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you are familiar with this mounting arrangement. As you can see the performance of these antennas is very respectable.

Well, in conclusion, through the presentation of data I hope I have shown you that antenna characteristics may be predicted only when all influencing parameters are taken into consideration. The support tower in most cases will influence the performance of an array. Even with the limited amount of data presented here, you can realize the difficulty of trying to analyze the distortion in various configurations a tower might present. Only through the use of mounting techniques and antennas which tend to minimize the effects of towers can accurate prediction be made. I hope the data contained in this paper will provide the CATV technician with a better understanding of antenna array performance and will provide a basis for improved techniques in fabricating antenna arrays. I thank you.

CHAIRMAN PALMER: Thank you, Blair Weston. Let's proceed with questions for Blair.

QUESTION: Is there any practical way of taking antenna array patterns on antennas already on a tower?

MR. WESTON: It's somewhat difficult to rotate towers to obtain patterns, although I believe one of the common practices in the broadcast field is proof of performance and such is to, in a transmitting situation, use the antenna as a transmitter and by covering a circular path around the antenna with a receiver on a vehicle to plot it out point by point. I don't know how far the FCC would let you get away with the applying power to your antennas and running around it to see what the characteristics are. But this is the only technique with which I would be familiar.

CHAIRMAN PALMER: Other questions?

MR. WESTON: As I understand the question, you wonder why we have not presented data on the parabolic antenna?

Well, literally speaking, we did not have available the parabolic antenna to evaluate. Secondly, the size and such of the parabolic antenna would not lend itself very well to the taking of measurements due to various problems you'd run into. Main reason, we have not had the availability of a parabolic antenna to evaluate.

CHAIRMAN PALMER: Further questions? Thank you, Blair.

Our next speaker is Bill Rheinfelder, Anaconda Astrodata. Bill was staff consultant at Motorola, high frequency applications 1957 to 1961. During the end of this period he also acted as a consultant for AMECO and left Motorola at that, somewhat thereafter, to go to AMECO as Director of R&D. Then in 1965 he joined Astrodata as Director of Research and Development - CATV in Anaheim, California. Bill Rheinfelder has his masters of science and electrical engineering from the Institute of Technology at Munich, Germany. Bill will talk to us on Advanced CATV System Concepts.

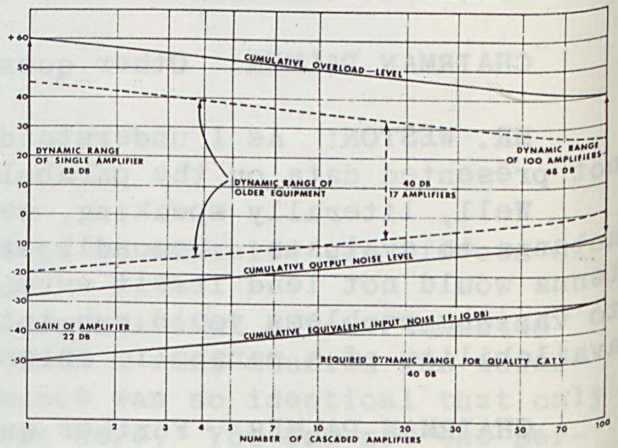
MR. WILLIAM A. RHEINFELDER (ANACONDA ASTRODATA): Recently new concepts for CATV Systems have been developed which together with a complete line of integrated equipment result in greatly improved performance quality and previously unheard of freedom from maintenance in CATV systems. In explaining these new concepts it is advantageous to go back to the basic STANDARD, which is the real criterion of system performance, and that is the signal to noise ratio at the subscriber's TV set. According to SMPTE and other standards 40 db signal to noise ratio defines a flawless, studio-type picture of the highest quality. All efforts in CATV system design are therefore directed toward maintaining a minimum signal to noise ratio of 40 db to the subscriber's home. When amplifiers are cascaded, well established derating formulas indicate a logarithmic degradation of system performance; for example, in a cascade of 100 amplifiers overload and noise level must be derated by 20 db each, leading to a total decrease of dynamic range by 40 db over that of an individual amplifer. Dynamic range is defined as overload to noise ratio. For a 40 db signal to noise ratio at the end of a system of 100 cascaded amplifiers, it is then necessary to use amplifers with a dynamic range of at least 80 db.

In the past, amplifiers of this quality were not available, either in tube or solid-state versions. Typical values achieved in the past for good quality equipment were 65 to 70 db dynamic range.

However, amplifiers are now available - due to a breakthrough in circuit engineering - with a far improved output capability of 60 dbmv and with an Extended Dynamic Range of 88 db, an improvement of about 15 db. In Figure 1 amplifier and system dynamic range is pictured. The typical amplifier presently in use in solid state CATV system (shown dashed) has a dynamic range of about 65 db, which is derated to 40 db after a cascade of only 17 amplifiers. After 100 amplifiers the signal to noise ratio is only 25 db and picture quality unacceptable.

The new line of amplifiers available now with Extended Dynamic Range is shown by the solid lines. After 100 amplifiers the system dynamic range is still 48 db; 40 db is reached after 250 amplifiers! The picture quality after 250 amplifiers would be the same as after 17 amplifiers of the old and presently used type!

FIG. 1 AMPLIFIER AND SYSTEM DYNAMIC RANGE



It is clear that dynamic range at this time is no longer the major obstacle in realizing long cascades with top quality, and we might ask ourselves what are the real limitations to better and better systems now that dynamic range, that is overlead and noise level of amplifiers, is less important, and what can be done to achieve the ultimate in CATV.

Advanced concepts which have been recently introduced deal with this particular subject. One of these concepts refers to a Fully Automatic

Maintrunk System, another concept leads to an optimized High Level Distribution System.

In analyzing existing systems, it is often found that even short systems fail to perform as expected. Where a signal to noise ratio of 40 db should be possible, only 30 db is realized. Tracing these difficulties it is found that the common cause for all these problems lies in inaccuracies of system equalization. It is easy to see that an error of 1 db at one channel per amplifier may lead after ten amplifiers to an error of 10 db, which causes the same picture degradation after ten amplifiers, which would normally result after 100 amplifiers if no alignment errors existed. Consequently, everything must be done to achieve the best possible flatness of equalization in the system. It is worthwhile, to examine the various sources of error in a CATV system as some of them are incompatible with a Fully Automatic Maintrunk System.

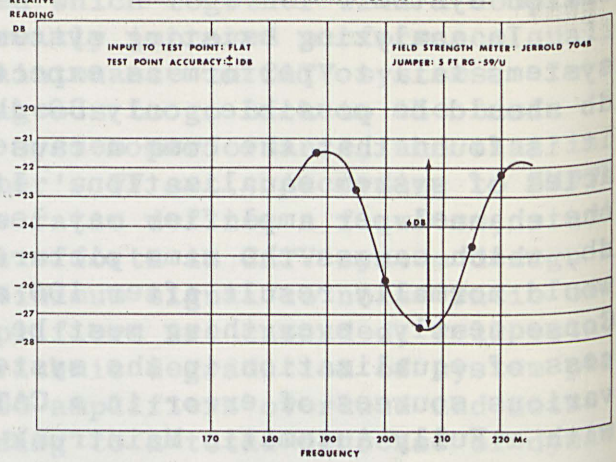
Foremost among the error sources are jumper cables [1)], external to equipment, or internal. Although it has been pointed out repeatedly that jumper cables are incompatible with quality system design, they still are the major offender. No matter how short or long, a jumper always causes trouble. With a VSWR of 1.1, a basic error of ± 1 db is possible. The length of the jumper determines the frequency of maximum error. A length of two inches is already too long, and there is just no other remedy than the complete elimination of jumpers in allband CATV systems. This, of course, requires the use of amplifiers specially designed for this service with built-on cable connectors and self-contained housings. Amplifiers of this type have been available for about two years. However, the problem of jumper cables continues right into the amplifier itself. A lead length of more than 1 inch from the input or output connector of an amplifier to the circuit itself leads to definite trouble, that is the unit may align flat on the test bench, while it will not be flat in the field, even without external jumper cables. Amplifiers with large housings and excessive modularity fall short in this respect, because this involves extra lead length, which in turn causes a different frequency response in the system than on the test bench.

Let us assume now that jumper cables and excessive connector lead lengths have been avoided and that we have a well-designed amplifier. What other problems do we encounter in the system which limit system length?

At this time, we should consider test points and field instrumentation. Although this point has been made elsewhere, [2)] I would like to repeat that at the present state of the art, there is no way of making sensible field adjustments except correction for coarse maladjustment. What I mean to say is, that the required alignment-accuracy of top quality systems of ± 0.25 db cannot be presently achieved by field adjustments but only at the factory. Test points from various reasons have a tolerance of ± 1 db, and field instrumentation is specified commonly at ± 2 db. To that is added the effect of jumper cables and you can see that field adjustments only make sense for gross errors of severl db, but are useless for top quality systems.

An example of typical errors in field measurements are given in Figure 2. These measurements were made on a popular amplifer using the most common type of test point. Although the output signal of the amplifier was flat to $\pm$.1 db for this test, the reading on the field strength meter shows the typical error curve due to the jumper cable from test point to field strength meter. A different length of jumper cable would merely shift the frequency of the peaks and nulls, without changing the peak to valley ratio. There are methods of reducing these measurement errors considerably without redesign of the test points. Also new concepts for highly accurate level indicators have been developed but even with these, a still better concept for the maintrunk is based on a Fully Automatic Maintrunk System.

FIG. 2 READING AT STANDARD 20 db TEST POINT



The key features of this concept are given in Table I.

TABLE I

FEATURES OF FAMS

1. Precision, factory-aligned maintrunk amplifiers.
2. Automatic correction for deviations in spacing to the field.
3. Automatic correction for cable variation with temperature.
4. Automatic system level control.
5. Automatic bridgers.

Precision, factory-aligned amplifiers are now available standardized for the modern spacing of 22 db, which is the optimum spacing for cascades of up to 160 amplifiers of the new Extended Dynamic Range Type. These amplifiers may be used without adjustment for a normal range of different spacings due to the effective circuits for automatic spacing correction which are used in the system.

Automatic correction circuitry is based on either open or closed loop systems. An open-loop system is a system where the error in the system is unrelated to the means of correction: it is not a feedback system. This is easiest explained in an example. Let us assume a circuit or amplifier has been designed to change in gain and frequency response with temperature, by using temperature sensitive components. Such an amplifier or equalizer might be designed to have an inverse frequency response with temperature to that of coaxial cable; for instance, as the cable loss increases with the temperature, the circuit loss decreases with temperature by an equal amount, thereby providing compensation of the cable variation.

In Figure 3a an open-loop system of temperature compensation is shown (top of Figure 3). Temperature input 1 to the cable controls loss in the cable, and temperature input 2 to the equalizer or amplifier affects compensation circuits. Such an open-loop system has been used frequently because of its simplicity, but it fails to perform sufficiently well for use in the maintrunk, although this has been attempted and in some systems is the sole and inadequate method of temperature compensation. The shortcomings of the open-loop systems are evident from the example of an amplifier or equalizer being in the shade of a tree while the cable is in the sun. Since the equalizer does not sense the cable temperature, it cannot compensate under such a condition. The open-loop system is useful where a low cost approach is needed and for short cascades. It is incorporated in the better class of distribution amplifiers and may be used on the maintrunk in conjunction with a well working closed-loop system which corrects for the deficiencies of the open-loop system.

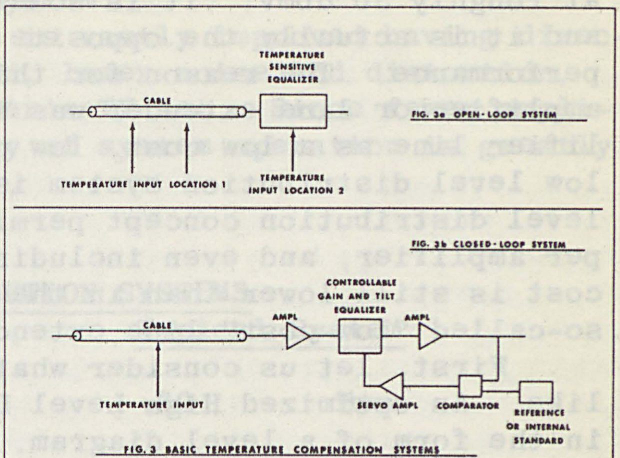


FIG. 3a OPEN-LOOP SYSTEM

FIG. 3b CLOSED-LOOP SYSTEM

FIG. 3 BASIC TEMPERATURE COMPENSATION SYSTEMS

In a closed-loop system, the actual error signal is determined by comparison with a reference signal and a correction is made so as to null the difference. The output signal is then automatically kept at the desired level. (Figure 3b). Circuits for automatic spacing and temperature correction are based on closed-loop principles. In addition to these features, automatic system level control incorporated in a new line of AGC-amplifiers has been referenced to internal voltage standards of such precision that it is now possible to calibrate field strength meters from the output of the amplifiers. The accuracy of new automatic level control circuitry is on the order of ±0.2 db or 2%, while the best field strength meters are often no better than ±2 db.

A system built on these concepts will, without field adjustments and only then, perform at the highest quality level. As an extension of this concept, it is logical to fully pre-align also the bridger amplifiers, since they are built into the same housing with the maintrunk amplifier to form a mainline bridger combination amplifier. This is done again mainly to avoid jumper cables and to allow high precision in alignment. Based on these concepts, it is now possible to construct a Fully Automatic Maintrunk System which is fully pre-adjusted and will function at top performance with normal errors due to spacing and temperature and without field adjustments.

Another new CATV concept which must be considered a major engineering breakthrough is based on an advanced High Level Distribution System. With the advent of amplifiers having an output capability of 60 dbmv, many improvements in CATV Systems are possible. It has been standard practice in the past to run the maintrunk at levels in the vicinity of 35 dbmv, with possibly a bridger output as high as 40 dbmv, and the distribution system at roughly 30 dbmv. It is somewhat unclear how this practice originated and it is actually the opposite from what is desirable for optimum system performance. The reason for this might have been that the distribution amplifier or line extender was treated as the stepchild of the whole amplifier line as a low cost, low quality circuit. However, the resulting low level distribution system is economically unsound. The new high-level distribution concept permits more than twice the number of subscribers per amplifier, and even including directional couplers throughout, the total cost is still lower than in the old low level distribution systems based on so-called "low-cost" line extenders.

First, let us consider what an ideal distribution system should look like. An optimized High Level Distribution System is shown in Figure 4 in the form of a level diagram. Starting at the output of a distribution amplifier (left side) with a level of +43 dbmv at channel 13 (top diagonal) this level decreases as we travel away from the amplifier due to cable losses until at 1,000 feet we are at the input of another amplifier. At 100 foot intervals 4-way directional taps are arranged which cause additional loss (insertion loss) indicated by steps. From each directional tap a vertical line indicates the tap loss taken in the unit; for example, 27 db. From the output of the tap a house drop (slanted line) causes further loss until the signal level at the subscribers TV set is as indicated by circles. Additional lines give performance at channel 2. The objective is to minimize variation in signal level at the subscriber's home and to feed the maximum number of homes per amplifier.

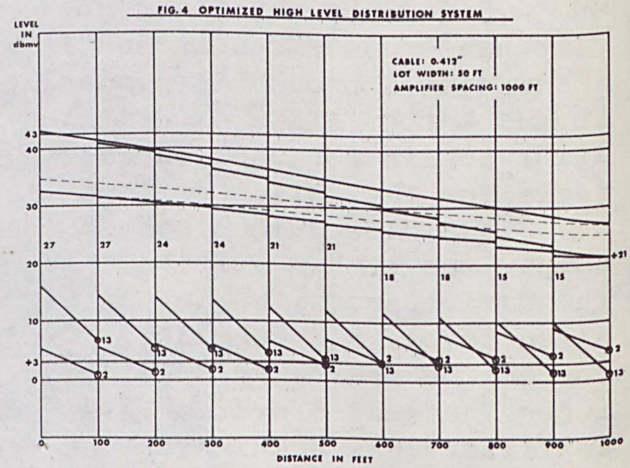


FIG. 4 OPTIMIZED HIGH LEVEL DISTRIBUTION SYSTEM

The gain in distribution amplifiers is used to compensate for losses in the distribution cable plus insertion losses of directional taps. These latter should be as low as possible because they result in wasted gain and increased distortion in the amplifiers. Insertion loss of any tapping devices decreases with increased tap loss. For example, a 15 db directional tap may have an insertion loss of 1.5 db, while a 21 db tap has an insertion loss of 0.5 db. It is therefore desireable to use directional taps with the higher tap losses for reduced insertion loss. Since the output of directional taps must be sufficient to allow for normal house drops, this in turn means that the level in the distribution system must be very high. As a matter of fact, if anywhere in the whole CATV system a high signal level is needed, it is in the distribution system, not in the maintrunk. The new optimized High Level Distribution System is based on a distribution level of +43 dbmv, that is the level of channel 13 at the output of each distribution amplifier. Also featured is increased cascadability. Careful optimization of the number and values of directional taps has led to a new standard distribution system which is compared in Table 2 with a typical and now obsolete system.

Please note that the advanced system is vastly improved having directional taps, full temperature compensation, lower noise and distortion, and less signal variation at the subscriber's TV set. Since fewer amplifiers are used per subscriber, reliability of system operation is greatly increased.

TABLE 2

COMPARISON OF DISTRIBUTION SYSTEMS

	Advanced System Concept	Typical System	
Distribution Level	+43	+30	dbmv
Number of Distribution Amplifiers in Cascade	10	4	-
Number of Directional Taps Per Span	10	4*	-
Level Variation at Subscriber	± 2	± 9	db
Subscribers per Amplifier	40	16	-
Total Number of Subscribers Per each of 4 bridger outputs	440	80	-

*Pressure of Capacitive Tap

These two concepts, of fully automatic precision maintrunk and optimized high-level distribution, are typical results of a new type of advanced system research now underway at Anaconda/Astrodata with the goal of better and better CATV.

CHAIRMAN PALMER: Thank you, Bill.

I have for years been a critic of the non-professional type technical presentations of NCTA Conventions. These papers were sales pitches, thinly disguised as technical presentations. The papers here today were professional and could have been presented at meetings of the IEEE or the SMPTE. I can make these comments as impartial comments since I have had no responsibility for the papers, obviously, or for the technical session which was set up by Mr. Archer Taylor.

Here's to continued professional technical presentations at NCTA meetings. Let's give all our speakers a big hand.

Session Adjourned.

TECHNICAL PROGRAM - II
Tuesday Morning, June 28, 1966

CHAIRMAN JAMES R. PALMER: Gentlemen, I'm Jim Palmer, C-Cor Electronics, welcoming you to the 8:30 A.M. Technical Session.

Our speaker is Blair Weston from Scientific-Atlanta, Inc. Blair studied electrical engineering at Auburn University not too many years ago, worked for awhile at Redstone Arsenal and Norton & Chimes Equipment Co. He has been with Scientific-Atlanta from 1961 to the present. Blair will talk on Analysis of CATV Antenna Array Characteristics Utilizing Radiation Pattern Measurements. Blair Weston.

MR. J. B. WESTON, JR. (SCIENTIFIC-ATLANTA, INC.): Thank you, Jim. First, I would like to express our appreciation for the opportunity of presenting this paper at the Convention this year. Before I get into the text, I would like to briefly explain the motivations which prompted the presentation of this paper.

Since the earliest days of CATV there has been little information available concerning the performance of tower-mounted antennas and antenna arrays. Most technicians have of necessity relied on manufacturers' literature concerning the mounting techniques and arraying techniques for antennas. At best this information has been incomplete. Secondly, since Scientific-Atlanta is a prime manufacturer of antenna pattern range test equipment, I had available a complete facility to analyze the performance of antennas and antenna arrays.

Radiation patterns, while not used extensively in the CATV field, provide a wealth of information. For example, the six most important specifications which determine the performance of an antenna or antenna array are gain, beamwidth, sidelobe levels, front-to-back ratio, null positions and VSWR. All of these features, with the exception of VSWR, can be readily determined or approximated from antenna radiation patterns. However, radiation patterns can be deceiving, if not interpreted properly. Consider this first slide. Of these 3 patterns, which would you prefer? Quite frankly, all 3 patterns are representative of the same antenna. The pattern in the upper left hand corner is plotted with respect to the power the antenna receives, and in the upper right hand corner with respect to voltage or field that the antenna receives. The lower pattern is a logarithmic or db plot of the same antenna. I believe you can see right off hand that the db plot at the bottom of the slide gives you a much better analysis of the lobe level, null positions, and generally speaking, a lot clearer presentation of the antenna's performance.

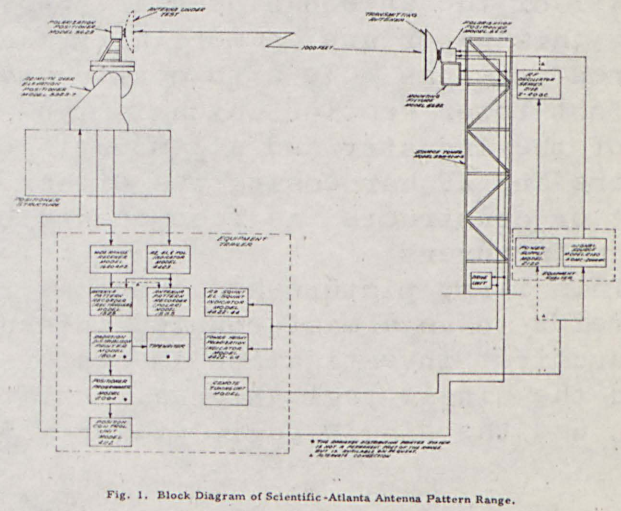


Fig. 1. Block Diagram of Scientific-Atlanta Antenna Pattern Range.

The next slide is a block diagram of the antenna range on which all the measurements in this paper were performed. Quite briefly, we have a transmitting antenna on the right hand side of the slide which is remoted from the receiving anteena or the antenna that you're testing. This receiving antenna is mounted on a three-axis positioner which allows you to rotate the antenna in azimuth, elevation and polarization. Synchronously coupled to this position is an antenna pattern recorder; the RF output from the antenna is fed through a receiver to the antenna pattern recorder. As we rotate the test antenna, the pattern recorder generates a radiation pattern of the antenna's characteristics.

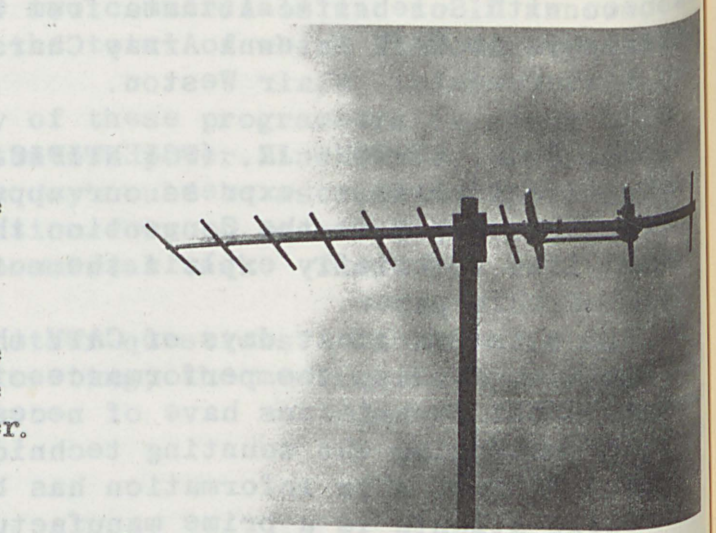


Fig. 2. Mast-Mounted Yagi

The next slide is a picture of the console. In the left hand side, middle left hand side, you can see the receiver. The center section shows the recorder, it's kind of hid by the front panel there, but this is the polar recorder. Lower right hand section is the control equipment for positioning the antenna. The clock-like dials across the top of the console are synchro indicators which allow you to determine the antenna's position at a glance. All the radiation patterns in this report were recorded on Scientific-Atlanta's pattern range. The over-all accuracy of the levels is plus and minus a half a db and the angular read-out accuracy is better than plus and minus a degree.

All of the antennas used in preparing this paper are commercially manufactured antennas. We also constructed a 12 foot tower section which is typical of the industry and all mounting hardware and RF harnessing was either bought or constructed as recommended by the manufacturers.

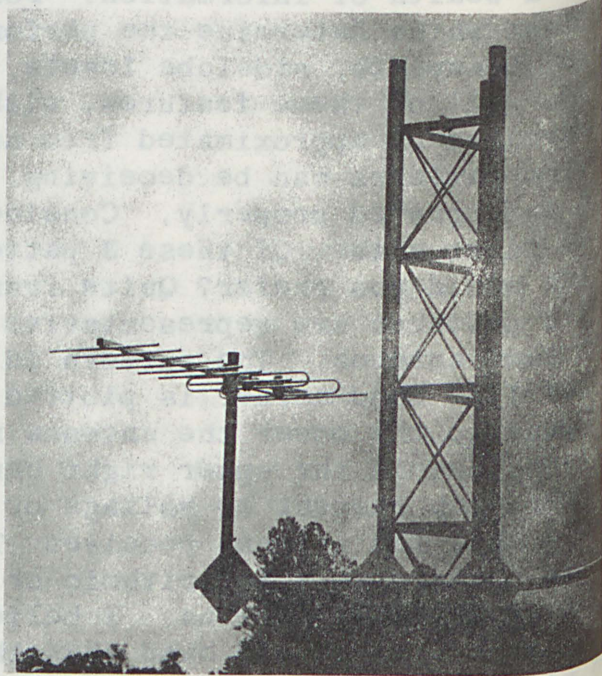


Fig. 3. Tower-Mounted Yagi

This first picture here is what I will refer to as a mast-mounted antenna, and our first investigation is centered around the single-yagi antenna. A lot of you use the single yagi, either a 5 or a 10 element yagi for reception of local channels. And we were interested in finding out exactly what effects a tower would have on the performance of this antenna. This shows the mounting arrangement which we use for measurements taking the data on these antennas. Here again, the same antenna just side mounted on a tower. Incidentally, the spacing was approximately six-tenths of a wave length which is a little bit greater than that recommended by the manufacturer.

Our next slide shows the relative performance between these two configurations. The top three patterns are representative of the radiation patterns of a single yagi antenna mounted on a pole or a mast. The bottom three patterns are representative of the same antenna mounted on the side of a tower. You notice three patterns in each group. All the measurements contained in this report are in the frequency range of channel 13; the left most pattern at at 210 megacycles, the center pattern at 213, your right hand pattern at 216 megacycles. General characteristics of the mast-mounted yagi indicate half-power beamwidths on the order of 50 degrees, front-to-back ratio of approximately 20 db. The tower-mounted yagi shows essentially the same beamwidths, 50 degrees. The front-to-back ratio is considerably larger, the lobe has split and there is a fair amount of distortion on the left hand side of the pattern which is the side that the tower was on.

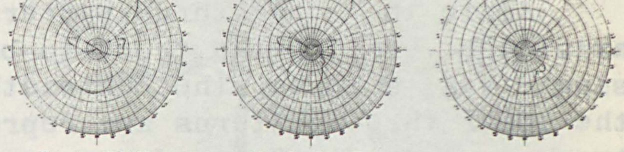


Fig. 4a. 210 MHz Fig. 4b. 213 MHz Fig. 4c. 216 MHz

Patterns of a Mast-Mounted Yagi

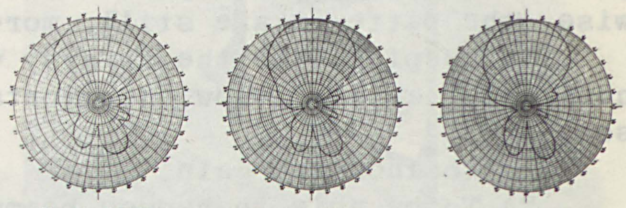


Fig. 4d. 210 MHz Fig. 4e. 213 MHz Fig. 4f. 216 MHz

Patterns of a Tower-Mounted Yagi

Continuing the investigation, we decided to analyze some of the performance specifications of vertical stacks. One of the more common vertical stacks is the so-called J stack. Here you see the configuration that we use for analyzing the performance of the J stack. Again, mast-mounted. We investigated two particular aspects of this J stack.

