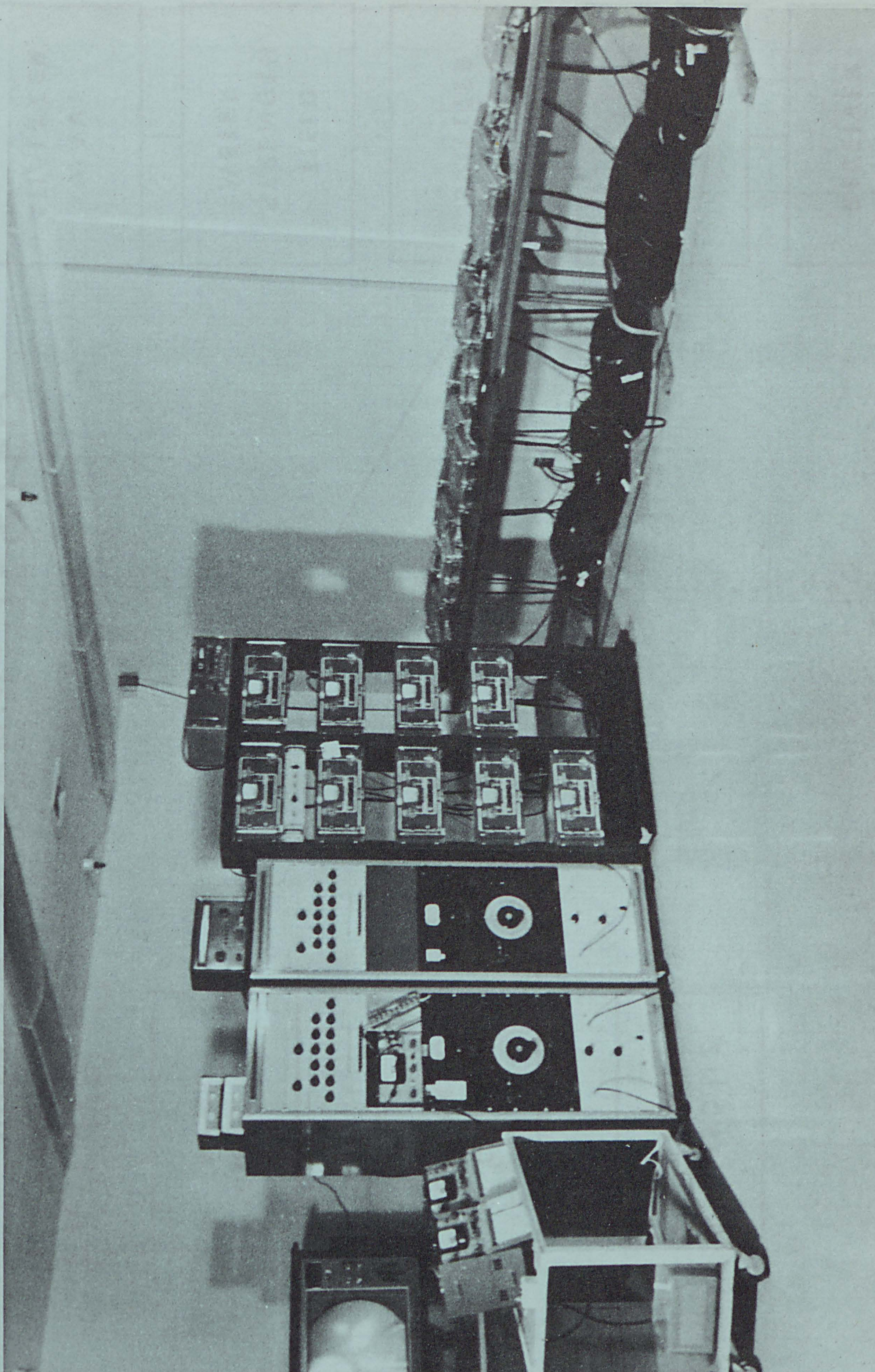


FIGURE 1 - LABORATORY TEST SET-UP

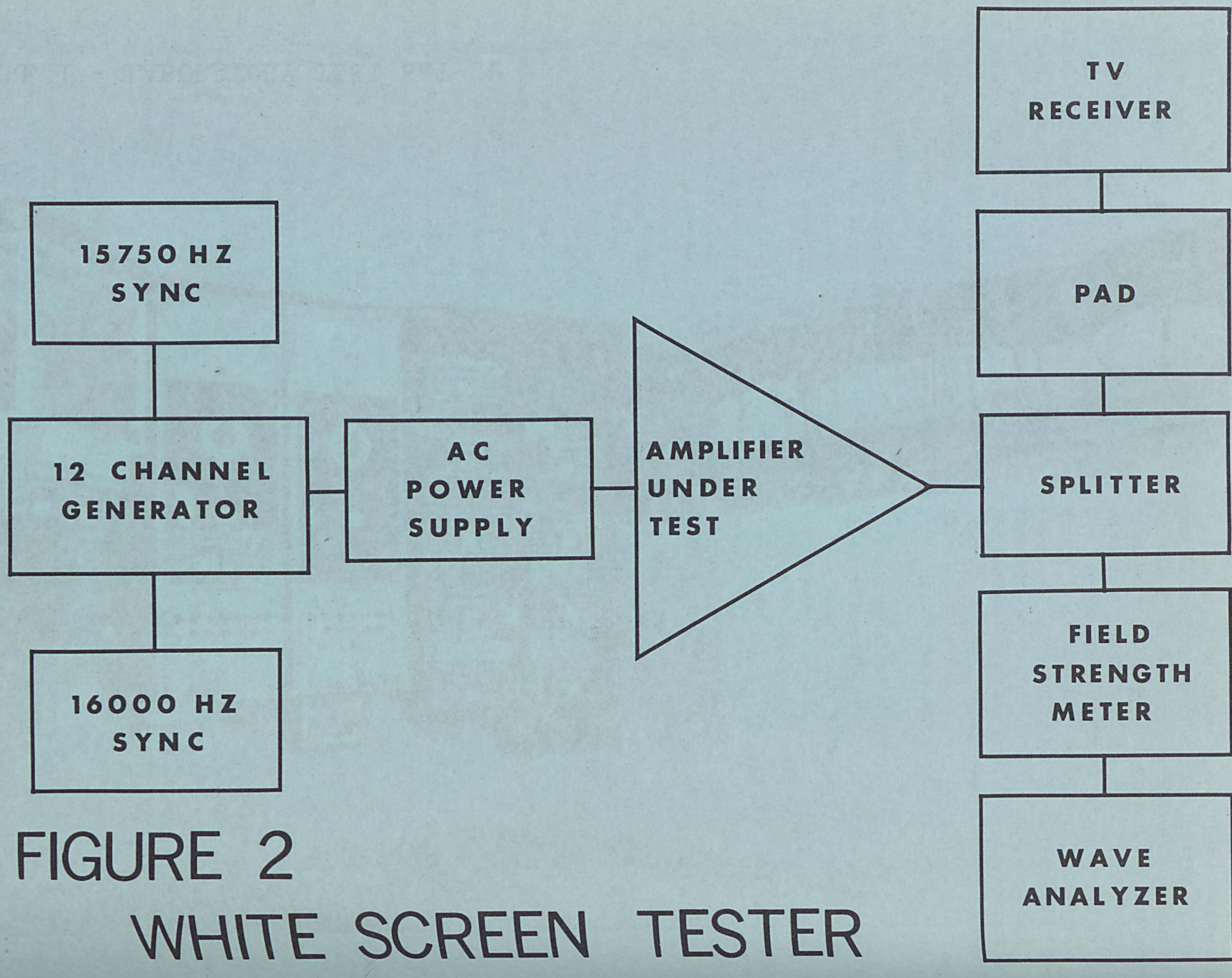
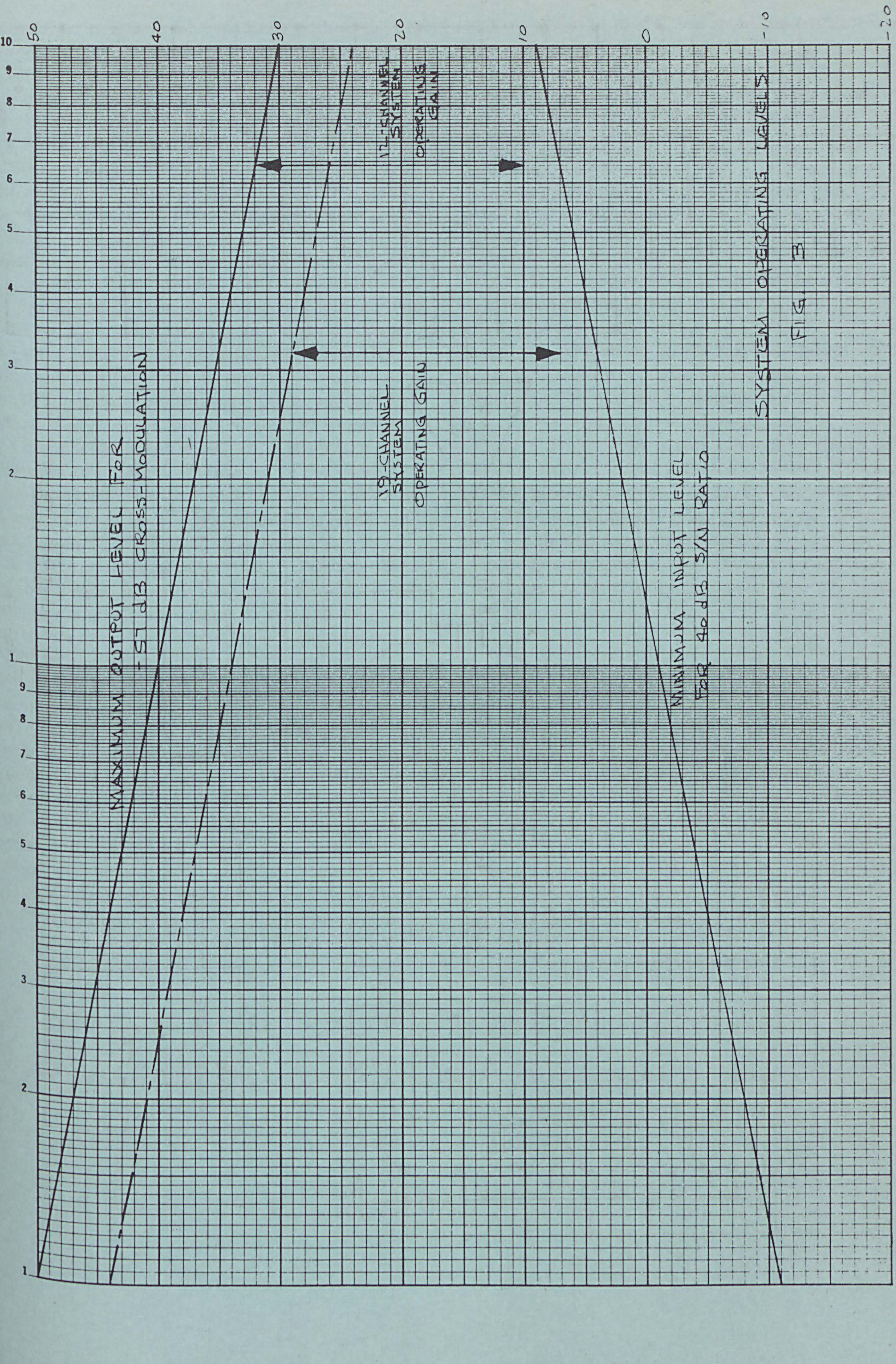
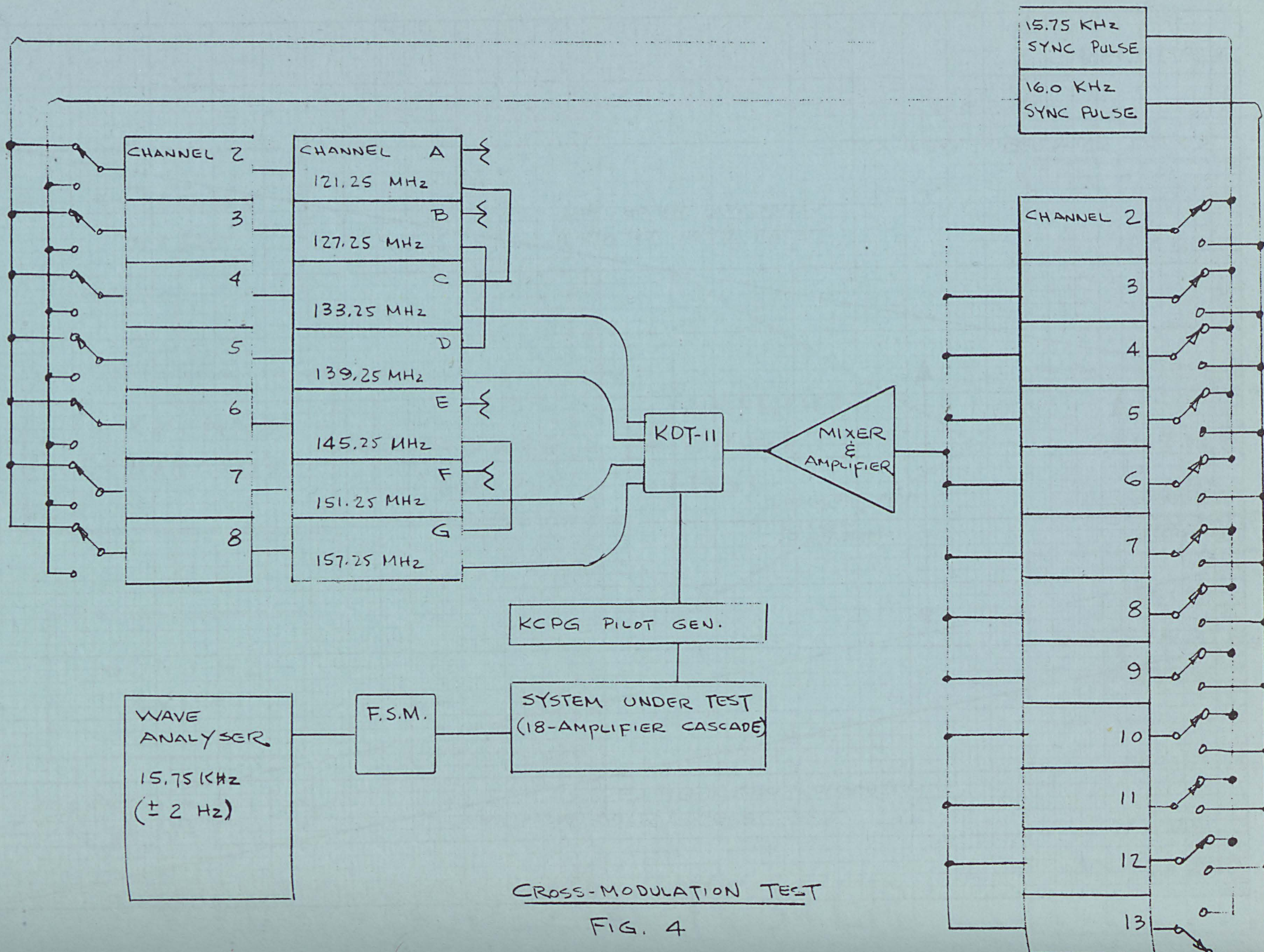


FIGURE 2
WHITE SCREEN TESTER



SYSTEM OPERATING LEVELS

FIG. 3



CROSS-MODULATION TEST

FIG. 4

single amplifier output level capability with a -57 dB cross-modulation indicated on all channels, minimum. The KAISER "White Screen Tester" (see Figure Nos. 1 & 2) is used in these tests.

The "White Screen" tester delivers signals that are very similar to standard television signals. These signals consist of the various video carrier frequencies with twelve (12) microsecond 15.750 KHz sync pulse modulation on a white screen level video modulation (85% ± 5% down from sync tip). The twelve (12) microsecond horizontal synch pulse is synchronous in all channels. For measuring cross-modulation on a particular channel, this sync pulse is replaced with a 16.000 KHz sync pulse on only the desired channel.

The wave analyzer is tuned to the 15.750 KHz frequency and will not indicate the 16.000 KHz modulation have identical rise time and pulse width characteristics, and it is therefore necessary to measure only one component of the modulation frequency spectrum in order to obtain an indication of the actual cross-modulation. The fundamental (15.750 KHz) is used inasmuch as it is of the greatest amplitude and provides the best-plus-noise to noise ratio.

It is well recognized in the CATV industry that the horizontal sync pulse of undesired television signals causes a significant portion of the cross-modulation detected by the viewer of a television receiver. This has led to the term "wiping" as a description of the effect produced by cross-modulation. To maximize the condition to the worst case, the "video signal" is made to go to the white screen video level between horizontal sync pulses. This produces the largest excursions of undesired signal level which may be experienced in actual CATV systems. Thus, it can be seen that use of the White Screen Tester in our investigation produces a more stringent trial of the system.

The mid-band television channels (A through G) are obtained by conversion of VHF television channels 2 through 8 from an identical "White Screen" tester, which is modulated from the oscillator used for channels 2 through 13. Modified Benavac head-end control units were furnished by BENCO TELEVISION CORPORATION for conversion of the standard VHF television channels 2 through 8 to the mid-band channels A through G. The following mid-band frequencies were used:

Mid-band channels A through G were mixed (see Figure No. 4) by nonadjacent channel looping and combined with the standard channels 2 through 13, using an eleven dB directional tap (KAISER Model KDT-11). The composite output of the nineteen (19) television channels was then mixed with the 166.5 MHz pilot carrier signal using the 10 dB directional coupler provided on the KAISER Model KCPG - Pilot Carrier Generator. The signals were fed into the first amplifier of the system under test.

The system consisted of eighteen (18) standard KAISER Phoenician Series trunk amplifiers with AGC at every second location. 22 dB of 75 ohm drop cable, similar to type RG-59/U, was used between amplifiers. Output levels, gain and tilt controls were adjusted for normal system operation. No "factory adjustments" for amplifier response were disturbed from the original setting as received from the stockroom.

LABORATORY TEST DATA AND THEORETICAL CALCULATIONS

Based upon single amplifier output capability for -57 dB cross modulation of +50 dBmV for 12 channel operation, the deration for 32 amplifiers would be 15 dB. This is based upon Figure No. 3 which illustrates a 10 dB per octave reduction in permissible output level. Theoretically, a 32 amplifier cascade would allow a +35 dBmV maximum output level for -57 dB cross-modulation. Using 5 dB block tilt, the following output levels apply.

FIGURE 5 - MID-BAND CHANNEL FREQUENCIES USED

Mid-Band Channel No.	Output Freq. (MHz)	Input Freq. (MHz)	Input Channel
A	121.25	55.25	2
B	127.25	61.25	3
C	133.25	67.25	4
D	139.25	77.25	5
E	145.25	83.25	6
F	151.25	175.25	7
G	157.25	181.25	8

FIGURE 6 - DESIGN OUTPUT LEVELS

Channel Number	12-Channel Operation dBmV	12-Channel Operation Millivolts	19-Channel Operation dBmV	19-Channel Operation Millivolts
2	+30	31.6	+24	15.9
3	+30	31.6	+24	15.9
4	+30	31.6	+24	15.9
5	+30	31.6	+24	15.9
6	+30	31.6	+24	15.9
A	---	----	+27	22.4
B	---	----	+27	22.4
C	---	----	+27	22.4
D	---	----	+27	22.4
E	---	----	+27	22.4
F	---	----	+27	22.4
G	---	----	+27	22.4
P.C.	+30	31.6	+30	31.6
7	+35	56.2	+29	28.2
8	+35	56.2	+29	28.2
9	+35	56.2	+29	28.2
10	+35	56.2	+29	28.2
11	+35	56.2	+29	28.2
12	+35	56.2	+29	28.2
13	+35	56.2	+29	28.2
Total	+55.3	583.0	+53.4	465.3

2 dB "Block Tilt" was used for the mid-band channels after consideration of the effect of the cable attenuation characteristics. It will be noticed that the total R. F. voltage existing across the output of each line amplifier is approximately the same for 19-channel operation (at the reduced output levels) as for the 12-channel operation (at maximum output levels).

The following cross-modulation measurements were recorded for the 19-channel operation through the 18-amplifier cascade.

On the basis of these test results, it was determined that thirty-two (32) amplifiers could be operated in normal cascade with nineteen (19) television channels and pilot carrier plus wide-band FM (at +14 dBmV maximum output level) provided the levels were adjusted in accordance with Test "A". The system was then connected through a bridging amplifier (KAISER Model KCBO-4) and two (2) line extenders (KAISER Model KCLE) operating at +35 dBmV (ch. 7-13), +33 dBmV (ch. A - G) and +30 dBmV (ch. 2 - 6). The output of this "feeder" system was connected to a television receiver converter furnished by INTERNATIONAL TELEMETER CORPORATION which was used to convert channels A through G to channel 2, and which permits channels 2 through 13 to pass directly to the television receiver.

No effect was measured upon the cross-modulation components of channels 2 through 13 due to the insertion of the television receiver converter. The following cross-modulation was recorded for the mid-band channels before and after conversion to channel 2.

No evidence of cross-modulation, spurious beats or harmonics were evident on the output of the INTERNATIONAL TELEMETER CORPORATION's converter when viewed on a television receiver. Off-the-air television signals were substituted for the corresponding channels furnished the "White Screen" tester, and the pictures did not exhibit perceptible degradation. Channels 3, 5, 10 & 12 were available, with color on all four normal channels and channels B & D, which were converted from channels 3 & 5. This permitted a qualitative evaluation of the system degradation with channels 3, 5, 10, 12, B & D displaying off-the-air pictures, and all other channels were synchronously modulated by the 15.750 KHz sync pulse.

Operating System Test - Merced/Atwater, California

In order to further evaluate the feasibility of adding additional television channels in the mid-band,

FIGURE 7 - MEASURED CROSS-MODULATION/SYSTEM

	Test "A"		Test "B"		Test "C"		Test "D"	
Ch. No.	Output Level (dBmV)	Cross Mod. (-dB)	Output Level (dBmV)	Cross Mod. (-dB)	Output Level (dBmV)	Cross Mod. (-dB)	Output Level (dBmV)	Cross Mod. (-dB)
2	+24	68	+23	67	+24	66	+22	74
3	+24	68	+23	67.5	+24	66	+22	74
4	+24	68	+23	68	+24	66	+22	75
5	+24	67	+23	66	+24	65	+22	72
6	+24	67	+23	67	+24	65	+22	69
A	+27	67.5	+28	68	+29	66	+27	69
B	+27	66	+28	67	+29	64.5	+27	67
C	+27	70	+28	71	+29	69	+27	71
D	+27	72	+28	72	+29	70	+27	71
E	+27	66	+28	67	+29	65	+27	68
F	+27	64	+28	64	+29	62	+27	66
G	+27	65	+28	65	+29	64	+27	69
7	+29	63.5	+28	64	+29	62	+27	70
8	+29	62	+28	61	+29	59.5	+27	66
9	+29	60	+28	60	+29	58.5	+27	65
10	+29	62	+28	62	+29	60	+27	66
11	+29	61	+28	61.5	+29	60	+27	66
12	+29	60	+28	60	+29	58	+27	64
13	+29	59.5	+28	60	+29	59	+27	64

the "White Screen" tester and mid-band Benavacs were transported to the Merced, California CATV system, operated by General Electric Cablevision Corporation.

This system presently has twelve (12) off-the-air television channels available at the head-end, and it is thirty-four (34) amplifiers "deep" from the head-end to the office with a total of forty-two (42) amplifiers in cascade from the head-end to the end of the system. General Electric constructed the system in accordance with KAISER's layout and specifications, using the Phoenician Series line amplifiers at 22 dB spacing. Although no summation sweep has been performed, the system response was "flat" within about 3 dB and has been in operation for about a year.

After sign-off of the normal television channels carried on the system, the "White Screen" tester was connected to the input of the trunk line at the head-end. The General Radio Wave Analyzer was connected to the service drop at the office and cross-modulation measurements made. As predicted from the laboratory tests, the cross-modulation was down -51 dB at the office; this being the result of a -57 dB cross-modulation level on the last trunk line amplifier and the normal degradation of a bridging amplifier and feeder system. Although the low and high band cross-modulation was only barely within the predicted level, the mid-band cross-modulation measured two to five dB better than expected (up to -55.5 dB down).

During the measurement of the cross-modulation, a television receiver was observed for indications of spurious beats and harmonics. No problems of this nature were indicated on the white screen displayed on the television receiver. The system levels were adjusted for +29 dBmV on channels 7 through 13, +27 dBmV on channels A through G, +24 dBmV on channels 2 through 6, and the pilot carrier was left at the normal +30 dBmV. The bridging amplifier and line extenders were set for a +35 dBmV on the high-band, +33 dBmV on the mid-band and +29 dBmV on the low-band.

As soon as the normally-carried channels resumed their transmission (about 8:00 A.M.), the system was returned to normal operation (+32 dBmV at channel 13 and +26 dBmV at channel 2 half-tilt output levels on trunk line amplifiers, and +40 dBmV at channel 13 on bridgers and line extenders tilted for about 15 dB of feeder cable).

Based upon the satisfactory quantitative evaluation, actual television channels in the mid-band (A through G) were added to the 12-channel head-end output with the system operating at the normally 3 dB higher trunk output levels and 5 dB higher feeder levels. The mid-band channels were added one at a time in order to check the system for any resulting degradation due to the expected over-load condition. A slight "beat" was observed on channel 5 (estimated to be 35 to 40 dB down) on the television monitor in the office. It

FIGURE 8 - MEASURED CROSS-MODULATION/CONVERTER

Channel Number	Cross-Modulation Direct	Cross-Modulation Converted
A	-63.5 dB	-60 dB
B	-62 dB	-59 dB
C	-63 dB	-61 dB
D	-64 dB	-61 dB
E	-62 dB	-59 dB
F	-60 dB	-58.5 dB
G	-61 dB	-60 dB

is believed this beat was a result of the simplified mixing method employed at the head-end for adding the mid-band channels. A KAISER Model KDT-11 directional tap was inserted into the head-end output with no additional traps, filters or other devices for isolation.

However, no noise, over-load or other types of picture degradation were observed. Therefore, in order to further evaluate the cable distribution of the nineteen channels, the pictures were observed under these abnormal conditions at the end of forty-two (42) amplifiers. Although it was anticipated that some cross-modulation or other indication of over-load would be apparent on the system at this extreme cascade, there was no indication of degradation of any kind. It was also noted that the "beat" on channel 5 was no worse than previously observed at the office.

Conclusion

Although it was successfully demonstrated that seven mid-band channels (A through G) could be added to the Merced, California CATV system without operating at lower levels -- and without noticeable degradation -- it is not implied that this proves that the 19 channels can be carried on all 42-amplifier cascades without system level deration.

The limitation existing on the insertion of additional, mid-band television, channels is a function of the individual amplifier output capability, primarily. It is, of course, necessary that the head-end conversion and mixing be free of all spurious frequencies and distortion and that the line amplifiers, as well, exhibit no appreciable harmonic distortion or intermodulation characteristics.

Amplifier noise figure determines the minimum amplifier input signal level, and to operate a system of 32 amplifiers in cascade at the levels used in this test will require a 17 dB MINIMUM Low-Band Noise Figure for a 40 dB signal-to-noise ratio.

A +35 dBmV maximum feeder level appeared to provide adequate distribution signal without noticeable distortion or cross-modulation. The television receiver conversion unit furnished by INTERNATIONAL TELEMETER CORPORATION did not appreciably contribute to the signal degradation when operating with normal (0 dBmV) input levels. The low noise figure and gain of the converter actually improved the picture definition. There was no sign of color degradation at any time.

In considering the addition of mid-band television channels to existing twelve-channel systems, the following factors should be carefully evaluated:

(1) Amplifier output capability must be sufficiently high as to permit the indicated deration. In addition, the amplifier must have linear output level vs. cross-modulation characteristics, i.e., a two-for-one reduction in cross-modulation should occur with incremental output level reduction over the maximum-to-minimum useable output level range.

Cross-modulation products increase by 6 dB each time the number of cascaded amplifiers is doubled, based upon the voltage addition factor, 20 log M. However, for each dB reduction in output level, the cross-modulation decreases by two (2) dB. Therefore, with a simultaneous system output level reduction of 10 dB per octave with increasing number of amplifiers in cascade, we accomplish the required 20 dB per octave reduction in cross-modulation to result in no over-all increase in the cross-modulation with cascade.

If, for example, you can operate one amplifier at +50 dBmV and maintain cross-modulation down 57 dB, then the cross-modulation would be down 63 dB, if that amplifier were operated at a +47 dBmV output level -- and two of these identical amplifiers in cascade would result in 6 dB worse cross-modulation, or at the +47 dBmV output level the cross-modulation would be down 57 dB on the output of the second amplifier.

(2) Deration for additional television channels is assumed to be on a voltage basis (20 log N). This is in accordance with accepted theory and may be mathematically proven. The test generally demonstrated the validity of this assumption.

(3) Conversion and mixing methods must result in clean head-end output with all spurious frequencies down at least 50 dB. The tests indicated there was no appreciable "build-up" of these beats, but no extensive investigation was conducted.

(4) Pilot carrier signals must be protected for adjacent channel interference on the system by adequate "guard band" separation.

(5) If normal amplifier spacing is retained, the amplifier noise figure must be sufficiently low as to permit the use of lower input levels without noise degradation.

(6) The television channel converter must be designed so as to provide adequate adjacent channel rejection, switching isolation, and add insignificant noise and cross-modulation products. It also helps if it is easily tuned and simple to operate, of course.

(7) No second order harmonic distortion problems were observed. However, it is logical to assume there are certain "forbidden" mid-band conversions. These conversions, where necessary, can be worked out I am sure by double conversation or other well known techniques.

In summary, we have demonstrated the practicability of adding seven (7) mid-band television channels on an existing twelve (12) channel CATV system with no modification of the Phoenician Series line amplifiers. Additional mid-band channels may be added with appropriate consideration of the seven (7) factors mentioned above.

The author would like to express his appreciation for the complete cooperation of BENCO TELEVISION CORPORATION and INTERNATIONAL TELEMETER CORPORATION in supplying the end equipment on short notice to permit the testing of the complete system. In addition, GENERAL ELECTRIC CABLEVISION CORPORATION encouraged the tests and made available the operating system at Merced, California, used to verify the laboratory results. Interested observers at Merced, who also participated in the field testing included Mr. M. Ferguson, Vice President and Chief Engineer of the Philadelphia Community Antenna TV Company, Mr. George Henderson of the Matador Construction Company, and Messrs, G. Dail, C. Nichols, J. Gannon and technicians of the Merced CATV system.

MR. KLEYKAMP: Mr. Chairman, I should like to add that I agree with Mr. Palmer that we have not exhaustively tested and investigated this use of mid-band channels, or any other channels other than the normal ones. So, although it was successfully demonstrated that seven mid-band channels, A through G, could be added to the Merced/Atwater, California, system without operating at lower levels and noticeable degradation, it is not, and I underscore "not", implied that the 19 channels can be carried on all 42 amplifier cascade systems without degradation.

Again, thank you. (Applause)

CHAIRMAN CLEMENTS: Does anyone have any questions of Mr. Kleykamp on the subject of the mid-band use?

Copies of his paper are available.

MR. KLEYKAMP: I would like to mention, also, that I have a couple of hundred more copies available in the exhibit area, and I will be there for the remainder of the day. I will not be leaving until tomorrow. If you do want to save your questions and see me personally I will be most happy to talk with you.

MR. JEFFERSON (Jerrold Electronics Corporation): I have a question. I appreciate that you recognize there are some signal distortion characteristics in the band you mentioned, but apparently they were not too offensive. I have made a few calculations on just a few of them, and I would like to bring this out as being of interest -- if you take the standard difference between the Channel 13 video and Channel 6 video, you get a beat at 128 megacycles, which is about a three-quarters megacycle beat on your Channel 8.

If you do Channel 12, you have another three-quarters of a megacycle beat above your Channel A.

As you add at the specific channel, such as your Channel A, that will cause a stone beat, which is three-quarters of a megacycle above Channel 7.

In addition, if you do the same thing on a different base with, let us say, Channel 11, you get a beat about three-quarters of a megacycle above Channel 5.

These beats, if you did the total spectrum, as I am sure we have all done, would be of a second order beat product, all over the mid-band; and in addition now, and more importantly as you add carriers into that band, you will then generate second-order beats all over the existing low and high bands.

And for measurement from our own figures, on particular amplifiers, as well as those of competitors, we find that typically for a system at the end of a normal operating system, where we, Jerrold, and others typically rate in the 57 and 51 bracket, that those second-order beat products at the end of the system are approximately 40 db down; maybe 42, or something similar.

We get into the subjective problem of what can you tolerate in second-order beat?

In our opinion, and in that of others, with whom we have talked, second-order beat, or triple beat, or any of the distortions should be in the neighborhood of 65 down; otherwise, they very definitely show up.

I am just curious to know what sort of a figure you put on your second-order beat products? Do you consider a beat range approximately 40 to 45 as an acceptable one?

MR. KLEYKAMP: My answer to that is, I was not attempting to evaluate the data. I was attempting to obtain and report data on an actual test.

This will have to come later. We have to do this sort of thing, the subjective evaluation as well as the objective evaluation.

I am merely saying that we have investigated this phenomena, and we saw no picture degradation. That is what the thing is all about. Let's get the pictures there.

Now, what numerical limitations we could place on any type of interference is, I feel, not fully defined at this time.

I merely wanted to report that the system worked; that it can be done. I am not saying that this is something that we can presently adequately and fully describe, all of the phenomena that contribute to obtaining pictures such as were displayed here.

MR. JEFFERSON: I would like to bring one other thing out, if I may, and I think most of you are aware and have been for many years that Jerrold has promoted full amplifiers in the low sub-region, and, indeed, we are faced with the same particular problems down there, and we felt a very definite need to go to those great lengths to have satisfactory pictures.

In a very similar fashion we attempt to operate outside of an octave and a single amplifier in the lower sub-region for transportation purposes, and we have many, many customers, and many on our own systems that use low subs in a transportation load.

We have very definitely discovered that we do have to go to a very expensive and elaborate method of minimizing second-order distortions that fall in the band because, indeed, the figures we get on single-line amplifiers are such that we did not consider them tolerable.

Thank you.

CHAIRMAN CLEMENTS: Thank you.

Are there any further questions or comments?

If not, we are going to move to our next speaker, who will be Mr. Donald C. Stewart, Director of Corporate Development, Superior Cable Corporation, and he is going to address us on the matter of PERT/CPM - USES IN CATV.

Mr. Stewart. (Applause)

MR. DONALD STEWART (Superior Cable Corporation): Mr. Chairman, Ladies and Gentlemen: First I had better explain what the PERT/CPM means. I have been asked several times what I am talking about when I refer to this.

Basically, PERT and CPM are tools or techniques to manage projects -- big ones; small ones -- all kinds of projects, either in CATV operation or in equipment manufacture and development, or in anything else.

So, I just want to run through what these techniques are, and make a few suggestions.

I want to challenge you to decide how you can use PERT and CPM in your business to get your work done.

Let's define PERT and CPM, first of all, and I shall begin by saying PERT, the four letters -- P-E-R-T -- is an acronym for the words "Program Evaluation Review Technique".

And the closely-related CPM just stands for "Critical Path Method".

Those are the magic words here.

Basically, these are techniques or tools to manage products; to plan; schedule; and control projects.

And, of course, the project we think of as something that has a definite beginning; a definite end; composed of a lot of component jobs or activities; and completion time and cost, are important. If you do not care when you get it done, you are not going to use this technique.

The visual representation of the project which you may have seen is the network -- just a bunch of lines hooked together.

This CPM example happens to be concerned with the rebuilding of a steelmaking furnace that U. S. Steel utilized. It is just an example of what it looks like, and incidentally, I would like to ask a show of hands of how many of you are generally familiar with PERT and CPM? I will assume that you have no knowledge at all so that we may lay the groundwork.

there will be a better understanding of the use of this technique.

To give a little of the historical development of PERT/CPM, it is not quite 10 years old. In 1958, PERT was developed on the Navy Polaris Submarine Missile Program. Booz Allen and Hamilton, Lockheed, and the Navy, working together, developed this technique in order to get the Polaris Missile Program operational. It is credited with a great portion of the success in getting the Program operational, approximately a year and a half sooner than the initial estimate.

This was a state of the art breakthrough. While they were not even certain they could make the system work, using PERT they were able to ramrod the Program to completion.

Since then, PERT has been successfully applied to many of the major Department of Defense and NASA projects. So, if you are in the area of defense production, you are probably having to use it whether you want to, or not. The government is really sold on it.

The other "grandfather" of the family of techniques, CPM, was first used in 1957 on a Du Pont chemical plant construction project. Here they knew exactly what they had to do, but they wanted to do it as fast and as economically as possible. They believe they saved up to a million dollars by getting the chemical plant built and getting it built more rapidly under this system.

Since then many different companies, many different people, have developed their tailormade systems. Someone has counted about 40 different acronyms, where people have put together tailor or custom-made plans to handle their problems.

We have names like RAMPS, PRIME, PERT/COST, et cetera; but it is all the same basic concept -- project management.

I think the best way to describe this system is to take a look at a small example in the CATV area. I call it the "bare bone demonstration project", because we have taken away all of the glamour and all of the elaboration, and we are just getting down to the essentials which are straight-forward. We have some exhibits here to show the way, and if we may have the first slide (slide) -- we are going to start with a list of the steps that one goes through in any PERT/CPM project.

What do we have to do to use this technique or tool?

I hope you can all read that, but I will try to read it, too.

First of all, we have to define the project. What are we trying to do?

This seems intuitively obvious, but I think in a number of cases people do not define their project, and that is the reason they never get it done.

Number two -- we have to identify the activities, the components, that together make up the project.

Number three -- following that, we draw the network, which is the visual portrayal that I held up a short time ago. It indicates how these activities tie together to get the project completed.

Number four -- following that we get time estimates for each activity in the project.

Number five -- next we go through the calculation, which is basically a matter of adding up the elapsed times from start to end through the various tasks in the network.

Number six indicates the critical path and slack, which is the key concept in this whole technique.

Number seven -- generally, the first time we run through a project we do not like the answer. We are not going to get enough done, so we go back and try to speed it up and expedite it.

After that, we have to update, and as time goes by, as we make progress, as changes occur, we want to take another look, perhaps every two weeks or every month, to see how the project is going. This is step number eight.

Number nine -- probably the most important of all, we have to follow up with action to get the job "on the road"; to get the project done.

Now let us go to Exhibit 2 (slide), and we will start with a small project in the CATV industry. We have chosen building a CATV system and getting it operating. We could just as easily have chosen the development of a new 20-channel amplifier. The project in this case is to build a CATV system.

Number two -- what are the project activities?

We have really "sweated the thing down" as you can see. Normally you would have hundreds of activities. In our example we will consider only these activities: We say we have to obtain the franchise. We have to make a signal survey. We have to obtain financing. We have to employ the staff, the people to operate the system.

We have to choose the turnkey contractor (assumed), by bidding or negotiation.

Then we have to actually build the system physically. Naturally, we have to sign up some subscribers to have a viable economic system.

So, those are the activities we have to get done in this small project.

(Slide) We have taken the list of activities, and we have put them into the network. Each of these lines (indicating), with the arrow, is an activity. That is a job; a component activity.

Each of the circles that are numbered, incidentally for identification, the circles are events which you can consider as points in time.

So, an activity is an arrow or a line which runs from a beginning event to an end event, and it consumes time, elapsed time.

Most people find in drawing networks they do better by starting at the end and working backwards. So in this case we would say we have a system operating; what has to be done just before we can have an operating system.

Obviously, we have to build it; and that is the activity at the top there, on the right, which is numbered "Five to Six" -- build the system.

We also have to get some customers, and that is the bottom activity on the right, Activity four to six -- sign up subscribers.

Staying with the subscriber signup at the bottom, before we sign up subscribers we have to have some people to go out and call on them. We are saying we have to employ the staff, which is Activity two to four.

Back on the construction side, at the top, before we build a system we have to have the money. That is Activity two to five. That is the predecessor activity before we can build the system.

We also have to have somebody to build it. So, we put in Activity three to five at the top, which is, choose your turnkey contractor, so you can build the system.

Then we work our way back toward the beginning, which is Activity one to two on the left, to get the franchise, from which everything else flows.

So now we have the network constructed. This is the way we see the activities fitting together.

The necessary predecessors to our activities before we can go on to the next step and get on to our goal, the operating of a CATV system, are indicated.

(Slide) The next step, once we have our network constructed, the interactions are pinned down, we want to estimate how long it will take to do each of these activities. Again we want to get realistic time estimates. We do not want any "pie in the sky". We do not want any wishful thinking. We want the best guess for each of these activities.

So, we try to go to the person who knows the most about each activity; and, of course, we are getting somewhat of an implied commitment here, too, for example we are saying in this case we think we can get the franchise in 20 weeks.

The signal survey -- let's say three weeks.

We think obtaining financing will take about two months, let's say eight weeks.

Employing the staff -- four weeks should take care of that.

Choosing the contractor, perhaps three weeks.

Actually building the system, 16 weeks, or roughly speaking four months.

Then the campaign, the promotional campaign to sign up the subscribers, we are saying will take six weeks.

Just as an aside here, the basic PERT system which was used on the Polaris Missile and in most of the government programs involves a very high degree of uncertainty in the research environment. The engineers will say, "We can't give you a good estimate."

To combat this they replied, "Give us three estimates -- an optimistic one if everything goes right; a most-likely, your-best-guess; and then, a pessimistic estimate."

In the calculations they worked out a weighted average time estimate, and they were also able to make a probability estimate on completion time.

On the other hand, in the CPM version they pretty much know what they have to do in construction, but they are very interested in cost, and also in how much additional cost if they go to a crash basis with a lot of overtime. So, for each activity in CPM you get a time and a cost on a normal scheduled 40-hour week.

You also get a time and a cost on a crash basis, with lots of overtime, with paying premium prices for quick delivery, and then you make a trade-off between time and cost.

In our "bare bones" example here, we are just going out and getting one time estimate for each of these activities.

We are now ready to go into the calculation routine.

(Slide) Now we are back to our network as we had it the first time, but we have added the estimates on each of those legs, each of those activities; the number of weeks we think it is going to take to do each of those activities, assuming that the necessary predecessor-activities have been completed.

You can see the first one on the left, concerning the obtaining of the franchise, one to two, is being quoted at 20 weeks. The calculation is just a matter of arithmetic. We just go through and add up the elapsed time for each of these tasks, through every possible path in the network. Only three are possible here, one across the top, one through the middle, and one down at the bottom. We add the elapsed time for each of these paths.

If you have a very large project you might want to go to the computer. I think all of the computer people have "canned" programs available in which you can plug in these time estimates and it will crank through the arithmetic. We have calculated networks with as many as six or eight hundred activities within half a day manually. So I would say, don't worry about the computer yet.

We add each of the possible paths. We find on the top we have 20 weeks plus 3 weeks plus 3 weeks plus 6 weeks or 32 weeks total.

In the middle we have 20 plus 8 plus 6. At the bottom we have 20 plus 4 plus 6 or 30 weeks.

The Middle path is the critical one. It requires 44 weeks. That is what we have to focus on; that is the heart of this technique, if we want to cut the time for this project, if we want to make sure it gets finished on time, we want to make doubly certain that these critical path activities are taken care of in good time.

To emphasize the critical path we make a heavier line along it so we have a visual picture of where our problems probably rest. On a typical "real world" problem, no more than, say 15 per cent of all the activities will be on the critical path. So, everyone can focus their attention on the critical path.

In this particular example we are saying that the project time estimate, which is the length of the critical path is 44 weeks, running through events one, two, five and six.

In this case our management, let's assume, is demanding 40 weeks. They want the system operating in 40 weeks, and no more. This is usually the case, of course, with an important project.

So, we say the project slack or spare time is negative four weeks. We are four weeks behind before we even get started!

Now we ask what changes can we make? How can we speed up the project? Of course, another thing to stress in PERT/CPM is we do not do it by pounding the table; by wishful thinking; by unrealistic promises. We try to go back as hardheadedly as possible and see what we can do to speed up this project to meet the 40-week demand by our superiors.

There are really only three ways we can speed up the project.

Number one -- we can add resources, such as going on overtime. We might have to pay more to the turnkey contractor. If he puts on another crew, works on Saturdays and Sundays and 12 hours a day, or something of that nature, this is one approach.

Another alternative is to just eliminate certain activities on the critical path. I do not think there are any obvious eliminations here, but in the Polaris Program they took a calculated risk and eliminated certain testing and prototype activities. They knew they were taking a chance, but they felt it was worth it; and it did pay off. They did save the time.

The third thing we can do is parallel activities. We do Activity A and Activity B at the same time rather than waiting for one to be complete before the next one is done. I think we could probably do something of that nature in this instance by starting our financing program; our campaign to get our financing, before we get the franchise. We should be able to do some paralleling there and compress the elapsed time in the length of the critical path.

You can see in this example we have done all of this analysis before the project starts. This is prior planning. Most people think that in a typical project you get, 50 to 75 per cent of all the benefits just going through these steps -- just laying out your project; getting a picture of it that everybody can look at; and planning how to do it best and quickest.

You also, however, should update. Time goes by and things happen. It is important to go back and refigure your network as the project proceeds toward completion and take action.

Let's recap the advantages that most people feel this PERT/CPM technique provides.

Number one -- it gets the project done -- very basic; very important.

Number two -- PERT/CPM saves time; it gets the project done faster; most people report a 15 per cent saving in time.

We also, want to save costs wherever possible; and again many people say they have realized savings up to 15 or 20 per cent of the total project cost through doing it more efficiently; eliminating those 100 per cent crash programs which are typical in the construction industry, where every activity goes on overtime whether or not it is a critical path activity.

PERT/CPM fixes responsibility, because each activity is related to a person, and you know whom to go to when a job does not get done on time. I think that increases the responsibility people feel for getting the job done. It also forces human beings to plan. I think most of us do not like to plan if we can avoid it. This forces us to get in there and make some estimates, and give the problem some organized throught.

It stresses management by exception. We can key in on this 15 per cent of the job that is really critical, the critical path. The visual aspect of the project network is extremely valuable in communicating status. We can lay out the job on a big piece of paper, and everyone can look at it and see what has to be done.

I was involved in the development of an electronic product several years ago using PERT. We had the draftsman draw large project network charts. We put them up in a conference room and brought in top management. It was really an eye-opener to them to see what had to be done to get this product on the market. They were much more amenable to giving us more resources-people; and also changing their time demands. The original schedule was impossible, and the chart was the only device that convinced them it was impossible.

This all sounds very good; but what is the trick here? There must be some limitations or some shortcomings to PERT/CPM.

Of course there are; and I think the most important is that it is a tool -- it is not a substitute for management action, and this cannot be stressed enough.

It also must be updated over a period of time. You cannot do it once, put it into the drawer, and expect the project to get done smoothly and on time These two factors, in my experience, have been most important in limiting results from PERT. If you want to call them "drawbacks", that is your privilege, but I submit they are not inherent limitations of the technique but rather misapplication.

A third limitation -- the concept is very simple as we demonstrated it. The application can be complex. You can get 500, 1,000, or 5,000 activities in a large project with much time and effort necessary to construct the network and get all of the estimates. Also PERT/CPM does have limitations in handling multi-project situations where the same resources -- people and equipment are needed on several of projects at the same time.

Despite all these apparent disadvantages, I think the advantages far outweigh them; and as most people who have used it will tell you, it has done a remarkable job in getting projects accomplished more quickly and economically.

Let us comment on some of the applications, and there have been thousands of them. A few examples will indicate the variety.

The defense and military area is dominant starting with the Polaris Submarine Missile Program, with which everyone is familiar.

They have gone to PERT with most of the major defense and space programs, and the government is extremely enthusiastic about the technique.

I think it has been proven that PERT/CPM has accelerated our weapons system progress.

Secondly -- the construction industry has really taken CPM to heart. Naturally the example of a project that first comes to mind is in construction, and the construction industry has made extremely wide use of CPM. Most of the major chemical and steel companies have handled plant construction and maintenance using the CPM technique. These include Du Pont; Olin Mathieson; U. S. Steel; Union Carbide; Wheeling Steel, PPG just to name a few.

Expo-67 was planned on PERT. I was up there a week ago, and I was extremely impressed with the job they have done in about three and a half years. They have built 200 buildings; a subway; a bridge; a new island in the river, and all of this was planned on PERT networks.

Actually I think they had 150 networks altogether, and they were dealing with approximately $750 million in cost. This application was so successful that the 1970 Japanese World's Fair is going to consider using PERT also.

The Atlanta Stadium was also PERTed. In Atlanta they were very anxious to get a major league baseball team, so they paid extra to compress the construction time. The stadium ready for a baseball team a year earlier than otherwise.

Sun maid Raisin, in California, put up a new plant using CPM, and they have indicated that they saved a million dollars because they had the plant ready for the growing season. In effect, they saved a year by getting the plant ready for the pack.

A number of the contracting firms have used CPM as part of their promotional effort. Rust Engineering and Catyltic Construction are two good examples. They use it in their advertising. They say they will build your plant more efficiently by using CPM.

A third major application area is in R and D and new products, where there are many opportunities to reduce the time to get a new product on the market.

Xerox, monitored their new "2400" copier development program on PERT, and they estimated that they saved about a year and a half. They originally planned the "2400" program on a six to seven year cycle. Management was not satisfied, so they went back and ultimately arrived at a five-year cycle. The speedup involves a great deal of overtime. This was a case where the president of Xerox insisted on seeing the PERT analysis. It was a $40 million investment, and he was very much interested in the program.

Winchester Arms used PERT to lay out the program for the M-14 army rifle and get themselves competitive in a government bidding situation.

The major auto companies have used PERT in the new model changeover, getting all of the component parts of the new car and the assembly line changes ready so they can start the new models sooner.

There are many other examples, such as the one I commented on about the electronic product. General Electric and other companies have used this technique in getting new products through the research and pilot plant stages to the market.

Still another large area for application has been accounting and data processing. People have speeded up their accounting closings by just flow-charting all of the things they have to do. Anaconda Aluminum and Collins Radio are two examples here.

People have installed new budget and cost systems using PERT/CPM, and I believe all of the major computer manufacturers use it in installing new computer systems. They try to get all of the programming taken care of; all of the makeready at the site, and all of the staff hiring controlled through a PERT network, so the customer has his computer turned on as rapidly as possible.

There is an entire range of miscellaneous applications. I just selected a few here for you: Kidney transplant operation in a hospital was PERTed; a Broadway play by the name of MORGANA was laid out on a PERT network to get the play to opening night. One of my friends moved his new family to a new house and used a CPM network, involving such things as "stop the milk"; "get the telephone hooked up", et cetera.

Management consultants quite often use PERT/CPM in planning their engagements. In fact, in one job in which I was involved, the client insisted on a PERT network as part of the proposal.

So, you can see there is no end to the number of applications. I think the only limit is your own ingenuity.

In CATV, I will just suggest quickly some applications. Building a CATV system is an obvious project, or expanding or rebuilding a system.

Turnkey contractors could also use PERT/CPM for their work in controlling the construction of systems.

Promotional campaigns come to mind, with advertising, house-to-house solicitation, and related publicity.

The program to get the franchise is another that lends itself to this technique with the various political and public relations aspects. Financing is still another possible project.

Of course the equipment and new product area is one of the best potential applications. We used CPM to plan a new cable plant for CATV-TV.

You can readily understand there are a great many potential applications. I do not think there are too many actual applications in CATV. I would like to hear about them.

This is all very good, but the next question, is how do I get started? What do I do next?

The first thing you can do is read. Many of the professional journals and business magazines have had articles; and we have here a short bibliography on the subject which you are welcome to take.

You can also go to PERT/CPM seminars. AMA conducts them, as do various other organizations. I do not think it is particularly necessary, but a great many people attend these seminars. I think the most important step and what I suggest is just to try a project; just select a project that is important to you and plan it out; and then you can decide for yourself whether this is going to help you in your work.

Thanks very much, and good luck. (Applause)

CHAIRMAN CLEMENTS: Thank you, Don.

This is most interesting. I would make just one remark on it, and that is with our highly-complex system in Manhattan Cable Television, this is used to a great degree. I imagine they will use 15 to 20 very large sheets a day with the PERT method, and I know we can adopt it to our use.

I wish to thank all of the panelists for being very prompt and for a selection of most informative material.

We have approximately a half-hour break, with the lunch at 12:30, and the business session at two o'clock.

Thank you, gentlemen, for your most appropriate remarks; and thank you, our audience, for your very fine attention.

We are adjourned.

(Technical Session 1 adjourned at twelve o'clock.)

June 26, 1967

The Monday Afternoon Technical Session of the 16th Annual Convention, National Community Television Association, held in the Adams Room of the Palmer House, Chicago, Illinois, convened at two-fifteen o'clock, Archer Taylor, Malarkey, Taylor & Associates, Engineering Management Consultant, Washington, D. C., Chairman presiding.

