RCA SEMINAR ON TV Color Transmission

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COLOR TELEVISION TRANSMISSION SEMINAR

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INTRODUCTION TO COLOR TV TRANSMISSION

A Review of Basic Concepts and Test Signals

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To "set the stage" for the specific discussions of practical problems in handling color television signals, I have been asked to present a brief review of the basic concepts involved in the generation of color television signals and to provide a short introduction to each of the most popular test signals used for checking transmission equipment.

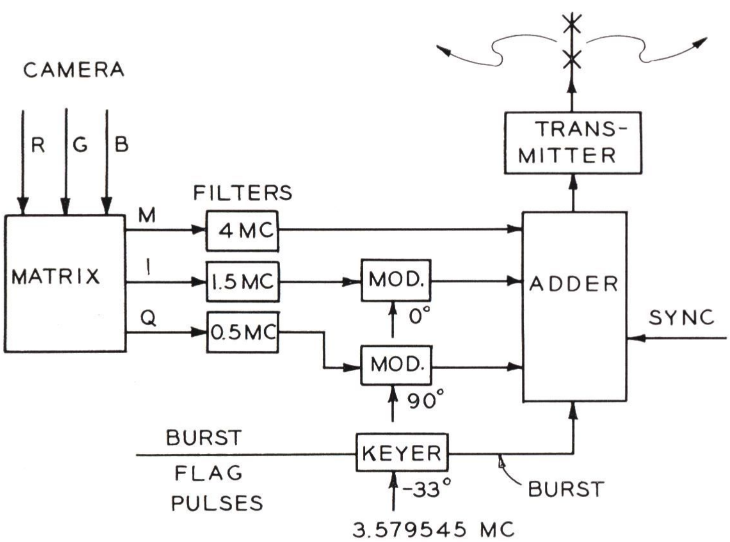


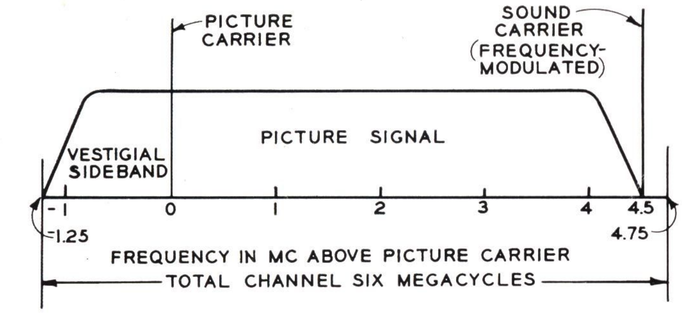
FIG. 1

Figure 1 provides a "visual summary" of the technical concepts involved in putting the signal together. Study of this diagram can help us to clarify our understanding as to why certain characteristics of the signal are exceedingly important. A color television signal must always provide three kinds of information. A color signal leaves the camera in the form of red, green, and blue video signals, conveying primary-color information about the scene to be transmitted. In a matrix network, we cross-mix the red, green, and blue signals to develop another set of three signals that we frequently call M, I, and Q. M stands for Monochrome, a particular mixture of red, green, and blue which is a very close approximation to the output of a monochrome camera chain. The M signal conveys brightness or *luminance* information. The I and Q signals we designate *chrominance* signals. They, too, are mixtures of red, green and blue and determine how the color to be reproduced in each area of the image differs from the neutral or gray condition along a pair of axes on the color diagram. The I and Q signals together give us all the chrominance information we need to establish the hue and saturation of each image area.

We then pass these signals through a group of filters which adjust the bandwidth of each signal component to match the requirement of the human eye. The monochrome signal we handle in exactly the same fashion that we handle standard monochrome signals. Somewhere in the broadcast system before the signal reaches the home receiver, there is inevitably a practical limitation in bandwidth, imposed by a transmitter, a tape recorder, or network transmission lines. As a practical matter, we have nominally 4 megacycles to work with as far as monochrome information is concerned. The I and Q signals are deliberately shaped by filters in the color encoding equipment. The nominal bandwidths are 1.5 mc for I, and a mere ½ megacycle for Q. Very narrow band, low resolution chrominance information is all that is required to reconstruct a very satisfactory color image.

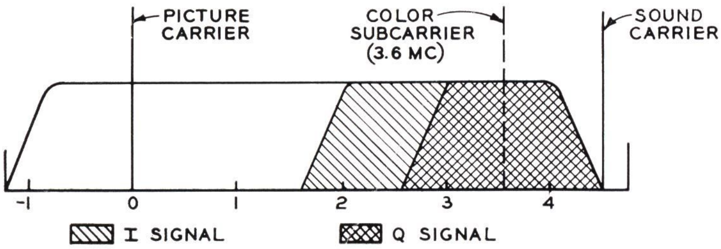
The band-shaped chrominance signals are then modulated on subcarriers of 3.579545 megacycles. If you've ever studied the principles of color television, you're aware that this very precise subcarrier frequency must be harmonically related to the line and field scanning frequencies. By making the subcarrier frequency an odd multiple of ½ the line frequency, we obtain a *frequency-interlaced* condition which lets us get away with a simple addition of the subcarrier signal to the monochrome signal. The I and Q signals are modulated in balanced fashion upon two carriers with a phase separation of 90 degrees, producing a subcarrier signal which varies in both phase and amplitude. The effect of the crosstalk which you might expect from the simple addition of the subcarrier to the monochrome signal turns out to be almost negligible as far as the final viewer is concerned, thanks to the frequency interlace effect. In parallel with the modulators, we also operate a burst keyer which puts out a sample of the subcarrier frequency. This keyer is controlled by burst flag pulses which cause the burst to occur in the back porch period right after every horizontal synchronizing pulse. We then add together a total of 5 signal components including the usual deflection sync pulses to form the complete color signal ready for transmission over the air. Of course, in a studio plant you'd normally have a complex system with more than one color camera chain, but this simplified diagram illustrates the basic principles that are involved.

Figure 2 shows the manner in which the 6 mc television transmission channel is used for both monochrome and color. It's well known by now that in compatible color television, we manage to get extra mileage out of the same spectrum space that in the past we've used only for monochrome, but the price we pay for such spectrum conservation is the necessity of handling three independent signals in the upper part of the channel. Mere inspection of this diagram is enough to give a serious minded engineer pause about the difficulty of the task we face in handling a color signal compared to what is involved in handling a monochrome signal. We have filled up the spectrum more completely,



MONOCHROME TV CHANNEL

FIG. 2a



COLOR TV CHANNEL

FIG. 2b

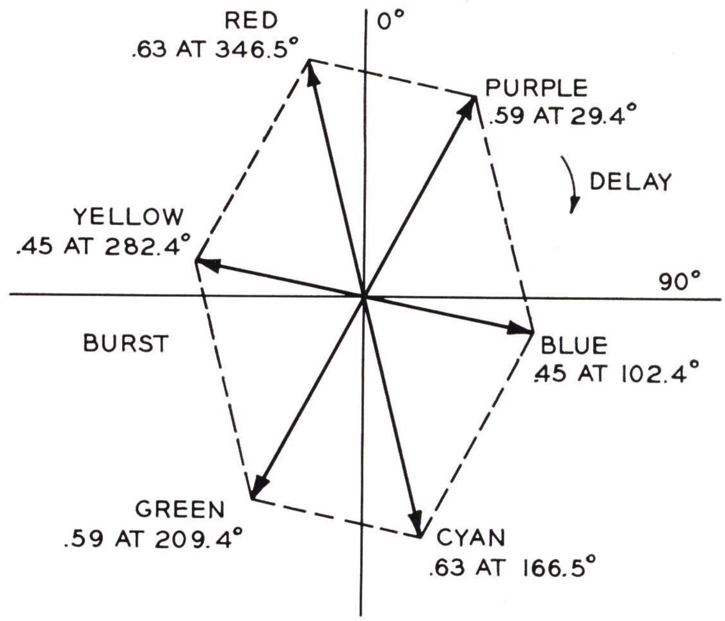


FIG. 3

and now have three signals which must remain independent if we are to reconstruct a proper color picture at the receiving end of the system. So we must be considerably more careful about how we handle the signal. You're aware, of course, that the I and Q signals are kept independent of each other by the two phase modulation technique, and the entire group of sidebands surrounding the color subcarrier are kept independent of the monochrome signal by virtue of so-called frequency interlace technique. It is still very important, however, that we pay close attention to what happens in the upper part of the frequency band, especially in comparison to the relatively lenient approach we can afford to take in the handling of a monochrome signal, since the very important chrominance information is confined to the upper part of the channel.

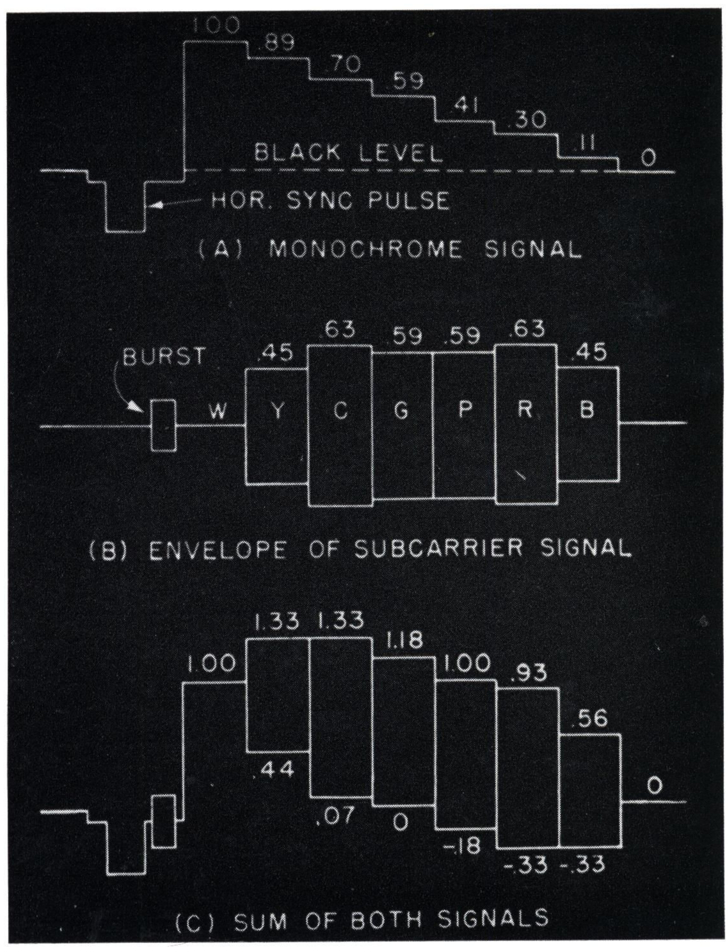


FIG. 4

Table I

BASIC TRANSMISSION REQUIREMENTS

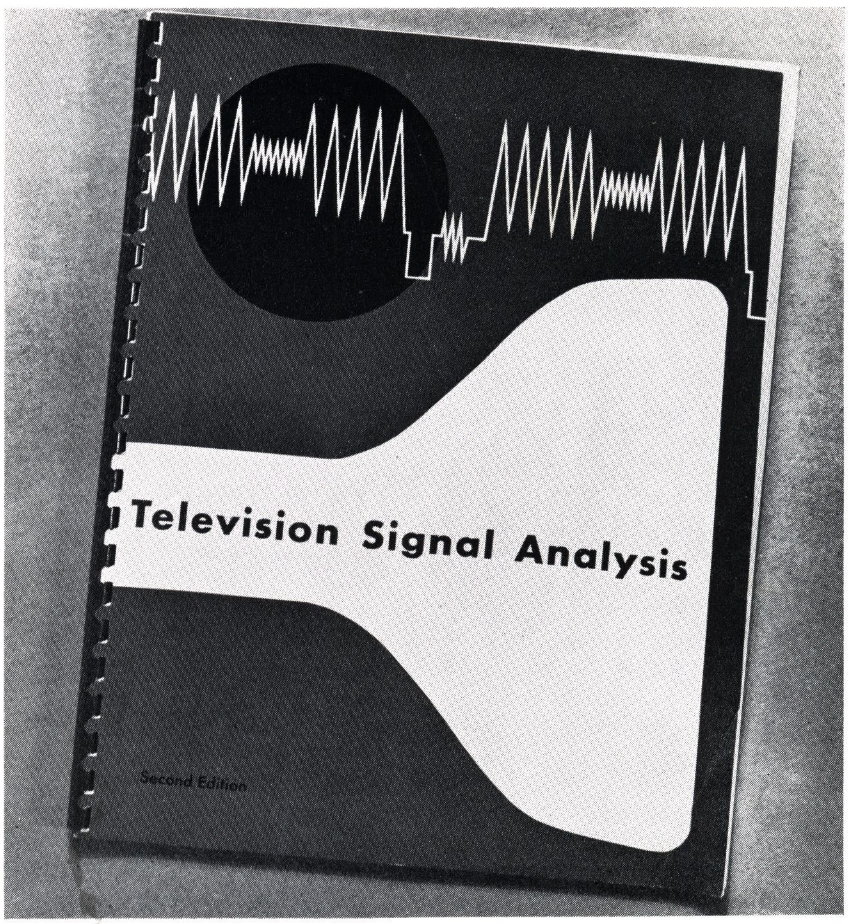
1. **Uniform Frequency Response**
2. **Uniform Time Delay (Linear Phase)**
3. **Minimum Differential Gain and Phase**

Table I summarizes the several basic transmission requirements. From mere inspection of the channel diagrams, you can quickly understand why it is that we must have very uniform frequency response. We must provide essentially the same response through the system for all parts of the color signal including that part transmitted in the upper portion of the video band. We must also be very much concerned about uniform time delay, or linear phase, over the entire video passband. The color signal is very complex, and in order to preserve its wave shape faithfully, we must make sure that all signal components arrive at the receiving end of the system with the same relative timing. This can only be done if the phase versus frequency characteristic is linear or if there's uniform time delay through the system for each and every frequency component.

We're also concerned about minimum differential gain and phase. We seldom talked about differential gain or phase in the early days of monochrome television, but they're very important in color for reasons that I think can best be made clear by considering Figures 3 and 4. Figure 3 is a vector diagram illustrating important characteristics of the subcarrier part of a color signal. As we noted earlier, the color subcarrier signal is formed by amplitude modulating, in suppressed carrier fashion, two carriers that are 90° apart in phase; the net result is the generation of a signal whose amplitude and phase are both subject to variation. It's common knowledge by now that the hue of a reproduced picture is determined directly by the phase of the subcarrier part of the signal. The saturation of each reproduced color is determined by the amplitude of the subcarrier signal. When anything happens to reduce the relative amplitude of the subcarrier part of the signal, the saturation will be decreased.

Keeping in mind that the subcarrier signal has a critical phase as well as a significant amplitude, let us consider Fig. 4, which shows the waveform sketch for a monochrome signal, the subcarrier part of the signal to be added to it, and the sum of both signals. Although the sketch happens to show a signal generated by a color bar generator, it illustrates the general principle with which we are concerned. Note that the monochrome signal is always somewhere between black level and reference white or unity. The signal levels represent various shades of gray up and down the gray scale. The subcarrier signal shown at (B) in the diagram is modulated in both amplitude and phase. While it's not possible to show phase modulation realistically on a waveform sketch of this sort, you must recognize that each color interval is transmitted with a different phase position. The sketch also shows the color synchronizing burst required for control of the receiver oscillators which regenerate the carriers that are needed to demodulate the chrominance information from the complex modulated wave. It's very significant that when the subcarrier signal is added to the monochrome signal, the various components which make up the modulated wave may be transmitted in entirely different parts of the amplitude range. Some of the color information, particularly that associated with the bright colors such as yellow and cyan, is transmitted relatively close to the white level, while some of the information is transmitted relatively close to the black level. We must be sure that the chrominance information is not distorted as a function of the position it happens to occupy in the black-to-white amplitude range. We want the same transmission conditions for the very important subcarrier signal up near the white level as we find down near the black level. If we find differences in amplification or in phase shift, we have what can be called *differential gain* or *differential phase*. Either effect can cause serious distortions to the color signal.

Turning now to the subject of test signals, we are pleased to recommend very highly the booklet entitled *Television Signal Analysis,* which we understand has been sent out by the Bell Telephone System to virtually all chief engineers of television stations throughout the country. This very useful handbook on television signal analysis shows the most popular test signals used by broadcasters and the networks for checking the performance characteristics of equipment that handles both monochrome



TELEVISION SIGNAL ANALYSIS is a very useful handbook compiled under the direction of a Joint Committee of Television Network Broadcasters and the Bell Telephone System. It is published by the Long Lines Department of the American Telephone and Telegraph Company.