1) We connected the antennas with coaxial tees, providing a common output.

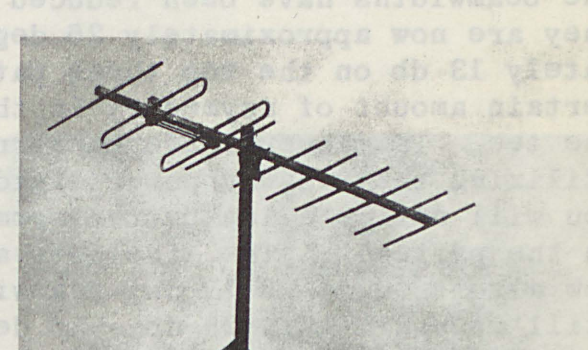


Fig. 5. Mast-Mounted "J-Stack" for Co-Channel Elimination

2) We connected the antennas with a two-way power splitter, to provide a single output.

As you know, the operation of the J stack is based on a physical separation of antennas of a quarter wave length and the use of a delay line to permit inphase reception off of the front of the antennas and out of phase reception from the rear. This is commonly used for co-channel rejection.

Again the upper three patterns are shown with respect to using a coaxial tee. Notice the front-to-back ratio has improved some 5 db over the single yagi antenna, the beamwidths are essentially the same at 50 degrees, the lower three patterns are representative of the same array utilizing a two-way power divider and, as you can see, the front-to-back ratio has improved substantially beyond that which we attain with coaxial tee. Otherwise, the patterns are still, more or less, identical.

In keeping with the arrays, we decided to analyze the performance of horizontal arrays. Now, horizontal stacking is used for a number of reasons:

1) To increase gain.
2) To be able to reduce beamwidths.
3) Use nulls to help eliminate co-channel.

The first horizontal array which we investigate here is the horizontal stack for optimum gain. We tried two particular configurations of this mast-mounted horizontal stack. Number one again utilizing a coaxial tee for connecting the antennas and, secondly, utilizing a two-way power splitter for connecting the antennas.

The next slide contains the performance of these two configurations. The beamwidths have been reduced considerably from the single antenna; they are now approximately 25 degrees. The side lobe level is approximately 13 db on the top three patterns; they average out around 13 db. Certain amount of asymmetry in the patterns which can be attributed to the tee. The lower three patterns are representative of the same array, utilizing the two-way power divider. You will notice a lot better symmetry in the patterns. The sidelobes are now almost equal at 13 db, beamwidths still approximately 25 db - 25 degrees.

Additionally we wanted to investigate the effects that a tower would have on this optimum stack and this optimum stack provides mounting the antennas approximately a wave length and a quarter apart.

So, the next slide shows the configuration in which we investigated the following:

Two antennas are mounted very similar to what you see in the industry with, again, one and a quarter wave length spacing.

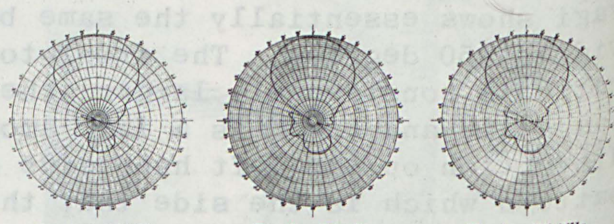


Fig. 6a. 210 MHz Fig. 6b. 213 MHz Fig. 6c. 216 MHz

Patterns of a "J-Stack" using Coaxial "Tee"

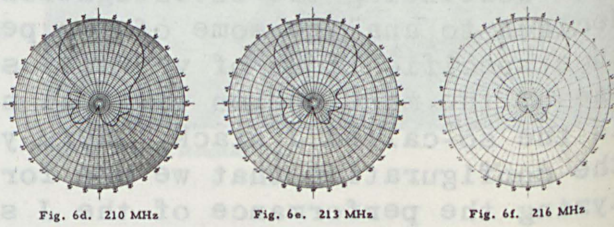


Fig. 6d. 210 MHz Fig. 6e. 213 MHz Fig. 6f. 216 MHz

Patterns of a "J-Stack" using Two-Way Power Divider

And the next slide contains the patterns from the previous data slide, the same three patterns at the top which show the mast-mounted stack, utilizing a two-way power divider. The bottom three patterns show the tower-mounted horizontal stack, with a two-way power divider. I think you can see quite readily that the sidelobe levels have increased some 3 to 4 db and the front-to-back ratio has increased somewhat with the definite enlargement of the rear lobes on the antenna patterns.

Horizontal spacing to force nulls is quite often used, and we additionally investigated some of the effects of horizontal spacing. The next slide shows our first investigation, that of forcing nulls at 40 degrees. As all of you know, I presume, it is quite readily calculated exactly what spacing is needed between antennas to force nulls. We wanted to force a null at 40 degrees; calculations indicate that 7/10ths wavelength spacing between antennas should be used. You can see the nulls are quite accurately predictable.

Here again we have with this particular spacing on a horizontal stack, beamwidths of approximately 36 degrees as opposed to 25 degrees for the optimum stack. The mast-mounted version of the top three patterns exhibits a front-to-back ratio very close to that of the performance obtained with the single antenna. Sidelobes are down considerably. The extra width of the pattern contributes overall to a gain reduction in the performance of this horizontal stack. The second three patterns are representative of this same array mounted on a tower. I believe it's quite evident the distortion introduced by the tower - essentially the nulls were lost in the confusion of the patterns. Front-to-back ratio is shot to -- just plain shot down.

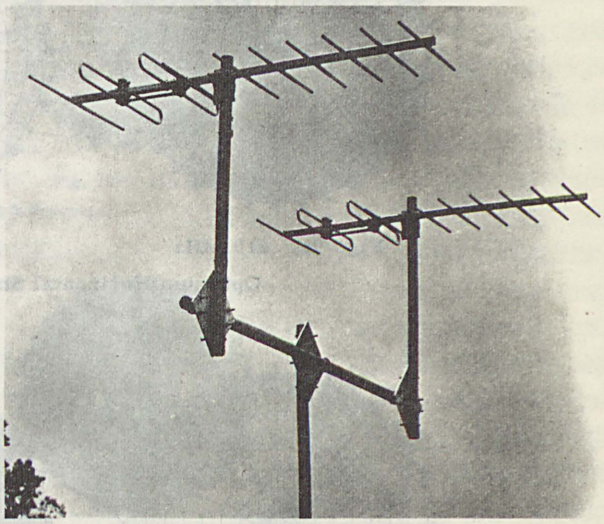


Fig. 7. Mast-Mounted Horizontal Stack

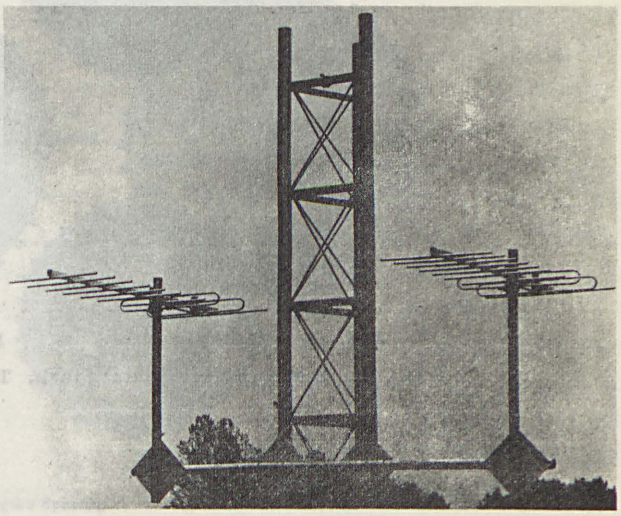


Fig. 8. Tower-Mounted Horizontal Stack

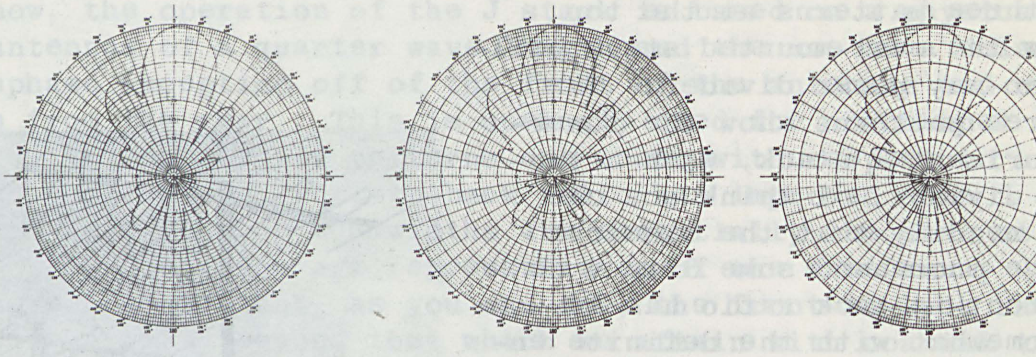


Fig. 9a. 210 MHz Fig. 9b. 213 MHz Fig. 9c. 216 MHz

Optimum Horizontal Stack, Mast-Mounted, using Coaxial "Tee"

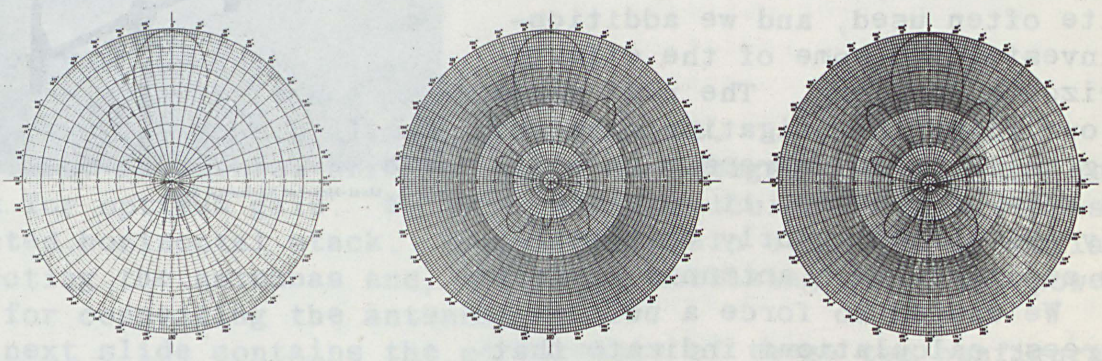


Fig. 9d. 210 MHz Fig. 9e. 213 MHz Fig. 9f. 216 MHz

Optimum Horizontal Stack, Mast-Mounted, using Two-Way Power Divider

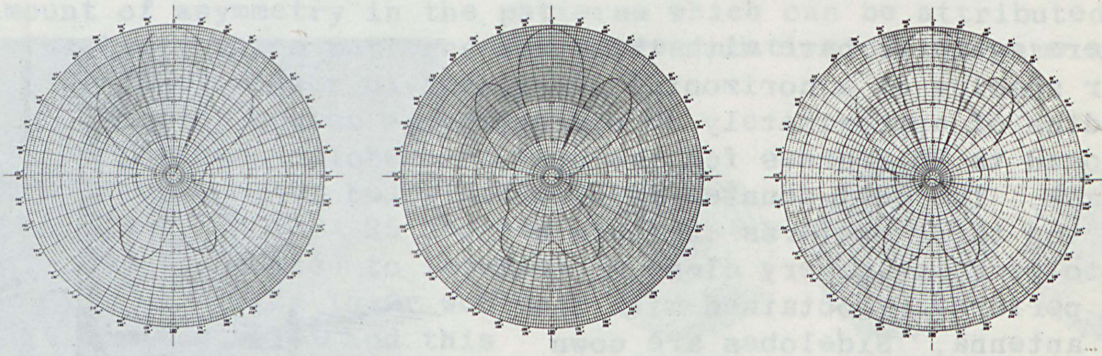


Fig. 9g. 210 MHz Fig. 9h. 213 MHz Fig. 9i. 216 MHz

Optimum Horizontal Stack, Tower-Mounted, using Two-Way Power Divider

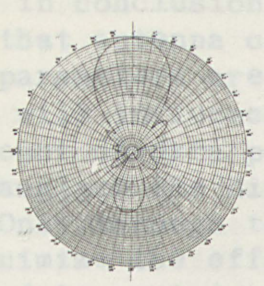


Fig. 10a. 210 MHz

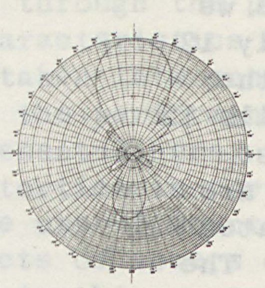


Fig. 10b. 213 MHz

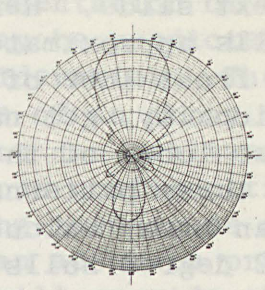


Fig. 10c. 216 MH-

Horizontal Stack, Mast-Mounted, 0.7 Wavelength Spacing

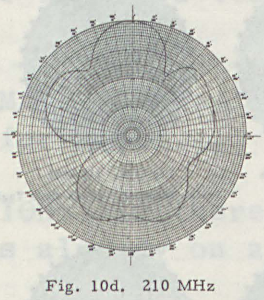


Fig. 10d. 210 MHz

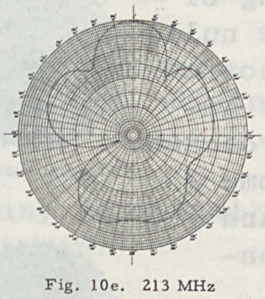


Fig. 10e. 213 MHz

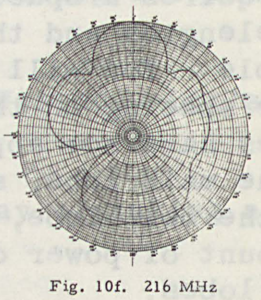


Fig. 10f. 216 MHz

Horizontal Stack, Tower-Mounted, 0.7 Wavelength Spacing

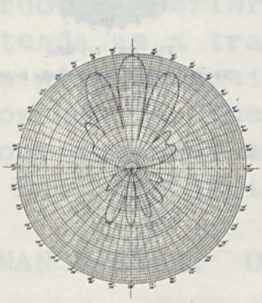


Fig. 11a. 210 MHz

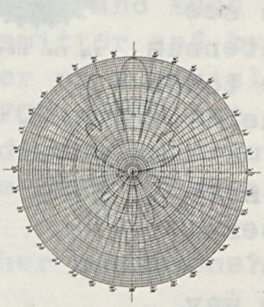


Fig. 11b. 213 MHz

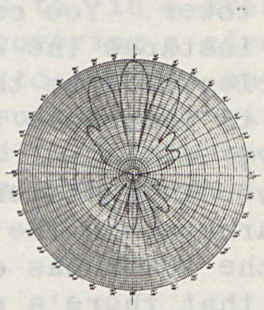


Fig. 11c. 216 MHz

Horizontal Stack, Mast-Mounted, 2.5 Wavelengths Spacing

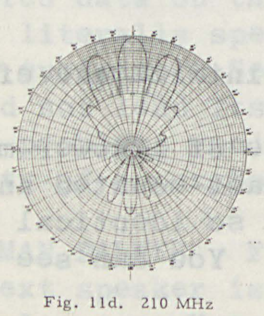


Fig. 11d. 210 MHz

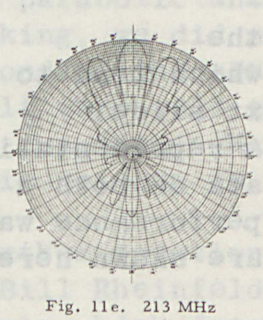


Fig. 11e. 213 MHz

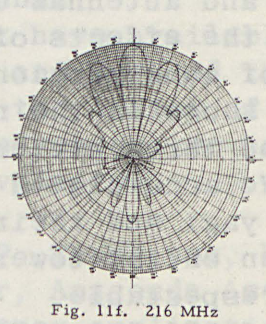


Fig. 11f. 216 MHz

Horizontal Stack, Tower-Mounted, 2.5 Wavelengths Spacing

The second investigation on the nulling utilizing horizontal stack is contained in the next slide. Here we wanted to place nulls approximately 12 degrees off of the front lobe of the pattern and, additionally, get nulls 12 degrees off the rear lobes of these patterns. The top three patterns are representative of an array calculated to provide these 12 degree nulls. The performance mast-mounted is as shown in the top three patterns. Again, calculating the nulls requires a spacing of two and a half wavelengths and the nulls are quite predictable. You will notice that with this wide spacing on the antennas the sidelobes have now approached the amplitude of the main lobe, some 2 or 3 db down from the main lobe, and there is a fair amount of power contained in the side lobes.

The second set of patterns on the bottom are representative of the same array mounted on a tower. You can see in this particular instance the antennas were remoted sufficiently from the tower to allow the tower to influence the characteristics very little.

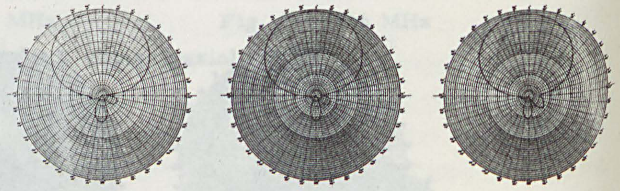


Fig. 12a. 210 MHz Fig. 12b. 213 MHz Fig. 12c. 216 MHz

Tower-Mounted, Screen-Back Yagi

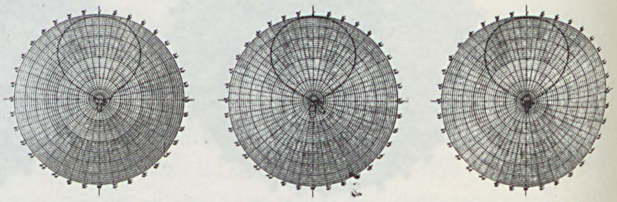


Fig. 13a. 210 MHz Fig. 13b. 213 MHz Fig. 13c. 216 MHz

Tower-Mounted, Log-Periodic Dipole

Now, perhaps you think after seeing some of these arrays and the serious effects that the tower has on their performance, that there's no way to get around it. But there are mounting configurations and antennas designed to minimize the effects of the tower. Two types of construction which tend to minimize the effects of support towers are shown in the next slide.

We have the top three patterns representative of a tower-mounted screenback yagi. We accumulated data on both a mast-mounted and tower-mounted screenback yagi and their performance was so identical that only those patterns taken on the tower are shown here. You can see the performance is quite respectable.

A second method of construction which tends to minimize the effects of towers is that of log-periodic dipoles. The second set of patterns on the bottom of the slide are representative of the performance obtainable with log-periodic dipoles mounted on a tower. Again the performance between the log-periodic dipoles on the tower and mast-mounted were so similar that only the tower-mounted patterns are shown. Incidentally, these antennas were cantilever-mounted from the tower. I trust all of you are familiar with this mounting arrangement. As you can see the performance of these antennas is very respectable.

Well, in conclusion, through the presentation of data I hope I have shown you that antenna characteristics may be predicted only when all influencing parameters are taken into consideration. The support tower in most cases will influence the performance of an array. Even with the limited amount of data presented here, you can realize the difficulty of trying to analyze the distortion in various configurations a tower might present. Only through the use of mounting techniques and antennas which tend to minimize the effects of towers can accurate prediction be made. I hope the data contained in this paper will provide the CATV technician with a better understanding of antenna array performance and will provide a basis for improved techniques in fabricating antenna arrays. I thank you.

CHAIRMAN PALMER: Thank you, Blair Weston. Let's proceed with questions for Blair.

QUESTION: Is there any practical way of taking antenna array patterns on antennas already on a tower?

MR. WESTON: It's somewhat difficult to rotate towers to obtain patterns, although I believe one of the common practices in the broadcast field is proof of performance and such is to, in a transmitting situation, use the antenna as a transmitter and by covering a circular path around the antenna with a receiver on a vehicle to plot it out point by point. I don't know how far the FCC would let you get away with the applying power to your antennas and running around it to see what the characteristics are. But this is the only technique with which I would be familiar.

CHAIRMAN PALMER: Other questions?

MR. WESTON: As I understand the question, you wonder why we have not presented data on the parabolic antenna?

Well, literally speaking, we did not have available the parabolic antenna to evaluate. Secondly, the size and such of the parabolic antenna would not lend itself very well to the taking of measurements due to various problems you'd run into. Main reason, we have not had the availability of a parabolic antenna to evaluate.

CHAIRMAN PALMER: Further questions? Thank you, Blair.

Our next speaker is Bill Rheinfelder, Anaconda Astrodata. Bill was staff consultant at Motorola, high frequency applications 1957 to 1961. During the end of this period he also acted as a consultant for AMECO and left Motorola at that, somewhat thereafter, to go to AMECO as Director of R&D. Then in 1965 he joined Astrodata as Director of Research and Development - CATV in Anaheim, California. Bill Rheinfelder has his masters of science and electrical engineering from the Institute of Technology at Munich, Germany. Bill will talk to us on Advanced CATV System Concepts.

generated by the tuning oscillator, providing the same tuned oscillator, frequency as generated with the 80 MHz channel. Because of this, both a highband and a lowband modulator should never be simultaneously connected to the input of the sideband analyzer.

Another useful feature of the sideband analyzer is that, as previously stated, the device is actually made up of two sections: a video sweep portion and a spectrum analyzer portion. These can, if desired, be used independently. The quality video sweep signal produced may be used as any normal video sweep generator, by simply disregarding the spectrum analyzer portion of the sideband analyzer. The same thing applies to the spectrum analyzer portion of the device. In other words, you might feed a multiburst or some other test signal or, if desired, an actual video signal into the modulator under test and observe the sidebands generated with the spectrum analyzer without using the video sweep section. Therefore, the versatile device actually serves as three useful test devices: a sideband analyzer, a video sweep generator, and a spectrum analyzer, providing, in one small package, most of the tools required for maintenance of your head-end modulators.

This paper is based primarily on the sideband analyzer manufactured by DYNAIR Electronics, Inc. and is similar to the other devices now on the market.

CHAIRMAN TAYLOR: Thank you very much Mr. Bates. Do we have any questions on the sideband analyzer?

QUESTION: Is there a plan to build into the analyzer or equipment for checking the audio portion of a modulator?

MR. BATES: I didn't mean to imply in my talk or to be too specific in referring necessarily to the sideband analyzer that DYNAIR happens to be manufacturing. I was trying to keep this general and not get down to specifics on our particular unit. To answer your question: No, not at this time.

CHAIRMAN TAYLOR: Thank You. Our next speaker, Mr. Lyle Keys, President of TeleMation Incorporated, will speak to us on what we may consider a dirty word, the technical problems of non-duplication. Lyle Keys.

MR. LYLE O. KEYS (TELEMATION INC.): Thank You. Gentlemen, Mr. Chairman: My paper is entitled "Design Considerations for CATV Non-duplication Equipment". There are copies of this paper on the table at the rear of the room.

The subject of CATV non-duplication can be divided into four areas:

1) requirements for program deletion
2) choice of substitute programming
3) method of switching
4) method of switcher programming

Non-duplication arrangements are not necessarily limited to the rules set forth in the FCC's Second Report and Order. CATV operators are free to negotiate different agreements with protected stations. For example, channels programable at one minute intervals. Unfortunately this design would be impractical because of the physical size and expense of these 120,960 memory bits using any memory device that would meet the other design criteria. This type of programmer can be simplified through elimination of redundancy. The trick is in knowing how far to go with this simplification. One approach is to change from a pulse-based system requiring 10,080 events per week to an elapsed-time based system where the event time is programmed along with the switching functions. This greatly reduces the total number of switcher events required, but requires a means of time encoding and time coincidence sensing.

Another way of eliminating redundancy, applicable where functions are to be repeated on more than one day of the week, is to design the programmer to scan all events daily performing switching functions on days so programmed while omitting the function on other days.

A further decrease in programmer size could be achieved by changing to binary coding of all timing functions.

TeleMation's new programmer utilizes the first two of these techniques, but for ease of programming, timing intervals are the usual days, hours and minutes.

Invariably we find operators who insist that the do-it-yourself route is better and/or less expensive. I have no great quarrel with this approach but feel compelled to point out a few of the pitfalls involved.

I have a slide here showing a simple programming clock. This clock costs about $60. and is capable of controlling one channel over a 24-hour period. Eighty-four of these clocks would provide 12 channel, 7-day capability, if a means of commutating between the clocks could be devised, and if switching accuracy were improved by about two orders of magnitude.

The second slide shows a non-duplication switcher which used reed delays as memory elements. This was a one-channel switcher capable of switching on half hours only. The cost per memory bit of this approach is extremely high compared to other systems.

This third slide shows another programmer offering six channel capacity and one minute switching intervals. It can be purchased from the Edwards Company for $300. which makes it quite economical on a cost per bit basis. Unfortunately, it would require anywhere from three to seven of them to handle even the simplest CATV non-duplication switching schedule. The reason is that like many programmers designed for ringing school beels, it lacks the capability of being programmed for different times on different days. This is because day selection can only be accomplished in two hour intervals so that only one day's schedule can be accommodated. Other days, requiring a different schedule in this same two hour period, would require additional programmers.

The fourth slide shows a typical pinboard. This one is manufactured by AMP. The cost of this approach per cross point is relatively low but it doesn't lend itself to use in an elapsed time base system. Therefore, it would require the previously mentioned 120,960 crosspoints to meet the criteria we have previously established. This would take a board eight feet on the side, if the crosspoints were on quarter-inch centers.

The fifth slide shows a programmed switcher which we have been supplying for some time now. It is built around commercial programmers, manufactured by Simplex. I think a number of you people have built your own using this programmer. We have to use two programmers; one scanned daily, carrying repetitive week day programming, and the other scanned weekly, carrying those events that occur once weekly. This provides a maximum capacity of 480 events per week. The two main disadvantages of this programmer are the programming expense where each program bar costs $.32 and can be used only once, and in its limited six channel capacity.

The sixth slide shows our newest programmer. Here we have gone to our own proprietary design rather than trying to make do with other available devices. The unit meets all of the previously listed criteria and uses plugged holes in a perforated metal drum as memory bits.

The last slide, by way of contrast, shows the non-duplication switcher which we built about five years ago. We believe this to be the oldest non-duplication switcher in existence. It incorporates toggle switch memory and stepper switch commutation. It occupied about 30 inches of rack space, had one-sixteen hundredth the capacity of our latest designs, and cost the same amount.

In conclusion, let me suggest that you make a thorough evaluation of your present, and anticipated, switching requirements before deciding on what approach to use. It is also well to look at your physical plant in terms of non-duplication requirements. It may be necessary to completely revamp your head end in order to utilize available switching techniques. In any event, be sure to provide the switcher manufacturer with complete switcher specifications or describe in detail exactly how the switcher will be used and obtain from the manufacturer a guarantee that the equipment furnished will meet your requirements.

I'd like again to depart from the text. Among the problems we have had in the sale of non-duplication switchers, 90% of them occur after we have delivered the switcher and the man finds out that the switcher does not do what he wanted it to do. He buys a switcher that is capable of switching video and he wanted to switch RF, or vice versa, and then when he finally gets this result, perhaps he can't program it; because of the complexity of programming or one thing and another, it doesn't meet its program schedule. This is a subject that is extremely complex. You only have to sit down with about ten TV stations' program schedules and work out one non-duplication program to understand just how complicated it can get. I do urge you to study it very carefully, in order to make sure that you can adequately accommodate it. That's the conclusion of my paper and I thank you.

CHAIRMAN TAYLOR: Thank you, Mr. Keys, very much. Do we have any questions about the non-duplication?

QUESTION: Why is a one-minute interval used for switching instead of some other shorter interval to fit commercial lengths?

MR. KEYS: Let me answer that in two parts. First of all, it would be desirable to build as much resolution into a programming system as is possible. If you went to ten second intervals, this would require six more time event sensing circuits and the reason that we have not adopted that philosophy is that station break intervals are usually, but not necessarily, one minute duration. If you can program to accomodate one minute breaks, then it should not matter to you whether you carry the first commercial of that break or carry all three of them. In the event they have a triple spot break, where generally they will have two commercials and an ID announcement, which takes about two seconds, the total of which it would take about 60 seonds.