CHAIRMAN TAYLOR: I would like to formally welcome you to the first technical session of the 16th Annual Convention of the National Community Television Association.

We have a very interesting group of technical papers to present this afternoon and in the other sessions in the convention; and I think, in spite of the absence of the slide projector for the moment, we will proceed.

The first speaker, fortunately, can do without the slide projector, so we can have his paper first. It is with great pleasure that I introduce Mr. Carmine D'Elio of the Vikoa Corporation.

Mr. D'Elio received his B.E.E. degree in 1960 from the City College of New York, his M.S.E.E. degree in 1963 from Drexel Institute of Technology. He is currently enrolled in a doctoral program at the Newark College of Engineering. Presently he is a section head for advanced engineering at Vikoa, and formerly was a transistor application engineer for R.C.A.

Mr. D'Elio's paper is on "Noise Figure—Its Meaning and Measurement." Mr. D'Elio. (Applause)

MR. CARMINE D'ELIO (Vikoa, Inc.): Thank you, Mr. Taylor and gentlemen.

This discussion is tutorial in nature, nothing new will be advanced. The aim hopefully, is to present information on noise figure and signal to noise ratio in general, and show how the information is used for determining the effects of noise on cable systems.

NOISE FIGURE AND THE SYSTEM SIGNAL TO NOISE RATIO

By

Carmine D'Elio - Vikoa, Inc.

Introduction:-

Everyone is well aware of the fact, that noise in an amplifier or system, serves to degrade the information of the desired signal. In a cable system it sets the limit on the minimum signal that can be transmitted along the cable and still provide a good quality picture. In order to describe the quality of the picture in a more concise manner, we establish a relationship between the signal and the noise, namely the signal to noise ratio. Since noise fluctuates randomly over a period of time, it would be meaningless to try to relate an instantaneous signal voltage to instantaneous noise voltage. Instead, we deal with averages over a long period of time and use the mean squared signal voltage and mean squared noise voltage. The ratio of these two voltages is then referred to, as the signal to noise ratio. Since the signal and the noise are measured at the same point in a system and therefore appear across the same load, the ratio of mean squared voltages is also the ratio of powers and thus represents the signal to noise power ratio. Using this relation, the quality of a T.V. picture can now be described with a number and the performance of a system, with respect to noise, can be rated by the signal to noise ratio.

Noise Figure

The higher the signal to noise ratio the better the quality of the picture. The signal to noise ratio continuously decreases as the signal passes through the system because additional noise is introduced by the components of the system. This additional noise added by the system can be determined by comparing the output signal to noise ratio and the input signal to noise ratio. This measure of noisiness is called the noise figure of the system and is defined by equation (1) commonly referred to as the "degradation" or "deterioration" ratio.

$$(1)\quad F = \frac{(S/N)i}{(S/N)o} \quad \text{where} \quad \begin{aligned} (S/N)i &= \text{input signal to noise ratio} \\ (S/N)o &= \text{output signal to noise ratio} \end{aligned}$$

and F = the noise figure (or noise factor). The noise figure in terms of db is $10 \log_{10} F$. An ideal system would be, where the (S/N)o = (S/N)i and F = 1. This would indicate that no noise was added by the system. As the amount of noise added by the system increases, F increases. The definition is the same for one amplifier or for a cascade of amplifiers. The noise figure of a black box can be determined, by simply measuring the input and output signal to noise ratio.

In an actual system design the problem is changed somewhat. The designer must be able to compute what the operating levels should be for a given amplifier and cascade, in order to achieve a given signal to noise ratio at the end of the cascade. The system noise figure is used just to enable the designer to determine what this output signal to noise ratio will be.

Overall Noise Figure

From equation (1), it can be readily seen that, if the output signal to noise ratio and the overall system noise figure are known, the required input signal to noise ratio can be calculated. In order to determine the noise figure of an entire system, it is important to know what the relative contribution of each part of the system is, to the overall noise output. If the noise figure of each amplifier is known, the overall noise figure of the cascaded amplifiers can be determined from equation (2)

$$(2)\quad F = F_1 + \frac{F_2 - 1}{G1} + \frac{F_3 - 1}{G2\ G3} + \frac{F_u - 1}{G1G2G3} \ldots\ldots\ldots \frac{F_n - 1}{G1G2G3 \ldots\ldots G_n - 1}$$

where the F's represent the noise factor of each individual network and the G's represent gains or losses whichever the case may be. Appendix I gives a detailed explanation and derivation of this equation starting with the definition of noise figure. To use equation (2) in its present form, to calculate the overall noise figure, of a cascade of more than two or three amplifiers, is quite unwieldy. The equation can be simplified, for calculating the noise figure of a cable system. In this case, the noise figures of all the amplifiers are equal, for all practical purposes. The gains are also the same and the cable losses between amplifiers are equal to the gains of the amplifiers, making the total system gain unity. Under these conditions equation (2) reduces to $F = N\,F_1$ or in terms of db

$$(3)\quad N.F. = (NF)_1 + 10\ \log._{10} N$$

where N.F. is the overall noise figure in db, $(NF)_1$ is the noise figure of one amplifier and N is the number of amplifiers cascaded.

Appendix II shows how equation (3) is derived from equation (2), using the premise of a unity gain system.

Input Signal to Noise Ratio

By the use of equation (3) the overall noise figure can be quickly calculated for any number of amplifiers, provided, the noise figure of each amplifier is the same and the amplifiers have been equally spaced and the gain is unity for the cascade. Once the overall noise figure has been computed the required input signal to noise ratio can be determined for any desired output signal to noise ratio, with equation (1). Since signal to noise and noise figure are generally given in terms of db, equation (1) can be expressed in terms of db for a direct calculation of the input signal to noise ratio. Equation (1) in terms of db is:

$$(4)\quad (S/N)i = (S/N)o + N.F.$$

where all the terms of the equation are expressed in db. As an example; if the desired (S/N)o is 44 db and ten amplifiers with a noise figure of 10 db are to be cascaded, the input signal to noise ratio would be calculated by first using eq. (3) to calculate the overall noise figure, in this example, $N.F. = 10 + 10\ \log._{10} 10 = 20$ db then from equation (4) the input signal to noise ratio is found to be, $(S/N)i = 44 + 20 = 64$ db.

Noise Voltage

The input signal to noise can be divided into two factors, the signal voltage and the noise voltage. If either of the two is known, the other can be calculated. The objective of the system designer, is to determine the minimum input signal level required to give the desired output signal to noise ratio. This can be accomplished by computing the noise voltage present at the beginning of the system.

The mean squared noise voltage for a resistor due to temperature is defined by equation (5)

$$(5)\quad \overline{E_n^2} = 4RKTB$$

R = resistor generating thermal noise
K = Boltzman's constant = 1.38 x 10^{-23} joules/°K
T = Absolute temperature in °Kelvin
B = Equivalent noise bandwidth

Noise levels for a T.V. channel are specified for a 4 MHZ bandwidth in C.A.T.V. The characteristic impedance of the cable used is 75 ohms and all components are matched to this impedance. The thermal noise resistance is therefore 75 ohms. The mean squared voltage can be calculated for any given temperature condition.

A more useful number to calculate is the R.M.S. noise voltage, because it can be compared to the R.M.S. signal voltage which can be measured directly. The R.M.S. noise voltage is found by just taking the square root of the mean squared noise voltage ($\sqrt{\overline{E_n^2}}$). Using equation (5), the noise voltage computed for a 75 ohms resistor with a 4 MHZ bandwidth and normal room temperature (298°K) is -59 dbmv. This is the level of noise that will be present at the beginning of a cable system.

Input Signal Level

With the signal to noise ratio in db and the noise voltage in dbmv the signal level in dbmv can be determined. The signal level in dbmv is equal to the signal to noise ratio in db plus the noise voltage in dbmv. So that for a signal to noise ratio of 64 db and a noise voltage of -59 dbmv ($S_i = (S/N)_i + N_i = 64 - 59 = 5$ dbmv). This indicates that a minimum signal level of 5 dbmv must be available at the beginning of the system in order to have a signal to noise ratio of 64 db.

Measurement of Noise Figure

There are many methods that can be used, for measuring the noise figure of an amplifier. The simpliest way, is to use an automatic noise figure meter. This instrument is commercially sold and permits a direct reading of the noise figure from a meter. Most other techniques become somewhat more involved and require a calibrated noise source. A Field Strength meter could be used also, but it must first be calibrated properly, to read the R.M.S. noise voltage. The F.S.M.'s used in the C.A.T.V. industry have peak detectors and are calibrated to read the R.M.S. voltage of a sinusoidal wave form. The relation between the peak noise voltage and its R.M.S. value is different than it is for a sine wave. The F.S.M.'s therefore can only give correct readings for a sine wave and will always be in error when the wave shape is other than sine wave.

C.A.T.V. Systems

Most of the preceding discussion has dealt with noise figure and signal to noise in a general way. There are some important features about a C.A.T.V. system and its relation to noise figure that should be stressed.

As we all know cable does not attenuate signals equally across the T.V. frequency range. The higher the frequency the higher the loss. Amplifiers are designed to compensate for this effect, in order to maintain a unity gain system. This compensation, is usually implemented by having a fixed amount of tilt in front of the amplifier and a variable tilt control in the middle stages of the amplifier. The number of db of loss introduced in front of the amplifier, increases the noise figure by the same number of db. The variable tilt may or may not degrade the noise figure, depending upon the design. The automatic noise figure meter will, under any setting of the amplifier's control, give the correct noise figure.

Most amplifiers employ 17 db of cable tilt equalization in the front of the amplifier. This means the noise figure at channel 2 is increased by 8.5 db over the noise figure measured without tilt. At first glance this situation would appear to be intolerable for proper system performance, but because the cable loss is less at channel 2 than 13 the input level is higher. This situation helps minimize the effect of the tilt and permits output signal to noise ratios to be comparable for channel 2 and 13.

Calculations, using hypothetical but typical numbers, will help clarify the preceding statements. Assume that the following numbers are specifications for a typical amplifier.

$$\left.\begin{array}{l}\text{N.F. @ Chan 13} = 10 \text{ db} \\ \text{N.F. @ Chan } 2 = 15 \text{ db}\end{array}\right\} \begin{array}{l}\text{amplifier set for 22 db gain} \\ \text{and 22 db tilt.}\end{array}$$

There are ten amplifiers to be cascaded, with 22 db of cable spacing between amplifiers. The output levels are set for 5 db block tilt, channel 13 will be at 35 dbmv output and channel 2 will be at 30 dbmv. The input levels to the amplifier will then be 19 dbmv at channel 2 and 13 dbmv at channel 13.

If this is the situation, we can then compute the output signal to noise for channel 2 and 13 with equations (3) and (4). The overall noise figure for the ten amplifier is as follows;

@ Chan. 13	N.F. = 10 + 10 log 10 = 20 db
@ Chan. 2	N.F. = 15 + 10 log 10 = 25 db

The input signal to noise is found to be;

@ Chan. 13	(S/N)i = 13 + 59 = 72 db
@ Chan. 2	(S/N)i = 19 + 59 = 78 db

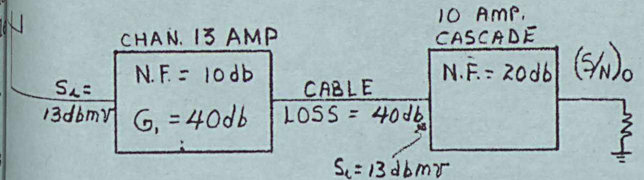
The output signal to noise is;

@ Chan 13	(S/N)o = 72-20 = 52 db
@ Chan 2	(S/N)o = 78-25 = 53 db

These calculations show that, although the tilt compensator does increase the noise figure, the systems performance is not degraded, below channel 13.

Effect of Headend Equipment on S/N

A complete analysis of a cable system must necessarily start at the antenna. The previous discussion assumed, that the input signal to noise ratio was established at the first amplifier. This was done just to facilitate the sample calculation. In reality, the signal to noise ratio is established at the antenna. Any loss between the antenna and the headend amplifiers, is a direct reduction in the signal to noise ratio. The noise figure of the headend amplifiers have very little influence, on the signal to noise ratio at the end of the cascade, provided the noise figure, is not much worse than the noise figure of the trunk amplifier. This can demonstrated, by including the headend amplifier noise figure in the calculation of the overall noise figure. Fig. 1 below depicts the situation for one channel, namely channel 13.



The figure shows the ten amplifier cascade as a single amplifier with a 20 db noise figure.

Assume the channel 13 head end amplifier has the following specs. N.F. = 10 db, Gain = 40 db, and the cable loss following the channel amplifier is 40 db. For this calculation equation (2) must be used.

$$(2)\quad F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1\ G_2}$$

F_1 = Noise factor of chan amp. = 10
F_2 = Noise factor of cable = 10^4
F_3 = Noise factor of cascade = 100
G_1 = Gain of chan. amp. = 10^4
A_2 = Loss of cable = $1/10^4$

$$F = 10 + \frac{10^4 - 1}{10^4} + \frac{100 - 1}{10^4\ 1/10^4}$$

$$F = 10 + 1 + 99 = 110$$

$$N.F. = 10 \log. 110 = 20.4 \text{ db}$$

The result shows that the channel amp. had very little effect on the overall noise figure. If there were more than ten amplifiers in the cascade the effect would have been even less. Equation (2) shows another interesting fact, that is, if the gain of the channel amplifier is substantially greater than the loss of the cable following it, the effect of the noise figure of the cascade on the overall noise figure can be reduced. For instance, if the input signal level were only 3 dbmv, the gain of the channel amplifier still 40 db, the cable would have to be shortened to 30 db loss to maintain a signal level of 13 dbmv into the first amplifier. Using equation (2) the overall noise figure would calculate to be 13.2 db. At first glance it appears as though the system performance has been improved for a smaller signal. A calculation of the output signal to noise for both cases shows this not to be true.

1st case (S/N)i = 72 db N.F. = 20.4 db (S/N)o = 51.6 db
2nd case (S/N)i = 62 db N.F. = 13.2 db (S/N)o = 48.8 db

The output (S/N) has been reduced in part by 3 db. This type of calculation is quite useful in determining whether or not a preamp. is practical to use, when a signal level at the antenna is marginal. Quite often the improvement obtained with the use of a preamp. is not worth the money, or effort to install it at the antenna.

These examples have indicated that the only way the output signal to noise ratio of a system can be improved is by decreasing the noise figure of the individual amplifiers or increasing the input signal levels.

APPENDIX I

Noise Figure is Defined as;

$$(1)\quad F = \frac{S_i/N_i}{S_o/N_o}$$

Where S_i = Input signal
N_i = Input noise
S_o = Output signal

But

$$S_o = GS_i$$

$$(2)\quad F = \frac{S_i/N_1}{GS_i/N_o} = \frac{N_o}{GN_i}$$

N_o = Output noise
G = Gain (or loss)
N_n = Noise generated in network itself

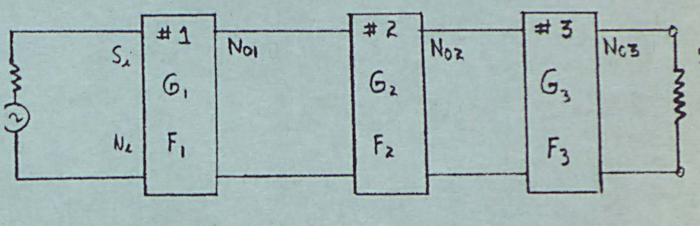
The noise output is comprised of two parts GN_i and N_n the noise generated in the network.

$$(3)\quad N_o = GN_i + N_n$$

Subst. eq. (3) into eq. (2)

$$(4)\quad F = \frac{N_i + N_n}{G\ N_i}$$

Equations (2) and (4) are sometimes used as the definition of noise figure. Using equation (2), (3), and (4) the overall noise figure of cascaded networks can be determined. Consider a cascade of three networks as shown in Fig. 2.



The noise out of the first stage is

$$N_{o1} = G_1\ N_i + N_{n1}$$

The second stage noise output is

$$N_{o2} = G_2\ N_{o1} + N_{n2} = G_2\ (G_1\ N_i + N_{n1})$$

the noise out of the third stage is

$$N_{o3} = G_3 N_{o2} + N_{n_3} = G_3 \left[G_2 (G_1 N_i + N_{n_1}) + N_{n2} \right] + N_{n3}$$

From equation (2) $F = \frac{N_o}{GN_i}$ in this case the N_o is equal to N_{o3} and the gain G is the total gain of the three stages therefore

(5) $F = \frac{N_{o_3}}{G_1, G_2, G_3 N_i}$ Subst for N_{o_3} in equation (5)

$$F = \frac{G_3 \left[G_2 (G_1 N_i + N_{n_i}) + N_{n_2} \right] + N_{n3}}{G_1 G_2 G_3 N_i}$$

$$F = \frac{G_3 G_2 G_1 N_i + G_3 G_2 N_{n_1} + G_3 N_{n_2} + N_{n_3}}{G_1 G_2 G_3 N_i}$$

(6) $F = 1 + \frac{N_{n_1}}{G_1 N_i} + \frac{N_{n_2}}{G_1, G_2 N_i} + \frac{N_{n_3}}{G_1, G_2, G_3 N_i}$

but from eq. (4)

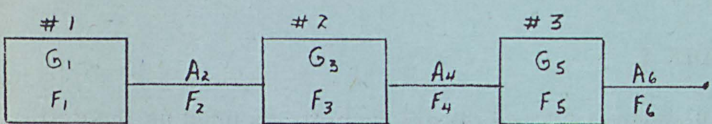
$F = 1 + \frac{N_n}{GN_i}$ or $\frac{N_n}{GN_i} = F - 1$ subst into eq. 6

(7) $F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1, G_2}$

These results can be easily extended to more cascaded networks.

APPENDIX II

To simplify the equation of the noise figure for cascaded networks, it will facilitate matters by using only three amplifiers to demonstrate the technique to be used. Fig. 3 below shows a block diagram of the layout for the three amplifiers.



$G_1 = G_3 = G_5$ Represent the gains of the amplifiers

$A_2 = A_4 = A_6$ Represent the loss of the cable between amplifiers

$G = \frac{1}{A}$ The gain in db equals the loss of the cable in db

$F_1 = F_3 = F_3$ Noise factor of the amplifiers

$F_2 = F_4 = F_6$ Noise factor of the cable

$F_2 = \frac{1}{A_2} = G$ *Noise figure of cable in db equal the loss of the cable in db.

(1) $F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 A_2} + \frac{F_4 - 1}{G_1 A_2 G_3} + \frac{F_5 - 1}{G_1 A_2 G_3 A_4}$

$+ \frac{F_6 - 1}{G_1 A_2 G_3 A_4 G_5}$ N.F. = 10 $\text{Log}_{10} F$.

Since all of the gains are equal and all of the losses are equal to $\frac{1}{G}$ it follows.

$$\text{N.F.} = 10 \text{ Log}_{10} \; F_1 + \frac{F_2 - 1}{G_1} + \frac{F_1 - 1}{1} + \frac{F_2 - 1}{G_1} + \frac{F_1 - 1}{1} + \frac{F_2}{G}$$

Combining terms

$$\text{N.F.} = 10 \log_{10} \left[3F_1 - 2 + 3 \frac{(F_2 - 1)}{G_1} \right]$$

since $F_2 = G_1$, $\frac{F_2 - 1}{G_1} = 1 \frac{-1}{G_1}$, approximately equal to 1

$\text{N.F.} = 10 \log_{10} (3F_1 + 1)$

since $3F_1 \gg 1$

$\text{N.F.} = 10 \log_{10} 3F_1$

For "n" amplifiers the overall noise figure would be

$\text{N.F.} = 10 \log_{10} nF_1$ which is equal to

$\text{N.F.} = 10 \log_{10} F_1 + 10 \text{ 10g}_{10} n$

* The fact that the noise figure of the cable, equals the loss of the cable in db, can be easily shown.

We know that as the noise voltage passes through a cable it is attenuated. We also know that the cable acts as a resistance and introduces noise, depending upon its temperature. Therefore the total noise-out is equal to the noise input times the loss of the cable plus the noise introduced by the cable. In mathematics this reads.

$N_o = AN_i + N_n$ but $AN_i + N_n = N_i$ therefore $N_n =$

$(1 - A)\ N_i$ using eq. (4) from appendix I $F = 1 + \frac{N_n}{AN_i} =$

$$1 + \frac{(1 - A)\ N_i}{A\ N_i} \quad F = \frac{A + 1 - A}{A} = \frac{1}{A}$$

CHAIRMAN TAYLOR: Thank you very much. (Applause) Does anyone have any questions from the floor? If not, I have some announcements to make.

(Convention announcements were made.)

CHAIRMAN TAYLOR (Continuing): In order to expedite the proceeding, I will take the presentations a little out of order to accommodate the mechanical problems we have with the slide projector.

Our next speaker will be Mr. Alan Ross of the Nelson-Ross Electronics Company. Alan Ross was educated at the City College of New York and Brooklyn Polytechnic Institute. He received his initial field experience with the Sperry Gyroscope Company. He then joined Polaroid Electronics Corporation where he specialized in spectrum analysis and R. F. instrumentation. He rose through the ranks to the position of chief engineer.

About four years ago, Mr. Ross organized Nelson-Ross Electronics, a firm which pioneered the concept of plug-in spectrum analyzers. He will discuss the application of such a spectrum analyzer to CATV systems.

It is with great pleasure that I present Mr. Alan Ross. (Applause)

MR. ALAN ROSS (Nelson-Ross Electronics, Inc.): I would like to preface this by saying that we have gone to a great deal of trouble to publish a paper which is almost vervatim of what I am going to say, with a lot of photographs of the CRT screen. Thanks to the printer, I couldn't get them here on time. I will give the paper, without referring to the photographs off the screen, but we do have some two-thousand copies printed which are probably being delivered to my office right now. Anybody who wants one has merely to ask me, and I will see that it is sent in the mail so that all of you can eventually see what I am talking about.

CATV AND THE SPECTRUM ANALYZER

By

Alan Ross, Nelson-Ross Electronics

In the past, newly developing electronic services have started with time-based instrumentation, measuring waveforms — and subsequently have adopted spectrum analysis techniques as systems became more complex. CATV — a young, rapidly developing giant among these services — has, by its very nature, been forced into spectrum analysis at its onset.

The best known and most widely used test instrument for CATV applications is the Field Strength Meter (FSM), which is really a nanually scanned spectrum analyzer. Starting with the FSM, the Spectrum Analyzer (SA) and its operating principles are evolved. A commercially available SA will be described, its advantages and limitations explored, and applications detailed.

The common FSM is a heterodyne receiver capable of tuning the frequency band of interest, usually 54 to 216 MHz, with a meter for indicating the input RF voltage. The block diagram for a typical CATV FSM is shown in Figure 1.

The RF stage provides RF preselection and amplification. The IF amplifier may have a center frequency of 25 MHz and will usually have a 3 db bandwidth of 600 KHz. The local oscillator and RF amplifier are ganged together for tuning. The detector usually provides a peak detecting function and output is indicated on a meter on the instrument. Image rejection is provided by the RF stage. Range selection is provided by input attenuators or IF gain controls or a combination of both. Range selection is necessary since the indicating meter will usefully cover a range of only 20 db at a time. Some FSM's have expanded range on the indicating dial, but this restricts the meter's use when a wide dynamic range is not desired.

A FSM could be converted into a spectrum analyzer by providing an automatic mechanical drive for the tuning mechanism, and displaying the detector output on an oscilloscope whose horizontal drive was sychronized to the tuning. This would provide a CRT display of signal strength against frequency. Such mechanical displays are impractical for high speed repetitive use and some electrical equivalent is desirable.

Varactor diodes could be used to provide electronic tuning in a FSM, but it is very difficult to build an RF stage that can be electrically tuned and that will track with an electronically swept local oscillator. Elimination of the RF stage reduces stage sensitivity and makes the receiver succeptible to spurious image responses. Thus a FSM without an RF preselector stage may have its local oscillator at 75 MHz when tuned to a 50 MHz signal (IF 25 MHz). It will be equally sensitive to a 100 MHz signal. It will be impossible to distinguish whether the noted response is from a 50 or 100 MHz signal at the input.

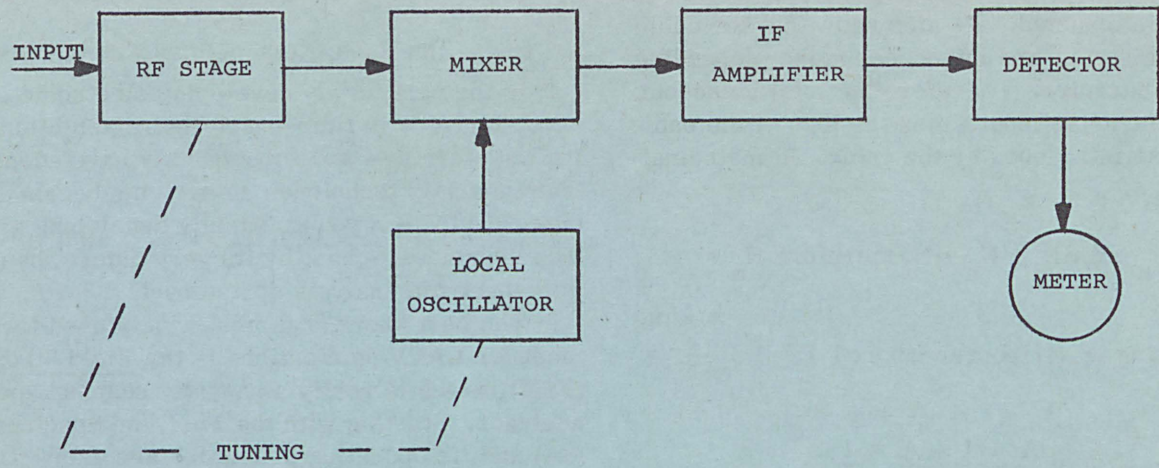


FIGURE 1

The image rejection problem can be overcome by using a very high IF frequency. If a 500 MHz IF is used with a local oscillator sweeping from 500 to 800 MHz, the receiver responses will be 0 - 300 MHz and 1000 - 1800 MHz. Since the 1000 to 1800 MHz sensitivity is not likely to be a problem in CATV applications we have a useful receiver — with a few additional complications. IF amplifiers for 500 MHz cannot be built with the narrow bandwidths needed for CATV work. Narrower bandwidths are obtained by additional conversions to lower IF's using fixed frequency local oscillators. Thus we may go progressively to IF's of 65 and 10.7 MHz and achieve bandwidths of 5 KHz and lower. This resultant instrument is an electronically swept spectrum analyzer.

While there are several available spectrum analyzers that could be used in the CATV industry, the only instrument specifically designed for such applications is the Nelson-Ross Mark I CATV Analyzer. This analyzer features complete frequency coverage in one scan, 60 db display dynamic range, 75 ohm input impedance (type F connector), video (600 kc) display capability, logarithmic, linear and square law vertical scales and ± 2 db overall flatness. The block diagram of this analyzer is given in Figure 2.

The sweep generator controls sweep width and center frequency, thus controlling center frequency and dispersion (tuning range). It also controls the sweep repetition rate. Receiver bandwidth is controlled in the 10.7 MHz IF amplifier. This amplifier normally has a 600 KHz bandwidth, but it can be restricted to 5 KHz by switching in a crystal filter. Logarithmic response is also provided at this stage by means of a front panel control. Square law and linear response can also be selected. The video amplifier provides the required drive for the vertical deflection system of the associated oscilloscope. A variable IF gain control is provided along with a step attenuator between the 65 MHz and 10.7 MHz IF stages.

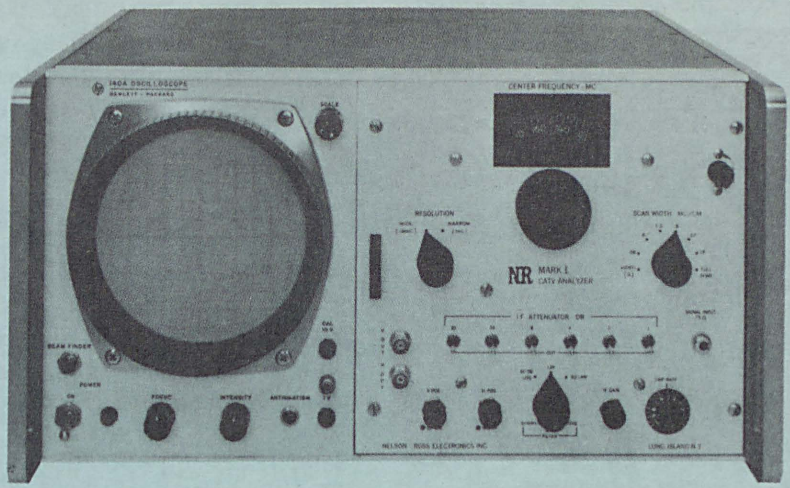
Some general characteristics of the spectrum analyzer should be considered before discussion of specific applications. A thorough understanding of advantages and limitations of the SA will help in understanding its principal applications and the application of the instrument to new uses.

SA Advantages

The SA gives a sweep frequency display. It shows everything that is going on in a given frequency band in a single oscilloscope display. In maximum dispersion, it displays the whole spectrum from zero to 300 MHz. In its narrowest dispersion mode it displays a 600 KHz segment of spectrum across the full width of the oscilloscope. It can also be operated in a "zero" dispersion mode. In this mode it acts as a regular receiver, displaying the demodulated video on the oscilloscope, subject to the bandwidth limitations of the IF and video amplifiers (600 KHz maximum bandwidth) and the horizontal sweep provided by the sweep rate control.

The SA has a wide dynamic range in a single display. Signals that differ in amplitude by as much as 60 db can be readily observed in the log mode, subject to distortion considerations to be discussed later.

The SA has resolving power comparable to the ordinary FSM when operated in the "wide" mode, and has very much greater resolving power (narrow bandwidth) when operated in the narrow (5 KHz) position. Narrow bandwidth operation permits separation of carriers, beats, etc., that are very close together; just how close depends on their relative levels. If they are about the same level, they would be just separated if they were 5 KHz apart. If they are of different levels, they will have to be more widely separated since one carrier will tend to disappear into the



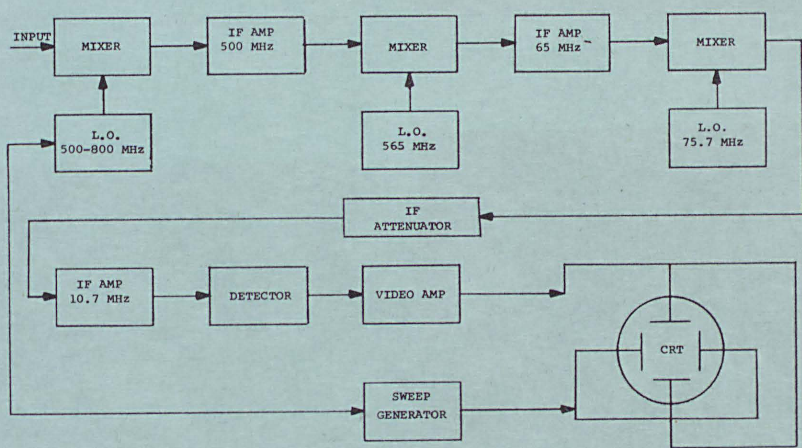


FIGURE 2

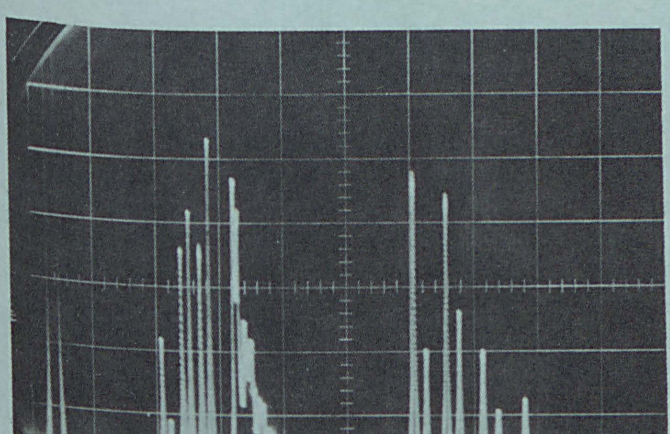


FIGURE 3: 300 megacycle scan of output of allband antenna in the New York City area. The large signal at left is zero frequency. Channels 2, 4 and 5 can be seen between 2nd & 3rd graticule lines. The FM band is immediately to the right. Channels 7, 9, 11 and 13 are visible between the 6th & 8th graticule lines. Note poor response to channels 2 & 13. (linear display)

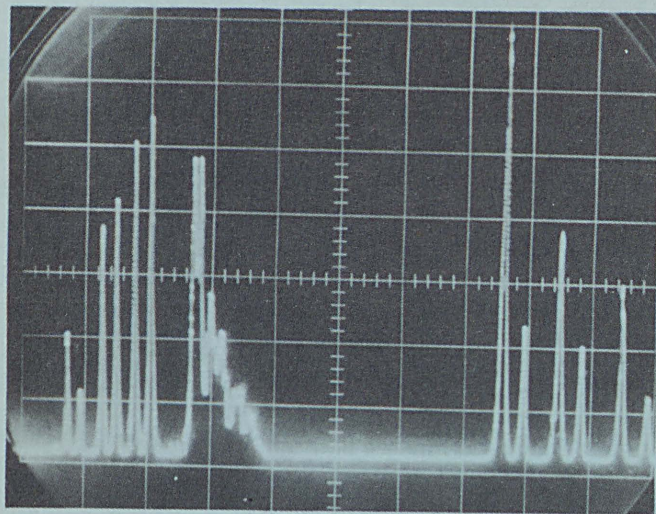


Figure 4: Same signal as in fig. 1 with analyzer dispersion reduced to 180 megacycles eliminating unnecessary upper & lower portions of the display. Note increased resolution. (linear display)

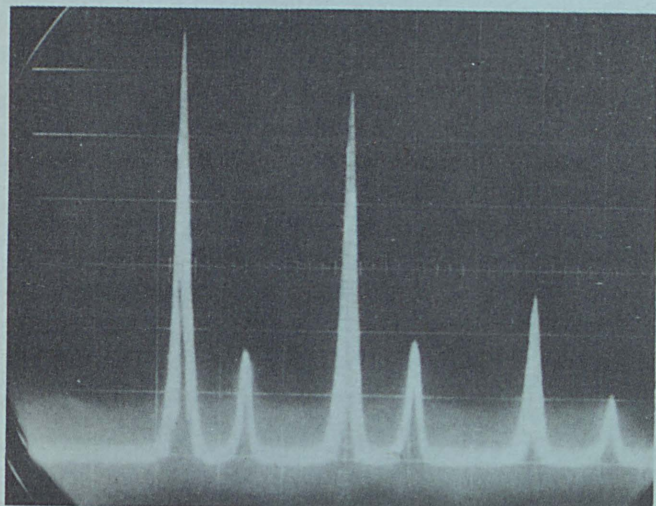


Figure 5: 6 megacycle/cm scan of channels 7, 9 and 11. Relative levels between carriers can be measured using I.F. step attenuator, will yield 7 picture: 0 db, 7 sound:-10 db, 9 picture: -1 db, 9 sound: -9 db, 11 picture: -7 db, 11 sound-14 db. Levels may be calibrated to dbmv (see text) (linear display).

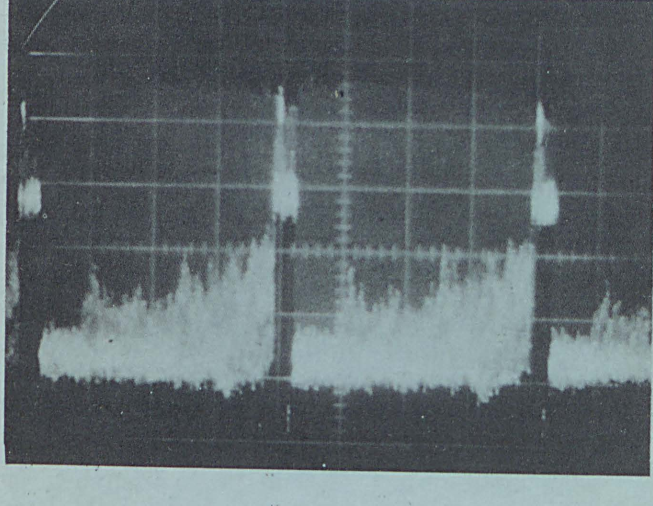


Figure 6: Video display (0 mc/cm dispersion) showing two frames of video. This setting provides V output signals suitable for inspecting sync pulses, etc. (linear display)

"skirt" of the other. Resolving power is still much greater than that of the ordinary FSM.

The SA has optional log, linear or square law response. In log mode, the vertical deflection is protional to the log of signal amplitude, thus giving a display that is linear in decibels. In linear mode display is proportional to amplitude of signal input. In square law mode, display is proportional to signal power (square of amplitude) thus accentuating differences between signals.

The SA oscilloscope display can be photographed (Polariod is preferred) for permanent reference and record, or recordings can be made on X-Y recorders using auziliary output jacks which are provided.

SA Limitations

The SA has high noise figure and low sensitivity. Having no RF stage and a high frequency IF the noise figure is set by the mixer loss and the noise figure of the 500 MHz first IF amplifier.

The SA is subject to overload problems. The mixer generates distortion products — harmonics, intermodulation, and cross modulation products, comparatively easily. It will overload at far lower levels than the more familiar FSM's.

The SA is difficult to calibrate for absolute readings. Gain depends very critically on sweep speed, particularly at narrow band width and wide dispersion. The SA does however make an excellent "transfer standard" permitting easy comparison of a standard reference and an unknown signal for both frequency and amplitude.

Applications of the Spectrum Analyzer

1. Swept Field Strength Meter for System Checking

Checking and setting CATV systems requires tuning the FSM back and forth and remembering or writing dow levels for the various channels of interest. This procedure can be simplified by use of the SA. The SA will display all the channels in an all band, low band, or sub

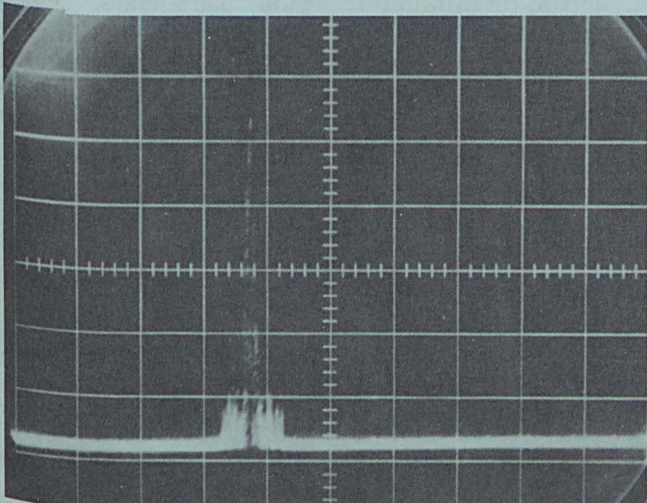


Figure 7: High resolution, low dispersion display - 5 kc resolution coupled with 60 kc/cm dispersion permits identification of FM multiplex transmission. Note grouping of low level modulation around multiplex sidebands (linear display).

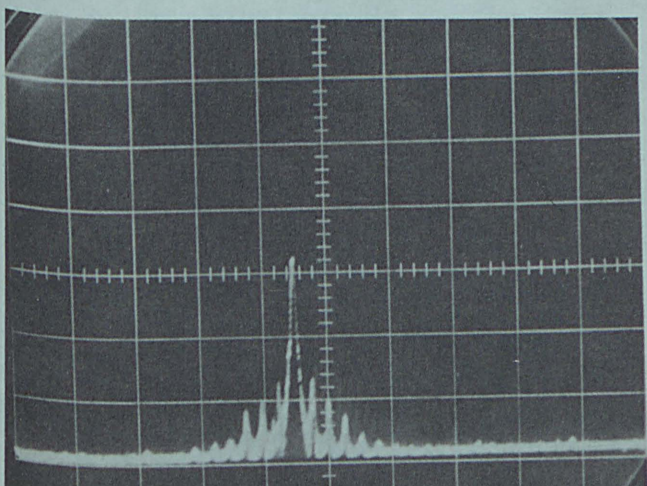


Figure 8: High resolution Log display shows 15.75 kc sidebands around picture carrier. The first sideband, while 20 db below the carrier is still clearly visible. (Log display)

low/low system simultaneously. Use "Wide" bandwidth for this application and set dispersion and tuning to display the band required. Calibrate the SA with any available reference generator. In the log mode, the analyzer will have a 10 db/cm vertical calibration. The SA used should be checked for flatness across the band to be sure that it meets the manufacturers specification of plus or minus two db. This can be done by feeding a good quality sweep generator into the SA. With the SA at a low sweep speed, note the envelope displayed. In log mode, the maximum peak to valley difference should be 0.4 cm (4 db). Greater sensitivity to level differences can be achieved in the linear mode. Adjust IF gain for suitable vertical deflection and check against reference source.

The SA displays all the carriers, picture and sound, at the same time, and the effects of adjustments of amplifier gain and tilt controls are readily observed. In the "wide" mode (600 KHz) the SA is not senstitive to changes in sweep speed and shop calibration at the start of the day can be relied on through the day. The oscilloscope power supplies are quite well regulated against line voltage variations. While the wide bandwidth mode does not give maximum sensitivity, it guarantees immunity against changes in sensitivity and resolving power caused by changes in sweep speed. Check to see whether displayed amplitude changes with sweep speed. Use slowest speed which gives readable display (flicker level tolerable) and which does not reduce displayed amplitudes. The narrow bandwidth position reduces sensitivity drastically — in wide dispersion for all band display, 180 MHz sweep, and with 15 sweep per second sweep rate, the sensitivity is reduced by about 17 db and the apparant resolving power reduced almost 50 times, i.e. effective resolving power becomes almost 250 KHz. The wide band display for setting or checking systems does not need the narrow bandwidth.

2. Precision Field Strength Meter

RF levels can be very accurately measured and set by using the SA as a "transfer standard". Select a hybrid splitter for balanced outputs (a high speed RF switch is handy for this). When sensitivity is not a problem an adder can be made from two 20 db attenuators and a tee. Use the splitter, to mix the signal from the reference generator with the signal being measured. The reference signal can be "walked" up against the signal being measured, by adjusting frequency until it stands right beside the other signal. Use wide bandwidth and narrow dispersions. Adjust the reference generator until signals have equal amplitude. Amplitude comparisons can be made more sensitive by changing to linear or square law mode. Signal amplitude can be read from level of reference generator. Frequency can be determined by tuning the reference generator until it lies right over the signal being checked. Beat effects will be small since the SA is presumably being operated with signal inputs at levels that cause minimum distortions. Signals can be compared in this way to small fractions of a decibel.

Be careful to watch for sweep speed effects. This should be minimal in "wide" band mode. Check for these by seeing whether sweep speed has any effect on amplitude of reference and test signals. Signals with wide band modulation, i.e. wide compared to SA bandwidth, are subject to sweep speed effects. Effect can be minimized or eliminated by using narrow dispersion, slow sweep speeds, and wide bandwidths.

3. Reception Interference

The great resolving power of the SA in its "narrow" band mode makes the instrument very useful for tracking down interfering carriers. Dispersion can be narrowed down to a width of one or two channels. The picture, sound and color carriers on the desired channel are easily identified. Interfering carriers, provided they have reasonable separation from desired carriers are easily identified. These may turn out to be spurious

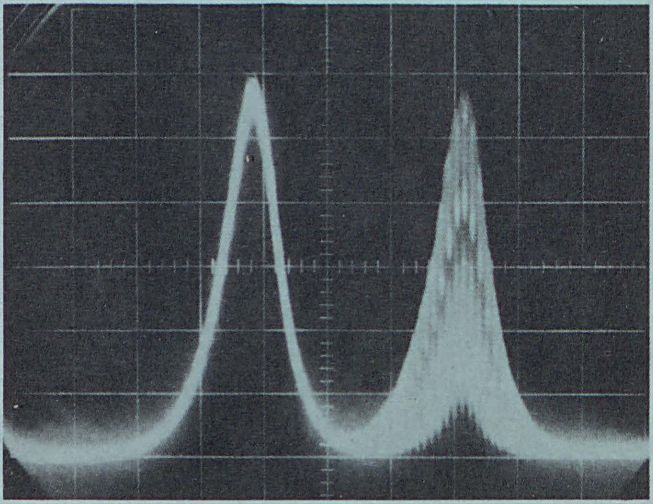


Figure 9: The spectrum analyzer as a transfer standard. The cw signal on the left was inserted via a power divider to calibrate the peak signal level of the video carrier on the right. When the two signals have been made equal the level may be read off the signal generator (linear display).

radiations from nearby transmitters, or may be spurious carriers generated somewhere in the CATV system.

A preselector of some kind is useful for this application. The preselector limits the input signals to the particular band of interest. This prevents generation of undesired distortion products within the SA which may be undistinguishable from the interference being studied. Simple passive band pass filters may be used for this purpose. Better results are obtained by use of an external receiver like a Channel Commander or a TV demodulator. The SA is connected to the IF of the receiver being used as the preselector. The SA scans the IF output of the preselector. The preselector is then tuned to the channel being examined. For applications requiring continuous tuning of the spectrum not provided by a TV demodulator tuner, a FSM may be used with adaptation to permit plugging the SA into the FSM IF. The SA then scans the 600 KHz IF of the FSM. This restricts examination to a 600 KHz "window" at a time, but it does permit continuous tuning within the main tuning range of the FSM.

Narrow dispersions and slow sweep rates should be used to preserve SA sensitivity and resolving power. Co-channel carriers are very difficult to resolve. They are separated by only 10 or 20 KHz from the main picture carrier, and unless they are of exceptionally high amplitude they get lost in the "skirt" of the main carrier. Interfering carriers spaced more than 100 KHz from desired carriers can usually be observed. They can then be tracked back through the system and their sources usually identified. A case history will illustrate:

A CATV system complained of intermittent color "drop out" on channel 2. Extensive equipment substitutions failed to turn up the problem. The SA was connected to the head end Channel Commander output. It was noted that a spurious carrier appeared quite close to the color carrier intermittently, causing color "drop out". This was traced back through the Channel Commander with the SA. It was identified as a nearby police transmitter on a frequency quite close to the IF color frequency. This Channel Commander had poor RF preselection on channel 2. The police transmitter "pulled"

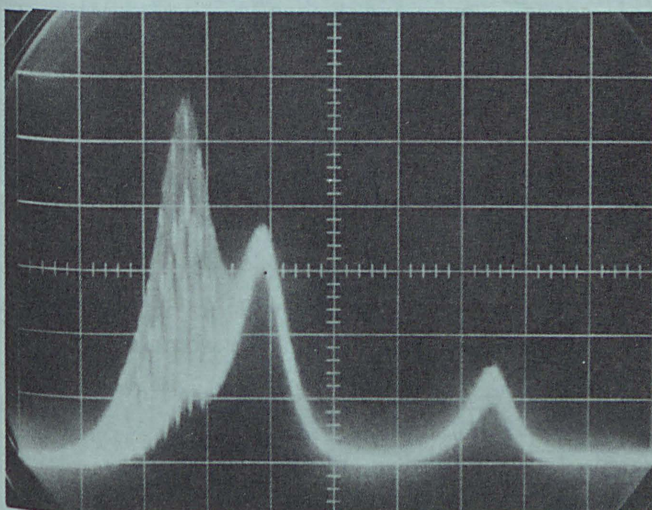


Figure 10: Interfering carrier as seen on the spectrum analyzer. A high level cw signal is interfering with the video portion of the channel under analysis. This signal will be clearly visible on the picture as a "herringbone" type of interference pattern (linear display).

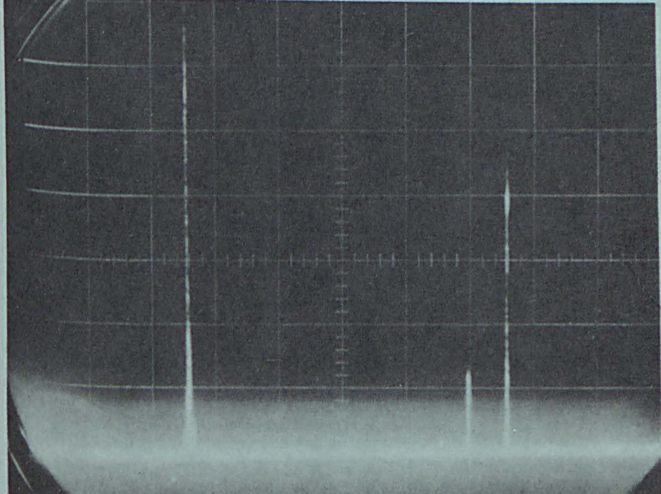


Figure 11: Interference located by means of high resolution examination of an individual channel. An interfering signal can be clearly seen between the sound carrier and color subcarrier (linear display).

right through the tuner into the IF where it interfered with the color carrier. Once the problem was identified it was easy to fix by adding a high pass filter in front of the Channel Commander to improve its RF selectivity. The continuous scanning of the SA permitted the technician to spot the intermittent offending interference. It would have been almost impossible to find in any other way.

Preselectors and preamplifiers considerably improve the performance of the SA by restricting its input to the portion of the spectrum of immediate interest. This prevents harmonic distortion products and intermodulation products from showing up in the spectrum being studied. The problem is common to all SA's that use "wide open front ends".

The SA can be checked for internally generated distortion products. In order to check whether a particular product noted on the screen is valid, or is internally generated, use an external step attenuator. Reduce input signal level by 10 db. If the displayed level changes by more than 1 cm (10 db) the input signal level is too high and should be reduced. All or part of the observed signal was being generated internally. It should also be noted that external preselectors in the form of tuners (Channel Commander, demodulators, FSM's) are also subject to overload distortion and should be checked in the same way. By careful choice and adjustment of preselectors it is possible to distinguish beats and other spurious carriers over a 60 db dynamic range. Such measurements have been made with the SA in connection with checking for spurious beats in tests of amplifier output handling capability.

Since narrow bandwidths are commonly used in this application, it is worthwhile at this point to discuss effect of bandwidth and sweep speed on sensitivity and resolving power.

Very narrow bandwidth IF's take some time to respond completely to changing frequencies. The effect of too fast a sweep for a given IF bandwidth is to reduce displayed amplitude and to increase effective bandwidth (reduce resolving power). Figure 12 can be used to calculate this effect.

In the Nelson-Ross CATV Spectrum Analyzer, the wide position is so wide that effects are negligible at normal sweep speeds. The narrow bandwidth position is subject to these effects. It is recommended that the narrow position be used only at lower sweep rates and narrower dispersions which will reduce effect on sensitivity and resolving power. Use of a long persistence phosphor (P-7) in the oscilloscope, facilitates use of slower sweep speeds. In extreme cases it may be desirable to use storage type oscilloscope (HP 141A) and modify the SA for lower sweep speeds.

4. Checking Amplifier Overload and Distortion

The SA can be used to check amplifier overloads and distortion by displaying the broad spectrum of beats and distortion products caused by serious amplifier overloads. These are generally easy to distinguish from the normal modulation sidebands observed in a working CATV system. Care should be taken, as noted previously, to control the SA input level to prevent internal generation of distortion products. With careful use of preamplifiers preselectors, distortion beats on what should be blank carriers can be observed to a -60 db level. Harmonic beats can also be displayed if care is taken with use of preselectors.

Cross modulation products are very difficult to display. The SA is a frequency domain instrument. The

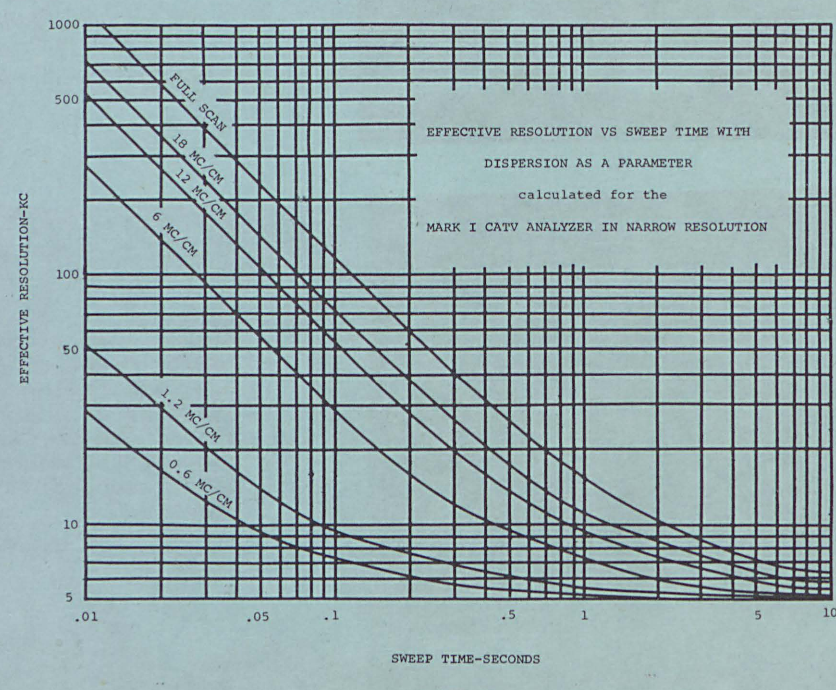
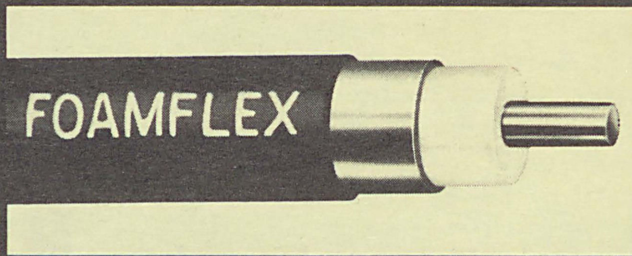


FIGURE 12



The other name on this cable is Phelps Dodge.

