increase the level in dbs, then you multiply the cross-mod by the number that is in the second column. But, again, as I said, there are many right ways of doing this thing and none is better than the other. Some are only more convenient. Thank You. (Applause)

MR. TAYLOR: Thank you, again, Dr. Shekel, very much. Maybe somebody will volunteer to be chairman of the Standards Committee. You can see the problems that arise in those deliberations.

Our next presentation will be on a subject that is somewhat new in this industry, Envelope Delay in CATV. Gaylord Rogeness from AMECO in Phoenix, Arizona, is our speaker, and his background, biographical sketch has been placed in your hands. Mr. Rogeness.

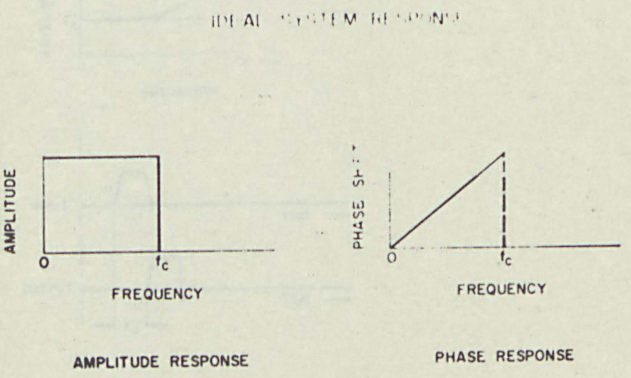
MR. GAYLORD ROGENESS: Thank you, Mr. Taylor. This morning I'm going to speak to you on the subject of Envelope Delay in CATV Systems.

Comparison of pictures produced by off-the-air signals and signals that have been transmitted through long cascades indicate that the off-the-air signal produces a sharper, more crisp picture. This effect is also more noticeable on low band channels compared to the high band channels. The low band channels produce a picture that is somewhat more fuzzy.

These effects exist even though the amplifier cascade has been aligned for optimum amplitude response, the cross modulation is at a minimum level, and the signal-to-noise ratio is high. Envelope delay distortion is a quantity which can explain some of these effects. Until recently, CATV systems have been providing pictures in areas where TV reception has not existed or has been very poor. Hence, there was little need to consider the more subtle transmission system requirements. However, as CATV moves into areas where competition with off-the-air reception exists, and the transmission of good color pictures is required, the effects of envelope delay have to be considered.

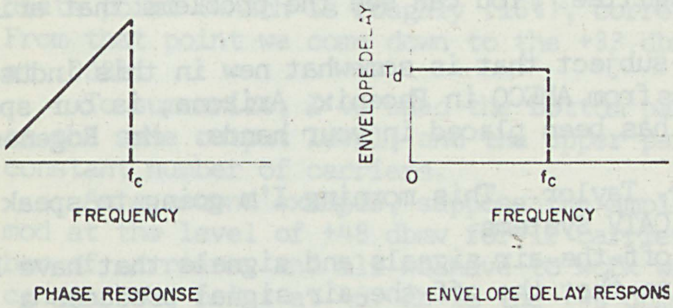
The objectives of my paper this morning are first to define envelope delay. Second, discuss the effects of envelope delay distortion of TV pictures. Third, discuss the sources of envelope delay, or where does envelope delay originate in the CATV transmission system? And finally, suggest possible measurement techniques and solutions to the problem of envelope delay distortion.

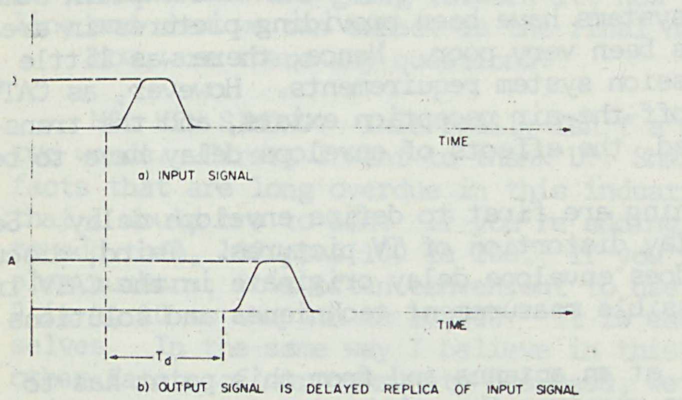
The CATV system receives a TV signal at an antenna and from this point has to transmit the TV picture signal to the home receiver through head-end equipment, cable and repeater amplifiers. Therefore, the transmission characteristics of this equipment should be as close to the ideal transmission characteristic as possible in order to provide the home receiver with the same picture quality that is received at the CATV antenna.



An ideal system has a flat amplitude response with respect to frequency and a phase shift characteristic that is linear. This is shown in FIGURE ONE. FIGURE TWO shows phase and delay characteristics of the ideal system. Envelope delay is defined as the rate of change of phase shift with respect to frequency. Or, in other words, envelope delay is the incremental slope of the phase shift curve versus frequency. In an ideal system the phase response is linear, so that the incremental slope of the phase response is constant. Hence, each frequency has the same value of envelope delay. It should also be noted that in an ideal system, time delay and envelope delay are equal.

IDEAL SYSTEM RESPONSE

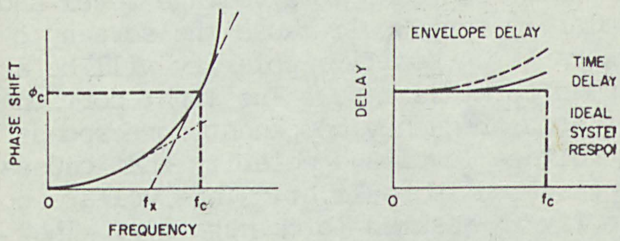




A TV picture signal consists of a sum of pulses which in turn are the sum of many frequency components. When this signal is transmitted through an ideal transmission system, each frequency component experiences the same delay. As a result, the TV picture signal at the output of the transmission system is the same as that at the input but delayed in time. FIGURE 3A shows a pulse applied to the input of a CATV system. If the ideal characteristic of flat amplitude and linear phase over the band of frequencies being transmitted exists, the output will be a delayed replica of the input as shown in FIGURE 3B. The output pulse waveform will be exactly the same as the input pulse waveform and will occur at a later point in time.