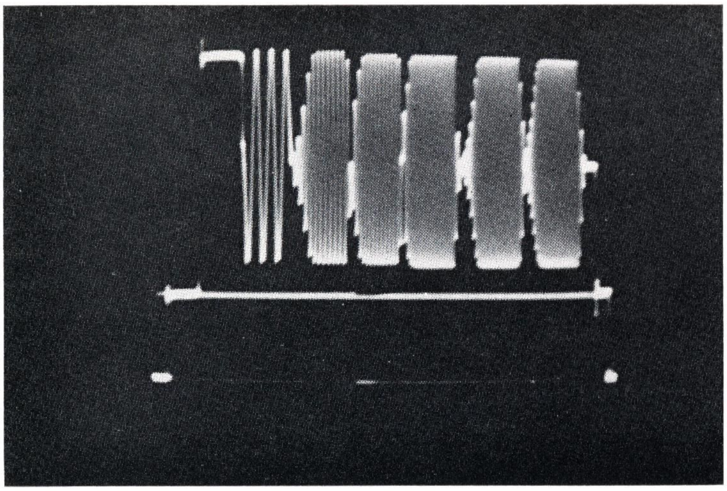


FIG. 5.

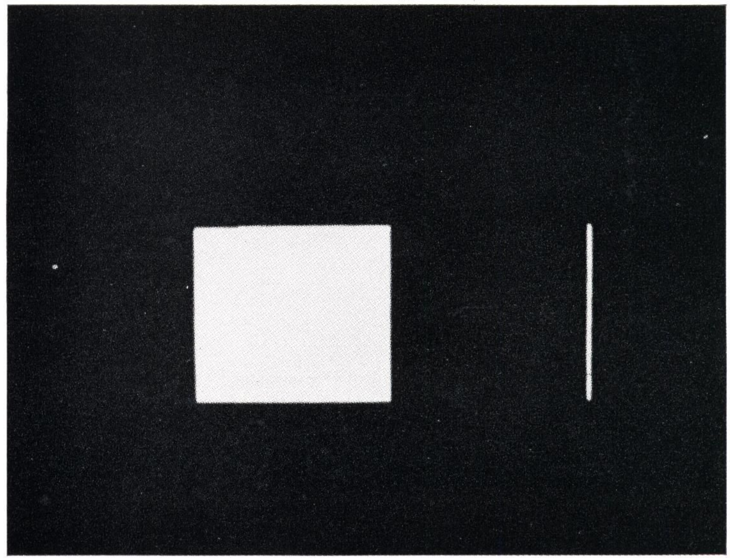


FIG. 6

and color signals. The manual is well illustrated with both kinescope photographs and waveform photographs which show both normal signals and a wide variety of distorted signals resulting from typical malfunctions or defects. Each of the signals I shall comment upon in this talk, and which will be used by all speakers in this program to illustrate their topics, is discussed in considerable detail in *Television Signal Analysis*.

Figure 5 shows the so-called multi-burst signal, a waveform which permits you to make a very rapid spot check of the frequency response of any piece of television equipment. It's enough like a true television signal, with the usual sync and blanking pulses provided, that it will pass through all standard TV transmission gear with no modification of clamps or other special circuits. The signal is fairly straightforward. It begins with a white pulse which gives you an opportunity to check the basic level or response at the very low frequencies (effectively at line frequency and the first several harmonics thereof). The signal then provides a series of bursts or samples of various frequencies; these are normally set at 0.5, 1.5, 2, 3, 3.6 and 4.2 megacycles. We understand that some telephone company circuits are checked with a slightly different group of frequencies, but those cited are used by the networks and most local broadcasters. The equipment that generates the multi-burst signal is usually adjustable within reasonable limits, but there is obvious advantage in conforming to a recognized standard for most routine tests. The multi-burst signal is widely accepted as a useful test signal for spot checks of frequency response.

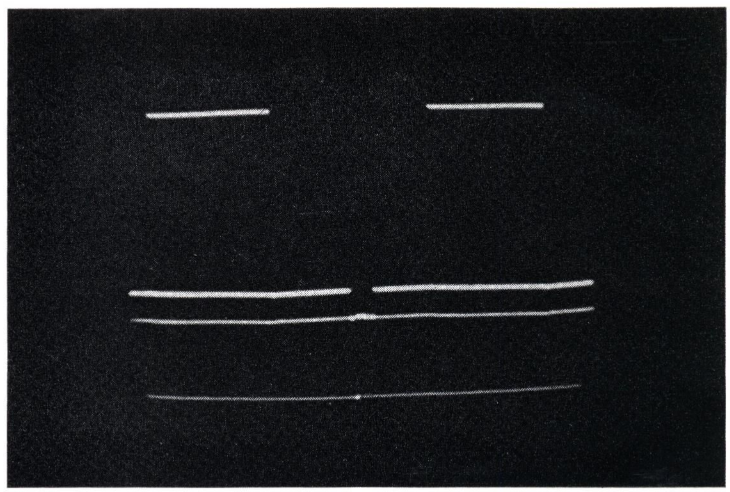


FIG. 7

Figure 6 shows the kinescope appearance of the so-called "window" signal, which provides a patch of white on a black background. Modern signal generators that provide this signal also provide a secondary line off to the right in the kinescope display; this is the kinescope display of a sine-squared pulse. The sine-squared pulse is actually more useful on a waveform monitor than on a kinescope screen, but there is no particular problem in combining it with the window and making one signal do double duty. The combined signal is extremely useful for checking transient response at both low and high frequencies. A transient response test is actually a slightly indirect way of measuring time delay or a phase-versus-frequency characteristic. A transient response test permits you to examine an *effect* rather than a *cause*, but direct phase measurements are normally so difficult that transient tests are usually recognized as one of the easiest ways to accomplish the objective.

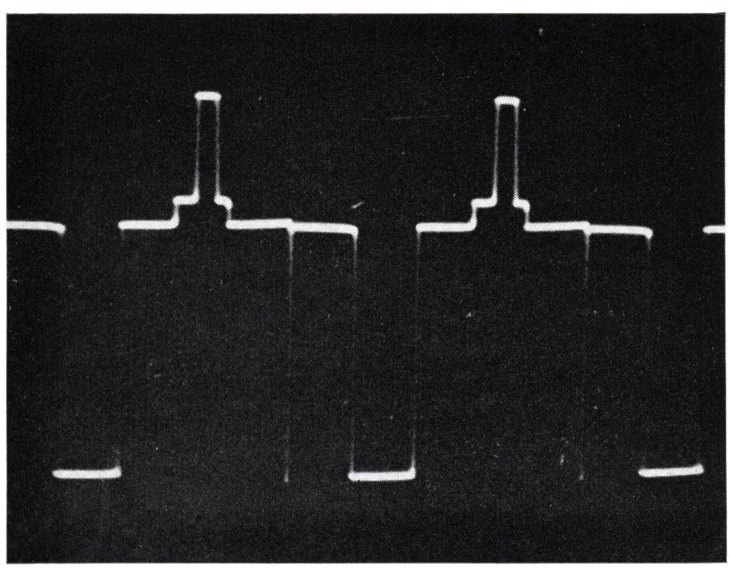


FIG. 8

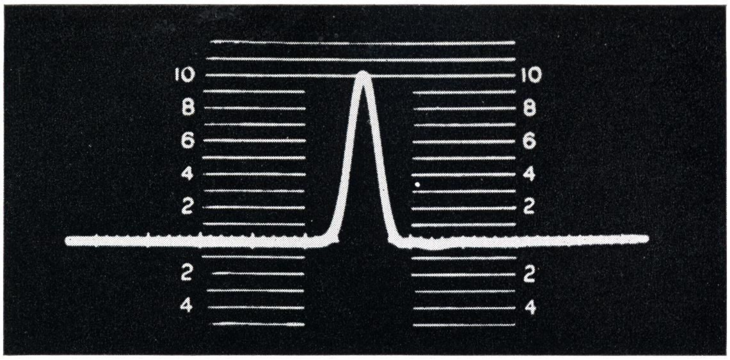


FIG. 9a

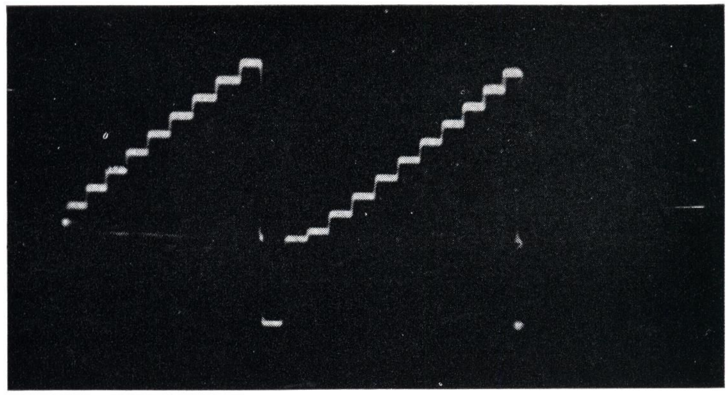


FIG. 10

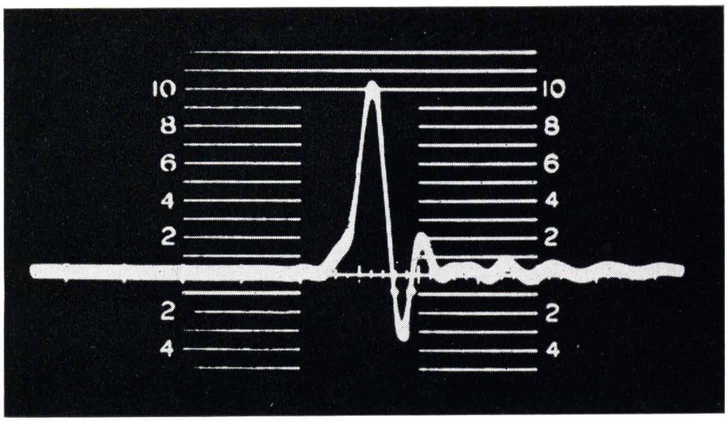


FIG. 9b

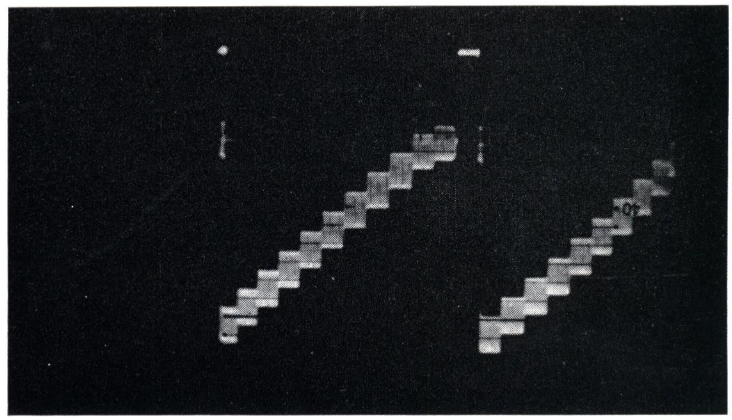


FIG. 11

The window display on the picture tube is very useful for detecting cases of streaking or certain other gross defects that are quite apparent when you look at the display and fail to see a clear white window on a black background. The signal is also useful on a waveform monitor, where it can be examined on several different time scales. For example, Fig. 7 shows the vertical-rate display for the window signal. What you see is essentially a 60 cycle square wave, nicely fitted up with sync and blanking pulses so that it will go through all standard television facilities. This signal provides a very sensitive test for tilt at the very low frequencies; in other words, it provides a good test of the low frequency response of a TV system. On the horizontal time scale, as shown in Fig. 8, you can get a good view of the effects of disturbances in the vicinity of the line frequency or the mid-band region; such disturbances cause tilt, rounding, or other distortions in the wide pulse corresponding to the window. To the right of the broad pulse, you see a narrow spike corresponding to the sine-square pulse. One point that usually is of some significance is the absolute height of this pulse. If the frequency response of a circuit under test has rolled off significantly, chances are this spike no longer reaches the same level as the window. Still more useful information can be gleaned from the sine-squared pulse by expanding it horizontally on the waveform monitor to yield the type of display shown in Fig. 9. Mr. Gronberg will give you a little more information about the derivation of the sine-squared pulse, but we should note here that it is essentially a transient-test signal with a predetermined energy spectrum. The pulse most commonly used is 0.125 microsecond wide at the 6 db points, and has an energy spectrum that closely matches that of typical television picture signals. This sine-squared pulse should pass through most *studio* systems with no apparent distortion, although you should expect some distortion in network lines and other band-limited devices or circuits. The sine-squared pulse permits you to detect both frequency response problems and, more importantly, phase response problems at the high end of the video band. Any time you get pronounced ringing effects or asymetrical transients of any sort as in the bottom view of Fig. 9, you have clear evidence of a phase or envelope delay problem in your system. Some of these effects will be discussed in later sections as we get into the program.

Figure 10 shows the so-called "stair-step" signal, which gives you a means of checking the *linearity* of a transmission system. Simple stair-step signals have been used for quite a number of years as a means of checking compression in amplifiers; distortion can be detected by noting whether or not the steps are squeezed at either the white or the black end of the scale. A more advanced signal for checking *color* transmission facilities can be formed, as shown in Fig. 11, by superimposing a subcarrier signal on top of the staircase. In the receiving equipment used for differential gain and phase tests employing this signal, arrangements are made for filtering off the subcarrier component only, so that it can be examined for any possible disturbance resulting from the fact that the subcarrier was transmitted at various levels all the way up through the gray scale. If you have no distortion, you should see a clean envelope for the subcarrier signal. If you have a case of white compression, for example, you would expect the level of this signal to drop off toward the end of each horizontal interval. The receiving equipment used with this signal also permits you to make phase measurements of each individual section of this subcarrier signal to measure differential phase.

I hope that this preliminary review helps to clarify in your mind the basic problems involved in the transmission of color television signals, and the objectives of the several test signals commonly used for testing practical facilities.

NETWORK COLOR TRANSMISSION

How to Monitor and Use the Test Signals

by HOWARD C. GRONBERG
Manager, TV Network Transmission
National Broadcasting Company, New York

All of us have a common goal—namely, to see that TV shows, particularly those in color, reach the home viewers in the best possible condition. I am going to talk specifically about network transmission and, in general terms, about what we can do to maintain quality from the time the video signal leaves the TV Master Control Room until it has been radiated from the TV transmitter.

There are three general areas of responsibility for seeing that on-the-air color is good. First, the origination point; second, network transmission; and third, the local stations airing the program. No matter how good the program is originated, color can be harmed or even ruined by either the network facilities or the local TV station.

In the past, most complaints have blamed either the Telephone Company or the video tape machines. The Telephone Company has slowly but surely improved its network transmission. The networks have greatly improved the average quality of the video tapes.

Recent experiences indicate that many stations have not kept their TV plants up-to-date and are in need of newer equipment, more test equipment, and better routine maintenance.

It is very fortunate that many types of signal distortions do not always add. In many instances, on both network facilities and in broadcasters equipment, there is considerable cancellation. Otherwise, the handling of color signals by the Bell System and the TV stations would be much more difficult.

A few stations watch the network test signals and send in waveform photos on a regular basis. Other stations observe the signals on a hit-or-miss basis, while the remaining stations don't bother to look at the test signals. These latter stations are prone to complain of bad off-the-air pictures when they don't know whether the trouble is at the pickup, in network transmission, or in their station. They seem surprised when we ask them how the network test signals look.

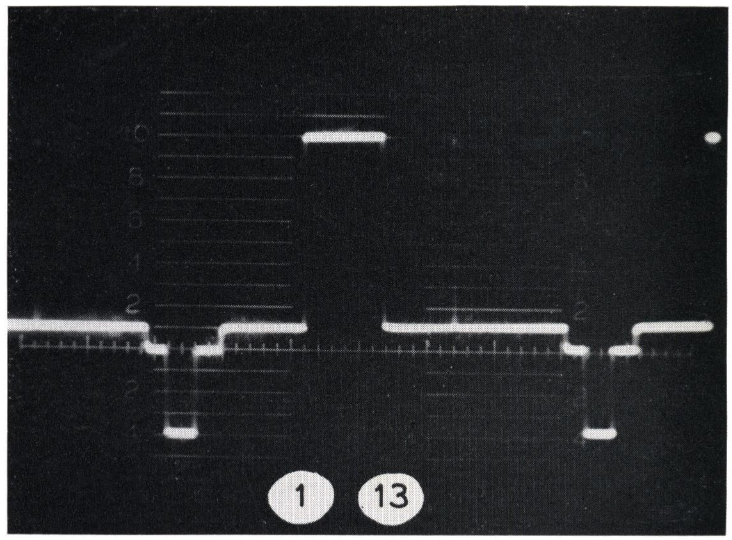
To keep color degradation to a minimum, it is *a must* that video test signals be used on a regular basis. We cannot emphasize too strongly that stations must—

1. Monitor the weekly network tests and take waveform photos when trouble is noted.
2. Check the keyed-in test signals at least once a day. Preferably, this should be done at the output of the TV transmitter, as well as at the control rooms.
3. Make regular routine checks of their TV plants.