Secondly, the switching accuracy of these programmers is about 2/10 of a second plus or minus the instantaneous power line error. The power line error at any time throughout the day could be as much as three or four seconds, so trying to get resolution down to accommodate this ten second commercial would be quite a monumental task. Thank you.

CHAIRMAN TAYLOR: Are there any other questions? If there is no further business to come before this meeting, the meeting is adjourned. Thank you gentlemen.

taken into consideration. If a VHF post amplifier were not used, the mixer would drive the cable and the cable loss would be added directly to the conversion loss. Citing the example used previously, UHF amplifier gain 10 db with a noise figure of 4 db, mixer gain - 6 db with a noise figure of 14 db, and a 600 ft. cable run; we have an overall noise figure of 12.3 db and a signal to noise ratio of 46.9db, see Table 3.

TABLE 3

Noise Figure Improvement Due to Post Amplifier

Configuration	10 db UHF Amp + Mixer	UHF Amp + Mixer + VHF Cable Loss	UHF Amp + Mixer + Post Amp + Cable Loss
F (db)	8.1	12.3	8.9
$\frac{S}{N}$ (db)	51.1	46.9	50.3

This is an increase in noise figure of 4.2 db over the 8.1 db found previously when the VHF cable loss was not included. Addition of a 10 db gain, 7 db noise figure post amplifier results in an overall noise figure of 8.9 db which is only a 0.8 db increase and a signal to noise ratio of 50.3 db. Further improvement in noise figure could be obtained by either increasing the UHF preamplifier gain or decreasing the post amp noise figure.

In many areas there are UHF stations separated by only two to four channels. Closely spaced channels can produce interference when they mix with multiples of the crystal frequency. Also, the received power level of undesired channels may be great enough to overdrive the UHF preamplifier. To alleviate this condition, a highly selective filter is necessary.

The requirements for such a device are, first of all, a low insertion loss, since the loss can be considered as adding directly to the noise figure. The bandpass should be wide enough to pass the desired channel but with approximately 20 db rejection 6 MHz to either side of the bandpass. The extremely narrow bandwidth and high close-in rejection predicates a high insertion loss. Consequently, a compromise must be made between low insertion loss and selectivity.

There are many basic types of filters, some of these being lumped constant, helical resonator, tuned line, cavity and strip line. Lumped constants can not be used since the frequency is too high for effective use. The helical resonator degenerates to the equivalence of a tuned line due to the high Q required. Strip line techniques cannot be used to full advantage since the frequency involved is too low. This leaves the tuned line and cavity as the most likely candidates for filter construction at VHF.

CHAIRMAN SCHLAFLY: Thank you very much, Ed. The Jerrold Handbook is available at the back of the room.

The next paper will be delivered by Clay Mahronic. The title of the paper is, "Effects of Cable Length and Attenuation on Structural Return Loss." Mr. Mahronic graduated from the Illinois Institute of Technology with a BSCE. He joined Amphenol Corporation in 1962 as a project engineer. He took over the quality control department as head in 1965. Clay.

MR. CLAY MAHRONIC (AMPHENOL CORPORATION): To determine whether a coaxial cable will funtion properly in a community antenna television system, the cable's voltage standing wave ratio (VSWR) must be determined for the frequency band in which it will be used. Normally, CATV cables are manufactured in lengths of at least 1,000 feet. Small diameter variations unavoidably occur along such lengths. These diameter variations cause impedance changes which collectively raise the cable VSWR.

CATV cables are tested first from one end, and then the other. Due to variations in a cable's physical profile, the VSWR results from both ends are not always identical. This leads to the dependence of SRL results on attenuation.

Cable VSWR is most often determined with a sweep generator, electronic switch, amplifiers, detector, oscilloscope, variable attenuator and a balanced bridge with a variable load.

With the cable under test connected to the bridge, a signal proportional to the cable reflection appears at the bridge output. This output is compared with that of a variable attenuator connected to the other arm of the electronic switch. By superimposing these signals, the cable VSWR can be read out in terms of structural return loss (SRL), expressed in decibels (db). This value of SRL may then be converted to reflection coefficient and VSWR.

The unusual length of CATV cables sometimes causes VSWR due to periodicity -- a problem seldom apparent in shorter lengths.

Periodicity is the result of numerous small discontinuities -- usually diameter variations -- spaced at intervals one-half wave length apart along the cable. To a signal passing through the cable, these diameter variations appear as small changes of impedance. Each impedance variation is so minute that with the aid of a time domain reflectometer, it is difficult, if not impossible, to locate them. Moreover, the reflected voltage of each discontinuity in themselves, may be unmeasurable.

But because each discontinity is one-half wavelength apart, the individual reflections arrive at the source IN PHASE. Because CATV cables are so long, the cumulative effect of these numerous discontinuities is a high VSWR.

Figure 2 is an oscilloscope pattern of a cable suffering from periodicity. In this test, the frequency range is 4-230 Mc, swept from right to left. The upper trace is a reference line representing an SRL of 26 db or a VSWR of 1.105:1. The middle reference line is 30 db, or a VSWR of 1.065:1. The uneven trace near the base line is that of the cable under test as seen by the bridge.

The large VSWR spike near the center of the photograph is due to periodicity. The frequency at which the spike appeared was 133 megacycles. The cable is basically flat, having an SRL of greater than 30 db, except at the frequency of periodicity. At this frequency, the cable had an SRL of 19.5 db or a VSWR of 1.24:1. One-half wavelength at this frequency is three feet.

The difference in test results when a 1,000-foot length of cable is tested from both ends, prompted further investigation of SRL versus length. Tests were conducted on 1,000-foot lengths of .412 inch, 0.500 inch, and 0.750 inch diameter cables.

Each cable was tested at its full length. Then, 100-foot sections were removed and the remaining cable again tested to determine its SRL.

Results of these tests are displayed. Starting with the 0.750 inch cable, the SRL at 1,000 feet was 18.5 decibels. It was necessary to cut off 400 feet of cable, leaving 600 feet for test before the SRL began to rise. Cutting off an additional 200 feet of cable, leaving a 400 foot length, the SRL had risen from 18.5 db to 20.3 db. When measured in a 100-foot section, the SRL was 29 db. This curve shows that discontinuities which are further than 600 feet from the end of the cable being measured do not contribute to the total SRL of the cable.

In the .412 inch and .500 inch cables, it was necessary to remove approximately 600 feet of cable before the SRL began to rise. The higher attenuation of these cables as compared to that of the 3/4 inch cable limits even greater the length of cable that contributes to low SRL due to periodicity. In all cases, the total cable length did not contribute to the SRL. The length of cable which contributed to the low SRL was governed by three factors:

1. Frequency at which the periodicity existed.
2. Attenuation of the cable at that frequency.
3. Magnitude of the discontinuities.

To better illustrate the results of the tests, a tabulation of data on all three cables is shown. The data on the .412 inch and .500 inch cables are very similar. The total length contributing to the SRL, attenuation in db/100 feet and total attenuation necessary to limit reflections are almost identical. They do differ at the frequency in which the periodicity exists. The different frequencies is due to the spacing of the discontinuities. In both cables, it is possible to see only slightly greater than 1/3 the total number of discontinuities in a 1,000-foot length of cable. The important difference of these two columns of data is the difference in the number of discontinuities contributing to the periodicity. Since the .412 cable can see only 54 discontinuities and the total SRL of the cables are almost equal, it follows that the magnitude of the discontinuities of the smaller cable must be larger than that of the 1/2 inch cable.

Due to the lower attenuation of the 3/4 inch cable, it is possible to see discontinuities which are 500 feet away from the end of the cable being tested.

Cable attenuation, being a limiting factor on the total reflection, was not unexpected. Theoretically, an incident wave traveling down a cable is attenuated. The first discontinuity sees almost all of the incident signal. As this signal propagates down the transmission line, the attenuation of the cable reduces the magnitude of the incident signal. The discontinuities located further down the line see less and less of the input signal. Therefore, the reflected voltage is less than that of the first discontinuity.

The attenuation which reduces the incident signal, also reduces the magnitude of the reflected signal af it propagates back to the source. Therefore, it is apparent that the attenuation is the reason why the more distant discontinuities contribute very little to the total reflection.

The relationship of SRL to the frequency of periodicity and attenuation can be better understood by comparing two 3/4 inch cables which suffer from periodicity but at different frequencies.

The cable in the left hand column of Figure 5 is the same as seen in the previous figure. As a comparison, the frequency of the cable in the right hand column was assumed to be 56 megacycles. This is the same frequency as that of the .412 inch cable. At this frequency, the attenuation is .45 db/100 feet. Holding the limiting attenuation constant at 3.25 db, it is possible to see 720 feet into this cable. Even though a greater length contributes to the periodicity, the spacing of the discontinuities differs. The result is that at 56 megacycles, 103 discontinuities contribute to the total SRL while 161 can be seen at 127 megacycles. The calculated SRL at 56 megacycles was 23 db. In other words, the VSWR has been reduced from 1.27:1 at 127 megacycles to 1.15:1 at 56 megacycles even though the total length of the cable contributing to periodicity was greater. Because of the "attenuation effect" in relation to the cable size, it is evident that the 3/4 inch cable is more sensitive to reflections than that of the 1/2 inch or .412 inch cable, thereby making this a more critical product.

Length and attenuation have been shown to limit reflections resulting from periodicity. Reflections resulting from large single impedance changes-usually due to dents in the outer conductor-are also limited by cable length and attenuation.

Evidence of this effect was observed in a 1,030-foot length of cable deliberately dented with a pair of pliers. This dent, about two inches long, was placed about 100 feet from the end of the cable.

Before we see the effect of this dent, let us look again. You will notice that the SRL of the cable is greater than 30 db. Figure 6 shows that the dent has caused a considerable change in the SRL pattern. At 220 megacycles, the SRL of this cable has been reduced from greater than 30 db to less than 26 db. The decrease in SRL at the upper frequencies is much greater than that at the lower frequencies. This is because the 2-inch dent more nearly approaches a quarter wavelength at the higher frequencies. When a single discontinuity reaches 1/4 wavelength, the reflection is at a maximum.

Additional proof of the effect of attenuation on SRL can be shown by testing the far end of this cable. In this case, the dent is 930 feet away from the bridge. The previous test showed the SRL due to the dent to be less than 26 db. In this case, the attenuation of the 930 feet of cable has attenuated the reflection so that the cable is still better than 30 db.

In conclusion, we wish to point out the importance of sweep testing both ends and rating the cable based on the lower reading.

Secondly, we also wish to point out the possibility of using attenuation to improve picture transmission. As a case in point, let us assume that there are two 1,000-foot lengths of cable to be placed between amplifiers. One cable has an SRL of greater than 30 db, whereas the other cable is somewhat less than 30 db. It is suggested that the cable of higher SRL be placed at the output of the first amplifier. The second cable is then placed between the end of the first cable and the input of the second amplifier, therefore, the attenuation of the better cable shields the VSWR of the second cable. In this way, the first amplifier sees only a cable which has an SRL of greater than 30 db.

CHAIRMAN SCHLAFLY: One or two questions. Dr. Schenkel?

DR. SCHENKEL: I only want to make a couple of comments on the talk. I agree to all the fact that were brought up, but I have some doubts about some of the conclusions. And I would want to show my point of view on a couple of these conclusions.

Now first of all, about this matter of shielding a worse piece of cable by having a better piece of cable ahead of it. Now, if the return loss only presented at the amplifier would give a reflection, then I would agree to this shielding. But I think return of the cable is also indicative of the cable transmission properties. And whenever we have a spike in the cable, even if it is hidden right inside the cable, and that we don't see it, this means that in transmission there would be a somewhat rapid change of phase in this transmission. So if that thing appears close to the color carrier or the picture carrier of a TV channel, this may cause some delayed distortion of the color. So even if the return loss is hidden inside the cable, still each piece of cable should be selected for use according to its own test and how it appears in the final span.

MR. MAHRONIC: Dr. Schenkel, in answer to what you have said, I have to agree with you. But what I am trying to say is that if we have two pieces of cable, if there is a choice on where to place the cable, I would rather place the better cable at the output of the first amplifier rather than the worst cable at the output of the first amplifier.

DR. SCHENKEL: Now, second point is: I wonder why you didn't mention the interesting fact that all the numbers on the bottom row of your tables were close to 4 db. Which I think is a false indication that whenever we want to use this length of cable for periodicity, we do not have to use a complete reel, but it is enough to just cut off a length of 4 db. At the loss frequency we are going to test and sweep it, and this will give us all the indication about periodicity.

MR. MAHRONIC: Let me get this straight, Dr. Schenkel. The tests we use to check how good a cable is is either by sweep testing it or with the use of a time domain reflectometer. All these tests, the results of these tests are a function of the attenuation and we have no test that we can perform that does not hinge upon the attenuation of the particular cable. So I don't see how we are going to do this unless we cut this into 500 ft. lengths and then couple these lengths together.

CHAIRMAN SCHLAFLY: I am going to cut that discussion right there, with a little question mark in the air. We are running so short of time that I do not want to impose on the good nature and patience of our last speaker. Thank you, Clay, and thank you, Dr. Schenkel.

The last speaker on the agenda this morning concerns a very interesting item of test equipment called the spectrum analyzer. This is a most interesting and useful tool. I am anxious to hear more about it. Allen Ross, who will deliver this paper, is President of Nelson Ross Electronics. Nelson Ross Electronics specializes in Plug-In Spectrum Analyzers. Allen Ross is a graduate of City College of New York and of Brooklyn Poly-Tech. He was with Polarad Electronic Corporation before forming NRE. He spent eight years with them and was in charge of advanced development, pioneering the solid state spectrum analyzer. He was the person who first implemented the Plug In Spectrum Analyzer concept. Allen.

MR. ALLEN ROSS (NELSON ROSS ELECTRONICS): I know it is late and we are running behind, so I will try and cut right to the meat of this. The spectrum analyzer is an instrument that is probably unheard of in this particular industry. It is a useful instrument which has been around for a long time, originating with the esoteric military requirements. The state of the art in spectrum analysis has gradually improved to the point where it is possible to build spectrum analyzers which cover very wide frequency bands. There are now a few people making analyzers which permit observation of the entire CATV spectrum -- channels 2 to 13 (including all the FM in between) in one sweep. These analyzers will permit very useful advances in the systems for testing CATV transmission.

Perhaps it might be appropriate for me first to describe what a spectrum analyzer is and how it operates. I don't know how many people can see this blackboard, so I will try and use a minimum of sketches. We will start with a familiar instrument - the field strength meter. If we start by drawing the block diagram of the most basic field strength meter, what we have would be a signal input which drives a mixer, which I shall designate "M", provided with a local oscillator signal, from a black box which I will designate "LO". The resulting difference frequency drives a narrow band filter, ultimately resulting in a meter reading. Signal F plus Delta F comes from the local oscillator producing Delta F at the mixer output, and depending upon the strength of the input, we get a meter reading. Anybody who has manually tuned one of these things back and forth for a few hours from channel 2 to channel 13 can tell you it gets to be a pain in the neck after awhile. You can make a very good and accurate set of readings of the relative levels of all the picture and sound and color carriers in the system, but it is time-consuming. It would be nice if we had some sort of a system for observing the meter readings on all the channels simultaneously, so we didn't have to tune. This is exactly what a spectrum analyzer does for you.

Suppose we were to replace the meter with the vertical deflection system of an oscilloscope. This presents no basic problem. When we tune through a signal, we would see the modulation (as limited by the band pass) as a wave form on the oscilloscope.

Suppose, in addition, instead of tuning the local oscillator particular point may vary from 73 to 77 ohms. It is quite possible that a 73 ohm end may be spliced to a 77 ohm end. This would give a reflection coefficient of 0.0267 or return loss of 31.5 db. Systems requiring better match would have to check such splices and select cable reels to give ends that match. The TDR when used with a suitable 75 ohm impedance standard can check cable impedance profiles with great accuracy.

Several problems have been encountered in application of the H-P instrument to CATV. The H-P TDR was designed for 50 ohm systems and has a source impedance of 50 ohms. When used in a 75 ohm system, there is a mismatch which causes some difficulty due to multiple reflections caused by reflection at the mismatch between TDR and 75 ohm cable. H-P have an adapter available which consists of a 25 ohm resistor in series with the cable. This back matches the cable since the reflected pulse sees the 25 ohms in series with the 50 ohm impedance of the TDR. This introduces a 6 db loss in sensitivity due to voltage divider action on both the incident and reflected pulses. A resistive minimum loss matching pad can be used with somewhat higher loss of sensitivity. For precise quantitative measurements, the instrument can be easily recalibrated to compensate for either adapter. I personally prefer to use the MLP or no adapter at all, making corrections for multiple reflections according to the formulas in H-P's application manual.

Some problem has been experienced with 60 cycle AC pickup particularly on cables on joint use poles. This is usally noticed on lines with low impedance shunts such as resistive terminations. The pickup seems to disappear when the line is completely opened. H-P is developing a unit called a "humdinger" to alleviate this problem.

We have found the TDR, particularly the version by H-P, to be a reliable, very useful instrument for routine use by CATV systems, large and small. In the words of one of our system managers - "I don't know how we ever got along without it".

CHAIRMAN TAYLOR: Thank you very much and I want to apologize first off for eliminating the punch line at my introduction. Mr. Switzer is a CATV consulting engineer in Lethbridge and also has been associated considerably with the famous players in their CATV systems throughout Canada.

Our next speaker, Mr. Isaac S. Blonder, Chairman of the Board of Blonder-Tongue Laboratories, Inc., will speak to us on the importance of technical training. Mr. Blonder.

MR. ISAAC S. BLONDER (BLONDER-TONGUE LABORATORIES, INC.): At the back of the room there is a table containing my speech and also another paper on CATV technical training that was prepared by Fred Schulz who is in charge of our sales training. I was delighted at the opportunity to be able to talk about technical training. I've done nothing else all my life.

Technical knowledge may be categorized as having four general divisions: scientist, engineer, technician, craftsman. Technical training is accomplished in these approximate areas: university, technical institute, high school, military, apprentice, self-study.

Measurement standards for the level of technical knowledge achieved are virtually non-existent. The CATV operator, and indeed every other employer of technical labor, is left adrift to find his own way out of the maze of conflicting testimony on the state of technical training available to him in these United States.

No universal measuring stick in the form of national examination or universally accepted standards of performance for students can be used to match the job to the available job applicant. The problem is further obfuscated by the present shortage of trained personnel. Available figures show that we are training about 15,000 engineers and the same number of technicians each year in electronics with a comparable quantity coming from military programs and probably a smaller number graduating from industry schools. Not only are we faced with a level below our needs, but the ratio of technicians to engineers for maximum efficiency should be about 3-1, indicating a need for technicians about 200% over the present supply!

For purposes of identification and analysis let us define the scientist as the pure researcher not normally needed in CATV, the engineer as the creative planner who is needed in small but vital quantities, the technician on whom falls the principal burden for the day-to-day operation, and the craftsman who is the installer and repairman.

The scientist and engineer are probably available as needed. Our universities are expanding, funds from the military provide some 60% of the needed financial support, and the present high engineering salary levels are attracting our best students. If anything, medical schools complain about the far lower level of students they are attracting today as a result of the brain drain to the sciences! American technical science leads in the development of electronics. Most of the universities maintain high standards of selection and performance and the possession of a degree is usually a worthwhile indication of intelligence and knowledge. We must recognize, however, that no universal standards exist to measure engineers on a national level, and the employer has no figures to guide him in his choice of an engineer, indeed every employer today is forced to use the services of an industrial psychologist to measure the comparative value of a prospective employee, and finds the diploma and college grades much less of a guide in his selection.

It is in the technician area where our problems really exist. Some small beginnings have been made to establish standards for technician training schools. The American Society for Engineering Education - Washington, D.C., among others, has established standards for schools awarding an associate degree for the completion of accredited two years curriculum in engineering technology and now accredits schools meeting these standards. But how many of these qualified graduates have you met? Blonder-Tongue doesn't find them in our employment office! Other than such pioneer efforts in establishing standards for the schools-not the students, incidentally!-we face a vast garbage dump of schools and standards purporting to train technicians. Lowest on the ladder for achievement are our public high schools. Since they are forced by law to take everyone and hold them in bondage until released by chronological growth, academic standards are non-existent, and the good scholars compulsively avoid the stigma of an inferior technical education. Even the category of craftsman, who should take pride in his accomplishments of the menial tasks, is not well served by our high schools where his sense of pride in doing well what he can do is degraded by the general atmosphere of a quasi-penal institution. It is too well known for repetition of the sordid facts, to point out in detail the non-existent standards of our privately owned technical training institutions, who advertise blatantly the financial opportunities in electronics for their graduates but fail to mention that no standards exist for admittance or graduation except the payment of tuition fees.

Faced with the never-ending shortage of electronic technicians, a school system incapable of producing them, and no immediate relief in sight, what can the CATV industry do?

1. Set standards of training and knowledge. If financially feasible for the parent NCTA, get up an examination and certification system to qualify both school and individual. The difficulty of this task should not be underestimated, since it has yet not been accomplished in the U.S., except for the certification of professional engineers by the individual states.

2. Set up your own training programs as most companies have had to do. Training is a never-ending task and is best done on a continuing basis with with regularly scheduled company time devoted to it. The more formal such a program the better, even to the extent of appointing a Director of Training and awarding of certificates.

3. Contract for outside training help. The U.S. Government has many areas in which they are striving to provide technical manpower for American industry and funds are flowing to local schools in your immediate vicinity. To review the present status of these programs would not only take time now but would serve no useful end since they are in such a maelstrom of change due to the fact that they are unsuccessful so far in meeting their stated objectives. As long as these emergency preliminary efforts can only deliver poorly trained craftsmen with questionable work motivations, our needs will go unfilled. But we should not criticize too harshly the first futile technical schools; the need is so urgent that wherever possible we should aid in the effort to train the untrained.

4. Look to industry for training courses and material. Blonder-Tongue, in its own sales interest, just as other manufacturers do, gives short training sessions to insure the proper use of its equipment. Our literature is technically oriented and the technician who is familiar with it can better accomplish his job even when he uses the products of another manufacturer.

We have passed out copies of a CATV training course given under the direction of Fred Schulz, Chief, Sales Engineering, and it will be our pleasure to describe how and when they are available to the CATV industry.

Technical training in this day and age is an absolute necessity in order to survive; the CATV technician is no exception. The following paragraphs intend to show the development of a training course for CATV technicians. A large number of successfully administered training courses, given by B-T in the last 15 years, particularly for MATV and CCTV technicians, furnished a wealth of practical experience.

The discussions are limited to a course intended to spread technical knowledge to CATV technicians and excludes technical sales meetings designed to sell a product line. There are two basic ingredients in training:

THE GOAL AND THE STUDENTS

Let us set the goal in very brief words:

OUR TRAINING SHOULD PRODUCE MEN WITH A THOROUGH UNDERSTANDING OF TV PRINCIPLES, SYSTEMS ENGINEERING BASICS AND HARDWARE KNOWLEDGE, SO AS TO BE ABLE TO SUCCESSFULLY MAINTAIN, EXPAND AND TECHNICALLY RUN A CATV SYSTEM.

This is quite a tall order.

The student, our 2nd basic ingredient, does not lend himself to such a quick treatment. Students are human beings and, therefore, quite complex. In short, we have individuals in front of us.

The background our students are bringing with them varies greatly and it is this variation that we must take into account to run a successful program. This point is probably the single most significant difference between public school training and our programs. This realization automatically rules out the vast available program material from colleges and technical schools.

Course participants cannot be required to show evidence of successful completion of pre-requisite courses as is customary in colleges, nor can they be required to take an entrance examination.

The educational level may run from graduate engineer to the man with an intuitive feel for CATV, but with little solid educational foundation to build on.

It is highly desirable to get information on the background of participants before a course is started; let the company provide this information.

The learning capability of anyone is limited, keep in mind that many course participants are practical men, little accustomed to sitting still for any length of time or able to concentrate over extended periods. This factor can be taken into account by providing ample and frequent breaks, (coffee breaks are particularly well received). It should also be mentioned to the students that learning and a good night's sleep go together very well.

How much time are people willing to spend on a training seminar is still another factor to be considered. There is no magic formula, however, a 3-day seminar is optimal in many cases because it can, for instance, begin on Tuesday morning, allowing travel on Monday. Running full 8 hour sessions on Tuesday and Wednesday, and with a mid-afternoon breakup on Thursday, allow the participants to return home that same day.

Where should one hold courses? The choice depends on the course material. If much material and equipment is needed, the home office is a logical choice; for other courses keep in mind: the shorter the travel time the more participants. A hotel or a motel with restaurant and meeting room facilities, as well as close to transportation facilities can be found just about any place in the U.S.A.

When to hold a meeting? Keep in mind that in many areas there is a strong seasonal demand on the CATV technicians' time. State and national association meetings often bring technicians together and a course may be scheduled before or after such a gathering.

The cost of a course varies greatly. Factors to be kept in mind are:

a) who pays the participants travel expenses, food, lodging?
b) cost of instructional material
c) travel cost of instructor(s)
d) cost of meeting room

It has been found desirable to let the participants at least bear part of the expenses. The desire to "get their money's worth" creates an eager learning climate, and if the students' bosses pick up the tab, the results are just the same.

The instructor, the link between goal and student. A good instructor is not easy to come by because he must fulfill a number of tough requirements.

1) He must be knowledgeable technically, both from a theoretical and a practical experience standpoint.
2) He must have the ability to teach adults.

Unique is the individual that combines both requirements, because a good engineer may fulfill the first requirement, but most engineers unfortunately fall down badly when it comes to teaching.

The instructor must be able to step in front of a group of strangers, establish a rapport with the group and stay confident. We mentioned the necessary gift of being able to handle people of vastly different backgrounds. A subject must be presented interesting to people already knowledgeable, yet instructive to people learning it. Like a salesman, our teacher must speak from conviction; must have self assurance, yet be reassuring to the participants. The man must be able to get material across without talking down to participants. Obviously, he must be able to stay on the subject during class discussions.

Sometimes, particularly when sessions are held at the home office, it may be possible to have specialists teach certain portions of a course; but make sure they have proven teaching ability.

Reference Material

Start a course by handing out the course outline, technicians will appreciate seeing that a course is well organized and taught in logical sequence.

Often a participant may find additional subjects he wishes to hear about and it may be possible to include them in the course. Other printed material suitable for distribution are:

a) spec sheets
b) application notes
c) manuals
d) reprints of articles
e) tables

Teach Aids

The instructor should use notes in order to keep continuity. Large scale drawings, slides, overhead projectors are good aids, but it should be kept in mind that darkening a room keeps most people from taking notes. A blackboard is still one of the best teaching aids. One should not forget that what is on the board goes in the students notebook; clear and clean sketches make the student's life easier.

Demonstration equipment is very valuable, allow enough time if it is necessary to hand it from student to student, or provide more than one unit.

Organizing a Training Course

Location and date should be proposed by the field men who know the area and the potential participants.

The home office should obviously coordinate the requests in accordance with a master schedule. Individual invitations should be sent by the field men, because it lends it a note of personal care. Invitations should be sent early. It should give lodging instructions. Hotels and motels are more than happy to furnish room reservation cards.

Conducting a Course

Start course sessions on time. The instructor should arrive early enough to familiarize himself with local conditions, setup demonstration gear and teaching aids. The student should feel that the company is expecting him and is prepared for him. After all technical training is still a means of winning customers (or keeping them).

Group lunches are desirable from a time standpoint as well as from a standpoint of getting the class to feel comfortable as a group. Encourage people to take notes, (provide pads), but allow time for writing, most people are not used to taking notes. Encourage questions.

Let participants know that they will benefit from increased knowledge, (prestige, greater satisfaction, advancement, better wages) this creates an "eager to learn" atmosphere.

Brief review of fundamentals always seems to help. Fundamentals are the most neglected part of courses, many people think they know, however do have only vague ideas. What's the use of knowing how a large CATV system functions, and not even know what makes up a TV channel? Review tools, like db and dbmv.