The difference between envelope delay and time delay is shown in FIGURE FOUR. These quantities are compared at the frequency f_c. Time delay is the phase shift at this frequency divided by the frequency, whereas envelope delay is the slope of the phase response at the frequency f_c. Note that the magnitude of envelope delay is larger than the time delay magnitude.

RELATION BETWEEN TIME DELAY AND ENVELOPE DELAY



PHASE vs FREQUENCY DELAY vs FREQUENCY

TIME DELAY = $\frac{\phi}{f_c}$

ENVELOPE DELAY = $\frac{\phi}{f_c - f_x}$

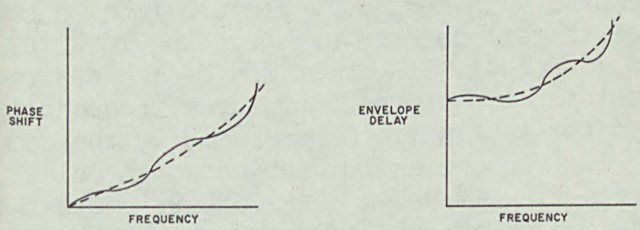
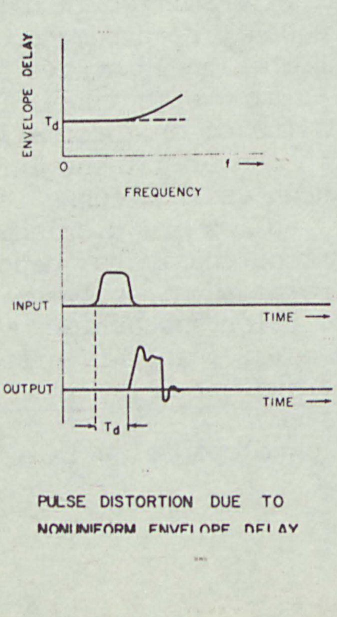


FIGURE 5. PHASE AND DELAY DEVIATION FROM LINEARITY. (NOTE THAT THE DOTTED LINE INDICATES THE SLOW DEVIATION FROM LINEARITY)



PULSE DISTORTION DUE TO NONUNIFORM ENVELOPE DELAY

FIGURE 4B shows a rough comparison of envelope delay and time delay over the frequency range of interest.

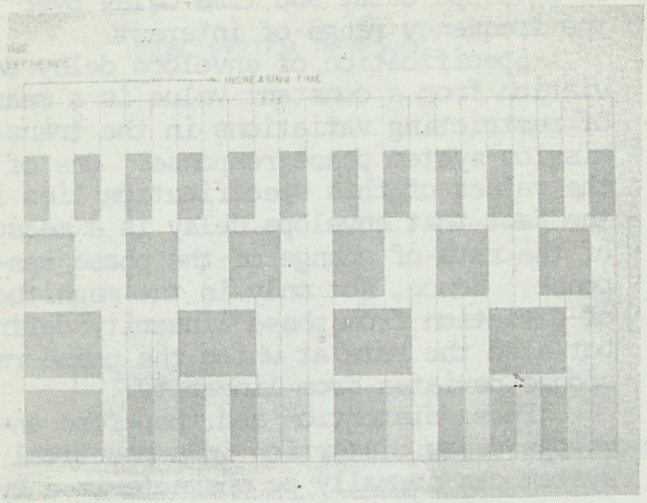
Specification of envelope delay deviation from a constant value is a means of restricting variations in the transmission system phase response. One of t the values of this specification lies in the fact that envelope delay is a measure of the rate of change of the phase response. Hence, not only is the magnitude of deviation from phase linearity defined, but also the rate at which the phase response deviates from linearity.

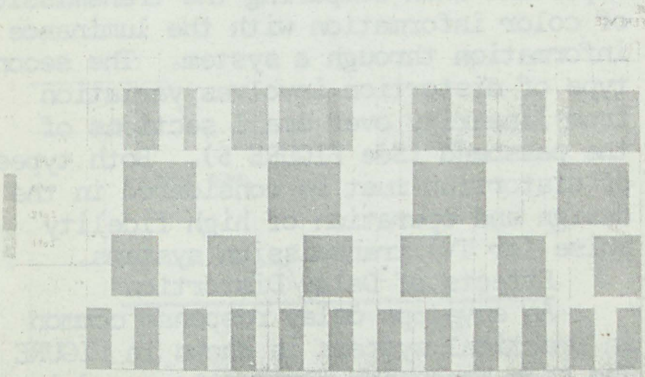
Phase distortion and therefore envelope delay distortion in a practical system can normally be characteriz-e by two descriptions. One is a gradual deviation from the linear phase characteristic, occurring over the major portion of the system passband. This distortion is important when comparing the transmission of color information with the luminance information through a system. The second type of distortion involves variation from linearity over small sections of the passband (See FIGURE 5). Both types of distortion must be considered in the design and operation of high fidelity pulse (or TV) transmission systems.

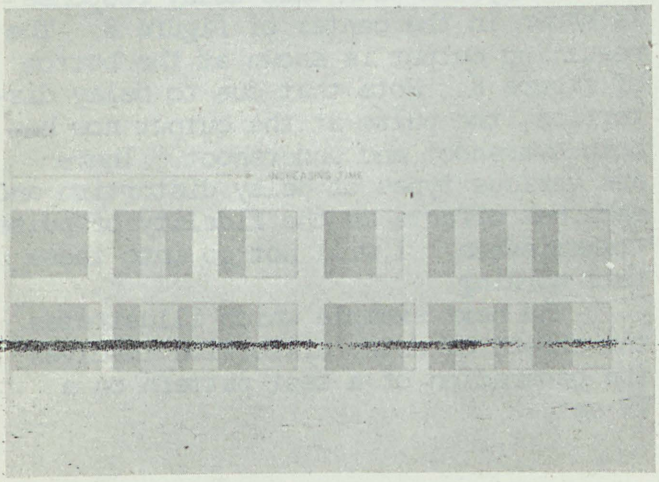
Effects of Delay Distortion

An envelope delay response common in practical systems is shown in FIGURE 6. The high frequency components are delayed by a greater amount than the low frequency components. A pulse applied to the transmission system with this delay response is shown in the center of figure 6. The resulting output is shown at the bottom of figure 6. Note that due to delay distortion, the pulse at the output now has both overshoot and undershoot. There are various types of delay distortion and each has effects on the fidelity of pulse transmission. I will not go into these this morning.