Network Test Signals

The three test signals most commonly used by the networks and the TV stations for local testing are the well known multi-burst, stairstep, and window signals. There are a number of varieties of each signal to meet specific applications. As an example, the keyed-in test signals do not have vertical components as they occupy only one or two lines per field. The window signal may or may not be accompanied by a sine-squared pulse.

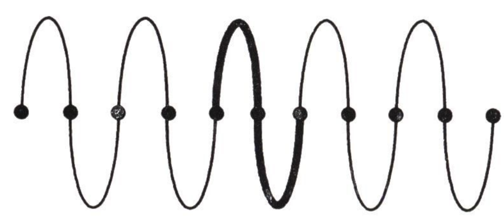
The only signal which may warrant a brief discussion is the sine-squared signal (Slide No. 1).



It consists of a standard white window and a pulse, both of which have sine-squared edges. The white window is primarily used for streaking tests and the pulse for ringing tests.

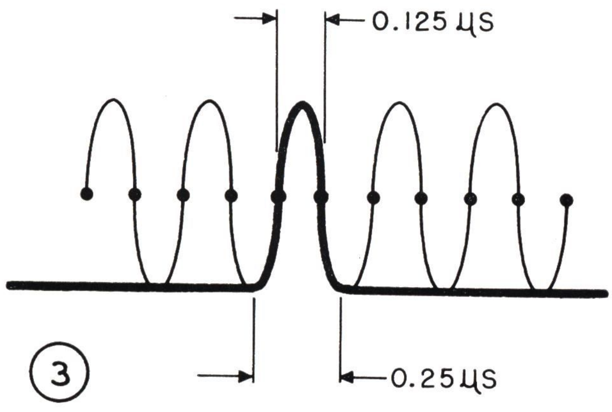
The window portion of the signal has a much slower rise-time than the pulse and usually contains no information beyond 4.0 mc. Therefore, it is an easy signal to transmit from a ringing standpoint.

The sine-squared pulse may be thought of as a single sine wave with the base line moved to the bottom. The next two slides illustrate this quite graphically. (Slide No. 2) A single cycle is indicated by the heavier trace.



2 DOTS = 0.125 μS

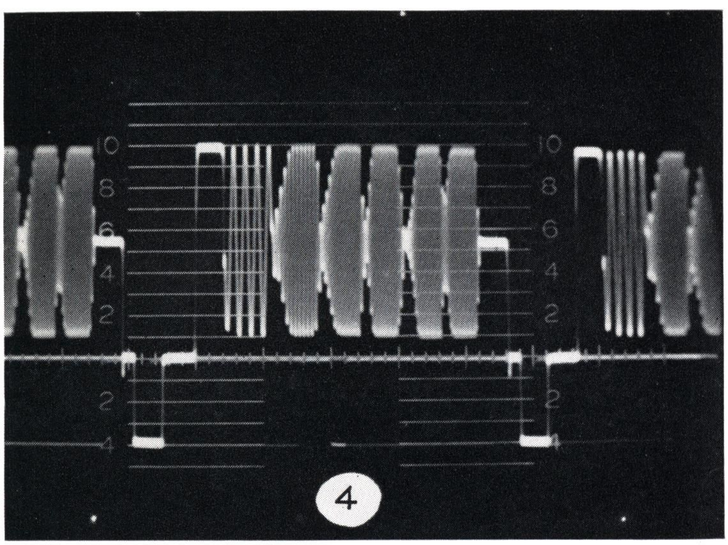
(Slide No. 3) This slide shows the same cycle with the base line moved to the bottom.



Although a sine-squared pulse could be produced this way, it is not practical from a design standpoint. Actually, it is produced by using a very narrow pulse which is widened and shaped by filters. Thus, one pulse and three sets of filters provide the ¼, ⅛, 1/16 microsecond pulses.

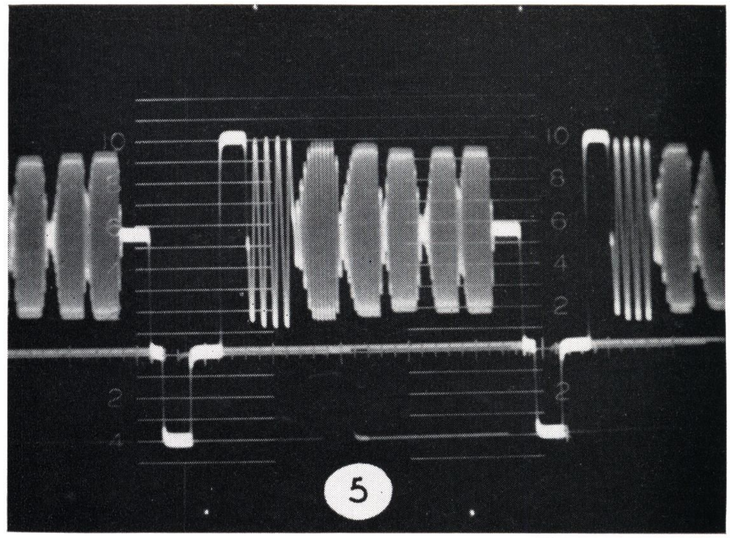
The energy contained in the ⅛ microsecond pulse is 6.0 db down at 4.0 mc and doesn't reach zero until 8.0 mc. Due to the energy between 5.0 and 8.0 mc, some distortion to the pulse will be experienced on all network circuits and is to be expected. In other words, the network stations should expect to see some irregularity before or after the pulse.

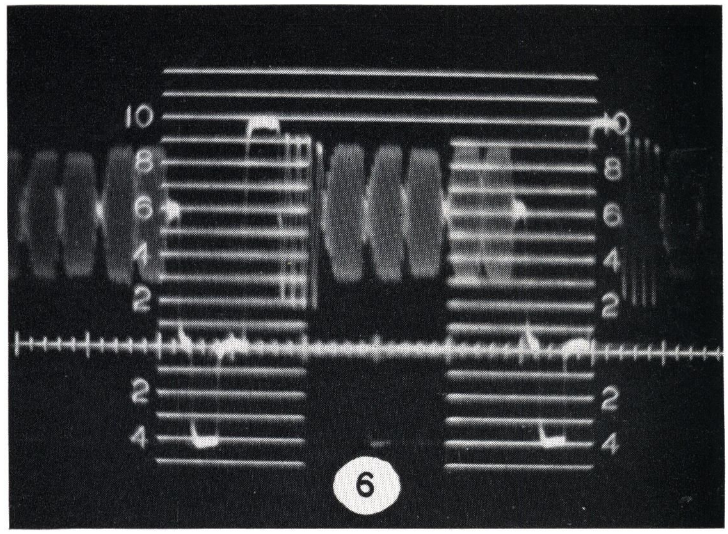
The fourth signal which is becoming increasingly important is the color bar signal. This signal is quite helpful since it can be viewed on a color monitor or displayed on a vectorscope. As more and more stations originate color and therefore obtain vectorscopes, this signal will allow them to quickly check the hues and saturation of the incoming color bar signal from the network.



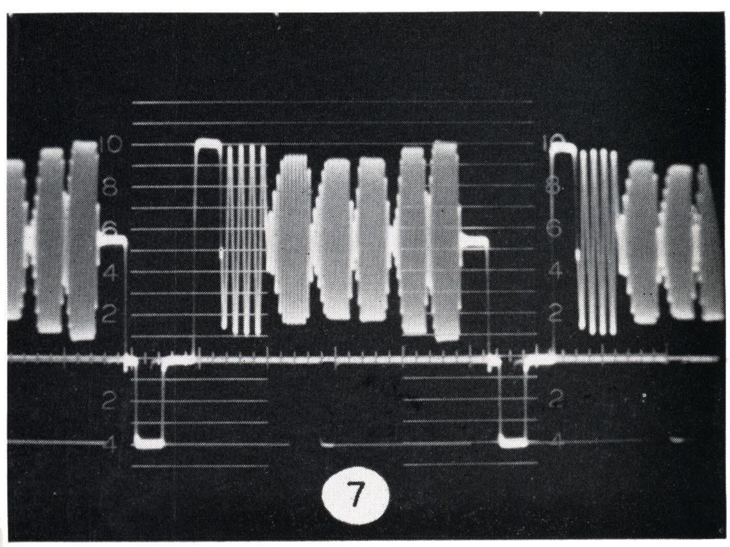
Test Signal Impairments

The multiburst signal leaves New York looking like this (Slide No. 4) and should not be overpeaked arriving at your control rooms. However, if it is rolled off not more than 10 IRE units, it is within commonly accepted limits. By 10 IRE units, I mean the 4.0 mc burst should not be less than 80 IRE units when the 0.5 mc burst is 90 units and the white bar is 100 units. (Slide No. 5)

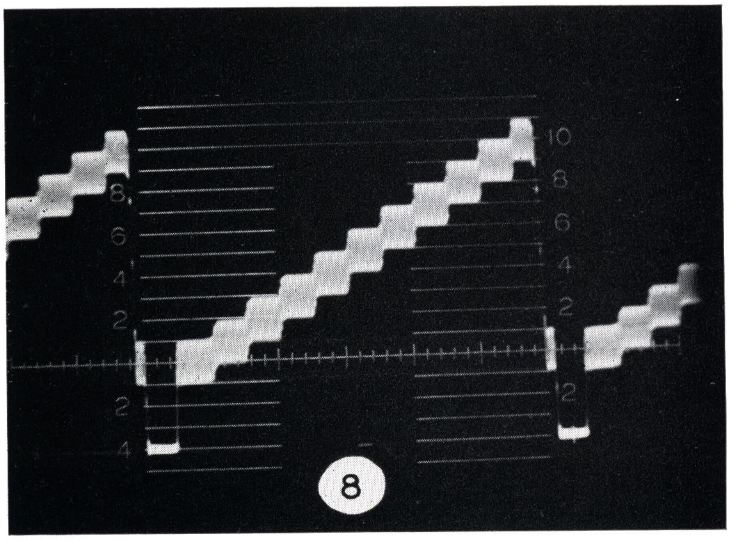




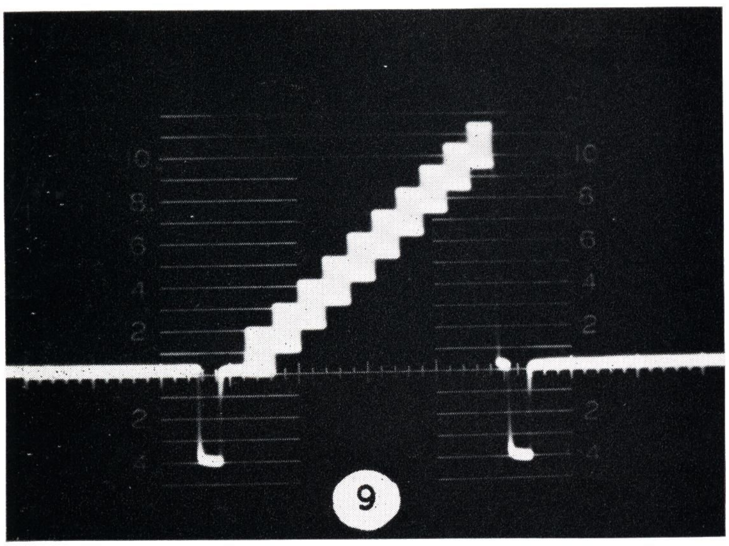
A condition which is not acceptable is shown by slide (No. 6). Although the high-frequency response as shown here is relatively flat, the level of the white bar indicates that there is a mismatch between the low frequencies and high frequencies. Another unacceptable condition is shown by this slide (No. 7) which illustrates an hour-glass response. There are two main objections to this type of response: (1) it accentuates ringing, and (2) it "softens" the monochrome rendition of color receivers.



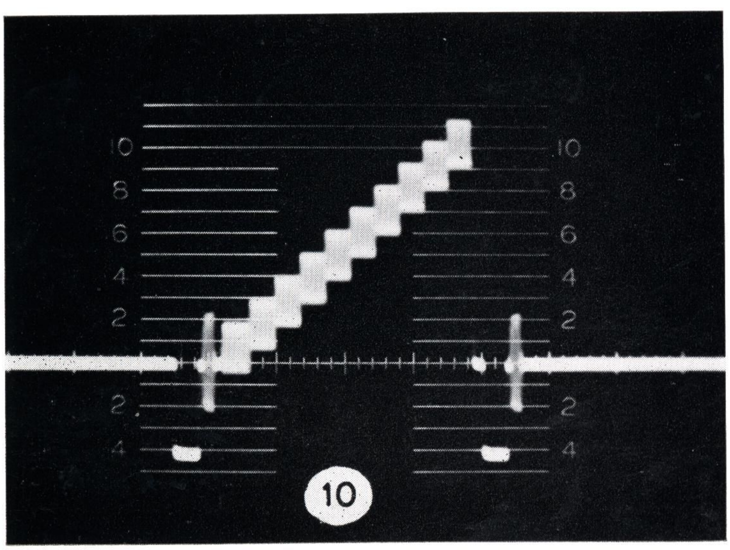
The stairstep signal leaves New York looking like this during the regular test periods (Slide No. 8)



and like this when it is keyed in during vertical blanking (Slide No. 9).



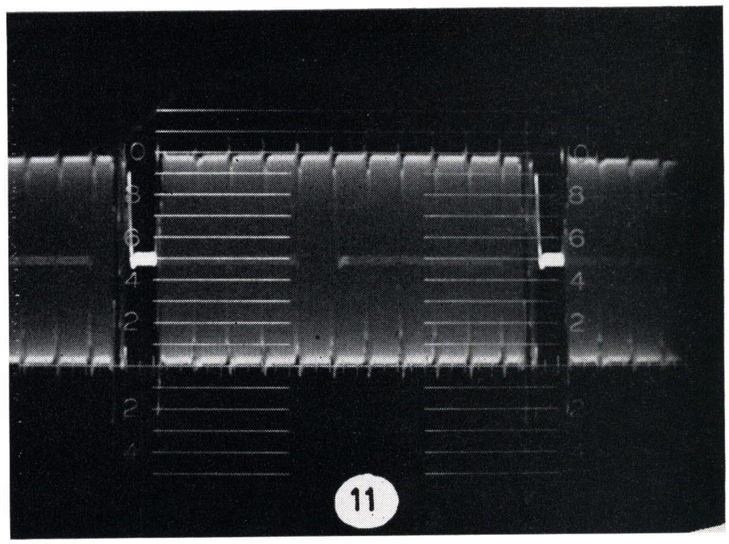
The actual stairs start late in this signal so the 3.5 mc sinewaves can start at the blanking level and still not interfere with the backporch burst during color shows (Slide No. 10).



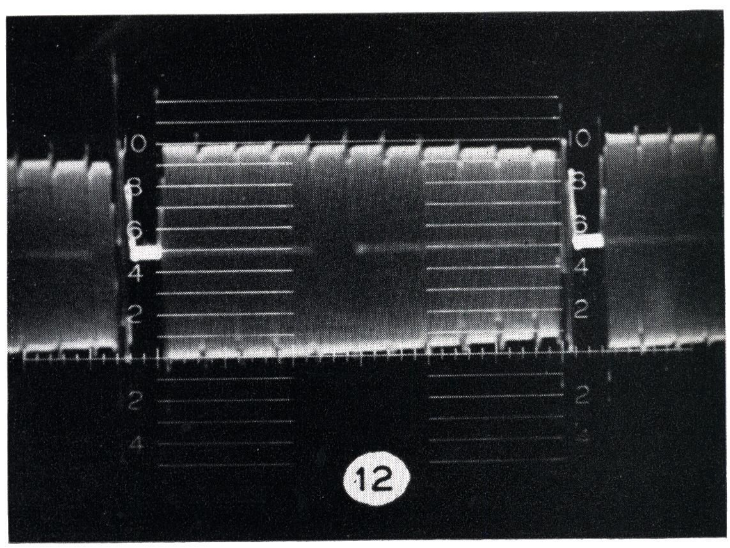
Taking waveform photos of the keyed-in test signals is no problem when using a CRO with a line selector, although it does take a little practice. However, photographing the keyed-in stairstep signal after it has gone through a high pass filter is another matter. One method which works fairly well is to use the sync output from a TA-9 stab amp and drive the CRO externally.