Main topics should be arranged logically, so as few assumptions as possible have to be made. Summarize at the end of each topic to detect blank spots in coverage. At the end of a course, encourage the technicians to practice self-development and give hints on how to go about it.

Course evaluation sheets filled out by the technicians (no name) can help to improve future courses. An attendance record is good for follow up and sales purposes. The issuance of a certificate will boost the ego of the participants.

CATV Technician Training Course Outline

The following course can be covered in 5 days, it could also be worked into approximately 20 lessons suitable for mailing or the most important topics may be covered in a 3-day seminar.

1. Greeting. Introduction of participants, purpose of course and outline.

2. TV-FUNDAMENTALS
   a) scanning standards
   b) synchronizing and blanking
   c) resolution
   d) composite TV signal
   e) modulation (AV modulator, standard TV-channel)
3. Portions of the frequency spectrum we work with; Video, Audio, AM Broadcast-Band, Sub-channels, VHF low band, FM, VHF - High Band, UHF, Microwaves.
4. The db and dbmv as tools in our work.
5. TV-Signal Propagation: signal strength, line of sight, etc.
6. Antennas; characteristics and applications
7. Signal quality at the antenna (S/N, ghosting co-channel, etc.) TASO- Standards.
8. Pre-amplifiers: Importance of low noise figure, maintaining good S/N etc.
9. Amplification and other means of signal processing:
   a) AGC, min. input
   b) adjacent channel; sound reduction
   c) amplification, conversion, trapping, mixing, equalizing
   d) demod. - remod. systems
   e) IF - type processors
10. Headend AC supply
   a) line voltage fluctuations
   b) voltage regulators
   c) surge protection
11. Cables: Distribution System
   a) need for cable (location of subscribers, radiation limitation, interference prevention, unauthorized use of signal, etc.)
   b) basics of coax cables
   c) types of available cables
   d) cable deficiencies (return loss, weather resistance, eccentricity, etc.)
12. Basic limitations of amplifiers
   a) noise figure
   b) max. output
13. Basic system limitations:
   Cascading amplifiers
   a) tolerable S/N
   b) tolerable cross-modulation
   c) system tolerance
   d) temperature compensation
14. Principles of CATV-signal distribution:
   The need for an untapped trunk.
15. Typical distribution systems.
16. Distribution Equipment:
   Splitting devices (asymmetrical and hybrid splitters)

Equalizers
Duplexers
Automatic level control
Automatic tilt control
Matching transformers
Home splitters
Tapoffs: Pressure taps, hybrid types, isolation, thruloss.

17. Accessories: housings mountings
18. Test instruments and their uses, particularly the field strength meter.
19. Servicing and installation:
    Signal probing, checking of cables, grounding, weather proofing, use of test equipment, trouble shooting by symptoms, checking defective distribution lines, preventive maintenance.
20. Specifications: Interpretation and writing.
21. Cost estimates.
22. Pole line construction.

CATV - AUXILIARY PROGRAMS

23. Basics for closed circuit (CCTV) program origination.
    a) lighting
    b) lenses
    c) types of cameras
24. Weather channel, sub-channels, microwaves

CHAIRMAN TAYLOR: Thank you very much. Does anyone want to ask Ike questions about this training program?

QUESTION: Is this training available to anyone, and on what basis?

MR. BLONDER: We have conducted seminars throughout the United States, usually in regions, conducted by our Regional Sales Manager. I must admit that we have concentrated much more on the NATV area in which we have had, in the past, a greater interest, but we are setting up a new program. If you will indicate to us your interest in participating, you will find that we will have a regional meeting in your area eventually to which you are certainly invited.

CHAIRMAN TAYLOR: Our next speaker is Mr. George Bates, Vice President of Engineering for DYNAIR Electronics, Inc. Mr. Bates will speak on the use of the sideband analyzer and its applications. Mr. Bates.

MR. GEORGE W. BATES (DYNAIR ELECTRONICS, INC.): The "sideband analyzer" is well-known to the television broadcast engineer; it's one of the basic tools of his trade. However, for some unknown reason, the average CATV engineer - who has even more need for this device - is not familiar with its application in CATV and, in many cases, doesn't even know it exists.

CHAIRMAN SCHLAFLY: Thank you, Gay. The next speaker is Ken Simons. It says here, Kenneth A. Simons. I don't recognize that name, Ken. Ken has been active in radio since 1927. You started very young, didn't you? He has been in TV since 1939 and with Jerrold some 15 years, since 1951 he has here, and is Vice President in Charge of Research and Development at the Hatboro, Pennsylvania laboratory. He has participated in the design of various things, like the 704B field strength meter, 900B sweep generator, starline, and other of the Jerrold products. He is a member of the NCTA Standards Committee, and is a principle contributor to the handbook that his company has reissued again this year. Mr. Simons' paper is on reducing the effects of reflection in CATV feeders.

MR. KENNETH A. SIMONS (JERROLD): The pressure tap is a convenient and economical way of connecting the customer drop to the feeder in a CATV system. Because of this convenience, the large majority of taps in use today are of this type. Hundreds of thousands of them are providing satisfactory service in systems all over the country. Unfortunately there is a penalty attached to the pressure tap's convenience. Because it must tap into the feeder cable with no opportunity for series compensation, the pressure tap inevitably introduces reflections into that cable. This article will show how these reflections are minimized by careful design, and how their adverse effect on the transmission of picture signals can be greatly reduced by grouping taps in optimum arrangements.

Up to the present time, Jerrold has manufactured four basic types of pressure tap. The earliest designs, Models PTR and PTC, employed a series resistor or a series capacitor connecting the pressure point to the center conductor of the drop line, as illustrated in Fig. 1. The resistor tap (PTR) was used for line-to-tap losses of 30 db and over, the capacitive tap for lower loss values. This design had the advantage of simplicity, and low cost. While the capacitive tap had high efficiency (i.e., the loss on the feeder line, for a given feeder-to-drop loss, was low compared to other designs) it introduced reflections on the feeder that were much worse than those introduced by transformer taps having the same line-to-tap loss.

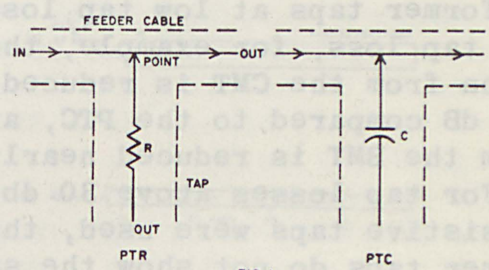


FIG 1

Fig. 2 shows the schematic diagram of a transformer-tap. A tightly coupled auto-transformer steps up the impedance of the load to a high, and essentially resistive impedance bridging the feeder line. A coupling capacitor isolates the primary at low frequencies, and a series resistor raises the output inpedance so the tap

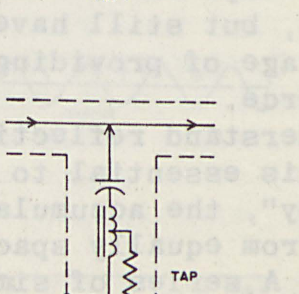


FIG 2

acts as a well-matched source for the drop line. Jerrold manufactures two kinds of transformer taps which are similar electrically but differ mechanically. The CMT tap is convenient as a replacement for the older taps. It is mechanically interchangeable with the PTR and PTC. However, the 3/8 inch hole into which these units thread is too small for optimum electrical performance. The BMT transformer tap uses a 1/2 inch hole, and the increased clearance allows a reduction in stray capacitance with a considerable improvement in high frequency performance.

Table I compares the reflections introduced into an otherwise reflectionless 75 ohm line by single taps of each type.

TABLE I

Reflection Introduced into a Feeder by One Tap at the Worst Frequency (216 MHz)

Loss from Line to Tap at 216 MHz	Resistive and Capacitive Taps		Transformer Taps			
35 dB	PTR(6)	26 dB	CMT(35)	22.0 dB	BMT(35)	26.0 dB
30 dB	PTR(3)	25.5 dB	CMT(30)	21.0 dB	BMT(36)	28.0 dB
25 dB	---		CMT(25)	22.0 dB	BMT(25)	29.0 dB
20 dB	PTC(W)	19.5	CMT(20)	21.6 dB	BMT(20)	26.7 dB
16 dB	PTC(R)	16.4	CMT(16)	21.4 dB	BMT(16)	25.4 dB
12 dB	PTC(Y)	14.2	CMT(12)	19.5 dB	BMT(12)	21.1 dB

Note: Reflection figures on this table were obtained by measurement of production units selected at random. Published specifications show somewhat greater reflection in each case.

Notice the substantial reduction in reflection accomplished by the use of transformer taps at low tap losses. At 16 dB tap loss, for example, the reflection from the CMT is reduced nearly 6 dB compared to the PTC, and that from the BMT is reduced nearly 10 dB. For tap losses above 30 db, where resistive taps were used, the transformer taps do not show the same improvement, but still have the important advantage of providing a back-matched source.

To understand reflections on CATV feeders it is essential to understand "periodicity", the accumulation of reflections from equally spaced discontinuities. A series of simplified examples may help to explain the effect. Fig. 3 illustrates conditions existing on a lossless 75 ohm transmission line perfectly terminated with

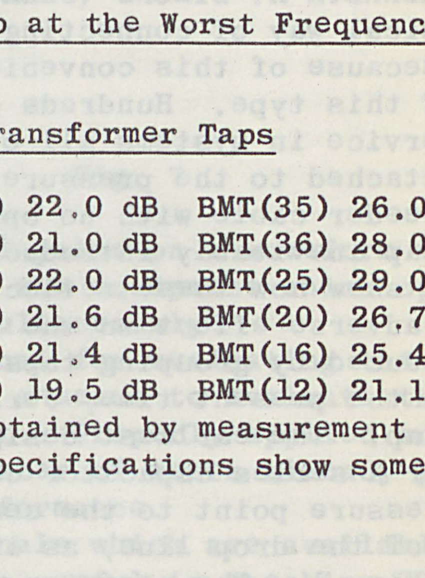


FIG 3

a 75 ohm resistor. There is no reflection at any frequency (b), so the input impedance is constant at 75 ohms (c), and the application of a pulse to the input results in no echo (d).

Now consider what happens when a 3700 ohm resistor is bridged across the line at a distance from the input end equal to 1/2 wavelength at 25 MHz (Fig. 4a) This discontinuity across a 75 ohm line produces a constant 1% reflection at all frequencies (b); as a result the input impedance varies from a minimum of 73.5 ohms (75 minus 1%) when the reflected voltage wave arrives at the input 180° out of phase with the input, to a maximum of 76.5 ohms (75 plus 1%) when the two waves are in phase (c). The application of a pulse to the input results in a single echo following the input pulse by a time corresponding to the round trip delay from the input to the discontinuity and back (d).

Next two equal discontinuities spaced at equal distances are bridged across the line (Fig. 5a). At zero frequency, and at multiples of the frequency at which the spacing is one-half wavelength, the two reflected waves arrive at the input with the same phase, so they add to produce a net reflection twice either one (b). At frequencies where the spacing is an odd multiple of one-quarter wavelength, the two reflected waves arrive at the input 180° out of phase and cancel, so there is no net reflection at those frequencies. The input impedance varies as shown in (c), reaching a minimum of 72 ohms at the frequencies of peak reflection, and touching 75 ohms at the odd quarter-wavelength frequencies where there is no reflection. Following the input pulse there are two echoes (d).

Four discontinuities, Fig. 6(a), produce complicated variations in reflection (b) and impedance (c).

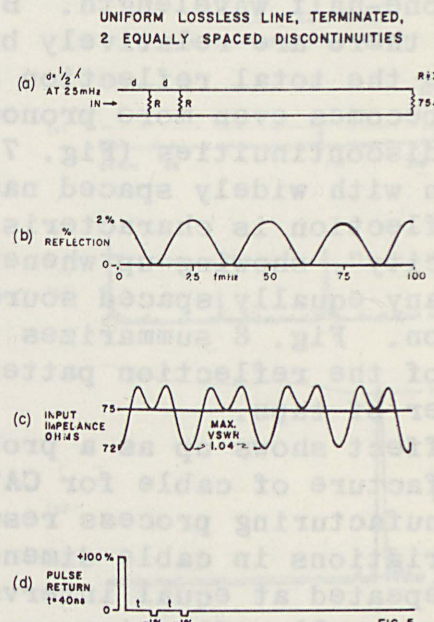


FIG 5

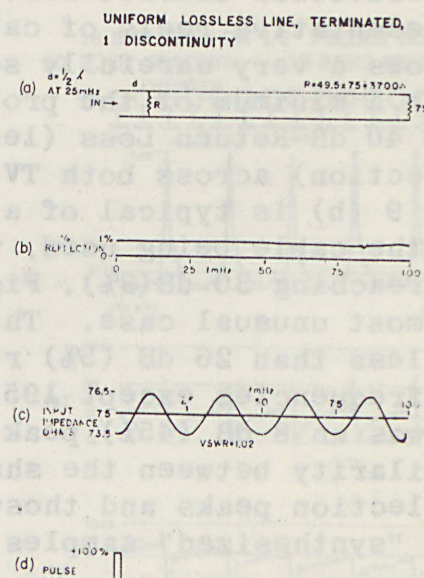


FIG 4

Certain general tendencies become clear. With many equally spaced discontinuities the reflections add to produce relatively narrow peaks of reflection centered at frequencies that are multiples of the one where the spacing is one-half wavelength. Between peaks there are relatively broad ranges where the total reflection is low. This becomes even more pronounced with eight discontinuities (Fig. 7). This pattern with widely spaced narrow peaks of reflection is characteristic of "periodicity", showing up whenever there are many equally spaced sources of reflection. Fig. 8 summarizes the dependence of the reflection pattern on the number of taps.

This effect shows up as a problem in the manufacture of cable for CATV. When the manufacturing process results in small variations in cable dimension which are repeated at equal intervals, the resulting small reflections can add to produce severe effects at certain frequencies. Great care is required in the production of this cable to avoid the problem. Figure 9 illustrates the reflection characteristics of some representative reels of cable. Fig. 9(a) shows a very carefully selected reel with a minimum of the problem greater than 40 dB Return Loss (less than 1% reflection) across both TV bands. Fig. 9 (b) is typical of a majority of the cable being used, with a few peaks reaching 30 dB(3%). Fig. 9 (c) shows a most unusual case. This reel showed less than 26 dB (5%) reflection at all frequencies except 195 MHz, where there was an 8 dB (45%) peak! Note the similarity between the shape of these reflection peaks and those shown in the "synthesized" samples preceding.

If care is not exercised, periodicity can cause problems when pressure taps are installed on a feeder. With telephone poles spaced at regular intervals along the street, there is a

UNIFORM LINE, TERMINATED
4 EQUALLY SPACED DISCONTINUITIES

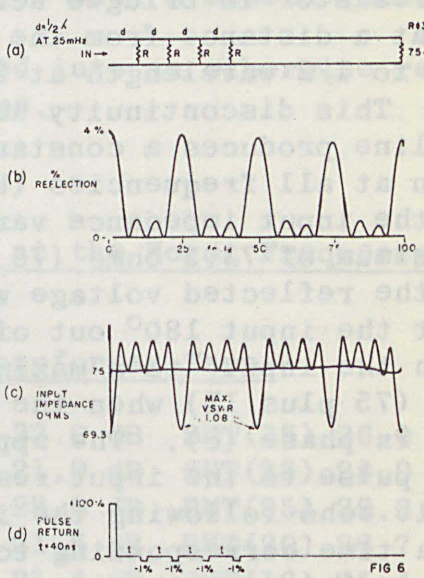


FIG 6

UNIFORM TERMINATED LINE,
8 EQUALLY SPACED DISCONTINUITIES

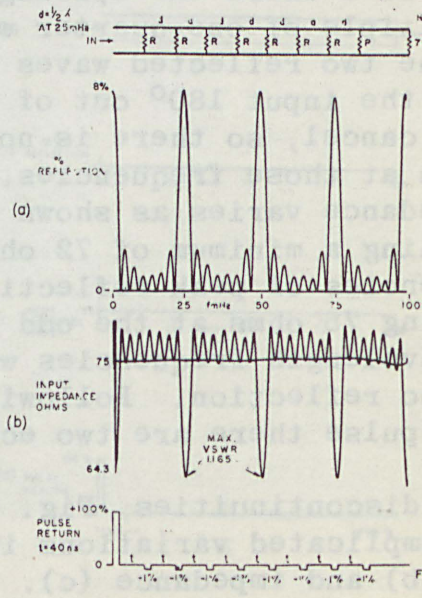


FIG 7

INCREASE IN REFLECTION WITH
1 TO 8 EQUALLY SPACED DISCONTINUITIES

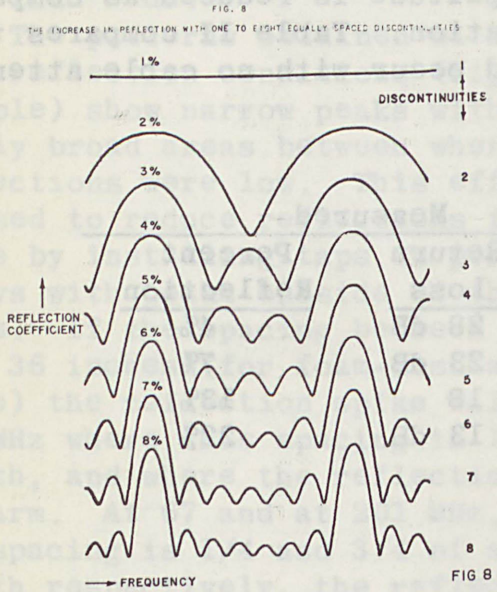


FIG 8

REFLECTION vs FREQUENCY
3 REELS OF CATV CABLE
SHOWING EFFECTS OF PERIODICITY

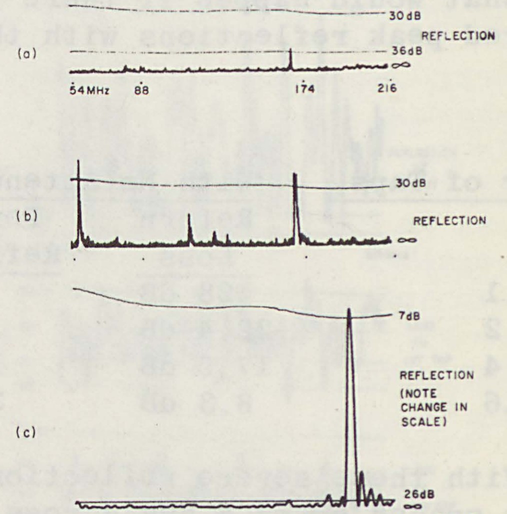


FIG 9

ADDITION OF REFLECTIONS
PRESSURE TAPS SPACED AT 50' INTERVALS
ALONG 1/2" FOAM CABLE

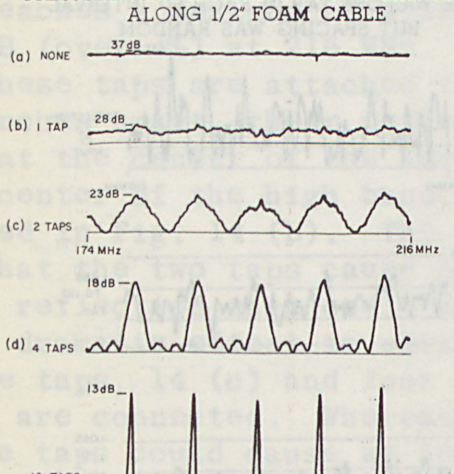


FIG 10

16 BMT TAPS ON 1/2" FEEDER 800' LONG
50' FOOT SPACING HI BAND PERFORMANCE

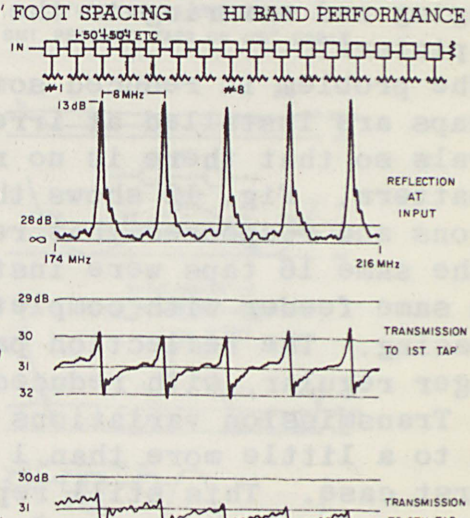


FIG 11

tendency to space taps at regular intervals along the feeder cable. This can cause severe trouble. Fig. 10 shows the neasured buildup of reflections on a feeder with various numbers of BMT taps spaced exactly 50 feet apart on a 1/2 inch foam-insulated cable.

The effects of cable attenuation can be seen by comparing this with Fig. 3 to 7, inclusive. This cable has an attenuation of about 1.3 dB. As a result the reflections from the more distant taps are reduced in amplitude, so the shape of the patterns and their peak amplitude is reduced as compared with what would happen if there were no attenuation. Table II compares the measured peak reflections with those that would occur with no cable attenuation:

TABLE II

Number of Taps	With No Attenuation		Measured	
	Return Loss	Percent Reflection	Return Loss	Percent Reflection
1	28 dB	4%	28 dB	4%
2	22.4 dB	7.7%	23 dB	7%
4	17.5 dB	13.3%	18	13%
16	8.3 dB	38.1%	13 dB	22%

With these severe reflection spikes spaced every 8 MHz across the high-band, transmission of the TV signal through the tap to the customer's receiver is distorted. Fig. 11 shows the frequency response through the first and eighth taps, with response variations of more than 2 dB across a single channel. This condition might well lead to ringing and smearing in the reproduced picture.

The problem is reduced somewhat when taps are installed at irregular intervals so that there is no repetitive pattern. Fig. 12 shows the reflections and responses that resulted when the same 16 taps were installed on the same feeder with completely random spacing. The reflection pattern is no longer regular, with reduced amplitude. Transmission variations are improved to a little more than 1 dB in the worst case. This still represents a situation somewhat short of one that would guarantee excellent picture transmission.

The importance of optimizing the design of the individual tap for minimum reflection is illustrated by Fig. 13.

16 BMT TAPS ON 1/2" FEEDER 800' LONG
HI BAND PERFORMANCE
THERE WAS ONE TAP IN EACH 50' INTERVAL
BUT SPACING WAS RANDOM

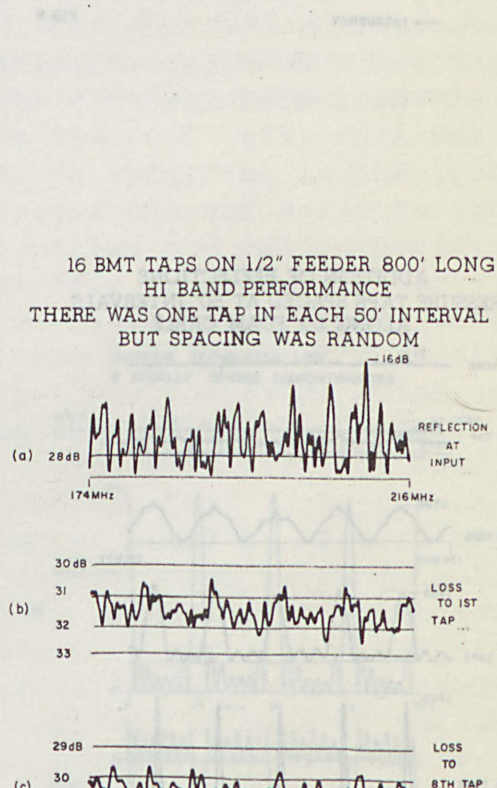


FIG 12

This shows a situation identical with Fig. 12, except that the poorer transformer taps (CMT) were substituted for the better ones. This increases the peak reflection from 16 dB (16%) to 11 d B(28%), and increases the variation from a little over one dB, to more than 3 dB.

The patterns obtained with simplified reflection conditions (Fig. 7, for example) show narrow peaks with relatively broad areas between where the reflections were low. This effect can be used to reduce reflections in the TV bands by installing taps in periodic arrays with peaks outside of these bands. If the spacing between taps is made 36 inches (for foam-insulated cable) the reflection spike will be at 135 MHz where this spacing is 1/2 wavelength, and where the reflection does no harm. At 67 and at 201 MHz, where the spacing is 1/4 and 3/4 of a wavelength respectively, the reflections from successive taps will cancel, causing a minimum effect for the TV channels between 54 and 88 and between 174 and 216 MHz.

Fig. 14 illustrates this. 14 (a) shows a plot of reflection vs. frequency for a single transformer tap (BMT25) It reaches a maximum of a little below 28 dB (over 4%) at 216 MHz. When two of these taps are attached to the line 36 inches apart, their reflections cancel at the center of the low band and the center of the high band, as illustrated in Fig. 14 (b). The net effect is that the two taps cause somewhat less reflection than one! An even more dramatic effect is obtained when three taps, 14 (c) and four taps, 14 (d), are connected. Whereas four of these taps could cause as low as 16 dB return loss (16% reflection) if they were installed so their reflections added in phase, by scientific grouping they can be made to give less reflection within the TV bands than one tap alone.

16 CMT TAPS ON 1/2" FEEDER 800' LONG
HIGH BAND PERFORMANCE
THERE WAS ONE TAP IN EACH 50' INTERVAL
BUT SPACING WAS RANDOM

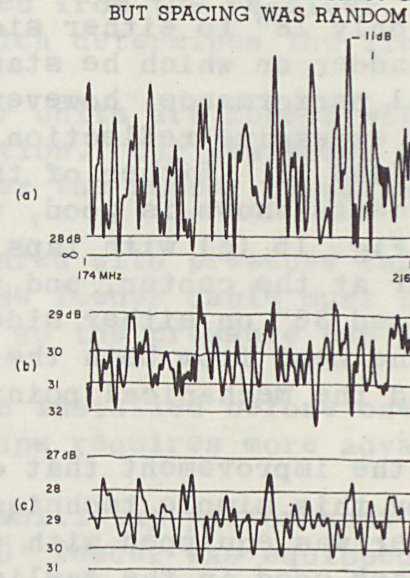


FIG 13

REFLECTION VS FREQUENCY
BMT PRESSURE TAPS ON 1/2" CABLE

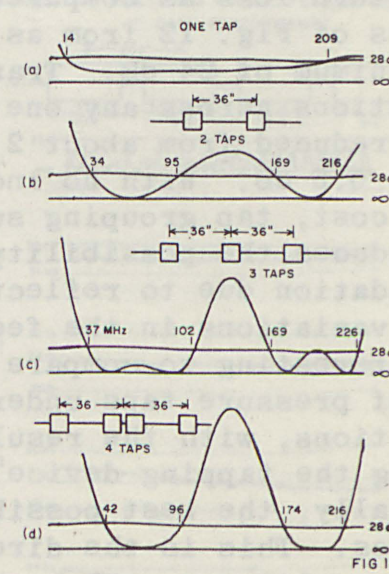


FIG 14

When four taps are to be installed at a given location, a fairly common situation in a CATV system, several arrangements are possible. Fig. 15 shows the reflection plots for some of them. The arrangement shown in Fig. 15 (a) is probably the most convenient physically, in that the installer has to reach out only 18" to either side of the pole or ladder on which he stands. Its electrical performance, however, is poor, showing excessive reflection on Channels 6, 7 and 13. Either of the other arrangements shown is good, the one shown in Fig. 15 (c) with taps close together at the center, and the other two spaced 36" on either side, seems to be the best from both the electrical and the mechanical point of view.

To show the improvement that can be obtained by this simple technique an 800 foot feeder was equipped with the same 16 BMT taps used in the earlier examples. They were installed in four groups of four, each group arranged in the pattern illustrated in Fig. 14 (d). Fig. 16 shows the result. (Note that the vertical scale of 16 (a) is doubled to exaggerate the reflections.) Grouping of the taps in this way increased the feeder return loss as compared with the conditions of Fig. 12 from as low as 16 dB to a minimum of 24 dB. Transmission variations across any one TV channel were reduced from about 2 dB down to about 0.5 dB. With no increase in equipment cost, tap grouping substantially reduces the possibility of picture degradation due to reflections and response variations in the feeder.