That means something extra.

It seems to us that when you buy a cable for your CATV system you want something more than just a method to carry your signal. How about the need for absolutely reliable cable performance?

As a source, only Phelps Dodge offers a unique combination of years of cable manufacturing experience, an in-depth staff of trained technical people, unfailing service from a country wide network of sales offices and warehouses.

You can easily see that when you've made up your mind about the cable you want, who you buy from becomes very important. That's why, when you choose us you get a certain something extra. That's the comforting assurance that we have the size, strength, capability and willingness to stand in back of our cable from the moment your order is received. We do this simply because we can't afford not to.

One of the cables we sell is Foamflex, an all-purpose jacketed aluminum sheathed cable available in nominal lengths of 4,000 feet at a cost competitive with unjacketed cable. To you, this means one cable usable for all types of installation, aerial, buried, or duct.

Foamflex, the original aluminum sheathed foam dielectric coax offers average VSWR of 1.05 on all channels, uniform electrical properties over a wide range of temperature variations, low loss, no radiation, stable attenuation at high band frequencies, light weight for easy installation, long-term operating life.

For complete details on new Foamflex and listing of our sales service stocking centers across the country, write, wire, TWX or telephone Phelps Dodge Copper Products Corporation, 300 Park Avenue, New York, New York 10022. Telephone (212) 751-3200. TWX (212) 867-7455.

PHELPS DODGE COPPER, ALUMINUM AND ALLOY PRODUCTS frequency domain manifestation of cross modulation is the appearance of AM modulation sidebands on a carrier that should be free of modulation sidebands. Sideband levels are normally 6 db down from main carrier, plus the depth of modulation. Thus a carrier with -40 db cross modulation will have a spectrum in which side-bands are 40 + 6 = 46 db down from main carrier. Present cross modulation testing techniques call for sensitivities in the range of -40 to -90 db. This means that sidebands in frequency domain will be 46 to 96 db down. This exceeds the dynamic capability of the spectrum analyzer. The situation is further complicated by the fact that present cross modulation testing techniques call for use of 15.750 KHz from main carrier. This sideband soon is lost in the "skirt" of the main carrier. Modulation frequencies of more than 100 KHz would be more readily observed but would still suffer from the 60 db dynamic range limitation of the SA. Cross modulation up to about -50 db with modulating frequencies of 1 MHz or so could be checked with the SA.

Harmonic distortion products in a sublow/low system could be observed to a -55 to -60 db level by careful use of preselectors to prevent generation of distortion products within the SA itself.

5. Checking Modulation Spectra

Spectra of various modulations are not generally of interest in CATV systems except possibly as an aid to identification of spurious carriers. Use of narrow bandwidth, narrow dispersion modes will display modulation spectra and permit identification of modulation type (FM or AM) and some information on modulation bandwidth.

6. Checking Spurious Outputs

The wide display range and continuous scanning of the SA permits easy checking of amplifiers and other system components for spurious outputs. Be sure to check for possible internal generation of spurious responses, and use preselectors if necessary. The 60 db dynamic range of the SA permits easy recognition of low level spurious outputs in presence of stronger main signals. Undesired local oscillator radiation is also easily checked and measured with the SA.

7. Signal Reconnaisance and Field Strength Recording

The wide scanning nature of the SA makes it suitable for signal reconnaisance work. A broad band antenna and preamplifier would be desirable. All carriers in the band of interest would be displayed. Signal strengths could be recorded by using a data camera capable of sequential frame data photography. The camera would be set to photograph the SA screen every minute or at other desired intervals.

A standard reference level signal can be mixed in with the test signals to provide continuous calibration. The log mode permits recording a wide dynamic range of signal levels, and the continuous scan display would permit recording of differential fades between channels, and between sound and picture carriers. Intermittent interfering carriers would also be recorded, depending on their relationship to the interval of the data recording camera. Signals from several narrow band antennas and preamplifiers could be combined for simultaneous display on the SA.

ACKNOWLEDGEMENTS

The author wishes to thank Mr. Alan Ross of Nelson-Ross Electronics for reviewing this article as well as supplying the photographs.

Thank you. (Applause) I would like to acknowledge the work of Mr. Switzer for preparing the rough text for this paper. Thank you again very much. (Applause)

CHAIRMAN TAYLOR: Thank you very much, Mr. Alan Ross. I wonder if we have any questions of Mr. Ross on the spectrum analyzer and its applications?

QUESTION: You spoke of using a pre-selector such as a Channel Commander. You are now using a dispersion of about six megacycles, I presume. What scan rate and what resolution can go or, rather, what scan rate and what resolution can you get at a six megacycle dispersion?

MR. ROSS: At six megacycles you probably wouldn't want to use the wide resolution. You could use the 600 kc, which is roughly ten per cent of the display. I don't know if anybody can see this, but I have a picture of those exact conditions on the front of my paper here, the 600 kc dispersion condition, and that is the picture and sound carrier. That was from Channel 4 and off my home antenna.

I also have pictures further on where you can sweep six megacycles, and I am guessing from experience at five or six sweeps per second, and you can literally see everything that goes on, including the modulation spectrum around the picture carrier. I have that here also. You can see the color carrier, and you can see any spurious signals or interference that may occur in between.

I have seen, for example, an operating CATV system where there has been an ignition noise which is very easily and very quickly identified, because it forms a random pattern of spikes between the picture and sound carrier on a setup like this, and I was able to trace it down to find out it wasn't coming in the antenna but coming in because of a bad connector some place.

CHAIRMAN TAYLOR: Are there any more question I still have not figured out how to use the spectrum analyzer when I can't get delivery on the scope. (Laughter) Are there any other questions? Putting my fingers on the terminals doesn't help much. (Laughter)

PRACTICAL SYSTEM DESIGN BASED ON COMPLETE EQUIPMENT EVALUATION

by

Jerry A. Laufer
Total Telecable, Inc.
Seattle, Washington

Robert J. Brown
Tele-Vue Systems, Inc.
Everett, Washington

EQUIPMENT SET-UP AND TEST PROCEDURE

About eight months ago it became obvious to the engineering department of Tele-Vue Systems, Inc., that we were having too many disappointing experiences with the new solid state equipment. Such as, why was the tilt changing in the system, why were we getting beats, why the excessive noise, etc.?

We were planning on building about 1000 miles of new plant over the next two year period, plus modernizing our existing 600 miles. It was rather clear to me that we could not afford to make that kind of expenditure without knowing in advance whether the equipment would meet our specifications.

Our company is selling in areas where we are competing against from two to five channels of off air reception. We have found that we get deeper penetration by selling in these markets before the plant is built. To encourage the people to sign up at that time, the connect charge is waived. Under these conditions, because the prospective customer has nothing to lose, it is not unusual to achieve 60% penetration, and currently we are selling between 70% and 80% of the occupied homes. We cannot make any mistakes under these conditions. If we do, the customer disconnects.

Because of this highly aggressive sales philosophy, the trunk lines getting longer, more channels being carried, the competition of off air signals, all of these factors add up to one thing. We cannot afford to experiment in the field. We must confine our experiments to the lab under controlled conditions.

It was at this point that we set about to put together a testing facility that would enable us to accurately measure all parameters of CATV equipment. Although Tele-Vue Systems, Inc., for whom I work, financed this venture, Jerry Laufer, who is Vice-President of engineering for Tele-Cable, contributed a vast amount of time, energy and knowledge, in putting the test facility together. Without his help, we would not be where we are today in our testing program.

TEMPERATURE

For testing the effect of temperature we didn't feel that single unit tests without the associated cable and other accessories would tell us what we wanted to know. We purchased an 8' x 10' walk-in freezer which had a 2000 watt defrost coil built in. The freezer will hold a ten amp cascade and all its associated accessories and cable very nicely. To create the heat, the defrost coil is manually switched on and is held at some preset temperature with a thermostat. We are capable of going from minus 40 to plus 140 safely, but for the purposes of our test minus 20 to plus 120 is adequate. The cable presently used is bare .412 aluminum in 22 db lengths. We will be changing to 1/4 inch alum in the near future to give us more room for a possible additional 10 amp cascade. Also, with the smaller cable, it will not take as long to complete a cycle. It now takes about 30 hours to go from 70 to 120 to minus 10 and back to 70 degrees fahrenheit. Cross-modulation, noise and response measurements are made at these temperatures.

NOISE

Noise measurements are made as described on page 5.

CROSS MODULATION AND BEAT MEASUREMENT

The test set consists of two parts -- a 12 channel signal source, and a cross modulation and beat measurement set.

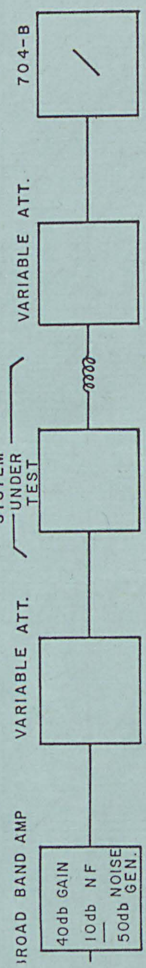
The 12 channel signal source at present consists of a Jerrold TM modulator operating on channel 6. The modulator is modulated by 15.750 KHz square waves from a Hewlett-Packard square wave generator. The modulated channel 6 carrier is suitably attentuated and converted to IF frequency by a Jerrold Channel Commander, tuned to channel 6. The IF output is split down into 12 outputs using hybrid splitters and made available at a co-axial patch-pannel. The patch panel also connects to the inputs of 12 Jerrold CCV up-converters, which convert the IF to the 12 standard VHF TV channels. The CCV outputs are combined in a filter network adapted for antenna mixing networks into a single 12 channel output. A final output step attenuator provides output level control. Individual level control on each channel is achieved by individual bias controls for each CCV unit. These are mounted on the patch panel. The signal substitution oscillator provides an unmodulated carrier at IF frequency. This unmodulated carrier is made available at the patch panel. Use of BNC connectors at the patch panel makes it possible to substitute modulated and unmodulated carriers quickly on any desired channel.

Output signal levels are measured with a Jerrold 704B field strength meter. A Hewlett-Packard 608C signal generator is available for calibrating the field strength meter before and after tests.

The Cross modulation and beat distortion measuring section is contained in a separate rack. A step attenuator controls input levels. A hybrid splitter splits the incoming signal. A Jerrold 704B field strength meter serves to measure levels and as a demodulator for the cross modulation measurements. The video output from the field strength meter goes through a passive 15.750 KHz preselective filter into a Sierra wave analyzer which acts as a tunable voltmeter with wide dynamic range. The wave analyzer is capable of separating the 15.750 KHz cross modulation fundamental and measuring it at microvolt levels. The cross modulation ratio is the ratio of 15.750 KHz fundamental when carrier is modulated at standard level to 15.750 KHz level when unmodulated carrier is substituted. This test set is capable of measurements down to about -75 db cross modulation. Accuracy at this level is improved and range extended to still lower cross modulation levels (-100 db) by use of a preselector filter in front of the 704B. Use of the preselector permits higher input levels to the 704B without generating excessive distortion in the 704B itself. The higher input levels are required to overcome noise which becomes a limiting factor at these low cross modulation levels.

A Jerrold TD demodulator is used for beat checks. The video output drives a conrac video monitor for visual observation of cross modulation and beats. The IF test point feeds a Nelson Ross spectrum analyzer which scans the demodulator IF for undesired spurious beats. Very low level beats at low frequency might be missed by this IF scan. If these are suspected they are checked with a low frequency wave analyzer examination of the video output. A low frequency spectrum analyzer will soon be installed for this function. The spectrum analyzer permits a 60 db dynamic range measurement of beats to be made, when used with the TD as a preselector. Precision level and frequency measurements are made by using the spectrum analyzer to compare test signals with reference signals from the H-P 608C signal generator or other standard sources such as marker generators.

Figure 1 NOISE MEASUREMENT



1. SET UP BROAD BAND AMPLIFIER AND VARIABLE ATTENUATOR AT INPUT TO 1ST. AMPLIFIER IN THE SYSTEM UNDER TEST.
2. TURN INPUT ATTENUATOR TO MAXIUM ATTENUATION.
3. WITH NO ATTENUATION IN OUTPUT OF ATTENUATOR AND 704-B IN MANUAL GAIN POSITION, ADJUST FOR + 8 db READING.
4. NOW SWITCH IN 3 db IN OUTPUT ATTENUATOR AND REMOVE ATTENUATION ON INPUT UNTIL THE SAME 8 db READING IS OBTAINED.
5. SUBTRACT REMAINING ATTENUATION ON INPUT ATTENUATOR FROM OUTPUT OF NOISE GEN. AND THAT IS THE NOISE FIGURE OF SYSTEM UNDER TEST.

NOTE: IF THE SYSTEM HAS AGC, BE SURE TO FEED IN THE PROPER SIGNAL FOR SYSTEM TO WORK, AT NORMAL OPERATING LEVELS USE ATTACHED CHART FOR COMPUTING SYSTEMS SIGNAL TO NOISE RATIO.

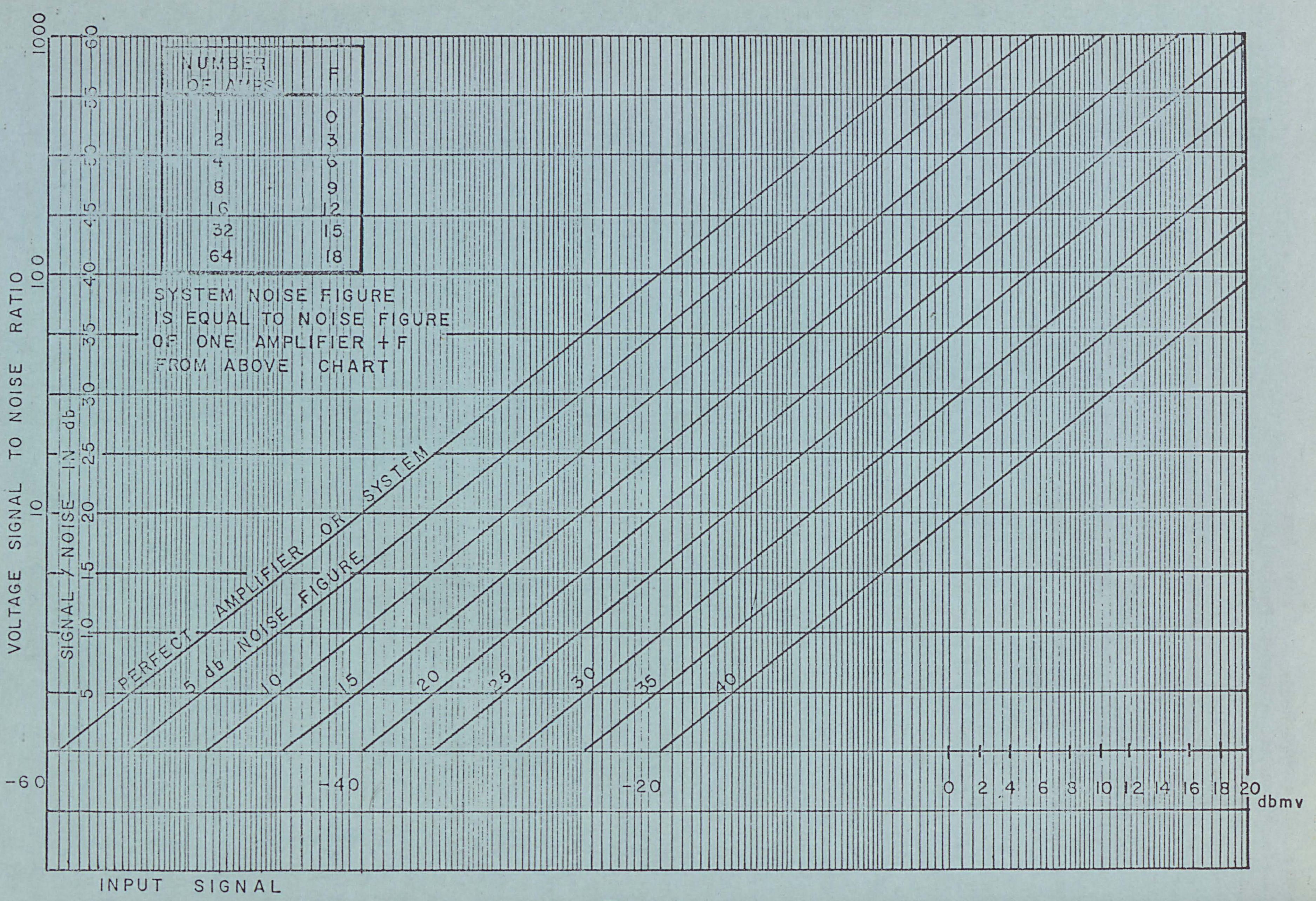

NUMBER OF AMPS
F
1 0
2 3
4 6
8 9
16 12
32 15
64 18
SYSTEM NOISE FIGURE
IS EQUAL TO NOISE FIGURE
OF ONE AMPLIFIER + F
FROM ABOVE CHART
PERFECT AMPLIFIER OR SYSTEM
5 db NOISE FIGURE
10
15
20
25
30
35
40
VOLTAGE SIGNAL TO NOISE RATIO
1000
100
10
SIGNAL / NOISE IN db
5
10
15
20
25
30
35
40
45
50
55
60
-60
-40
-20
0
2
4
6
8
10
12
14
16
18
20
dbmv
INPUT SIGNAL

Figure 2

Figure 3

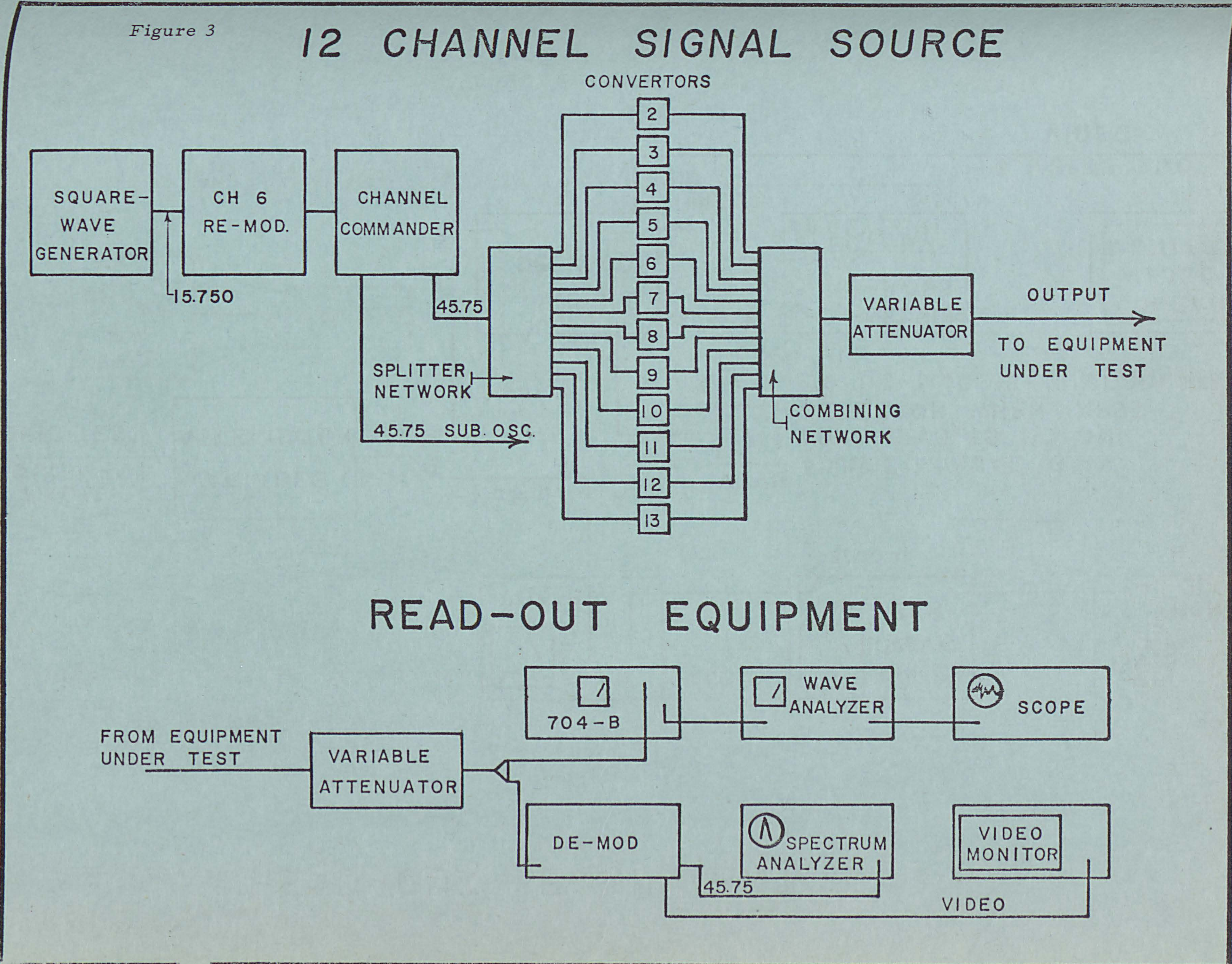

12 CHANNEL SIGNAL SOURCE
CONVERTORS
2
3
4
5
6
7
8
9
10
11
12
13
SQUARE-WAVE GENERATOR
CH 6 RE-MOD.
CHANNEL COMMANDER
15.750
45.75
SPLITTER NETWORK
45.75 SUB. OSC.
COMBINING NETWORK
VARIABLE ATTENUATOR
OUTPUT
TO EQUIPMENT UNDER TEST
READ-OUT EQUIPMENT
704-B
WAVE ANALYZER
SCOPE
FROM EQUIPMENT UNDER TEST
VARIABLE ATTENUATOR
DE-MOD
SPECTRUM ANALYZER
VIDEO MONITOR
45.75
VIDEO

Figure 4

READ-OUT EQUIPMENT

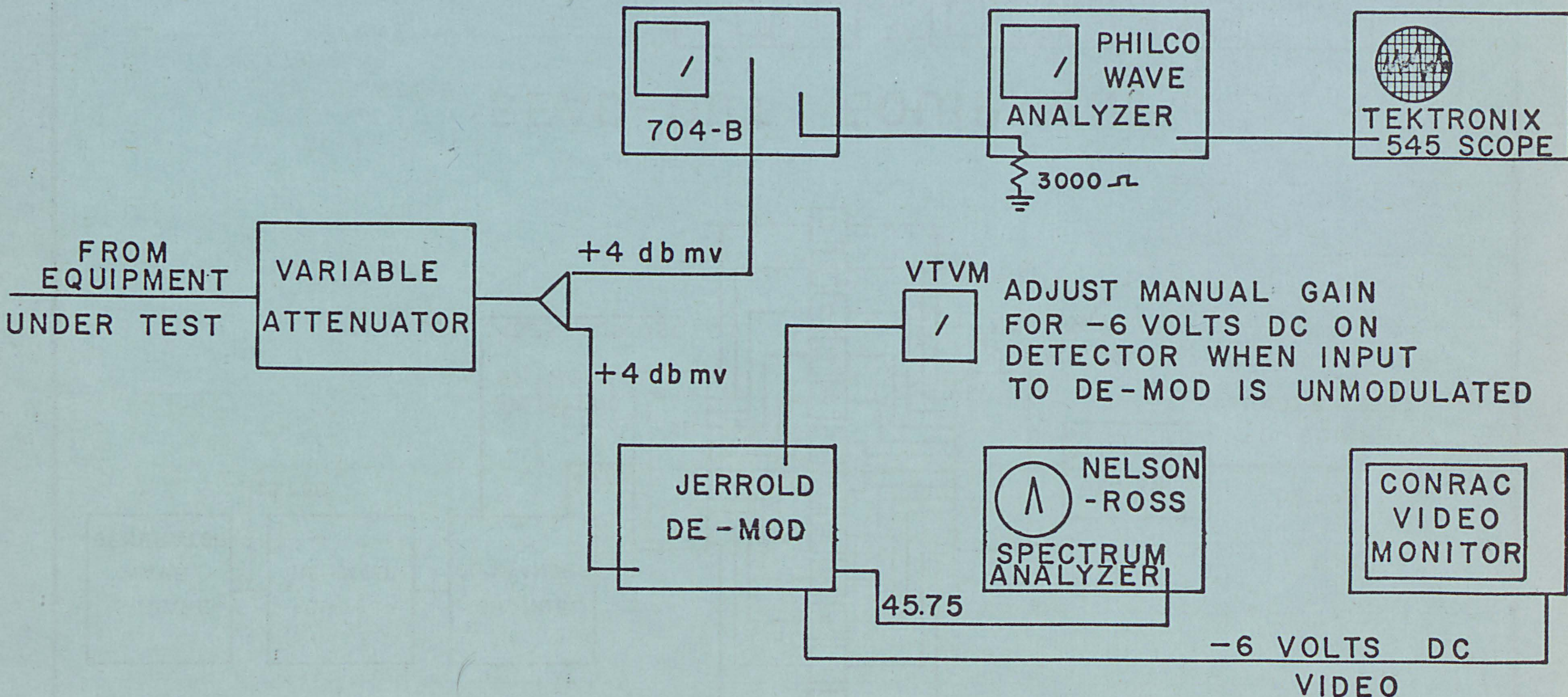
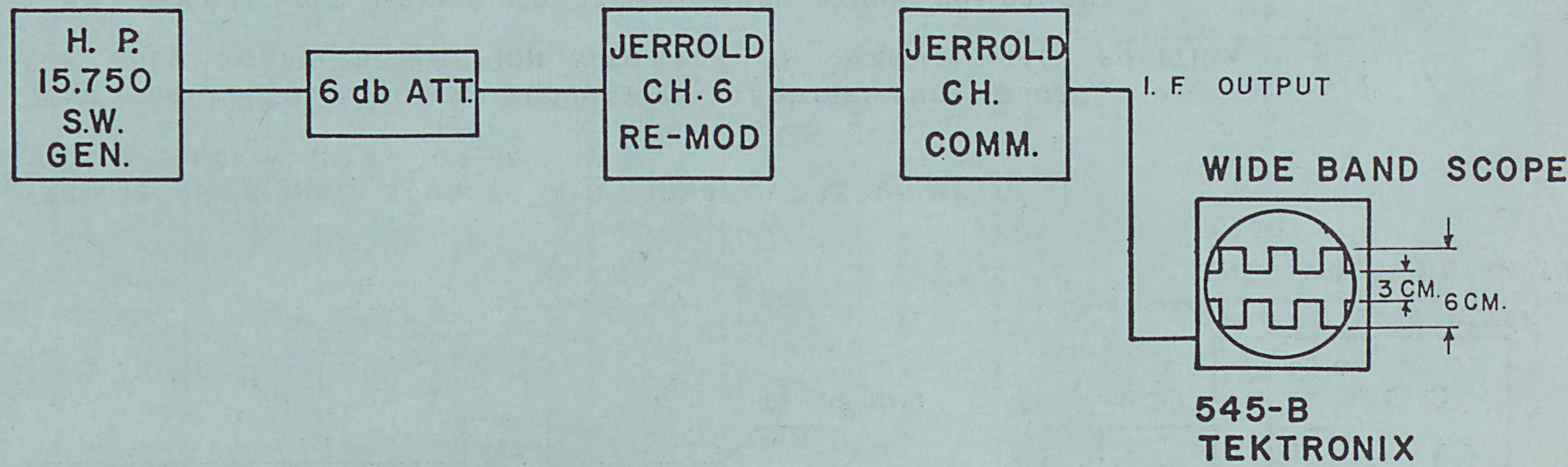


Figure 5

CALIBRATING % OF MODULATION



(1) SET UP EQUIPMENT AS SHOWN ABOVE

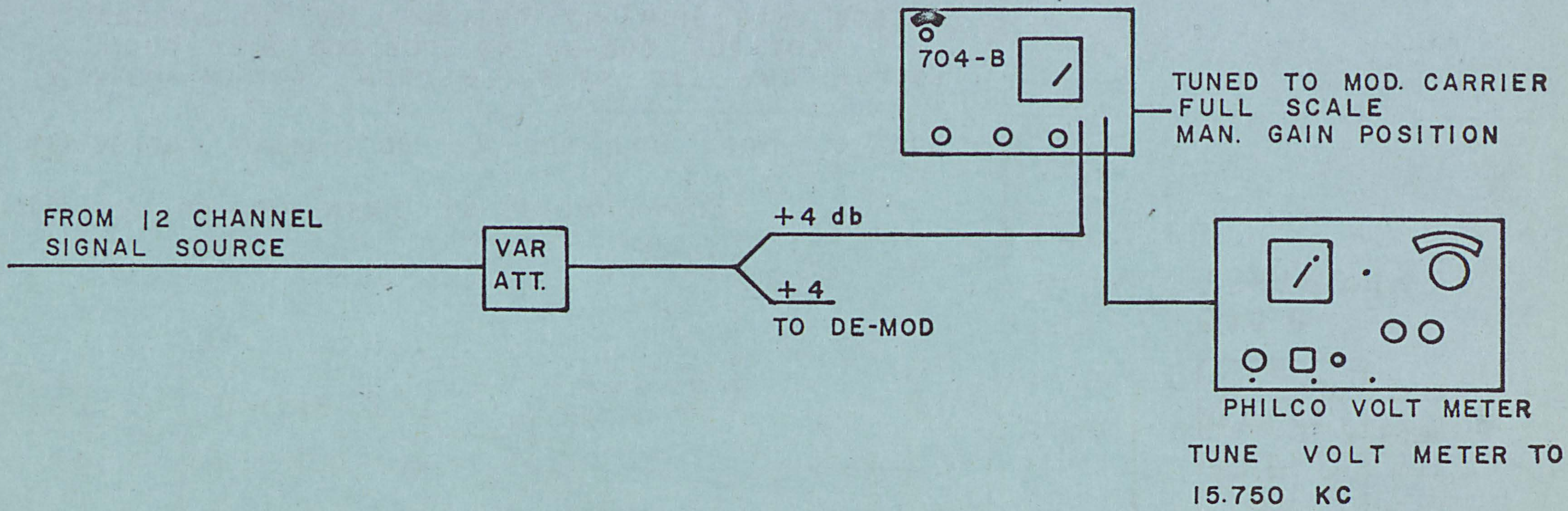
(2) ADJUST OUTPUT OF S.W. GEN. FOR ABOUT 1 VOLT

(3) FEED RE-MOD THROUGH 6 db ATT. AND ADJUST VIDEO GAIN CONTROL ON RE-MOD FOR 50% MODULATION AS INDICATED ON WIDE BAND SCOPE

(4) REMOVE 6 db ATT. MODULATION IS NOW 100%

Figure 6

CALIBRATING OUT ERRORS DUE TO THE NON-LINEAR 704 DETECTOR AND MODULATION ERRORS DUE TO INABILITY OF RE-MOD TO BE MODULATED AT 100%



1. FEED 12 CH. SIGNAL SOURCE INTO READ OUT EQUIPMENT WITH A +4 dbmv INTO 704-B.

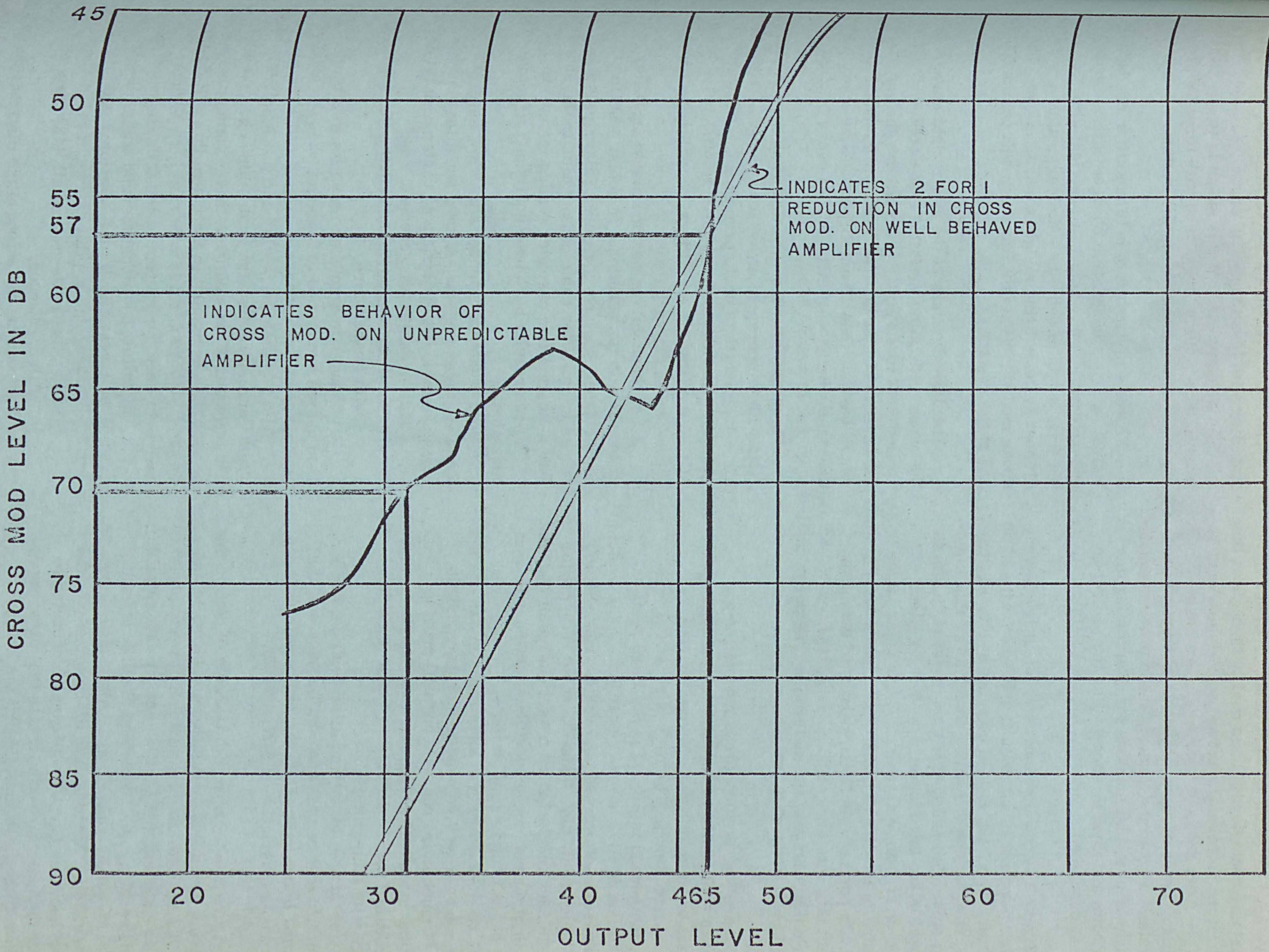
2. TUNE 704-B TO A 100% MODULATED CARRIER AND ADJUST FOR FULL SCALE DEFLECTION WITH 704 IN MANUAL GAIN POSITION.

3. TUNE PHILCO VOLT METER TO 15.750 MODULATION COMPONENT.

4. SWITCH IN 60 db ATTENUATOR ON FRONT OF 15.750 S.W GEN.

5. SWITCH OUT 60 db OF ATTENUATION ON PHILCO VOLT METER AND ADJUST CALBRATION CONTROL FOR A "O" READING

6. RETURN ATTENUATORS TO NORMAL. AT THIS POINT THERE WILL BE A SLIGHT ERROR IN ATTENUATOR TRACKING DUE TO ERRORS STATED ABOVE, BUT EQUIPMENT HAS BEEN CALIBRATED AT THE MODULATION LEVEL AT WHICH IT WILL BE USED. (-60 db REGION)



45
50
55
57
60
65
70
75
80
85
90
CROSS MOD LEVEL IN DB
20
30
40
46.5
50
60
70
OUTPUT LEVEL
INDICATES 2 FOR 1 REDUCTION IN CROSS MOD. ON WELL BEHAVED AMPLIFIER
INDICATES BEHAVIOR OF CROSS MOD. ON UNPREDICTABLE AMPLIFIER

Figure 7

We have experienced significant problems in maintaining consistent picture quality throughout the temperature extremes in our area. A typical day will vary from 35° to 65° which is more constant than many areas of the country. In attempting to understand why we were having these problems and to discover practical methods for overcoming them, Bob Brown and myself embarked on the project he has just described.

Figure 1 shows how input and output levels vary with temperature in a 3 amplifier cascade with 22 db spacings. The input is held constant at plus 31 dbmv. The variations are caused by changes in cable attenuation only. You will notice the largest variation is the input of the third amplifier which is a total change of 11.7 db AGC range. The largest output variation is the second amplifier which is 7.8 db. The main point of this illustration is to establish the fact that with perfect amplifiers, changes in cross modulation and signal-to-noise will occur due to cable variations only.

Figure 2 shows how cross modulation and signal to noise ratio varies with temperature in a cascade of 10 amplifiers. Three different systems are shown. The first is no AGC amplifiers, the second is AGC at every third position and the last is AGC at every position. In the system with no AGC, total cross mod varies from -84.5db to -37.8db or 46.7db. Signal-to-noise ratio varies from 58.35db to 42.97db or a total change of 16.38db. This is of course, an impossible situation even in a short cascade of 10 amplifiers.

If we AGC every 3rd. amplifier you can see that cross mod varies 7.7db and S/N changes 6.57db. This is much more realistic and will provide a practical system if temperature variations are not too wide and the amplifier's response doesn't change with temperature.

If we AGC at every amplifier position, cross modulation will remain constant because output at all amps is constant. Only the inputs will vary and this causes a variation in S/N of 3.9db.

Figure 3 is a graph with two sets of curves that illustrate how cross modulation and signal to noise ratio change with temperature and cascade length. This is a system that is AGC'd every 3rd. amplifier and all spacings are 22db. The amplifiers have a maximum output capability of 48dbmv and a noise figure of 8db. The top curve of the cross mod set is -20° and each curve is 30° steps increasing to 130° at the bottom. You will note that cross mod changes in the first amplifier, at the lower left corner of the graph, are almost as great as the cross mod changes at the tenth amplifier.

The curves become straight lines after the tenth amplifier with less than 0.5db error.

The primary point of this graph is to show that most of variations in cross mod with temperature occur in the first amplifiers in the system.

Figure 4 is a graph of a 10 amplifier cascade illustrating cross modulation changes with temperature and cascade length. This is a practical situation where the first length of cable is 40db long, which is typical of most systems using a high output head end. The total cross mod variation is 9.7db which will continue to the end of the system.

The dashed curves at the upper right corner, are the cross modulation variation that would occur if we applied AGC to the first six amplifiers thereby limiting the variation to 3.5db. The variation in cross mod for a longer cascade than 10 amplifiers will be approximately the same. Balance of amps AGC'd every 3 RD amp.

Figure 5 shows the variation of signal to noise ratio with temperature and cascade length. This also has a 40db length of cable preceding the first amplifier. We are using AGC at every third amplifier. If we use AGC at the first six amplifiers, we will have some improvement in the variations.

All of these curves assume stable amplifier performance with temperature. In actual practice this is not the case. We have measured an average of 6db errors in amplifier cable equalization in the chamber with a 10 amplifier cascade, cycling from 0° to 120°.

These results have been confirmed in actual system operation.

Most of our experience is with low band AGC systems. In these systems we have found that the low band remains stable but the high band varies with temperature. This is due to two reasons.

1. Improper system cable equalization changes with temperature.
2. Changes in amplifier response with temperature.

This causes cross mod to increase when the temperature drops and vice-versa.

The ideal solution would be to use amplifiers that would correctly follow the cable slope changes with temperature. I feel confident that manufacturers will be supplying equipment in the future that will do this. However, our problem is with existing systems. We have stabilized our system by the following methods.

1. Installing additional thermal equalizers where our layout allowed the additional insertion loss.
2. By changing the pilot carrier level at the head end to change the gain of all AGC units as temperature changes.
3. By lowering the output of the distribution amplifiers and line extenders that are past the 15th. trunk amp by 2db. This gives us a little more tolerance to the changing levels.

A system with high band AGC, compared to a system with low band AGC that has the same temperature problems, will perform better. This is because the high band is operating at a higher level with more channels and is the major contributor to cross mod. % of contribution LO = MI =. By holding the high band constant with AGC and allowing the low band to vary, much less visible changes in picture quality will occur. I believe the ideal system is pilot carriers in both high and low bands with active closed loop control on both gain and tilt. This would allow much less critical amplifier design as far as temperature is concerned.

During the equipment evaluation program, the most outstanding fact that we confirmed is the lack of standard specifications between different manufacturers.

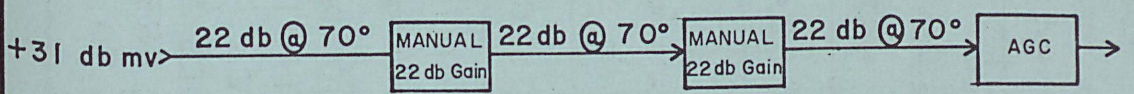
Cross modulation is the most serious difference we found. Our method of measurement, right or wrong, is at least the same for all amplifiers. We have evaluated most of the equipment available and found as much as 15db difference between published output capability and measured output capability. This tells us that it is impossible today to design a system by using published specifications and reliably predict the results, unless we know what basis the specifications are derived from.

We as an association must push hard for the final adoption of the NCTA standard for amplifier output capability and measurement techniques.

We have taken far too long in finalizing this standard. The final form that is adopted is not as important as getting it adopted.

I submit that we must move now to establish additional industry standards for total system performance as soon as possible. These should include system operation under all temperature conditions. The manufacturers could provide leadership in this area by providing more complete data on their equipment and it's application. I doubt very much if all CATV operators are willing to invest the time and money required to test amplifiers and determine for themselves what its limitations are.

Figure 1



TEMP.	IN	OUT	IN	OUT	IN	OUT
130°	7.35	29.35	5.70	27.70	4.05	31.00
100°	8.15	30.15	7.30	29.30	6.45	31.00
70°	9.00	31.00	9.00	31.00	9.00	31.00
40°	9.78	31.78	10.56	32.56	11.34	31.00
10°	10.50	32.50	12.00	34.00	13.50	31.00
-20°	11.25	33.25	13.50	35.50	15.75	31.00

TEMPERATURE	-20°	10°	40°	70°	100°	130°
CABLE ATTENUATION	19.75	20.50	21.22	22.00	22.85	23.65
10 AMPS NO AGC — CROSS MOD.	-37.8	-50.8	-61.2	-71.0	-79.0	-84.5
10 AMPS NO AGC — S/N	58.35	56.30	53.73	50.00	44.12	42.97
10 AMPS 3 AGC — CROSS MOD.	-66.3	-67.7	-69.3	-71.0	-73.2	-74.0
10 AMPS 3 AGC — S/N	53.91	52.47	51.32	50.00	48.46	47.34
10 AMPS 10 AGC — CROSS MOD.	-71.0	-71.0	-71.0	-71.0	-71.0	-71.0
10 AMPS 10 AGC — S/N	52.25	51.50	50.78	50.00	49.15	48.35

ASSUME
1. 22 db SPACING AT 70°
2. MAXIMUM OUTPUT FOR -57 db CROSSMOD = +48 db mv
3. NOISE FIGURE = + 8 db
4. AMPLIFIER DOES NOT CHANGE WITH TEMPERATURE
5. ALL LEVELS ARE CHANNEL 13
6. INPUT LEVEL TO ALL SYSTEMS = +31 db mv

Figure 2

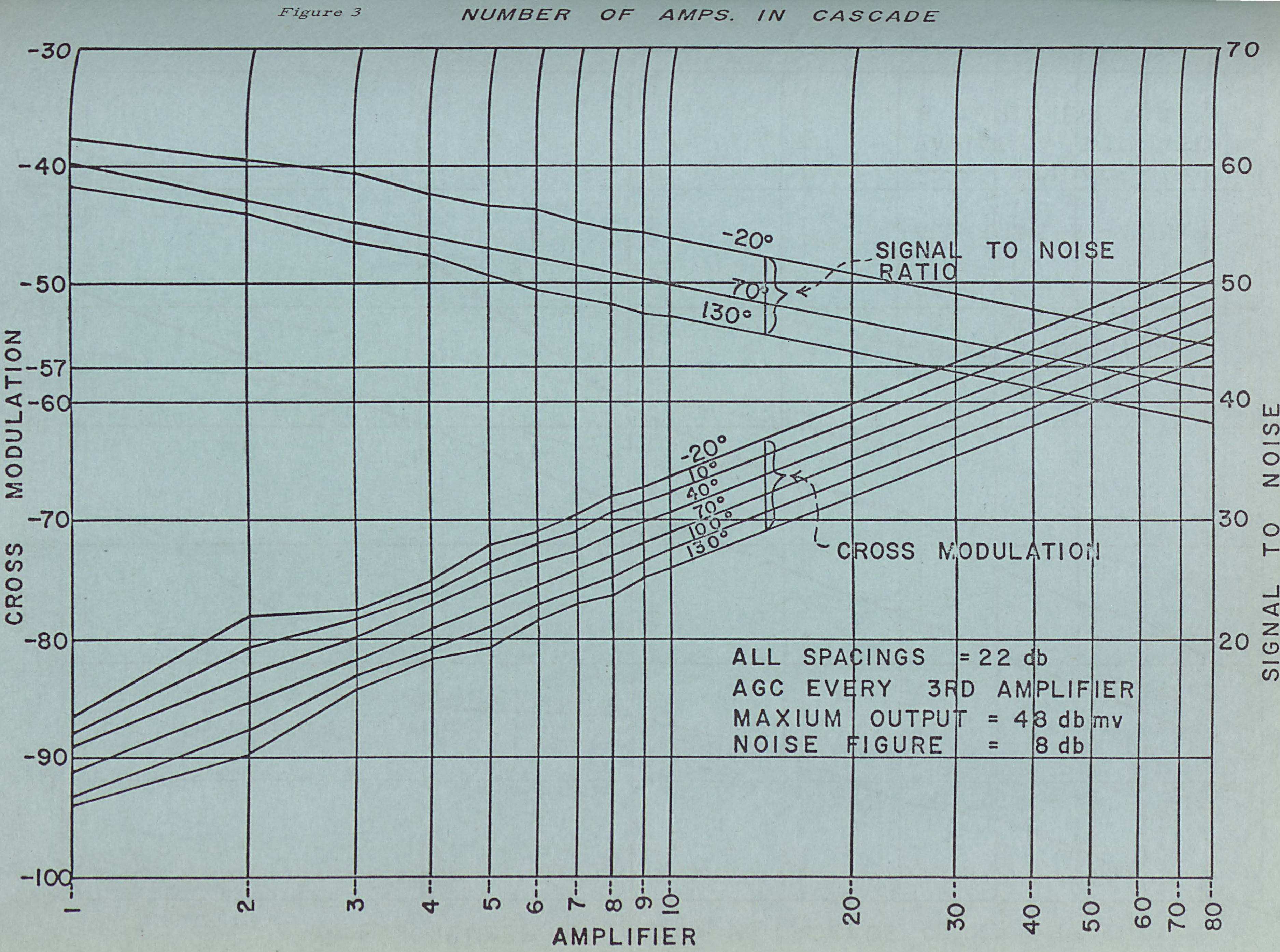

NUMBER OF AMPS. IN CASCADE
CROSS MODULATION
SIGNAL TO NOISE
AMPLIFIER
-30
-40
-50
-57
-60
-70
-80
-90
-100
70
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
-20°
70°
130°
SIGNAL TO NOISE RATIO
-20°
10°
40°
70°
100°
130°
CROSS MODULATION
ALL SPACINGS = 22 db
AGC EVERY 3RD AMPLIFIER
MAXIUM OUTPUT = 48 db mv
NOISE FIGURE = 8 db

Figure 3

Figure 4 NUMBER OF AMPS. IN CASCADE

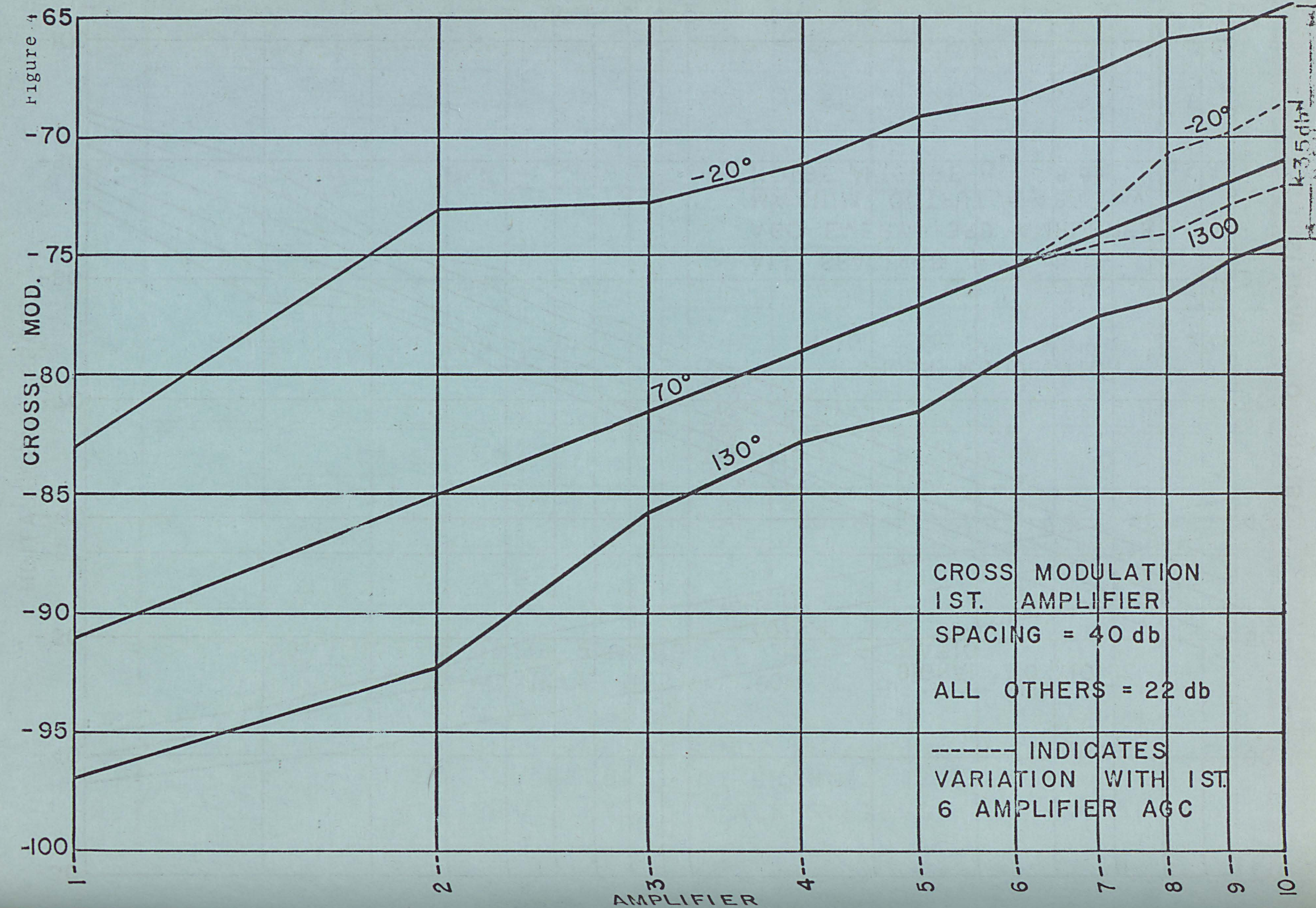
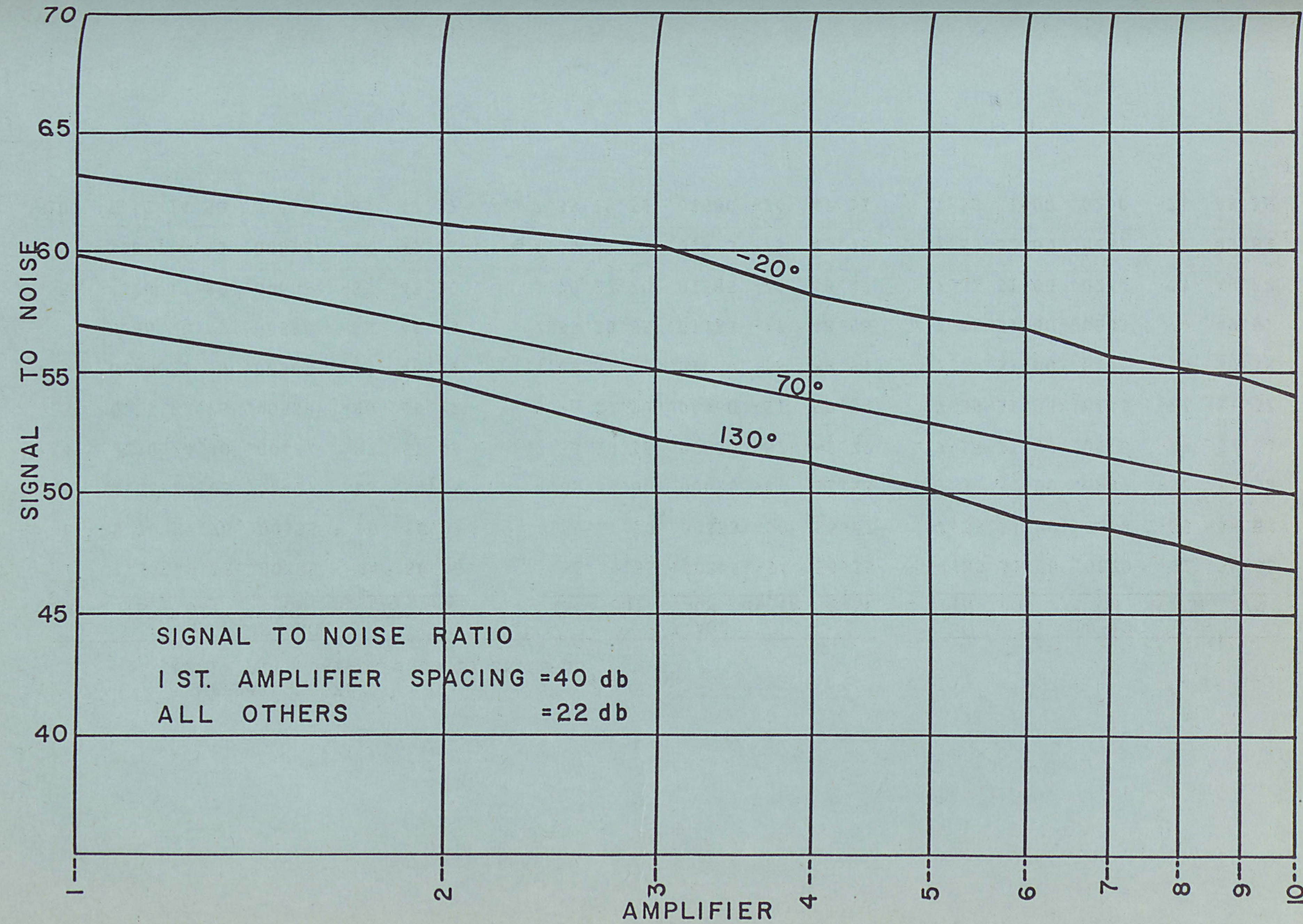