The stairstep signal has two important purposes: (1) to show differential gain which actually is nothing but a measurement of high-frequency gain measured in small increments between the blanking level and white level, and (2) the measurement of differential phase which actually is a measurement of hue shift in small increments between blanking level and white level.

Differential gain can be measured several different ways. The easiest way is to feed the received signals through a high pass filter and view it on a CRO. This slide (No. 11) shows the signal as it leaves New York as viewed through a high pass filter.



Ten per cent differential gain is shown by the next slide (No. 12). That is, 5 per cent at top, plus 5 per cent at bottom.

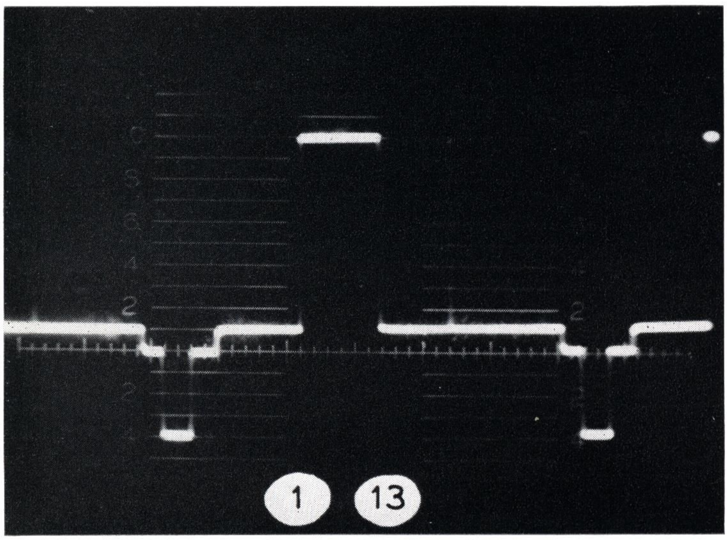


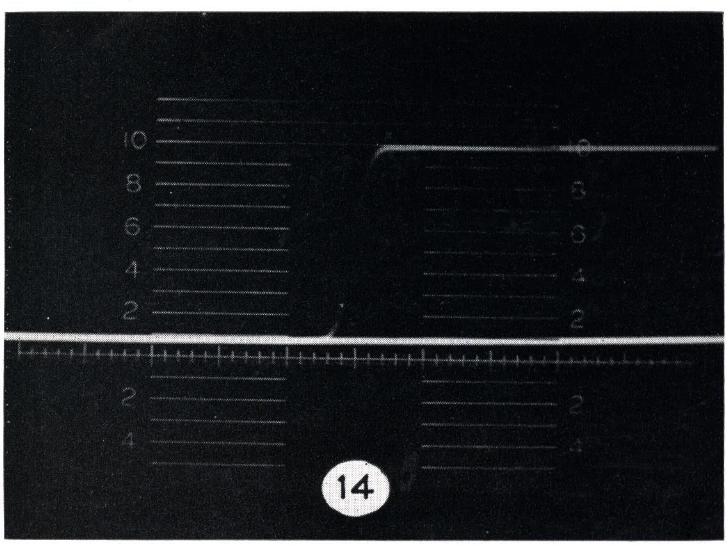
We attempt to keep the 2,300-mile video round robin at less than ten per cent. However, where a station on a leg receives network service over several circuit sections, a more practical limitation is fifteen per cent.

Differential phase is very important and must be kept to a low value if color is to be handled satisfactorily. We believe acceptable limits for network transmission are 4.0 degrees for stations on the video round robin and not more than 5.0 degrees for the remaining stations. Properly maintained, local video circuits will normally have less than 1.0 degree. These tolerances are for measurement made at the output of the Telco equipment.

Two manufacturers have recently introduced small transistorized units to measure differential phase. They are the Riker Industries (Model 970) and Telemets (Telechrome Model 3701-A1). It is probable that both units are transistorized versions of the original Telechrome 1004-B test receiver which has been a very good unit.

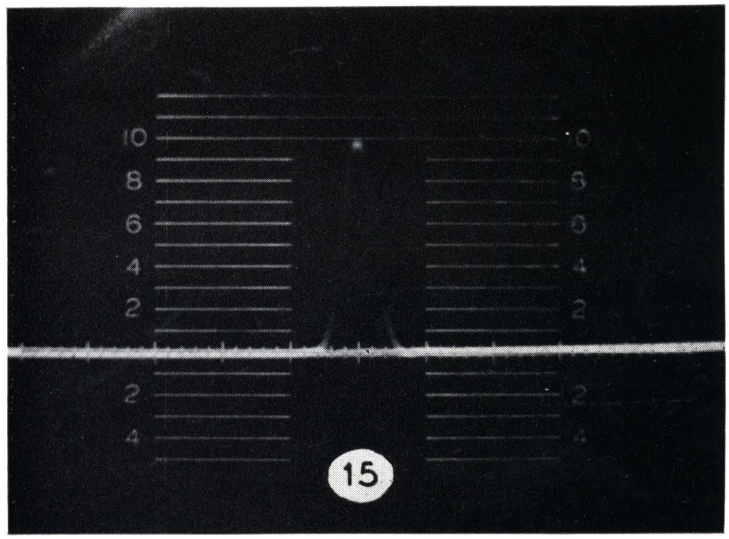
The sine-squared signal leaves New York as shown by the next slide (No. 13). Please note that the corners of window look fairly square.



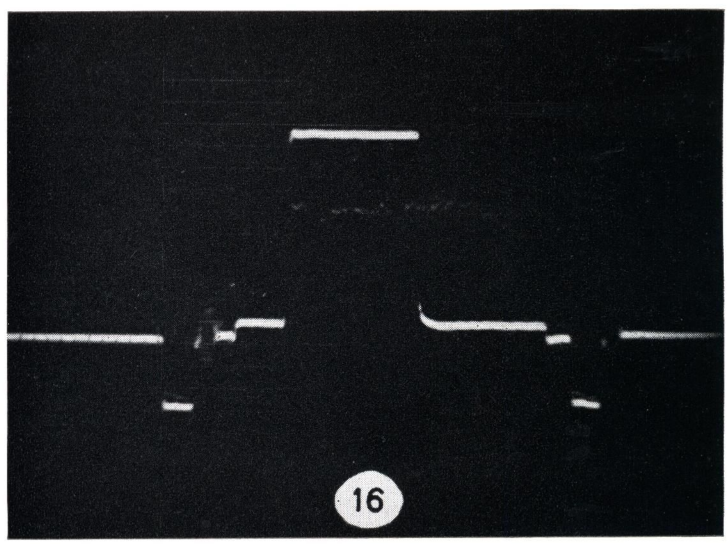


However, when the left side of the window is blown up, it appears slightly rounded and looks like a sine-wave (Slide No. 14). Thus, overshoots do not normally leave the control room. Since there is no energy in the edges of the window signal above 4.0 mc, any appreciable ringing occurring at the top left corner means there is in-band trouble and should be reported.

The next slide (No. 15) shows a blow-up of the sine-square pulse. It has little if any overshoots.

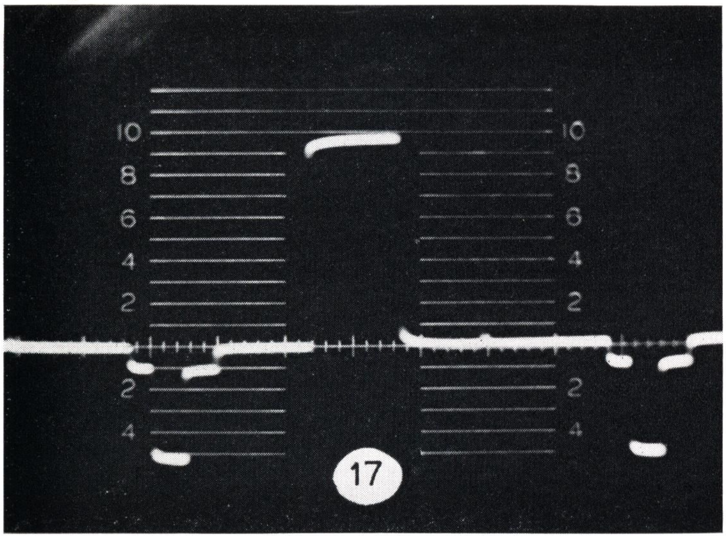


As viewed in your control rooms, the top of the window should be flat and not have excessively rounded corners. The sine-square pulse should not have excessive undershoots or overshoots.

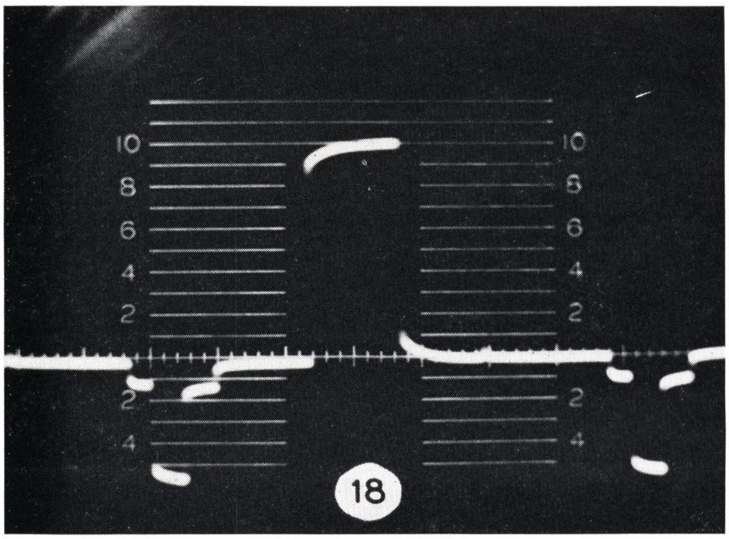


This slide (No. 16) shows the video round robin under average circumstances. The streaking as shown by the rounding of the corners can be more easily seen and photographed if the CRO is set on the IRE roll-off position. Note that the top left corner of the window is almost square but that there is some rounding of the bottom right corner. This is considered to be the present state of the art.

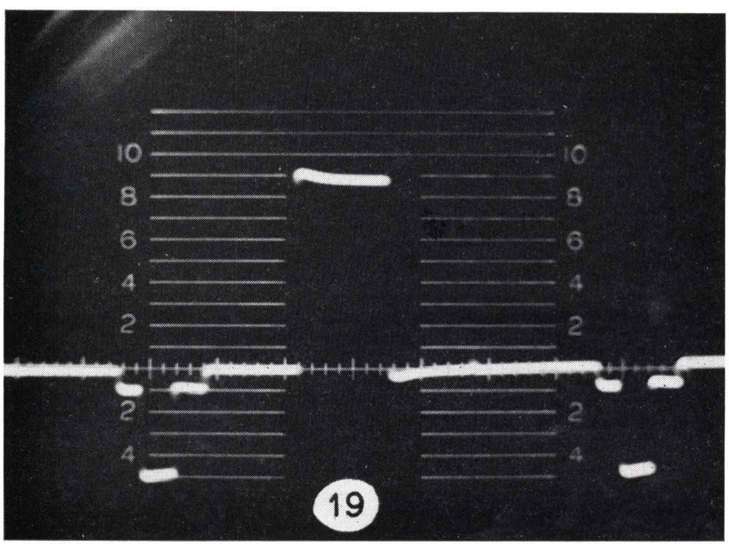
This slide (No. 17) shows moderate streaking.

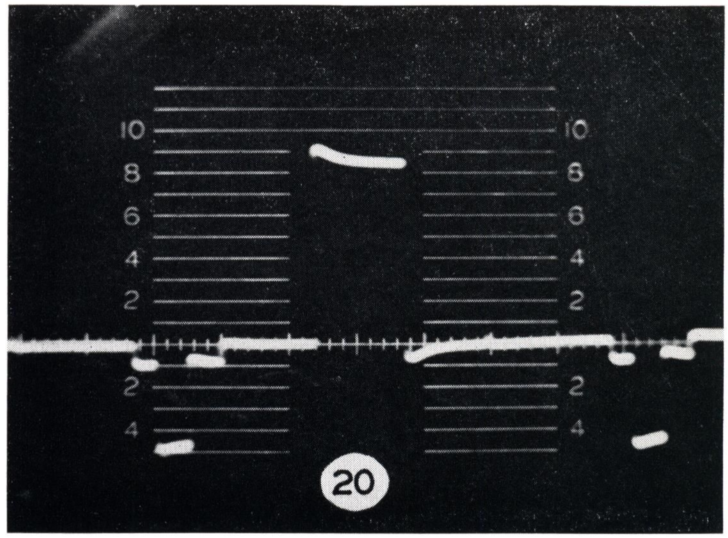


while this slide (No. 18) shows heavy streaking.



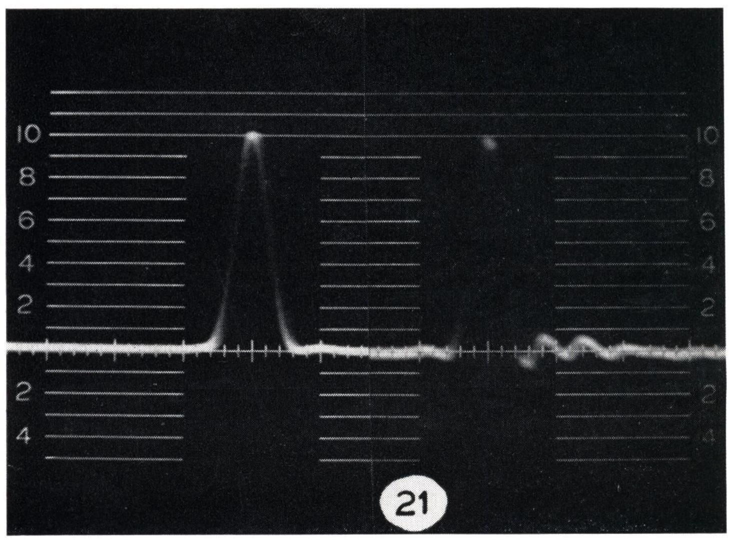
Both of these are excessive and indicate trouble. The slides we have just shown represent positive streaking (excessive lows). The next two slides are just the reverse of the last two slides and show negative streaking. (Slide Nos. 19 and 20.)





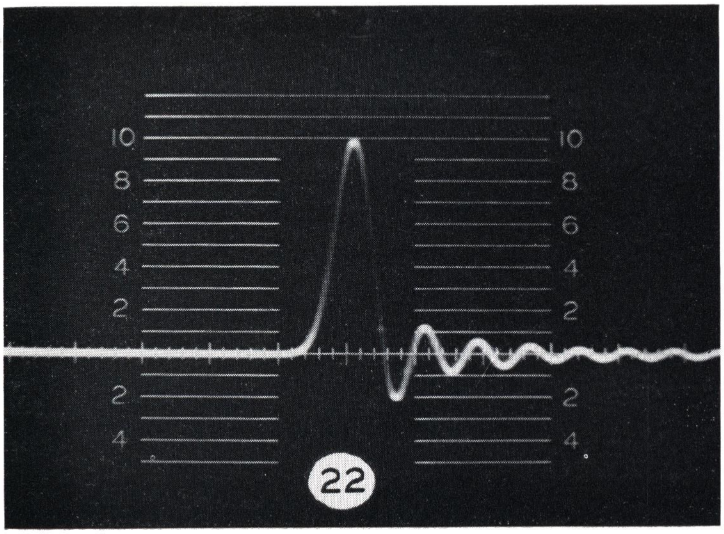
Don't forget your incoming local video loop. If you have long streaking or *any* length negative streaking, the chances are it is due to your local video loop.

