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.

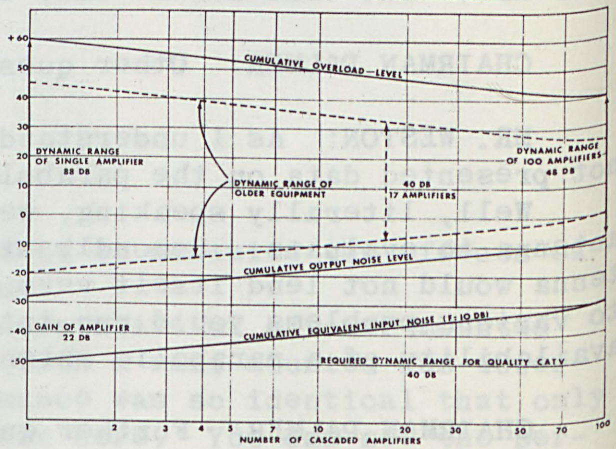
Our next speaker is Bill Rheinfelder, Anaconda Astrodata. Bill was staff consultant at Motorola, high frequency applications 1957 to 1961. During the end of this period he also acted as a consultant for AMECO and left Motorola at that, somewhat thereafter, to go to AMECO as Director of R&D. Then in 1965 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.

FIG. 1 AMPLIFIER AND SYSTEM DYNAMIC RANGE



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!

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.

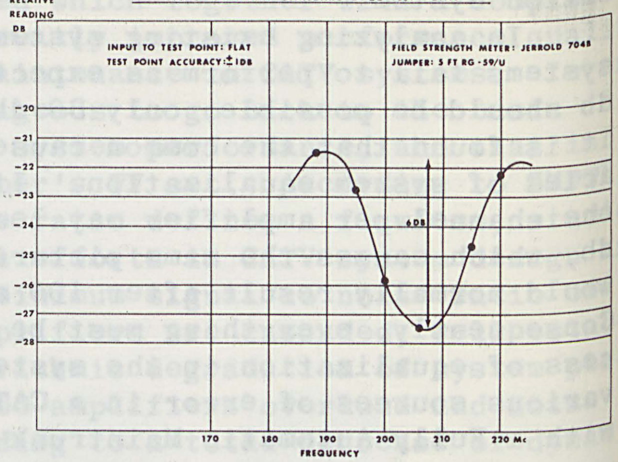
Foremost among the error sources are jumper cables [1]), external to equipment, or internal. Although it has been pointed out repeatedly that jumper cables are incompatible with quality system design, they still are the major offender. No matter how short or long, a jumper always causes trouble. With 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 sum. 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.

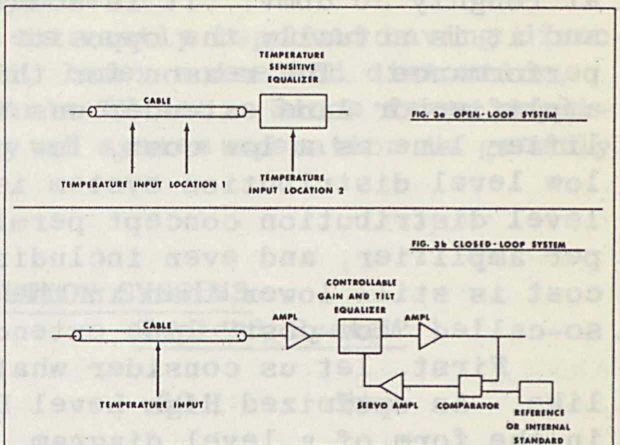


FIG. 3 BASIC TEMPERATURE COMPENSATION SYSTEMS

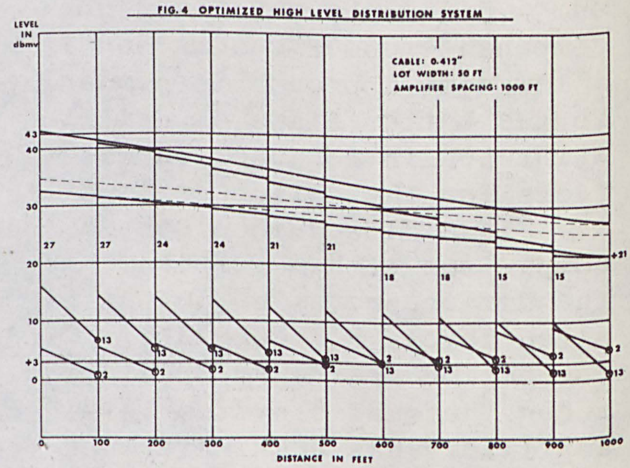
In a closed-loop system, the actual error signal is determined by comparison with a reference signal and a correction is made so as to null the difference. The output signal is then automatically kept at the desired level. (Figure 3b). Circuits for automatic spacing and temperature correction are based 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.