The next example which illustrates the effect of delay distortion involves the generation of a test pattern on a TV set.







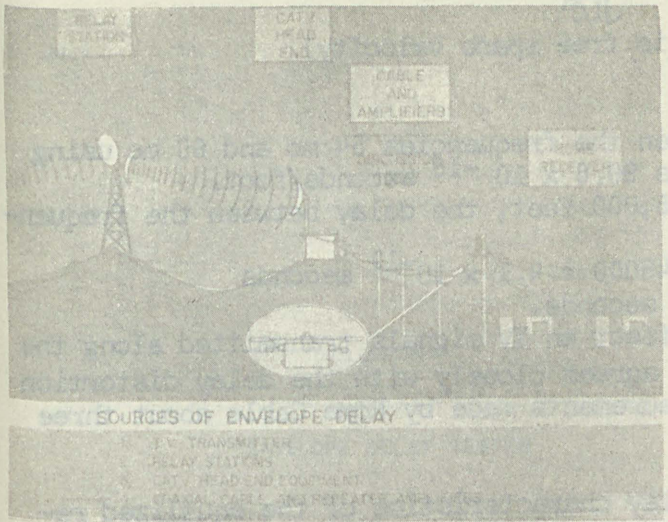
The bottom line of FIGURE 7 shows the desired test pattern. This test pattern is generated by the sum of three frequencies occurring in the time phase shown. The black portion of each frequency component shown corresponds to a voltage level and polarity that would cause the screen to be dark. A positive polarity will be assumed for this case. The light portion of each frequency component corresponds to a voltage level and polarity that causes the screen to be light. This voltage polarity is assumed to be negative. The darkest portion of the composite test pattern is then generated when all three positive voltages add at the same time. The dark gray is produced when only two positive voltages add. A completely white bar is produced when the negative voltages of all three frequency components add at the same time.

When all three frequency components are not delayed by the same amount during transmission to the TV picture tube, a composite test pattern as shown in FIGURE 8 could result. A comparison of the desired test pattern produced by three frequencies and the test pattern generated by the same three frequencies but subjected to delay distortion is shown in FIGURE 9. Note that the distorted pattern does resemble the desired pattern.

Consider next the effects of time delay distortion on a color picture. The color picture is composed of two main signals - the chrominance information which contains color information and the luminance signal which contains the brightness information. These signals are transmitted in different parts of the frequency spectrum, so it is important that both signals arrive at the TV picture tube at the same time. Due to delay distortion the color information may not coincide with the brightness information and an effect known as the "funny paper effect" occurs. Colors are displaced to the right or left of the image, depending upon the delay relationship between the picture carrier and color subcarrier. The red color is most sensitive to this effect.

Sources of Envelope Delay in a TV Transmission System

Sources of envelope delay in a TV trans-



mission system are depicted in FIGURE 10. A responsibility of the TV station is to transmit TV program material over the air. In so doing, the TV signal passes through equipment which have amplitude and phase characteristics that are frequency dependent.

Next a relay station may be necessary before the CATV system received the signal. This relay station is a second source of distortion in the system.

The CATV system consists of head end equipment, coaxial cable, and equalized amplifiers. Each of these three items is a potential source of distortion.

The signal finally arrives at the home receiver where it is processed and displayed. Many sources of amplitude and delay distortion exist in a TV set that is not properly aligned.

The FCC regulates the characteristics of the color TV signal being transmitted. The TV transmitter must have a prescribed envelope delay characteristic. This delay characteristic is specified to compensate for the delay distortion produced in the frequency selective circuits of the home receiver. The manufacturers of TV receivers use the specified delay characteristics of the transmitter to set design and manufacturing tolerances on their TV sets. Therefore, any picture transmission equipment placed between the TV transmitter and home receiver must be near perfect in order to minimize distortion.

Phase characteristics of the coaxial cable and equalized repeater amplifiers used in CATV systems will be discussed at some length today.

Phase Characteristic of Coaxial Cable

The transmission of energy along a coaxial cable is defined by the complex propagation constant. The propagation constant has a real and imaginary component. The real part describes attenuation along the cable and the imaginary component defines the phase shift constant of the coaxial cable. The propagation constant is

$$\gamma = \sqrt{(R+jwL)\,(G+jwC)} \quad (1)$$

For low loss cable, such as that used in the CATV industry, it is possible to simplify equation one and write the phase shift constant

$$\beta = \sqrt{LC}\,\left[1 + \frac{1}{8}\left(\frac{R}{WL}\right)^2\right] \quad \text{radians/unit length} \quad (2)$$

R, L., and C are the cable resistance, inductance, and capacitance per unit length and w is 2π times the frequency in cycles per second.

Remembering that envelope delay is the rate of change of phase shift with respect to frequency, the derivative of equation 2 yields the cable envelope delay.

$$T_E = \frac{dB}{dw} = \sqrt{LC}\,\left[1 - \frac{1}{8}\left(\frac{R}{WL}\right)^2\right] \quad \text{seconds/unit length} \quad (3)$$

Note that envelope delay is not constant with frequency because of the $\left(\frac{R}{WL}\right)^2$ term. However, the magnitude of this deviation from a constant value is small enough to have negligible effect. A numerical example will show this:

Constants taken from a cable manufacturer's data sheet for 75 ohm Alucel 1/2" coaxial cable are

Capacity $C = 16.5$ pf/foot

Velocity of Propagation $V_c = 0.82\ V_o = \frac{1}{\sqrt{LC}} = 7.87 \times 10^8$ ft/sec

Attenuation (V_o is free space velocity)

$\alpha = 0.006$ db/ft at 54 mc

$\alpha = 0.0065$ db/ft at 60 mc

The difference in envelope delay between the frequencies 54 mc and 60 mc using the cable constants listed and equation 3 is 90.6×10^{-18} seconds/foot.