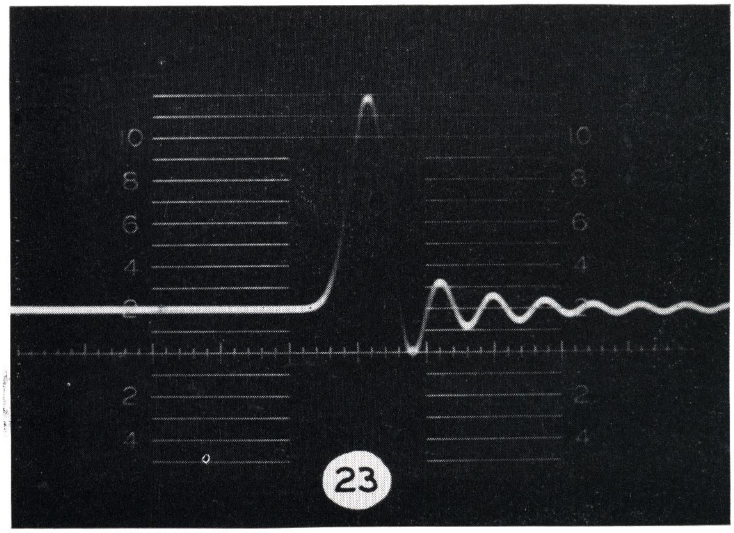
Tolerances for ringing can be more easily defined than streaking. With the advent of the sine-squared pulse with its known rise time, we have been given a signal which gives reproducible results. The left side of the next slide (No. 21) shows the pulse as it leaves New York, and the right side shows the same pulse as it returns to New York after a trip around the video round robin.



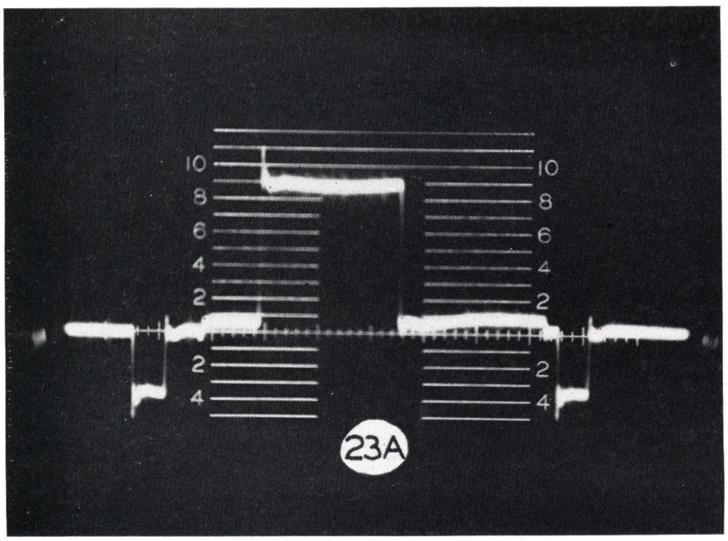
The easiest way to measure the pulse distortion is to adjust the CRO vertical gain and centering until the pulse is between zero and 100 on the IRE scale (Slide No. 22). Then adjust vertical centering until the most negative excursion is at zero and measure the top of the most positive excursion. The measurement will then be in per cent. (Slide No. 23). Photos taken for submission to Telco or your network representative should be centered as in Slide No. 22.

For this method of measurement, a tentative value of 20 per cent was adopted by NBC on April 1, 1961, and has proved to be a stiff tolerance for even stations fed from the backbone circuits. However, it can be met! Due to work under way by the Bell System, it is expected this value of 20 per cent will become increasingly easier to meet and eventually will be reduced. Slide Nos. 22 and 23 illustrate the preferred method of calibrating photos and measuring per cent ringing.

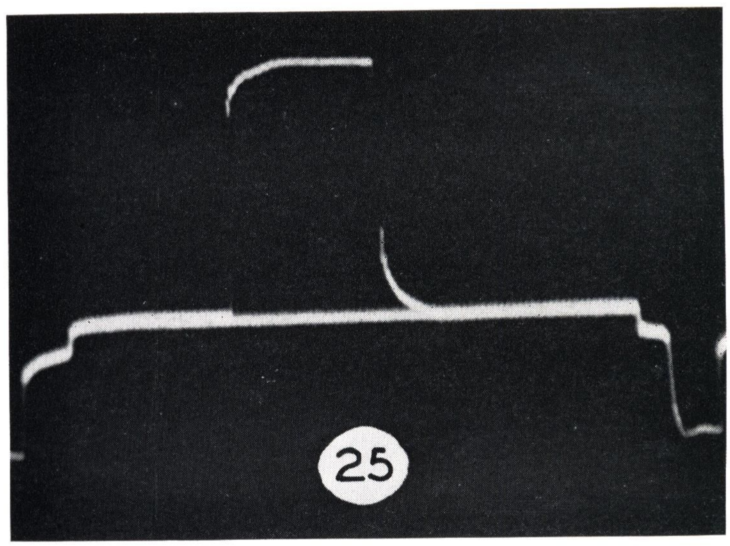




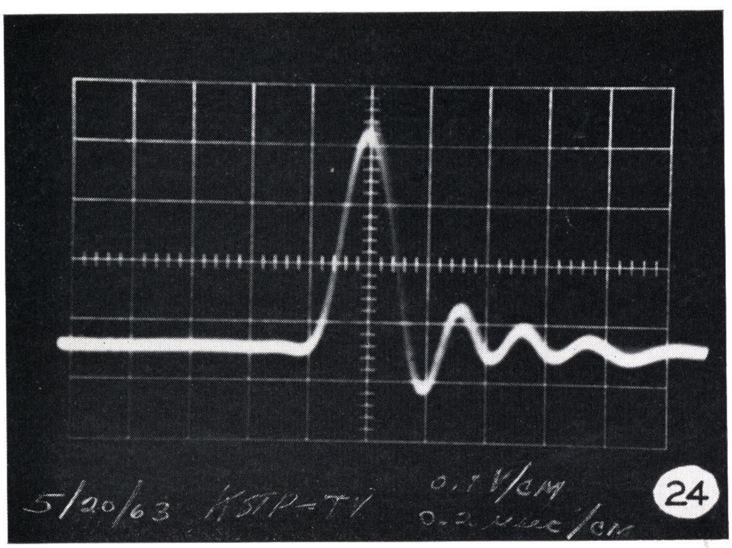
A few actual waveform photos taken recently show some of the many reoccurring problems. (Slide Nos. 23A, 24, 25, 26)



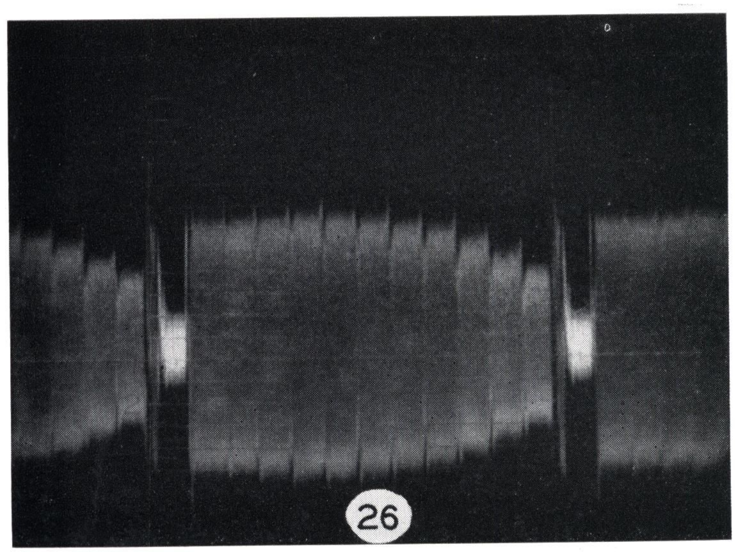
Slide No. 23A shows excessive spiking.



Slide No. 25 shows heavy positive-type streaking.

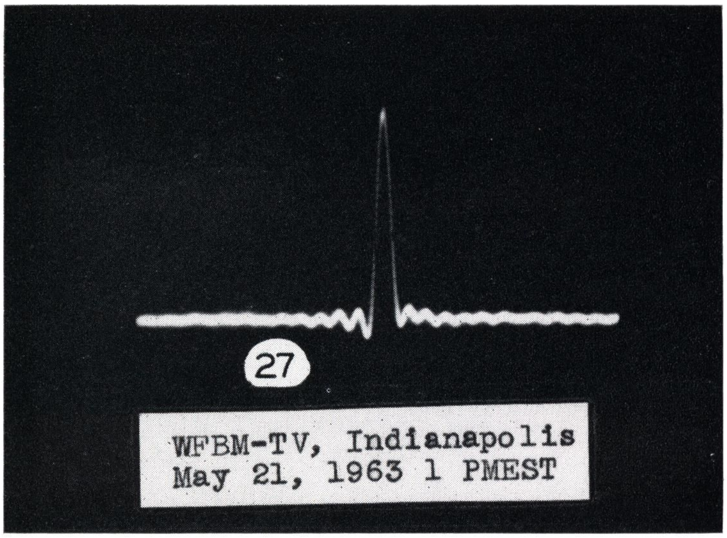


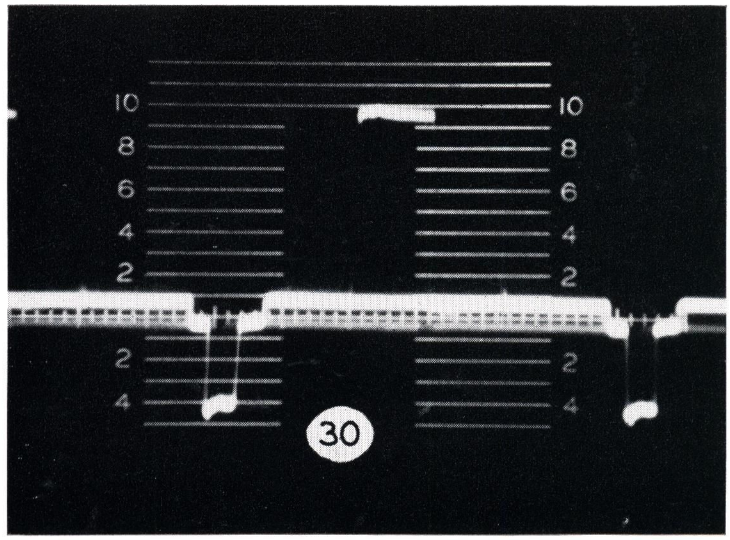
Slide No. 24 shows excessive ringing.



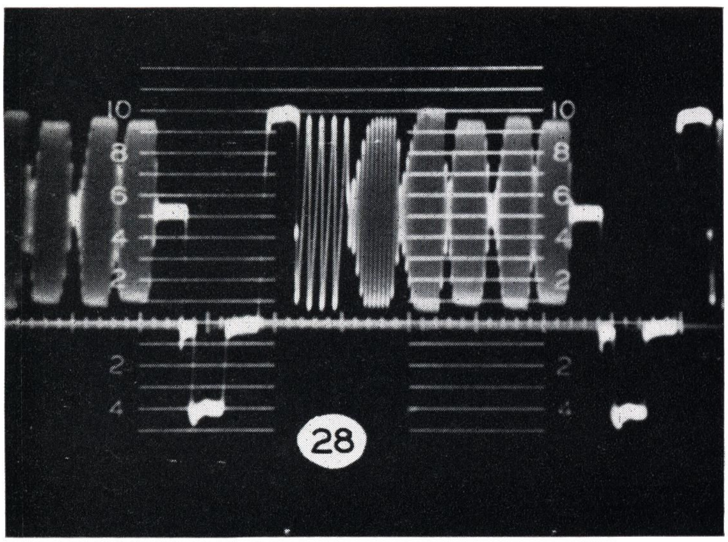
Slide No. 26 shows a large amount of differential gain.

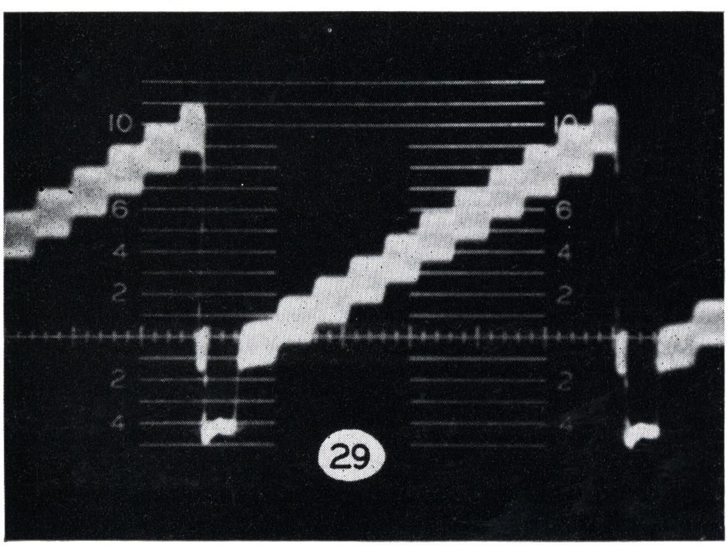
An interesting photo is one sent from Indianapolis (Slide No. 27). It shows a usual ringing condition due to the L3 cable from Louisville to Indianapolis.





The next three photos (Slide Nos. 28, 29, 30) illustrate slightly better than average transmission. While not perfect, they do represent quite satisfactory transmission.





During the past year, we have discovered that colored outlines around the right side of objects were being experienced by a number of southern stations. Until quite recently, the stations believed these were a video tape phenomenon. However, it has now been established that the effect is due to network transmission, not the tape machines. It is due to out-of-band ringing being reduced in frequency to such a value that the ringing frequency will be within the chrominance pass band of the color receivers. When this happens, it will appear as several cycles of ringing on black and white receivers and as a colored outline on color receivers. The Bell System believes this to be due to a non-uniform delay characteristic of the microwave relay system.

Reporting Transmission Problems

When transmission impairments are noted, it is important that you notify the Telephone Company immediately. Don't wait! If possible, report the trouble while it is on the air. If the trouble continues, keep advising the Telephone Company as often as you feel the trouble warrants. Don't just sit and wait.

For instance, I was out in the field when DST started and heard 20 minutes of bad audio during one of our important evening shows. I was repeatedly told the trouble was located at the pickup. Upon calling New York, I learned it was o.k. there. Several phone calls later, it was admitted to be a telephone line problem. So be suspicious if a trouble persists.

If you do not receive a satisfactory answer or the impairment is not cleared in a reasonable time, then advise your network contact via TWX or telephone.

In addition to the verbal reporting, it is important and very helpful to us if you will take two sets of waveform photos of the network test signals. Send one copy to your Telephone Company contact (usually the Chief Testboardman or Video Supervisor) and send the other set via air mail to your network contact. Be sure to write on the back of the photos the station call letters, date, time, etc.

Chief Engineers should take the initiative and regularly visit the local TOC and become acquainted with their Telephone Company counterpart, usually the Chief Testboardman or Central Office Chief.

Checking Broadcasters Equipment

Experience has shown that if there is trouble in a TV plant it probably will be located in a stabilizing amplifier, STL link, TV transmitter, or associated input equipment.

I definitely recommend that converted TA5 stab amps, TA7A color stab amps, and colorized tenth watt microwave relay equipment be replaced or given the deep six treatment; They were good in their day—but their day has passed! The same thing holds for similar equipment made by other manufacturers.

Some stations use two stabilizing amplifiers, one at the control room and one at the transmitter. The stabilizing amplifier at the control room may be found to be in excellent shape while the one at the transmitter may be in trouble, or vice versa. One weak link in the chain can do a lot of harm to color. I recommend that if possible only one stab amp be used, probably at the transmitter. A variable gain amp on the incoming net feed will usually be satisfactory for control room use.

Stabilizing amplifiers should be completely routined every six months—*not just checked.*

Stations which are having trouble making video tapes of network signals due to horizontal timing errors following the vertical interval should check their stabilizing amplifiers and processing equipment. Slight timing errors on the network can be greatly emphasized by certain types of amplifiers, particularly those using regenerative clipping, and make the video tape unusable. It may be advisable to contact your manufacturing representative for modifications.

Receiver-type demodulators often give misleading results. They should be returned to the factory for re-alignment every two to three years, oftener if trouble is suspected. In fact, they shouldn't be trusted except when they are in agreement with the transmission line diode. It is preferable to use the transmission line diode when making differential gain and phase measurements.

The only way to be sure you are handling color programs satisfactorily is to set up a system of routine tests and see that they are carried out regularly. In addition to the usual daily check, a more comprehensive test should be made on a weekly basis. This test should be on an overall basis from the input to the control room to and through the TV transmitter. The three standard test signals—multiburst, stairstep, and window signals—should be used and waveform photographs taken at the transmitter output and given to the Chief Engineer. The amount of differential phase measured should be marked on the reverse side of the photo of the stairstep signal.

Since a large proportion of the distortion will usually be due to the transmitter, it is important that any degradation occurring in the control room and STL be held to a bare minimum.