Figure 5 NUMBER OF AMPS. IN CASCADE



TEMPERATURE 130°
CABLE ATTENUATION @ CH-13 23.65 db

AMP #	No AGC					3 AGC					10 AGC				
	IN	OUT	% CM	db CM	S/N	IN	OUT	% CM	db CM	S/N	IN	OUT	% CM	db CM	S/N
1	7.35	29.35	.00205	-94	58.35	7.35	29.35	.00205	-94	58.35	7.35	31.00	.0029	-91	58.35
2	5.70	27.70	.00335	-90	56.07	5.70	27.70	.00335	-90	56.07	7.35	31.00	.0058	-85	55.34
3	4.05	26.05	.00427	-88	54.53	4.05	31.00	.00625	-84	53.53	7.35	31.00	.0087	-82	53.58
4	2.40	24.40	.00492	-87	52.03	7.35	29.35	.00830	-82	52.29	7.35	31.00	.0116	-79	52.34
5	0.75	22.75	.00538	-86	49.17	5.70	27.70	.00960	-81	50.94	7.35	31.00	.0145	-77	51.37
6	-0.90	21.10	.00567	-85	46.59	4.05	31.00	.01250	-78	49.51	7.35	31.00	.0174	-76	50.58
7	-2.55	19.45	.00588	-85	44.43	7.35	29.35	.01455	-77	48.95	7.35	31.00	.0203	-74	49.91
8	-4.20	17.80	.00603	-85	47.30	5.70	27.70	.01585	-76	48.27	7.35	31.00	.0232	-73	49.32
9	-5.85	16.15	.00612	-85	45.21	4.05	31.00	.01875	-75	47.45	7.35	31.00	.0261	-72	48.81
10	-7.50	14.50	.00619	-85	42.97	7.35	29.35	.02080	-74	47.11	7.35	31.00	.0290	-71	48.35

TEMPERATURE 100°
CABLE ATTENUATION % CH-13 22.85 db

AMP #	No AGC IN	No AGC OUT	No AGC % CM	No AGC db CM	No AGC S/N	3 AGC IN	3 AGC OUT	3 AGC % CM	3 AGC db CM	3 AGC S/N	10 AGC IN	10 AGC OUT	10 AGC % CM	10 AGC db CM	10 AGC S/N
1	8.15	30.15	.00230	-93	59.15	8.15	30.15	.00230	-93	59.15	8.15	31.00	.0029	-91	59.15
2	7.30	29.30	.00435	-88	56.52	7.30	29.30	.00435	-86	56.52	8.15	31.00	.0058	-85	56.14
3	6.45	28.45	.00598	-85	53.94	6.45	31.00	.00725	-83	53.94	8.15	31.00	.0087	-82	54.38
4	5.60	27.60	.00728	-83	52.07	8.15	30.15	.00955	-81	52.79	8.15	31.00	.0116	-79	53.14
5	4.75	26.75	.00838	-82	50.53	7.30	29.30	.01160	-79	51.71	8.15	31.00	.0145	-77	52.17
6	3.90	25.90	.00930	-81	49.18	6.45	31.00	.01450	-77	50.67	8.15	31.00	.0174	-76	51.38
7	3.05	25.05	.01003	-80	47.96	8.15	30.15	.01680	-76	50.10	8.15	31.00	.0203	-74	50.70
8	2.20	24.20	.01061	-80	45.88	7.30	29.30	.01885	-75	49.49	8.15	31.00	.0232	-73	50.13
9	1.35	23.35	.01113	-80	45.00	6.45	31.00	.02175	-74	48.85	8.15	31.00	.0261	-72	49.62
10	0.50	22.50	.01154	-79	44.12	8.15	30.15	.02405	-73	48.46	8.15	31.00	.0290	-71	49.15

TEMPERATURE 70˘
CABLE ATTENUATION % CH-13 22.00 db

AMP #	No AGC					3 AGC					10 AGC				
	IN	OUT	% CM	db CM	S/N	IN	OUT	% CM	db CM	S/N	IN	OUT	% CM	db CM	S/N
1	9	31	.0029	-91	60										
2	9	31	.0058	-85	56.99										
3	9	31	.0087	-82	55.23										
4	9	31	.0116	-79	53.98										
5	9	31	.0145	-77	53.00			S A M E					S A M E		
6	9	31	.0174	-76	52.22										
7	9	31	.0203	-74	51.55										
8	9	31	.0232	-73	50.97										
9	9	31	.0261	-72	50.46										
10	9	31	.0290	-71	50.00										

TEMPERATURE 40°
CABLE ATTENUATION @ CH-13 21.22 db

AMP #	No AGC					3 AGC					10 AGC				
	IN	OUT	% CM	db CM	S/N	IN	OUT	% CM	db CM	S/N	IN	OUT	% CM	db CM	S/N
1	9.78	31.78	.00365	-89	60.78	9.78	31.78	.00365	-89	66.78	9.78	31.00	.0029	-91	60.78
2	10.56	32.56	.00775	-83	58.15	10.56	32.56	.00775	-83	58.15	9.78	31.00	.0058	-85	57.77
3	11.34	33.34	.01295	-78	56.75	11.34	31.00	.01065	-80	56.75	9.78	31.00	.0087	-82	56.01
4	12.12	34.12	.01875	-75	55.85	9.78	31.78	.01430	-77	55.29	9.78	31.00	.0116	-79	54.77
5	12.90	34.90	.02605	-72	55.21	10.56	32.56	.01840	-75	54.17	9.78	31.00	.0145	-77	53.80
6	13.68	35.68	.03425	-70	54.75	11.34	31.00	.02130	-74	53.56	9.78	31.00	.0174	-76	53.01
7	14.46	36.46	.04455	-67	54.40	9.78	31.78	.02495	-73	52.80	9.78	31.00	.0203	-74	52.34
8	15.24	37.24	.05615	-66	54.12	10.56	32.56	.02905	-71	52.26	9.78	31.00	.0232	-73	51.77
9	16.02	38.02	.07095	-63	53.90	11.34	31.00	.03195	-70	51.85	9.78	31.00	.0261	-72	51.26
10	16.80	38.80	.08915	-61	53.73	9.78	31.78	.03560	-69	51.32	9.78	31.00	.0290	-71	50.78

TEMPERATURE 10°
CABLE ATTENUATION @ CH-13 20.50 db

	No AGC					3 AGC					10 AGC				
AMP #	IN	OUT	% CM	db CM	S/N	IN	OUT	% CM	db CM	S/N	IN	OUT	% CM	db CM	S/N
1	10.50	32.50	.00410	-88	61.50	10.50	32.50	.00410	-88	61.50	10.50	31.00	.0029	-91	61.50
2	12.00	34.00	.00980	-81	59.17	12.00	34.00	.00980	-81	59.17	10.50	31.00	.0058	-85	58.49
3	13.50	35.50	.01810	-75	57.95	13.50	31.00	.0127	-78	57.95	10.50	31.00	.0087	-82	56.73
4	15.00	37.00	.02970	-71	57.31	10.50	32.50	.0168	-76	56.65	10.50	31.00	.0116	-79	55.49
5	16.50	38.50	.04620	-67	57.00	12.00	34.00	.0226	-74	55.74	10.50	31.00	.0145	-77	54.52
6	18.00	40.00	.06920	-64	56.74	13.50	31.00	.0255	-73	55.20	10.50	31.00	.0174	-76	53.73
7	19.50	41.50	.10170	-60	56.56	10.50	32.50	.0296	-71	54.08	10.50	31.00	.0203	-74	53.06
8	21.00	43.00	.14770	-57	56.44	12.00	34.00	.0354	-69	53.55	10.50	31.00	.0232	-73	52.49
9	22.50	44.50	.20570	-54	56.36	13.50	31.00	.0383	-69	53.21	10.50	31.00	.0261	-72	51.98
10	24.00	46.00	.29570	-51	56.30	10.50	32.50	.0424	-68	52.47	10.50	31.00	.0290	-71	51.50

TEMPERATURE -20°
CABLE ATTENUATION @ CH-13 19.75 db

AMP #	No AGC					3 AGC					10 AGC				
	IN	OUT	% CM	db CM	S/N	IN	OUT	% CM	db CM	S/N	IN	OUT	% CM	db CM	S/N
1	11.25	33.25	.00485	-87	62.25	11.25	33.25	.00485	-87	62.25	11.25	31.0	.0029	-91	62.25
2	13.50	35.50	.01305	-78	60.24	13.50	35.50	.01305	-78	60.24	11.25	31.0	.0058	-85	59.24
3	15.75	37.75	.02685	-72	59.36	15.75	31.00	.01334	-78	59.36	11.25	31.0	.0087	-82	57.48
4	18.00	40.00	.04985	-66	58.91	11.25	33.25	.01819	-75	57.56	11.25	31.0	.0116	-79	56.21
5	20.25	42.25	.08835	-61	58.66	13.50	35.50	.02639	-72	56.75	11.25	31.0	.0145	-77	55.24
6	22.50	44.50	.15235	-57	58.52	15.75	31.00	.02929	-71	56.34	11.25	31.0	.0174	-76	54.45
7	24.75	46.75	.26235	-52	58.44	11.25	33.25	.03414	-70	55.35	11.25	31.0	.0203	-74	53.78
8	27.00	49.00	.44735	-47	58.39	13.50	35.50	.04234	-68	54.86	11.25	31.0	.0232	-73	53.21
9	29.25	51.25	.75735	-43	58.36	15.75	31.00	.04524	-67	54.59	11.25	31.0	.0261	-72	52.70
10	31.50	53.50	1.33735	-38	58.35	11.25	33.25	.05009	-66	53.91	11.25	31.0	.0290	-71	52.25

Cable to first AMP = 40 db @ 70°, 35.8 db @ -20° and 43.0 db @ 130°
All other spacings = 22 db @ 70°, 19.75 db @ -20° and 23.65 db @ 130°

AMP #	-20° IN	-20° OUT	-20° % CM	-20° db CM	-20° S/N	130° IN	130° OUT	130° % CM	130° db CM	130° S/N
1	13.20	35.20	.0073	-83	63.20	6.0	28.00	.00147	-97	57.00
2	15.45	37.45	.0230	-73	61.15	4.35	26.35	.00250	-92	54.74
3	17.70	31.00	.0232	-73	60.27	2.70	31.00	.00540	-86	52.20
4	11.25	33.25	.0281	-71	58.14	7.35	29.35	.00745	-83	51.26
5	13.50	35.50	.0363	-69	57.24	5.70	27.70	.00875	-82	50.16
6	15.75	31.00	.0392	-68	56.76	4.05	31.00	.01165	-79	48.94
7	11.25	33.25	.0441	-67	55.68	7.35	29.35	.01370	-78	48.47
8	13.50	35.50	.0523	-66	55.14	5.70	27.70	.01500	-77	47.86
9	15.75	31.00	.0552	-66	54.85	4.05	31.00	.01790	-75	47.10
10	11.25	33.25	.0601	-65	54.13	7.35	29.35	.01995	-74	46.89

CHAIRMAN TAYLOR: Thank you both very much. (Applause) Are there some questions?

MR. KEN SIMONS: This is not exactly a question but I would like to take this opportunity to thank Jerry and Bob for an excellent paper. I would also like to express the hope that their pioneer effort shows the way toward a future in which CATV equipment will be sold based on specifications measured by both the supplier and the user. Our industry must grow past the era of extravagant claims into one of solid engineering accomplishment.

CHAIRMAN TAYLOR: Thank you again very much. Bob, please accept my apologies for omitting your name from the program.

We will now move on to the final paper of the afternoon. Mr. William Rheinfelder received his M.S.E.E. degree from the Institute of Technology in Munich, Germany. For the past two years he has been director of research and development at Anaconda Astrodata. From 1960 to 1964 he was with Ameco as director of research and development. Prior to his entry into the CATV field, Mr. Rheinfelder was staff scientist for communications research at Motorola Semiconductors. Mr. Rheinfelder is a senior member of the I.E.E.E., the S.M.P.T.E. and a member of the A.E.S. Mr. Rheinfelder will speak on the subject of "Distortion Measurement Techniques for CATV."

June 27, 1967

The Technical Session, held in the Adams Room of the Palmer House, Chicago, Illinois, convened at nine o'clock, a.m., Col. DeWolf Schatzel, A. Earl Cullum, Jr., Consulting Engineers, Dallas, Texas, presiding.

CHAIRMAN SCHATZEL: Good morning, ladies and gentlemen.

For the benefit of any of you who do not know where you are or what you are doing here (laughter), let me announce that this is the Tuesday morning Technical Session of the NCTA Convention.

My name is "Dutch" Schatzel, and I have the pleasure of presiding over the meeting this morning, and more particularly of introducing the speakers.

We have a great deal of highly important and interesting information to pass on to you today through our various speakers, so we are going to endeavor to be as brisk as possible and move along rapidly adhering to the schedule as closely as possible.

Our first presentation this morning is a sort of a "double play" actually, for we have two speakers. I am going to introduce the first, who will then introduce the second speaker, after, I understand, some brief remarks.

The subject is one we have all been following with great interest for the past couple of years. The subject is SHORT HAUL MICROWAVE, another means for getting information in large volume from one point to another rather nearby point.

The people who have been doing this represent a joint venture, as I understand it, of the TelePrompTer Corporation and Hughes Aircraft Corporation.

Our first speaker this morning represents Hughes Aircraft Corporation, and is a graduate of the University of Utah, where he also received his Doctorate.

He has had 12 years of very wide experience in microwave developments of all kinds, and at the present time is the Manager of the Microwave Components Department of the Research and Development Division of Hughes Aircraft Company.

It is a great pleasure to introduce Dr. Howard Ozaki (Applause).

DR. HOWARD OZAKI (Hughes Aircraft Company): Thank you very much.

This paper is a joint effort of Mr. Lyle Stokes and myself, and will be presented by Mr. Stokes who is a Senior Scientist in the Research and Development Division of the Hughes Aircraft Company where he is presently Head of the Telecommunications Group Staff.

His past credits include responsibility for the subsystem design for the receiver signal processing, transmitter and television sub-systems for the Surveyor Spacecraft. Before that time he had worked in many missile and electronics radar applications.

More important to us in our department, he was one of the chief instigators and contributors to the AML short haul microwave concept, and he has been working with us since the beginning of the program. What you have seen and are to see is in great part due to his early efforts in this program.

With that, I introduce Mr. Lyle Stokes. (Applause)

MR. LYLE S. STOKES (Senior Scientist, Systems Laboratory, Research and Development Division, Aerospace Group, Hughes Aircraft Company, Culver City, California):

In May 1965, a representative of the TelePrompTer Corporation came to Hughes Aircraft to discuss some of their hopes for the future. It was suggested that there was a need for a particular kind of microwave link, and the discussion continued on as to the possibility of doing something about it.

As a result, I had a call wanting to know if I would like to be involved in the project.

It developed that they desired to transmit 12 channels of television to multiple receivers in a metropolitan area in order to eliminate the necessity for digging up the streets to lay coaxial cable. In addition, they wanted to be able to use such a system for point-to-point operation to satellite cities. There was also involved the possibility of jumping barriers such as rivers and other obstacles that would be very costly in getting around by ordinary means.

I gave it some thought and began to wonder how we were going to do this. I continued thinking about it, and approximately a month later we did get together with the TelePrompTer people, and I asked them what they were going to call this?

They indicated it would be known as the Short Haul Multiple Channel Microwave Link.

As you can readily understand this represents quite a mouthful, and we decided to shorten it and call it AML . . . meaning Amplitude Modulated Link. Several weeks later we had an operating "breakboard" which is shown on the first slide (slide).

This really contains all of the components of the link as we eventually camp up with it. You have the transmitter, which is located in this lower region (indicating), adjacent to the horn.

Our desire was to put complexity into the transmitter and make the receiver simple because we hoped to use a number of them with each transmitter. You can readily see that we achieved that goal.

We invited our division director down to see this, and gave him an opportunity to view all of Los Angeles' television signals coming over, and all of the Los Angeles' frequency modulation station as well. He looked at Channels 2, 4, 5, 9, 11, and 13, and he indicated he thought it was great.

We sent on to the experimental stage. First at X Band, and then at 18 gigahertz.

We chose this, first, because it was not crowded; and second, it was also one that had reasonable losses in terms of weather.

We desired 12 channels, and we have 12 channels now.

We aimed at 57 db overall as the system inter-modulation specification where each inter-modulation product should be at least that far below the peak carrier.

The range of six miles was one which we achieved with a rather low-power transmitter which I will mention later as we move along.

It provided a wide beam so as to cover a large section of the city. The output was equal to the input frequencies. This was important where the eventual signal coming to the home would be in competition with the signal from the TV station itself. We wanted to have them identical so that there would be no beat notes between the two signals. We have achieved that by a phase-lock receiver.

(Slide) Here we see a transmitter block diagram. We have omitted the proprietary lines from this. We really have two transmitters, divided in half, with a line going through that area (indicating).

The klystron is synchronized or phase-locked to a crystal, and that crystal is in the synchronizer. The synchronizer has a signal that also comes to this lower converter (indicating), where a tone is placed between Channels 4 and 5. You will note the 4 megacycle gap, and the tones put into that gap are the ones which we use in the receiver to develop our synchronous receiver local oscillator.

The oscillator, then is coherent with the crystal frequency, or the klystron, as shown here (indicating).

The important step is the converter that shifts the incoming signals to a higher frequency, and from there they filter off into a single side band filter, and to the transmission amplifier.

In the particular case indicated, the RF signals add in space, eliminating any loss you might encounter.

(Slide) The receiver is the sort of elemental structure you would have in a UHF down converter. We are using UHF a little higher in this case. It has an additional feature that you do not find in most UHF converters, namely a phase-lock loop which gets rid of the beat problem that I mentioned earlier.

A pilot tone filter of about one megacycle bandwidth removes all channels of the 4 TV channels and leaves just the pilot tone at a frequency between channel 4 and 5. Then the phase detector compares that tone with the solid state multiplier frequency. This is all done automatically.

(Slide) We have gone through the block diagram. We know the frequency we will operate at, and the next is the question of the parameters.

This (indicating slide) represents a diagram of those parameters.

The required output signal to noise ratio is 45 db peak to RMS, which is an excellent quality TV signal. We have a 12 db receiver noise figure. The receiving antenna has a gain of 44 db which corresponds to a 4-foot dish.

We have for the transmitter chosen to use a 27 db gain antenna which provides a large fan (approximately 15 degrees wide) and two degrees in height for the six mile range.

With higher gain antennas you can well imagine that longer ranges are available.

The design margin of 7 db is to provide for propagation effects such as rain, fog, and snow. With this particular set of parameters you can endure a rain rate of one-half inch per hour, which is called by the weather bureau "heavy rain", and there is still no loss in signal to noise ratio.

(Slide) The next few slides will show the experimental stages.

This is the converter stage.

(Slide) This is the power amplifier.

(Slide) This is our "breadboard" receiver. The antenna remains pretty much the same as in the prototype which we will see in a moment.

(Slide) This shows the inside of the receiver. The output of this unit can feed directly into the home receiver, and the TV signals are available there.

We now had a transmitter-receiver experimental version, and the next thing to do was to conduct experiments with it.

(Slide) We found that, indeed, we could put 12 channels through the system. We determined where the inter-modulation level came out. We found that the transmitter noise figure was suitably low with the type of up-converter and the type of traveling wave tubes we knew we could make.

We had identical input and output signal frequencies because of the pilot tone that had been added.

The next thing we needed to do was to conduct some rain tests. We did them in New York City. These were made over a period of four or five months. The data was analyzed.

This (indicating slide) represents a summary of that data. It turned out about as you would expect in computing weather statistics. Most weather data will state that it rained an inch during a particular day. It may have happened in a minute, or some very short period of time, and this may wipe you out. If it happened all day, it would not bother you.

As far as I know, only one person has done work on short term weather effects and in this instance it is a gentleman by the name of Bussey. This individual has analyzed the statistics for one minute; one hour; and one half-hour. Using the data he had available there for the types of weather and comparing it with weather data we actually observed in New York City, we came up with this curve (indicating), which shows the New York City-Washington, D.C. expected performance.

If you will look at this line (indicating) for 40 db, it indicates that the performance of our system we expect to be 40 db or better except for six hours a year, at a six-mile range. At a four-mile range, for instance, it indicates that signal to noise ratios should be 40 db or better except for about two and a half hours a year.

So, there is a very small time each year when we expect the signal to go down below the 45 db excellent picture quality. These two, three, or four hours, however, will give us a type of "snow" picture in the 20 db range, and it may occur between midnight and three o'clock in the morning, when not too many people will be watching.

With these experimental tests being conducted, Hughes and TelePrompTer embarked in a joint venture called Theta-Com, and decided to build some prototypes.

(Slide) Many of you have seen the receiver in the display. This is the inside of it.

This box is now approximately 14 inches by 9 inches by 2-1/2 inches.

The package is done in a casting. It has a separator down the center, and there is an upper and lower level; and it provides the RF shielding between various portions of the receiver.

This entire unit is shielded with a copper sheet over top and bottom before being hermetically sealed.

It has, as you can see, two wires going in, and this represents a 28-volt DC as required, with the third wire, which is the VHF output, which goes directly into the CATV system.

(Slide) This is the driver unit, the prototype driver unit, that you may have seen in the display. It has two outputs that can be combined into a single output if desired, or can drive two separate amplifiers.

(Slide) One thing that was required for the prototype was a sufficiently high power traveling wave tube. There are none available. Hughes, however, has built a number of traveling wave tubes. In fact, they are presently aboard the Surveyor and other satellites used by NASA. They are aboard the Boeing Lunar Orbiter; the JPL Mariner; and Apollo Spacecraft.

The traveling wave tubes developed have collectively accumulated over 10 years in space without a single failure so far. These traveling wave tubes have also been put in high-power radars with average powers in the order of many hundreds of watts.

So, we would like to have a traveling wave tube that has low noise and high power and operates in the 18 gigahertz band.

We asked what could be done?

As we realize, high power and low noise do not go together.

We, however, designed a tube that was built specifically for high power and low noise. This is the "innards" of that tube. (Slide)

At the far end, at the top of the picture, is the black item which is the electron gun, next is the traveling structure, next the input and output wave guide flanges; the collector heat sink; and at the end it has its own private ion pump to take care of the loose ions that might be floating around.

This TWT has a saturated output of 250 watts.

Actually, you would operate this tube at about one and a half to two watts total output power in order that the IMP be sufficiently low.

There are two of these units, plus the drive unit, plus the receiver unit, which make a complete system. It has, however, several options depending on the type of range required.

(Slide) This is the prototype unit. We have the receiver, the receiver antenna, and they are shown in the next slide (slide), and in this you will recognize the prototype as you have seen it in the display.

This is a completely weatherproofed unit and is suitable for us in any of the various available AML configurations.

(Slide) This shows a transmitter antenna. It is a side view indicating the input flanges and mounting brackets.

(Slide) This shows a front view of the antenna, and here you can see how two antennas are combined into one package. The idea is that each of these sections is driven by a single power amplifier, and here is where the diplexing is done, rather than having a diplexing loss before the antenna structure is encountered.

Those are the antennas, and that is the prototype system.

Right now we have reached the point in the pilot line production where we have a number of receivers; we are working on a number of transmitters; and we are moving along on a system that gives over 100 megacycles of base band capability.

Thank you very much. (Applause)

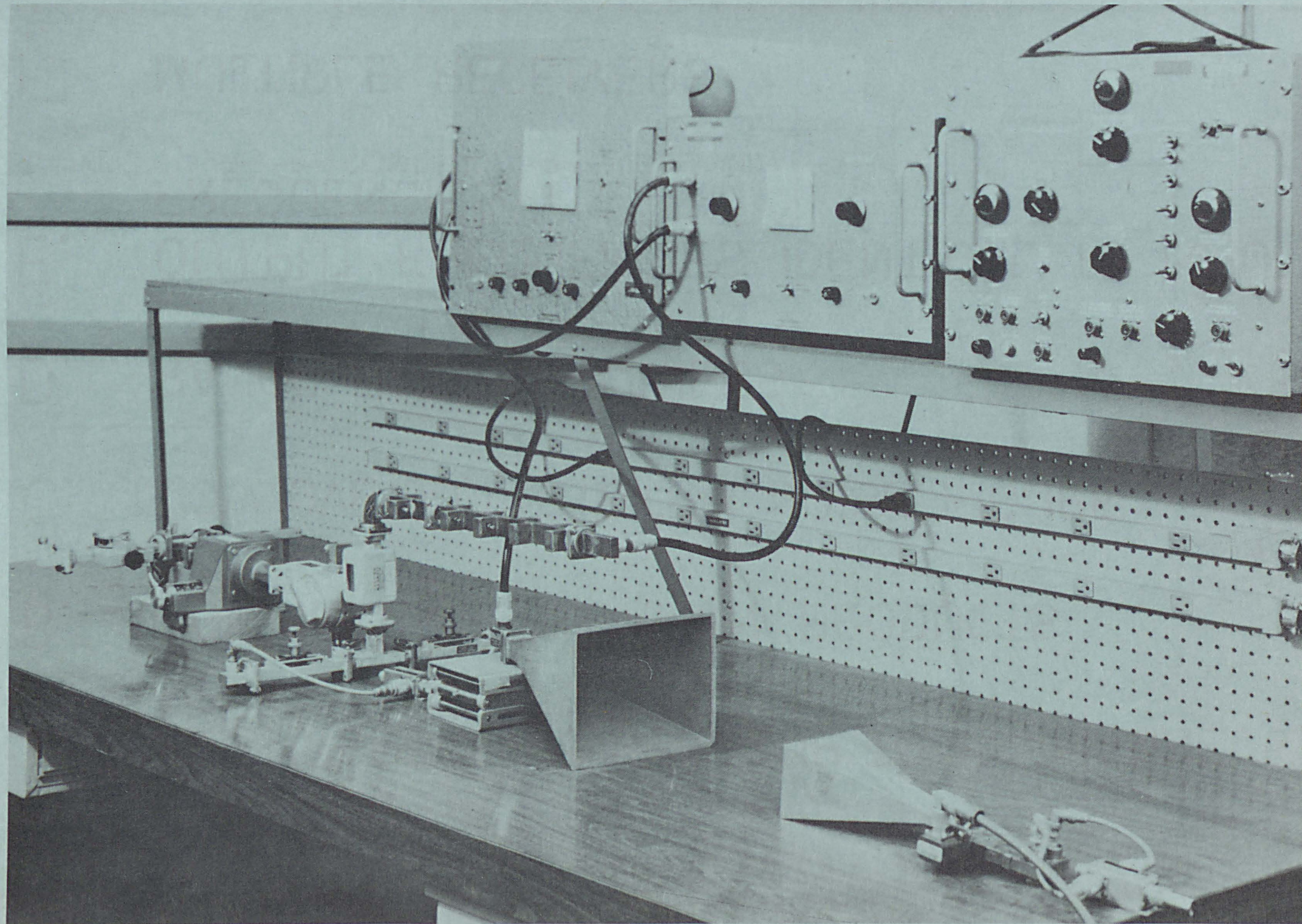


Figure 1 X-band Breadboard of AML system

18 gHz MICROWAVE LINK

A. MULTIPLE CHANNELS (UP TO 12 CHANNELS)

B. LOW INTERMODULATION PRODUCTS

C. LOW OVERALL SYSTEM NOISE FIGURE

D. RANGE UP TO SIX MILES

E. OUTPUT FREQUENCIES IDENTICAL TO INPUT FREQUENCIES

F. MULTIPLE RECEIVERS

Figure 2 AML Overall specificiation

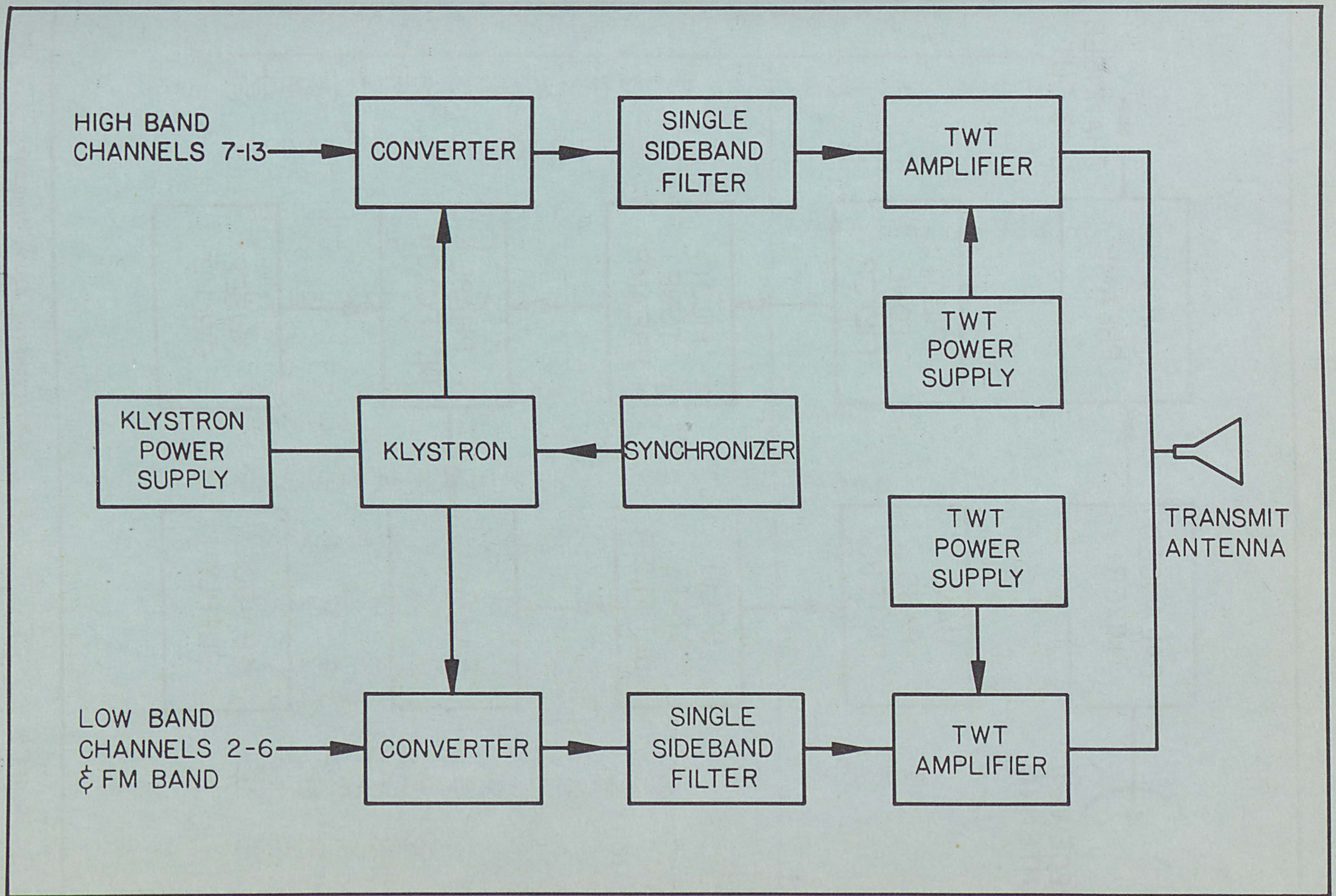


Figure 3 AML transmitter block diagram

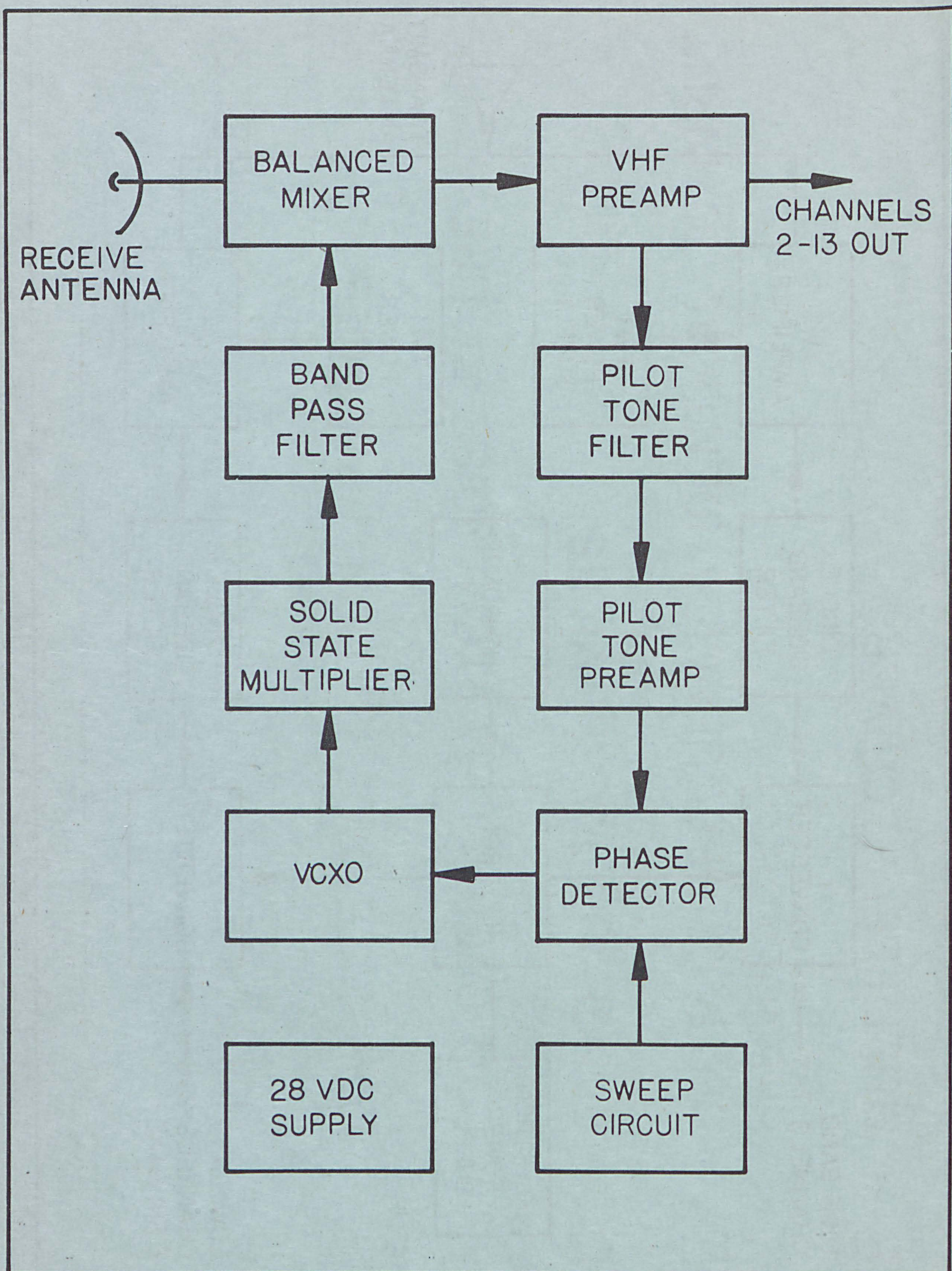


Figure 4 AML receiver block diagram

Figure 5 AML operating parameters

THERMAL NOISE (KTB) DENSITY	−59 dbmv (−108 dbm)
NOMINAL RECEIVER NOISE FIGURE	12 db
RECEIVER NOISE DENSITY (PER 4 mc CHANNEL)	−47 dbmv (−96 dbm)
REQUIRED PEAK SIGNAL TO RMS NOISE RATIO	45 db
MINIMUM RECEIVED PEAK POWER PER CHANNEL	−2 dbmv (−51 dbm)
RECEIVER ANTENNA GAIN	−44 db
PROPAGATION LOSS (6 MILES)	+138 db
TRANSMITTER ANTENNA GAIN	−27 db
MINIMUM TRANSMITTER PEAK POWER PER CHANNEL	+65 dbmv (+16 dbm)
MINIMUM TRANSMITTER PEAK POWER FOR 12 SYNCHRONOUS CHANNELS	+76 dbmv (+27 dbm)
DESIGN MARGIN	7 db
TOTAL TRANSMITTER POWER	+83 dbmv (+34 dbm)

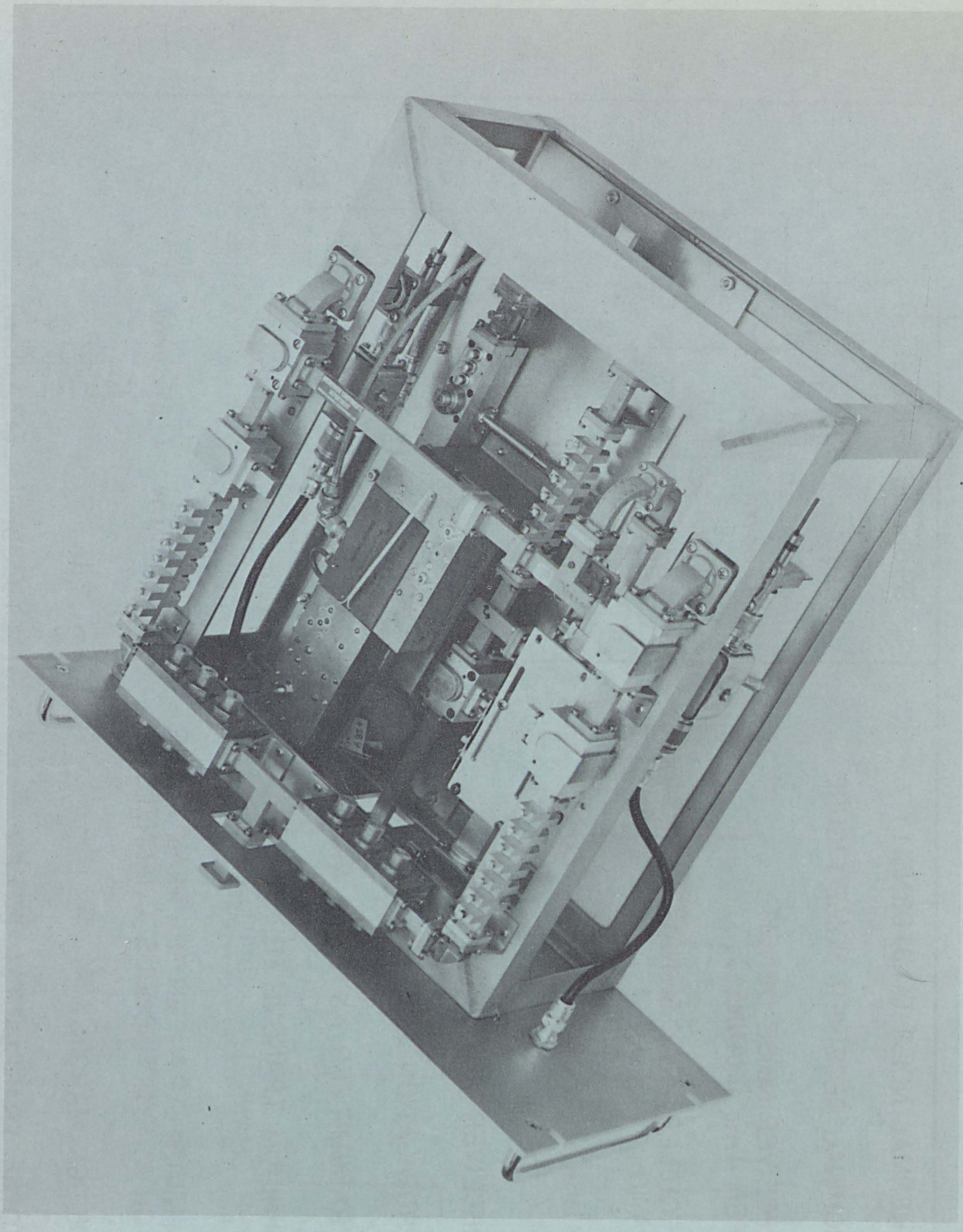


Figure 6 AML experimental model upconverter

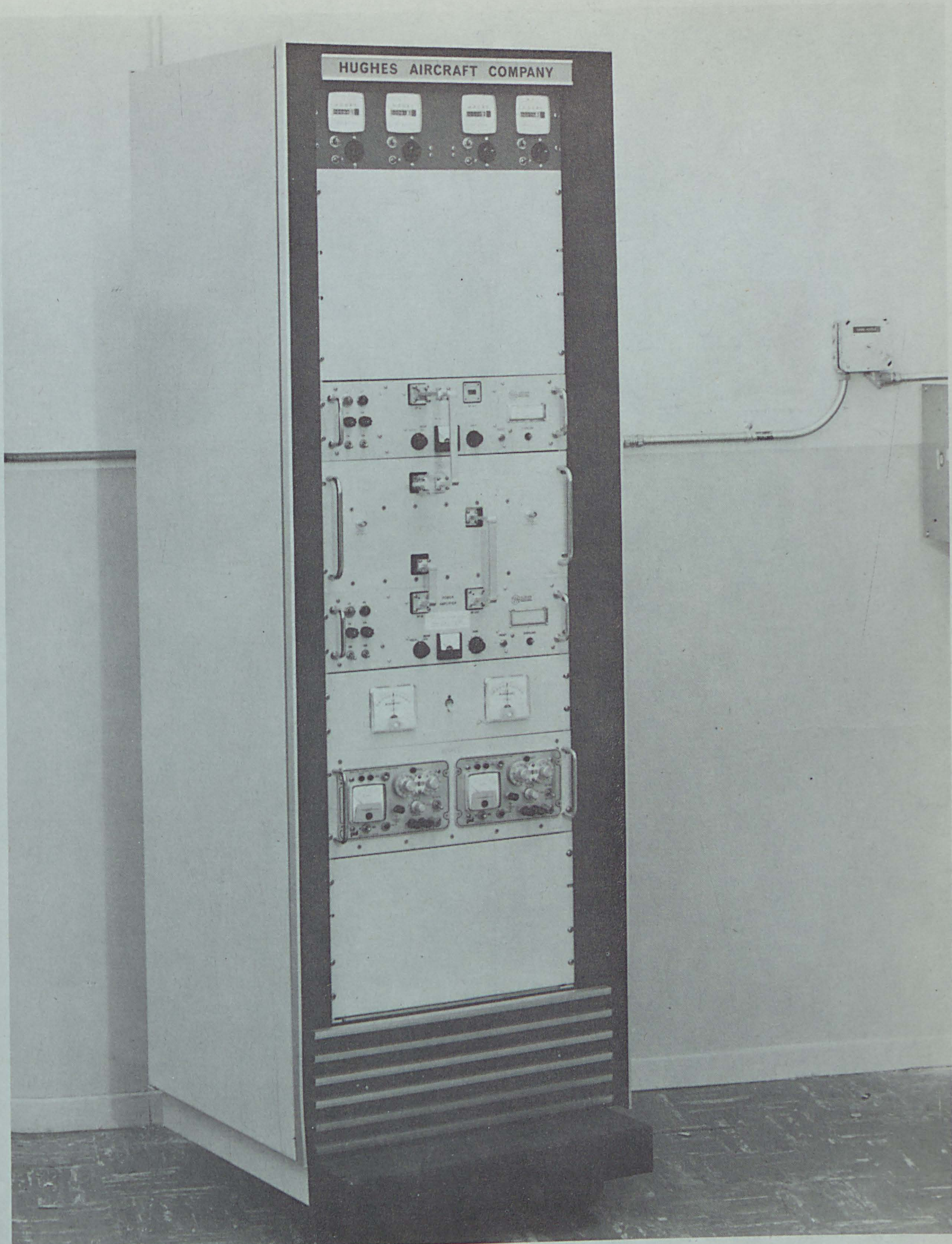


Figure 7 AML Experimental Power Amplifier

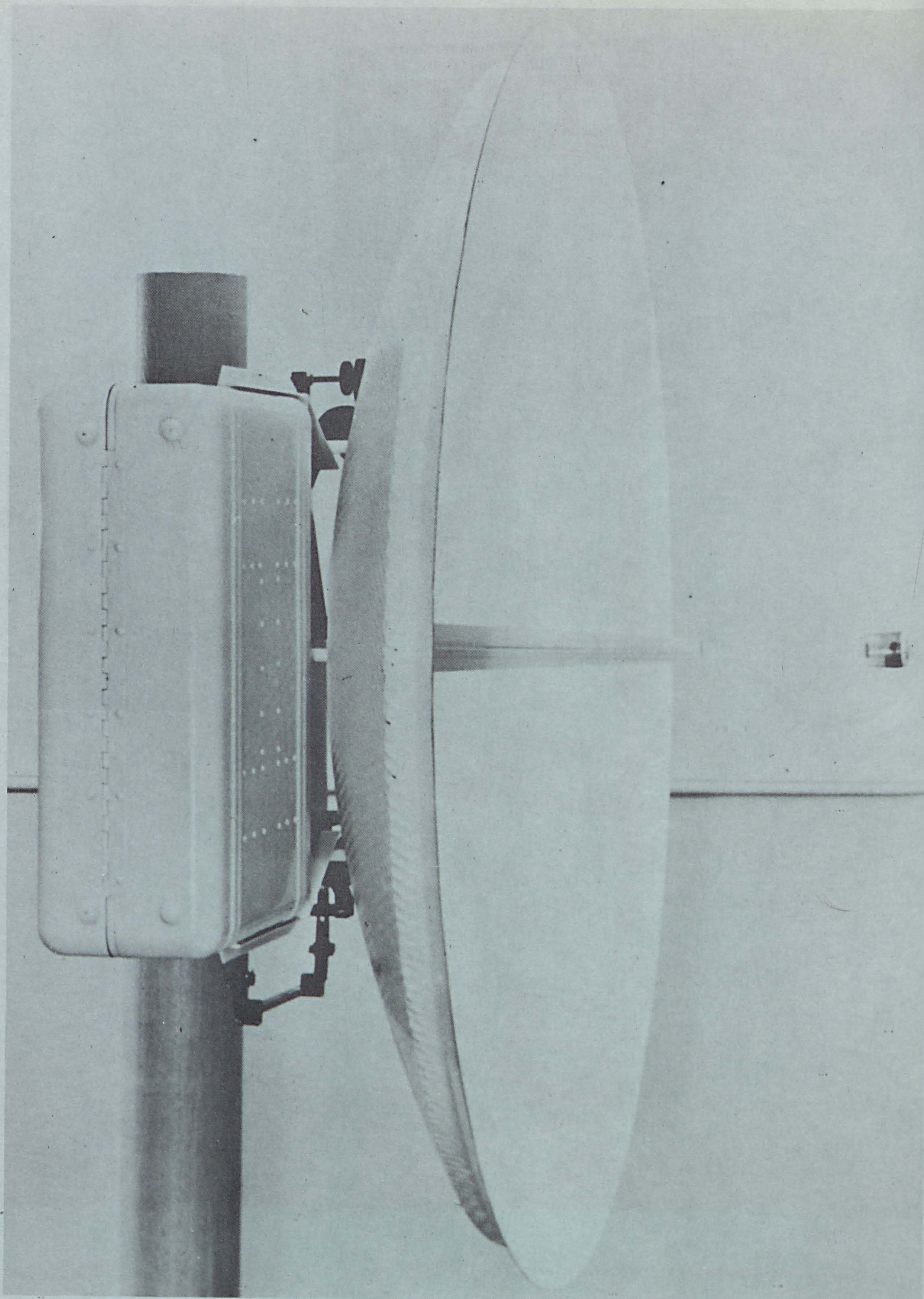


Figure 8 AML experimental receiver and receiving antenna

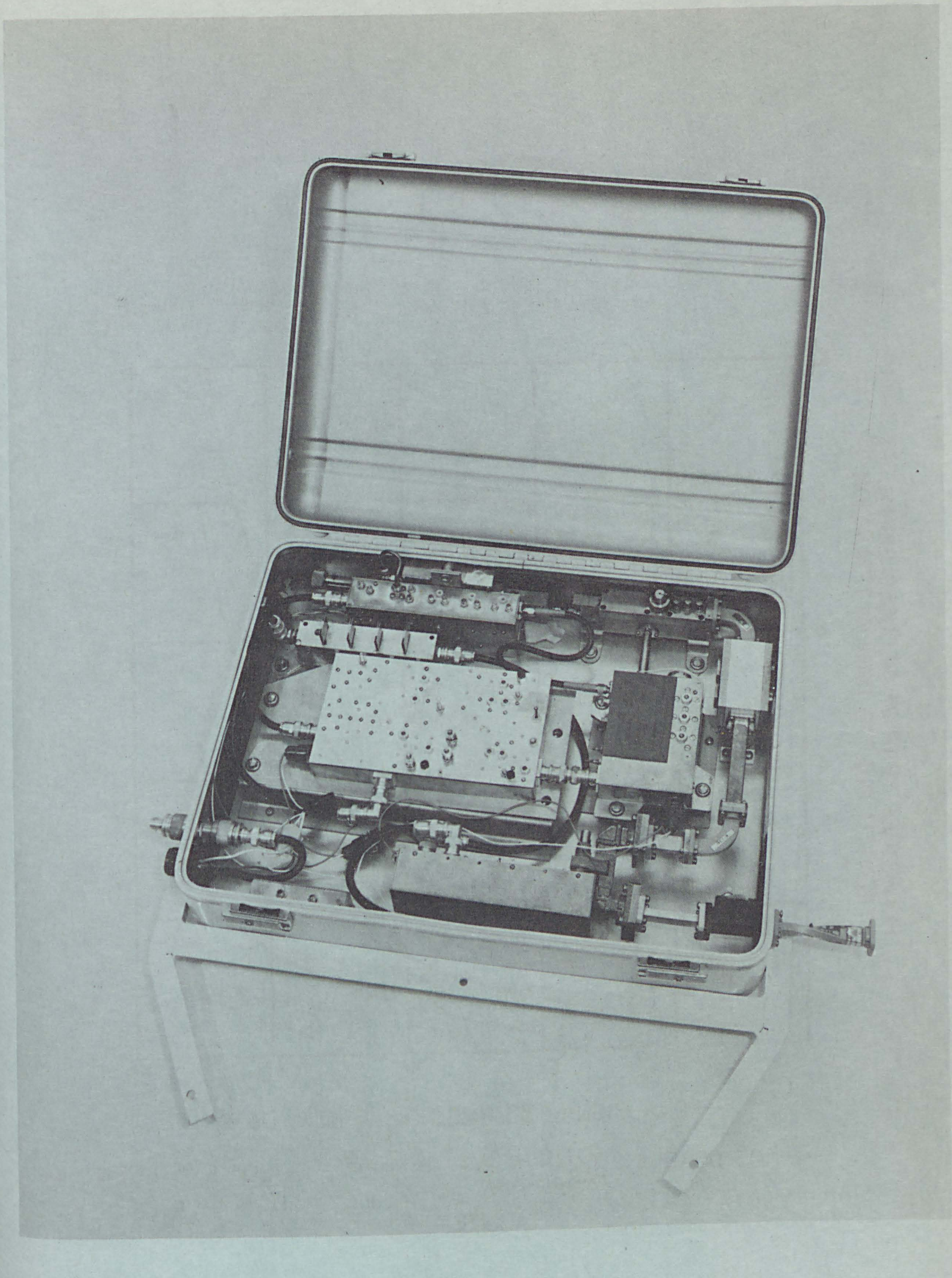
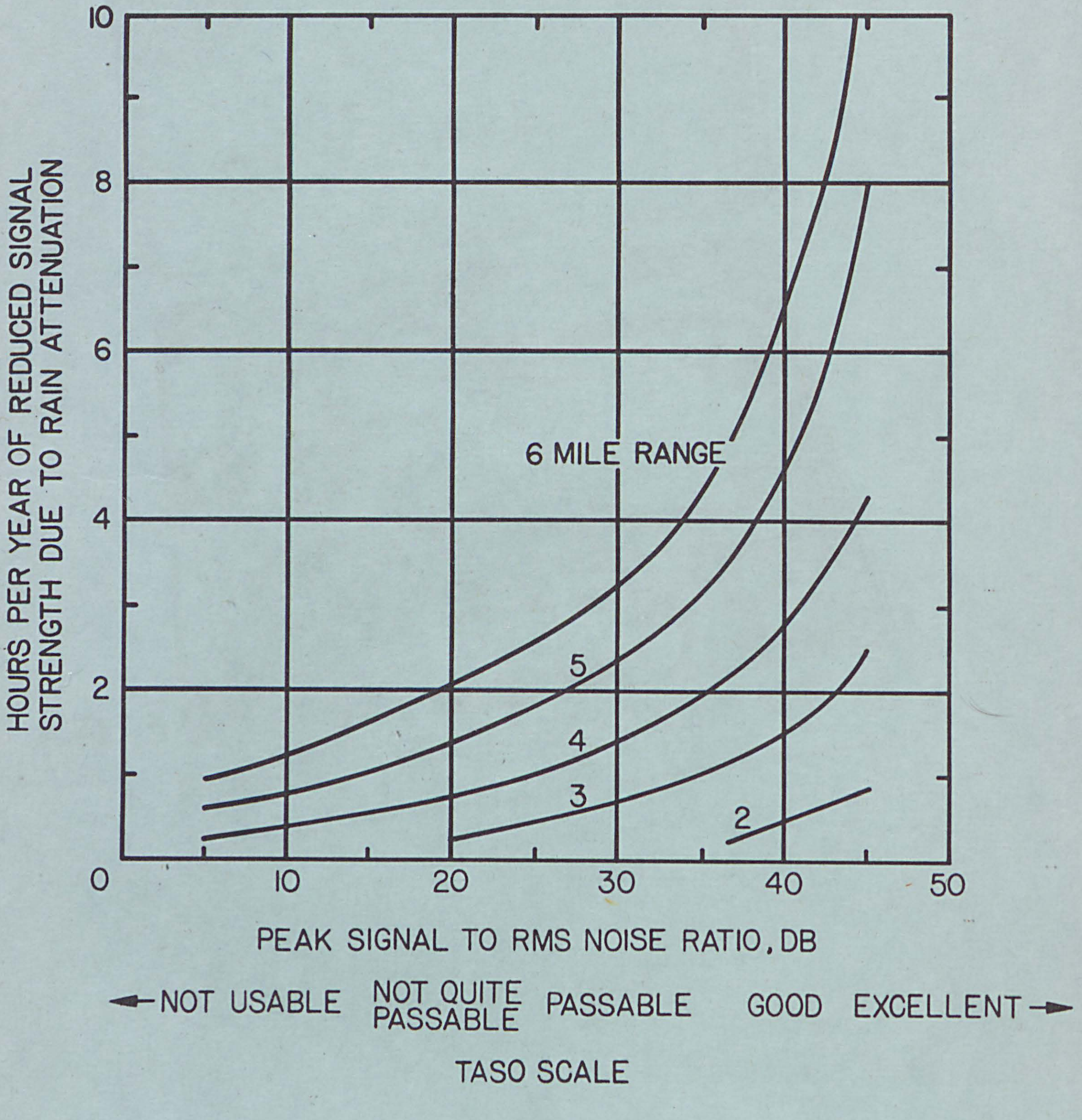


Figure 9 Inside view of AML experimental receiver

Figure 10 Subjective effect of rain on AML performance for one year in the Washington, D. C./New York City area.