For a 30 amplifier cascade extending 45,000 feet, the delay between the frequencer 54 mc and 60 mc is

$$T = 90.6 \times 10^{-18} \times 45000 = 4.1 \times 10^{-12} \text{ seconds}$$

$$T = 4.1 \text{ micro-micro seconds.}$$

This delay distortion has negligible effect on TV signals transmitted along the cable. This number of 4.1×10^{-12} seconds agrees closely with the delay distortion calculated from velocity of propagation measurements made by Rome Cable about three years ago.

Repeater Amplifier Delay Characteristics

The next problem is to describe the delay characteristics of the equalized repeater amplifier. A theoretical response for the equalized repeater amplifier was postulated for an 18db length of cable. The amplifier response was assumed maximally flat at both the low and high end. The high end roll off was assumed more steep than the low end because of the cut off characteristics of the transistors.

The transfer function of an equalized amplifier can be written:

$$\frac{e_{out}}{e_{in}} = \left[\frac{1 + j\frac{w}{w_1}}{1 + j\frac{w}{w_2}}\right]\left[\frac{\left(j\frac{w}{w_3}\right)^n}{\left(1 + j\frac{w}{w_3}\right)^n}\right]\left[\frac{1}{\left(1 + j\frac{w}{w_4}\right)^m}\right] \quad (4)$$

To calculate the envelope delay of this expression the phase response is first derived and is

$$\text{Phase} = \tan^{-1}\left(\frac{w}{w_1}\right) - \tan^{-1}\left(\frac{w}{w_2}\right) + 90^\circ = \tan^{-1}\left(\frac{w}{w_3}\right)^n - \tan^{-1}\left(\frac{w}{w_4}\right)^m \quad (5)$$

The envelope delay is the derivation of equation 5 with respect to w ($2\pi f$).

$$T = \frac{1}{f_1}\left[\frac{1}{1+\left(\frac{w}{w_1}\right)^2}\right] - \frac{1}{f_2}\left[\frac{1}{1+\left(\frac{w}{w_2}\right)^2}\right] - \frac{n}{f_3}\left[\frac{\left(\frac{w}{w_3}\right)^{n-1}}{1+\left(\frac{w}{w_3}\right)^{2n}}\right] - \frac{m}{f_4}\left[\frac{\left(\frac{w}{w_4}\right)^{m-1}}{1+\left(\frac{w}{w_4}\right)^{2m}}\right] \quad (6)$$

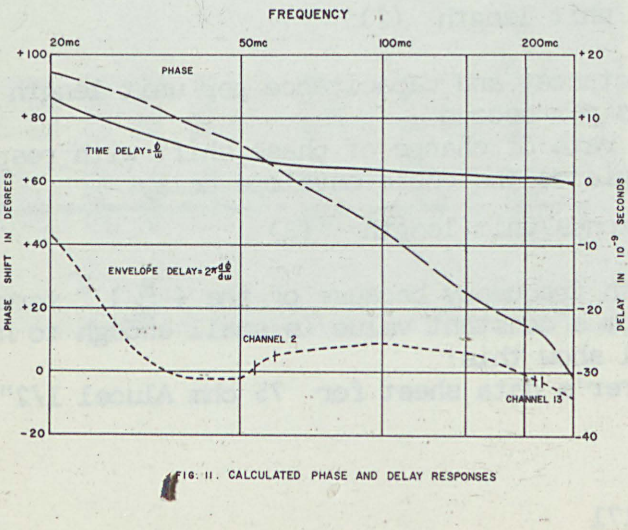


FIG. 11. CALCULATED PHASE AND DELAY RESPONSES

Phase, time delay, and envelope delay were calculated as a function of frequency using equation 5 and 6 are shown in FIGURE 11. The following values were used in the calculations:

$w = 2\pi f$

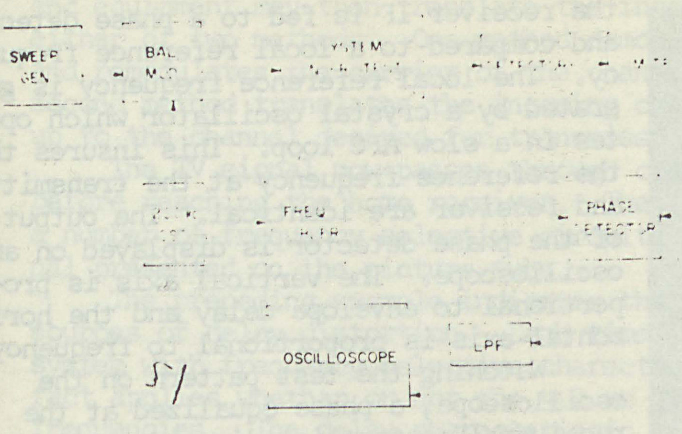
$w_1 = 2\pi \times 49.5 \times 10^6$ $\quad n = 2$

$w_2 = 2\pi \times 334 \times 10^6$ $\quad m = 4$

$w_3 = 2\pi \times 40 \times 10^6$

$w_4 = 2\pi \times 250 \times 10^6$

Note that envelope delay is not constant with frequency as is required for an ideal transmission system. Also note that channel 2 is more susceptible to response irregularities than channel 13 because it occupies a higher percentage bandwidth.