Control rooms should be held to two degrees or less. The average transmitter can be held at 6.0 degrees. Some transmitters cannot meet this value; others can better it substantially. Certainly for good transmission, the overall differential phase should not exceed 10.0 degrees.

Differential gain should be held to 10 per cent if at all possible. If this value cannot be met, every effort should be made to meet it as closely as possible.

The amplitude-frequency response should be essentially flat; and to avoid ringing, it must not be peaked at the high frequency end. A roll-off tolerance of 10 per cent should be met if possible. However, from a practical standpoint, it may be diffcult to meet a tolerance of less than plus or minus 10 per cent.

The window signal should not show any appreciable streaking, tilt, or spiking when using a good receiver-type demodulator at the transmitter. Low-frequency irregularities occurring on the top of the window signal should be of such a low amplitude as not to be visible in the received picture. Incidentally, the window and multiburst signals are excellent to use when checking video monitors for streaking and frequency response.

Color Monitoring

The following item was included in an engineering memo to all NBC Stations but applies to any station carrying color programs.

The recent increase in color programming and color bar transmissions during network test periods requires the use of good color monitoring equipment in control rooms.

There are two approaches to the problem of providing good color monitoring. One approach is to use a 21-inch color monitor. The other is to use a recent vintage color receiver and a video modulator of the I-F type. This latter approach is indicated where the cost of the video monitor might preclude its purchase. Also, the combination requires no modifications to be made to the receiver as the modulator is completely plug-in.

Final Remarks

It is the responsibility of the TV stations to see that they are transmitting color with a minimum of distortion. Many stations do not have adequate test equipment to properly routine their plants. Usually, this means that the station management is not convinced as to the necessity of spending money for test equipment or possibly the Chief Engineer has not been aggressive enough in convincing his management.

Routine maintenance doesn't necessarily cost more money, but it does call for careful planning, training, and efficient use of personnel.

It also is the responsibility of the TV stations to see that the incoming network signal is reasonably satisfactory. During last year's DST period, the B Network suffered very excessive hue shift for several weeks. If only one affiliated station had measured the differential phase and reported the trouble to us, it would have been remedied within a few hours. In other words—*don't blame the pickup for everything;* we have enough problems without being blamed for other people's problems.

HANDLING THE COLOR TV SIGNAL

Checking and Monitoring Terminal and Distribution Equipment

by JOHN W. WENTWORTH
Manager, Educational Electronics
RCA Broadcast and Communications Products Division

In this paper, we shall consider the problems of handling color signals through the "master control" facilities normally found in a television station.

Part II, by Mr. Gronberg, reviewed the steps taken by the networks and the telephone companies to assure delivery to your station of the highest possible technical quality in color television signals and offered comments on some of your own responsibilities in this area. Parts IV and V by Messrs. Bullock, Marye and Small discuss the specialized problems involved in handling color signals through microwave relays and broadcast transmitters. Let me remind you that the main objective of this entire series of seminar papers is to provide information that will help you, as a local station chief engineer, supervisor, or operator, to deliver better color pictures to your broadcast audience.

We shall be concerned here with three basic categories of equipment: stabilizing amplifiers, switchers, and general-purpose distribution amplifiers. I shall also comment on the test equipment we recommend for use in the studio plant, and we'll discuss a number of practical test and alignment techniques as we proceed.

There may be some question as to whether it is really appropriate to consider stabilizing amplifiers in a paper devoted to "master control" equipment. While some stations still make it a standard practice to pass an incoming network signal through a stabilizing amplifier before injecting it into the master control switching and distribution system, more and more stations are finding that it is desirable to abandon this practice, and to use only a single stabilizing amplifier at the transmitter location as recommended in Mr. Gronberg's paper. This writer strongly endorses Mr. Gronberg's suggestion that you avoid the use of stabilizing amplifiers wherever possible — use one at the master control point only if there is a clear reason for doing so. Inclusion of the stabilizing amplifier in this particular paper was planned only to make sure that we cover some of the important problems related to his equipment; the information is not repeated in the Part V paper on transmitters, even though the stabilizing amplifier is perhaps more likely to be used at the transmitter than at the master control point.

Recommended Test Equipment

A brief list of test equipment that we recommend for use around the studio plant is presented in Table I. (A few additional items are required for specialized measurement problems at the transmitter, as pointed out in Part V.) In order to keep these seminar papers on a non-commercial level, we have avoided the use of specific type numbers or MI numbers, but your local RCA field representative would be happy to advise you concerning the specific items in each category which would best serve your needs.

I should like to comment in fair detail on color monitors and television oscilloscopes, but I believe we might first discuss very briefly the other items listed. The "Multi-Test Signal Generator" is a device which generates the specific test waveforms reviewed in my introductory paper (Part I) and used by Mr. Gronberg to illustrate Part II. While you can gain a great deal of useful information by viewing the signals which the network line brings into your plant, chances are these signals are somewhat distorted or degraded before you even receive them. You may also experience difficulty in routing the network signal through the specific pieces of equipment you want to check at the times when network test signals are available. Thus, we strongly recommend that you acquire your own multi-test signal generator so you will have a convenient source of good clean test signals of all basic types to check your local plant equipment.

A necessary accessory to the multi-test generator for differential phase measurements is a Color Signal Analyzer or its equivalent. The item designated by this name in the RCA test equipment

Table I

RECOMMENDED TEST EQUIPMENT FOR STUDIO USE

COLOR MONITOR
TELEVISION OSCILLOSCOPE
MULTI-TEST SIGNAL GENERATOR
VECTORSCOPE OR COLOR SIGNAL ANALYZER
VIDEO SWEEP GENERATOR
OSCILLOSCOPE CAMERA

product line has now been discontinued, but the function it performed is now available in the Vectorscope manufactured by Tektronix, Incorporated and available through your RCA field representative. In principle, the Color Signal Analyzer is nothing more than a phase detector with a calibrated phase shifter. We shall comment in greater detail on differential gain and phase measurement techniques a little later in this paper.

In view of the current popularity of the multi-burst test signal for frequency response measurements, you may be a little surprised to see that a video sweep generator remains in our list of recommended test equipment. While we heartily endorse the multi-burst test signal for routine checking purposes, we still feel there is great virtue in the traditional sweep signal for actual maintenance work, such as the alignment of peaking coils. The multi-burst signal checks the response at only a few specific frequencies, while the sweep shows the entire characteristic above a few hundred kc. A sweep generator with good detector circuits and a dual-trace oscilloscope offers the most sensitive test facility for critical alignment tasks where you must be concerned with accuracy of the order of 1 per cent or so.

The oscilloscope camera deserves recognition both as a test instrument and as a communications tool. Mr. Gronberg has pointed out the great value of waveform photographs as a means of describing to outside persons, such as telephone company or network representatives, any difficulty you may be having. You will also find that periodic photographs of test signals made at the major check-points throughout your system can be a valuable addition to your maintenance records. If you have a case of ringing, for example, that looks a little more severe than you remember from previous tests, you'll find that its very handy to be able to pick up a photo made several weeks earlier to help you decide whether or not something has changed.

You will note that the color bar generator is not included on this list of basic test equipment, because such a bar generator is of relatively limited value in testing the "master control" equipment which is our primary concern in this paper. A color bar generator is quite essential, however, if you operate any color origination equipment (either live or film), or if you operate a color tape recorder. A color bar signal is also extremely useful in setting up color monitors, so if you operate a number of color monitors and have any serious plans about eventually acquiring color origination equipment, you can probably justify an investment in the equipment involved in generating the standard color bar signal. (In addition to the color bar generator itself, you will probably need a Colorplexer and color accessories for your studio sync generator.)

The Importance of Color Monitors

Incredible as it may seem, we find that some stations are attempting to broadcast network color signals without owning or operating a single color monitor! In my judgment, this practice violates common sense. While you can learn a great deal about the quality of a color signal by viewing on a black-and-white monitor and by inspection of the signal waveform, there is still no substitute for actually viewing the color picture. I believe it is wise to keep reminding ourselves that the entire television industry is in the business of making illusions — our viewers *actually* see nothing more than patterns of light, shade, and color on fluorescent screens, but we want them to *think* they are seeing studio or outdoor scenes with as much realism as possible. Soon after I began my television engineering career, a "senior scientist" in the television industry impressed upon me the concept that

FIG. 1

a television system doesn't necessarily have to work—it just has to *look* like it works! In other words, *the picture is the thing*, and if you're trying to transmit color pictures it is very important that you have reasonable facilities for inspecting the product you are delivering.

Because there is only one color monitor designed as a "quality control" instrument available on the American market, I believe that we can, without violating the non-commercial theme of this seminar, make a rather direct recommendation that you install and use at least one RCA TM-21 Color Monitor (Fig. 1) at your master control position. In addition to its ability to display a high-quality color picture, this monitor can also serve as a useful test instrument in its own right. A color receiver modified to accept a video feed offers a lower-cost approach to the problem of displaying a color picture, and such an arrangement is quite satisfactory in many locations where the viewing requirements are not particularly critical. Color receivers have been improved steadily over the past ten years or so, and now require no apology whatsoever as consumer products for use in the home. For use as station monitoring equipment, however, even the best color receiver may leave something to be desired in the sense of absolute stability. When you see something wrong in a color picture at your master control location, you would like to have more than a guess as to whether the problem is in the signal itself or in the device displaying the signal. The TM-21 Color Monitor is sufficiently well stabilized that you can, in fact, be quite sure that it is indicating the true quality of the *signal* itself. You will probably find that the somewhat lower-cost, utility-type color monitors now becoming available are intermediate (between color receivers and the TM-21) with respect to both basic picture quality and long-term stability.

Although part of the stability of the TM-21 Color Monitor results from the use of thoroughly regulated power supplies and very conservative design techniques in the deflection circuits, the major differences between this monitor and the typical mass-produced receiver are to be found in the decoder, which is shown in block diagram form in Fig. 2. This decoder employs a variety of techniques, such as feedback stabilization and a gated form of d-c restoration, which are clearly too expensive to be practical in home instruments. It is also significant that the monitor has separate filters for the I and Q channels which make full use of the information contained in the color signal. (Most receivers are compromised in this respect, and fail to make full use of the 1.5 mc nominal bandwidth of the I signal component.) The TM-21 can also display a monochrome picture of higher quality than most receivers, since the "color killer" circuits in this monitor not only disable the chrominance channels but also increase the bandwidth of the monochrome channel when the incoming signal has no color synchronizing burst.

Waveform Monitors and Oscilloscopes

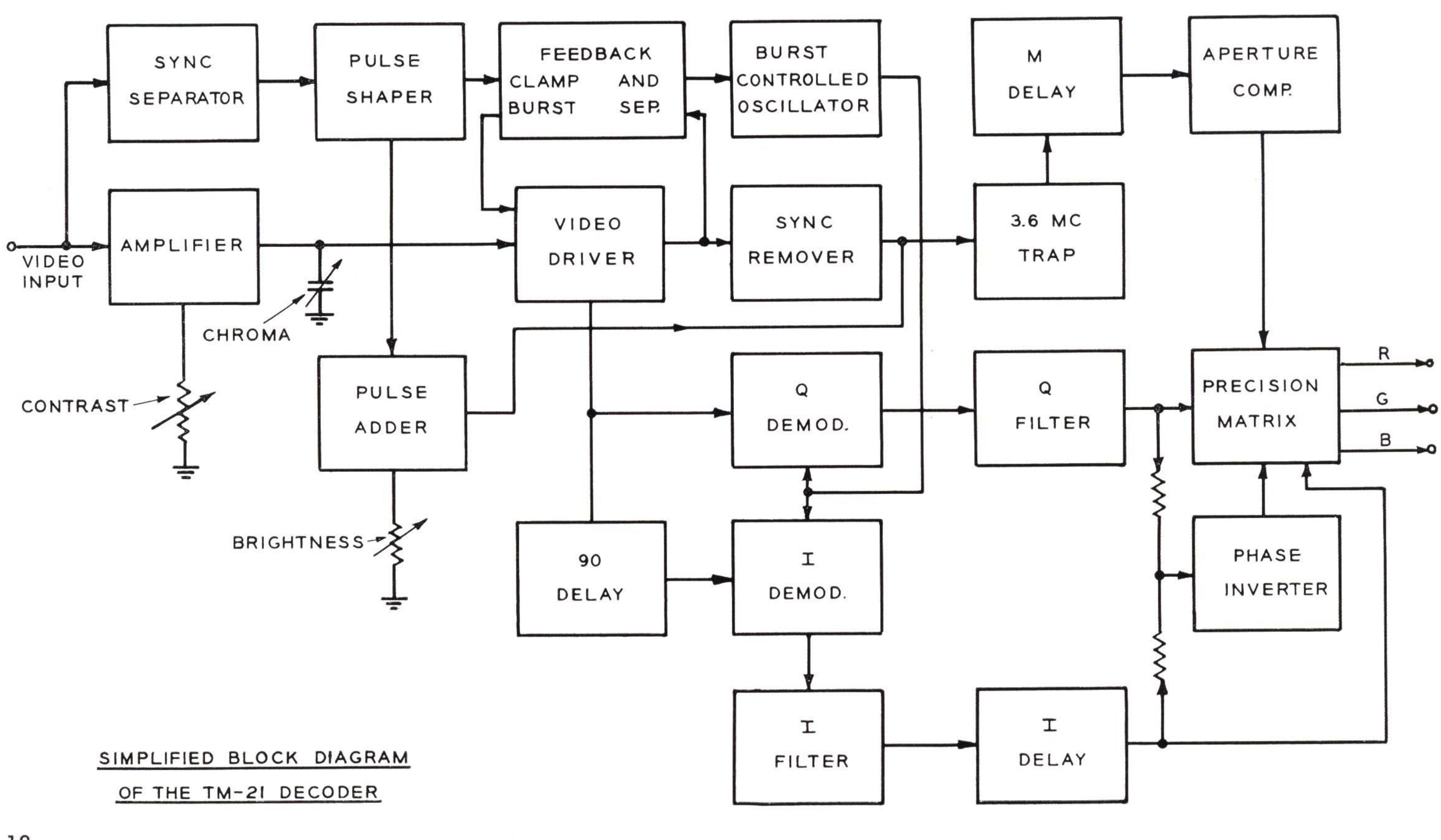
The oscilloscope is certainly one of the most basic test instruments for use in a television studio plant. You probably have two relatively distinct needs for oscilloscopes, in addition to those included in the master monitors associated with your camera chains. You need at least one good waveform monitor "built in" at your master control point, where it is always available for quick inspection of any of the signals passing through your plant. You also need at least one good maintenance instrument, preferably mounted on a "tea wagon" or dolly which can be moved around the racks and utilized wherever it is needed.

The role of the waveform monitor in the "quality control" of television signals is so well known that little time need be spent here in extolling its virtues. If you have not yet had much experience in color, however, you may not be aware how much you can learn about a color signal by careful inspection of the waveform *on a monitor of known characteristics*. The standard color bar signal shown in Fig. 3 is particularly suitable for waveform analysis.

For those of you who are not already familiar with this waveform, I might point out that you are seeing a superimposition of two signals, corresponding to both portions of what is, in effect, a vertical "split screen" display. In the upper half of the picture produced by the standard color bar signal, each line is divided into seven nominally equal intervals, corresponding to "pure" colors in the following sequence: White, yellow, cyan, green, purple, red, and blue. This entire sequence of colors is transmitted at 75 per cent of the maximum possible level in order to produce a signal which does not exceed the reference white level; hence the "white" bar in this basic sequence extends only 75 per cent of the way between black level and reference white level. In the lower half of the picture, there are only four basic intervals, used to transmit samples of I sub-carrier, reference white, Q sub-carrier and black; the black interval covers nominally half of the entire line. (The samples of I and Q sub-carrier are superimposed on black level, and are transmitted at peak-to-peak levels of 40 IRE units.)