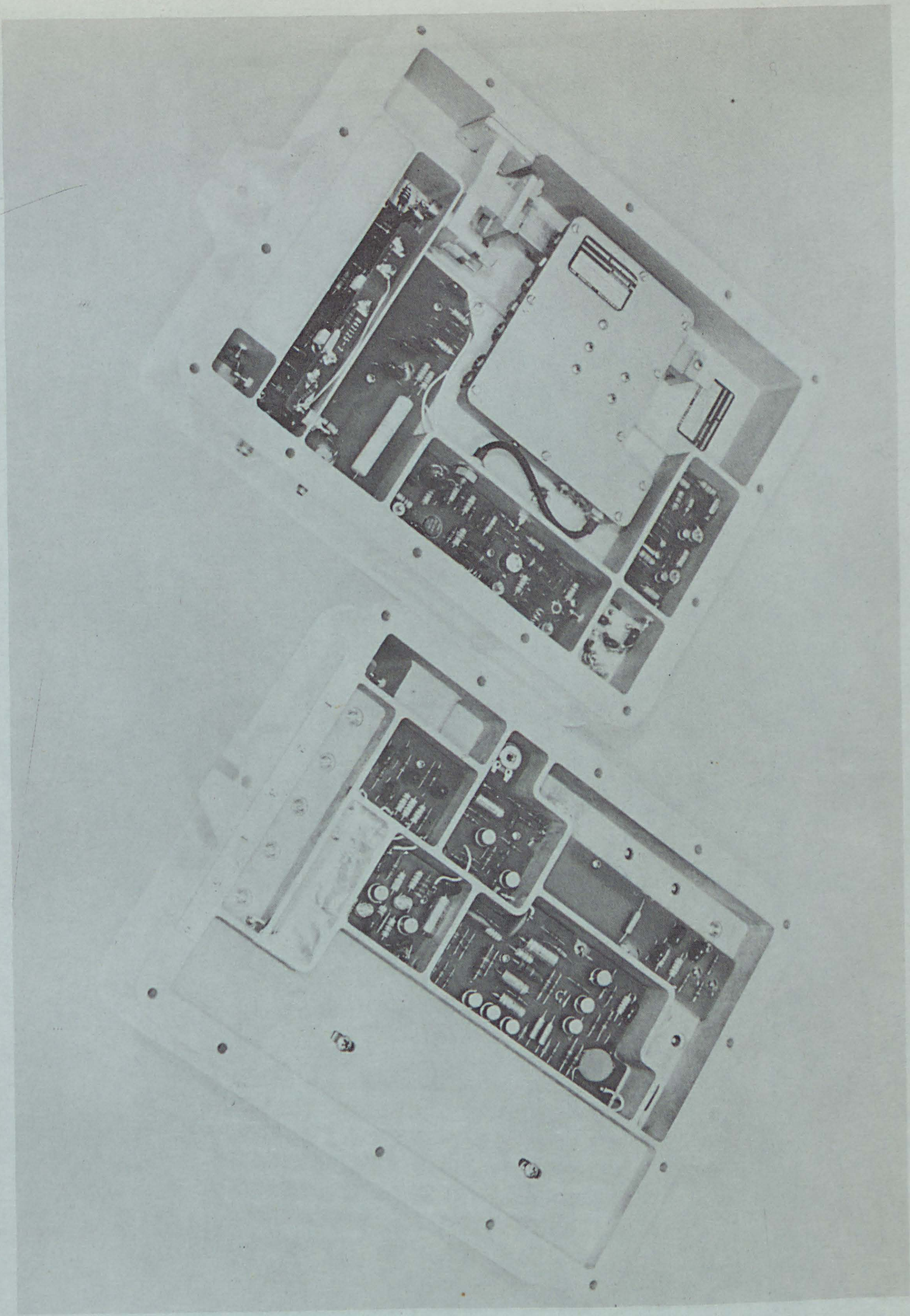


Figure 11 Inside view of the prototype AML receiver

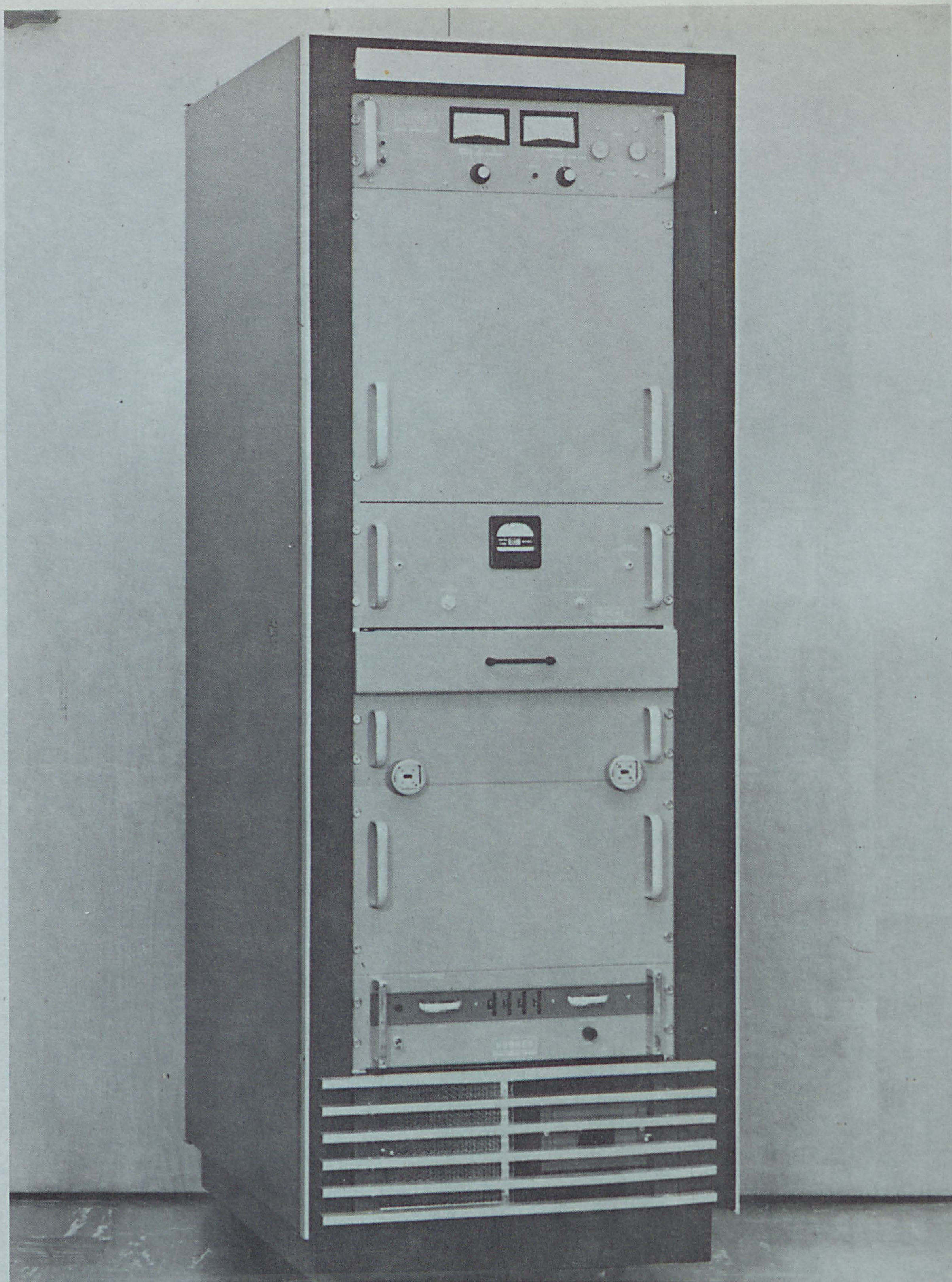
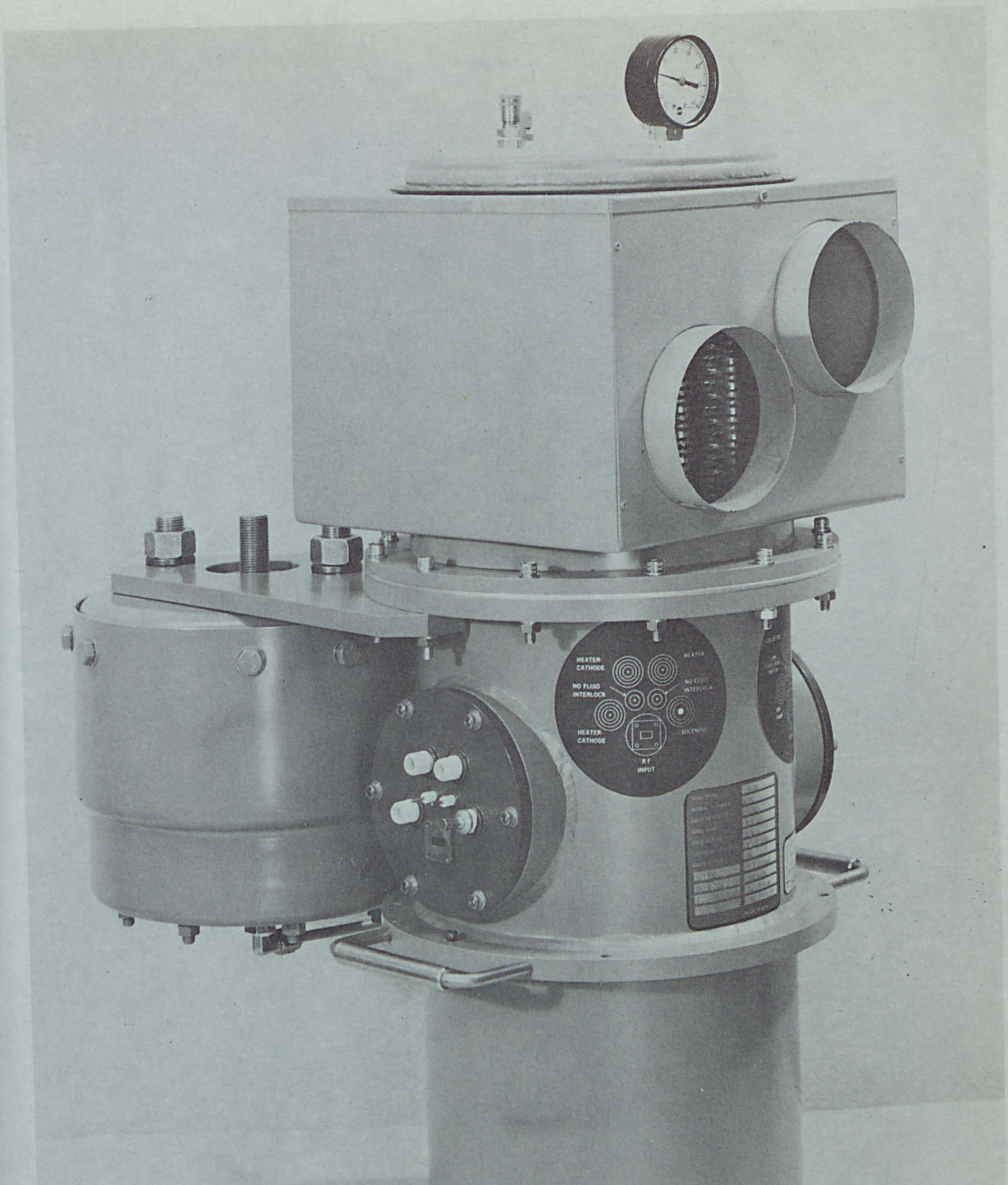


Figure 12 Prototype AML driver unit


HEATER-
CATHODE
HEATER
NO FLUID
INTERLOCK
NO FLUID
INTERLOCK
HEATER-
CATHODE
SOLENOID
RF
INPUT

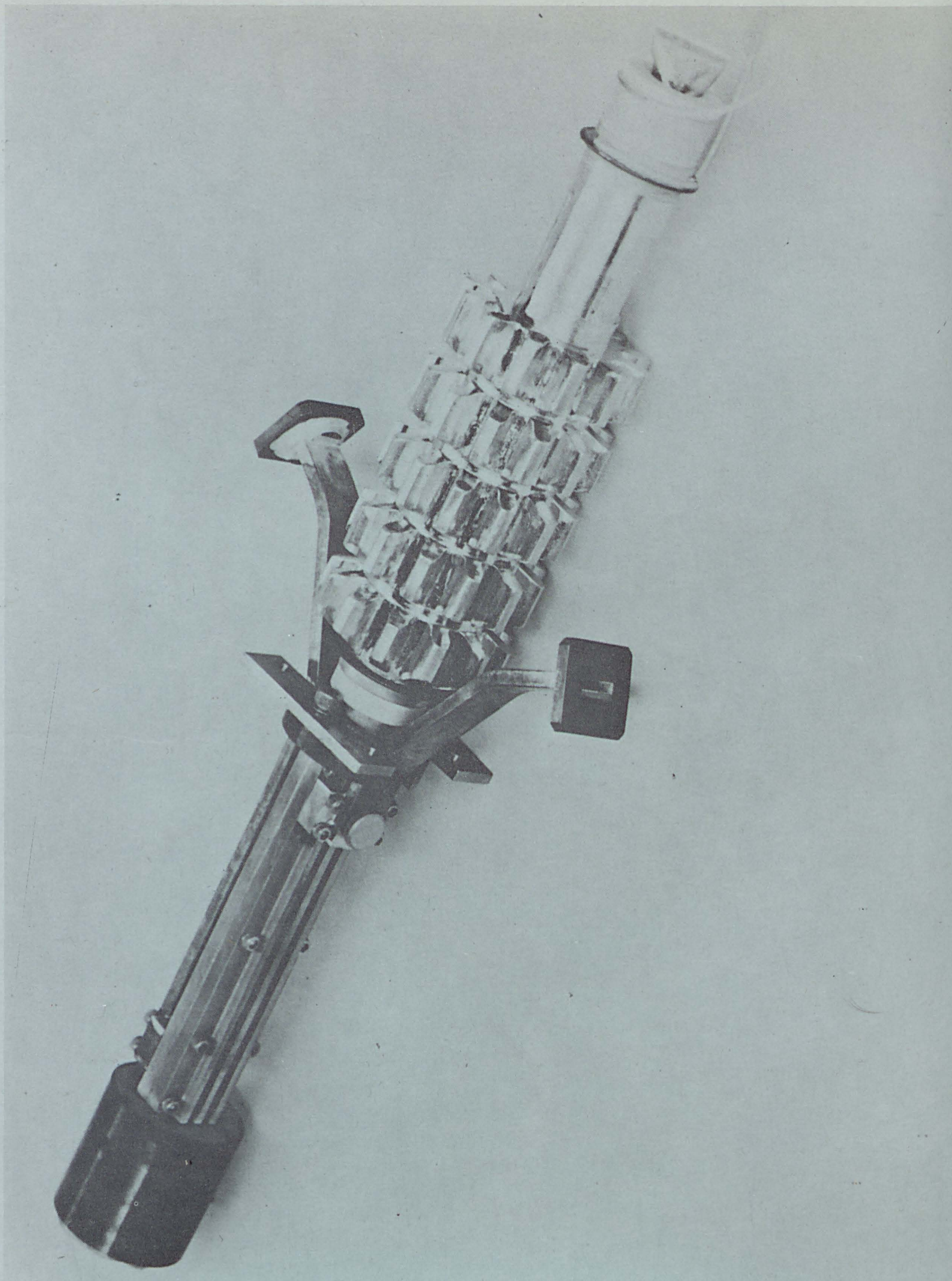


Figure 13a, b Internal views of the AML prototype TWT

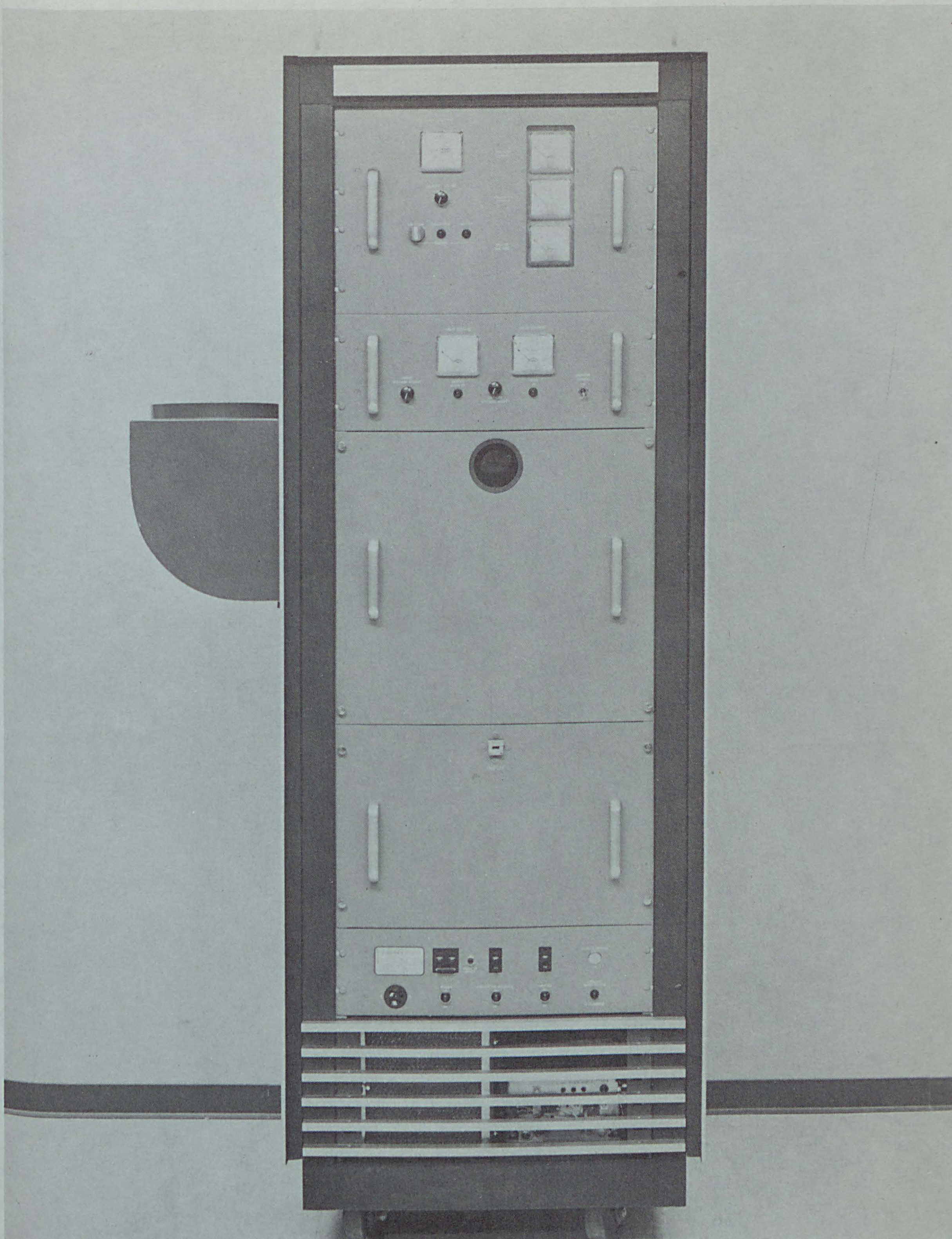


Figure 14 AML prototype transmitter power amplifier

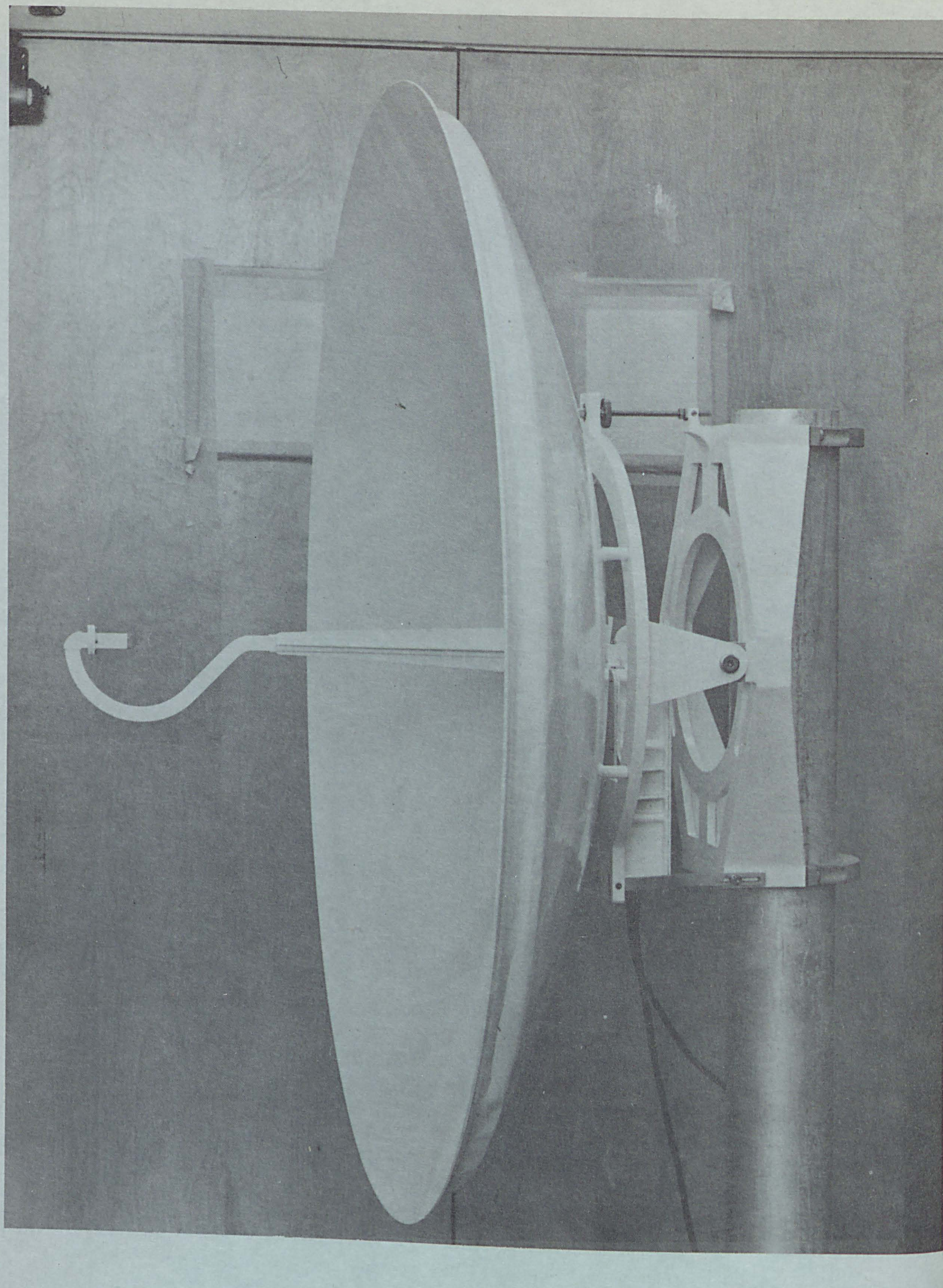


Figure 15 AML prototype receiver and receiving antenna

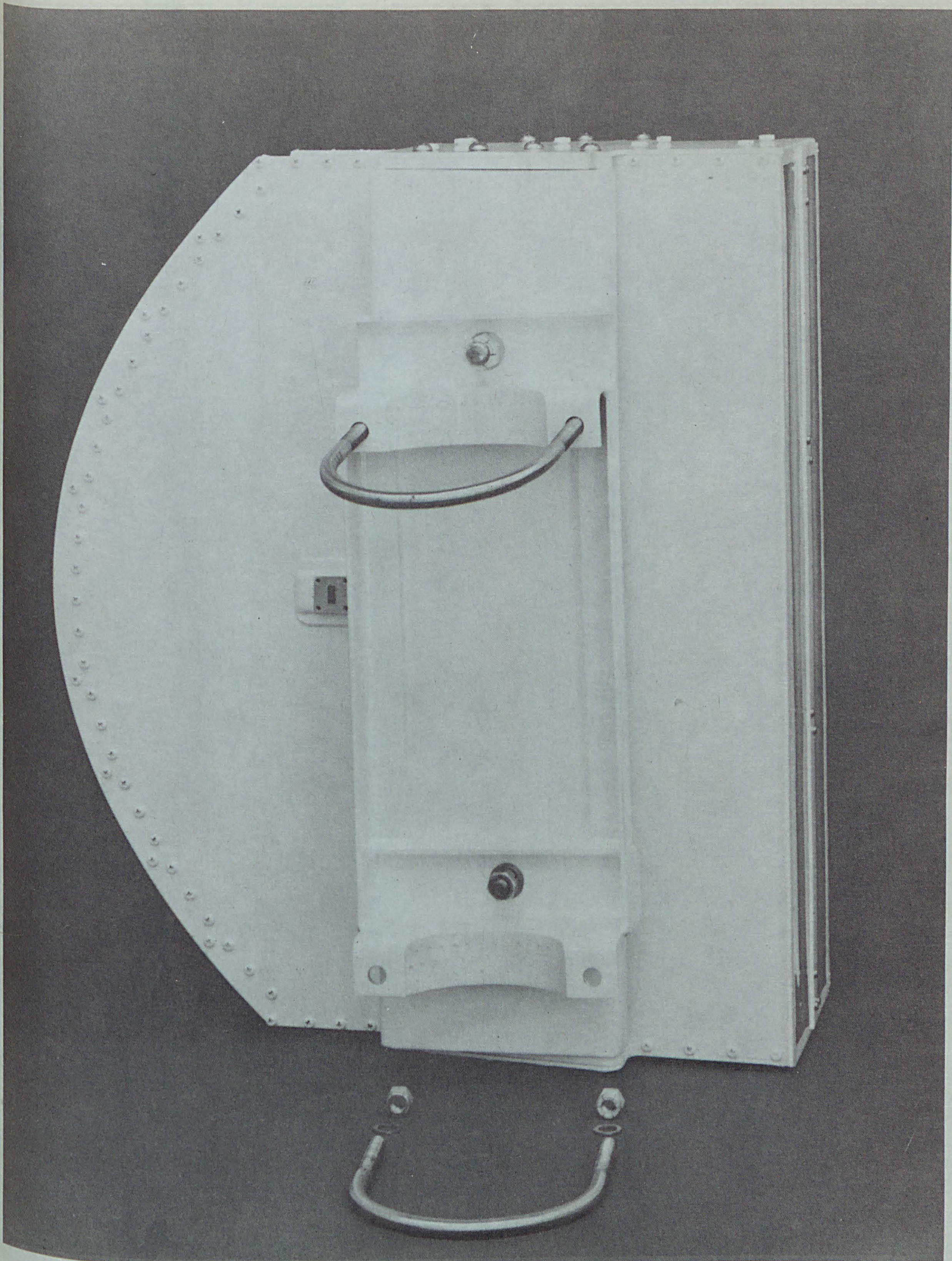


Figure 16 AML prototype transmitting antenna, side view

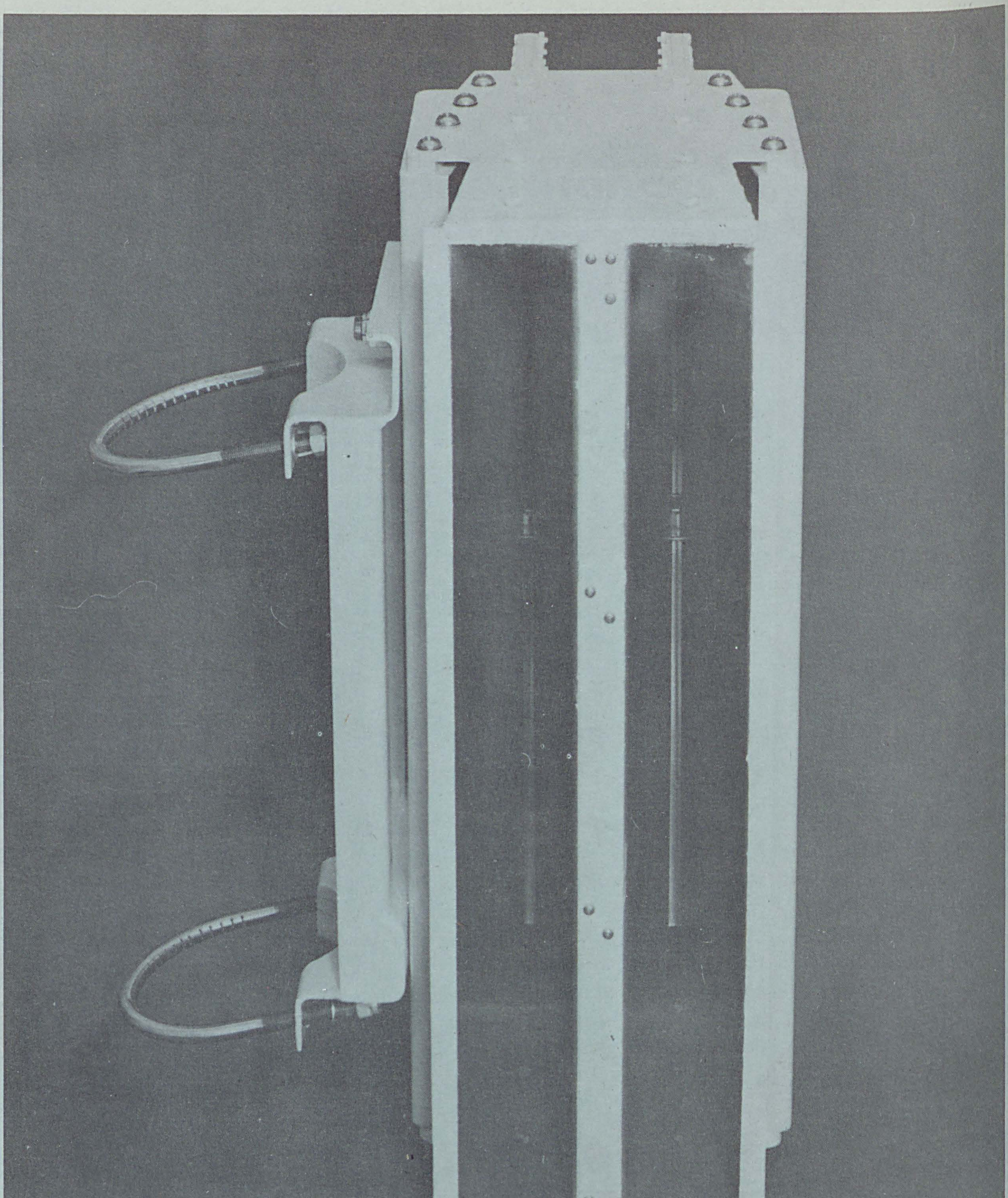


Figure 17 AML prototype transmitting antenna, front view

CHAIRMAN SCHATZEL: Thank you very much. I think this team from Hughes Aircraft Company given us an extremely worthwhile progress report a development that I am sure we will see a great al more of as the years go by, the FCC willing, and hope that they will be willing.

Due to the rather limited time we have available s morning, I am not going to be able to entertain ore than perhaps two questions of Mr. Stokes or r. Ozaki, and then we must move on with our agenda. I believe, however, that both of these individuals ll be very happy to answer any questions that you ay wish to put to them privately after they have left e platform.

Are there questions now?

MR. EDWARD DAVIS (CBS Television): Your Di- sion Director's question was uppermost in my mind. In his own terms, do you suppose you could give s a comment, just in round numbers, what the kind of mparison, let us say, between that which we might e interested in, that is, in terms of ground base uipment, microwave or standard microwave equip- ent as compared with this particular unit, would dicate?

I am asking, in effect, for a comment on the cost ot in precise terms, but in round numbers or in com- rative terms between what we now know as terms of e cost of a single microwave length?

DR. OZAKI: First of all, any number that we give ur Division Direction turns out to be too high by def- ition.

We have looked at the relative cost of this system n terms of our extrapolation of these costs, in quan- ity production versus a similar type, perhaps not a multiple-channel but a microwave system that con- ains all 12 channels. We believe that this system is less expensive than that kind of approach.

In terms of going the full 12 channels in the sys- tems versus having 12 single channels, I believe that there would be a marked difference in the cost.

Does that answer your question?

MR. DAVIS: You have said it is less than or comparable to?

DR. OZAKI: It is less than. It is my belief that it is less than; and, of course, here again is the ques- tion of how many do you make at one time?

MR. DAVIS: Certainly.

CHAIRMAN SCHATZEL: We have time for one more question.

MR. SIMMONS (Jerrold): With regard to the inter-modulation, do we understand that this is what we call cross-modulation; that is, modulation trans- ferred from one channel to another? And, did if fol- low the theoretical law of two for one?

DR. OZAKI: This matter of inter-modulation, with respect to TV pictures, is slowly becoming more and more clear to us. The inter-modulation we are talking about does follow the two-to-one law. They are what are commonly called third order products.

CHAIRMAN SCHATZEL: Thank you very much.

(Announcements)

The next topic is truly a "bread-and-butter" topic for people in the CATV business.

The subject is TV SIGNAL PROPAGATION, and this is almost the first question we have when we consider a CATV system. We want to know what sort of signals we are getting at the head end.

The gentleman who is going to discuss this for us this morning is the Manager of the Antenna and Microwave Products Division of Scientific Atlanta, Inc., which has a wide reputation in the antenna field, as you know.

He is an engineering graduate of Mississippi State University, and has been working for the past 10 years in the field of antenna microwave. It is my pleasure to introduce Mr. Thomas D. Smith, of Scientific Atlanta, Inc.

MR. TOM D. SMITH (Scientific Atlanta, Inc.): First, I would like to express my appreciation for allowing Scientific Atlanta to participate in NCTA's Technical Sessions.

THE THEORY OF TELEVISION SIGNAL PROPAGATION

by

T. D. Smith

Introduction

Cable technicians need a knowledge of the propa- gation of television signals when performing signal surveys, locating head-end sites, determining sources of interfering signals, and in the designing or specify- ing of antenna arrays. The purpose of this paper is to review basic propagation theory with the hope it will provide better understanding of the propagation of television signals. First, this paper defines and

Apparently the British Post Office has charge of all kinds of communications in Great Britain.

He left there in 1947, and went with Rediffusion, of the British Broadcasting Agency, in London, and there he designed and installed the first cable system in England.

He grew up with the CATV industry in England, and in 1953, came across to Canada where he became the Chief Engineer for the first large CATV system in Canada, at Montreal.

Later, he joined Famous Players Canadian Corporation, in Toronto; and in 1963 became Vice President in charge of their CATV operations which serve and which involve systems serving 120,000 subscribers, which is approximately one-third of all the CATV subscribers in Canada.

He was active and he has been active in the Canadian Association.

It is my privilege and my pleasure to introduce for a discussion of SPACE DIVERSITY RECEPTION, Mr. Ken Easton. (Applause)

SPACE DIVERSITY RECEPTION FOR CATV

by

K. J. Easton

CATV has by its very nature always been at the frontiers of long-distance television reception. When the FCC in the United States first laid out its table of frequency allocations for television broadcasting it did so in the belief, uncontested by technical knowledge or experience at that time, that broadcast signals in the VHF band could only be received over line-of-sight paths and the coverage area of a station would therefore be limited literally to the horizon visible from the transmitting antenna.

It was soon found that this was very far from being the case, and that in fact stations could be received beyond the visible horizon. This threw the whole frequency allocation plan into the melting pot because the co-channel interference caused by propagation beyond the horizon proved to be much greater than anticipated, and in 1949 the FCC had to impose a freeze on the licensing of new television stations while the whole thing was sorted out. By the time the freeze was lifted some two years later a new frequency allocation plan had been prepared which allowed for this propagation beyond the horizon by imposing longer co-channel and adjacent channel spacings.

In the meantime it was this same freeze that gave birth to CATV, an industry that literally started by taking advantage of this same beyond the horizon feature of television propagation to bring television to people who otherwise could not enjoy this new entertainment medium. From that time up to the present therefore CATV has always been concerned with long-distance reception, and much knowledge and ingenuity has been used to constantly improve the quality and reliability of pictures brought in from beyond the TV horizon.

Just as the television channel allocations prior to 1949 were based on the concept that VHF signals were limited to a line-of-sight path, so far some years after this time during the early development of CATV it was thought that all beyond-the-horizon reception was due to a propagation condition known as smooth-earth diffraction. This is a condition arising from the electrical characteristics of the atmosphere which cause radio waves to bend in the direction of the earth and thus extend the radio horizon to a point approximately one third further than the visual horizon. Now it is a characteristic of a smooth-earth diffraction path that the path length can be extended, or alternatively the signal received at a given point can be increased by increasing the height of the receiving antenna above the ground--the well known height--gain phenomenon, so during this phase of CATV receiving antenna development it was usual to seek maximum height, either by locating the receiving station on high ground or by elevating the antennas well above ground level on high towers.

Since maximum antenna gain is also a prime requirement in order to extract the maximum signal from the field strength available at the location, multiple arrays became the order of the day for long distance reception. Unfortunately multiple arrays and high towers are incompatible for mechanical reasons, and this type of receiving equipment imposed a practical limitation on the strength of signal which could be received from a distant television station.

In the meantime during the early 1950's considerable scientific investigation was going on to learn more about long distance radio propagation in the frequency range from 40 to 10,000 MHZ, and in 1955 a number of papers were published under the sponsorship of the Institute of Radio Engineers describing a mode of long distance propagation which became known as "tropospheric forward scatter." It was found that communication was practicable at distances up to at least 300 miles under favorable conditions, and that diffraction theory could not account for the substantial field strengths that are produced at these ranges. A number of theories were put forward to account for this mechanism none of which were fully proved, but the most popular was that this long distance propagation resulted from atmospheric turbulence in the region between the stratosphere and the surface of the earth, known as the troposphere. This turbulence is thought to produce "blobs" of atmosphere whose refractive indices are sharply different from those of the surrounding atmosphere. When irradiated by a high frequency signal those blobs reradiate the signal scattering it in all directions. Some of this scattering is in the forward direction and it is this which produces the field at the receiving location.

These papers summarising this work led directly to an explosion of interest in this type of long distance radio communication, and in the succeeding 12 years since that date more than a hundred such communications systems have been built in many parts of the world for both military and commercial applications.

I should point out at this stage that all these systems were designed for point to point voice and data transmission, and there was no application for, and no attempt to adapt these techniques to long distance television transmission. Once again it was left to the CATV industry, whose specialty is long distance television reception, to pioneer the application of tropo-scatter in this field.

The first experiments were carried out in Canada and culminated in the first commercial use of tropo-scatter on a CATV system in North Bay, Ontario in 1963, providing reception of television programs from stations 240 miles from the community being served. Since then there has been a rapidly growing interest in this technique and a number of similar receiving systems have been installed both in Canada and in the United States. Experience with these systems has resulted in a growing knowledge and understanding of the techniques involved, resulting in steadily increasing improvement and sophistication.

Regardless of the true mechanical of tropo-scatter propagation much is now known about the characteristics of the radio frequency energy field propagated beyond the horizon. It has been learned through observation of a large mass of empirical data collected from operational tropo links.

First, it is known that the average amplitude of the field propagated beyond the horizon is greatly attenuated with respect to the transmitted field. For this reason it is necessary to use a receiving antenna with a very high gain. Conventional discrete-element antennas such as the Yagi are unsuitable for this purpose, and it is standard practice in tropo reception to use parabolic reflectors having a very large capture area and capable of concentrating the received signals onto a collector antenna located at the focal point of the paraboloid.

Second, the amount of attenuation can be calculated as a function of the angular distance between the transmitting and receiving sites. Angular distance is a parameter that takes into account the curvature of the earth, terrain configuration, and climatic conditions over the path, and is a measure of the intercept angle in the troposphere formed by the intersection of straight lines drawn from the transmitting and receiving sites to their respective horizons. For all but the most unusual circumstances angular distance is closely related to the linear distance between the two sites. Although site elevation is important in that it determines the distance to the horizon and therefore affects the angular distance, it is not nearly as significant as it is in the case of reception by diffraction, and the concept of height gain for the receiving antenna does not apply. For this reason, and because of the considerable mechanical difficulties in elevating a large parabolic antenna, it is usual to build these antennas virtually at ground level with an effective height of only 30 or 40 feet.

Third, the amplitude of the received field varies substantially with time over a given path. A mass of data on these variations has been gathered and analysed so that it is now possible to predict the amplitude-time distributions for most paths with a high degree of accuracy. For convenience these amplitude variations are separated into short-term and long-term distributions. Short-term aplitude-time distributions are those measured over periods shorter than a few minutes. The long-term distribution represents the variation of hourly median levels over a longer period of time-usually a month, a season, or a year.

Long-term variations of signal amplitude vary considerably with the season of the year and with geographical location, and when a system is being designed these factors must be taken into consideration. Determination of system parameters and design is usually based on the worst propagational month of the year--usually February or March in the Northern Hemisphere. Since long term variations on a given path are dependent on climatic conditions--temperature, humidity, etc. they affect both tropo-scatter and diffraction paths and must be taken into account in the design of any system.

Since tropo-scatter is apparently a mechanism associated with atmospheric turbulence, and since turbulence by its very nature is a state of constant change, short-term variations in signal amplitude are particularly apparent on tropo reception. Experience has shown that tropo-scatter reception of television signals using parabolic antennas is subject to fades which, although deep, are usually of quite short duration, generally less than a minute. Furthermore these fades do not occur simultaneously over a broad wave front, and if they are observed on two antennas located some distance apart they are completely uncorrelated, that is they occur at random and will not usually coincide at the two antennas. The application of this phenomenon to methods known as diversity techniques has been developed to counteract this fading and improve the propagational reliability.

Diversity can be defined as the utilization of more than one independent and uncorelated transmission path to provide greater reliability than that provided by a single transmitter and receiver at each end. There are two types of diversity used in point to point communications links--space diversity and frequency diversity. In space diversity two antennas are used separated in space by a minimum of 50 wavelengths and preferably 100 wavelengths or more. Signals separated in space by this distance show an almost complete absence of correlation. In frequency diversity two frequencies, separated by between one and ten per cent depending upon the frequency band in use, are transmitted over the path from the transmitting to the receiving station. Here again there is a minimum of correlation between the signals received on the two frequencies.

Although space and frequency diversity may be utilized independently in dual diversity, both may also be used simultaneously to afford quadruple diversity. For high reliability circuit requirements and in applications where the path length might otherwise produce a marginal circuit quadruple diversity is the preferred solution, and it is used in the vast majority of tropo-scatter communications links. Unfortunately in the application of tropo-scatter techniques to television reception the use of frequency diversity is out of the question since the transmitter already exists and only the receiving end of the system is under our control. Nevertheless considerable improvement in signal reliability can be obtained by application of dual space diversity, that is the reception of the same transmitted frequency on two separate antennas spaced a certain distance apart across the propagation path.

In planning a receiving system for signals being transmitted over a path on which substantial fading can be expected it is necessary first to determine what is the minimum signal to noise ratio that can be tolerated for an acceptable grade of service to the subscribers, and second, what the reliability of that grade of service will be, that is how constantly that grade of service will be available, or expressed another way, for what percentage of the time the grade of service will fall below the standard set.

In 1959 the Television Allocations Study Organization presented a lengthy and detailed report to the FCC which included the results of a measurement program to determine the subjective effects of various types of interference on television viewing both in black and white and in color. Based on the results from this report it has been determined that the minimum performance criteria are pictures rated passable or better by 50% of the viewers, and that so far as random noise is concerned this requires a signal to noise ratio at the antenna of not less than 29db.

Since the level of a tropo-scatter signal and, to a lesser extent, that of a diffraction signal, varies both within the hour and from hour to hour, some percentage of time must be affixed to this signal to noise ratio. It is usual on communications links to require the expected grade of service to be equalled or bettered at least 99.9% of the time, but in the case of television reception since it is an entertainment service and is not in use 24 hours a day it is possible to reduce this requirement.

Because signal conditions for tropo-scatter propagation are generally poorer in the afternoon, and since the prime viewing time is from 6 to 11 p.m. a recommended percentage of time for the value of acceptable signal to noise ratio to be equalled or exceeded is 99% of all hourly medians. This means that the hourly median value of signal to noise ratio may be below the recommended minimum value for approximately 90 hours each year or on an average about 15 minutes per day. Since prime television viewing time occupies only about 20% of the 24 hours this implies that on an average the grade of service will be below the recommended acceptable standard for about 3 minutes in prime time each day.

When planning a tropo-scatter receiving system we have to determine whether the required signal to noise ratio of 29 db available for at least 99% of the time can be achieved. This is done first by plotting the propagation path from transmitter to receiving site to determine the angular distance and hence the total path loss, and then equating this to the system parameters, including effective radiated power of the transmitter, receiving antenna gain, and receiving equipment noise figure.

Of these the parameter most readily under our control is antenna gain, and one of the reasons for using parabolic antennas for this type of reception is the availability of a relatively high gain, typically of the order of 28 db on the low band and 38 db on the high band for a reflector having an aperture of 13,500 square feet, that is 50 feet by 270 feet wide. Having determined the net loss over the path using an antenna of given gain it is then necessary to determine what signal to noise ratio can be expected for 99% of the time by the application of probability theory to measured data. If this value equals or exceeds 29db we can assume that the receiving system can be expected to provide the required grade of service from that television transmitter. If it is less than 29db then either we decide that the signal from that transmitter should not be used as part of the CATV service, or if we must use it we can expect that its reliability will be lower than might otherwise be considered desirable.

So far we have been discussing long-term fading, that is the fading represented by changes in hourly median signal levels. Even when these critera are met we may still be left with the short term fades, and from experience, with tropo-scatter reception using parabolic antennas it is a characteristic of the short term fades that they generally last for something less then a minute. The picture may be lost momentarily in a deep fade and then come back again within a very short space of time. Frequently these fades are of sufficiently short duration that they do not substantially affect program continuity, but even so they are annoying to the view, and it would be an improvement if their effects could be eliminated or at least reduced.

This is where the use of space diversity comes in. If two antennas are used, spaced at least 50 to 100 wavelengths apart, there will be very little correlation between the signals received from the two antennas, that is when the signal on one is fading out there is a high probability that the signal on the other is still at or above its median value. If therefore we can arrange to continuously measure the signal level on each antenna, and select the higher of the two for use on the system the probability is good that these short-term fades can be eliminated so far as their effect on the service given to the subscribers is concerned.

The question of cost of course immediately arises. A typical installed cost of a 270 foot parabolic antenna, exclusive of the head end equipment, is of the order of $17,000. If two of these are to be used for space diversity then the cost of the antennas alone would be $34,000. However a large proportion of the cost of a parabolic antenna is in the supporting towers and foundations, so that the cost is related closely to the number of towers used. A standard 270 foot antenna uses ten towers, and if this is split into two antennas using five towers each, the total cost of the two need not exceed about $18,000, the extra $1,000 being accounted for primarily by some additional end guying and the need for two focal point antennas instead of one. This arrangement results in the use of two 120 foot antennas instead of one 270 foot antenna, and the question then arises, since only one antenna is feeding the system at a time what effect will this smaller antenna have on the signal to noise ratio and will it still be within the acceptable limits?

A 120 foot antenna has an aperture of 6,000 square feet compared with 13,500 square feet for a 270 foot antenna, and since antenna gain is proportional to aperture, its gain will be 3.5db down compared with the larger antenna. However the use of diversity on signals derived from two similar antennas has the effect of improving the long-term hourly median by 2.5db, so that the net effect is a loss of gain from the antenna combination of only 1db, and certainly we would not be justified in spending an additional $16,000 just to pick up 1db of gain. It would in fact be possible to obtain the same net gain from two 150 foot antennas requiring a total of twelve towers instead of ten, for an additional cost of the order of $3,000, but whether this is justified is a question of how marginal the predicted results will be and how necessary it may be to squeeze every ounce of signal out of the system.

