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 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:

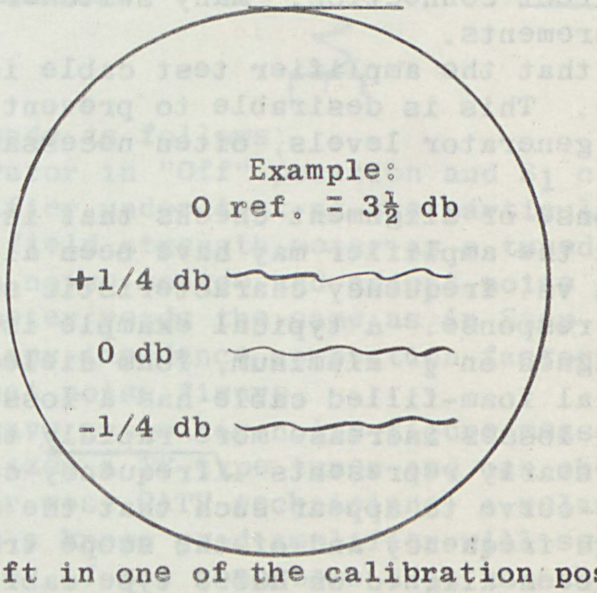
1. The amplitude response flatness should be typically $+\frac{1}{4}$ db or better over the frequency range of interest.

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.

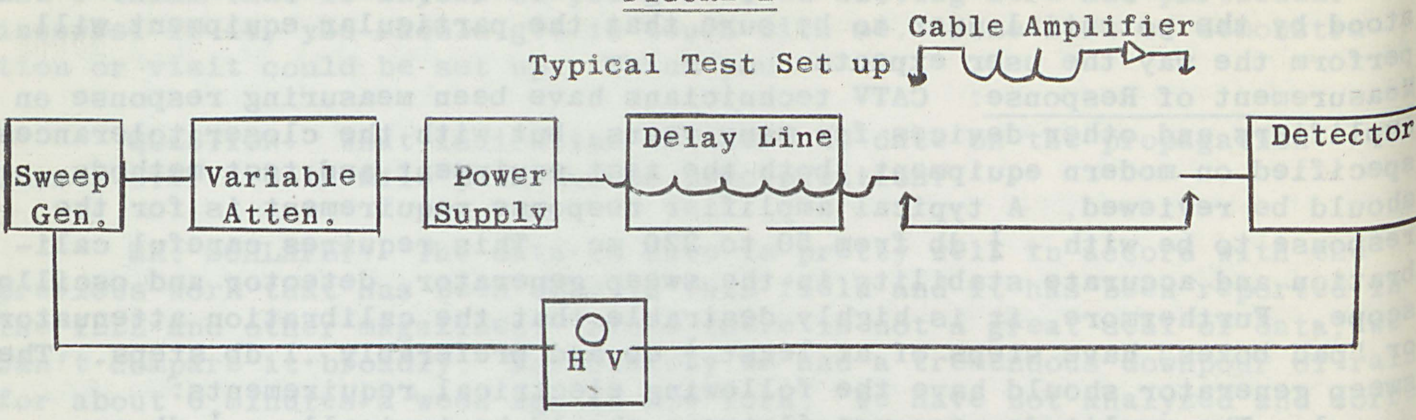
FIGURE 1



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.

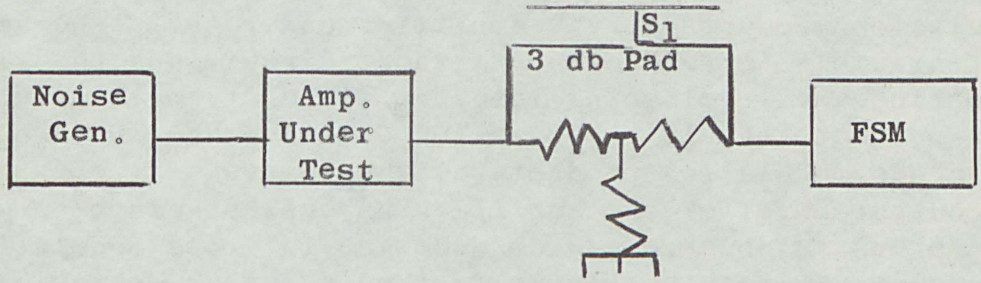
One factor in response or alignment checks that is frequently overlooked, is the fact that the amplifier may have been aligned using a cable which has an attenuation vs. frequency characteristic slightly different than that used to check response. A typical example is to test a mainline amplifier, which was aligned on ½" 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 end 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