It is interesting to compare the performance of pressure taps under these optimum conditions, with the results obtained using the tapping device having, electrically, the best possible characteristics. This is the directional coupler multi-tap. It has three important advantages over the pressure tap:

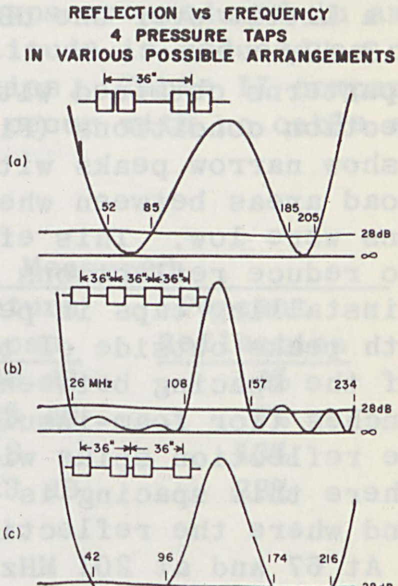


FIG 15

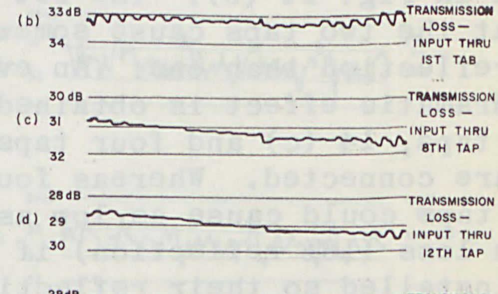


FIG 16

1. Directivity: It is more sensitive to waves coming down the feeder than to waves traveling back up the feeder, and thus discriminates against reflections or spurious signals coming from taps or receivers further down the line.
2. Lossless Backmatch: With a transformer tap approximately half the energy tapped off the line is lost in the backmatch resistor. With a directional coupler none of this energy is lost, the reverse termination acts only to absorb energy reflected from the receiver. Thus the efficiency of a directional coupler (which determines the line loss for a given tap) can be very high.
3. Multiple Outputs: This means that fewer units are needed with correspondingly fewer possibilities of reflection. Our new Model DCM coupler has four outputs, so only one-quarter the number of units are required as compared with a pressure tap.

The multi-tap has two disadvantages, as compared with pressure taps:

1. Installation: To install a multi-tap the feeder cable must be cut. This takes time and interrupts service, so the pressure tap is more convenient.
2. Pre-loading: A complete coupler must be installed before one customer can be connected, so the use of multi-taps requires more advance planning and investment.

To allow comparison of directional coupler multi-tap performance with the foregoing pressure tap arrangements, the 800' feeder was equipped with four DCM units at 200' intervals. The reflection and response characteristics are shown in Fig. 17. It can be seen that the coupler has slightly higher return loss (28 dB vs. 24 dB) as compared with the best arrangement of pressure taps (Fig. 16) and less response variation (about 9.3 dB vs. 0.5 dB), but their performance is quite comparable. The coupler requires no care in regard to spacing, and has the other advantages listed above.

This article has presented a technique for minimizing the reflections from pressure taps by careful grouping. While the best results are obtained with the better type of transformer taps (BMT), the same improvement will be experienced with any pressure taps. The directional coupler multi-tap is shown to have slightly better performance than the best that can be obtained from pressure taps. With its other advantages this suggests the use of the coupler for situations where the very best performance is desired and where the necessity of cutting the cable is not

FOUR DCM MULTITAPS ON 1/2" FEEDER 800' LONG
HI BAND PERFORMANCE

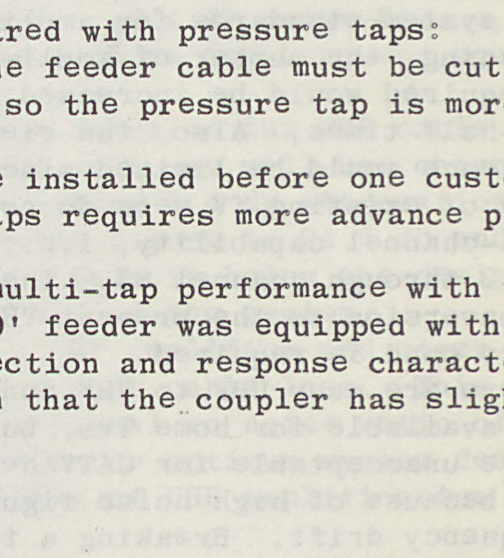


FIG 17

too great a deterrent, and the use of pressure taps in other situations.

CHAIRMAN SCHLAFLY: Thank you, Ken. Our next speaker is Mr. Edward Wuermser of Entron Inc., to speak on UHF to VHF converters for CATV.

MR. EDWARD WUERMSER (ENTRON INC.): The general public is showing increased interest in Ultra High Frequency (UHF) TV programs and, therefore, this service must be added to CATV systems. UHF, as transmitted, is at too high a frequency to be compatible with present CATV systems because of the high cable losses (Figure 1) and difficulty in constructing distribution system amplifiers for UHF frequencies. In addition, all present CATV systems would be obsolete, since by present system standards for amplifier spacing, the number of amplifiers required would be increased two and one-half times. Also, the viewing audience would be limited since a majority of existing TV sets do not have all-channel capability; i.e., channel 2 through channel 83. Therefore, conversion to the present VHF frequency band is required.

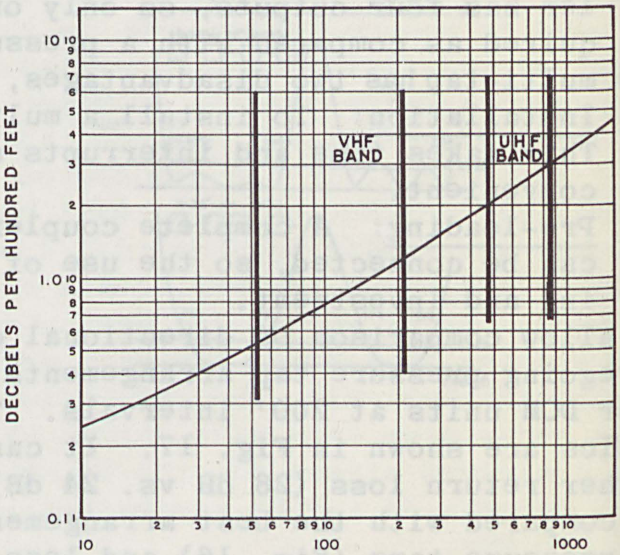


FIG. 1

There are many UHF to VHF converters available for home TVs, but these are unacceptable for CATV head-end use because of high noise figures and frequency drift. Breaking a typical converter into functional blocks (Figure 2) one finds at the input, a tunable filter which, in turn, feeds a diode mixer. The converting local oscillator or (LO) is tunable so that the unit will tune over the entire UHF spectrum. The output of the mixer is fed to a filter to reject the unwanted signals. In some cases VHF amplification is provided. There are variations using a transistor mixer or using one transistor as a mixer-oscillator.

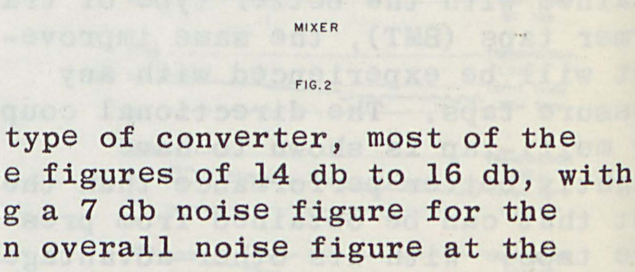


FIG. 2

Considering the noise figure of this type of converter, most of the diodes used for mixing have published noise figures of 14 db to 16 db, with conversion losses in excess of 6 db. Using a 7 db noise figure for the amplifier following the converter, gives an overall noise figure at the head-end of 16.1 db. See Table I.

TECHNICAL PROGRAM - I
Monday, June 27, 1966

CHAIRMAN ARCHER S. TAYLOR: I want to welcome you all to the First Technical Paper Session of this Convention. We have a number of quite interesting presentations. Our time is somewhat limited. I'm going to ask the speakers to confine themselves to approximately 25 minutes and, if possible, we will have a question period. Keep your questions in mind and we will try to give you an opportunity to raise them with the speakers if time allows.

For our first speaker we have Mr. Hubert Schlafly, Vice President of the TelePrompter Corporation in New York and all over the country. Mr. Schlafly is going to speak on the short-range multichannel microwave. Mr. Schlafly.

MR. HUBERT SCHLAFLY (TELEPROMPTER CORPORATION): Gentlemen, it is a pleasure to be with you here in Miami.

About a year ago, at the NCTA Convention in Denver, the project now referred to by the somewhat cryptic name of AML--meaning Amplitude Modulated Link, but more descriptively called "Short Range Multi Channel Microwave"--had already been in active study and/or experimentation for six months.

Today, the result of this conceptual, theoretical, engineering, laboratory, design and construction work is a physically operating system. This system is transmitting up to 12 color grade, standard television channels, modulated on a single carrier, over a six-mile path in New York City, under an Experimental License issued by the Federal Communication Commission.

I immediately hasten to emphasize that we do not as yet know if these experimental studies will lead to a practical operating system--the reason for the experiments is to collect operational, component, propagation and performance data which will help us arrive at an opinion on operating practicality. Furthermore, there is hardly any need to remind an experienced group such as this that the granting of an experimental license by the FCC does not indicate, suggest or even imply that the project will qualify for a commercial frequency allocation or that operators applying for such service will be granted a license. Do not underestimate either one of these two points. The first point is important because we are striking out not only into a new frontier of technique, specifically the multi channel - single transmitter concept, but also because we have dared to push into a portion of the electromagnetic spectrum which is beyond the boundary of today's commercial equipment and components.

The second point of caution is the familiar point of the necessity for the Commission carefully to examine each proposed use of the radio spectrum, and to determine whether it is in accord with the Commission's over-all policy, under the Communications Act of 1934, as amended, of concern for the welfare of the general public.

It is my opinion that the Commission does look with interest upon this experimental project. First of all, the engineering staff of the Commission has always shown great interest in, and given great encouragement to, anyone who will stick his neck out by investing substantial dollars in a project which extends our knowledge of the frequency spectrum and its efficient utilization. This project involves research, development and engineering which cannot help but extend man's fund of knowledge. Even the telephone company, which hastened to protest any possible future commercial use of the 18 GC spectru, said that it would not oppose pure experimentation. The second reason for FCC interest is that the AML project offers a fresh point of view and new technical possibilities for the solution of some of the problems that the commissions are currently considering.

AML enjoys a means of modulating a microwave carrier and throwing away all of the components of that modulation except one sideband. This sideband contains sufficient intelligence to permit reproduction of the entire range of input information, including the precise frequencies of that input.

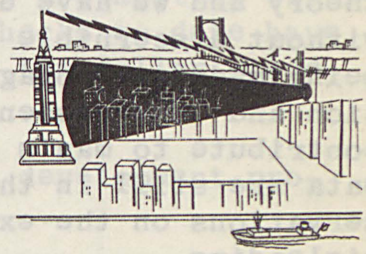
Thus, if a conventional CATV coaxial cable, including all of the information and frequencies from 54 to 216 megacycles that are normally carried on that cable is used as the input to an AML Transmitter--then all of these exact same frequencies will be delivered into the coaxial cable that is connected to the output plug of that AML Receiver. In effect, the AML concept permits an invisible coaxial cable, without the benefit of telephone poles, wires, messengers, hardware, amplifiers, power supplies and real estate, to deliver full CATV service from a "head-end" terminal to one or to many "distribution" terminals, which conceivably could be located anywhere within a few miles of that head end.

The AML concept does not eliminate cable--as some of the trade publications have speculated by referring to the project as "cableless TV." The final distribution in a local area requires exactly the same cable, and devices, that are used now. AML does permit the full complement of head end signals to be delivered to particular distribution terminals, at one or a large number of locations, without long, costly, or difficult cable runs through unproductive areas. Once a transmitter terminal has been established, with an antenna pattern as narrow or as wide as is necessary to illuminate a desired area with microwave energy--then a high gain, (approximately 1° beam) receiving antenna may be located anywhere within this illuminated area and output converter provided this location has line of sight to the transmitter and exceeds a minimum field strength, allowing for propagational fades, the receiver can immediately obtain all of the CATV signals available at the transmitter site itself.

If this illuminated area includes an isolated farmhouse, or a small cluster of houses in a subdivision, or a substantial suburb across a canyon or a river, each of these locations could have full channel CATV service by the simple expedient of installing a receiver site. Thus, service does not have to be extended in geographic continuity. Service can be delivered immediately to the areas of greatest need regardless of whether or not they are in accord with the construction program for extension of trunk line cable. Furthermore, the equipment necessary to do this job is salvageable. If, for example, signal delivered to a farmhouse were no longer necessary because the people moved away--there would be no loss resulting from an extended pole line installation. Disconnect the receiver and move it to a new location, where it can immediately be productively useful. The user would not be left with miles of plant which would have to be removed and which would have questionable salvage value.

In a large metropolitan area, such as New York City -- and I happen to have an intimate personal knowledge of the trials and tribulations of installing cable in New York City -- the AML approach would permit delivery of CATV signals--through the air--into one receiver located in each block. Once into the block, normal feeder cables, amplifiers and drops would be made into the dwellings of subscribers in that block. The importance of this approach is that the CATV system would not have to obtain assignments or pull cables through the underground ducts, and its construction crews would not have to enter manholes in the streets, or impede traffic with equipment or subsidiary conduit constructions. We are indeed very sensitive of the fact that during the public hearings in New York City, prior to the granting of a CATV franchise by the Board of Estimate, the counsel for the telephone company opposing such a grant, warned the city that by allowing CATV operators the privilege of using communication ducts in the public streets, they would place 3 million phone connections in jeopardy, risk disruption of civil defense networks and increase the likelihood of another power blackout of the entire east coast of our nation. While we dispute this gratuitous conclusion, we hasten to point out that by removing the necessity of having cable in the streets at all, we have made it physically impossible for such dire predictions to come true. As powerful as this argument may be, I somehow do not have the feeling that we will thereby win the unstinting support of the telephone company for the AML project.

I do have one slide which shows an artist's conception of the metropolitan area usage of AML. Broadcast signals from a tall building, which vaguely resembles the Empire State Building, are received at an AML Head End, converted to microwave and radiated with a pie-shaped beam over a portion of the city where receivers are located on rooftops of buildings in individual blocks receive this signal, return it to VHF and distribute the signals by cable within the boundaries of that one block.



Now let's examine the frequency that was selected for the microwave experiment of AML. Why did we select an 18,000 megacycle frequency. Basically, the reasons were these:

1. Below 12 KMC, the spectrum is already overcrowded with Government, Common Carrier and Commercial Users. Furthermore, these frequencies are allocated to comparatively narrow bands, split up between the services. AML, in order to carry the entire VHF spectrum from 54 to 216 MC, would require 162 megacycles of total bandwidth; this is about 0.8% of the 18 GC microwave carrier frequency. Further efficiencies might reduce this to 100 or 108 megacycles.

Above 12 KMC, there is a 500 megacycle band between 12.7 and 13.2 which might be considered. But this band is already subdivided into 12.5 MC channels for which there is a highly competitive demand in the television pickup, STL and CARS Services.

Above 13.25, all frequencies are assigned to government use including

Radio Navigation, Earth-Space, and Radio Astronomy, until 17.7 GC.

The current Table of Frequency Allocations provides a non-government band for Industrial, Fixed and Mobile use from 17.7 to 19.3. This 1600 megacycles of virgin spectrum (since to the best of our knowledge no applications have been granted for this frequency band) does not have the crowding or the bandwidth limitation of the 12.7 band and seems to have many logical reasons for an AML-type service.

2. The AML service is intended to operate over limited ranges. As presently conceived, transmission distances in the order of 6 miles, possibly as high as ten or twelve miles, seem adequate for extensive utilization. Therefore, the recognized factor of increased path attenuation and weather effects is less bothersome than it would be for a service which desired relay distances of 20, 30, 50 or more miles. Therefore, the future or projected congestion in the 18 GC band is also favorable to the AML service.

3. And finally, the state of the art, as understood and extended by competent engineering groups into the one centimeter wavelength region, has reached a point where sound design and totally reliable equipment for continuous duty service seems likely and practical.

So the three points which influenced this 18 GC decision are--in reverse order:

A. We are confident we can master the technical design.

B. Its propagation limitations are not limitations for the kind of service we contemplate.

C. We stand a better chance of obtaining an allocation for this commercial service at a higher rather than at a lower frequency.

How is the experiment working? I am personally very well pleased with our results to date. We have had no surprises or major deviations from theory and we have demonstratably excellent picture quality on 12 channels without discernible cross modulation or noise. Continuing measurements are being made on propagation characteristics, multipath phenomena, beam defraction and other essential factors which will influence future design and contribute to man's knowledge of this portion of the frequency spectrum. Data are still in the process of being collected--conclusions or even observations on the experiment to date would be premature and possibly even misleading.

Recognition of the importance of these experiments to TelePrompTer and to the CATV industry has resulted in the expenditure of a tremendous amount of dollars, and executive time and thought on the project. The fact that Mr. Caywood Cooley, TelePrompTer's Engineering Vice President, has been assigned full time to this particular undertaking, is an indication of the project's importance in the eyes of our President and Board of Directors.

But while the evaluation of need, the pointing of the way, and the detailed industry application have been supplied by TelePrompTer, the real guarantee of success of the project from the technical point of view, is the total support and major project status given by the executives and engineering staff of Hughes Aircraft Company. This company, since it was convinced of the merit of the undertaking, unhesitatingly committed the engineering knowhow and facilities that produced the tremendous engineering successes of the Syncoms I and II, Early Bird, and most recently the astounding first-try bullseye of Surveyor. I consider that the Hughes Aircraft Company interest is a sincere compliment to the stature of the NCTA and CATV industry. It is a recognition of growth of a service from the small beginning of individual ingenuity and enterprise towards its goal as a major American industry.

CHAIRMAN TAYLOR: Thank you, Mr. Schlafly. We have a little time for questions, if anyone would like to inquire on the subject.

QUESTION: Does this transmitter broadcast in a omnidirectional or is it a highly directional beam?

MR. SCHLAFLY: The beam shape can be tailored to your needs. In New York City, for example, it is our intent to use either a 15^{o} or 20^{o} pie-shaped beam horizontal, but quite narrow vertical. In this way we don't lose all of the gain in the antenna, but we still have an area coverage rather than a pea shooter-type of operation. The receiving antenna will be extremely narrow. We expect to use the 1^{o} beam between the half-power point that I mentioned in the paper. This directivity will assist us in multipath discrimination and air plane flutter and possibly other situations.

QUESTION: How much will this cost compared to cable?

MR. SCHLAFLY: The dollars seem to make sense to us. We can't answer you specifically because we haven't progressed to the point of final equipment design. We are more concerned at the moment on the propagation difficulties, component design, and so on. But all of our checks to date have indicated that it would be a very practical system from the dollar standpoint.

QUESTION: How long would it take to complete this development project?

MR. SCHLAFLY: Considering the number of variables, I don't really know. The experiments that I have mentioned are under way now. One of the prime factors is the reaction of the Commission. Incidentally they have been quite interested in the experiment.

The answer depends on how lucky we are. It could be as short as six months to a year, or if we run into troubles it could be 18 months before we have commercial operation.

QUESTION: Are they going to demonstrate to the industry in the near future?

MR. SCHLAFLY: I don't think there is going to be an open house. We have, after all, the serious program of collecting data on this set-up that we have operating in New York City now. We have demonstrated the set-up and I think that if anyone of you gentlemen sitting here had particular interest in it, you should get in touch with me. Some sort of demonstration or visit could be set up. Thank you.

QUESTION: What indication is there to date on the propagation losses over a 6-12 mile path due to precipitation?

MR. SCHLAFLY: The data to date is pretty well in accord with the previous work that has been done in this field and it has been reported in the IEEE and other magazines. Since there is not a great deal of data, we can't compare it broadly. Fortunately we had a tremendous downpour of rain for about 6 minutes a week ago in New York. We have not analyzed and correlated this exact amount of the rainfall with the propagation recording charts as yet. I don't think I am prepared to give you a definitive answer on that, but it is being studied.

QUESTION: What power levels are expected to be used based on the data collected so far?

MR. SCHLAFLY: The power levels that we are using now are quite small. I think the radiated power that we have is in the order of miliwatts. We are taking that into account in the collection of data. The objective, however, is to deliver transmitter power to the antenna in the order of $2\frac{1}{2}$ to 5 watts, somewhere in that region.

QUESTION: What type of modulation? Has there been any work on cascading in these units?

MR. SCHLAFLY: The name itself is descriptive of the type of modulation. It is an amplitude-modulated carrier, with suppression of the carrier and filtering out of one of the sidebands. So its a simple sideband transmission. As far as cascading goes, I am not prepared to say on that. I am most pleased with our performance to date, in terms of cross modulation, but I cannot say how far we could go using repeaters.

CHAIRMAN TAYLOR: Thank you again, Mr. Schlafly. I'm sorry to terminate question on this, but I'm sure Mr. Schlafly would be delighted to talk to you individually afterwards, but we have some more papers.

Next I would like to introduce to you Mr. Richard R. MacMillan, Chief Engineer of the Kaiser-Cox Corporation, who is going to speak on test equipment and methods. Mr. MacMillan.

MR. RICHARD R. MACMILLAN (Kaiser-Cox Corp.): With the introduction of second generation transistorized amplifiers, requirements for longer cascaded systems and better system performance, it is many times necessary to take a second look at the test equipment and test methods being used for equipment evaluation and maintenance.

The CATV industry has not yet standardized on either system performance specifications or equipment test methods and a detailed understanding and I think that if anyone of you gentlemen sitting here had particular interest in it, you should get in touch with me. Some sort of demonstration or visit could be set up. Thank you.

QUESTION: What indication is there to date on the propagation losses over a 6-12 mile path due to precipitation?

MR. SCHLAFLY: The data to date is pretty well in accord with the previous work that has been done in this field and it has been reported in the IEEE and other magazines. Since there is not a great deal of data, we can't compare it broadly. Fortunately we had a tremendous downpour of rain for about 6 minutes a week ago in New York. We have not analyzed and correlated this exact amount of the rainfall with the propagation recording charts as yet. I don't think I am prepared to give you a definitive answer on that, but it is being studied.

QUESTION: What power levels are expected to be used based on the data collected so far?

MR. SCHLAFLY: The power levels that we are using now are quite small. I think the radiated power that we have is in the order of miliwatts. We are taking that into account in the collection of data. The objective, however, is to deliver transmitter power to the antenna in the order of $2\frac{1}{2}$ to 5 watts, somewhere in that region.

QUESTION: What type of modulation? Has there been any work on cascading in these units?

MR. SCHLAFLY: The name itself is descriptive of the type of modulation. It is an amplitude-modulated carrier, with suppression of the carrier and filtering out of one of the sidebands. So its a simple sideband transmission. As far as cascading goes, I am not prepared to say on that. I am most pleased with our performance to date, in terms of cross modulation, but I cannot say how far we could go using repeaters.

CHAIRMAN TAYLOR: Thank you again, Mr. Schlafly. I'm sorry to terminate question on this, but I'm sure Mr. Schlafly would be delighted to talk to you individually afterwards, but we have some more papers.

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MR. RICHARD R. MACMILLAN (Kaiser-Cox Corp.): With the introduction of second generation transistorized amplifiers, requirements for longer cascaded systems and better system performance, it is many times necessary to take a second look at the test equipment and test methods being used for equipment evaluation and maintenance.

The CATV industry has not yet standardized on either system performance specifications or equipment test methods and a detailed understanding of how the equipment manufacturer specifies his equipment should be understood by the potential user to be sure that the particular equipment will perform the way the user expects.

Measurement of Response: CATV technicians have been measuring response on amplifiers and other devices for many years, but with the closer tolerances specified on modern equipment, both the test equipment and test methods should be reviewed. A typical amplifier response requirement is for the response to be with + $\frac{1}{4}$ db from 50 to 220 mc. This requires careful calibration and accurate stability in the sweep generator, detector and oscilloscope. Furthermore, it is highly desirable that the calibration attenuators or "pad boxes" have steps of at least $\frac{1}{4}$ db and preferably .1 db steps. The sweep generator should have the following electrical requirements:

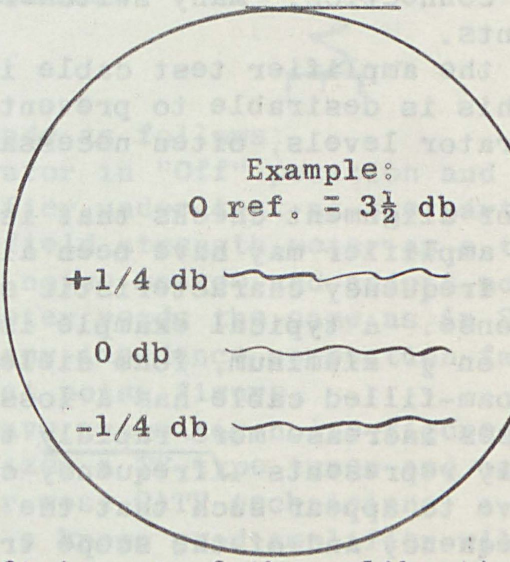
1. The amplitude response flatness should be typically + $\frac{1}{4}$ db or better over the frequency range of interest.

2. The amplitude stability over the period of measurement should be within .1 db or better.

3. The output impedance of the sweep generators should be, for CATV use, 75 ohms, to eliminate any repetitive standing waves.

The detector should be d.c. coupled and is generally of the full wave doubler type. The oscilloscope need not be of the high frequency type but should be of high sensitivity (typically 10 mv/cm), d.c. coupled, with the d.c. vertical amplifier stability such that equivalent drifts of less than .05 db occur during the measurement time. With the use of stable test equipment employing d.c. coupling, a large percentage of the oscilloscope face can be used for measurement with the base line not visible on the screen. The system should use the substitution method of calibration, where + $\frac{1}{4}$ db, 0 db and - $\frac{1}{4}$ db calibration lines have been drawn on the face of the scope with a grease pencil.

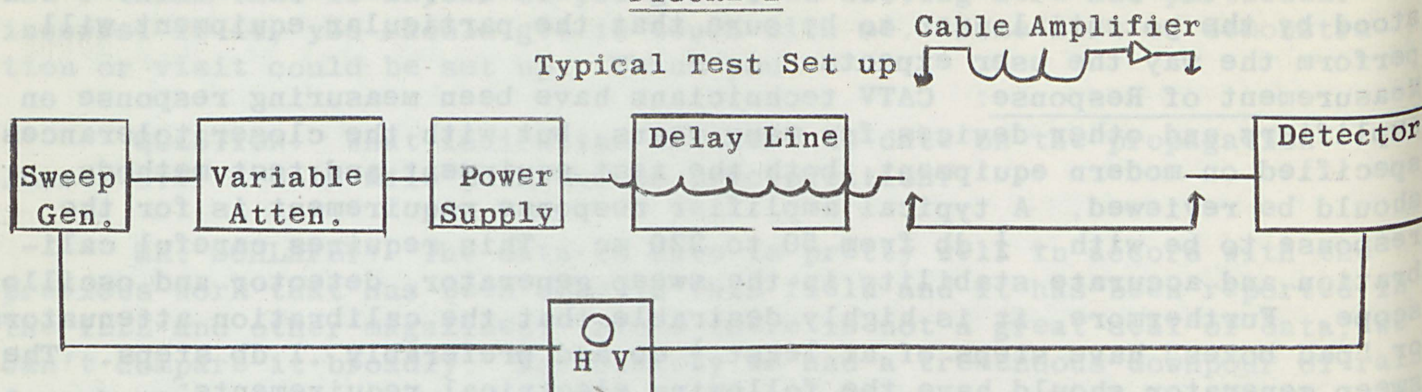
FIGURE 1



The system may be left in one of the calibration positions for a long enough time to insure that the d.c. drift for any reasonable measurement time is negligible. The amplifier and its cable are then placed in the system, appropriate adjustments of amplifier gain and tilt made, and the response observed.