In tropo-scatter communications systems the carrier frequency used is usually in the band of 900 to 2,000 MHZ and the system band width is a very small percentage of the carrier frequency. Under these conditions it is practical to combine the signals from the two antennas, the resulting output signal being the sum of the two. However in television reception in the VHF band the channel bandwidth is a significant percentage of the carrier frequency and frequency selective fading can occur within the video band. If now the signals from the two antennas were combined it is probable that whilst certain sideband frequencies might be in phase other frequencies might be out of phase and this would give rise to serious distortion of the output signal. It is therefore necessary to arrange for continuous measurement of the signal levels from each antenna and switching of the system to the antenna producing the strongest signal.

The switching system consists essentially of two solid-state television receivers, one connected to each antenna. The demodulated output of each receiver is then connected to a D.C. comparator which compares the levels of the receiver outputs and produces a signal dependent upon which of the levels is higher and this operates a solid-state switch. The switch in turn is connected to the outputs of the antennas and determines which of the antennas is connected to the system. Synchronisation of the switching function to the vertical blanking interval is desirable in order to avoid loss of vertical synch and hence picture roll on subscriber's receivers when switching takes place. However solid-state switches are available with switching times of the order of 1 microsecond or better, and the use of these should make vertical blanking switching unnecessary. A delay of the order of one second is built into the switch and also a provision that switching will occur when there is a predetermined minimum difference between the two signal levels in order to prevent frequent switching taking place when the two levels are similar.

If more than one station is being received on the antenna system, which is generally the case, then it is necessary to switch the individual channels rather than the antennas themselves. It is not normal to receive adjacent channels on the same antenna system so that even on the high band there will be a difference between the channel frequencies of at least 3%, and this is sufficient to give rise to a substantial degree of frequency diversity, that is the signals from the two or more stations will not fade simultaneously. Separate diversity switches must therefore be used on each channel received.

To my knowledge the only CATV application of diversity so far in the United States has been on a system in Marlin, Texas, although I have no information on the design or performance of this system. Two dual space diversity television receiving systems for CATV in Canada have been built in the Ottawa area. The one with which I am associated uses four 120 foot parabolic antennas and two spaced Yagi arrays. Two of the parabolics are to be used for reception of channels 10 and 12 from Montreal. The axes of these antennas are spaced 400 feet apart giving a spacing of 79 wavelengths on channel 10 and 84 wavelengths on channel 12. The second pair of antennas will be used for reception of channel 7 from Watertown, N. Y. and channel 11 from Kingston. This layout becomes a little more complicated because there is a 38° difference between the paths from these two stations. One antenna is lined up on Kingston and the other on Watertown. The spacing between the antenna axes on Kingston is 400 feet which is 81.5 wavelengths on channel 11, but the spacing between the axes on Watertown will be only 213 feet due to the mutual slewing of the antennas and this is only 38.5 wavelengths on channel 7. It is probable this will be insufficient to obtain a good space diversity effect on this channel, but predictions indicate this may not be essential and it will give us a useful opportunity to determine by experience the minimum spacing required.

Another point arises from the use of the same antennas for reception of signals from stations which are 38° apart. The median level of the signal received from Kingston on the Watertown antenna 38° off the antenna axis is calculated to be 7db down on the median level of the same signal received on the axis of the Kingston antenna. With this difference in levels the 2.5 db effective diversity gain disappears so that the median signal level will in fact be 3.5 db down on the level which would be received using a 270 foot parabolic. However the improvement in reliability against short-term fading should still apply.

Two yagi arrays in space diversity are being used for reception of Plattsburg, N. Y. on channel 5. Yagis are being used instead of parabolics because predictions indicate that this is primarily a diffraction path and height gain becomes significant. However, depending on the results of tests being carried out we may apply space diversity also to this path. The spacing is 600 feet equivalent to 48 wavelengths on channel 5. This is close to the theoretical minimum spacing. However it will again give us an opportunity of checking the degree of correlation at this spacing, and if we find the spacing is inadequate we can readily increase it to 1200 feet or more to provide a spacing of the order of 100 wavelengths.

The construction of these antennas is now completed, but the diversity switching equipment is not yet ready for installation. In the meantime tests have been carried out to check the extent and effect of the diversity reception by monitoring color pictures and sound from each antenna of a pair and simultaneously measuring the picture carrier levels, and it is already clear from these tests that the use of diversity reception will result in a significant improvement in the reliability of the service given to subscribers. Even under conditions of heavy and frequent short-term fading it is estimated that at least 90% of the time when the picture from one antenna is lost due to a deep fade the other is still quite acceptable, and it is very apparent looking at the two pictures side by side that, when the better of the two can be selected for transmission to the system, the effect of these fades will be very greatly reduced with a corresponding improvement in service reliability.

Another interesting phenomenon that has been observed on these tests is the way in which a fade appears to sweep through the frequency band. Frequently there will be a rapid fade on sound followed a few seconds later by momentary loss of color and then later a deep fade on the picture carrier. Clearly the fading mechanism is very frequency selective and continuously changing, so that it would appear to sweep across the band of the channel concerned, first affecting the sound carrier, then sweeping through the adjacent color sub-carrier, and finally passing through the video carrier and its associated sidebands. It is possible that by demodulating the received signals and with some additional equipment complexity diversity switching could be applied independently to the sound carrier and the color subcarrier as well as to the picture itself, but experience will have to determine whether such added complexity would be justified.

It seems to me that the use of space diversity could be another major step forward in the improvement of the general standards of long distance television reception at no great increase in cost, and if the results bear out our expectations this technique could have a wide application in the CATV industry.

CHAIRMAN SCHATZEL: Thank you very much, Mr. Easton.

We are now going to leave the theoretical and more esoteric world for a few minutes and get down to something very practical.

I should apologize to Mr. Easton. I did not mean to imply that his antennas are not practical (laughter), because I am sure they are, but the subject we are going to talk about now is a more prosaic, humdrum one. It is, nonetheless, a very important one.

We have two gentlemen who are going to bring us up to date on the work that has been going on in connection with the National Electrical Code and the National Electrical Safety Code.

For the past couple of years there has been a considerable effort devoted to bringing CATV under the "umbrella" of these codes, and this has presented both problems and opportunities.

The gentleman who is going to tell us about CATV and the National Electrical Code is Mr. James Stilwell, who is Vice President of Engineering for TeleSystems Corporation.

Mr. Stilwell is a Mechanical Engineer who has picked up enough knowledge of electricity as he has gone along to give him a position of leadership in our industry.

So, without any further introduction, James Stilwell. (Applause)

MR. JAMES STILWELL (Vice President-Engineering, TeleSystems Corporation): Thank you, Mr. Chairman.

I think the inclusion of a talk on the National Electrical Code and the National Electrical Safety Code is pertinent to our group because for many years there was considerable confusion, in my own mind, as to which was what, and what applied to what we were doing.

I will attempt to describe what the National Electrical Code represents.

It is basically applicable to installations on private property, and if you think of its origin you had better understand what I mean. It was originated in 1897 by the united efforts of various groups of insurance companies; electrical manufacturers; architectural groups, and other allied associations, in an effort to standardize on installations so that the danger of fire hazard would be greatly lessened.

It continued in a somewhat disorganized manner until 1911, when the National Fire Protection Association took over complete sponsorship and continued to date.

As I mendioned, it is applicable to private property installation; yet, it is applicable to both inside building attachments as well as outside attachments, both on-pole or outside of buildings.

The limitation to private property I think is understandable if you consider that these are places where fire insurance claims might be made against a fire insurance carrier for specific property as opposed to an installation on a private utility pole which might fall on a public domain.

The Code itself is comprised of many different sections, each section trying to cover a certain, particular type of problem and application.

The Code is developed itself in accordance with a specific, definite procedure in preparation.

There are 18 so-called codemaking panels, all of which operations are coordinated by what is called a Correlating Committee. Serving on the panels and on the Committees are experienced men representing all of the various interests that might be involved.

The panels, the codemaking panels themselves, have specific calendar steps of time for the action which they are called upon to take.

The Code itself is issued on the basis of every three years with a major revision being undertaken to provide editions that are expected and hoped to carry on for a period of the following three years. It is possible for interchange to be approved and passed, but in general the editions that you would have to refer to would be effectively those that are in existence for a three-year period.

The present Code edition that we are operating under at the moment was published in 1965. Revisions at the present time, however, are under way for revisions to produce a new edition for 1968, and it is at this point where we become involved ourselves.

The Code panels themselves involved with the communications and telesystem specifications in the present Electrical Code realize the inappropriateness of the descriptions and the material that is presently embodied in the Code. They looked around and found that unfortunately our neighbors to the North were already a step ahead of us, and the Canadian Electrical Code had already been revised to incorporate a complete section relating to CATV, per se.

The Code panel committee then, the United States Code Panel Committee, began their study by taking the Canadian panel recommendations as they had adopted them, and used this as a guideline for their consideration.

We were fortunate, I think, in that about that time our CATV people became aware of the revisions that were under way, and were invited to meet with some of the Code panel chairmen to discuss what contributions we might make in their efforts to revise the Code.

We had a very interesting session. I had the pleasure of attending that initial talk. There was quite a bit of mutual discussion and quite a bit of exchange of information.

It was certainly obvious that these men had really insufficient insight into CATV to properly represent our interests in making up a code applicable to our business.

The matter was then taken to our NCTA Standards Committee, and it had a series of meetings, the result of which was to prepare a set of recommended rules for adoption as a special section in the 1968 Code, to be headed CATV SYSTEMS.

This special section is of interest, and I might call to your attention the fact that it is intended to pertain specifically to coaxial cable systems.

The Electrical Code as it exists today has two sections in it, one for communication, and one for antenna systems; and if you look at them carefully you will find that they refer to radio systems and mention specifically unshielded wire-type distribution systems.

The purpose, then, of collating all the CATV regulations into one section is obvious. When we have coaxial cable we do not have lightning section problems of the center conductor, so that one of the points in our discussions that we did cover was the fact that we are not going to be obligated to provide lightning protection in our systems once we get inside the shielding of a coaxial cable.

In our discussions several major points came up that affect all of us in our everyday way of doing business. It was of some surprise to ourselves because in our operations as a multiple-system operator, it has not been our practice to ground our house drops. In the discussions with the Code panel members they were just as shocked as I was, the opposite way, to find that we were not grounding our house drops.

We did get into a discussion, and it was the estimate that perhaps as high as 80 per cent of the CATV system subscribers were not presently grounded; and this was quite a shock to the Code panel members. They felt that the Code itself already contained references which should have called to our attention the desirability of such grounding.

This subject is now an important one to all of us in that it represents dollars out of our pockets through the expenditure for the devices and the labor necessary for making such grounding. It was the universal reaction of your Standards Committee that we had no defense to properly support our procedure of not grounding house drops. I say this because it was pointed out that although our system is totally grounded throughout the entire town, that the chance, remote as we might think it is, still exists in which a power line or other high-tension line might drop on our house drop cable, cause it to be severed, and that the severed portion on the house side could then carry the hazard voltage.

As a result, the NCTA's proposed specifications for consideration by the Code panel committee contains the following paragraph, and I am quoting now verbatim:

"Grounding of outer conductive shield of a coaxial cable. Where coaxial cables are exposed to lightning or to accidental contact with lightning or power conductors operating in a potential exceeding 300 volts, the outer conductive shield of the coaxial cable shall be grounded on the building premises as close to the port of entry as practicable."

The suggestions and specifications go on in detail as to what we recommend should be considered in terms of routing of the ground wire; making it as straight as possible; trying, if possible, to use a water pipe ground; also, attempting to use a common ground that the telephone and power units already may have in use. I will not go into the details of those.

Another point of major concern, however, to our group in discussing this with Code panel committees was our concern about the use of cable power equipment in a communications area. We covered this thoroughly, and I think we are reasonably satisfactorily covered in the statement, which reads as follows:

"The coaxial cable may be used to deliver low energy power to equipment directly associated with its radio frequency distribution system provided the voltage is limited to 60 volts and where the current supply is from a transformer or other device having energy-limiting characteristics."

I think that the opportunity which we have had of participating in the discussions leading to the preparation of this proposed revision for the 1968 Code has been a great step forward in our own recognition of the responsibilities that we do have from the safety angle, as well as the opportunity that we long since deserve in having a voice in the rules and regulations under which we must abide.

I thank you. (Applause)

CHAIRMAN SCHATZEL: Thank you, Mr. Stilwell.

The other portion of this presentation relating to the National Electrical Safety Code is going to be handled by another TeleSystems Vice President, Mr. William F. Karnes.

Mr. Karnes is the Vice President and General Manager of TeleSystems Services Corporation.

I am going to sum up his long record of experience by saying he has been in the CATV business for quite a while and knows a great deal about it. He is going to tell us about CATV and the National Electrical Safety Code.

Mr. Karnes. (Applause)

MR. WILLIAM KARNES (Vice President and General Manager, TeleSystems Services Corporation): That is the shortest, most complete, and most accurate introduction I have ever experienced.

The National Electrical Safety Code, as Mr. Stilwell pointed out, differs from the National Electrical Code in that it is primarily, concerned with the construction of electrical facilities on pole lines chiefly outside the property line of the private building, dwelling, or whatever service area is concerned.

The National Electrical Safety Code is sponsored by the National Bureau of Standards. It is written, amended, and controlled by what is called Sectional C-2 Committees of the National Bureau of Standards, headed by Mr. William J. Meese.

Without going into minute detail as to how the Code functions, I can tell you that about a year ago NCTA became concerned that here was a document under which nearly every one of us operate, because almost every pole attachment contract ever signed specifies the system will be built in accordance with this Code, and yet very few people are aware of the Code requirement, primarily because the Code is not easy to obtain in written form.

All of you I think are familiar with the basic 12 inches from Bell; 40 inches from power, et cetera, et cetera--the things we live with every day. Many of you may, or may not be aware of some of the other requirements--grounding; strength requirements; guy strength; structure conflict; conductor conflict;--things of this nature which are technical requirements that you are supposed to observe, but may or may not know about; and represent a matter of concern to each and every one of you.

Surprisingly enough a lot of telephone and power company engineers had never read the Code either; (perhaps it is not so surprising). (Laughter)

There are two points that I specifically would like to make with regard to the National Electrical Safety Code as it affects your daily operation, one of those being that CATV, as we all know, is a growing, dynamic industry, which is suddenly under the scrutiny of every public agency in the United States, including the utility commissions; the FCC; the railroad commissioners; you pick one and it is involved. Everybody is looking at CATV, and most of them want to control it in one way or another.

One of the areas in which I think we can be most vulnerable is that of proper construction. This Code spells out the rules. If they are ignored, and we have had a sample of that already, the telephone companies will say, "You see how those people build! We should do this construction" (and control the industry).

The TV industry will say, "You see how those people build. We'd better regulate them."

I would like to emphasize that the Code requirements are not unusually restrictive. I would, however, like to ask all of you as technicians and engineers to secure a copy of this Code and attempt to live by it. I do not say you should all go back and attempt to rebuild every system in the country; but in any area of new construction or system expansion; I would like to see all of these regulations observed so that we are not vulnerable to any criticism from that standpoint.

Some utility engineers, chiefly telephone company people, are attempting to establish a concept of communications and power space on a pole. I want to bring this up because it can result in dollar expense to you if you are not equipped to discuss, intelligently, with these people, their ideas. Many of them will cite the Code and say that the Code requirement establishes X inches of communication space, and this space varies around the country.

New York Telephone has one number; New Jersey has another; California has another, depending on their engineers. They will attempt to tell you that in order for you to attach to a pole you must preserve this X number of inches of space for them because the Code calls for it. I would like to emphasize the Code does not call for any communication space.

One of my favorite projects is to fight, wherever I can the concept of reserved space. I do not wish to see the belief grow any further that there is reserved space on any pole for anybody, "according to the Code." If the two utilities involved want to get together and decide this for themselves, that is their prerogative; but the Code does not call for it. I would not like to see any engineer be successful in using the National Electrical Safety Code to cost you money in that manner.

We had one instance in Michigan, incidentally, involving a telephone company engineer, where an attempt was made to force a very costly change on a cable operator, using the Code as the background, insisting that the cable operator had used a type of construction which was not permitted; in that he used the same thing most of us do, quarter-inch strand which has a breaking strength of 4,750 pounds. This engineer insisted that the Code called for 7,000-pound strand. Therefore, the cable operator was required to tear down all of his stand and replace it.

I hope nobody is ever again faced with that proposition. We were able to go back to the Code, however, and point out that the rules did not require this; and the engineer had to back down.

My point, however, is that had the CATV operator not been aware of the Code requirements and in a position to argue with the engineer, he could very well have spent a great deal of money without really having had to do so.

I said earlier that the Code is not too familiar to many people, because it is not easily available. The National Electrical Code has been reprinted and very widely distributed by the electrical suppliers, such people as Graybar, Westinghouse, and others. The National Electrical Safety Code is available, should any of you wish to order a copy of it, from the Superintendent of Documents, U.S. Government Printing Office, Washington. It is Handbook H-81, and it costs $1.75. It could very well be the cheapest investment you ever made; and I strongly urge that each of you secure a copy of it.

This concludes my remarks, Mr. Chairman. (Applause)

CHAIRMAN SCHATZEL: Thank you very much, Mr. Karnes; and again we say thank you, Mr. Stilwell.

I believe we all appreciate the work these two gentlemen have been doing to further the interests of the CATV industry in connection with these Codes.

Serving with Mr. Stilwell on this Committee is a gentleman who is in our audience, and I note that he wishes to make a comment.

MR. H. J. SCHLAFLY, JR.: Mr. Chairman, I did serve with Mr. Stilwell on this Committee, and I want to emphasize a point that he spoke of, and that is that the draft on the National Electrical Code has not been approved nor adopted by the NEC as yet.

I want to read a word of caution from our current print:

"The above draft has been proposed by the NCTA Standards Committee and delivered to the appropriate NEC panels for their consideration, but there has been no assurance nor indication that the draft will be adopted in this form for the 1968 publication as part of the Code."

So, if it comes out in the end with slightly different flavor than we have been able to report today, please do not be too greatly surprised; but your Standards Committee will endeavor to retain it in its present form if at all possible.

CHAIRMAN SCHATZEL: Before going to the next speaker I would like to present an announcement.

(Announcements)

We are going to change the agenda, moving past the panel which was scheduled to appear next, and going to the last of the morning items which is entitled, COMPARISON OF DEMODULATOR-MODULATOR VERSUS HETERODYNE SIGNAL PROCESSING FOR CATV HEAD ENDS.

The speaker who is going to discuss this subject, I heard a couple of years ago in Denver, when he discussed transmission distortion in CATV. At that time, as I recall it, he was discussing envelope delay distortion, and it was a most interesting paper. What he was talking about was a problem that was facing us in transmitting signals over CATV systems.

It is my hope this morning that perhaps he is going to give us some of the answers to that problem, among others.

Our speaker is Mr. Gaylord Rogeness, who holds Bachelor's and Master's Degrees in Electrical Engineering from the University of Illinois. After several years of experience with various companies in the electronics industry, he joined AMECO, where he is now the Director of Engineering, located in Phoenix.

At AMECO he developed the solid state heterodyne signal processor which AMECO has recently introduced. He has, also contributed to several other items developed by his company.

It is a privilege and a pleasure to introduce Gaylord Rogeness. (Applause)

COMPARISON OF DEMODULATOR-MODULATOR VERSUS HETERODYNE SIGNAL PROCESSING FOR CATV HEAD ENDS

by

Gaylord G. Rogeness

1. Introduction

Two techniques which have been used to receive and process television signals before they are applied to the cable system are the Demodulator-Modulator combination and the Heterodyne converter. The intent of this paper is to compare the two techniques.

With present day microwave relay equipment, at least one demodulatin-modulation is required before the television signal can be applied to the cable system. Hence it is imperative that the demodulator and modulator have characteristics which will minimize distortion of the television signal. However, when the choice between use of a heterodyne converter or a demodulator-modulator pair exists, the heterodyne converter is currently the best choice. Reasons for this choice will be given in the paper.

2. Heterodyne or Converter with IF Amplifier

The VHF converter with IF Amplifier, which will be referred to as heterodyne in the remainder of this paper, must convert any incoming VHF channel to any desired output VHF channel. The signal received from the antenna must not be degraded during the conversion process. Ideally, one requirement of the system is a flat passband from 750 khz below the picture carrier to 4.18 mhz above the picture carrier.

Figure 1 shows a block diagram of the heterodyne. The VHF signal input is amplified by an RF amplifier before it is converted to IF frequencies by the local oscillator in the input mixer. Adjacent channel trapping is accomplished in the IF amplifier. The IF sound carrier is normally separated from the

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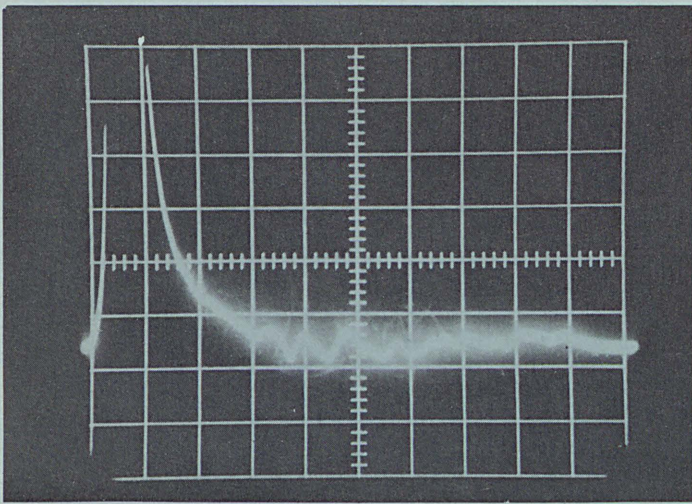


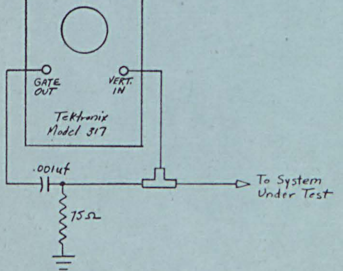
This is the same cable with the time base of the scope changed to .2 microseconds per division and the gain increased to .05 volts per division. At this setting of the scope, each division is worth about 80 feet of cable and you can see it is well riddled with reflections.

You have seen a few examples of what this type of testing can produce and with practice you can evaluate what is seen on the trace. We use this almost daily on our system, if not on the lines - in the shop for measuring partial reels of cable or displaying video wave forms from our microwave terminals.

For those interested in photography, the slides were taken using a 35 mm camera with a set of three portrait lenses attached. The lens opening of F4 and a shutter speed of 1/15 of a second and Ektachrome high speed type B film. We also take Polaroid pictures of wave forms using an old model 95 Polaroid camera and high speed film. Our total investment, including the "custom" mount for the scope is $100.00.

CHAIRMAN TAYLOR: Thank you very much. Are there any questions?

MR. SCHERPENSEEL: Somebody asked me to draw the diagram of the differentiating circuit, and I had better do that.



CHAIRMAN TAYLOR: Are there any other questi

Don't you have a tendency to do a lot of unnecess work of checking equipment when this doesn't check fr quency?

MR. SCHERPENSEEL: No, we are looking for fa This is a fault finder. We know and we check both ends and you can see what is going on in between.

CHAIRMAN TAYLOR: Are there any other questi

This is not a question, but we have a lot of system that cannot afford a TDR or something similar, and the use the same technique on a television set for ghosting conditions. What they do is look at the output of the amplifier with a "T" monitor and by taking a ratio between the ghost and the width of the screen they can determine the location.

CHAIRMAN TAYLOR: Thank you very much. Do have any other questions or contributions?

From your title it seems to me it is "A Low Cost TDR," but when I look at the picture you have a fairly high priced scope. I wonder where the saving is?

MR. SCHERPENSEEL: It is relative. The TDR is around $3,000. It is all relative.

CHAIRMAN TAYLOR: Are there any other questi If not, we will take a short break for a moment.

(A short recess was taken.)

CHAIRMAN TAYLOR: It is always a pleasure at these functions to have guests from our Sister Country Canada. Our next speaker, I. Switzer, was born and educated in Calgary, Alberta. He received his B.Sc. degree in physics from the University of Alberta in 1949 and spent three additional years in post graduate study in physics.

His professional experience includes a number of years in electronic instrumentation and mathematical problems in petroleum geophysics, several years in applications analysis and programming in the electronic computer field, and association with the CATV field since 1954.

Mr. Switzer was a charter member of the Board of Directors of the Computing and Data Processing Society of Canada. He has been a director of National Community Television Association of Canada for a number of years. He is a member of I.E.E.E., S.M.P.T.E., and the British Society of Relay Engineers.

Mr. Switzer is presently chief engineer for Maclean Hunter Cable TV, Ltd. Maclean Hunter is a large Canadian publishing company diversifying into the cable TV field. Mr. Switzer. (Applause)

SUMMATION SWEEPING CATV SYSTEMS

By

I. Switzer,
Maclean Hunter Cable TV Limited
Toronto, Ontario, Canada

Performance standards for CATV systems are constantly being raised while the growing size of systems makes it constantly more difficult to achieve these standards. The setting of system operating levels and overall frequency response is one of the most important adjustments in the set up of new systems and the maintenance of established systems, and is usually very difficult to achieve to the desired standards of accuracy. This paper presents a practical technique for setting system operating levels and frequency response in an accurate and reasonably simple way.

System operating levels are usually checked and adjusted by measuring levels of individual channels with a field strength meter (FSM). Frequency response is conventionally observed by using swept frequency techniques. Combining swept frequency and level measurement techniques and applying them to a whole CATV system presents some special problems.

The first approach to the problem is to feed a sweep generator into the system "head end" and then observe and adjust the frequency response at each amplifier station down the line. Several problems arise:

1. adjustment of amplifier gain and level
2. synchronization of 'scope sweep
3. effect of sweep signal on amplifier AGC.

Most CATV sweep generators use the AC power line as a sweep drive. Sync and phase adjustment of remote displays is easily accomplished by locking the 'scope display to the power line. Many of the popular, low cost 'scopes used for CATV sweep displays have built in provision for horizontal drive from the power line. In cable powered, transistorized amplifier systems the detector and scope system are usually powered from some kind of generator system carried in a test van and the usual internal power line sync and phasing provisions of the 'scope cannot be used. In such cases we tap the AC power from the amplifier being adjusted and use it to provide a synch and phasing signal to the 'scope's horizontal deflection system. The circuitry details depend on the 'scope being used but can generally be worked out in a way that will provide the necessary horizontal deflection signal for the scope without loading the system's cable power. This permits good synchronization of the sweep generator at the head end with the detector and scope system at the system amplifier station under adjustment.

Some sweep generators can be operated in either a free running or line triggered linear sweep mode. In such cases 'scopes with a reasonably versatile sweep triggering system can be synchronized to the head end sweep.

A comparison technique is used to adjust the amplifier gain and operating level at the same time that "flatness" of response is observed. The sweep signal being observed is put onto one side of a high speed co-axial switch while a reference CW signal is put onto the other side of the switch. When the switch is operated at its normal 15 or 30 Hz speed, the reference signal and sweep are both displayed. The sweep appears in its normal form, while the reference appears as the top of a 15 or 30 Hz square wave arising from the chopping action of the co-axial switch. The two signals can be easily compared and the sweep coming out of the amplifier can be adjusted to the desired level and flatness using the amplifiers gain and tilt controls. Thus tilt and level are observed and adjusted at the same time.

Any frequency can be used for the reference CW source as long as it is within the flat frequency response of the detector used. We have used low cost kit type RF generators, monitoring their output level with a good FSM. In other cases we have used lab type RF signal generators. The reference used will depend on availability of equipment and the accuracy desired. The reference source permits "average" level to be measured as well as depths of "peaks" and "valleys" in system response.

It is convenient, when using this technique, to work on the basis of "flat output" at an amplifier. Each amplifier is adjusted to exactly compensate for the losses and tilt of the immediately preceeding cable section. This technique will result in an overall system response that is flat. Final system operation may be on a full tilt, partial tilt, or block tilt basis, but this adjustment is made by adjusting channel levels at the head end. The transmission system itself must be flat irrespective of the tilt system used in actual operation.

Some systems will have a very long cable stretch between head end and the first amplifier section to take advantage of the fairly high output capability of most head end signal processing units. In this case we have found it necessary to carefully adjust an accessory equalizer to compensate for the extra cable length, so that the combination of first cable section and first amplifier will be flat.

One of the aims of this technique was to develop a technique that would make all necessary adjustments under actual system operating conditions. This requires activation of the system's AGC during adjustment. We have accomplished this by mixing the required pilot carrier with the sweep signal at the head end. A trap is used to notch the sweep at AGC pilot frequency to prevent undesired beat effects and to prevent the sweep signal from activating the amplifier AGC's.

The response of amplifier AGC to swept excitation should be carefully studied. We first found it a serious problem when we undertook the set up of a 43 amplifier string of Jerrold Starline amplifiers. We had installed a narrow "high Q" trap as an AGC notch to trap 73.5 MHz out of the head end sweep signal. As we moved down the line adjusting amplifiers we found a peculiar hump building up around 73.5 MHz. It took a while to determine that the amplifier AGC system had fairly broad frequency response and was responding to sweep frequency signals around 73.5 MHz even though 73.5 MHz itself had effectively been trapped out of the sweep. We made a careful study of the response of the AGC system in this particular series of amplifiers and found that we had to broaden our trap considerably in order to completely suppress response of the amplifier AGC to sweep signals around 73.5 MHz. In this particular case we ended up with a notch about 4 MHz wide around 73.5 MHz. This trap was built by adapting a channel reject filter. Be sure that traps used for this purpose have flat response outside the reject band.

Some ingenuity is required to devise systems for bringing the amplifier being adjusted down into the service van. In the case of the Jerrold Starline chain previously mentioned we used a carefully selected medium sized jumper of minimum length. The amplifier plug in module was brought down to the van. In this particular equipment series the cable power continues through the amplifier housing even when the amplifier module is removed. A light weight jumper was used to bridge the cable power to power the amplifier in the test van and to provide the synchronization signals for the 'scope and high speed co-axial switch. The jumper was selected for quality and average impedance match to the main line cables in use by checking with bridge and TDR. We are working toward a very light weight portable instrument system that will be light enough to be carried up to the amplifier and which will permit test and adjustment of the amplifier in place in its messenger mounted housing. This will require development of a very flat, high impedance, active probe that will permit accurate monitoring through the test points provided.

Some problems were experienced with the comparatively low output levels at which amplifiers in large systems operate. A typical level is about +32 dbmv. This level will drive most detector and 'scope systems in a satisfactory way, if all of it is available, i.e., if the full amplifier output is available to drive the detector. If output must be monitored through a -20 or -30 db test point some problems arise. These can be overcome by using good quality calibrated booster amplifiers, very sensitive detector and scope systems, or by use of a good quality high impendance "active" test probe to bridge the amplifier output.

In the 43 amplifier chain previously cited it was possible to achieve correct set up of each amplifier's operating level to the accuracy of the reference generator used, in this case a Measurements model 80 signal generator, and to achieve an overall system response at the 43rd amplifier of $\pm 1\ 1/2$ db, or 3 db total peak to valley. Amplifiers had been carefully prealigned on the bench through actual lengths of the cable type used on the line and then installed at the station for which they were intended. Jumpers were carefully chosen to match average main line cable used in order to minimize jumper effects. Amplifier gain and tilt adjustments were then made to get the desired response and operating level. In these particular amplifiers it was found necessary to try different equalizers, to make fine adjustments to equalizer trimmers, and to adjust the input and output match trimmers to get optimum flat response. Internal response trimmers were occasionally adjusted. Remember that a consistent 1/4 db misalignment in each amplifier adds up to almost 11 db in a 43 amplifier chain. If any drastic adjustments are necessary we check the response at the input to see whether there is any problem in the cable itself. In this case of setting up a new system, the cables had previously been very carefully checked with bridge and TDR before acceptance from the cable installation contractor, and no cable problems were experienced. We did have some troubles with badly matched fixtures on the line. These were immediately apparent as ripples in the response of the system caused by standing waves set up by the mismatches. It is interesting to note that the "fine structure" in a system's overall frequency response is related to mismatches and ghosts in the system. Detailed studies in the field require slow sweep speeds and 'scope systems capable of displaying such slow sweeps.

CHAIRMAN TAYLOR: Thank you very much. (Applause) Do we have any questions on this subject of "Summation Sweeping CATV Systems" as given by Mr. Switzer?

You mentioned the problem of not enough level on the tapped outputs. Have you noticed any problem of non-linear on the tapped output in comparision to the input?

MR. SWITZER: In the case of the Starlines, without giving them a very intentional sales boost, they use the same test probe that you carry along with you from one amplifier to another, so you are working consistently with the same one. These are the only amplifiers we have done a great deal of work on with the summation sweeping system. We make a practice now of actually checking the test points on the amplifiers, to callibrate them and make sure that they do agree. We run a calibration on them for those types of amplifiers.

I was wondering what kind of generator is used at the head-end equipment?

MR. SWITZER: We have used several.

How flat is the generator used?

MR. SWITZER: The final overall flatness of the sweep is dependent on the flatness of the notch filter that we use. We generally check it in place at the head-end, and if it becomes really critical, you can subtract it out by marking it on your screen or taking a picture of it so that you know if was flat to this degree at the head-end. We are not looking for an absolute straight line.

CHAIRMAN TAYLOR: Any other questions?

I know Mr. Switzer, and I was with him when we originally set the system up.

MR. SWITZER: I will commend Ted in having been the chief technician on the system when we first pioneered this system three years ago. Ted and I went out to set up the first all-channel system we had ever dealt with, and we were following the manual with the manufacturer's instructions which said, "Tune to Channel 2 and read the level. Then tune to Channel 13 and read the level." We did that with just one station, as we felt there should be a better way.

As you know, we had quite a problem with the higher frequencies at the time. I have not followed up on this technique because it was very unsatisfactory. I have about five or six amplifiers, but I notice you were talking about the Starline with the amplifiers, or where the cable goes right into the amplifier. Do you consider this still a problem with the cable going through connectors and jumpers, and so forth, and what effect does this have on the long system?

MR. SWITZER: The problem we had back in those years, Ted, on that particular system was that the system had the old UHF connector right through, and this gave us a very serious standing wave problem, particularly at higher frequencies with jumper systems, but with careful attention to the impedence of jumpers, by having access to good bridges and TDR systems now, we can keep this standing wave problem under control. If we backed it up on the older system with newer connectors and a better standing wave situation in general in your older system, you would find it works out nicely.

CHAIRMAN TAYLOR: Any other questions?

At the end of it do you see any amount of noise?

MR. SWITZER: This depends on the level. The hum might be cleaned up by a better balanced detector, but we have preferred to hold the RF levels in the detector up to the plus 30 level, and there the grass is not a problem. We don't use it to try to evaluate noise at that point. This is a completely separate measure.

CHAIRMAN TAYLOR: Any further questions? If not, thank you very much. (Applause)

For our next presentation a name was omitted from the program. This next paper will be presented by two men, both of whom are systems operating technicians, and I need to apologize profusely to Bob Brown for the omission of his name as a co-author of this paper.

Robert J. Brown is the engineering manager of Tele-Vue Systems at the home office in Seattle, Washington. He was technical vice president of the Pacific Northwest Cable Television Association. He spent twelve years in Community Antenna Television from installer to his present position as engineering manager. He has been with the same employer through all of this time in a long and noteworthy career in CATV.

Joining with Mr. Brown will be Mr. Jerry Laufer, Vice President, Engineering of the Telecable, Inc., of Seattle, Washington. He has also been technical vice president of Pacific Northwest Cable Television Association, and he is at this time.

He has eight years with the U.S. Air Force as an electronics technician, seven years in Community Antenna Television at Eugene, Oregon, Great Falls, Montana, Laguna Beach, California and as a sales engineer for Jerrold Electronics.

He joined Telecable in 1956 as vice president for engineering. Bob will speak first; and it is with great pleasure I present Bob Brown and Jerry Laufer who are presenting a very interesting presentation on "Practical Design Based on Complete Equipment Evaluation."

TEMPERATURE, TEMPERATURE DESIGN, AND AUTOMATIC LEVEL CONTROL FOR CATV.

BY

James R. Palmer

SUMMARY

The development of a high-output solid-state amplifier has given new dimensions to CATV transmission system design and operation.[1] The application of such amplifiers to trunk lines is discussed in this paper. The inherent advantages of high-output trunk and bridging amplifiers are analyzed. The environment in which a CATV transmission system operates is examined with particular emphasis on temperature. Automatic level control and its operation with temperature change is explained. The overall result is improved system reliability through a great reduction in the number of amplifiers in the system and through improved level control as a result of better design. An important by-product is a reduction in the cost of electronic equipment.

One table and several definitions given in an earlier paper[1] are reproduced here under the heading, "Objectives and Definitions".

OBJECTIVES AND DEFINITIONS

Transmission Design Objectives
12 Channel CATV System
0-4 mc

	Top Quality
Signal to Noise Ratio (SNR), dB	45
Cross Modulation Index, dB	52
Subscribers Signal Level, dBmV at 75 ohms	0 to 10
Echo Rating, dB	-34 dB
Radiation FCC Sec. 15, Par. 15.161-5	
Hum	-60 dB
Gain Stability:	
Short Term	±0.5 dB
Long Term	±4 dB
Differential Gain	±2 dB
Differential Phase	±3°

	Good Quality	Minimum Acceptable Quality
SNR, dB	38	34
Cross Modulation, dB	49	48

Other specifications are the same as Top Quality.

The following quality grade definitions are those used in the above table. "Fine" is the TASO grade No. 2.

Top Quality. 95% of observers viewing pictures at all parts of the system would rate the Picture Quality as "Fine". At least 80% of observers viewing pictures at the extremity of the system would also rate the Picture Quality as "Fine". The picture is of high quality providing enjoyable viewing. Interference is perceptible.

Good Quality. 85% of observers viewing pictures at all parts of the system would rate the Picture Quality as "Fine".

Minimum Acceptable Quality. 70% of observers connected at all parts of the system would rate the Picture Quality as "Fine".

Two definitions used frequently are:

Tilt. Tilt is the ratio expressed in dB between the signal level of Channel 2 visual carrier relative to Channel 13 (or Channel 6 in five-channel systems). Tilt is positive when Channel 2 is at lower level than Channel 13 (or Channel 6). Tilt refers to signal level.

Slope. Slope is the ratio expressed in dB between the gain of an amplifier at Channel 2 relative to its gain at Channel 13 (or Channel 6). By considering attenuation as negative gain, the definition may also be applied to cable or other passive devices. Slope is positive when the gain at Channel 2 is less than at Channel 13 (or channel 6); and is negative for coaxial cable. Amplifiers are generally operated with a slope complementing the slope of the cable span with which it is associated. Slope refers to component of cable characteristics.

TEMPERATURE

In designing a CATV system it is essential to determine the environment in which the system is to operate. The environment has many components, including moisture and precipitation, corrosive elements such as gas and salt water, vibration, and temperature variations. Of these components, only temperature variation is considered in this paper.

Temperature extremes for nine different locations in the United States are shown in Table I, which incorporates maximum and minimum temperature data for the total number of years that the weather bureau stations have been in operation, as well as for a recent ten year period. The temperature ranges shown are for the full year and also for Summer and Winter. This kind of temperature data should be studied by the system designer and the specifying engineer whenever a new CATV system is contemplated.

If a system is designed to truly take care of temperature variations on a year-in and year-out basis, the resulting cost and complexity for, say, Greeley, Colorado, gives a system that definitely overperforms for Seattle, Washington. However, if a system is designed that will take care of

Seattle, Washington, throughout the entire year, it would also take care of Prescott, Arizona, if that system were adjusted twice a year, once for Summer and once for Winter. Temperature statistics are available at the local weather bureau office and should be referred to for the installation of quality television cable systems.

TABLE I

MAXIMUM AND MINIMUM TEMPERATURES, ^{O}F

LOCATION		PERIOD YEARS	YEAR HIGH	YEAR LOW	YEAR RANGE	SUMMER * HIGH	SUMMER * LOW	SUMMER * RANGE	WINTER * HIGH	WINTER * LOW	WINTER * RANGE
Prescott, Arizona		64	105	-21	126	105	13	92	87	-21	108
		10	100	- 5	105	100	22	78	83	- 5	88
Fairbanks, Alaska		18	93	-59	152	93	-21	114	74	-59	133
		10	93	-56	149	93	-19	112	74	-56	130
Los Angeles, Calif.		83	110	28	82	110	40	70	100	28	72
		10	110	32	78	110	46	64	96	32	64
Greeley, Colorado	+	64	107	-45	152	107	- 8	115	84	-45	129
		10	106	-39	145	106	0	106	79	-39	118
St. Augustine, Fla.		68	104	13	91	104	37	67	93	13	80
		9	102	22	80	102	38	64	93	22	71
Kearney, Nebraska	o	66	114	-34	148	114	0	114	95	-34	129
		10	113	-21	133	113	15	98	93	-21	114
Keene, N.H.	+	68	104	-32	136	104	1	103	85	-32	117
		10	102	31	133	102	13	89	76	-31	107
State College, Pa.	+	73	102	-20	122	102	1	101	86	-20	106
		10	98	- 4	102	98	18	80	74	- 4	78
Seattle, Washington	+	70	100	3	97	100	29	71	81	3	78
		10	100	13	87	100	35	65	67	13	54

* Summer, May through October; Winter, November through April, unless noted otherwise.
\+ Summer, April through October; Winter, November through March.
o Summer, April through September; Winter, October through March.

TRUNK SYSTEM DESIGN

The important performance criteria affecting the trunk system design are signal-to-noise ratio (SNR) and cross-modulation (Cross-mod). These two characteristics relate to the input and output capabilities of the amplifier. Another important factor interrelated between system design and equipment design is the system length. It has been shown[1] that different amplifier gains should be selected depending on the length of the system. For this reason, C-COR Electronics offers three different models of trunk amplifiers, with gains of 40, 34, and 28 dB, to provide for the different sized systems. Guidelines for selecting these amplifiers as a function of trunk length for various types of coaxial cables are given in Table II.

Transmission characteristics for these amplifiers are shown in Table III.

TABLE II

Amplifier Model	Gain dB	No. of Amps. Cascaded	Total dB	Trunk Length--Miles 1/2" Alum.	3/4" Alum.	0.375 P
TA-40	40	16	640	9.3	13.0	11.0
TA-34	34	32	1090	15.8	22.2	18.8
TA-28	28	64	1800	26.1	36.3	31.0

TABLE III

SPECIFICATIONS FOR TRUNK AMPLIFIERS

OUTPUT: (NCTA Standard) 58 dBmV output level for 12 TV channels at rated gain and full tilt.

RECOMMENDED OPERATION:

AMPLIFIERS	Model TA-28	Model TA-34	Model TA-40
Cascaded, Max. Number	64	32	16
Output level, Channel 13	40 dBmV	43 dBmV	46 dBmV
Amp. Spacing/Operational Gain	28 dB	34 dB	40 dB
Noise Figure			
Channel 13	8 dB	8 dB	8 dB
Channel 2	10 dB	10 dB	8 dB
MANUAL GAIN CONTROL RANGE:	4 dB	4 dB	4 dB

(0, 3, and 6 dB pads available)

AUTOMATIC LEVEL CONTROL: Range is ± 3 dB
Control is ± .5 dB for ± 3 dB input change and includes automatic tilt control. Utilizes Channel 13 picture carrier or pilot carrier.

SLOPE CONTROL RANGE:	22 - 28 dB	28 - 34 dB	34 - 40 dB

Specified as cable length in dB at Channel 13

BANDPASS: 54 - 216 MHz -- ± 0.25 dB
IMPEDANCE: 75 ohms
RETURN LOSS: 16 dB (VSWR 1.38 max.)
HUM MODULATION: -60 dB
TEMPERATURE RANGE: -40°F to 140°F. Unit meets all specifications throughout the temperature range.
POWER: 20 to 32 VAC cable powered.

TAP	OPERATING VOLTAGE	CURRENT
24V	20 - 26	1.3 A
28V	24 - 30	1.2 A
32V	28 - 33	1.1 A

TEST POINTS: DC Volts, ALC Voltage, RF input and output for measurements with high impedance probe TP-30. (not supplied)
BRIDGER OUTPUT: Output to feed bridger -20/-39 down 20 dB at Channel 2, 34 dB at Channel 13. Equalized to provide +6 dB tilt to bridger.

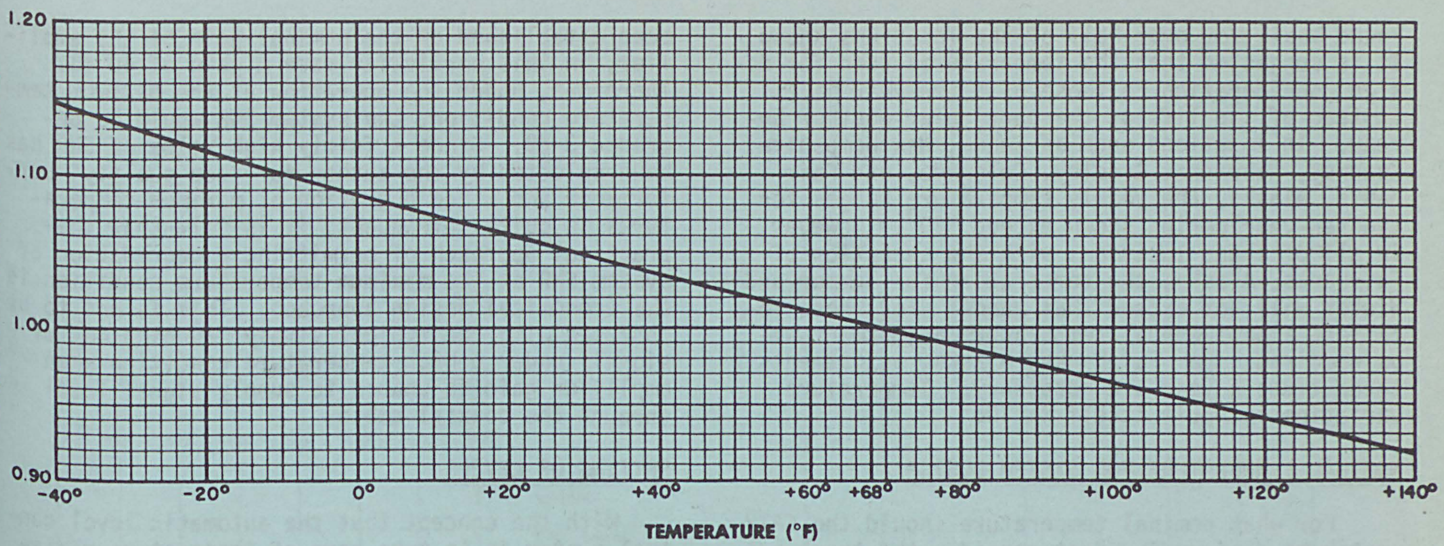
With the high output and low noise of the trunk amplifiers shown in Table III it becomes logical to use a part of this increased dynamic range as increased gain. With the use of a 40 dB gain trunk amplifier instead of a 22 dB gain unit, the reduction in the number of trunk amplifiers is highly significant, approximately 45%. Attendant savings in equipment costs and maintenance costs are readily apparent.

It is estimated that over half of the CATV systems can utilize the 40 dB gain trunk amplifier. These are systems that have maximum trunk lengths of 13 miles of 3/4" aluminum coaxial cable. Contemplated operations in New York City will utilize short trunk lengths from multiple antenna sites. Acceptance and licensing of the 18 GHz microwave service will accentuate this trend. In many metropolitan areas, multiple franchises have been given for different areas of the city--Philadelphia, for instance. In suburban areas contiguous to and a part of a metropolitan area, the fact that adjacent political subdivisions grant franchises to different companies precludes long trunk lengths. Why then, should these situations be saddled with a trunk amplifier that was designed to go a much greater distance?

The equipment designer has considerably more flexibility in the design of a high-gain amplifier than he does in the design of a low-gain amplifier. In the multistage amplifier, the multiple interstage networks can be used for equalization and automatic level control. Solid state devices with high output inherently have higher noise levels than low level devices. To be able to separate an input stage from an output stage with other stages gives the designer the latitude to select a low-noise, low-level input transistor at the input and a high-level output device at the output of the unit without one device affecting the other device to any marked degree.

TEMPERATURE DESIGN, TRUNK SYSTEM

Barring an accident and assuming good design, the only thing to change the signal level in a CATV transmission system is temperature. This, of course, assumes that the signals at the antenna site delivered to the transmission system are stabilized through the necessary equipment. Further, it assumes that the power voltage supplied to the amplifier is regulated and that transistors are reliable and do not fall off in gain as they age.



To correct attenuation to 68°F, use figures at left as multiplier. For example: 2db @ 100°F is known factor. To calculate attenuation @ 68°F, locate 100°F at bottom of chart, follow 100°F line to point of intersection with curve, move left to obtain multiplier of .96. 2 db x .96 equals 1.92 db @ 68°F.

When attenuation @ 68°F is known, use figures at left as divider to calculate attenuation at other temperatures. For example: 2 db @ 68°F is known factor. To calculate attenuation @ 120°F, locate 120°F at bottom of chart, follow 120°F line to point of intersection with curve, move left to obtain divider of .94. 2 db divided by .94 equals 2.13 db @ 120°F.

(Copper loss correction only; assuming dielectric losses constant with temperature)

FIGURE 1 ATTENUATION TEMPERATURE CORRECTION FACTOR

Temperature causes the loss in the coaxial cable to vary. Curves showing the coaxial cable attenuation temperature correction factor are given in Figure 1. In addition, the amplifiers themselves may have a variation in gain with temperature, although the designer attempts to eliminate or minimize this variation. An automatic level control system, therefore, should be designed to take care of temperature variation. Such a system will also tend to take care of "accidents" if they should occur. These will not be designed for, however, since they are of an unpredictable nature.

An intermediate design goal is to hold signal levels constant. (The primary design goal is to deliver good pictures to the subscribers all of the time). If levels are too low at an amplifier input the pictures go into the snow (system SNR is reduced). If amplifier output levels are too high the picture shows windshield wiper effects of cross-modulation. Without some sort of control system, temperature fluctuations will cause snowy pictures in hot weather and "cross in the pictures" in cold weather. An automatic level control system is therefore desirable to hold signal levels at the output of an amplifier at a constant value.

In order to effect signal level control it is desirable to utilize a closed loop control system adjusting the gain of the amplifier. The output signal level is sensed, referred to a reference and adjusted. Some systems utilize a system that senses a temperature and attempts to make a proportional adjustment based on that temperature change. This is an open loop control system. However, it is logical that the signal level itself should be measured and controlled since this is the desired goal. Since the temperature change causes the greatest variation at the highest frequency, the highest frequency signal should be used as a yardstick to control the level. The logical selection is Channel 13 picture carrier (with a standby oscillator at the antenna site) as the pilot signal for automatic level control operation. Further, since the temperature effects on the coaxial cable produce twice the dB change at Channel 13 as at Channel 2, the automatic gain function should change 2 dB at Channel 13 for every 1 dB at Channel 2. Any residual errors in the slope can be adjusted manually on a seasonal basis.

It has been found practical and economical to design an automatic level control system with C-COR's Model TA series amplifiers with a range of ±3 dB. With the Model TA-40 and with cable spacing of 40 dB, this ±3 dB range will accommodate 120^{o}F temperature range (±60^{o}F). With the Model TA-34 and the TA-28, with ±3 dB ALC range, the temperature ranges are ±70^{o}F and ±80^{o}F.

With reference to the maximum and minimum temperature chart of Table I a range of 120^{o}F can accommodate the temperature variations on a year-round basis for over half of the locations shown. It is suggested that the temperatures used for design consideration be those of a ten-year period instead of the life of the particular weather bureau. In locations such as Keane, New Hampshire; Kearney, Nebraska; Greeley, Colorado, and Fairbanks, Alaska, the yearly temperature ranges for the ten-year period shown exceed 120°. However, in all of these locations with the exception of Fairbanks, Alaska, the temperature for Summer and Winter will not exceed that range. For these locations a semi-annual temperature adjustment will be required. For Fairbanks, Alaska, adjustments three times a year are necessary. Temperature variation in April itself is 106°.

NOMINAL TEMPERATURE FOR SYSTEM DESIGN

For what nominal temperature should the CATV system be designed? First consider the trunk system and more specifically a system using the Model TA-40 trunk amplifier. This amplifier has a nominal 40 dB gain for 40 dB cable spacing. The automatic level control has a rated control range of ±3 dB. The amplifier meets all of its performance specifications at the limits of the ALC operation, 37 dB and 43 dB gain. It is necessary to have sufficient gain so that the signal level does not get progressively lower under hhe maximum temperature conditions. We could, therefore, design with 43 dB of gain and 43 dB of cable spacing at the maximum temperature. The level control range of ±3 dB corresponds to ±60°F of cable attenuation change at 216 MHz. A 70°F ambient with ±60°F change gives temperature extremes of 10°F to 130°F. Since 130°F is almost always a maximum design temperature, one can design with the nominal gain and the temperature at a nominal ambient of 70°F.