The standard color bar signal has a number of "check points" which enable you to determine readily whether or not the Colorplexer which produced the signal is properly adjusted, and whether serious degradation has occurred in the transmission equipment or recording equipment through which the signal may have passed before inspection. For example, the state of "carrier balance"

FIG. 2



SIMPLIFIED BLOCK DIAGRAM OF THE TM-21 DECODER

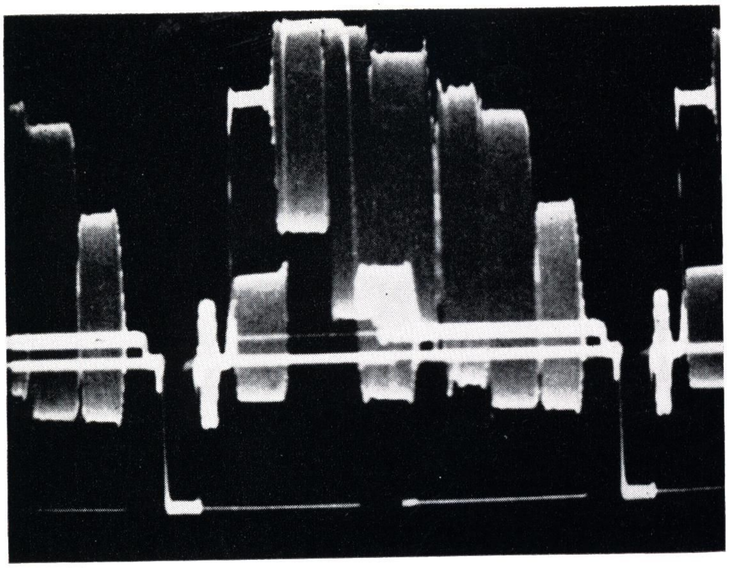


FIG. 3

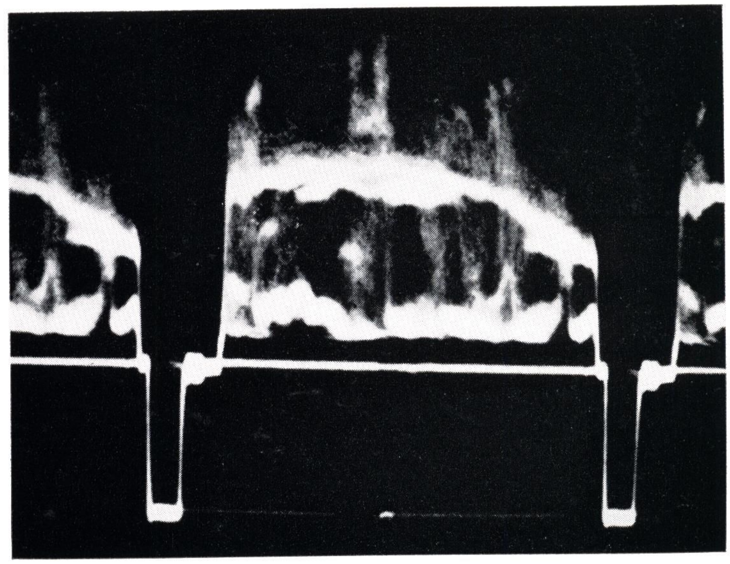


FIG. 4

adjustments is clearly indicated by the residual sub-carrier at the blanking level, and proper "white balance" is indicated by the absence of sub-carrier in the reference white and 75 per cent white pulses. When "chroma gain" is set correctly, the lower excursion of the sub-carrier for the green bar should just touch the black level, and the upper excursion for the purple bar should line up with the 75 per cent white level. If the chroma gain is correct and the I and Q signals are in proper phase quadrature, the "undershoots" for the red and blue bars should line up evenly, and the "overshoots" for the yellow and cyan bars should line up with each other and with the reference white pulse. Burst gain is correct if the signal as a whole shows proper chroma level and the burst has a peak-to-peak amplitude of 40 IRE units (the same as the sync pulse).

It is not possible, of course, to learn nearly as much from the inspection of normal color *program* signals as in the case of the color bar signal, but you can often get a pretty good indication as to what is happening to the chrominance part of the signal by careful inspection of the color synchronizing burst. If your waveform monitor is essentially flat to 4.0 mc, you should expect the burst amplitude to remain constant at 40 IRE units—if it fluctuates appreciably, chances are there is a corresponding variation in the chrominance part of the picture signal, unless you see other evidence to indicate that burst distortion is taking place because of faulty clamping somewhere in the system. The *envelope* of the burst also contains useful clues. Most colorplexers deliver a burst with a good rectangular envelope, and if you detect "football" shaping or other distortion in the burst envelope, you have good reason to suspect that the entire color signal has been subject to some type of high-frequency amplitude or phase distortion, the seriousness of which can best be judged on a good color monitor.

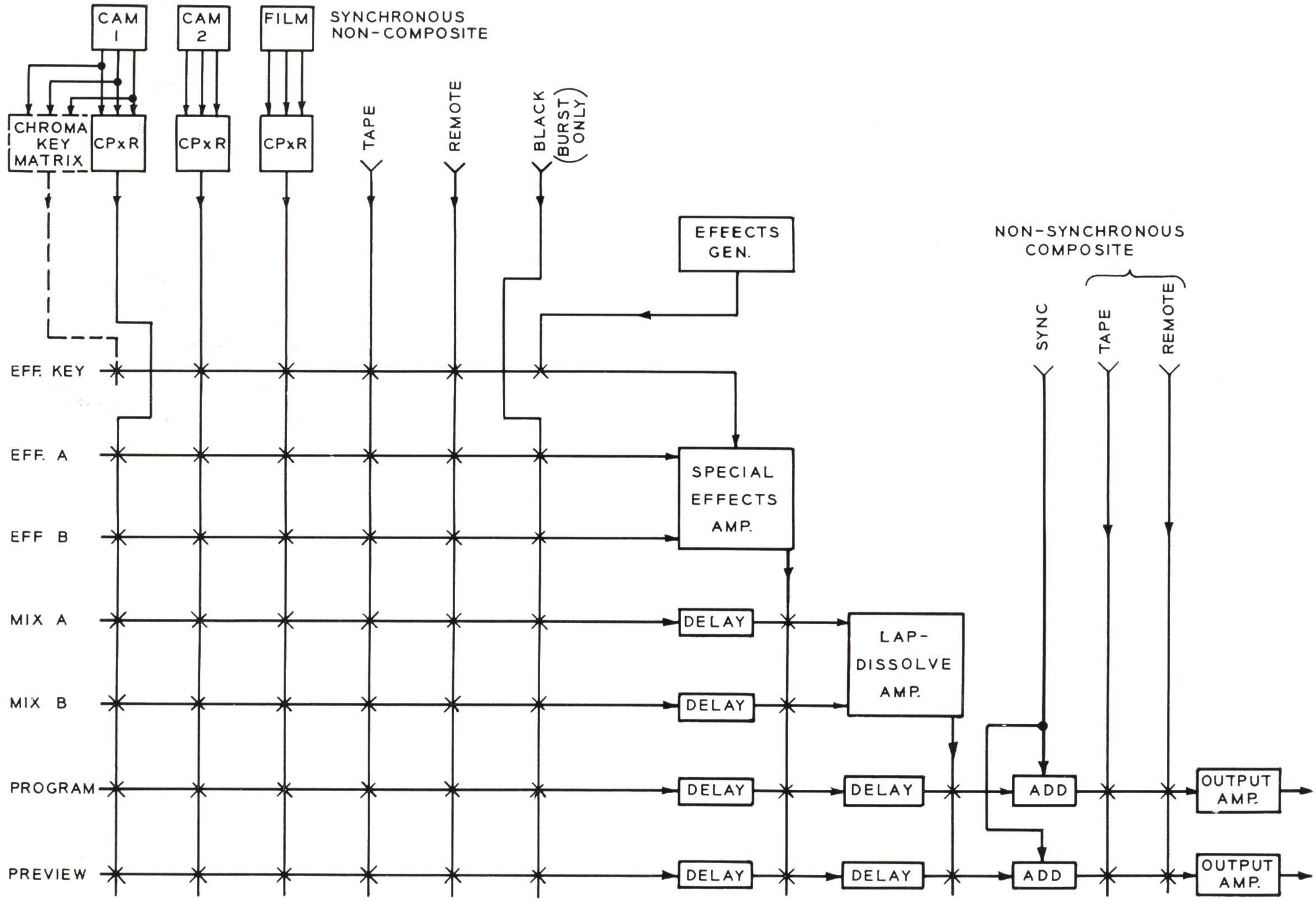
Incidentally, it is recommended that a waveform monitor with the IRE roll-off characteristic be used for routine level-riding purposes, so that judgment as to where "white level" should be set is not unduly influenced by either sub-carrier overshoots or narrow "spikes" in the luminance signal. When the IRE roll-off filter is in use, you must expect to see the color synchronizing burst severely attenuated, as shown in Fig. 4.

In addition to its use in inspecting actual color signals, a good waveform monitor is essential for proper interpretation of any of the test signals we have been discussing throughout this seminar. If your waveform monitor shows some consistent defect, such as smearing or ringing, you should be certain that the instrument itself is beyond reproach in these respects before you proceed to trouble-shoot your entire system.

For general maintenance work, many stations find that the 524 series of Tektronix oscilloscopes still satisfy all their needs, but more and more broadcasters are beginning to recognize that an oscilloscope with dual-trace capability expedites a great many trouble-shooting and maintenance procedures, especially where television tape equipment is involved. If you are contemplating the purchase of a general-purpose oscilloscope in the near future, I strongly recommend that you consider one of the dual-trace type. Our field representatives would be happy to discuss with you the characteristics of the several types available.

Switching Systems

Individual stations differ widely in their requirements for switching equipment, so you may be concerned with passing color signals only through very simple, "direct" switchers comparable to the RCA TS-11, or you may have a very elaborate system with remote controls and a great many features, such as those provided in the RCA TS-40. In no case should you anticipate any particular difficulty in passing color signals *through the switching elements themselves*. If the switching elements are of the metallic-contact variety (coupled either to pushbuttons or relay armatures), there is obviously little opportunity for signal distortion, assuming that the contacts are kept clean so that they close reliably. Even in the newer solid-state switching systems, where the actual switching elements may be transistors or diodes, you have a right to expect from any reputable manufacturer a reasonable choice of signal levels and bias voltages or currents that asures distortion-free handling of color signals through the actual switching circuits. The major problems in handling color signals through switching systems are normally external to the actual switching elements. Capacitance loading effects, variable timing



SIMPLIFIED BLOCK DIAGRAM OF A COLOR STUDIO SWITCHING SYSTEM

FIG. 5

problems, and the distortion introduced by isolation amplifiers or output amplifiers are more likely sources of difficulty.

The block diagram shown in Fig. 5 represents a color television studio switching system providing facilities comparable to those used in relatively large local stations. You will note that the system provides both special effects and lap dissolves, and has both program and preview output buses. The diagram is greatly simplified in that it does not show the full number of camera inputs that would normally be required, nor all of the isolation amplifiers and other items that may be required in "transporting" signals from point to point throughout the system, but it does serve to illustrate some of the basic problems involved in color switching systems.

In designing and maintaining color television switching systems, you must, of course, be concerned about uniformity of frequency response through all possible paths; tolerance limits in this area are much tighter than for monochrome switching systems because of the presence of the vital chrominance information in the upper part of the video band. Thus, the variable capacitance load that may be found across a given "cross-point" or switching element must be held within close limits for a color system, while the same characteristic may be quite unimportant for a monochrome system. Even the distributed inductance of switching buses can be troublesome; you will find that in many color switchers the buses consist of relatively heavy copper straps of rectangular cross-section instead of the traditional round wires. It is also necessary to match path delays in color switching systems so that the color synchronizing bursts are not subjected to rapid changes in phase as various signal sources or effects are "punched up". A basic approach to the delay problem is shown in Fig. 5. Note that delay networks matching the delay characteristics of special-effects amplifiers and lap-dissolve amplifiers are provided so that a signal takes the same amount of time to arrive at the output of the system no matter what route it follows.

Color Genlock Facilities

Detailed discussion of design details in color switching systems is beyond the scope of this paper, which is concerned primarily with the *handling* of color signals through facilities which we must assume were properly designed and installed. Actually, in many stations concerned only with *network* color signals, color performance requirements must be met only in the relatively nominal "master control" facilities shown in the lower right-hand corner of Fig. 5 (where the network signal is treated as a non-synchronous, composite REMOTE input). Some stations, however, may encounter a need for color genlock facilities so that network or other remote signals can be passed through special effects or lap dissolve amplifiers along with local signals. (A TA-9 stabilizing amplifier can be used to remove synchronizing pulses from color signals to obtain the noncomposite signals required for most effects amplifiers.)

One possible approach to such genlock facilities, patterned after the arrangement actually used by NBC in the New York City area, is shown in Fig. 6. This particular approach is based on the use of a two-way video feed between the main plant and a remote location. The outgoing signal from the main plant may have only sync pulses and color synchronizing bursts, but the same line might also be used for a video cueing signal, a film chain output, or some other signal needed at the remote location. The actual color genlock facilities at the remote location consists of a standard monochrome sync generator with built-in genlock for the conventional deflection sync pulses, plus a burst flag generator and a burst-controlled oscillator. (The burst-controlled oscillator may have a "sync stripper" suitable for supply pulses to the genlock input of the monochrome sync generator; alternatively, a stabilizing amplifier could be used for this function.) Note that a Color Frequency Standard is not required at the remote location. Even though the sub-carrier and the pulse signals may be "locked in" to the master control signal through two nominally independent AFC loops (one in the burst-controlled oscillator, the other in the monochrome genlock), they retain the harmonic relationship specified in the FCC standards. In a situation where you cannot afford a two-way video circuit between master control and a remote location, you can still operate in a "genlocked" mode by making your main plant a "slave" to the remote signal during the period when synchronous operation is required.

The Importance of Complete System Tests

In studio switching and distribution systems of normal complexity, it is not too unusual to find as many as ten isolation amplifiers or distribution amplifiers in cascade in typical signal paths. Thus, while each such amplifier may not be a significant source of degradation in handling a color signal (ignoring the temporary problems resulting from obvious tube or component failures), the accumulated distortion resulting from a number of such units in tandem can become quite serious. If you attempt to analyze or align individual units with such precision that you can be sure of satisfactory performance in the complete system,

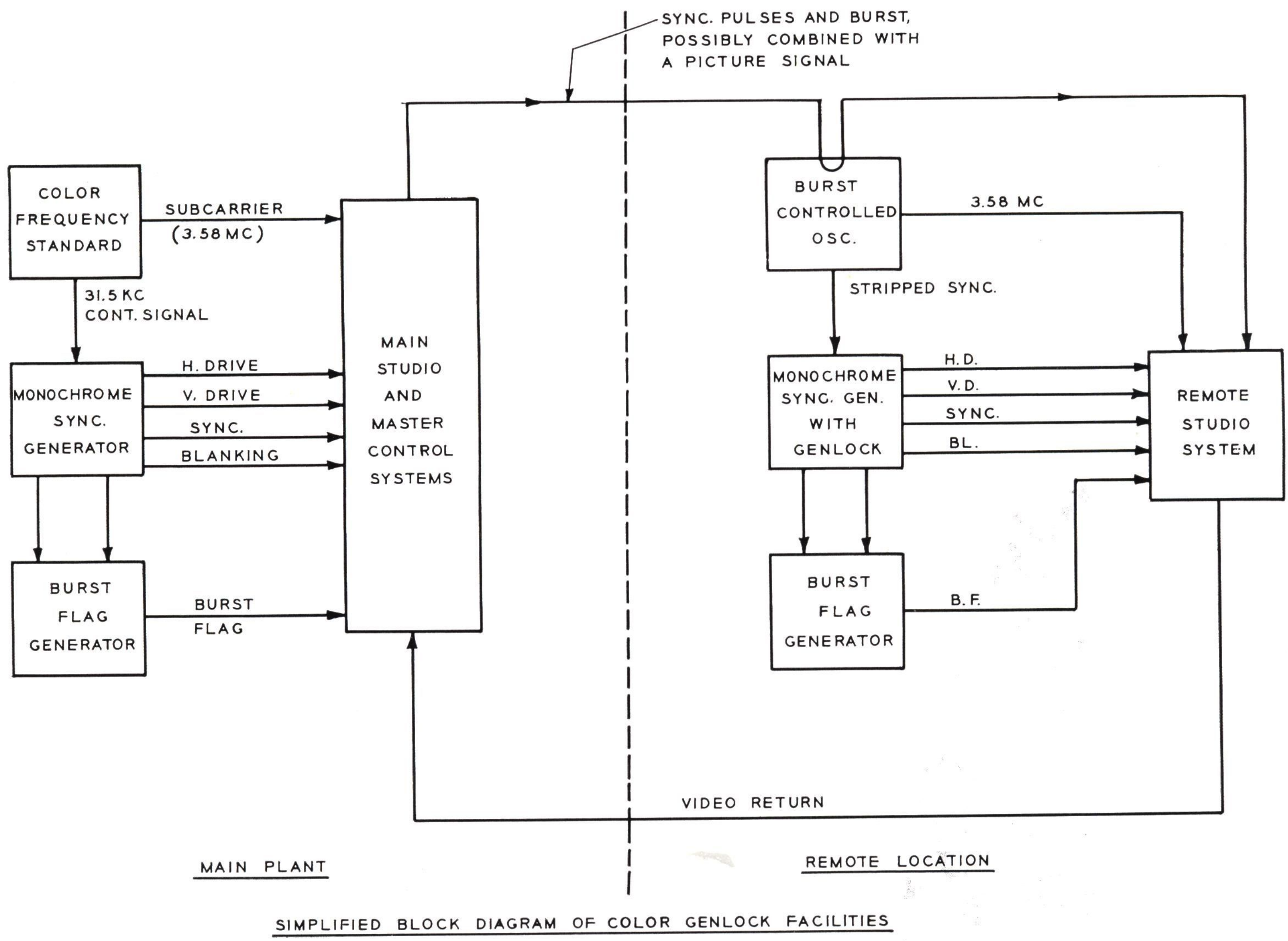


FIG. 6

chances are you will exceed the "resolution limits" of your test instruments. It is more practical, therefore, to align most distribution amplifiers *within the context of the system*. You should, for example, inject test signals at your network input point, and examine the signals as they leave your studio system, preferably with all possible signal paths "punched up" in succession so that you check out all possible signal routes and detect differences between them. Of course, when you discover problems through this approach, you must "track down" the major source of the problem in order to take reasonable corrective measures.