FIGURE 2

Typical Test Set up



Typical Test Setup: A variable or switchable pad is used after the sweep generator to establish the reference lines (Figure 2). The delay line is used in the system to eliminate the problems of response variations due to jumper cables. All jumper cables should be as short as possible, with direct connections from the delay line to the amplifier test cable, between the test cable and the amplifier, and between the amplifier and the detector.

The calibrate condition consists of connecting the detector directly to the output of the delay line, with the variable attenuator switched to a small amount of attenuation (Figure 1 utilized $3\frac{1}{2}$ db). The $+\frac{1}{4}$ and $-\frac{1}{4}$ reference lines can then be obtained by setting the attenuator to $3\frac{1}{4}$ db and 3-3/4 db, tracing the reference lines with the grease pencil.

If a coaxial switcher is used to establish the reference, cross talk and reflections from the switcher must be small enough not to affect the amplifier response. A check can be made by tracing the responses when the coaxial switcher is used and then compare it to the response when the switcher is replaced by a direct connection. Many switchers have a noticeable effect on accurate measurements.

It should be noted that the amplifier test cable is positioned before the amplifier (Figure 2). This is desirable to prevent overloading of the amplifier by high sweep generator levels, often necessary for a good detector response.

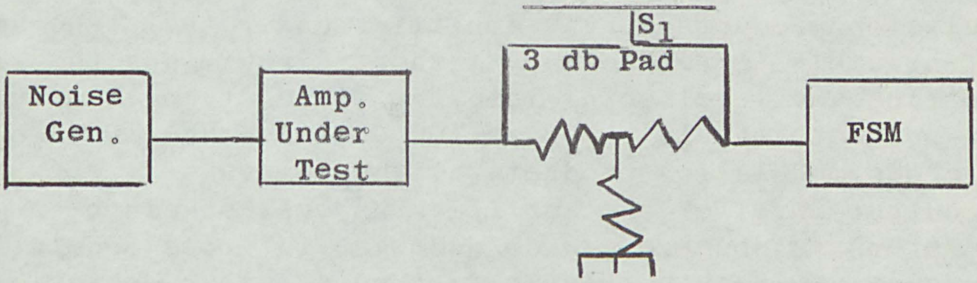
One factor in response or alignment checks that is frequently overlooked, is the fact that the amplifier may have been aligned using a cable which has an attenuation vs. frequency characteristic slightly different than that used to check response. A typical example is to test a mainline amplifier, which was aligned on $\frac{1}{2}$" aluminum, foam dielectric cable, using RG59U type cable. Typical foam-filled cable has a loss characteristic where the high frequency losses increase more rapidly than $\sqrt{\ }$ frequency whereas RG59U type very nearly represents $\sqrt{\ }$frequency cable. The end result is for the response curve to appear such that the amplifier peaks in gain slightly at the high frequency and of the scope trace, or conversely, if amplifiers that have been aligned on RG59U type cable are cascaded in a system using channel 13 for a reference, the low frequency channels will appear to increase in level. It is best, therefore, to align amplifiers utilizing cable similar to that which will be used in the system. It is also recommended that for alignment and accurate response checks of amplifiers, that automatic coaxial R.F. switching devices are not used since very small amounts of crosstalk can affect the true response curve and give erroneous results.

Measurement of Noise Figure: The measurement of noise figure and its relationship to signal to noise ratio of a CATV system is one which most CATV technicians can accomplish only by comparison using a field strength meter, applying a field strength meter correction, measuring the gain of the amplifier, and substituting in the following equation:

Noise Figure = Noise out of amplifier +59 - Amp Gain + detector + FSM bandwidth correction.

This system will give comparative results, but to utilize this method where an input equalizer is used, the over-all gain must be measured with the equalizer in position. Hence, if the insertion loss of the input equalizer is over a db or two, and noise figures are measured at normal operating gains, it is not unusual to find that the limiting equivalent noise figures and thus signal-to-ratio occurs at the low channels, whereas with an amplifier that has the equalization distributed within the electronics, the limiting signal-to-ratio occurs at the high channels. The classical method of measuring noise figure utilizes a noise generator in conjunction with a 3 db pad, and as applied to CATV, is shown in Figure 3.

FIGURE 3



The measurement is made as follows:

1. With noise generator in "Off" position and S_1 closed, measure noise out of the amplifier under test at the particular frequency of interest utilizing a field strength meter as a tuned voltmeter.
2. Open S_1, turn on noise source and adjust noise output so that the field strength meter reads the same as in Step 1.
3. Add or subtract any impedance correction factors to noise generator reading for actual noise figure.

Most manufacturers have automatic noise figure measuring equipment, one such instrument utilizes a TV type tuner and can check noise figure on each TV channel. For most CATV technicians, a relative measure of noise figure obtained from a known good amplifier will serve adequately for equipment maintenance, if one remembers that the absolute measurements have a considerable error.

Measurement of Cross-Modulation: Just as equivalent noise figure is a limiting factor on amplifier cascadeability, the increase of cross-modulation with output signal level limits the permissible output level of the amplifier. Many methods of cross-modulation evaluations have been tried by both component and equipment manufacturers and most agree that multi-channel tests must be made to insure that realistic results are obtained. Transistor circuits can be optimized at any specific two channels, leading to very erroneous results if the output levels are derated by normal voltage equations. Several manufacturers have built elaborate cross-modulation testers. The cross-modulation testers consist of 12 channel generators, of which 11 channels are modulated with a common modulating signal (usually a 15 kc square wave or 15 kc simulated horizontal sync signal) at a high modulation percentage such as 85° - 90°%. The remaining channel (the one to be observed or measured) is either a CW signal or modulated at a slightly different frequency near 15 kc, again at a high modulation percentage. The signals are controlled in amplitude and combined in an appropriate network and fed into the unit under test. The signal out of the unit under test and any compensating cable, is connected to a calibrated field strength meter for level measurement and demodulation, where the output of the field strength meter is cabled to a very narrow tuned voltmeter. The system is calibrated by applying modulation of a normal level to the channel to be measured, to establish the 100% modulation reference, and then the channel oscillator is either operated CW or with a modulation frequency outside the passband of the tuned voltmeter. The modulation level is then read as X db below the 100% modulation reference.

To insure that the cross-modulation tester is not significantly contributing cross-modulation products to the amplifier under test, the amplifier and compensating cable is replaced by a short circuit and the signal levels raised to the same level going into the field strength meter. The cross-modulation products should be 90 to 100 db below the 100% modulation level. With cross modulation products at these levels, i.e., 90 to 100 db down, the output level of the amplifier under test can be reduced in appropriate steps to observe a 2 db decrease in cross-modulation products for a 1 db decrease in output level, to insure proper operation in cascaded systems. Since the channel generator of the measured channel can be operated either CW or modulated at a high level, a correlation is needed between the two measurements and it is generally accepted that the modulated system will be down 6 db more than a CW measurement. The author prefers the use of a simulated TV-type sync signal (approximately 10 μs pulse of 85% modulation) with the channel to be measured modulated with a similar sync type signal outside the passband of the tuned voltmeter. This most nearly represents the system in actual use since objectionable wiping is viewed on an active channel with normal sync signals triggering the sweep circuits of the TV set.

Measurement of Level: The most convenient instrument for the measurement of level is the field strength meter which in general terms is a tuned voltmeter. The accuracy should be ± 1 db or better over the range of 50 to 220 mc and the input VSWR should be 1.05 or better. Present meters do not meet these requirements and special techniques should be used when accurate measurements are desired. When measurements are made utilizing a jumper cable, an inline attenuator, or the meter switchable attenuator should be used to properly terminate the jumper cable. This is extremely important when measuring amplifier test points, since most test points present a high source impedance and thus the jumper cable, if not properly terminated, can have multiple reflections, with the indicated level dependent on the length of the jumper.

The problem of calibration of the field strength meter has been lessened with the commercial availability of accurate RF thermocouple transfer standards, such as the Model 440 Selby Micropotentiometer offered by Ballantine Laboratories. These units are inexpensive and can be calibrated by either the manufacturer or can be calibrated by the Bureau of Standards Calibration Labs to an accuracy of better than ± 1 db over the VHF range.

To summarize, the requirements to measure the performance of modern CATV equipment requires accurate and stable test equipment. Furthermore, test methods and actual laboratory setups should be reviewed to insure that problems or improper techniques do not exist, whereby the equipment to be evaluated is not measured properly.

CHAIRMAN TAYLOR: Thank you very much Mr. MacMillan. We have just a few minutes to ask questions on test equipment to Mr. MacMillan. (No questions)

It is of particular pleasure to introduce our next speaker, Mr. I. Switzer from Lethbridge, Alberta. We always enjoy having our Canadian friends and counterparts attending our convention. Mr. Switzer's subject this afternoon will be time domain reflectometry. Mr. Switzer.

MR. I. SWITZER (LETHBRIDGE, ALBERTA, CANADA): The RF transmission lines used in CATV system are important and critical parts of the system. Emphasis in CATV marketing techniques on quality in pictures delivered to the subscriber makes it increasingly important that our coaxial cables have the best possible transmission characteristics when installed and that these characteristics should be maintained to a very high standard during the useful life of the cable.

Common CATV system practice for cable testing has progressed from simple transmission sweep testing, through "frequency domain reflectometry" to the present well accepted practice of use of the Swept RF Impedance Bridge for cable testing. The RF bridge provides a very sensitive test, in the frequency domain, for cable imperfections and flaws.

Recent developments in the precision oscilloscope field now make time domain reflectometry a practical and useful tool for CATV system application.

Reflectometry I shall refer to as the measurement of system characteristics by measuring reflections caused by imperfections. Measuring reflections as a function of frequency is reflectometry in the frequency domain; measuring reflections as a function of time is reflectometry in the time domain.

In general the frequency and time domains are related mathematically by the Fourier transform, and a description in either domain is a complete

Equalizers
Duplexers
Automatic level control
Automatic tilt control
Matching transformers
Home splitters
Tapoffs: Pressure taps, hybrid types, isolation, thruloss.

17. Accessories: housings mountings
18. Test instruments and their uses, particularly the field strength meter.
19. Servicing and installation:
    Signal probing, checking of cables, grounding, weather proofing, use of test equipment, trouble shooting by symptoms, checking defective distribution lines, preventive maintenance.
20. Specifications: Interpretation and writing.
21. Cost estimates.
22. Pole line construction.

CATV - AUXILIARY PROGRAMS

23. Basics for closed circuit (CCTV) program origination.
    a) lighting
    b) lenses
    c) types of cameras
24. Weather channel, sub-channels, microwaves

CHAIRMAN TAYLOR: Thank you very much. Does anyone want to ask Ike questions about this training program?

QUESTION: Is this training available to anyone, and on what basis?

MR. BLONDER: We have conducted seminars throughout the United States, usually in regions, conducted by our Regional Sales Manager. I must admit that we have concentrated much more on the NATV area in which we have had, in the past, a greater interest, but we are setting up a new program. If you will indicate to us your interest in participating, you will find that we will have a regional meeting in your area eventually to which you are certainly invited.

CHAIRMAN TAYLOR: Our next speaker is Mr. George Bates, Vice President of Engineering for DYNAIR Electronics, Inc. Mr. Bates will speak on the use of the sideband analyzer and its applications. Mr. Bates.

MR. GEORGE W. BATES (DYNAIR ELECTRONICS, INC.): The "sideband analyzer" is well-known to the television broadcast engineer; it's one of the basic tools of his trade. However, for some unknown reason, the average CATV engineer - who has even more need for this device - is not familiar with its application in CATV and, in many cases, doesn't even know it exists.

The purpose of this paper is to introduce the sideband analyzer to the CATV engineer and to show the many reasons why it is almost mandatory that this device be used for efficient maintenance of today's complex CATV systems. In our opinion, there is no other method which will enable a head-end to be maintained-economically-in top operating condition. This device, which replaces a multitude of expensive test equipment, enables the engineer to precisely determine the quality of his modulators, in a matter of minutes, without even removing a dust cover!

Almost anyone who has worked around a television modulator of any type is familiar with the time-consuming point-to-point method of determining over-all video and RF response. A typical test setup for this method is shown in Figure 1. The required equipment consists of a wideband oscilloscope, an RF marker generator, an RF sweep generator, a video sweep generator, a VTVM, an attenuator, detector probes, and about a dozen miscellaneous cables - roughly $8,500.00 worth of precision test equipment!

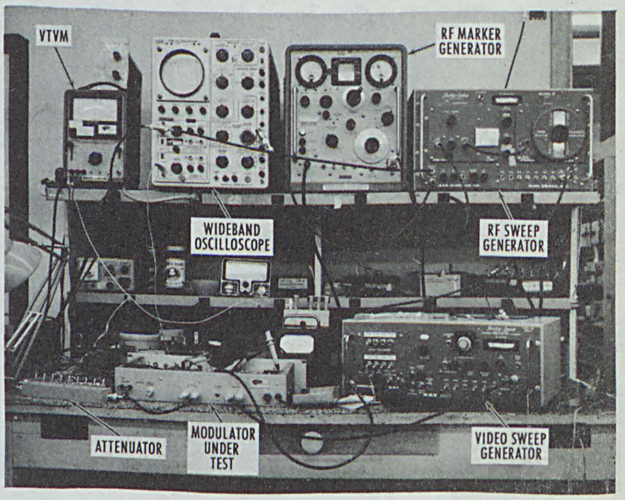
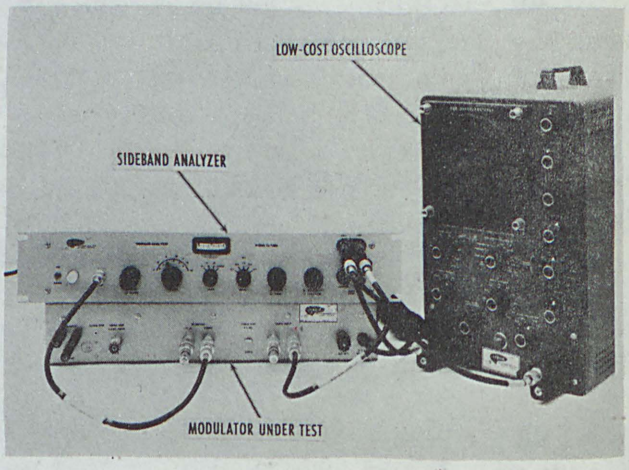


Figure 2 illustrates a test setup for performing the same function, with the same accuracy, only using a sideband analyzer, an inexpensive oscilloscope and four miscellaneous cables - total cost of equipment here: roughly $1,150.00. (Sideband analyzer - three popular models are available - range in price from $950.00 to $3,500.00, with a low-cost oscilloscope costing about $200.00.)

The test as performed with the sideband analyzer will only take a few minutes and, if desired, can be performed with the modulator mounted in a rack. However, the point-to-point method shown in Figure 1 requires, from start to finish, usually a minimum of 2 hours, and is much more involved, consisting of: (1) removing the modulator from the rack, (2) removing the dust covers, (3) clipping into certain parts of the circuitry, (4) sweeping the video amplifier, (5) sweeping the RF amplifiers, and (6) reassembling the modulator and reinstalling it in the rack.

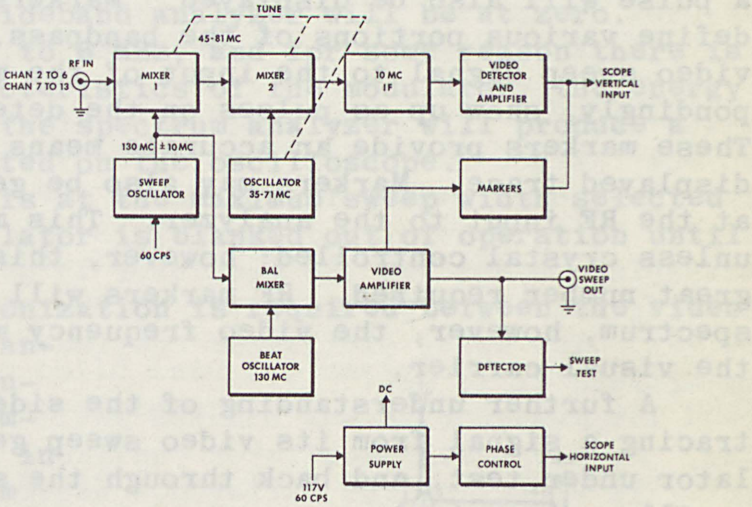


Problems are also involved which further decrease the desirability of the point-to-point method. The RF input coupling is, in most cases, extremely critical, with improper coupling producing inferior and uncertain results. Even when properly performed, the point-to-point method will not assure a quality picture when the modulator is returned to the system.

On the other hand, the sideband analyzer checks the modulator as it actually operates in the system, assuring a precise evaluation. Any spurious frequencies present are seen, and the test gives a true evaluation of the quality of picture the modulator will produce.

Other rather obvious advantages of using the sideband analyzer are: (1) less space is required for test equipment, (2) it is extremely simple to operate, and (3) none of the ground-loop problems involved in most sweep techniques are encountered.

When using the sideband analyzer, an internally generated sweep signal is applied to the modulator input. The RF output of the modulator is connected to the RF input of the sideband analyzer. Separate horizontal and vertical oscilloscope outputs are provided on the sideband analyzer which are cabled to their respective oscilloscope inputs. The sideband analyzer is then tuned for maximum vertical deflection at the modulator's operating frequency (operating channel). With power applied to the units, and controls set for normal operating, the oscilloscope will display the bandwidth characteristics of both the video and the RF stages. (See Figure 3) Markers are provided to establish various pertinent points throughout the video bandpass.



As indicated by the previous test setup description, operation of the sideband analyzer is relatively simple. However, it should be noted that what is actually occuring is most complex in nature. In other words, the operation is simple, but the sophisticated circuitry involved in generating the oscilloscope display requires more of an explanation.

The sideband analyzer is essentially a combination of two separate test devices: a spectrum analyzer and a video sweep generator. The spectrum analyzer sweeps continuously through the bandwidth range of the modulator under test, measuring the sidebands and any spurious emmissions of the output signal. Since the spectrum analyzer tracks perfectly with the sweep signal supplied to the modulator by the sweep section of the sideband analyzer, the oscilloscope will trace the sideband generated in the modulator by the video sweep. (This precise tracking function is very essential and is best accomplished with a swept oscillator that is common to both the spectrum analyzer and the video sweep generator portions of the sideband analyzer.)

The basic principle of the device can be compared very closely to a tuneable voltmeter; a voltmeter with an input which is sensitive only to a specific pre-selected narrow frequency range. The sideband analyzer also generates a sweep signal which is applied to the modulator under test, which must be precisely synchronous with the frequency of the tuneable voltmeter input.

If the frequency response of the modulator under test is perfectly flat, and the frequency sensitive voltmeter is tracking at exactly the frequency of the modulator output, the oscilloscope trace will be a perfectly flat line. As the outer skirts of the modulator output begin to roll off (due to the band-limiting characteristics of the modulator), the output of the tuneable voltmeter will roll off correspondingly, causing a similar indication of roll off to appear on the oscilloscope trace.

A pulse will appear on the oscilloscope trace at the visual carrier. If the aural carrier is on at the point the video sweeps through 4.5 MHz, a pulse will also be displayed. Markers are included which may be used to define various portions of the bandpass. The markers are applied with the video sweep signal to the input of the modulator under test and, correspondingly, show up as pulses on the detected sideband analyzer output. These markers provide an accurate means of determining frequencies on the displayed trace. Markers may also be generated at RF frequencies and mixed at the RF input to the analyzer. This method is generally very unstable unless crystal controlled; however, this becomes impractical due to the great number required. RF markers will appear at only one point in the spectrum, however, the video frequency markers appear both above and below the visual carrier.

A further understanding of the sideband analyzer can be gained by tracing a signal from its video sweep generator section, through the modulator under test, and back through the spectrum analyzer section to the oscilloscope outputs.

The video sweep signal generated by the sideband analyzer starts at 8 to 10 MHz, the exact frequency being determined by the adjustment of the video sweep width. As the signal sweeps from 8 to 10 MHz to zero MHz and back to 8 or 10 MHz, the tuned input of the spectrum analyzer is sweeping from 8 or 10 MHz below the visual carrier, through the carrier, and then to 8 or 10 MHz above the carrier.

As the video sweep signal lowers to approximately 1.25 to 1.5 MHz, the response of the modulator under test should be extremely low; this is the lower adjacent aural carrier in the spectrum, and the sideband is attenuated greatly in the modulator. Correspondingly, the detected output of the sideband analyzer will be very low. As the video sweep signal lowers further to .5 MHz, which is .5 MHz below the visual carrier, the modulator response should be reasonably high. At the exact time the video sweep signal reaches zero MHz, the spectrum analyzer section is responding to the visual carrier.

As the video sweep signal returns to 1 MHz, it amplitudes-modulates the visual carrier in the modulator, causing sidebands to occur at 1 MHz above and below the visual carrier frequency. At precisely this time the spectrum analyzer portion of the sideband analyzer is responding to 1 MHz above the visual carrier.

As the video sweep signal proceeds to 2 MHz, the sidebands also move to 2 MHz above and below the visual carrier, and the spectrum analyzer is now responding to this frequency. If the modulator response is still flat, the detected output of the sideband analyzer will be identical to that of the 1 MHz signal.

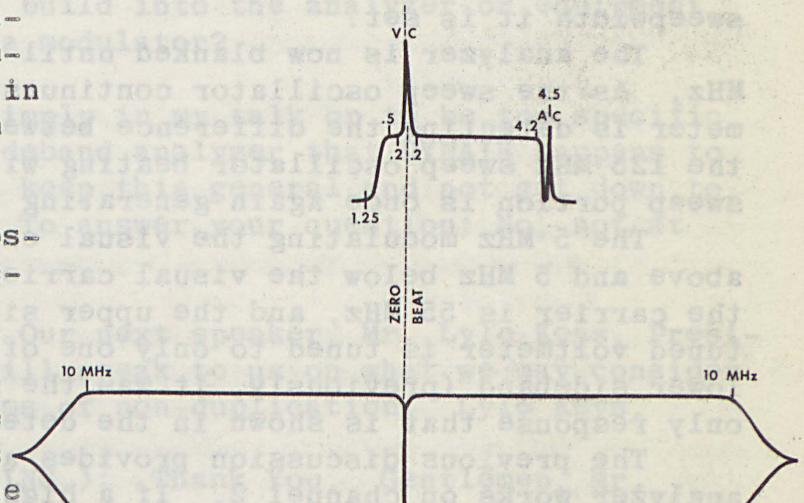
As the video sweep signal proceeds to, for example, 4.3 MHz, where the modulator output should begin to roll off, the video sweep signal is still modulating the visual carrier at 4.3 MHz and the spectrum analyzer is still measuring the amplitude of the sideband; however, because the modulator output is rolled off, the sideband displayed on the oscilloscope will be down several DB at this point.

When the video sweep signal rises to 4.5 MHz, and if the aural carrier of the modulator is being generated, a large pulse will appear on the detected output of the sideband analyzer. As the sweep signal moves to 5 MHz, if there is no response in the modulator, there will be no sideband, and the detected out put of the sideband analyzer will be at zero.

As the sweep signal proceeds to 6 MHz, and for some reason there is a slight rise in the bandpass characteristics of the modulator, the energy level will rise accordingly, and the spectrum analyzer will produce a small output which will be presented on the oscilloscope.

When the video sweep signal is at the maximum sweep width selected (8 to 10 MHz), the sweeping oscillator is blanked out of operation until it returns to the starting point.

Obviously, very close synchronization is required between the video sweep generator and the spectrum analyzer portions of the sideband analyzer. The methods used in accomplishing this can be seen in part in Figure 4, which is a block diagram of a typical sideband analyzer.



As seen in the diagram, the heart of the device is the sweep oscillator. The sweep oscillator deviates above and below its center frequency (usually 120 to 130 MHz) by the amount of sweep width required (usually 8 to 10 MHz). The output of this sweep oscillator is applied to both mixer No. 1 and the balanced mixer.

In developing the sweep signal, assuming, for example, that the sweep oscillator is at 120 MHz, it beats against a fixed 130 MHz signal produced by the beat oscillator, resulting in a 10 MHz output of the balanced mixer. As the sweep oscillator deviates to 130 MHz, the difference signal is zero MHz, and as the sweep oscillator continue to 140 MHz the difference is again 10 MHz.

In developing the spectrum-analyzed output, the sweep oscillator is applied to mixer No. 1, an untuned mixer, where it is beat against the incoming sidebands of the modulator under test. In this case, the difference output of the two signals becomes the first IF (tuneable IF) of the spectrum analyzer. For example, Channel 2, with the visual carrier in the neighborhood of 55 MHz, would produce a difference signal of 75 MHz (130-55 = 75). This would become the tuneable IF output of the first mixer. This signal would then be applied to mixer No. 2, where it is beat against the output of the fixed tuning oscillator. This is the actual tuning oscillator which is used to select the desired channel.

In the case in question, the 75 MHz output of mixer No. 1 must be heterodyned down to a lower IF frequency, which is normally in the area of 10 to 20 MHz. If a 10 MHz IF is used, the beat oscillator must produce a 65 MHz signal to produce a 10 MHz difference signal, which is then applied to the next stage, a fixed IF amplifier.

The fixed IF amplifier is a relatively narrow-band device, with the bandpass being down about 20 DB at the 100 KC bandwidth points. This assures resaonably good selectivity in viewing the modulator RF output plus any spurious emissions it might contain.

When the sweep oscillator proceeds to 135 MHz, the output of the first mixer remains at 75 MHz, and the difference between the 135 and 75 MHz is 60 MHz. Since the sweep oscillator is now at 135 MHz and is beating with the fixed oscillator of 130 MHz in the video sweep portion, the difference signal being generated is exactly 5 MHz. The tuneable voltmeter is now measuring 60 MHz and the modulator is producing a sideband of the visual carrier which is approximately 55 MHz plus the 5 MHz of video which is again 60 MHz. The sweep oscillator continues on out to 138 MHz, or to whatever sweepwidth it is set.

The analyzer is now blanked until the sweep oscillator returns to 122 MHz. As the sweep oscillator continues upwards to 125 MHz, the tuned voltmeter is detecting the difference between 75 and 125 MHz, or 50 MHz, and the 125 MHz sweep oscillator beating with the 130 MHz fixed in the video sweep portion is once again generating 5 MHz.

The 5 MHz modulating the visual carrier is causing sidebands 5 MHz above and 5 MHz below the visual carrier. The lower sideband is 50 MHz, the carrier is 55 MHz, and the upper sideband is 60 MHz. However, the tuned voltmeter is tuned to only one of these, which in this case is the lower sideband (previously, it was the upper sideband), so this is the only response that is shown in the detected output of the sideband analyzer.

The previous discussion provides a general idea of how the sideband analyzer works on channel 2. If a higher channel modulator were tested, say, for example, one with a carrier of about 80 MHz, the difference between the 130 MHz and the 80 MHz would be 50 MHz. In order to convert this 50 MHz into a fixed IF of 10 MHz, an oscillator frequency of 40 MHz must be generated by the tuning oscillator. Past this point in the circuitry, the signal would be processed in exactly the same manner as described for channel 2.

If a highband modulator were tested, say for example one operating on 180 MHz, the difference between the 180 MHz and the 130 MHz would be 50 MHz. In this case, the RF carrier is actually above the 130 MHz sweep oscillator, where on the low channels the RF was below the sweep oscillator. This 50 MHz difference is again converted into the 10 MHz IF with a 40 MHz signal generated by the tuning oscillator, providing the same tuned oscillator, frequency as generated with the 80 MHz channel. Because of this, both a highband and a lowband modulator should never be simultaneously connected to the input of the sideband analyzer.

Another useful feature of the sideband analyzer is that, as previously stated, the device is actually made up of two sections: a video sweep portion and a spectrum analyzer portion. These can, if desired, be used independently. The quality video sweep signal produced may be used as any normal video sweep generator, by simply disregarding the spectrum analyzer portion of the sideband analyzer. The same thing applies to the spectrum analyzer portion of the device. In other words, you might feed a multiburst or some other test signal or, if desired, an actual video signal into the modulator under test and observe the sidebands generated with the spectrum analyzer without using the video sweep section. Therefore, the versatile device actually serves as three useful test devices: a sideband analyzer, a video sweep generator, and a spectrum analyzer, providing, in one small package, most of the tools required for maintenance of your head-end modulators.