The author believes that this is a satisfactory design approach. There is one limitation, however. The system design criteria for SNR have been established on the nominal gain of the amplifier, in this particular case a gain of 40 dB. Therefore, under the operation at the maximum temperature condition, the system SNR would be degraded 3 dB. Since a fairly high value of SNR has been selected by the author for "top quality" performance and since operation at maximum temperatures is quite infrequent, it is felt that the practical approach of permitting a degradation of system SNR at the maximum temperature condition is the economical design approach. This is not to be confused with the typical simply "running out of signal" under a high temperature condition when amplifier gain is unable to supply signal level through the coaxial cable.

SETTING OF LEVELS

With the concept that the automatic level control system is to take care of temperature variations, the level control operating position must be set in the field as a function of temperature. If it is desired to have the ALC function over a temperature range of 10 to 130°F then the ALC operating point must be adjusted so that it is at one extremity of its control range at 130°F and at the other extremity at 10°F. The manufacturer must provide the service technician with a temperature-ALC setting chart so that the technician, upon checking the ambient temperature, will set the level control system operating point at the correct point.

FEEDER SYSTEM DESIGN

The high-output bridging amplifier operational characteristics are shown in Table IV.

TABLE IV

SPECIFICATIONS FOR BRIDGING AMPLIFIERS

Models BA-2 & BA-4

OUTPUT: (at each output port) (NCTA Standard) 53 dBmV output level for Model BA-2 and 50 dBmV output level for Model BA-4 for 12 TV Channels with 12 dB output tilt at maximum gain and 0 dB slope.
GAIN: BA-2 -- 42 dB, BA-4 -- 40 dB typical. 40 dB and 38 dB guaranteed minimum @ channel 13 with gain control at maximum.
GAIN CONTROL RANGE: 4 dB continuous, 0, 3, 6, 9 and 12 dB pads available. (Zero dB pad supplied).
BANDPASS: 54 - 216 MHz ±0.5 dB
ISOLATION BETWEEN OUTPUT PORTS: 20 dB minimum
IMPEDANCE: 75 ohms
RETURN LOSS: 16 dB (VSWR 1.38) all ports
TEMPERATURE RANGE: -40°F to 140°F
Temperature compensation provides stabilization of gain to better than ± 1 dB over total temperature range. Unit meets all specifications throughout the temperature range.
HUM MODULATION: -60 dB
POWER: Full isolation "power saver" tapped transformer.

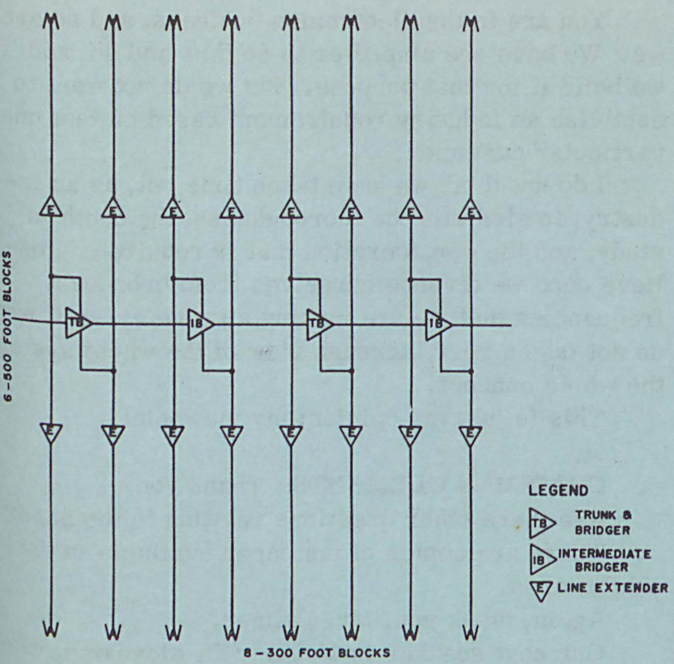


FIGURE 2 CONVENTIONAL 22 dB GAIN AMPLIFIER

The output of 53 dBmV for each port of a two-port bridger or 50 dBmV for each port of a four-port bridger allows feeder lengths over 40% longer than were previously possible (without line extender amplifiers). In fact, the high-output bridger has greatly reduced the number of line extender amplifiers necessary in a system and as a result has concentrated more of the amplification at fewer locations, resulting in easier maintenance and higher reliability.

Therefore, it is extremely important that the bridging amplifier itself have a gain-temperature characteristic that does not aggravate the situation. With C-COR bridging amplifiers, the gain-temperature characteristic is flat. With the bridger output (operational) of 47 dBmV (each of 4 ports) and the resulting long feeder lengths, temperature variations in the typical situation nal level variations in the typical situation at the end of the feeder of ±1.5 dB to 2 dB. It is felt that this range can be adequately taken care of with the AGC of the television receiver itself, particularly since the design criterion has limited signal level variation at the receiver of 0 to 10 dBmV under nominal conditions. However, it is readily apparent that another 2 dB change due to bridging amplifier gain change may aggravate the situation to the point of causing picture degradation.

TYPICAL SYSTEM LAYOUTS

Two systems layouts are displayed in Figures 2 and 3 showing an idealized section of a system. The system shown in Figure 2 utilizes conventional 22 dB gain amplifiers. The system shown in Figure 3 utilizes C-COR's high-output trunk and bridging amplifiers. For a forty block area

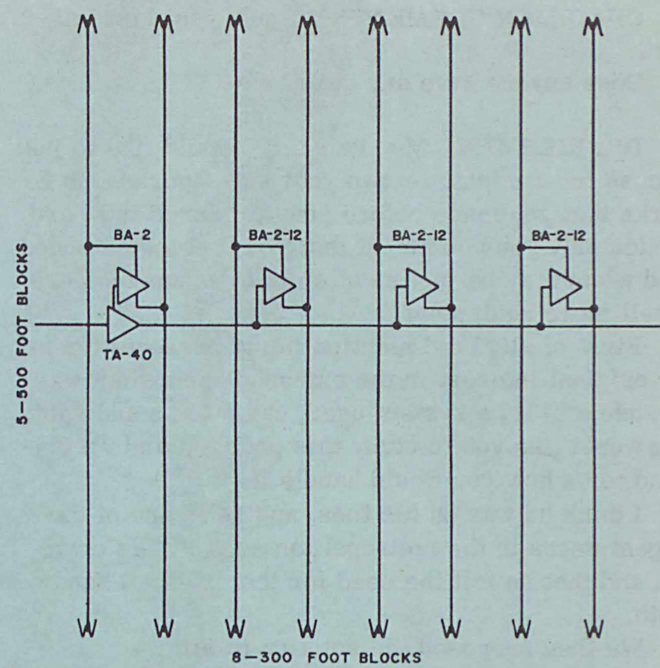


FIGURE 3 C-COR SYSTEM

C-COR uses five amplifiers while the 22 dB system uses sixteen amplifiers. In this case the cost reduction for amplification is 25%.

CONCLUSIONS

A considerable reduction in amplifiers can be made in a CATV system utilizing high-output units. System costs are also lower. An automatic level control system utilizing a closed loop control system results in higher quality performance. Careful consideration of temperature is important in good CATV system design.

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1 Palmer, James R., "CATV System Design Philosophy and Performance Criteria as the Basis for Specifying Equipment Components", Paper presented at the 16th Annual Broadcast Symposium, I.E.E.E. Group on Broadcasting, Washington, D.C., September, 1966.

CHAIRMAN CLEMENTS: Thank you, Mr. Palmer.

Does anyone have any questions?

DR. RIEBMAN: Mr. Palmer, I would like to just discuss for a minute or two your extemporaneous remarks that you made before your prepared talk, and particularly your comment that you feel the extended band width may be just an attempt by manufacturers to sell more equipment.

First of all, I did mention in my presentation that our original interest in the extended band width was because a user, a system user, came to us and said, "We would like you to study this problem and recommend to us how you would handle it."

I think he was on his toes, and he is one of the largest users in the metropolitan area in this country, and that he felt the need for the extended band width.

We then proposed the solution to him.

I feel the manufacturer has a responsibility to his customers to look ahead and try to make his equipment compatible with what future needs might be, and several questions came from the floor about the concern of, "Are we going to buy equipment now and then next year have to replace it?"

Our company, AEL, is making an effort, every effort that we humanly can, to protect our customers against obsolescence. In fact, we are trying to make our equipment compatible with future expected needs. We are recommending for the future.

We are indicating that 300 megacycle cable should be utilized now. It costs you nothing. We have made our system modular. I think we have pioneered the modular concept for the very purpose of minimizing the cost in changing the system in the future.

Rather than be criticized I think we should be commended for trying to help the users and save them future expense.

Now I would just like to raise a question to you in these metropolitan areas, which I think are concerned with this problem first, although it is spreading all over the country. What is your answer to the difficulty of how to attract a subscriber who can already get nearly 12 or more than 12 channels off the air; or 12 channels?

MR. PALMER: I agree with you that we ought to install coaxial cable that goes up to 300 megacycles.

For the rest of your comment, all I can say is that I disagree with you for the reasons I have stated. I just, pure and simple, do not agree. I think it is wrong to take the solution to a particular problem for a particular customer, and offer it as an industry solution.

You are in the electronics business, and so are we. We have one amplifier to do thus and so, and we build it for that purpose. But we do not want to establish an industry requirement based on that one particular customer.

I do not think we have taken time yet, as an industry, to give this the thoroughness, the depth in study, and the consideration that is required. I believe once we divorce ourselves from broadcast frequencies that we are making a grave error if we do not take a very thorough view of the whole system, the whole concept.

This is just my opinion; my viewpoint.

CHAIRMAN CLEMENTS: Thank you.

Are there other questions relating to the paper?

There are copies of the paper available in the exhibit area.

Again, thank you, Mr. Palmer.

Our next speaker is Mr. Gay C. Kleycamp, who is going to address us on the subject of MID-BAND USE IN CATV SYSTEMS. (KAISER CATV)

Mr. Kleycamp. (Applause)

MID-BAND USE IN CATV SYSTEMS

BY

GAY C. KLEYKAMP

INTRODUCTION

This is a report on a series of tests and simulated as well as actual CATV system operation with the application of additional TV channels in the 120 to 175 MHz frequency spectrum. This region is generally referred to as the "mid-band". Standard production unmodified Phoenician Series trunk line amplifiers (KAISER Model Nos. KGAA and KGMA) were used with normal 22 dB spacing.

In assigning the frequencies for the various mid-band channels, it was considered practical to use 6 MHz separation between each of the video carriers with the lowest mid-band channel (Channel "A") at 121.25 MHz. No attempt was made to use mid-band frequencies above 157.25 MHz (Channel "G") in order to avoid interference with the 166.5 MHz pilot carrier used in the KAISER equipment. The lower frequency limitation of 121.25 MHz was selected in order to avoid any possibility of interference with aircraft navigational radio devices.

LABORATORY TESTS

All KAISER Phoenician Series amplifiers are tested for a +50 dBmV, 12-channel plus pilot carrier

Our next speaker is well known to most of us, Mr. Ken Simons, Vice President of Research and Development of The Jerrold Corporation. Mr. Simons received his BSc in electrical engineering at the Moore School of Electrical Engineering at the University of Pennsylvania. He has been active in radio since 1928, active in television since 1938 and has been active in CATV since 1951.

It is with great pleasure that I present Mr. Ken Simons to talk about "Distortion in CATV Amplifiers." Mr. Simons. (Applause)

MR. KEN SIMONS (Jerrold Electronics Corporation): Before I begin I would like to comment to Alan Ross that we are delighted to have him refer to our Channel Commander by name if he has something nice to say about it. Otherwise he should call it a headend converter. (Laughter)

THE FUNDAMENTALS OF DISTORTION IN CATV AMPLIFIERS

by Ken Simons, Jerrold Corporation

Introduction:

Distortion in sound reproducing equipment is familiar to anyone who has heard a worn-out jukebox, or an overloaded public address system. This harsh, unpleasant sound presents the essential nature of all distortion: What comes out of the system is different from what went in! In a CATV system distortion does not show up in the same way, but it is present, and it places restrictions on system operation which must be understood if it is to be intelligently planned and operated.

The amplifiers used in CATV have only one intended function: to increase the signal levels. The other things they do, the differences they generate between the outgoing signals and the incoming signals are distortion. What forms does this distortion take? Several effects properly called distortion, such as the addition of noise to the signal, hum modulation and variations in amplifier frequency response are not the subject of this paper. It is concerned with only one kind of distortion: effects due to the same causes that create "harmonic distortion" in audio amplifiers. This distortion is due almost entirely to amplitude non-linearity in the transistors. Its worst effect is cross-modulation, crossing over of the modulation from one channel to another, which causes "windshield wiper" effects in the picture. Other effects include harmonics, where an unwanted signal is generated at a frequency which is some multiple of the frequency of a wanted one; and beats, where two or more wanted signals combine to generate an interfering one. A study of distortion will help in understanding how CATV amplifiers can be operated to avoid these problems.

Distortion less Amplification:

Perhaps the simplest way to describe amplitude distortion is to say what it is not. A distortionless amplifier would be one which increased the amplitude (voltage swing) of the input signal without changing its waveform. Suppose, for example, an amplifier could be built so that the output voltage, at each instant, was exactly 10 times the input voltage. A graph showing the output voltage plotted against the input voltage would be a straight line, as illustrated in Fig. 1. Such a graph is called the "transfer characteristic" or "input-output curve", for the amplifier. A transfer characteristic which is a straight line is called a "linear transfer characteristic".

Mathematically, the performance of this amplifier would be described by the equation: $e_{out} = 10\, e_{in}$; where e_{out} is the instantaneous output voltage, and e_{in} is the instantaneous input voltage. Calculating for particular voltages would give a table:

e_{in}	e_{out} (= 10 e_{in})
0	0
-0.2	-2
-0.4	-4
-0.6	-6
-0.8	-8
-1.0	-10

e_{in}	e_{out} (= 10 e_{in})
0	0
+0.2	+2
+0.4	+4
+0.6	+6
+0.8	+8
+1.0	+10

This is the table from which the characteristic of Fig. 1 is plotted.

The way in which such a linear transfer characteristic results in an undistorted output is shown in Fig. 2. A plot of the sinusoidal input voltage against time is illustrated (Fig. 2(a)). If, at each point along the time scale, the instantaneous input voltage is projected downward to the transfer characteristic (Fig. 2(b)), the corresponding output voltage is found. Projecting this to the right, and plotting against the same time scale constructs graphically the waveform of the output voltage (Fig. 2(c)). For example, when the input is 0.75 volts and decreasing (point "A"), the output is 7.5 volts and decreasing (point "B"). Since the output voltage at each time is simply ten times the input voltage, the output duplicates the input waveform. Each point on the output waveform corresponds exactly with the corresponding point on the input, so there is no distortion.

The action has nothing to do with the input voltage waveform. Whatever that waveform is, it is duplicated in the output. Fig. 3, for example, shows a similar diagram with a pyramidal input, showing how an identically-shaped pyramidal output results.

Amplication with Distortion:

Unfortunately, amplifiers that can be built using real-life transistors do not have a linear relationship between the input voltage and output voltage. Figure 4 illustrates a non-linear transfer characteristic which might be found in a real amplifier. As the input voltage swings either way from 0, the output changes along a curve which produces less and less change in output voltage as the input swings further and further from 0. In the example illustrated, were the output to continue increasing along a straight line at the same rate it follows near 0, it would reach about +20 volts when the input was +1 instead of the +10 it actually reaches.

When a varying voltage is applied to an amplifier with a characteristic of this sort, the output voltage will have a different waveform from the input voltage. Consider the examples shown in Figure 5. Figure 5(a) illustrates the output voltage waveform obtained when a sinusoidal voltage with a voltage swing between +1 and -1 volts is applied to the amplifier whose characteristic is illustrated in Figure 4. Since the transfer characteristic is symmetrical, both peaks of the output voltage are squashed by the non-linearity giving the waveform illustrated.

A 0.5 volt peak-to-peak sinusoidal voltage applied to the input of the same amplifier and biased at -0.5 volts so that it varied between 0 and -1 volts would produce an output varying between 0 and -10 volts with the waveform illustrated in Figure 5(b). The lower peak is squashed because the curve bends over at -1 volts input, the upper peak is faithfully reproduced because the curve is very nearly a straight line near 0.

Reducing the amplitude of the input voltage is 0.2 volts peak-to-peak and biasing it at 0 so that it varies between +0.1 and -0.1 volts gives the output voltage shown in Fig. 5(c). Because the signal was varying along a nearly linear part of the characteristic, this is almost an undistorted reproduction of the sinusoidal input.

It should be clear from these examples that the nature as well as the degree of distortion is dependent not only on the transfer characteristic of the amplifier but equally on the amplitude of the input signal and on the operating point (bias). Two very different and significant kinds of distortion are illustrated: one where the peaks are squashed symmetrically [Fig. 5a)] and the other where only one peak is squashed [Fig. 5b)]. In what follows these two cases will be explored more thoroughly.

Second order Distortion:

In the section on distortionless amplification, it was shown that a linear transfer characteristic could be expressed in very simple mathematical terms. The equation "$e_{out} = 10e_{in}$" says very clearly that the amplifier in question has a gain of ten times and no distortion. Since all practical amplifiers cause distortion, a sensible question is: "Can the transfer characteristic of a practical amplifier be expressed in some simple mathematical way which will allow analysis of the distortion generated?" The answer is yes, of course, and the subject of what follows is how this is done.

First, consider an amplifier which generates the kind of distortion illustrated in Figure 5(b). The transfer characteristic causing this kind of distortion can be approximated by an equation having the form "(e_{out}) equals (some number times e_{in}) plus (some other number times e_{in}^2)."

The following may help to understand how this works. Consider first the curve that results when e^2 is plotted against e. The numbers come out like this:

e	e^2	e	e^2
-1.0	+1.0	+1.0	+1.0
- .8	+ .64	+ .8	+ .64
- .6	+ .36	+ .6	+ .36
- .4	+ .16	+ .4	+ .16
- .2	+ .04	+ .2	+ .04
0	0	0	0

This curve is plotted in Figure 6. Notice that it is symmetrical about 0, curving up smoothly for both positive and negative values of e.

Next consider an example of what happens when a curve of this sort is added to a linear transfer characteristic. The output voltage is separated into two parts:

for the linear part: $e_1 = 10\, e_{in}$

for the "squared" part: $e_2 = 5\, e_{in}^2$

and for the total: $e_{out} = e_1 + e_2$

$$= 10e_{in} + 5e_{in}^2$$

The numbers come out like this:

e_{in}	$10\ e_{in}$	e_{in}^2	$5\ e_{in}^2$	$10\ e_{in} + 5\ e_{in}^2$
-1	-10	+1	+5	-5
-0.8	- 8	+0.64	+3.2	-4.8
-0.6	- 6	+0.36	+1.8	-4.2
-0.4	- 4	+0.16	+ .8	-3.2
-0.2	- 2	+0.04	+ .2	-1.8
0	0	0	0	0
+0.2	+ 2	+0.04	+ .2	+2.2
+0.4	+ 4	+0.16	+ .8	+4.8
+0.6	+ 6	+0.36	+1.8	+7.8
+0.8	+ 8	+0.64	+3.2	+11.2
+1.0	+10	+1.00	+5	+15

Fig. 7 shows the two curves plotted separately (a and b) and the total (c). Notice the similarity between this total curve [Fig. 7(c)], the plot of a simple mathematical equation, and the lower half of a particular non-linear transfer characteristic (Fig. 4).

Fig. 8 illustrates graphically how the introduction of a sinusoidal voltage into an amplifier having a square-law transfer characteristic results in an output of the one-peak-stretched, one-peak-squashed variety. Since this kind of distortion results from the addition to the linear characteristic of a quantity involving e^2, it is called "second order" distortion. In these terms it is said that Fig. 8 shows that "a square-law transfer characteristic (or a characteristic having second-order curvature) causes second-order distortion of the output." Observe that not only is the upper peak of the output voltage stretched by the action of the second-order distortion and the lower peak squashed, but also the entire curve is shifted upward so that its average is above 0.

Second-order Distortion by Addition of Components:

As has been shown, one way to study second-order distortion mathematically is to use a square-law equation. There is a second approach which is also very useful. This approach involves the addition of d-c and sinusoidal voltages to produce a distorted total. Figure 9 illustrates how this works. Because the "parts" or "components" that go to make up a distorted waveform are being considered, each component is given a name. This diagram shows how a distorted output can be generated by adding together three components: the fundamental component, a sinusoidal voltage having a frequency of 1 MHz (1 cycle in 1 microsecond) in this example; the second harmonic component, a sinusoidal voltage having twice this frequency, 2 MHz (2 cycles in 1 microsecond); and a positive d-c component.

Notice first that the total voltage has a waveform identical with that produced when a sinusoidal voltage is passed through the square-law characteristic of Figure 8. Now see how the three components add together in Fig. 9: At 0 time on the diagram, the fundamental component is 0, the second harmonic is at its negative peak (-2.5 volts) and the d-c component is at +2.5 volts. Adding the three together gives the total voltage which is 0. At 0.25 microseconds the fundamental has gone through one-quarter cycle to its positive maximum (+10 volts), the second harmonic component has gone through one-half cycle to its positive maximum (2.5 volts) so the three add together to produce the peak voltage of the total (+15 = 2.5 + 2.5 + 10). At 0.75 microseconds the second harmonic and the d-c are at +2.5 volts so they subtract from the -10 volt peak of the fundamental to give the squashed peak of the total (-5 = -10 + 2.5 + 2.5).

This diagram illustrates one case of a very important general principle: Any non-sinusoidal periodic waveform can be produced by adding together an appropriate combination of d-c and sinusoidal components.

Spectrum of a Voltage with Second-Order Distortion:

A very convenient way of measuring any varying voltage is to plot its "spectrum". A spectrum is simply a graph which plots in the vertical direction, the peak voltage or amplitude of each sinusoidal component and in the horizontal direction, shows the frequency at which each of these components exists. Its importance rests on the fact that "spectrum analyzers" are available which plot these diagrams automatically, providing tremendously useful tools for distortion analysis. The spectrum of a sinusoidal voltage is a single spike showing the amplitude and frequency of that voltage. Figure 10, for example, shows the spectrum of the fundamental component voltage in Figure 9. It says three things: (1) this voltage is a pure sine-wave (there is only one spike); (2) its peak amplitude is 10 volts (the vertical reading at the top of the spike); (3) its frequency is 1 MHz (the horizontal position of the spike).

Figure 11 illustrates the spectrum of the distorted output voltage of Figures 8 and 9. It shows three components: the 2.5 volt peak, 2 MHz second harmonic; the 10 volt, 1 MHz fundamental; and the 2.5 volt 0 frequency (d-c) component. (Note that most spectrum analyzers do not show d-c components so that only the other two would be displayed.)

Third Order Distortion:

In the previous section it has been shown that the kind of non-linearity which results in the "one-peak-squashed" kind of distortion can be expressed by a simple square-law mathematical equation. In very much the same way, the kind of distortion which results in both peaks being squashed can be expressed by a cube-law equation. This equation has the form: (e_{out}) = (some number x e_{in}) + (some other number x e_{in}^3). It approximates a transfer characteristic of the "both-peaks-squashed" type, as illustrated in Fig. 5(a).

Consider the curve that results when e^3 is plotted against e. The numbers come out like this:

e	e^3	e	e^3
-1.0	-1.000	+1.0	+1.000
- .8	-0.512	+ .8	+0.512
- .6	-0.216	+ .6	+0.216
- .4	-0.064	+ .4	+0.064
- .2	-0.008	+ .2	+0.008
0	0	0	0

This curve is plotted in Fig. 12. It is "skew symmetrical"; that is, the curve for negative values of e has the same shape as for positive values, but is upside down.

When this curve is added to a linear transfer characteristic, it affects both extremes in the same way, since the linear part and the "cubed" part go positive together and negative together. Consider an example:

for the linear part of the characteristic take:

$$e_1 = 10\, e_{in}$$

for the "cubed" part take: $e_3 = 3\, e_{in}^3$

to get a curve which squashes the peaks, the cubed part is subtracted from the linear part, so the total is:

$$e_{out} = e_1 - e_3 = 10e_{in} - 3e_{in}^3$$

The numbers come out like this:

e_{in}	$10\, e_{in}$	e_{in}^3	$3\, e_{in}^3$	$10\, e_{in} - 3\, e_{in}^3$
-1	-10	-1.000	-3.000	-7.000
-0.8	- 8	-0.512	-1.536	-6.464
-0.6	- 6	-0.216	-0.648	-5.352
-0.4	- 4	-0.064	-0.192	-3.808
-0.2	- 2	-0.008	-0.024	-1.976
0	0	0	0	0
+0.2	+ 2	+0.008	+0.024	1.976
+0.4	+ 4	+0.064	+0.192	3.808
+0.6	+ 6	+0.216	+0.648	5.352
+0.8	+ 8	+0.512	+1.536	6.464
+1.0	+10	+1.000	+3.000	7.000

Fig. 13 shows the two component curves plotted separately (a and b) and the total (c). Notice the similarity between this total curve, the plot of a simple equation, and the non-linear transfer characteristic shown in Fig. 4.

Fig. 14 illustrates graphically the way in which the introduction of a sinusoidal voltage into an amplifier having a "cube-law" transfer characteristic results in an output of the "both-peaks-squashed" variety. Since this kind of distortion results from subtracting a quantity involving e^3, it is called "third order" distortion. In these terms it is said that Figure 14 shows that "a cube-law transfer characteristic (or a characteristic having third order curvature) causes third order distortion of the output."

Third Order Distortion by Addition of Components:

In the foregoing it was found possible to duplicate the effects of second order distortion by adding sinusoidal components. In a similar way, the effects of third order distortion can be obtained. Figure 15 illustrates the addition of a 10 volt peak, 1 megacycle fundamental component (a) and a 1 volt peak, 3 megacycle third harmonic component (b) to produce a distorted total (c) having the same waveform as that generated by the cube-law equation illustrated in Fig. 14. Because of the 3:1 frequency relationship, the third harmonic voltage is opposite in phase to the fundamental at its positive peak with the result that the total is squashed, and is again opposite in phase at its negative peak so the total is also squashed at that time.

Spectrum of a Voltage with Third Order Distortion:

Figure 16 illustrates the spectrum of this distorted voltage. Since the distortion waveform is duplicated by the sum of two components, the spectrum shows only these two: a 10-volt-peak fundamental component at 1 MHz and a 1-volt-peak third harmonic at 3 MHz.

A "Beat"; the Sum of Two Sinusoidal Voltages of Different Frequencies:

Since a major object of this article is to investigate the effects that occur in broadband amplifiers when many "channels" are handled simultaneously, it is necessarily concerned with what happens in an amplifier when more than one sinusoidal voltage is introduced into it. Although the picture carrier on each channel is not a constant-amplitude sine-wave (since it is modulated with the picture information), a great deal can be learned about the nature of distortion in this case by temporarily pretending that it is. The first question then is: What is the waveform of the voltage resulting when two sine-waves having different frequencies are added?

To answer this question it is helpful first to consider the way in which two sinusoidal voltages add when each has the same frequency and amplitude, but they have various phase relationships. Fig. 17 illustrates several cases showing each voltage separately (a and b) and the resulting total voltage (c).

When each voltage is sinusoidal, the frequencies are identical, and the voltages are exactly in phase, the two reach their peaks at the same instant and at that time they add directly (e.g. 1.0 + 1.0 = 2.0) so the peak voltage of the total is the sum of the two components (shown as the 0° condition).

When there is a 90° phase difference between the two, the total reaches its maximum at a time when each of the components is at 0.7 of peak, so the peak voltage of the total is reduced to 0.7 of the sum of the peak voltages of the components e.g. + 0.7 + 0.7 = 1.4 (the + 90° and - 90° conditions) . When the two voltages have opposite phase (180° out of phase), they are equal and opposite at all times, and the total is 0 (the 180° condition).

Next consider the addition of two sinusoidal voltages having different frequencies. Figure 18 (a and b) illustrates the waveforms of two particular voltages. Each is sinusoidal, with a peak amplitude of 2 volts. One has a frequency of 5 MHz, a time-per-cycle of 1/5 microseconds; the other has a frequency of 6 MHz, and a time-per-cycle of 1/6 μsec. Thus, the former completes 5 cycles in a microsecond while the latter is completing 6 cycles.

Superimposing the two waveforms on each other Fig. 18(c) shows clearly a highly significant fact, the phase relation between them is changing constantly. Initially they are in phase (both at positive peak). After 1/4 microsecond the 5 MHz voltage has gone through 1-1/4 cycles and is 0, going negative, while the other has gone through three half-cycles and is at its negative peak. They differ in phase by 90°. After 1/2 microsecond the 5 MHz one is at its negative peak, while the 6 MHz one is at its positive peak, and they are 180° out of phase. As time goes on, they go through all possible phase relations, coming back to the "in phase" condition once each microsecond.

Now what happens when these two voltages are added? The total follows the principles illustrated

Fig. 17. When the two components are in phase, they add to produce a maximum peak voltage, when they are 180° out they cancel, and in between the peak amplitude changes from one condition toward the other. The resulting waveform is illustrated in Fig. 19(a), showing the two component voltages and the total superimposed, and Fig. 19(b), showing the total alone. The total voltage reaches a 4-volt maximum peak initially when the two are in phase, the peaks reduce on successive cycles reaching 0 after 1/2 microsecond when the two components are 180° out of phase, and building up again to a 4-volt maximum peak after one microsecond when they come back in phase again.

This "beat" voltage, the sum of two particular sinusoidal voltages, demonstrates several characteristics common to all sums of two such voltages without regard to their frequencies. One characteristic is the variation in the peak voltage of the total. For the sum of two equal voltages with <u>any</u> frequencies, the total peak voltage varies from maximum to 0 and back to maximum at a frequency which is the difference of the frequencies of the components. (In this example, the peak voltage varies at a frequency of 1 MHz = 6 - 5.) What does a spectrum analysis of the total voltage show? As indicated in Fig. 20, the analysis shows two 2-volt components, one at 5 MHz and one at 6 MHz, and that is all. How can that be? The peak of the total voltage certainly increases and decreases at a frequency of 1 MHz. Is there no 1 MHz "signal" or "component" there? The answer is that there is none, and the reason goes right back to what is meant by the term "component". A set of lines on a spectrum chart, or a statement "There are frequency components present at these specified frequencies" means only one thing: that the waveform of the voltage in question can be duplicated precisely by adding together sinusoidal voltages having the indicated amplitudes and frequencies. In the example, the initial condition showed that this waveform is generated when a 5 MHz component is <u>added</u> to an equal 6 MHz component. They were added, nothing else was added so the total voltage cannot, by definition, contain any other components. A basic principle is involved:

> Only when there is non-linear distortion are frequency components generated in the output which were not present in the input.

What about the 1 MHz variation in peak voltage? Is it "there"? Of course, it's there. It is evident on the waveform, but the fact that something (i.e. the peak voltage) in this waveform varies at a frequency of 1 MHz, does not mean that there is a 1 MHz component present. No 1-MHz sinusoidal voltage component is needed to duplicate this waveform. If the variation over a full microsecond is inspected, it can be seen that the "beat" voltage varies in such a way that it spends exactly as much time below 0 in each half cycle as it does above, so on the average there is no variation at the 1 MHz frequency.

<u>A Beat Voltage with Second Order Distortion:</u>

It has been shown that, when two sinusoidal components are fed into a distortionless amplifier, the output contains only the two original components, or saying the same thing, the output waveform is the same as that of the input. Fig. 21 illustrates again the waveform and spectrum in this case, showing how the total peak voltage varies at the difference frequency $(f_2 - f_1)$ as the phase relation between the components changes.

Now consider what happens when the two sine-wave voltages are added and introduced into an amplifier with second order distortion. Fig. 22(a) illustrates the result, the distorted waveform that occurs when a "beat" voltage (the sum of two sine-waves) is fed through an amplifier having only second order distortion.

Since the output waveform has a decidedly different shape from the input [compare Fig. 22(a) and Fig. 21(a)], it is clear that there must be components at frequencies other than the two original ones. Fig. 22(b) illustrates the five new frequency components that are added to the output voltage by second order distortion. Since the positive peaks in the output are stretched, and the negative peaks squashed, there is a general shift in level in the positive direction, and there must be a corresponding positive d-c component. Since the peaks above 0 no longer average out with the peaks below 0, there is also a component at the difference frequency $(f_2 - f_1)$. For a similar reason, there is a component at a frequency which is the sum of the frequencies of the two originals signals $(f_1 - f_2)$. And of course, each of the original signals generates a second harmonic (at $2f_1$ and $2f_2$). Thus, the spectrum of the output signal looks like Fig. 22(b) with components at the two original frequencies as well as at the five new ones.

An important conclusion can be drawn from this one example: Whenever more than one sinusoidal voltage (that is when more than one signal) is introduced into an amplifier which has second order distortion, the output will include signals at certain frequencies differing from those of the input signals. There will be a d-c component, a shift in the average collector current of the distorting stage which generally does not show up in the output, a component at a frequency which is the difference of the two original frequencies, a component at a frequency which is the sum of the original frequencies. When the original signals are modulated with picture information, each of these spurious signals will carry the modulation of both of the original signals from which it comes.

Why Second Order Distortion is Unimportant in Present CATV Systems:

Anyone who has worked with CATV equipment in the past recognizes the fact that very little attention has been paid to the problem of second order distortion. The usual amplifier specification states the noise figure, gain and cross-modulation but does not mention sum or difference frequency beats or second harmonics. The reason for this has to do with the standard channel frequency assignments established by the FCC. If one takes any pair of picture carrier frequencies in the standard 12-channel assignment, their sum or difference does not fall in any of those channels. Similarly, with one minor exception (channel 6 sound carrier), the second harmonics of all low band carriers fall between the two bands. Figure 23 shows the spectrum obtained when 12 CW signals on the normal picture carrier frequencies were introduced into a CATV amplifier at levels somewhat higher than normal operating level. This shows the spurious signals resulting from second order distortion illustrating how they fall below and between the bands, but not within the channel limits. Since this is true, second order distortion has no bad effects on an amplifier carrying up to twelve standard TV channels, and it is not normally considered in this case.

Beat Voltage with Third Order Distortion:

Figure 25(a) illustrates the appearance of the output voltage of an amplifier having third order distortion when a beat input signal similar to Figure 21(a) is introduced into the input. The squashing of the larger vertical peaks is clearly evident. A spectrum diagram showing the frequency components in the output is shown in Figure 25(b). In addition to the two original sinusoidal components (at f_1 and f_2) spurious signals occur at the following frequencies:

$2f_1-f_2$	This falls below f_1 at a spacing corresponding to the frequency difference between f_1 and f_2.
$2f_1-f_1$	This falls above f_2 at a spacing corresponding to the frequency difference between f_1 and f_2.
$3f_1$ and $3f_2$	These are the third harmonics and the spacing between is three times the spacing between f_1 and f_2.
$2f_1+f_2$	This falls above $3f_1$ at a spacing corresponding to the frequency difference between f_1 and f_2.
$2f_1+f_1$	This falls below $3f_2$ at a spacing corresponding to the same difference.

Cross-Modulation and Compression:

The spurious signals generated by third order distortion in present CATV systems. This is "cross modulation", one of two important effects of third order distortion which do not result in components at new frequencies. Each of these effects represents a change in gain at the channel frequencies rather than the generation of new frequency components. Figure 26 illustrates these effects. These spectrum diagrams illustrate the input and output components in an amplifier which has severe third order distortion. The upper diagrams illustrate the input signal components, the lower diagrams illustrate the resulting output signal components. The amplifier voltage gain, for small signal input, is 10 times. Thus, as illustrated in Figure 26(a), an input of 2 millivolts gives an output of approximately 20 millivolts. It can be seen by inspecting the shape of any third-order distortion characteristic [Figure 13(b) for example] that the effective gain decreases as the signal amplitude increases. Thus, as shown in Figure 26(b), increasing the input signal of this amplifier to 10 millivolts results in an output of about 90 millivolts, rather than 100 millivolts which would be obtained if the gain were not reduced by the effects of third order distortion. This effect, the reduction in gain at a single frequency as the signal amplitude increases, is called compression and results in distortion of the modulation envelope on any modulated signal going through such an amplifier. When this effect occurs in an amplifier carrying a single TV-modulated signal, it results in a squashing of the sync peaks which is called "sync compression". Figure 26(c) shows what happens when a signal is introduced at low level on another frequency. Several effects can be seen: The output level on the new frequency is somewhat below the 20 millivolt it would reach if the strong signal were not ent; the strong signal output is slightly re- d by the presence of the new signal [compare (b)], and a spurious component at $2f_1-f_2$ can be .

As shown in Figure 26(d), increasing the second t signal to full amplitude results in a further re- ion in gain so that both output signals at the inal frequencies are below 60 millivolts and the ious signals increase in amplitude. The most ificant effect here is that the gain on each nel is reduced not only by an increase in level at channel but also by the increase in level on other channel. This results in a transfer of any ation, or modulation, on one carrier to any r carriers going through the same amplifier. s transfer is called cross-modulation and repre- ts the worst effect of non-linearity in present- CATV amplifiers.

This effect is further illustrated in Fig. 27. ure 27(a) shows the output signal obtained when inusoidal input is applied to an amplifier with a all amount of third order distortion. Figure 27(b) ows what happens when a second signal, fully odulated, is fed through the same amplifier. The tput includes the modulated signal (which shows p in the frequency spectrum as a carrier with aller sidebands on each side), the output at the equency of the original CW signal, and two urious sideband components which show up ad- cent to the CW signal frequency as a result of ird order distortion. It is clear how this distor- on results in a transfer of modulation from one gnal to the other.

Conclusion:

This article has attempted to describe all of the effects which result from the simplest kinds of non-linearity, second order and third order distortion, in amplifiers of the type used for CATV systems. It has shown that second order effects are generally unimportant with present-day frequency assignments and that, of all the third order effects, cross-modulation is the most important, representing the factor which limits the output level at which the amplifiers in these systems may be operated without causing disturbance to the customer's reception.

A LINEAR TRANSFER CHARACTERISTIC

Figure 1

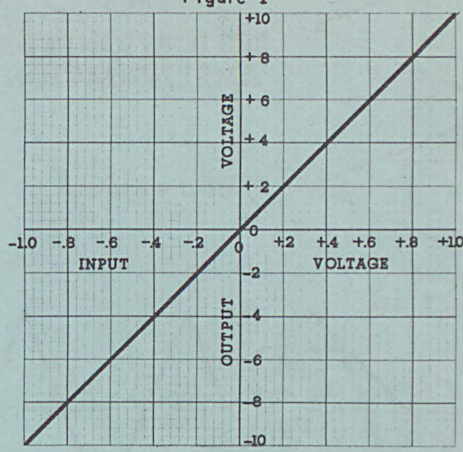


Figure 1

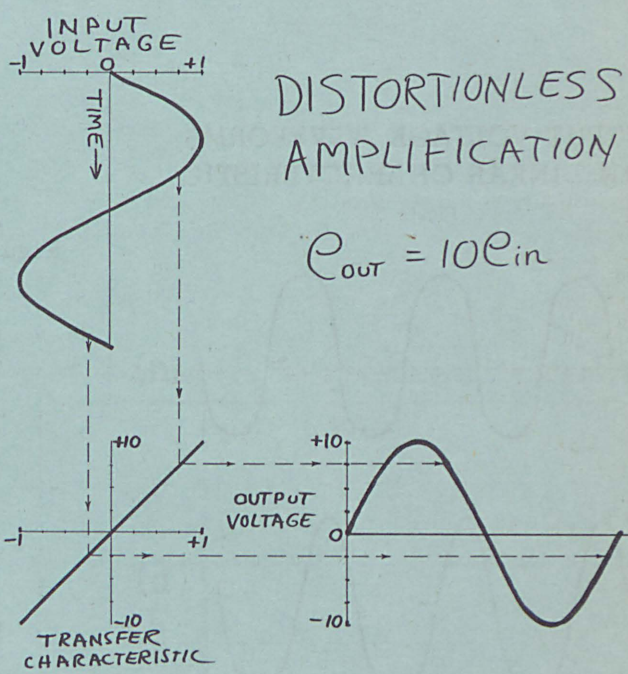


Figure 2

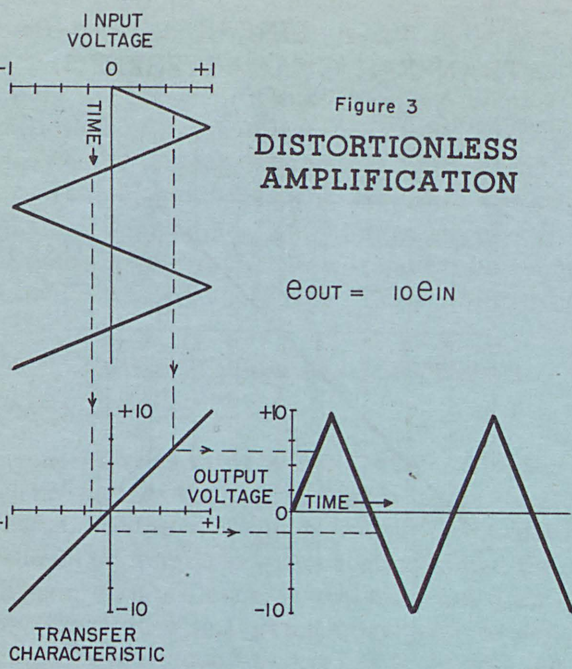
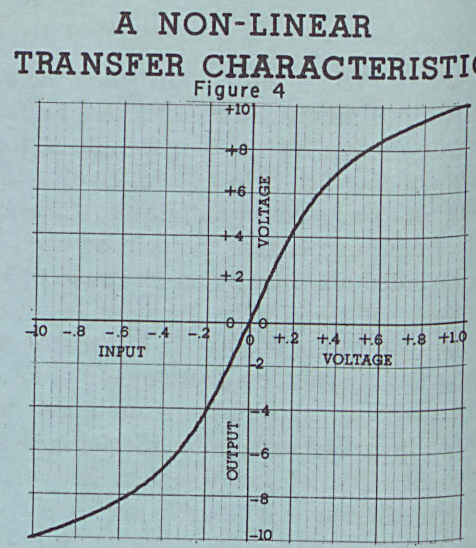


Figure 3



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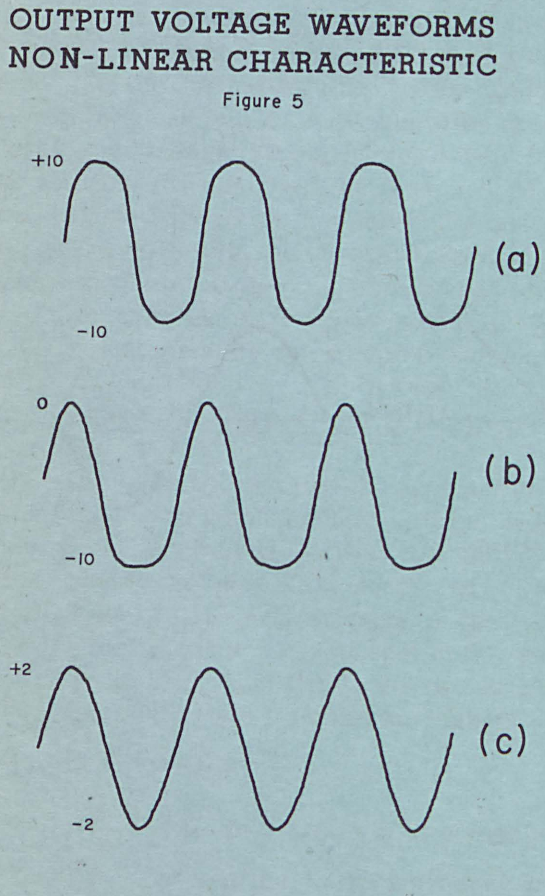
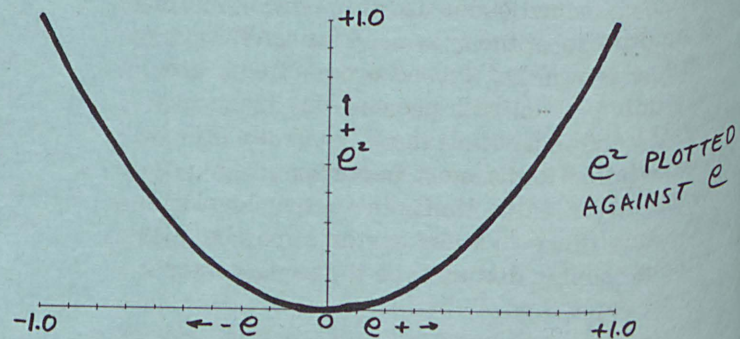
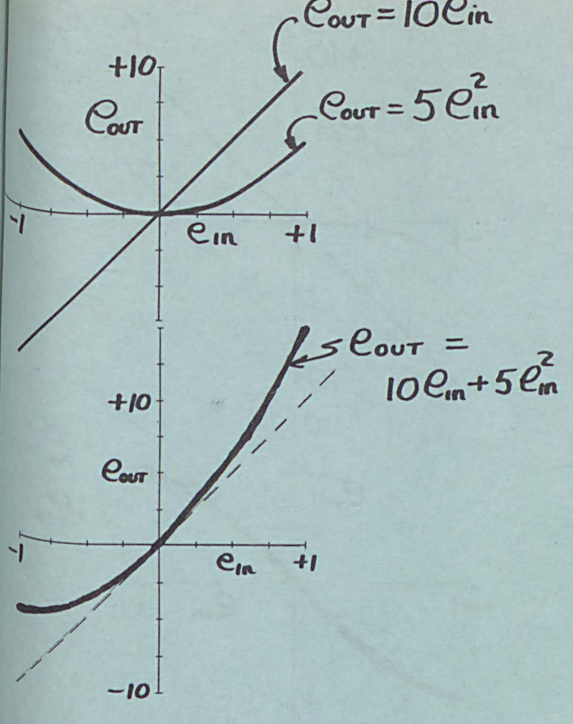


Figure 5

Figure 6





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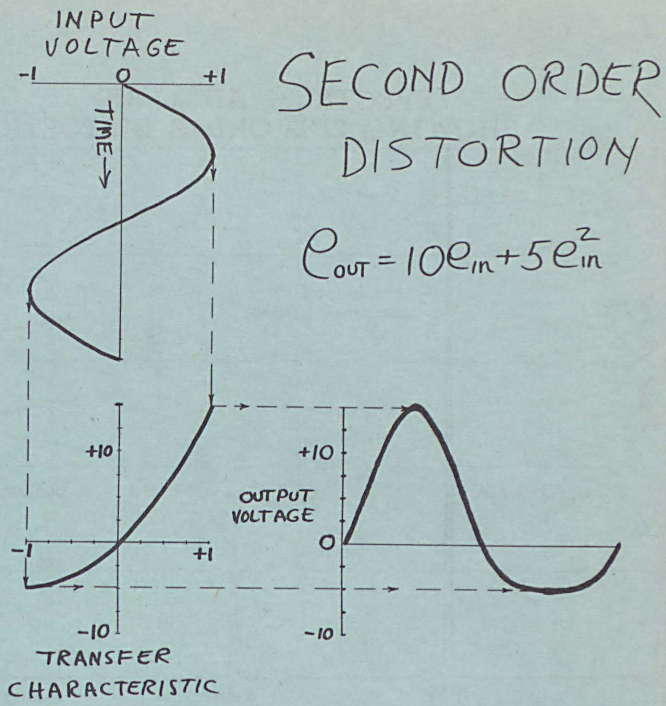

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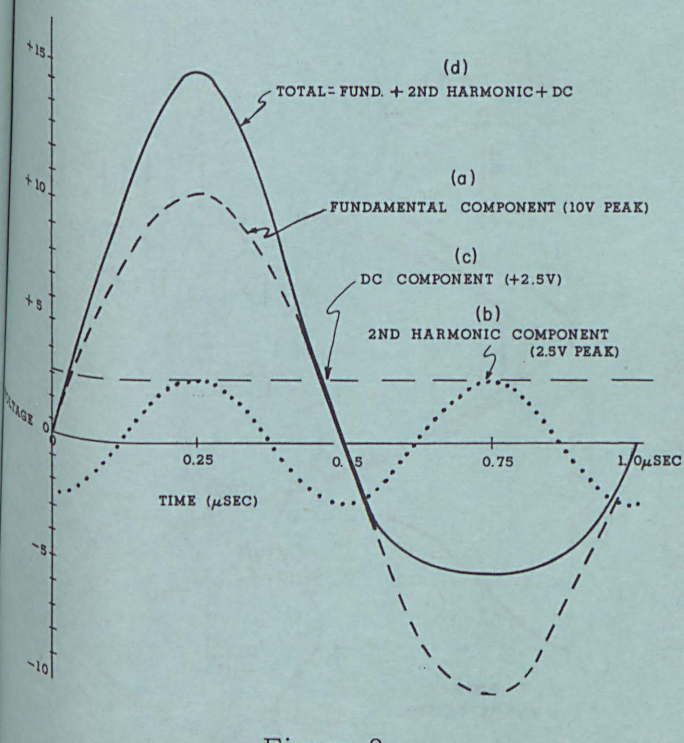

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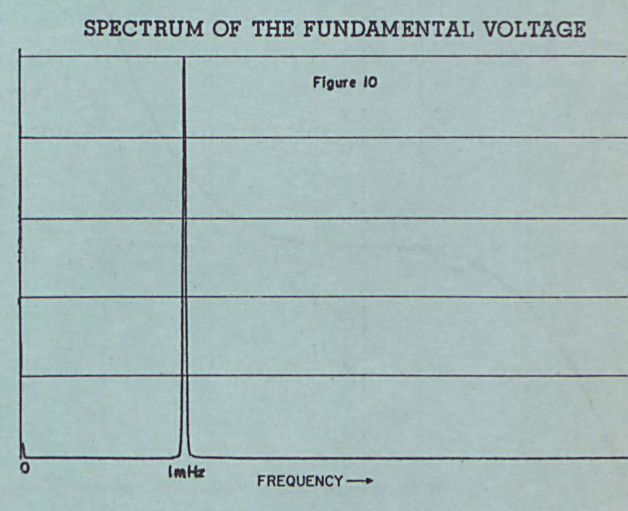

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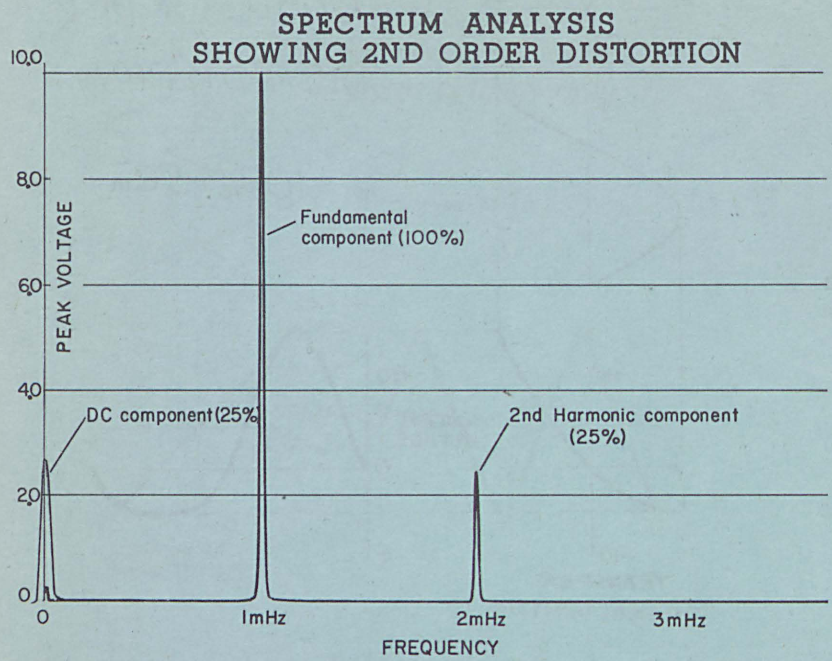