ENVELOPE DELAY TESTER

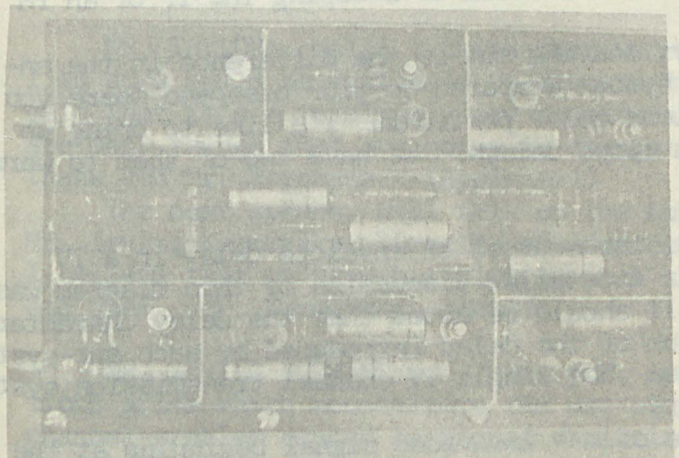
(6 mc bandwidth at 54 mc compared to 210 mc).

Envelope Delay Testing

A block diagram of a test set that measures envelope delay is shown in FIGURE 12. The 200kc reference oscillator output is applied to a frequency doubler and balanced modulator. The second input to the balanced modulator is a sweep generator. The output of the balanced modulator is two frequencies spaced at twice the reference oscillator frequency. These two signals are applied to the system under test and are swept across the frequency spectrum maintaining a constant spacing.

The test signals are detected at the output of the system under test and then passed through a limiter. The test signal at the output of the limiter is then compared in a phase detector with the output of the frequency doubler. Each of these signals is at the same frequency. However, the doubler output has a constant phase reference while the signal passed through the system under test is measuring the incremental slope of the system phase response. The output of the phase detector is a DC voltage proportional to the envelope delay of the system under test.

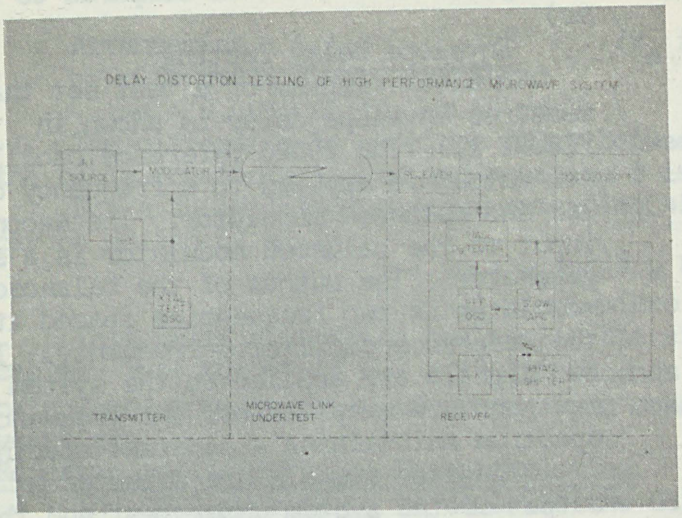
The oscilloscope displays envelope delay on the vertical axis and frequency on the horizontal axis. The vertical scale can be calibrated in terms of electrical degrees or directly in units of time (microseconds or nanoseconds). A frequency marker can be inserted into the test set for calibration of the horizontal scale.



An envelope delay test set was constructed by utilizing the principles described in the preceding three paragraphs. This test set is shown in FIGURE 13. Unfortunately, time did not permit the completion of many delay measurements before the convention. However, the envelope delay of a cascade of three AMECO ATM-70 amplifiers and 75 db (220mc) of coaxial cable was measured. The envelope delay characteristic was constant from 40 mc to about 90 mc and then began gradually sloping through the high band. The difference in delay across any high band channel was less than three nanoseconds (3×10^{-9} seconds).

The purpose of this next example is to point out that phase distortion, and hence delay distortion, can be measured and corrected in the field even though the transmitted and received signals are physically separated by large distances. The block diagram of a test set used by a manufacturer of microwave equipment to measure delay distortion of a microwave link is shown in FIGURE 14 (next page).

The crystal reference oscillator operates at about 500kc and modulates the RF source. The reference oscillator frequency is divided down to provide a sweep voltage to sweep the RF source through the passband of the transmission system. The swept RF signal is transmitted over the microwave link and is received at the remote



location of the receiver. The output of the receiver IF is fed to a phase detector and compared to a local reference frequency. The local reference frequency is generated by a crystal oscillator which operates in a slow AFC loop. This insures that the reference frequency at the transmitter and receiver are identical. The output of the phase detector is displayed on an oscilloscope. The vertical axis is proportional to envelope delay and the horizontal axis is proportional to frequency.

Watching the test pattern on the oscilloscope, a phase equalized at the receiver IF output is adjusted until the transmission system delay distortion is minimized.

Today I have defined envelope delay as the rate of change of the transmission system phase response. Some of the effects of delay distortion on the transmission of TV pictures were mentioned as a loss of crispness of the black and white signal and a funny paper effect on color pictures.

I believe that we must now develop test equipment to accurately measure the CATV system delay characteristics. After the delay characteristics have been measured, phase and/or delay equalizers can be designed to compensate for existing delay distortion. Thank you. (Applause)

MR. TAYLOR: Thank you very much. I think we would have time for one or two questions if somebody would like to. I see one here.

MR. WILLIAM CRUZ, (Collins Radio): I think it should be important at this point and time with your fine speech here to separate the distinction of envelope delay of your sweeping, the RF spectrum where cable activities -- it's all very proper, very correct. I agree with you completely. Your discussion of sweeping the IF of an FM or microwave system is also correct.

One other thing you are, sorry to say, leaving out is the difference in the envelope delay of your RF system or your IF system compared to your baseband where you are considering the envelope delay of various color portions. I'd like to bring up the point that they are quite different envelope delays. We have two of them to worry about. Thank you.

MR. ROGENESS: Referring to figure 10, the sources of envelope delay in a TV transmission system are shown pictorially. A detailed discussion of this diagram was not made because of the time limitation. It should be noted that the delay characteristic of a linear system is equal to the sum of the delay introduced by each sub-system contributing to the overall system response. The single TV channel transmission system delay characteristics are of importance here.