This paper is based primarily on the sideband analyzer manufactured by DYNAIR Electronics, Inc. and is similar to the other devices now on the market.

CHAIRMAN TAYLOR: Thank you very much Mr. Bates. Do we have any questions on the sideband analyzer?

QUESTION: Is there a plan to build into the analyzer or equipment for checking the audio portion of a modulator?

MR. BATES: I didn't mean to imply in my talk or to be too specific in referring necessarily to the sideband analyzer that DYNAIR happens to be manufacturing. I was trying to keep this general and not get down to specifics on our particular unit. To answer your question: No, not at this time.

CHAIRMAN TAYLOR: Thank You. Our next speaker, Mr. Lyle Keys, President of TeleMation Incorporated, will speak to us on what we may consider a dirty word, the technical problems of non-duplication. Lyle Keys.

MR. LYLE O. KEYS (TELEMATION INC.): Thank You. Gentlemen, Mr. Chairman: My paper is entitled "Design Considerations for CATV Non-duplication Equipment". There are copies of this paper on the table at the rear of the room.

The subject of CATV non-duplication can be divided into four areas:

1) requirements for program deletion
2) choice of substitute programming
3) method of switching
4) method of switcher programming

Non-duplication arrangements are not necessarily limited to the rules set forth in the FCC's Second Report and Order. CATV operators are free to negotiate different agreements with protected stations. For example, CHAIRMAN SCHLAFLY: I am going to cut that discussion right there, with a little question mark in the air. We are running so short of time that I do not want to impose on the good nature and patience of our last speaker. Thank you, Clay, and thank you, Dr. Schenkel.

The last speaker on the agenda this morning concerns a very interesting item of test equipment called the spectrum analyzer. This is a most interesting and useful tool. I am anxious to hear more about it. Allen Ross, who will deliver this paper, is President of Nelson Ross Electronics. Nelson Ross Electronics specializes in Plug-In Spectrum Analyzers. Allen Ross is a graduate of City College of New York and of Brooklyn Poly-Tech. He was with Polarad Electronic Corporation before forming NRE. He spent eight years with them and was in charge of advanced development, pioneering the solid state spectrum analyzer. He was the person who first implemented the Plug In Spectrum Analyzer concept. Allen.

MR. ALLEN ROSS (NELSON ROSS ELECTRONICS): I know it is late and we are running behind, so I will try and cut right to the meat of this. The spectrum analyzer is an instrument that is probably unheard of in this particular industry. It is a useful instrument which has been around for a long time, originating with the esoteric military requirements. The state of the art in spectrum analysis has gradually improved to the point where it is possible to build spectrum analyzers which cover very wide frequency bands. There are now a few people making analyzers which permit observation of the entire CATV spectrum -- channels 2 to 13 (including all the FM in between) in one sweep. These analyzers will permit very useful advances in the systems for testing CATV transmission.

Perhaps it might be appropriate for me first to describe what a spectrum analyzer is and how it operates. I don't know how many people can see this blackboard, so I will try and use a minimum of sketches. We will start with a familiar instrument - the field strength meter. If we start by drawing the block diagram of the most basic field strength meter, what we have would be a signal input which drives a mixer, which I shall designate "M", provided with a local oscillator signal, from a black box which I will designate "LO". The resulting difference frequency drives a narrow band filter, ultimately resulting in a meter reading. Signal F plus Delta F comes from the local oscillator producing Delta F at the mixer output, and depending upon the strength of the input, we get a meter reading. Anybody who has manually tuned one of these things back and forth for a few hours from channel 2 to channel 13 can tell you it gets to be a pain in the neck after awhile. You can make a very good and accurate set of readings of the relative levels of all the picture and sound and color carriers in the system, but it is time-consuming. It would be nice if we had some sort of a system for observing the meter readings on all the channels simultaneously, so we didn't have to tune. This is exactly what a spectrum analyzer does for you.

Suppose we were to replace the meter with the vertical deflection system of an oscilloscope. This presents no basic problem. When we tune through a signal, we would see the modulation (as limited by the band pass) as a wave form on the oscilloscope.

Suppose, in addition, instead of tuning the local oscillator mechanically we somehow were able to tune it electrically. The oscilloscope has - driving the horizontal plates - a sweep generator producing a repetitive sawtooth. If we force the oscillator frequency to follow the sawtooth, we get what is called a panoramic display. In other words; as the spot travels from left to right across the face of the CRT, the field strength meter is tuned across the band of interest. I would like to sketch what the resulting display would be.

Let us assume, first, that the wave meter was tuning across one TV channel. You go through the guard band, and then when you come to the picture carrier, you would see a vertical deflection, the amplitude of which would be proportional to the picture carrier level at the input. There are other signals in there, but they consist mostly of the video modulation. These signals, surprisingly enough, contain very little energy and don't appear until you get to the color carrier which then appears as another vertical deflection, and as you continue, finally you will see the sound carrier.

Of course the display of one TV channel is really of no interest. As Ken pointed out earlier, anything that is passing channel 2 to 13 is certainly going to be reasonably flat over any one channel. However, there are spectrum analyzers available which make it possible to observe all 13 channels at once, and this, of course, becomes useful.

What you see is a flat base line with pairs of pulses wherever there is a channel being transmitted in your system. If you are carrying the FM band, you would see the station carriers in addition to each of the picture and sound carriers. You can observe this at a glance. Of course, an imaginary line drawn through the tops of the carriers is the slope of your transmission system.

The advantage of a device like this, of course, is to the speed with which equipment can be serviced. If there is a question on a pole, you can find out in approximately 30 seconds of observing time whether there is a problem. Get into the tap on the amplifier with the input to the spectrum analyzer and you are looking across the band. You see immediately all your carriers (present and absence) and you see the location, if any, of any interfering signals that might be causing problems. If there is a flatness adjustment which has to be made, you can make it while observing the carriers, limited only by the reaction time between your hand and your eye, which means a very fast adjustment. Obvious things, like the absence of signals, of course, are no problem; you find out right away.

There are many side aspects of the use of the spectrum analyzer which we are still beginning to find out about. A few people are beginning to use these instruments to service in CATV systems. I was told that in Canada, where they have one of our analyzers (I think it was in London), there was one channel where they had no color, where they couldn't get any color, even though they knew darn well that the picture carrier, the sound carrier, and the color carrier were all present, and they could see it at the headend. This turned out to be a spurious transmission which was 10 or 20 kc away from the color sub-carrier and was being picked up at the headend. Every time it came on it destroyed the phase information in the color carrier and all the color pictures just disappeared and became black and white. They couldn't find this by other means, but when they put a spectrum analyzer on it became immediately obvious. Every time this guy went on the air, you could see a nice big spike rise. The solution was a question of filtering. But once you know what frequency it is at, then you know what to do about it.

We don't really know yet what other things might be done with the instrument, but we do know, for example, that there is some problem in identifying co-channels from other areas. The sligh offset from channel to channel, in the same channel in different areas can be observed on a spectrum analyzer. If you narrow down the bandwidth of the filter so that you are looking at the sound and the picture carrier of one channel, and you were picking up a channel from another area at a lower level, it would be slightly offset, and you could tune your system, rotate your antenna, and make whatever adjustments you find necessary using the spectrum analyzer as a measuring instrument. This is a much more quantative measure than simply judging the windshield wiper effect you see on a CRT of a television receiver, so you can make a much more precise and accurate adjustment. Of course, the obvious uses are the observation of relative levels, picture and sound in each channel and the presence or absence of noise as IM products.

It has also been suggested that the spectrum analyzer be used for preventative maintenance. There are times at night when some channels in an area go off the air, and it is possible to insert a non-modulated carrier in place of the picture carrier. This I understand is a common practice of some places. Also there are occasionally un-modulated pilot tones, or pilot tones with simple modulation which travel down the system. Now, if your system has IM, the synchronization pulses of channels that are on the air, theoretically, should produce IM distortion on the unmodulated pilot carrier. So if you tune to the unmodulated pilot carrier and it looks perfectly clean, you have no IM in your system. Of course, it is never going to look perfectly clean, because no system is perfect. There is going to be some level of IM which appears as synch pulse bumps on the display and they crawl across with the same windshield wiper effect you would get between two stations whose horizontal and vertical frame rates would not synchronize with one another.

If you know, from experience - and you do after a while - what is normal for your system, you can anticipate failures. If, at any particular place in your system, you notice that these levels begin to increase, you can see that you are beginning to have trouble with something in the system between the headend and that point. It gives you a warning. I don't think there is any other device around yet which might give you this kind of a warning - but a spectrum analyzer will.

The plug-in concept was mentioned. That is a vague general word. I think that perhaps I ought to explain what it is. Up until a few years ago, all spectrum analyzers were complete instruments. They were quite expensive because a spectrum analyzer is a combination of many instruments. The local oscillator is a sweeper, which in itself is an expensive instrument. The receiver portion is a receiver and the rest of it is an oscilloscope. You can see, you are really buying three instruments, each of which in its own right, is fairly expensive and elaborate. This, of course, has been one of the reasons why spectrum analyzers, up until recently, have not been in too common use. The plug-in concept helps considerably. There are a great many excellent oscilloscopes on the market which have plug-in vertical amplifiers. The oscilloscope of course is at least half, if not 2/3, of the spectrum analyzer. It provides all the power, it provides the sawtooth for the sweeper, and it provides the CRT display and the amplification. The rest of the analyzer can be built into a package which is identical in shape and size with the conventional vertical amplifier. Plug this in and you have a spectrum analyzer. This is the kind of instrument I am talking about. Plug-ins are currently available for all the standard Tektronix and Hewlett-Packard oscilloscopes.

The oscilloscope is unaffected by the insertion of the plug-in. Pull it out, put your regular amplifier in and you have an oscilloscope again. The advantages are obvious. For example, with the HP140A oscilloscope you can get a time domain reflectometer, a vertical amplifier with reasonable bandwidth and a spectrum analyzer. They all plug in to the same oscilloscope. So there is a considerable saving in money and you have a complete set of equipment capable of making quite sophisticated measurements on your cables.

I have an instrument here. I brought one with me and Hewlett-Packard was kind enough to lend me an oscilloscope. I have since found out that the signal in this area is quite strong. If anybody is interested, I will be delighted to show them this display after the meeting. Thank you.

CHAIRMAN SCHLAFLY: Gentlemen, I thank you for your attention and interest in the papers. I thank the speakers. Thank you very much for your attention.

accurate measurements are desired. When measurements are made utilizing a jumper cable, an inline attenuator, or the meter switchable attenuator should be used to properly terminate the jumper cable. This is extremely important when measuring amplifier test points, since most test points present a high source impedance and thus the jumper cable, if not properly terminated, can have multiple reflections, with the indicated level dependent on the length of the jumper.

The problem of calibration of the field strength meter has been lessened with the commercial availability of accurate RF thermocouple transfer standards, such as the Model 440 Selby Micropotentiometer offered by Ballantine Laboratories. These units are inexpensive and can be calibrated by either the manufacturer or can be calibrated by the Bureau of Standards Calibration Labs to an accuracy of better than + 1 db over the VHF range.

To summarize, the requirements to measure the performance of modern CATV equipment requires accurate and stable test equipment. Furthermore, test methods and actual laboratory setups should be reviewed to insure that problems or improper techniques do not exist, whereby the equipment to be evaluated is not measured properly.

CHAIRMAN TAYLOR: Thank you very much Mr. MacMillan. We have just a few minutes to ask questions on test equipment to Mr. MacMillan. (No questions)

It is of particular pleasure to introduce our next speaker, Mr. I. Switzer from Lethbridge, Alberta. We always enjoy having our Canadian friends and counterparts attending our convention. Mr. Switzer's subject this afternoon will be time domain reflectometry. Mr. Switzer.

MR. I. SWITZER (LETHBRIDGE, ALBERTA, CANADA): The RF transmission lines used in CATV system are important and critical parts of the system. Emphasis in CATV marketing techniques on quality in pictures delivered to the subscriber makes it increasingly important that our coaxial cables have the best possible transmission characteristics when installed and that these characteristics should be maintained to a very high standard during the useful life of the cable.

Common CATV system practice for cable testing has progressed from simple transmission sweep testing, through "frequency domain reflectometry" to the present well accepted practice of use of the Swept RF Impedance Bridge for cable testing. The RF bridge provides a very sensitive test, in the frequency domain, for cable imperfections and flaws.

Recent developments in the precision oscilloscope field now make time domain reflectometry a practical and useful tool for CATV system application.

Reflectometry I shall refer to as the measurement of system characteristics by measuring reflections caused by imperfections. Measuring reflections as a function of frequency is reflectometry in the frequency domain; measuring reflections as a function of time is reflectometry in the time domain.

In general the frequency and time domains are related mathematically by the Fourier transform, and a description in either domain is a complete and sufficient description of the system; which representation is most useful depends on the application of the information. One might say that frequency domain information about a cable is most useful for considerations of frequency response and envelope delay. Time domain information is most useful for considerations of "ghosts". Strictly speaking, frequency domain implies measurement of both amplitude and phase. Because of instrumentation problems, phase is very rarely measured directly and for this reason most frequency domain measurements and techniques are, strictly speaking, deficient because of lack of phase information. Time domain measurements, are on the other hand, complete since only a plot of waveform versus time is required.

By way of example of the correspondence between time and frequency domain, the following example may be cited: The transmission characteristics of a television system can be determined in the time domain by recording the response of the system to a standard pulse of some kind. The output pulse may be compared to the input pulse and the characteristics of the system determined. Since television pictures consist of a complex pulse train, such a description is a very good test of a television system. However, if something is wrong with the system, it may be difficult to determine what and where the trouble is. The transmission characteristics of the system may also be determined by frequency domain testing. The response of the system may be plotted as plots of both amplitude and phase as a function of time. The amplitude response is the familiar frequency response curve. The phase plot is not so frequently seen but is an important part of the system test. It is not usually drawn because of uncommonness of phase instrumentation. Nevertheless, phase information is important, particularly for color transmission systems. Frequency domain description of the transmission system may in some circumstances be a very valuable guide to finding system troubles. Strictly speaking, the two tests are completely interchangeable, and the one used depends on the nature of the problems to which it is being applied.

In the field of transmission line testing there has been widespread application of TDR testing for many years. The transmission lines, however, were large power transmission lines, and the equipment used was not applicable to our coaxial cables. TDR testing is a kind of radar in which a pulse is sent down the line and reflections from imperfections are received and timed to give information on the location of the fault. The resolving power and accuracy of TDR systems depends on the "rise time" of the system. Pulses must have fast rise times and the oscilloscope systems for viewing the reflections must have sufficient response to display the rise times of reflections. The development of fast rise time pulse generators and "sampling mode" oscilloscopes has made application of TDR techniques practical for CATV system use. A typical modern TDR instrument has a system rise time of about 150 picoseconds, corresponding to a frequency response of 0-2, 300 MC.

The Hewlett-Packard Company introduced a TDR system as a plug in for their 140A oscilloscope system in 1964. We felt that this would be a very suitable instrument for CATV application and we introduced the use of this instrument into some of our systems in the summer of 1965, being possibly the first CATV systems to make practical study of cable and connector systems. A number of cable manufacturing companies also took up use of the instrument soon after its introduction.

High resolution TDR techniques had been used on a laboratory basis since sampling mode oscilloscopes were introduced a few years ago, but the H-P instrument made available a simple "black box" at a moderate price.

The TDR puts out a unit step function with a system rise time of 150 picoseconds and at a 1 volt level. The sampling system is capable of displaying reflections which are 60 db down (0.1%) from the incident pulse without overloading the system. When used for tests on short lengths of cable, the system is capable of very high resolution. We often use the TDR system for evaluating competing connector systems and fittings and we have been able to distinguish the rear part of an AF-201 type connector from an F-81 and terminating resistor at the other end of the connector, i.e. we can distinguish the front and back parts of a connector about $1\frac{1}{2}$ inches long.

We use a special version of the H-P instrument called the HO-5 modification which has an extra position on the range scale extending the calibrated range to about 2,500 feet.

Since the resolving power, and hence the ability of instrument to accurately determine the position of a fult depends on cable rise time or frequency response, there is a considerable loss in resolution in longer cable lengths because of the rapid loss of high frequency components implied by fast rise times. The frequency domain spectrum associated with the unit step function shape of the TDR pulse has high frequency components which go down at a 6 db per octave rate. If the dynamic range of the instrument is considered to be 60 db, and since pulses have to go both ways through the cable before they are observed as reflections, a 1,000 foot piece of cable may be considered to have a cut off at the frequency at which its two way attenuation is 60 db. For .412 aluminum cable this is about 500 Mc. This same 1,000' piece of cable has a DC loss (two way) of only 0 5 db.

Since time and distance in the cable are related by propagation velocity, we can use the TDR to determine the nature of a fault and its position. Frequency domain techniques will tell us that there is a problem at a certain frequency or band of frequencies, but they will not tell us where the problem is. The TDR shows us where the fault is and tells us something about the nature of it. The precision of fault location depends on the accuracy of time scale calibration of the instrument and the echo rise time which depends on cable length and high frequency attenuation. The basis time scale accuracy on the instrument is 5%, but translation to distance requires accurate information on propagation velocity. We have noticed some variance in cables from published specifications and wherever possible we calibrate the instrument on the actual piece or type of cable being checked by measuring time to a known termination or discontinuity. This improves accuracy considerably.

In terms of practical application, we have found the TDR most useful in checking new cable during construction. The TDR detects any construction flaws, such as kinks, cracks, dents, and also checks quality of connections and terminations. We are even able to detect connectors that have been out on by running and tubing cutter right through the sheath instead of cracking the sheath through in the approved manner. Use of the instrument has a powerful psychological effect on construction crews since they know that every part of the cable is being "radar monitored" for quality. The instrument should be used in conjunction with a return loss bridge since it is possible to have small periodic defects which an operator might pass by TDR as acceptable without realizing that their periodic spacing is adding up to a serious frequency domain effect.

In operating systems we use the TDR for cable troubleshooting. It rapidly spots bad taps, connectors and terminations. An accurate tape measure is an essential accessory. We have found that when the TDR points out a bad tap 183 feet down the line, that is exactly where it is and we have been mislead several times by eyeballing distances indicated by the TDR or by pacing them out instead of measuring them.

Wet cables, connectors and splices are easily detected. The moisture alters the dielectric constant of the dielectric which changes the characteristic impedance of the cable and hence causes reflections which the TDR displays. Wet sections are pinpointed for drying out or replacement. One of our systems more than paid for the cost of its TDR on this one application by using it to examine all the cable in a system that was considered due for replacement in an all-band conversion program. Certain cable sections were found still quite serviceable and were left in place.

Another application is evaluation of connectors. We evaluate connectors which vendors offer us and have found for example that there are significant differences in the match of different manufacturers versions of the same connector, for example the common F-81 connector. When we first got our TDR we layed out some scrap cable sections with different connectors and examined them with the TDR so as to train our technicians to recognize the characteristic display from different fittings. We then started to kink the cable and pound in dents with a hammer. We found that the return from a very serious dent (which we would have rejected by visual inspection) was no worse than the return from the splice connector which we would have used to repair it!

Since the TDR principle is directly related to the situations that cause ghosts in our system, it is a powerful instrument for tracking down ghost sources and correcting them. One must take care not to over use the instrument in this kind of application. The TDR output pulse has frequency components to 2,300 Mc and the oscilloscope system is capable of displaying these frequencies. Normally the instrument should be restricted to broad band systems where a fault will cause "broad band reflections" which are valid reflections at virtually all frequencies. In complete CATV systems we have components which are good impedance matches in only a comparatively narrow band of frequencies. For example amplifiers are usually adjusted to present a good termination to an input line at only the frequencies normally used, typically 54-200 Mc. A perfectly good amplifier could reflect energy in the TDR pulse outside these frequencies and show up as a bad match on the TDR display, which indeed it is at frequencies outside its working band. In such cases the TDR frequency response, rise time, should be restricted by filters. We are experimenting with low pass coaxial filters for this application. Reflections still apparent in this frequency limited system are of concern. Their position cannot be accurately determined because of the restricted rise time of the filtered system, but the filter can be removed for more accurate determination of location of the fault.

We are beginning to believe that we may be over emphasizing the importance of some of the cable flaws that we have been detecting and rejecting with the TDR because of the great resolving power of the instrument. Corrugated sheath cables and disc insulated cables are very commonly used in CATV systems. We know these to be good cables in our frequency range because although the corrugations and discs are strictly speaking impedance discontinuities, their dimensions are so small compared to the wave lengths we use that they have negligible effect on transmission at our frequencies. If we had TDR with even greater resolving power than our present instruments, we would be able to distinguish the discontinuities caused by corrugated sheath and disc insulators. If we extend this principle to wave lengths closer to those we use, we realize that the TDR system has frequency components ten times greater than our highest frequency of interest, and these high frequency components are showing us flaws that are really quite small compared to our wave lengths and which do not materially contribute to transmission degradation. We are experimentally applying our low pass filters to such situations to see whether we are indeed being too fussy about cable flaws now that we have such a powerful cable examination tool. The TDR is capable of extreme precision in determining impedance of cables. For ordinary cables it is capable of comparing their impedance within 0.1 ohms. I have said "comparing impedance". Actual impedance cannot be determined with a standard to compare to. Unfortunately there do not appear to be any 75 ohm standard transmission lines available. Standard 50 ohm sections are available with calibration traceable direct to NBS. Comparison of 75 ohm cables to 50 ohm standards would reduce accuracy to about + - 2 ohms. Resistances are difficult to measure at VHF and a 75 ohm termination may be considered to be that termination that perfectly terminates a 75 ohm transmission line. A 75 ohm transmission line can be defined in terms of dimensions of inner and outer conductors and characteristic of dielectric but so far we have been unable to obtain accurately constructed 75 ohm line sections to use as an absolute standard with our TDR systems.

We buy equipment items with specified VSWR or return loss or characteristic impedance without too much concern about the accuracy of the specification checks. We may run into some problems if we are building systems with tight impedance match requirements or specifications in puting together items from different sources which have been checked for impedance match against questionable standards. The situation becomes apparent in considering specification of cable. A typical aluminum-sheathed cable spec calls for impedance of 75 ohms + - 2 ohms. This is measured usually by a method that gives the average impedance for a piece of cable. Additional specs on frequence domain measurements specify return loss at minimum 25 db. Again this is an average for the whole length of cable. The TDR permits checking the impedance profile along the whole length of cable. The impedance at the end of the cable when it is cut at any particular point may vary from 73 to 77 ohms. It is quite possible that a 73 ohm end may be spliced to a 77 ohm end. This would give a reflection coefficient of 0.0267 or return loss of 31.5 db. Systems requiring better match would have to check such splices and select cable reels to give ends that match. The TDR when used with a suitable 75 ohm impedance standard can check cable impedance profiles with great accuracy.

Several problems have been encountered in application of the H-P instrument to CATV. The H-P TDR was designed for 50 ohm systems and has a source impedance of 50 ohms. When used in a 75 ohm system, there is a mismatch which causes some difficulty due to multiple reflections caused by reflection at the mismatch between TDR and 75 ohm cable. H-P have an adapter available which consists of a 25 ohm resistor in series with the cable. This back matches the cable since the reflected pulse sees the 25 ohms in series with the 50 ohm impedance of the TDR. This introduces a 6 db loss in sensitivity due to voltage divider action on both the incident and reflected pulses. A resistive minimum loss matching pad can be used with somewhat higher loss of sensitivity. For precise quantitative measurements, the instrument can be easily recalibrated to compensate for either adapter. I personally prefer to use the MLP or no adapter at all, making corrections for multiple reflections according to the formulas in H-P's application manual.

Some problem has been experienced with 60 cycle AC pickup particularly on cables on joint use poles. This is usally noticed on lines with low impedance shunts such as resistive terminations. The pickup seems to disappear when the line is completely opened. H-P is developing a unit called a "humdinger" to alleviate this problem.

We have found the TDR, particularly the version by H-P, to be a reliable, very useful instrument for routine use by CATV systems, large and small. In the words of one of our system managers - "I don't know how we ever got along without it".

CHAIRMAN TAYLOR: Thank you very much and I want to apologize first off for eliminating the punch line at my introduction. Mr. Switzer is a CATV consulting engineer in Lethbridge and also has been associated considerably with the famous players in their CATV systems throughout Canada.

Our next speaker, Mr. Isaac S. Blonder, Chairman of the Board of Blonder-Tongue Laboratories, Inc., will speak to us on the importance of technical training. Mr. Blonder.

MR. ISAAC S. BLONDER (BLONDER-TONGUE LABORATORIES, INC.): At the back of the room there is a table containing my speech and also another paper on CATV technical training that was prepared by Fred Schulz who is in charge of our sales training. I was delighted at the opportunity to be able to talk about technical training. I've done nothing else all my life.

Technical knowledge may be categorized as having four general divisions: scientist, engineer, technician, craftsman. Technical training is accomplished in these approximate areas: university, technical institute, high school, military, apprentice, self-study.

Measurement standards for the level of technical knowledge achieved are virtually non-existent. The CATV operator, and indeed every other employer

TECHNICAL SESSION - III

Wednesday Morning, June 29, 1966

CHAIRMAN HUBERT J. SCHLAFLY: Gentlemen: I would like to welcome you, on behalf of the NCTA, to the technical program for Wednesday morning. The weather has cooperated greatly by being miserable outside, and we are happy to have you here with us. I have been looking forward to this session; there are many interesting papers that I will be most interested in listening to and perhaps asking questions about. I think perhaps your presence here shows that you have the same type of feeling.

Because we have a long session this morning with many very prominent speakers, I would like to get underway now. The first speaker is Mr. Gaylord Rogeness. Mr. Rogeness has a Bachelor of Science and a Master of Science degree in electrical engineering from the University of Illinois. At Interstate Electronics Corp. in Anaheim, California, he designed and developed equipment on fixed price contract for custom instrumentation and telemetering systems, which were used both in the military and by NASA. In a consulting position with Goodyear Aerospace Corporation in Litchfield, Arizona, he designed and developed a systems in circuits for airborne reconnaisance mapping radars. One model of the Goodyear Radar Set is presently employed in the RF4C aircraft and is operational in the Vietnam area. In 1965 he joined AMECO. And for the last 3 months has functioned as the director of engineering of AMECO Engineering Corporation. Mr. Rogeness' paper is on Transient Response Testing of CATV Systems.

MR. GAYLORD ROGENESS (AMECO ENGINEERING CORPORATION): Ideal CATV system performance requires that the TV signal delivered to each subscriber be equal in quality to the signal received by the CATV antenna. In order to approach ideal performance, the CATV equipment must be designed to meet certain minimum standards, and then it must be tested under operating conditions in the field to insure that it is meeting its design goals.

The intent of this paper is to discuss a test which can supplement the number of tests already being performed on CATV systems. Use of a transient response test to evaluate system performance provides a dynamic test which simulates the actual TV picture signals.[1] It provides a more direct means to test the phast characteristics of the system. It provides an additional objective test of system performance which augments the final subjective test of viewing a TV receiver picture fed by CATV equipment. It provides a direct means for making critical alignment adjustments which are difficult to make with existing techniques.

Figure 1 shows a block diagram of alternate TV signal transmission paths.

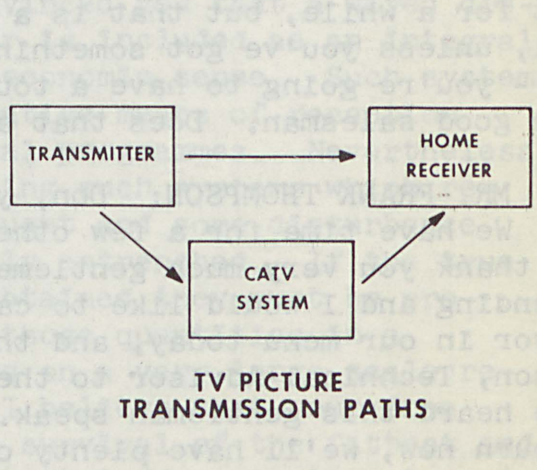


Fig. 1

The TV picture signals travel either directly over the airways to the home receiver, or the TV signals are received by a CATV system and delivered to the home receiver via cable.