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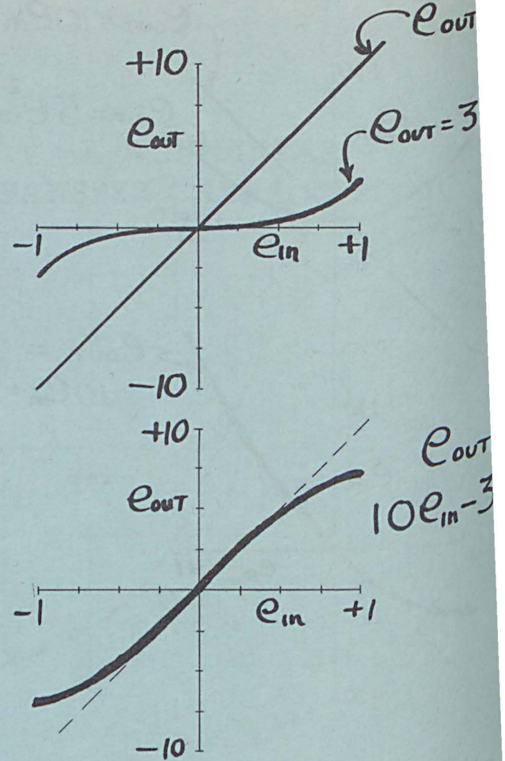
Figure 11



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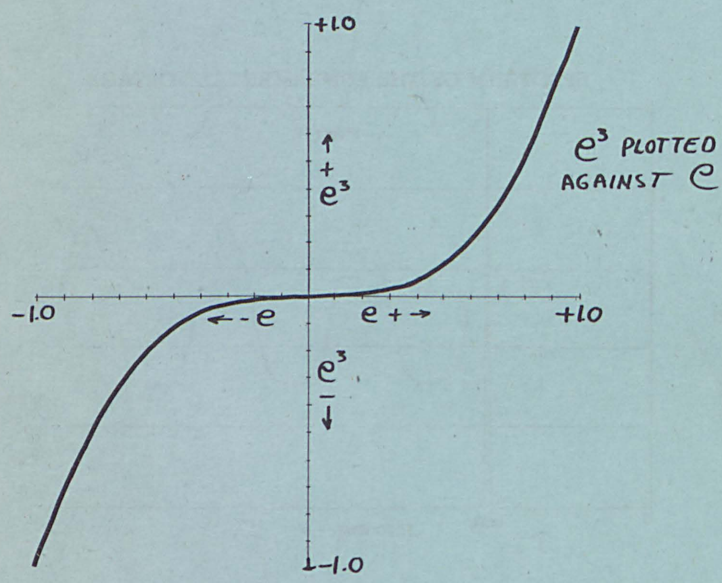

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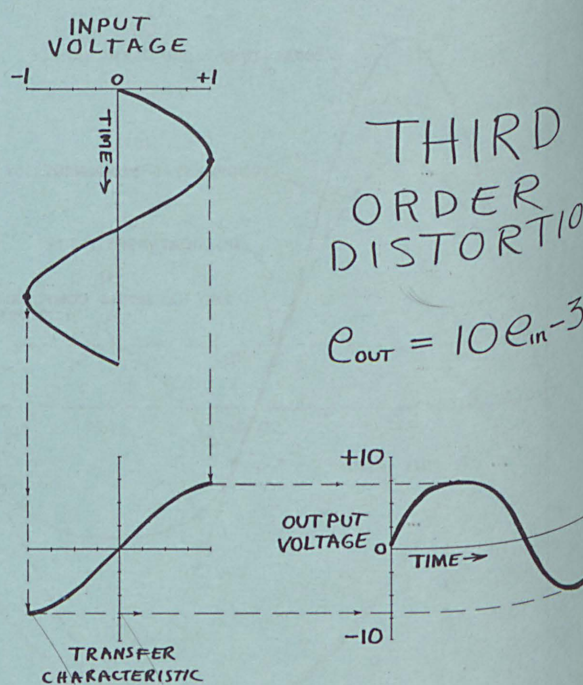

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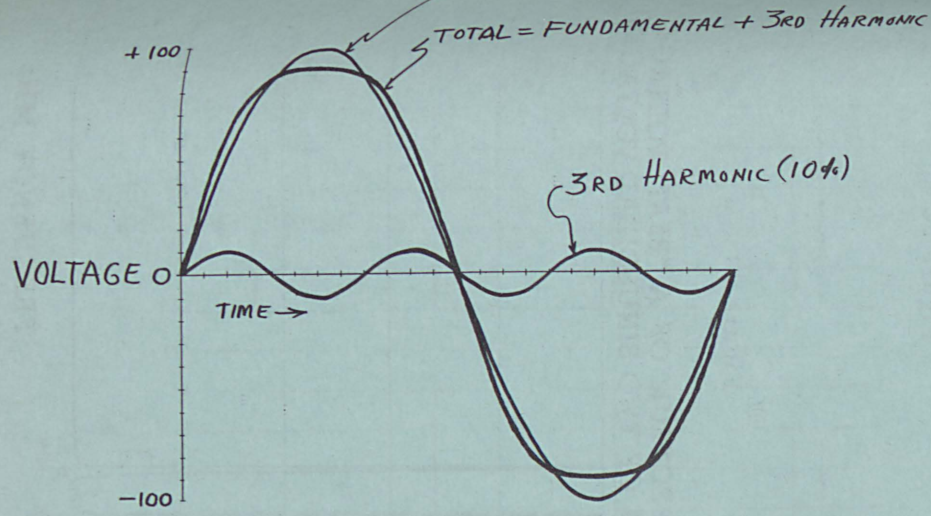


Figure 15

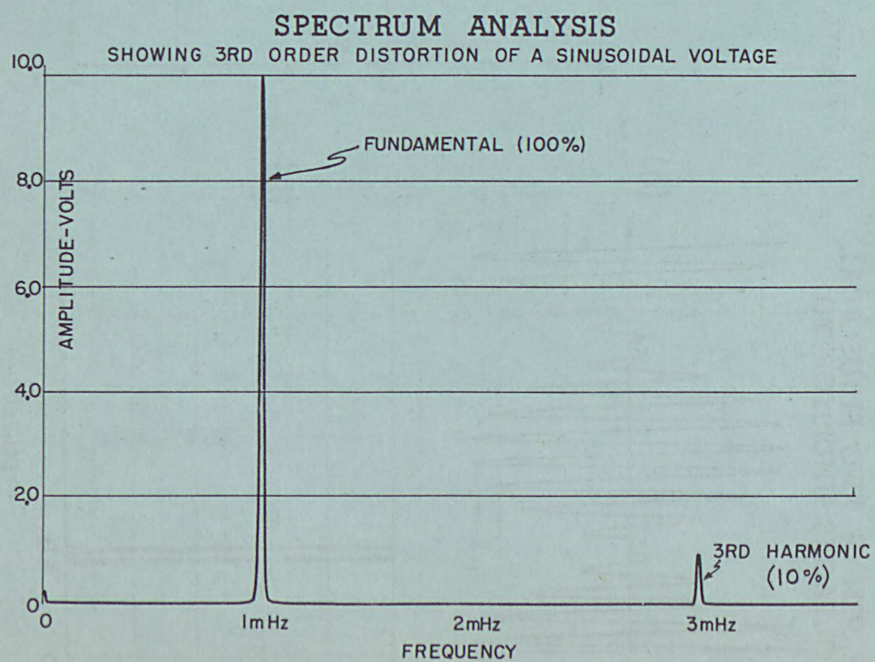


Figure 16

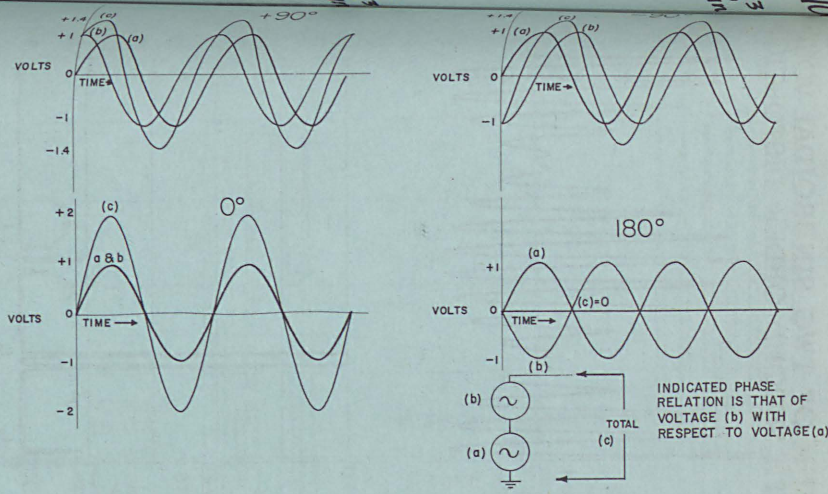
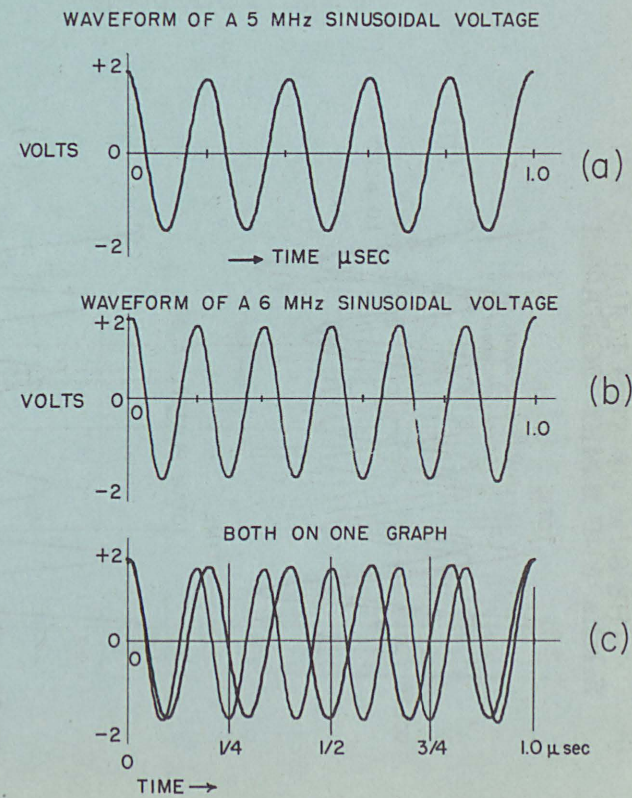


Figure 17



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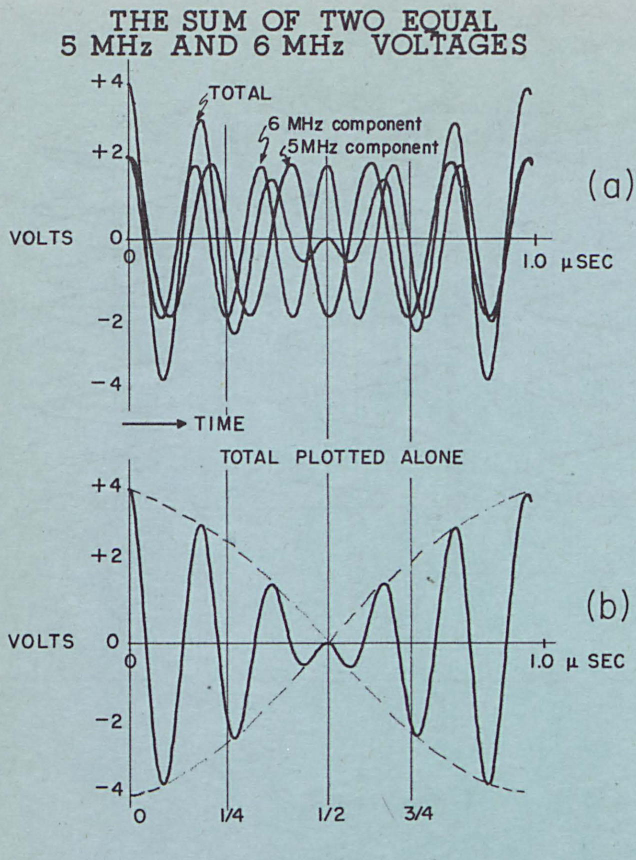

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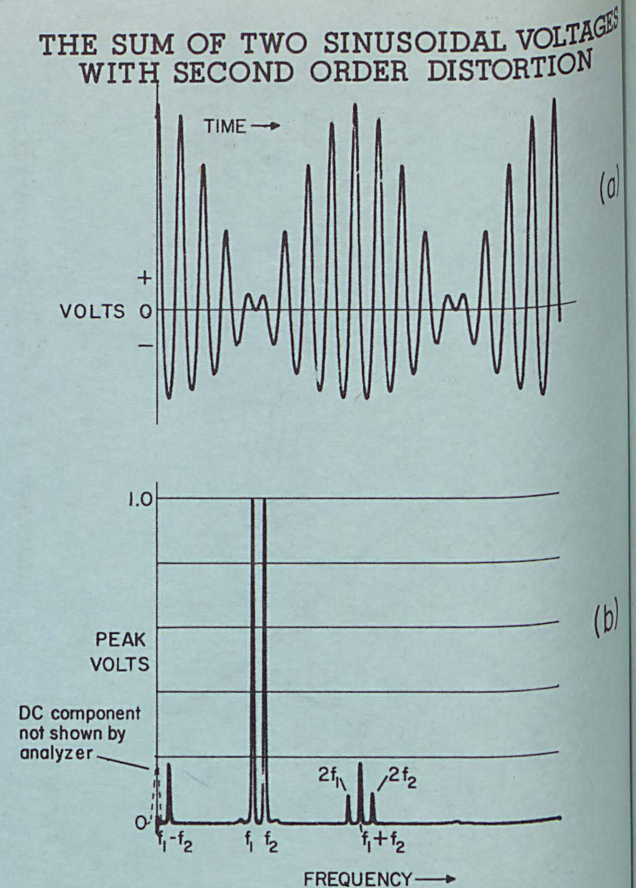


Figure 22

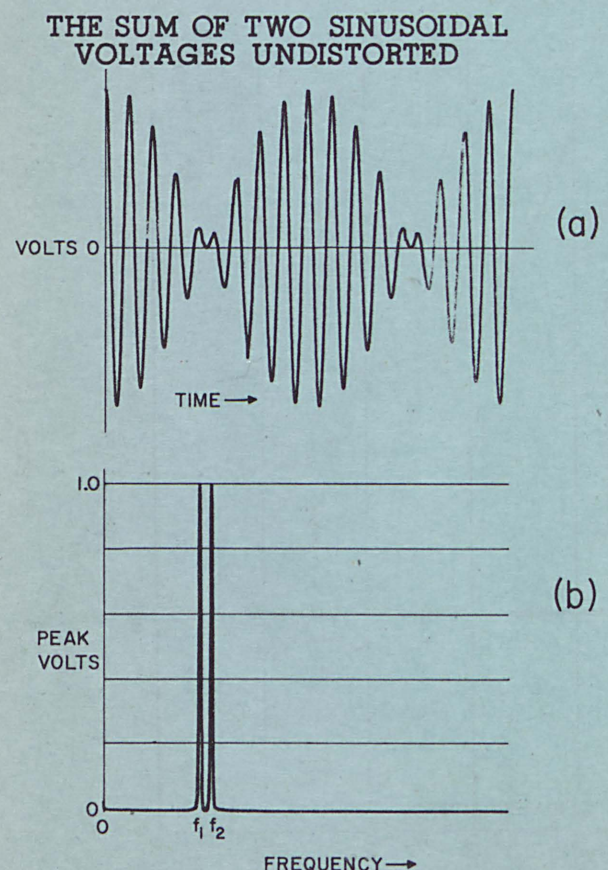
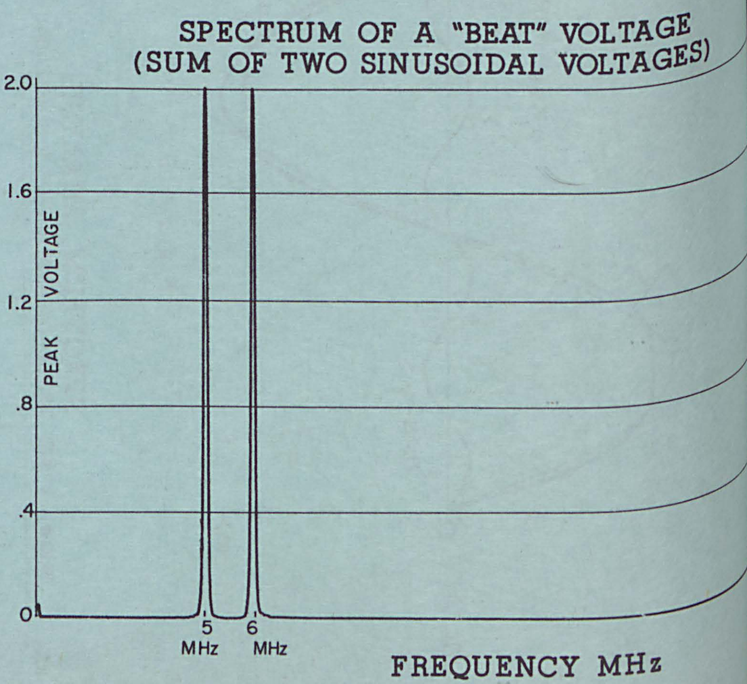


Figure 21

Figure 20



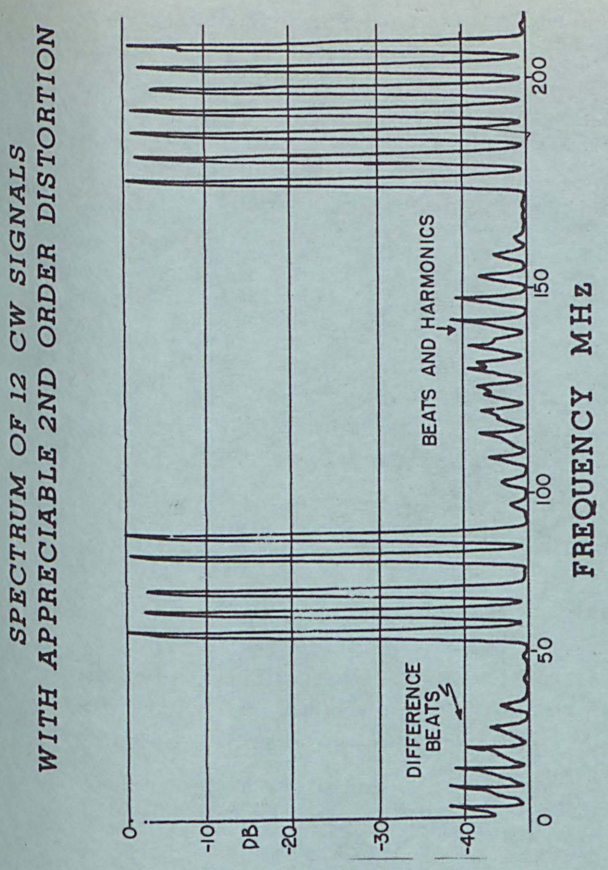


Figure 23

No Figure 24

THE SUM OF TWO SINUSOIDAL VOLTAGES WITH THIRD ORDER DISTORTION

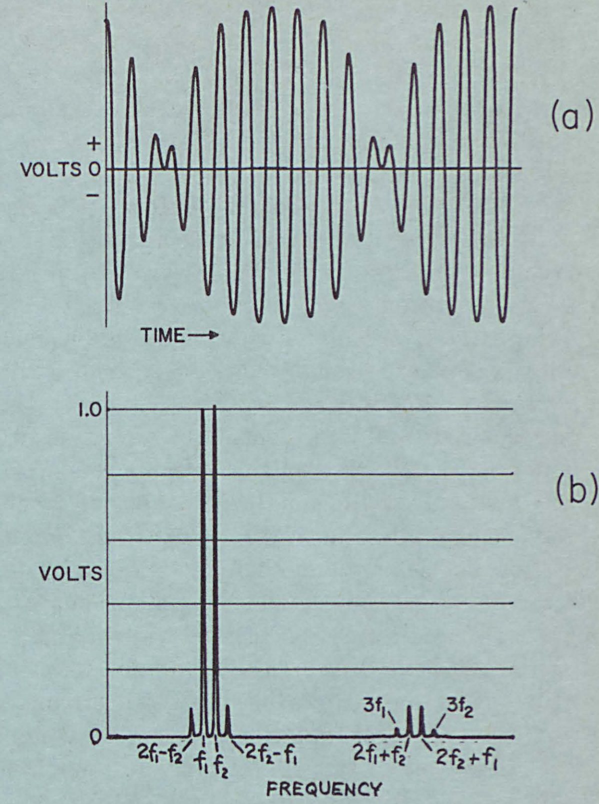


Figure 25

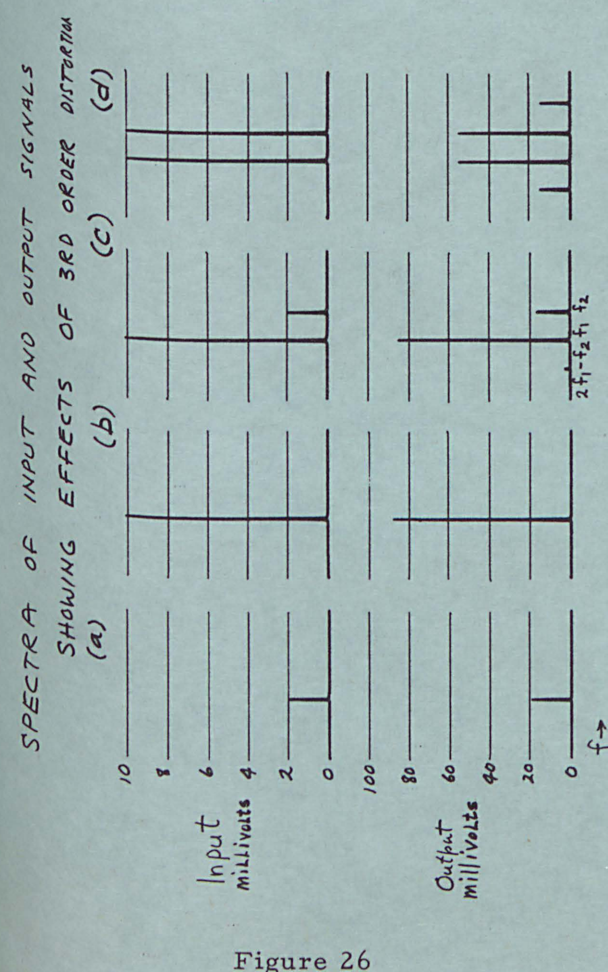


Figure 26

SPECTRUM SHOWING CROSS-MOD

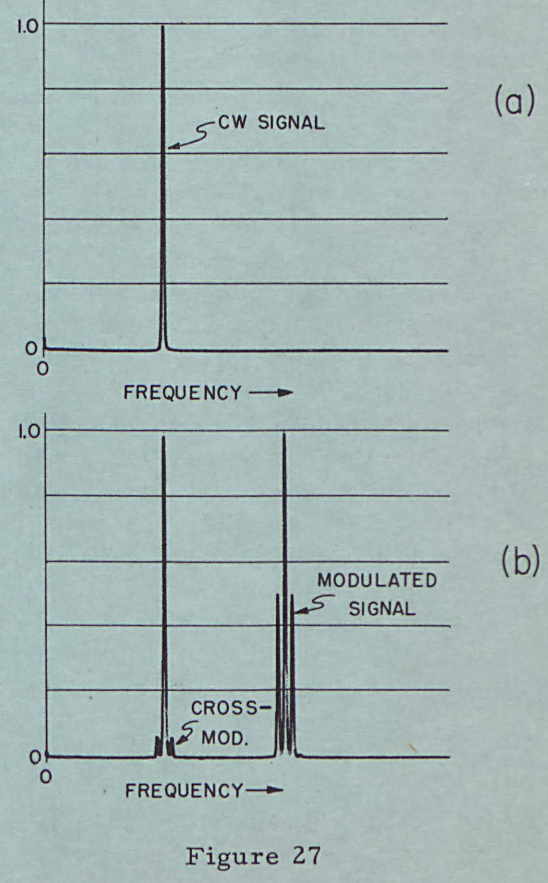


Figure 27

CHAIRMAN TAYLOR: Thank you very much. Does anyone have any questions?

I have a question regarding the effects of cross-modulation on the weaker carriers in a system. If we take a hypothetical case involving one strong carrier and say 8 or 9 weak ones, does the cross-modulation affect all channels equally or is there a difference?

MR. SIMONS: At this point I believe it is necessary to bring out something that was not stressed in my paper. In this presentation I have been talking about "mathematical" amplifiers. By a "mathematical" amplifier, I mean one which follows exactly the same way at all frequencies. With such an amplifier the cross-modulation from all channels on to any one channel would be identically the same.

The unfortunate thing about this approach is it doesn't work. Real-life amplifiers just don't behave this way. Generally speaking, the cross-modulation which shows up on any one channel in an amplifier is not the same as that showing up on any other channel. These differences are not very great so it is still useful to consider the "mathematical" amplifier as an approximation, but the differences are such that we must measure all combinations of channels if we are to be sure of amplifier performance. Generally speaking, there is no difference between weak channels and strong channels, the difference has more to do with the frequency of the particular channel.

CHAIRMAN TAYLOR: Are there any other questions? Thank you very much, Ken. I think it is quite significant in a matter with which I am quite pleased at this convention that we have several systems operators presenting ideas that they have developed in their systems which can be of use to other operators. This is so in the next paper.

Mr. Robert Scherpenseel is the general manager and microwave technician for the Northwest Video of Kalispell, Montana, a system I know a little about. He was chief engineer with WEVR FM of Troy, New York, chief engineer with KBTK radio, and engineer with KMSO-TV electronics technician at Montana State University in installing and maintaining their television and radio and recording systems. Mr. Scherpenseel is going to talk on "A Low Cost TDR". (Applause)

A LOW COST T.D.R.

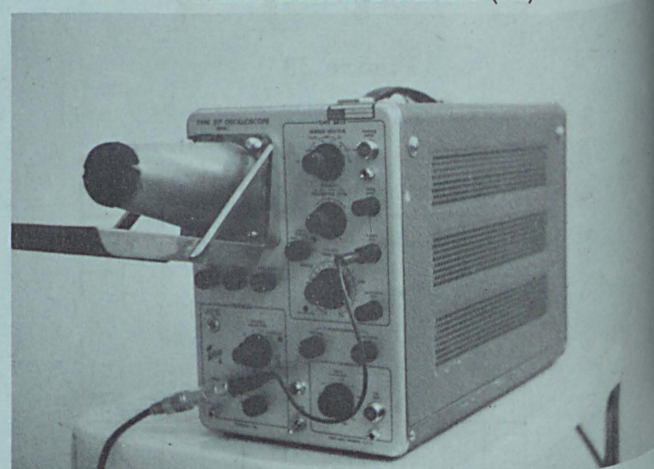
By

Robert H. Scherpenseel

We are probably being a little facetious in calling this instrument a low cost time domain reflectometer. The 1967 catalogue price is $875.00. In a way it is a TDR but with limitations.

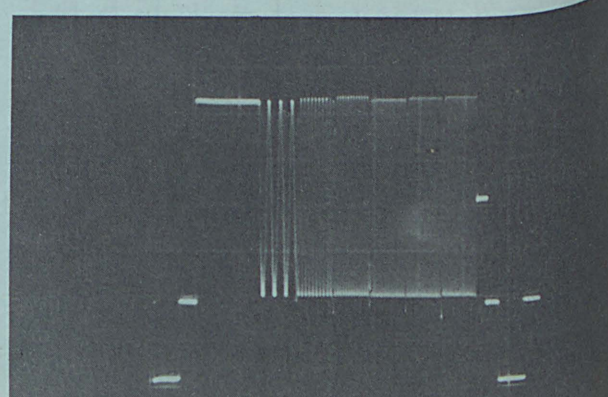
Actually, it is a high quality oscilloscope that has a calibrated time base and a vertical amplifier with a ba pass of DC to 10 megaHertz. This is a limiting factor b cause no determination can be made concerning the fre quency characteristics of the information displayed be 10 megaHertz.

NEXT SLIDE PLEASE (#2)



This is a picture of the scope with the camera mou in place.

NEXT SLIDE PLEASE (#3)



CHAIRMAN SCHATZEL: Thank you very much. I think this team from Hughes Aircraft Company given us an extremely worthwhile progress report a development that I am sure we will see a great al more of as the years go by, the FCC willing, and hope that they will be willing.

Due to the rather limited time we have available this morning, I am not going to be able to entertain more than perhaps two questions of Mr. Stokes or Mr. Ozaki, and then we must move on with our agenda. I believe, however, that both of these individuals will be very happy to answer any questions that you may wish to put to them privately after they have left the platform.

Are there questions now?

MR. EDWARD DAVIS (CBS Television): Your Division Director's question was uppermost in my mind. In his own terms, do you suppose you could give us a comment, just in round numbers, what the kind of comparison, let us say, between that which we might be interested in, that is, in terms of ground base equipment, microwave or standard microwave equipment as compared with this particular unit, would indicate?

I am asking, in effect, for a comment on the cost not in precise terms, but in round numbers or in comparative terms between what we now know as terms of the cost of a single microwave length?

DR. OZAKI: First of all, any number that we give your Division Direction turns out to be too high by definition.

We have looked at the relative cost of this system in terms of our extrapolation of these costs, in quantity production versus a similar type, perhaps not a multiple-channel but a microwave system that contains all 12 channels. We believe that this system is less expensive than that kind of approach.

In terms of going the full 12 channels in the systems versus having 12 single channels, I believe that there would be a marked difference in the cost.

Does that answer your question?

MR. DAVIS: You have said it is less than or comparable to?

DR. OZAKI: It is less than. It is my belief that it is less than; and, of course, here again is the question of how many do you make at one time?

MR. DAVIS: Certainly.

CHAIRMAN SCHATZEL: We have time for one more question.

MR. SIMMONS (Jerrold): With regard to the inter-modulation, do we understand that this is what we call cross-modulation; that is, modulation transferred from one channel to another? And, did if follow the theoretical law of two for one?

DR. OZAKI: This matter of inter-modulation, with respect to TV pictures, is slowly becoming more and more clear to us. The inter-modulation we are talking about does follow the two-to-one law. They are what are commonly called third order products.

CHAIRMAN SCHATZEL: Thank you very much.

(Announcements)

The next topic is truly a "bread-and-butter" topic for people in the CATV business.

The subject is TV SIGNAL PROPAGATION, and this is almost the first question we have when we consider a CATV system. We want to know what sort of signals we are getting at the head end.

The gentleman who is going to discuss this for us this morning is the Manager of the Antenna and Microwave Products Division of Scientific Atlanta, Inc., which has a wide reputation in the antenna field, as you know.

He is an engineering graduate of Mississippi State University, and has been working for the past 10 years in the field of antenna microwave. It is my pleasure to introduce Mr. Thomas D. Smith, of Scientific Atlanta, Inc.

MR. TOM D. SMITH (Scientific Atlanta, Inc.): First, I would like to express my appreciation for allowing Scientific Atlanta to participate in NCTA's Technical Sessions.

THE THEORY OF TELEVISION SIGNAL PROPAGATION

by

T. D. Smith

Introduction

Cable technicians need a knowledge of the propagation of television signals when performing signal surveys, locating head-end sites, determining sources of interfering signals, and in the designing or specifying of antenna arrays. The purpose of this paper is to review basic propagation theory with the hope it will provide better understanding of the propagation of television signals. First, this paper defines and discusses the various regions of propagation. Second, the propagation medium and its influence on signals is discussed.

Regions of Propagation

For convenience, the distance from the transmitting antenna is divided into several regions; the boundaries of the regions cannot be sharply defined. The names given to the various regions denote some pertinent property of each region.

The region immediately next to the transmitting antenna is known as the "line-of-sight" region. This region extends out to radio horizon. The distance from the transmitting antenna to the radio horizon is given by the formula:

$$D = \sqrt{2h_T}$$

where D is the distance to horizon in miles and h_T is the height of the transmitting antenna in feet. The radio horizon is assumed to be on the ground, if the earth is a relatively smooth sphere. Any obstruction along any given path must be taken into consideration.

If the receiving antenna is also elevated, the maximum line-of-sight is given by the formula:

$$D = \sqrt{2h_T} + \sqrt{2h_R}$$

where h_R is the height of the receiving antenna in feet.

It the propogation path in the line-of-sight region is sufficiently free from objects that might absorb or reflect radio energy, this region can be further subdivided into a region known as "free space." The free-space region is seldom realized, because of the presence of the earth's surface. Briefly, the usual condition is such that one wave travels directly from the transmitter to the receiver. A second wave from the same transmitting antenna strikes the ground between the two antennas and then is reflected to the receiving antenna. In this instance, the ground acts as partial reflector and as partial absorber. The ground-reflected wave has traveled farther, therefore the phases of the two waves at the receiving antenna are different. The result of this phase difference is an oscillatory signal level whose amplitude and frequency vary with respect to the height and distance from the transmitting antenna. As the energies of these two paths unite in phase, the resultant is a maximum. As they unite out of phase, the resultant is a minimum. A typical plot of signal level of height for "line-of-sight" conditions is shown in Figure one.

The space beyond the line-of-sight region is known as the "beyond-the-horizon" region. This region is shadowed from direct rays by the curvature of the earth, or other obstruction. Beyond-the-horizon region is subdivided into the diffraction region and scatter region.

The diffraction region lies adjacent to and below the radio horizon. This is the region in which most CATV towers are constructed. Energy reaching this region must be bent or reflected by some process. One such process is diffraction, which is a fundamental property of wave motion. Sharp shadows, such as would be created by a beam of light striking a solid object, are not created when RF waves encounter large obstructions. Reception is possible behind the obstruction for a short distance, but there is a shadow which is somewhat fuzzy and there is a gradual transition in signal level, rather than a sharp transition as there is in very short wavelengths such as light. While diffraction does make transmission beyond the line-of-sight possible, it introduces large losses. In the diffraction region the mean field strength decreases approximately exponentially with distance; while the mean field strength increases exponentially with antenna height.

In the past, diffraction was considered the only mechanism whereby VHF and UHF energy was supplied beyond the horizon. However, during World War II and into the late Forties, other mechanisms were discovered. One of these mechanisms is known as "tropospheric scatter." Tropospheric scatter is caused by random irregularities of the dielectric constant of the atmosphere, or "blobs."

These blobs are always present and cause faint signals to be reflected to the ground. The reflections fall well beyond the horizon in much the same way that the overhead light beam of a searchlight can be seen from the ground, or the lights of a distant city can be seen as a glow from beyond the horizon.

It should be noted that two types of signal fading are encountered in scatter propagation. The first is the rapid fade caused by multi-path transmission in the atmosphere. The multi-path condition is caused when a signal is reflected from many blobs which are random in location and have random motions. The received signal is the sum of these random reflected signals. The received signal may change from maximum to minimum and back to maximum in a matter of seconds. Fast multi-path fading tends to reduce the allowable bandwidth to less than five MHz. This reduction in bandwidth is caused by the time delay associated with the different paths.

The second type of fading encountered in scatter propagation is slower. It has a period of hours, or even days. These slow changes in signal level result from a combination of variations in atmospheric refraction from day to night and of humidity and temperature changes along the scatter path.

here is one other important mechanism by which s are propagated beyond-the-horizon. Waves can ropagated by reflections from a portion of the ion- ere known as the "Sporadic-E" layer. Occasion- , clouds of very high ionization are found in the on of the E-layer. The effects of these clouds are e well known -- their cause, however, is still sub- to speculation. Sporadic-E skip distances vary a minimum of 500 miles to a maximum of about 0 miles for a single hop.

Propagation Medium

For purposes of discussion, the atmosphere is ded into various layers or regions; these are osphere, stratosphere, and ionosphere as shown Figure . The portion of the earth's atmosphere nding from sea level to a height of about six miles he troposphere, or weather layer. This is the re- n of winds, storms, and rain. The temperature of troposphere decreases about 20°F per mile of in- asing altitude and reaches a minimum value near F at the upper limit of the region. Meteorological nges in this part of the atmosphere are responsible many variations in the received signal levels.

Directly above the troposphere is the stratosphere, constant-temperature zone. The stratosphere ex- ds to a height of about 40 miles. This region has e effect upon VHF propagation.

The E-Layer of the ionosphere is located 50-70 es above the surface of the earth. Bombardment this region by radiation from the sun produces ized molecules. Sometimes clouds of very high ization are sufficiently dense to reflect signals in e 50- 100-MHz range, as was discussed above.

In free space, or a vacuum, a wave expands out- rd from its source. Each part of the wave travels ng a radial line and has a constant velocity equal that of light. In a homogeneous, isotropic dielec- ic medium, a wave will travel as it does in free ace, but with a reduced velocity. The ratio of the ee space velocity to the velocity in the dielectric edium is called the index of refraction of the med- um.

In a windless "standard" atmosphere, the tem- perature and water-vapor content decrease steadily with increasing altitude. This normal gradient is own in Figure 3. This decrease in temperature nd water-vapor content, associated with altitude in- reases, causes a decrease in the index of refrac- on with altitude. This results in the velocity of ansmission increasing with height above the ground, nd as a result the wave is bent or refracted toward he earth. As long as the change in dielectric con- ant is linear with height, the net effect of refraction s the same as if the wave continued to travel in a traight line, but over an earth whose radius is 4/3 (1.33) times the true radius.

Most technicians have noticed that signal strengths are higher in the evening and early morning than during mid-afternoon. This phenomenon is caused by the following conditions; as the sun goes down, air immediately adjacent to the earth cools rapidly, while the air at higher altitudes cools much more slowly. This causes the dielectric constant of the air near the earth to increase, thus creating a greater change in dielectric constant with altitude. With this increasing dielectric gradient, the effective earth radius increases. In the early morning hours, the sun warms the air at higher altitudes before the air adjacent to the earth is warmed. Consequently, the effective earth radius is again larger than 1.33 times the true radius.

When the dielectric constant decreases about 10^{-7} per foot of height (in the standard atmosphere the decrease is 10^{-8} per foot), it has the effect of making the earth flat. Under such a condition, a wave that starts parallel to the earth will remain parallel. When the dielectric constant decreases more rapidly than 10^{-7} per foot of height, as shown in Figure 4, radio waves that are radiated parallel to, or at an angle above, the earth's surface, may be bent downward sufficiently to be reflected from the earth. After reflection, the wave is again bent to- ward the earth as it passes through the atmosphere, and the resulting path of a typical wave is similar to the path of a bouncing tennis ball. The radio energy appears to be trapped in a duct or waveguide between the earth and the troposphere. This phenomenon is referred to as either trapping or ducting.

How can one determine on a given day whether or not standard propagation conditions exist? Un- fortunately, this is very different to determine from normal meteorological data published by local weather bureaus. However, the following meteorological conditions are conducive to non-standard or trapping conditions, although they may not necessarily produce non-standard conditions.

1. A barometric high
2. Calm or light winds
3. Clear skies
4. Nocturnal cooling of ground with clear skies
5. Flow of warm dry air over colder air producing a temperature inversion.

The following conditions are conducive to standare propagation conditions:

1. Barometric low
2. Strong winds
3. Overcast skies

Conclusions

A detailed study of propagation theory allows one to draw the following conclusions about the propagation of TV signals.

Over propagation paths where the earth can be considered a relatively smooth sphere, and at times of near standard atmosphere or known atmospheric conditions, signal levels can be calculated with good accuracy by the method described in National Bureau of Standards Technical Note 101, Revised May 1, 1966, entitled Transmission Loss Predictions for Tropospheric Communication Circuits. Over mountainous paths, it is usually necessary to resort to actual on site signal-level measurements, because calculations which take into account the effect of rought terrain are complicated.

When signal surveys are being made, the survey should be conducted over a sufficient length of time to allow for the possibility of non-standard propagation conditions that can exist for one or more days. Otherwise, erroneous or misleading data would be obtained.

Sporadic-E can cause severe co-channel interference on Channels 2-6 only. Instances of the E-Layer being sufficiently dense to reflect signals of frequencies higher than 100 MHz have not been confirmed. Consequently, Sporadic-E cannot account for severe co-channel interference on Channel 7-13. In order to have interference via Sporadic-E, the interfering stations must be a minimum of 500 miles away. As a consequence the co-channel beat can be either 20 kHz, 10 kHz, or 0. Sporadic-E occurs most often in the late afternoon. Little, if anything, can be done in the selection of a head-end site, or receiving antenna array design, to minimize Sporadic-E interference.

Most co-channel interference of a prolonged and constant nature on Channels 2-6, and all co-channel interference on Channels 7-13, is caused by propagation through the troposphere. This type of co-channel interference will usually occur from stations within 200-300 miles of the receiving antenna. In most cases, there will be a 10- or 20-kHz beat associated with the interference, and on rare occasions a 0 beat. Proper design of the receiving antenna array and selection of the head-end equipment will minimize this type of co-channel interference.

With a thorough understanding of propagation theory, and a knowledge of its influence on the level of received signals, a technician can better determine which channels can be received with reliable, high-quality pictures.

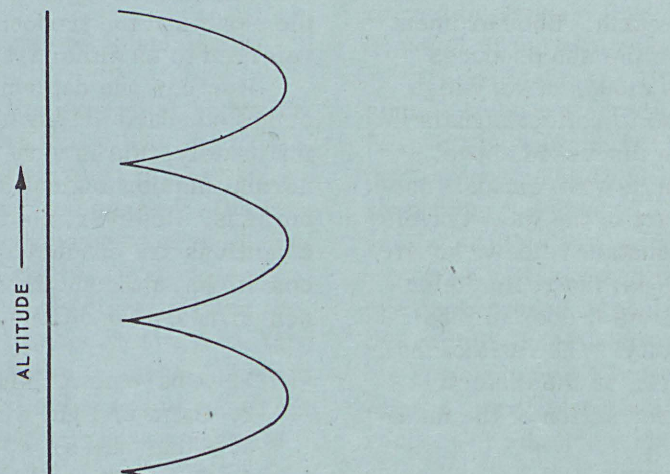


FIGURE ONE

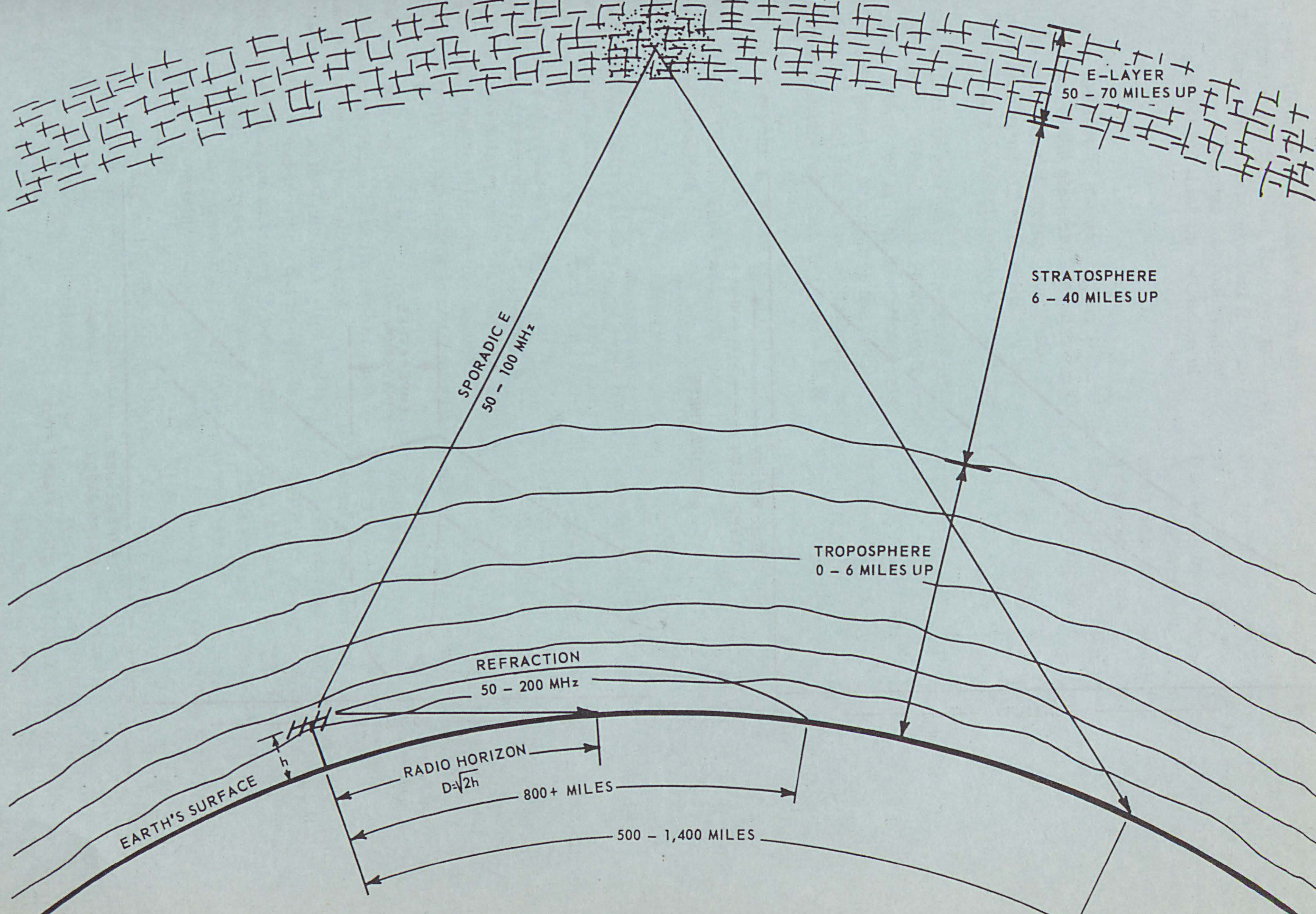

E-LAYER
50 – 70 MILES UP
STRATOSPHERE
6 – 40 MILES UP
SPORADIC E
50 – 100 MHz
TROPOSPHERE
0 – 6 MILES UP
REFRACTION
50 – 200 MHz
h
RADIO HORIZON
D=√2h
800+ MILES
500 – 1,400 MILES
EARTH'S SURFACE

FIGURE TWO

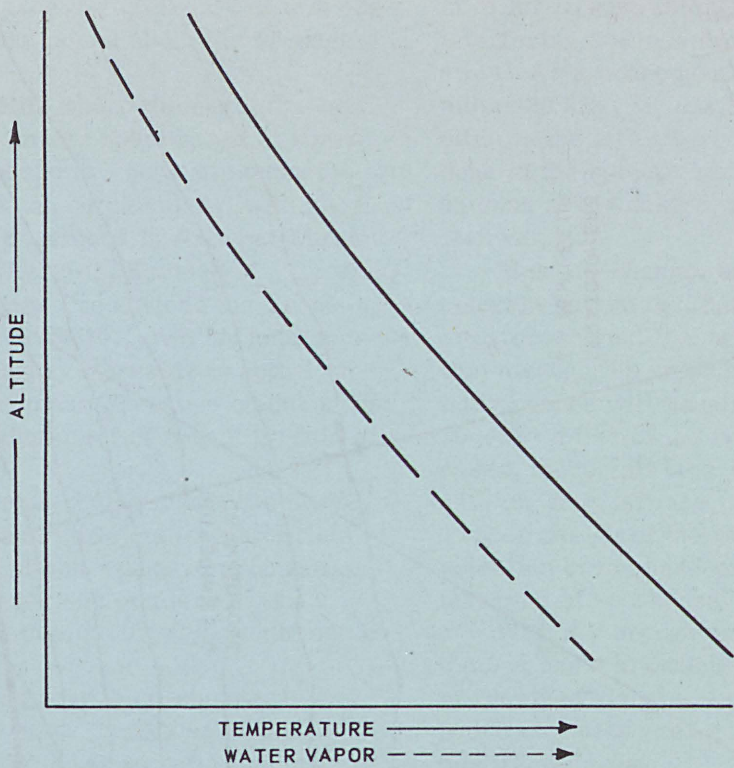


FIGURE THREE

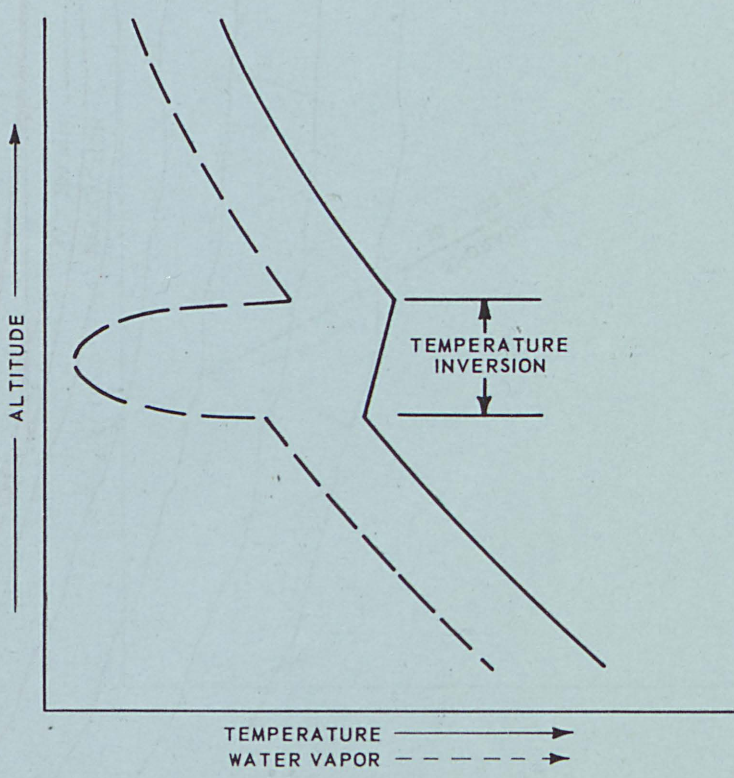


FIGURE FOUR

CHAIRMAN SCHATZEL: Thank you very much, Mr. Smith.

I am sure we will have some questions on this, and I would like to ask the first one, if I may, and that is if you would clarify your statement that from co-channel stations 200 or 300 miles we would expect a 10 or 20 kilocycle offset? I think that would be of interest.

Why not zero beat?

MR. SMITH: Because of the way the FCC has specified frequencies of the stations. Through subjective tests, the FCC has determined that if the frequency of the interfering signal is shifted either 10 or 20 kilocycles, it is less noticeable to the average observer.

I think the FCC in its wisdom has assigned offsets which will result in either 10 or 20 kilocycle beat if the stations are within 300 miles. Sometimes this is violated, but as a general rule this is the case.

Prolonged co-channel interference, however, can occur sometimes between two stations which will result in a zero beat.

Does that answer your questions?

CHAIRMAN SCHATZEL: Yes, thank you.

Are there other questions?

Yes, sir --

MR. KEN ARNOLD (City Cable TV): I would like to have you elaborate a little more on what you said, and ask, are you saying in effect that you could determine the distance the station is by the beat?

In other words, a station has, for instance, a higher beat; you could determine it is more than 300 miles away? Could you do this with any degree of reliability, is really what I am asking in my inquiry?

MR. SMITH: No, I do not believe that is the case. All I am saying is that it is useful, but not completely definitive to know what is the beat.

There is available on the market a filter which will allow you to detect and measure the amplitude of this resulting beat, and identify it as to being either 10 or 20 kilocycles; and as a result of this you can eliminate many possible co-channel interfering stations that are not perhaps causing the particular problem you are encountering.

I am not, however, saying just by the fact you know what the beat is that you can precisely determine where your station is and which one is involved. This is only useful in eliminating a few and providing some clues as to which one it might be.

CHAIRMAN SCHATZEL: If I understood the question correctly, I believe the query was whether the beat is higher if the station is farther away? I do not think that is the case.

I think the point that Mr. Smith was making was that the FCC allocation plan generally provides that co-channel stations that are within 200 or 300 miles of the station that you are receiving will be offset in frequency by 10 or 20 kilocycles. If it is exactly on the same frequency, or zero beat, it would be farther away than that, because the allocation plan would put a station exactly on the same frequency farther away than 200 or 300 miles.

Isn't that it?

MR. SMITH: Three hundred miles; yes.

CHAIRMAN SCHATZEL: Are there any other questions?

MR. ARCHER S. TAYLOR: I might make a comment on this offset.

The TELEVISION FACT BOOK lists the allocations of channels with a plus or a minus. The plus means that station is 10 kilocycles higher than the nominal frequency for that channel.

The minus means it is 10 kilocycles below.

Therefore, you can look at these channel allocations in the FACT BOOK and determine whether you would expect a 10 or 20 kilocycle beat or a zero beat. In that way you could determine something as to the stations with which you are concerned.

CHAIRMAN SCHATZEL: Thank you very much, Mr. Smith.

We will move now to our next subject, which is really related to some of the information we have just heard, because of the variations in the structure of the atmosphere, which Mr. Smith described, and when we measure signal strength we find that it fluctuates; generally if fluctuates with varying rapidity; and to a varying extent, depending on where we are with respect to the television station.

These fluctuations, particularly as they go downward, are a source of great grief to the CATV industry, and we work very hard to reduce the amount of fluctuation, or at least the depths to which the fluctuations go.

One of the techniques for doing this is diversity reception.

We have various types of diversity reception. There is frequency diversity; height diversity; space diversity, et cetera.

We are going to hear this morning a discussion of SPACE DIVERSITY RECEPTION.

Our speaker comes originally from across the water. He started his career in the British Post Office, in the Telephone Engineering Department.

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