As an example, follow the transmission of a 4.2mc video signal beginning at the output of the TV camera at the broadcast studio and ending at the home receiver. In the transmission of this 4.2mc video signal from the broadcast studio to the home receiver, the video signal will be translated a number of times. For example, the video signal at the broadcast studio is mixed or translated to an RF frequency for broadcast. A microwave relay station may then receive this signal, translate it to IF frequencies and amplify it, and then mix back up to a microwave frequency for transmission at microwave. The next relay station may then translate the signal from microwave back to RF frequencies for re-transmission.

At this point a CATV system may receive the signal off the air. The CATV head-end equipment may then translate the incoming channel to a different channel by either of two methods. One method demodulates the incoming TV channel to baseband and remodulates the carrier of the channel to be transmitted over the cable. A second method translates the incoming channel down to IF frequencies and then back up to the channel desired for transmission over the cable.

The TV signal now passes through coaxial cable and equalized repeater amplifiers before reaching the home receiver. The TV signal in the home receiver passes through a number of frequency selective circuits before it is demodulated and the video signal presented on the picture tube.

The preceding example indicates that the 4.2 mc video signal is subjected to many sources of delay distortion. Each time it passes through a network or transmission system with frequency selective characteristics, delay distortion is possible. This fact applies whether or not the 4.2 mc TV signal is at video, IF, RF or microwave frequencies. The delay characteristic of the TV transmission path between TV camera and the TV picture tube in the home receiver is equal to the sum of the delay characteristics of each frequency selective network that the TV signal passes through.

The CATV system has control of the transmission characteristics of the head-end equipment and the cable system. Therefore, from a knowledge of the delay characteristics of the transmission systems external to the CATV system and a knowledge of the overall delay characteristic required to transmit an undistorted TV picture, the CATV system delay response can be specified.

MR. SABIN FLORESCU, from Carlsbad Cable Division: We were talking about envelope problems in the RF transmission systems, just the same way Bill Cruz said it. Our biggest problems are in the modulators. What do we do about them?

MR. ROGENESS: There are two types of phase distortion. One is differential phase which is a cross modulation of the color and luminance signals and is a function of the nonlinearity of the modulator; whereas envelope delay -- or the characteristics I was talking about were related to the phase response of the transmission system which are constant.

The delay response of head-end equipment between CATV antenna and coaxial cable must be constant with frequency in order to solve Mr. Florescu's problems.

MR. TAYLOR: Well, I think that we're running a little behind time. Mr. Rogeness I am sure would be available to discuss this question. I think it can also be safely said that it's a relatively new consideration in our industry and I am sure there are many things that are going to change in the future as a result of this discussion. Thank you Mr. Rogeness. (Applause)

The next speaker will talk on the subject of "Automatic Gain Control in CATV". Mr. Irving Kuzminsky, Director of Advanced Product Engineering of Entron, Inc. And, I believe that we have his biographical sketch to circulate if the pages will circulate them. Mr. Kuzminsky, please.

MR. IRVING KUZMINSKY: Thank you, Archer. In a CATV system, two types of situations arise which necessitate the use of gain control. One is a narrow-band single-channel problem caused by signal variations at the antenna. The other is a wide-band variation in the transmission system caused by changes in either the cable or the amplifiers.

In order for the system to function properly, it is necessary to first eliminate the variations in signal level which are normally encountered at receiving sites. Let us consider what might happen at the customer's receiver if this were not done.

Most present day CATV systems utilized adjacent-channel transmission as a means of most efficiently carrying the maximum number of channels at a minimum cost. However, as far as the receivers are concerned, the adjacent channels are potential sources of interference. This was the reason that, in the early days of CATV, some people thought that adjacent-channel systems would not work. In order for these systems to work properly, it is necessary to accurately control the levels of the signals with respect to each other so that the receiver is able to pick out the selected signal without objectionable interference from other signals.

Once the single-channel signals are combined onto a common line, random variations of these signals would be impossible to handle. This is because the gain of the trunk amplifiers is controlled on a wide-band basis. That is, the gain is varied in a coherent manner to all channels in the amplifier passband simultaneously. With random variation of each channel's signal, cross modulation and noise problems would be encountered in the trunkline system. With some signals going up, some going down, and others remaining constant, gain control would be impossible, and the problems generated are obvious. Thus, stabilization of the antenna signals is mandatory before the signals are inserted into the trunk system.

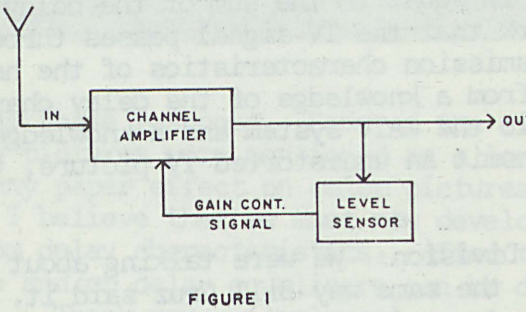


FIGURE 1

The variation in antenna signal level is usually handled by the method shown in FIGURE 1. The signal is amplified in a single-channel RF amplifier. The output signal is detected and provides a DC control signal which is indicative of the output signal level. This control signal is used to vary the operating point of the intermediate stages and, by this means, the gain of the amplifier so as to maintain the output at a nearly constant predetermined level.

FIGURE 2 is a plot of the output level of a typical single-channel AGC amplifier. The amplifier being considered has a gain of 60 db. Curve A indicates that, with no AGC there is a linear relation between input and output except for high levels where the amplifier overloads. Curves B, C, and D show that, for small signals, the output follows the input. However, once the AGC threshold is exceeded, the output remains almost constant. Thus, for proper AGC operation, a minimum signal level is required depending on the setting of an output level control.

This is called "delayed AGC" because gain control is delayed until the threshold signal is reached. Curves B, C, and D represent different delays. The maximum allowable input level is determined by the overload characteristics of the amplifier.