Many years of engineering study and design were required to develop transmitter and receiver characteristics, within certain tolerances, which are complementary. The overall transmission characteristics between television scene and home receiver, therefore, allow reproduction of acceptable color and black and white pictures. If no picture degradation is to occur, any system placed between transmitter and home receiver, such as a CATV system, must not alter the characteristics of the transmitter-receiver path.

Critical CATV system performance specifications are listed in Table I. The items listed are those which would have the greatest effect on picture quality, if they were not within acceptable limits. The specifications listed apply to both head end and line equipment.

Also listed in Table I, opposite the performance specifications, are the tests usually performed on CATV equipment which guarantee that the equipment is in the best possible operating condition. In essence, test number six checks the sum total of all of the system characteristics. However, note that no direct test is made to check the envelope delay response of the equipment. A qualitative test of the system envelope delay response can be made through use of the $\sin^2$ pulse.

TABLE I

CRITICAL CATV PERFORMANCE SPECS	TESTS TO INSURE OPTIMUM PERFORMANCE
1. Noise Figure	1. Noise Figure and/or S/N Ratio
2. Linearity	2. Cross Modulation and Spurious Signals
3. Amplitude Response	3. Sweep Amplitude Response
4. Delay Response	4. No Direct Test
5. Impedance Match	5. VSWR or Return Loss
	6. Observation of Picture on TV Receiver

The $\sin^2$ pulse has been chosen as a test signal for testing television transmission systems for a number of reasons. It is described in many articles and reports.

Some of the general considerations given for the choice of the $\sin^2$ pulse as a test signal are:

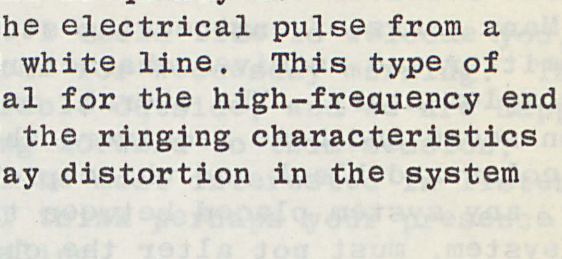
1. Convenience for practical measurement;
2. Ease of reproducibility; and
3. A relatively simple mathematical function that can be used in theoretical studies.

Figure 2 shows the frequency spectrum envelope of a repetitive $\sin^2$ pulse and square pulse. The repetitive square pulse has the well known $\frac{\sin x}{x}$ frequency spectrum, whereas the frequency spectrum of the $\sin^2$

pulse is $\left[\frac{\sin x}{x}\right]\left[\frac{1}{1-x^2/\pi^2}\right]$. Note that most of the energy of the $\sin^2$ pulse is contained below twice the fundamental frequency f.

The $\sin^2$ pulse very closely resembles the electrical pulse from a television camera corresponding to a scanned white line. This type of pulse has definite advantages as a test signal for the high-frequency end of the band. It provides a stringent test of the ringing characteristics of the transmission path. Any phase and delay distortion in the system will cause direct asymmetry of the $\sin^2$ pulse about its ordinate through the peak amplitude point. Hence, the $\sin^2$ pulse provides a means to evaluate the system response.

The $\sin^2$ 2T-pulse is shown in Figure 3 after passing through a system with an ideal characteristic. The 2T-pulse has a half amplitude duration of 0.25 μsec and should pass through the 4.2 mc bandwidth TV channels with minimum distortion.

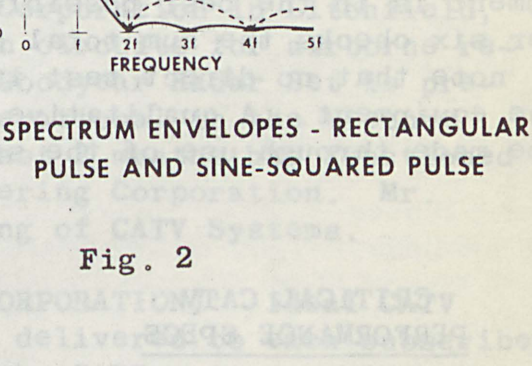


SPECTRUM ENVELOPES - RECTANGULAR PULSE AND SINE-SQUARED PULSE

Fig. 2

The $\sin^2$ pulse is used most often to test the 4.2 mc bandwidth TV transmission system. The T-pulse has a half amplitude duration of 0.125 μsec and is shown in Figure 4 before and after passing through an ideal system. The effects of one type of delay distortion on the T-pulse response are shown in Figure 5. Note that delay distortion causes the $\sin^2$ pulse to be assymmetrical about its ordinate.

The delay distortion characteristic shown in Figure 5 causes ringing on the trailing edges of narrow pulses and after rapid transitions in luminance level. In some instances, the visual effects of ringing are similar to those produced by reflections caused by impedance mismatch. Seriousness of the ringing is measured by the amplitude and duration of the "rings".



2T-PULSE RESPONSE

Fig. 3

If the frequency axis of Figure 5 were reversed, low frequency components of the signal would experience greater delay than the high frequency components. As a result, it is possible to produce echoes or ghosts which precede the desired image. For this condition the T-pulse response would have anticipatory undershoots and overshoots which precede the main pulse.

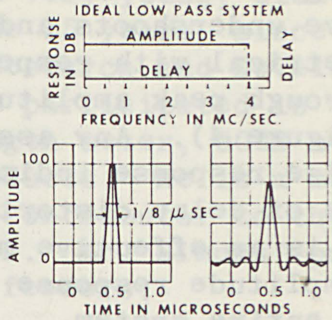
One of the most obvious and disturbing effects of delay distortion is misregistration of color on the image. Color can either precede or follow the desired image, depending upon the overall delay characteristic of the transmission pulse.

A block diagram of a test setup to check a CATV system is shown in Figure 6. The sin^2 pulse and VITS signal (to be described later) appear to be most useful in testing the CATV head end equipment. However, waveforms can be checked along the amplifier cascade to insure that optimum transmission is maintained. The effects of noise and crossmodulation products are more prevalent in the repeater amplifier cascade. Phase and amplitude distortion in any one 6 mc band are more prevalent in the head end equipment.

Two options for obtaining test signals are noted in Figure 6. One test method requires the use of a sin^2 generator and a modulator for each channel to be tested. The second source of test signals is the Vertical Interval Test Signals (VITS) which are transmitted by the networks and therefore available off the air.[6] The VITS occur during the vertical blanking intervals. The VITS format is shown roughly in Figure 7 for the first field. Line 18 of a frame contains a multi-burst signal and Line 19 contains the sin^2 pulse. The VITS are used by the three major networks and provide a good source of in-service waveform monitoring.

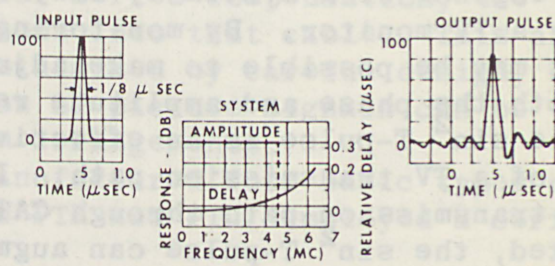
The presence of VIT signals can be seen on any TV receiver by rolling the picture with the vertical hold control. The VIT signals manifest themselves as white dashes and dots in a single line in the vertical blanking area above the top of the picture.

System performance can be measured by comparing the signals into and out of the CATV system on a waveform monitor. Multi-burst and T-pulse waveforms at the output of a test signal generator are shown in Figure 8.



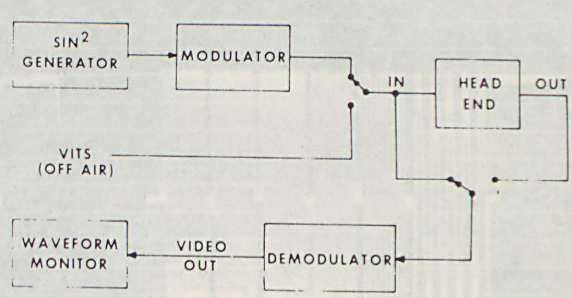
T-PULSE RESPONSE

Fig. 4



EFFECT OF IN-BAND DELAY DISTORTION

Fig. 5

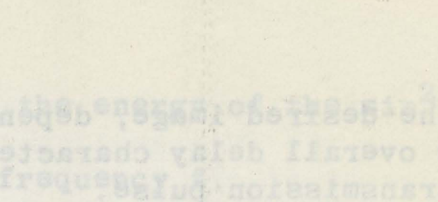


TEST SETUP FOR OBSERVING TRANSIENT RESPONSE OF HEAD END EQUIPMENT

Fig. 6

The sin^2 T-pulse waveform is displayed on a wideband oscilloscope and if passed through a band limited system, it would have undershoots and overshoots symmetrical with respect to its ordinate through peak amplitude (refer to Figure 4). Any assymmetry in the T-pulse response indicates the presence of delay distortion. The multi-burst is an effective means to check the amplitude response of the head end or entire system.

At the present time, most equipment is aligned for a specific amplitude response. The phase and delay response which result from the given amplitude response is then accepted. It is difficult to optimize the phase response of a system by only viewing a TV monitor. By monitoring the sin^2 T-pulse on a waveform monitor, it may be possible to make adjustments in the equipment which optimize both the phase and amplitude response simultaneously.



VERTICAL-INTERVAL TEST SIGNALS (VITS)

Fig. 7

The sin^2 T-pulse is an effective test signal for evaluating the response of a TV transmission path. It provides a means to evaluate the TV signal transmission path through CATV equipment. Properly applied and interpreted, the sin^2 T-pulse can augment the number of tests already performed on CATV equipment to insure optimum performance.

The sin^2 pulse is included in the VIT signals which are available off the air. Other signals included in VIT are also useful in checking CATV equipment alignment.

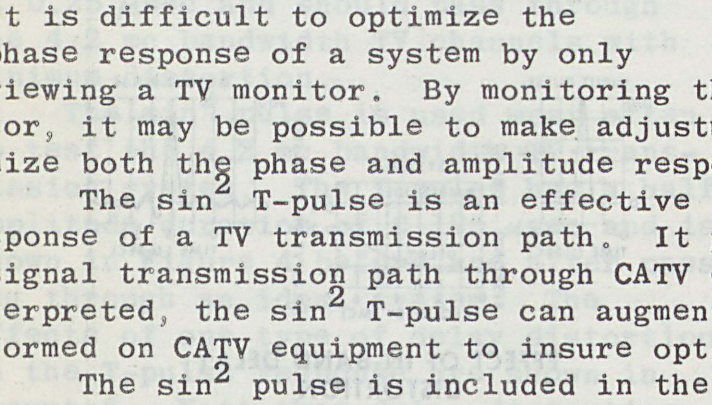
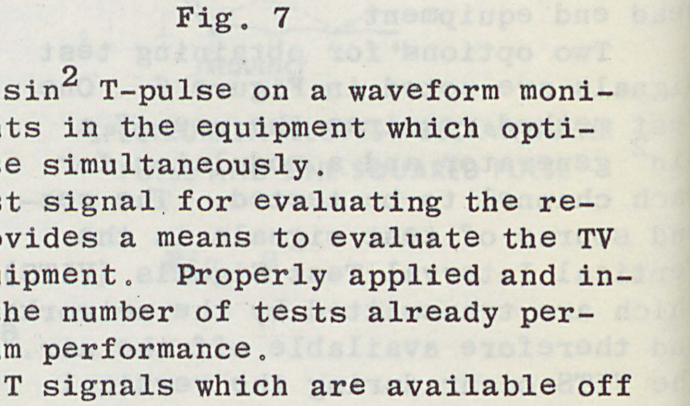


Fig. 8



Multi-burst and Sin^2 T-pulse at Test Signal Generator Output.

too great a deterrent, and the use of pressure taps in other situations.

CHAIRMAN SCHLAFLY: Thank you, Ken. Our next speaker is Mr. Edward Wuermser of Entron Inc., to speak on UHF to VHF converters for CATV.

MR. EDWARD WUERMSER (ENTRON INC.): The general public is showing increased interest in Ultra High Frequency (UHF) TV programs and, therefore, this service must be added to CATV systems. UHF, as transmitted, is at too high a frequency to be compatible with present CATV systems because of the high cable losses (Figure 1) and difficulty in constructing distribution system amplifiers for UHF frequencies. In addition, all present CATV systems would be obsolete, since by present system standards for amplifier spacing, the number of amplifiers required would be increased two and one-half times. Also, the viewing audience would be limited since a majority of existing TV sets do not have all-channel capability; i.e., channel 2 through channel 83. Therefore, conversion to the present VHF frequency band is required.

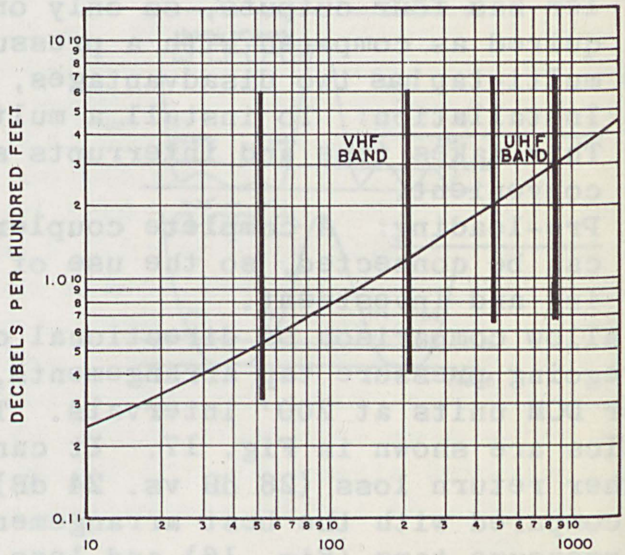


FIG. 1

There are many UHF to VHF converters available for home TVs, but these are unacceptable for CATV head-end use because of high noise figures and frequency drift. Breaking a typical converter into functional blocks (Figure 2) one finds at the input, a tunable filter which, in turn, feeds a diode mixer. The converting local oscillator or (LO) is tunable so that the unit will tune over the entire UHF spectrum. The output of the mixer is fed to a filter to reject the unwanted signals. In some cases VHF amplification is provided. There are variations using a transistor mixer or using one transistor as a mixer-oscillator.

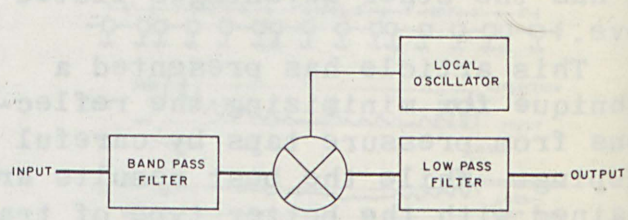


FIG. 2

Considering the noise figure of this type of converter, most of the diodes used for mixing have published noise figures of 14 db to 16 db, with conversion losses in excess of 6 db. Using a 7 db noise figure for the amplifier following the converter, gives an overall noise figure at the head-end of 16.1 db. See Table I.

TABLE I

Noise Figure Improvement Due to UHF PreAmplifier

Configuration	Mixer	Mixer + UHF CABLE Loss	10 db UHF Amp + Mixer
F (db)	16.1	24.5	8.1
$\frac{S}{N}$ (db)	43	35.7	51.1

The signal to noise ratio at the antenna with 1 mV of signal available across 75 ohms and a noise bandwidth of 4 MHz is 59.2 db. This is the maximum signal to noise ratio possible since it contains only the noise generated by the antenna source impedance. Any active device, amplifier or converter, after the antenna adds noise; thereby, decreases the signal to noise ratio. Referring to the example with a 16.1 db noise figure, the S/N = 43 db; which is below the recommended 50 db for head-end equipment.

The previous example did not take into consideration the UHF cable loss from antenna to converter. Applying a typical case, we will use channel 36, 602 MHz, and a 300 ft. run of 1/2" cable having 8.4 db attenuation. The added cable loss causes an increase in noise figure to 24.5 db and a decrease in signal to noise ratio to 35.7 db. This is below the design goal of a 40 db signal to noise ratio at the end of the system.

Consider now the above mixer preceded by a UHF amplifier and mixer mounted at the antenna, thereby deleting the 8.4 db cable loss. This produces an overall noise figure of 8.1 db and a signal to noise ratio of 51.1 db, which is better than the 50 db minimum for optimum system design. This gives a positive indication of the benefits of UHF amplification before conversion.

Next, consider the frequency drift of the inexpensive converters. Most tunable oscillators have long term stability of no better than ±.1%. When a conversion from channel 83 to channel 2 is made, the LO frequency required is 830 MHz. Therefore, the variation could be ±830 KHz and this variation in LO frequency is transferred to the VHF signal. To receive the picture properly, the individual TV set local oscillator would have to be changed in frequency with the fine tuning control. Interference is caused by the converted adjacent channels now being displaced from their normal IF frequencies and the traps for the picture and sound of the adjacent channels are no longer at the right frequency thus allowing these signals to pass through the IF and cause a low frequency beat with the video signal. The variation in frequency is acceptable for an individual set for which the converter was designed since all VHF signals are blocked out by the converter when in use and, therefore, there would be no adjacent channel to cause interference.

By using a crystal controlled oscillator and multiplying the crystal frequency up to the required LO, one can achieve a stability of ±.005%. Using the same LO frequency as in the previous example, ±.005% of 830 MHz is ±41 KHz. This slight variation is not great enough to move the adjacent channel carrier out of the traps and cause interference.

Now that the inadequencies of TV set converters and some of the remedies have been described, let us investigate the requirements of a converter for CATV use and discuss each block in the diagram (Figure 3). The portion within the dotted line will be discussed first.

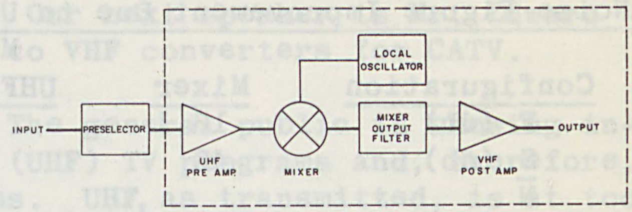


FIG.3

The UHF amplifier can be designed using either tubes or transistors. Present day tubes, ceramic planar triodes, can produce 16 db to 20 db gain with noise figures of 7 db to 9 db across the UHF band. The main disadvantages are high power consumption, the need for 2 to 3 separate supply voltages and the limited life due to the decrease in cathode emission.

Transistors, on the other hand, have lower gain, 6 db to 10 db, but also lower noise figures, 3 db to 6 db. The benefits are that only one supply voltage is required and there is no deteriation in performance with aging of the device. The shortcomings are temperature sensitivity, very little isolation between the input and output, and emitter peaking is required to obtain usable gain.

The next block is the mixer. Just as non-linearities in amplifiers cause the generation of frequency components other than those injected at the input, so will any active device, when operated non-linearly, generate frequencies other than those supplied to it. If two frequencies are injected at the input, the output will contain the two original frequencies; the sum and difference frequencies; harmonics of the frequencies, and all combinations of the sum and difference of the harmonics. A CATV converter uses the difference frequency f_1-f_2, where f_1 is the UHF signal and f_2 is the LO.

Conversion of the signal frequency with the lowest possible noise figure is the primary function of the mixer with the least loss possible. The LO, in many cases, is close in frequency to the UHF signal, therefore, care must be taken to avoid absorption of signal power by the LO source since this will decrease the available input power. Consequently, loose coupling of the LO source to the mixer is necessary, causing a loss of LO power.

The LO power delivered to the mixer diode should be greater than the signal power so that the conversion loss is determined by the LO level and not the signal level. There is a maximum limit for the LO power level delivered to the diode since as LO power is increased, the noise generated in the diode increases (Figure 4), Therefore, a trade off between high LO power for minimum conversion loss and low LO power for minimum noise generated is necessary. One other factor to consider is the change in conversion loss versus a change in LO power. As shown in figure 4, the conversion loss decreases with increasing LO power until it reaches saturation and then levels off. Operating above the knee of the curve has the advantage in that small variation in LO power level will not appreciably affect the conversion loss.

Next, we will consider the local oscillator block. As was described earlier, an oscillator operating at the LO frequency has one serious drawback. It does not have the stability required for a CATV converter, therefore a crystal oscillator-multiplier must be used. Owing to the high level required for Class C multiplication and the poor isolation of transistors, the final output of the multiplier string will contain spurious outputs which are multiples of the crystal frequency. Extensive filtering and use of overtone oscillators will decrease the level and the number of these spurious. One point to emphasize is the fact that the LO level at some points in the oscillator-multiplier may be one volt while at the mixer the signal level is only one mV. This is a 60 db difference and adding to this the requirement that spurious responses in the band be down at least 50 db from signal gives a required 110 db rejection between various points in the circuit. This virtually predicates the need for the crystal frequency to be chosen such that no multiples of the crystal frequency will fall in the output band. Since crystal activity and consequently oscillator output power decreases with increasing order of overtone, overtone crystals greater than the 7th overtone are not generally used. The choice of crystal frequency is therefore a compromise between the closeness of spurious frequencies and the activity of overtone crystals.

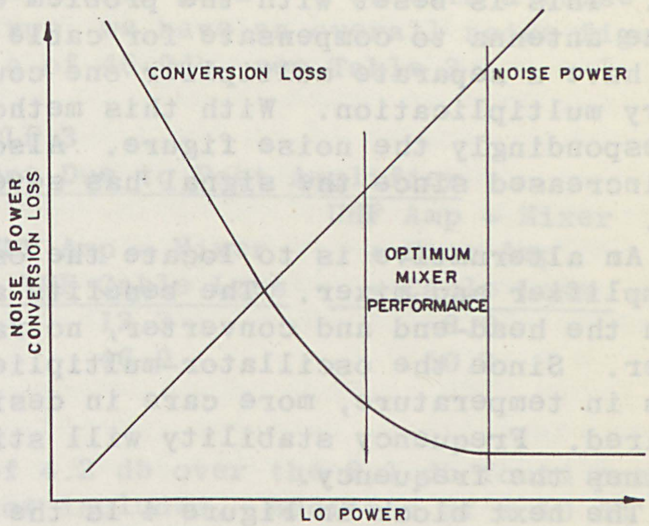


FIG. 4

The benefits of locating the UHF preamplifier and mixer at the antenna have already been shown. Next for consideration is the location of the oscillator-multiplier. Locating it in the head-end has benefits in that the design is less rigorous and less expensive parts may be used since the temperature variations in the building are not as severe as at the antenna. In addition, should maintenance be required, it would be much easier. There are several undesirable features; these being, the need for two cables interconnecting the LO and mixer, or for the single cable operation, the need of diplexers to separate signal and LO at each end of the cable. For low VHF band conversion this is no great problem since the LO frequency is well removed from the signal frequency; i.e., for channel 14 to channel 6 conversion, the LO is 388 MHz while the signal is at 88 MHz. Isolation of these two frequencies would not be too difficult. But when one considers a conversion of channel 14 to channel 13 with the need for a 260 MHz LO and signal frequency of 216 MHz, it is quite evident that the diplexer will necessarily be complex or impossible to realize.

Another factor is the cable loss from head end to antenna. To maintain the proper LO power level at the mixer, the LO power at the head-end would have to be increased to compensate for this loss. Increasing the power at the head-end compounds the problem of radiating the multiples of the crystal frequency into other head-end equipment and causing interference on other channels.

An alternative is to generate 1/2 or 1/3 of the LO frequency at the head-end and complete the multiplication at the mixer to decrease cable loss. This is beset with the problem of amplifying the sub LO frequency at the antenna to compensate for cable loss before multiplying. Rather than have a separate multiplier one could use the mixer diode for the necessary multiplication. With this method the conversion loss increases and correspondingly the noise figure. Also the spurious and image problems are increased since the signal has several high level frequencies to mis with.

An alternative is to locate the oscillator-multiplier with the UHF preamplifier and mixer. The benefits are the need of only one cable between the head-end and converter, no radiation problems and no complex diplexer. Since the oscillator-multiplier will be exposed to greater variations in temperature, more care in design and choice of components will be required. Frequency stability will still be $\pm$.005% since the crystal determines the frequency.

The next block in Figure 4 is the mixer output filter, which must reject the UHF signal, the LO frequency and all spurious-signals in the VHF output band while passing the required VHF signal with minimum loss. In addition, its input impedance must be matched to the mixer at the VHF frequency and its output impedance matched to the line or input impedance of the post amplifier. The filter input should also exhibit a low impedance to the UHF signal and LO, if a series mixer is used, and a high impedance if a shunt mixer is used. Generally, the frequencies generated in the mixer are sufficiently removed from the desired signal and simple filtering will prove adequate, except when the second harmonic of the LO minus the signal falls in the desired band, $2F_{LO}-f_{UHF}=f_{VHF}$. This is impossible to prevent and therefore, these conversions must be avoided. See Table 2.

TABLE 2

List of Impossible and Undesired UHF Conversions

	Undesired 1	Impossible 2	Undesired 1	
From ch.	22	23,24	25	to ch. 7
From ch.	25	26,27	28	to ch. 8
From ch.	28	29,30	31	to ch. 9
From ch.	31	32,37	34	to ch. 10
From ch.	34	35,36	37	to ch. 11
From ch.	37	38,39	40	to ch. 12
From ch.	40	41,42	43	to ch. 13

1- Undesired because of image frequency on adjacent channel
2- Impossible because of image frequency on same channel

Continuing through the block diagram, we come to the last block which is the VHF Post Amplifier. The need for this is based on maintaining the established noise figure of the converter. Since some antenna towers are quite high, consideration of cable loss at VHF must still be taken into consideration. If a VHF post amplifier were not used, the mixer would drive the cable and the cable loss would be added directly to the conversion loss. Citing the example used previously, UHF amplifier gain 10 db with a noise figure of 4 db, mixer gain - 6 db with a noise figure of 14 db, and a 600 ft. cable run; we have an overall noise figure of 12.3 db and a signal to noise ratio of 46.9db, see Table 3.

TABLE 3

Noise Figure Improvement Due to Post Amplifier

Configuration	10 db UHF Amp + Mixer	UHF Amp + Mixer + VHF Cable Loss	UHF Amp + Mixer + Post Amp + Cable Loss
F (db)	8.1	12.3	8.9
S/N (db)	51.1	46.9	50.3

This is an increase in noise figure of 4.2 db over the 8.1 db found previously when the VHF cable loss was not included. Addition of a 10 db gain, 7 db noise figure post amplifier results in an overall noise figure of 8.9 db which is only a 0.8 db increase and a signal to noise ratio of 50.3 db. Further improvement in noise figure could be obtained by either increasing the UHF preamplifier gain or decreasing the post amp noise figure.

In many areas there are UHF stations separated by only two to four channels. Closely spaced channels can produce interference when they mix with multiples of the crystal frequency. Also, the received power level of undesired channels may be great enough to overdrive the UHF preamplifier. To alleviate this condition, a highly selective filter is necessary.

The requirements for such a device are, first of all, a low insertion loss, since the loss can be considered as adding directly to the noise figure. The bandpass should be wide enough to pass the desired channel but with approximately 20 db rejection 6 MHz to either side of the bandpass. The extremely narrow bandwidth and high close-in rejection predicates a high insertion loss. Consequently, a compromise must be made between low insertion loss and selectivity.

There are many basic types of filters, some of these being lumped constant, helical resonator, tuned line, cavity and strip line. Lumped constants can not be used since the frequency is too high for effective use. The helical resonator degenerates to the equivalence of a tuned line due to the high Q required. Strip line techniques cannot be used to full advantage since the frequency involved is too low. This leaves the tuned line and cavity as the most likely candidates for filter construction at VHF.

CHAIRMAN SCHLAFLY: Thank you very much, Ed. The Jerrold Handbook is available at the back of the room.

The next paper will be delivered by Clay Mahronic. The title of the paper is, "Effects of Cable Length and Attenuation on Structural Return Loss." Mr. Mahronic graduated from the Illinois Institute of Technology

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