Normally, the input and output stages are not varied, since varying the input stage affects noise figure and input match, and varying the output stage affects the overload level of this stage. Because of these noise and overload limitations, some other method should be used where large signal level variations exist.

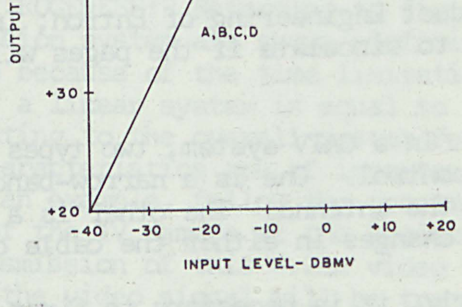


FIGURE 2

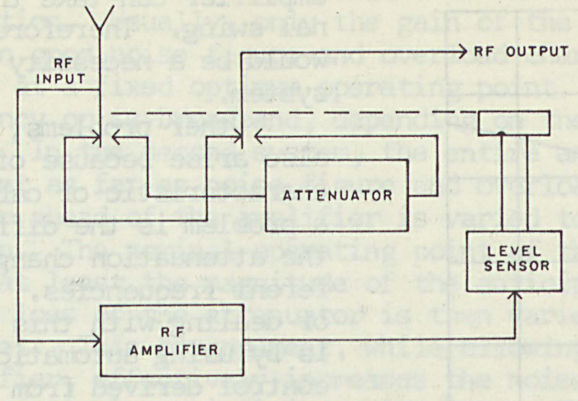


FIGURE 3

FIGURE 3

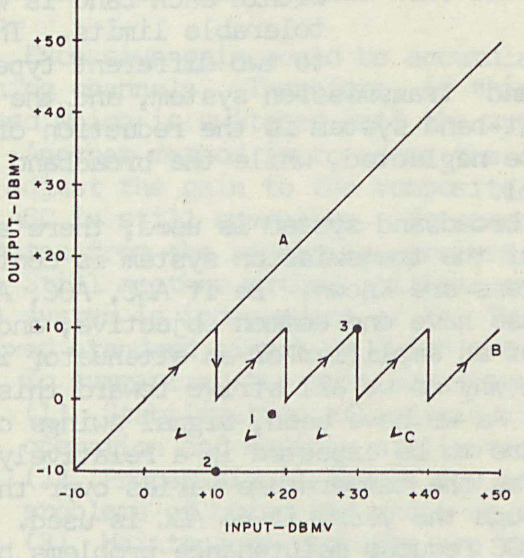


FIGURE 4

FIGURE 4

Consider the block diagram shown in FIGURE 3. The RF input signal is amplified and detected. When the detected signal exceeds a predetermined amplitude a delay is activated and an attenuator is inserted between the antenna and the head end equipment. When the signal decreases sufficiently, the attenuator is removed. A cascade of four such switchable attenuator sections--each section having 10 db attenuation-- effectively reduces a 60 db signal swing to 20 db. This smaller swing can then be handled by the AGC arrangement previously considered.

FIGURE 4 is a typical plot of output level vs. input level for a four-section controller. "A" is a plot of output level vs. input level with no compensation and, and, of course, the changes in output level follow the changes in input level. The output level vs. input level is shown by "B" for increasing, and by "C" for decreasing signal. At any given level, the input can vary over a 20 db range with no switching occurring. For example, at Point 1, with an input of 18 dbmv, two attenuators have been switched in so that the output is 18 - 20 or -2 dbmv. As long as the input signal level remains between +10 and 30 dbmv, no switching will occur, and operation will be along the joinging Points 2 and 3.

Once the signal levels at the head end are stabilized, the signals are ready to be inserted into the transmission system. Since the signals are stabilized, why is AGC necessary in the trunkline amplifiers? To answer this question, it is necessary to look at the entire trunkline system. While the signals may be stabilized at the input to the trunkline, they will still vary in the trunkline because of changes in cable attenuation with temperature variation and because of changes in amplifier gain. While the latter factor is a matter of conjecture, the change in cable attenuation is a well known fact and can be predicted.

If the last amplifier at the end of the longest trunk is capable of handling the largest signal swing expected then AGC is not required. FIGURE 5 (next page) shows the correction factor which must be applied to the 68° value of cable attenuation to obtain the attenuation at some other temperature.

We can see that the extreme temperature to which the cable may be subjected, attenuation correction factors are obtained of 1.06 at +120°F and 0.90 at -20°F. This means that for each 100 db of cable attenuation, there results an increase of 6 db at 120°F and a decrease of 10 db at -20°F.

A trunkline consisting of 1/2 inch foam dielectric aluminum jacketed cable may typically have an attenuation of 1.3 db per 100 feet at Channel 13 at 68°F. In a five mile line, this would amount to 340 db attenuation. However, at 120°F this would increase by 20.4 db, and at -20°F it would decrease by 34 db. No presently existing

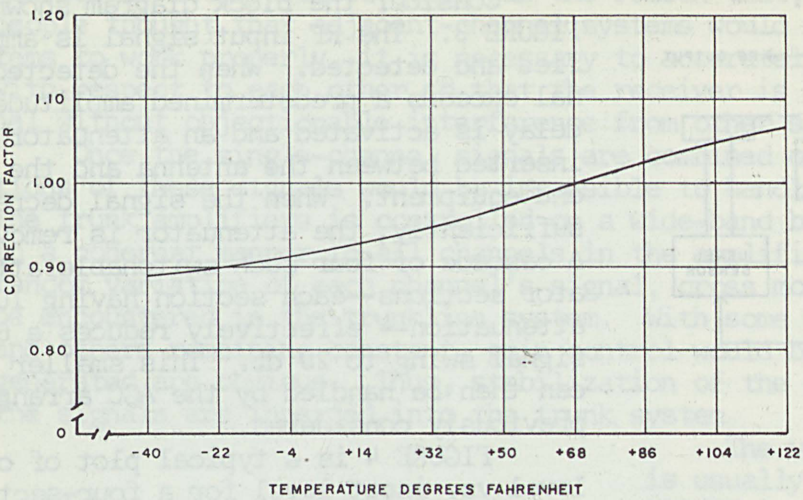


FIGURE 5

FIGURE 5

amplifier can take this signal swing. Therefore, AGC would be a necessity in this system.

Other problems, of course, also arise because of this characteristic of cable. Such a problem is the difference in the attenuation change at different frequencies. One way of dealing with this problem is by using automatic tilt control derived from two pilot carriers. Another way of dealing with the problem is to use thermal equalizers. A third way is to split the band so that the accumulated difference in cable attenuation within each band is within tolerable limits. This leads to two different types of transmission systems, the so-called "Split-Band" transmission system, and the broadband transmission system. The advantage of a split-band system is the reduction of change of tilt effects to the point where they may be neglected, while the broadband system must use some method of automatic tilt control.

Regardless of whether a split-band or a broadband system is used, there are still many methods in use today by which the gain of the transmission system is controlled. There are also many names by which these systems are known. Be it AGC, AOC, ALC, AVC, or A--you name it--C, all of the methods in use have one common objective, and that is to vary the gain or loss (in some cases) of an amplifier or an attenuator in an attempt to maintain a constant signal level. Why do we all strive toward this goal?

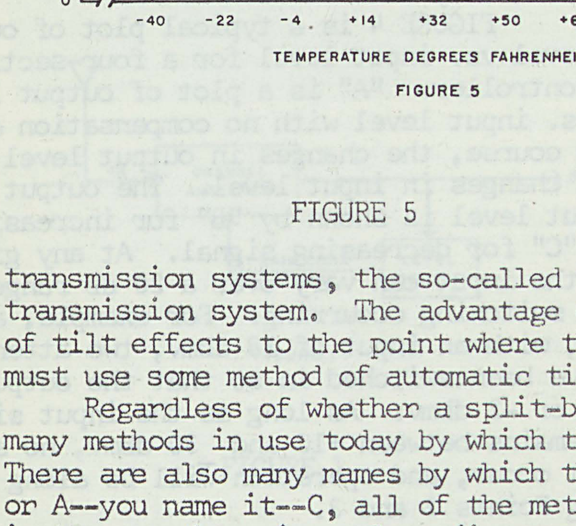


FIGURE 6

FIGURE 6

As we have seen, signal swings of 20 or 30 db are to be expected in a relatively short system as the temperature varies over the day and through the year, if no AGC is used. The use of AGC reduces maintenance problems by eliminating the need for periodic resetting of levels. Too, compensation for cable and equipment aging is provided to some extent. Let us look at some of the different methods that are used to achieve these goals.

Whether the transmission system is broadband or split-band, operation of the AGC circuits in either of these systems may be controlled by either TV signals or by pilot carrier signals. Also, either a single signal or a multiplicity of signals may be used for AGC purposes. Thus, many possible types of AGC systems exist. However, all of these methods are very similar in actual operation. FIGURE 6 is a block diagram which illustrates two methods which might be used with either TV signal or pilot carrier AGC systems.

In the first case, the amplifier is operated below its maximum gain capability so as to be able to compensate for anticipated changes in input signal in either direction. Usually, only the gain of the intermediate stages are varied so as to maintain good noise figure and overload characteristics while the input and output stages are at a fixed optimum operating point. The detector is tuned either to a single frequency or is broadband, depending on the type of AGC system used.

In the second system, the entire amplifier is maintained at its optimum operating point as far as noise figure and overload characteristics are concerned. The attenuator ahead of the amplifier is varied to change the overall gain at the amplifier station. The nominal operating point of the attenuator must provide an insertion loss of at least the magnitude of the anticipated downward change in input signal level. The loss of the attenuator is then varied up or down to correct for changes in input level. This arrangement, while allowing optimum operation of each stage of the amplifier, effectively increases the noise figure of the amplifier by the amount of the attenuator's nominal insertion loss. The best solution may be a combination of the two methods. That is, place the attenuator at an intermediate point in the amplifier. This would allow optimum operation of the active elements in the amplifier and, at the same time, provide a good noise figure.

As stated previously, the AGC may be derived from either TV signals or from pilot carrier signals. A single TV signal cannot be used alone to activate the AGC because if that channel went off for any reason, all amplifiers would run wide open.

Excessive gain would be accumulated, and overload would soon occur on the remaining channels. Therefore, if this method is used, a standby oscillator is required which is switched into the system if the primary source goes off.

Another method is to sense the composite signals in the passband of the amplifier and adjust the gain to the composite level. With this method, if a station goes off, the AGC is still operative. No standby oscillator is required since the AGC circuit operates from the remaining carriers.

Still another mtthod utilizes only pilot carriers to drive the AGC circuits. This system is independent of the TV signal levels and has the advantage of providing a fixed standard signal to which the entire system may be referenced.

To summarize, the main advantages of AGC are:

(1) Stabilization of individual channel signals permits adjacent channel operation and maximum utilization of the transmission system.

(2) Proper signal levels may be maintained in the trunk, thereby avoiding problems of noise and cross modulation.

(3) Maintenance problems are reduced by eliminating the necessity to reset levels with changes in temperature.

Thank you. (Applause)

MR. TAYLOR: I think we can take time for one or two questions. Anybody have a question they want to ask Mr. Kuzminsky? One in the back of the room.

UNIDENTIFIED SPEAKER: This might be going back to this envelope delay problem, but I notice on the color set there was another image to the right and I've had this problem on black and white. I don't know what it is. Is it miss match?

MR. KUZMINSKY: Well, sounds like it.

UNIDENTIFIED SPEAKER: Miss match?

MR. KUZMINSKY: Yes.

MR. TAYLOR: Thank you. Thank you very much, Mr. Kuzminsky. (Applause)

Our next speaker is Mr. Robert Cowart, Vice President in Charge of Construction for Viking Company. And, he's going to talk on "System Reliability". I believe the