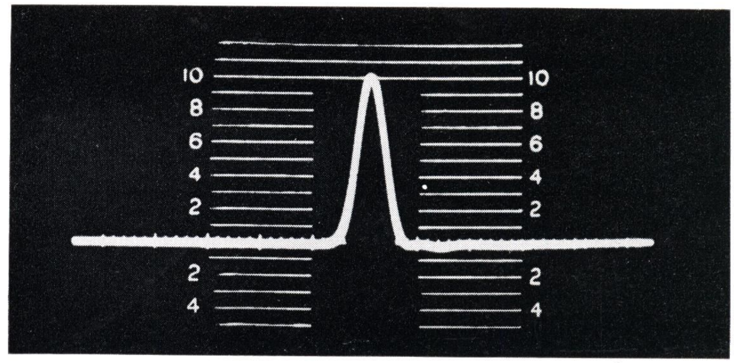
When you "sweep out" isolation amplifiers to adjust their frequency-response characteristics, we strongly recommend that you make it a point to have each amplifier terminated in the actual load which it drives in the system. Stated differently, we suggest that in sweeping out a complex switching and distribution system you start at the output and work back toward the input. If you start at the input, you usually find it necessary to place "dummy loads" on the output of each unit you encounter, if you start with the last amplifier in the chain, however, the output line itself can serve as the load across which you connect your monitoring instruments. Then, as you work back through the chain to the input, each amplifier is called upon to drive the load it actually handles in service. This approach is desirable because the loads to which isolation amplifiers are connected in actual service are seldom simple resistors; the reactances associated with switching buses and amplifier input capacitances can have a significant effect on the overall frequency response characteristics.

Transient Response Measurements

Most television engineers and technicians are quite familiar with basic frequency response measurements, using either the multiburst test signal for rapid routine checks or a video sweep signal for more detailed alignment procedures. The value of *transient response tests*, based on the window and sine-squared pulse signal shown in Fig. 7 may not be as widely understood.

As pointed out in my introductory paper in this series, the "window" portion of this test signal may be interpreted as a specialized square-wave test signal specifically designed to check the low-frequency response characteristics of television systems, and Mr. Gronberg has given you several good examples of the type of distortion you can detect with this signal.

The sine-squared pulse, which appears as the narrow "spike" in Fig. 7 and in enlarged form in Fig. 8, is a specialized transient-type test signal for detecting problems in both amplitude and phase response in the upper portion of the video band. This signal actually represents one of the most practical approaches known for the detection of phase response problems, which manifest themselves through assymmetry in the pulse waveform. The "ringing" distortion in the lower trace in Fig. 8 represents phase distortion far in excess of anything you should expect in a normal studio plant. As a matter of fact, you should expect a 0.125-microsecond sine-squared pulse to pass through your entire studio system with *no* visible distortion.



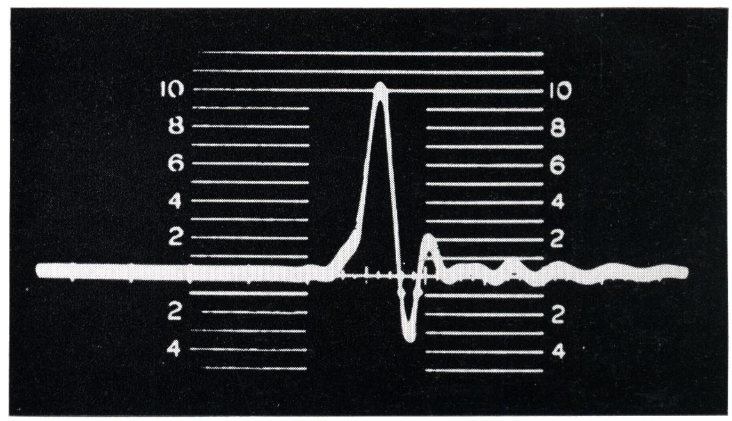


FIG. 8

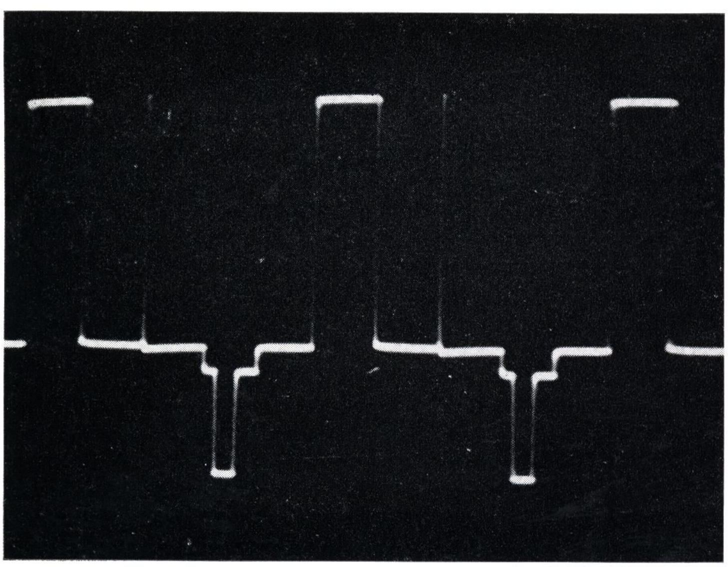


FIG. 7

An important advantage of the sine-squared pulse as a test signal is its predetermined energy spectrum. It is standard practice among television engineers to measure the width of sine-squared pulses at the 50 per cent level, as indicated in Fig. 9. A pulse 0.125 microsecond wide at the 50 per cent point is known to have an energy distribution curve which is 50 per cent down at 4.0 mc and effectively zero at 8.0 mc, as indicated by the lower sketch in Fig. 9. (For those who are mathematically inclined, it may be significant to point out this energy distribution is *Gaussian*;

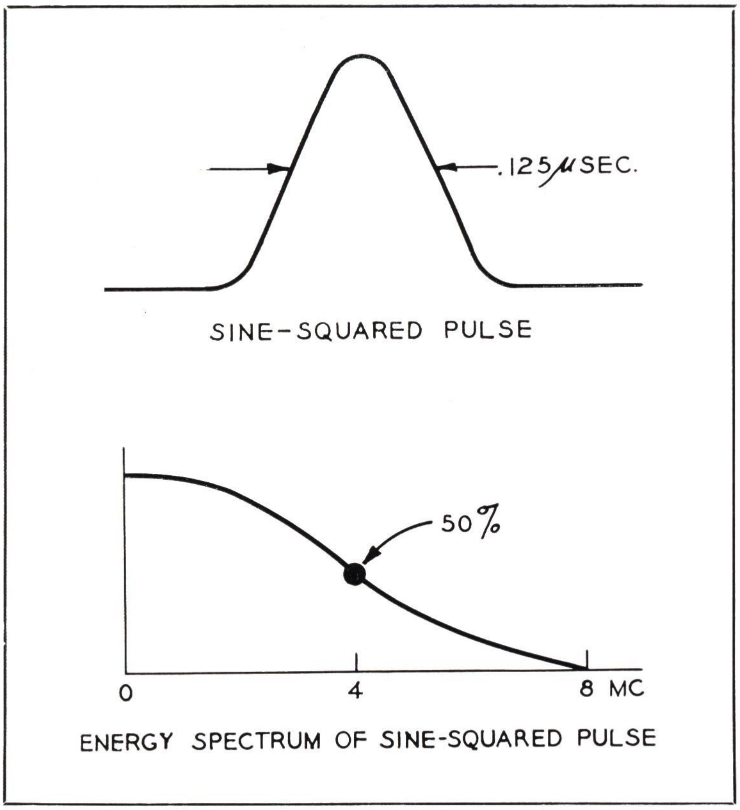


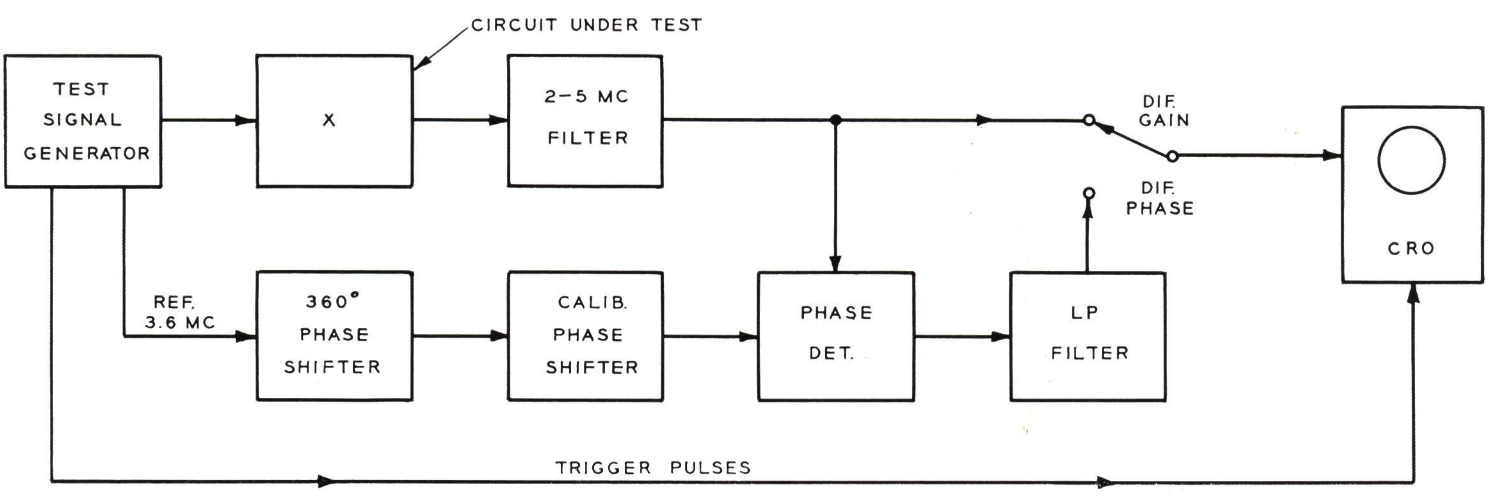
FIG. 9

combined with a mirror image of itself around the zero-frequency axis, the curve should form a probability function.) This energy distribution corresponds rather closely to that in an ordinary television signal, so the visible distortion in the sine-squared pulse gives a rather good indication of the fidelity with which program signals can be transmitted.

The energy distribution curve of the sine-squared pulse differs significantly from that of a square wave with very fast rise time—another type of transient test signal that is useful in some applications. A fast-rise-time square wave has an energy distribution which is essentially uniform well out into the frequency band, usually well beyond the pass-band of the system to be tested. For tests of a limited bandwidth device, such as a broadcast transmitter, where it is *desired* to see the "ringing" or overshoot effects associated with the cut-off characteristic, a fast-rise-time square wave is a very appropriate test signal. In the case of a studio plant, however, the cut-off region for individual distribution amplifiers is normally located well beyond the band of interest, and the high-frequency transients associated with this cut-off are of only academic interest because no normal video signal would have energy in that part of the spectrum. Hence the sine-squared pulse is most appropriate for checking studio facilities. While Mr. Gronberg has indicated that you must expect some degradation of the 0.125 microsecond sine-squared pulse when received through "long lines" facilities (because the bandwith of such circuits is usually less than 8.0 mc, and the cut-off characteristic of many "links" in tandem can become quite steep), you have reason to become concerned if you see *any* degradation of the same pulse in your studio facilities. Chances are that a distribution amplifier which fails to pass a sine-squared pulse satisfactorily has poor frequency-response alignment, a defective component, or a tube that has "slumped" enough to prevent a feedback loop from maintaining good phase and frequency response.

Differential Gain and Phase Measurements

As we tried to emphasize in the introductory paper in this series, good frequency and phase response alone is not enough to assure distortion-free handling of color signals—it is also necessary to keep differential gain and phase within relatively tight limits. A basic arrangement of test facilities for differential gain and phase measurements is shown in Fig. 10. The test signal generator would normally deliver a signal consisting of a stair-step with a sub-carrier superimposed upon it; this signal is passed through the circuit under test, and the sub-carrier component is recovered through a suitable band-pass filter. For differential gain measurements, direct inspection of the envelope of the sub-carrier signal on a CRO is usually satisfactory. Mr. Gronberg's paper



TYPICAL SETUP FOR MEASURING DIFFERENTIAL GAIN AND PHASE

FIG. 10

provides typical examples of "clean" and distorted differential gain test signals. For differential phase measurements, it is necessary to use some type of synchronous detector to compare the phase of each interval in the test signal with a reference sub-carrier signal. In some cases, this reference sub-carrier might be derived directly from the test signal generator (which may be a section of a multi-test signal generator), but if you wish to test a microwave link or some other extended system where it is not possible to gain access to the input and output ends simultaneously, you may need a burst controlled oscillator to provide the reference sub-carrier. In either case, a calibrated phase shifter of some type is normally used to vary the phase of the reference signal to permit measurements of phase displacements between the various intervals in the test signal.

Differential phase measurements represent one of the best ways to "log" the performance of feedback-stabilized amplifiers where the feedback itself tends to maintain reasonably uniform frequency response and gain stability until the tubes are near the end of their useful life span. Differential phase is usually one of the first characteristics to begin changing significantly as tube aging becomes serious.

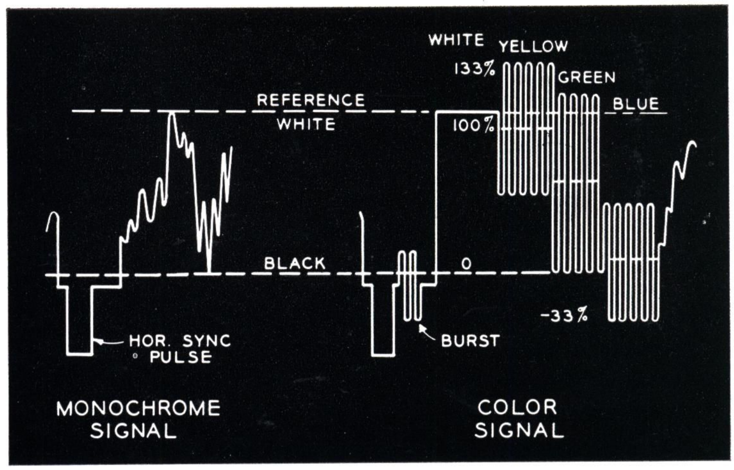


FIG. 11

Stabilizing Amplifiers

We noted earlier in this paper that stabilizing amplifiers should be avoided in a color television system unless there is clearly some type of signal degradation or some system objective that requires their use. It must be recognized that stabilizing amplifiers have always been relatively troublesome devices, not because the equipment is not well designed but because it is called upon to perform in a "substandard" environment and to perform a variety of complex and "delicate" operations on the television signal. (The very use of a stabilizing amplifier normally implies that you have some kind of trouble with your signal.) One of the first steps you can take to minimize stab amp trouble is to acquire the very best unit available. In the RCA product line, the best unit available is the TA-9, so the following discussion will be based on this unit. Since we have not manufactured any of the older types of units for many years, I believe we can, in good conscience, suggest that you consider a modern replacement for any older type that may be giving you problems in handling color signals.

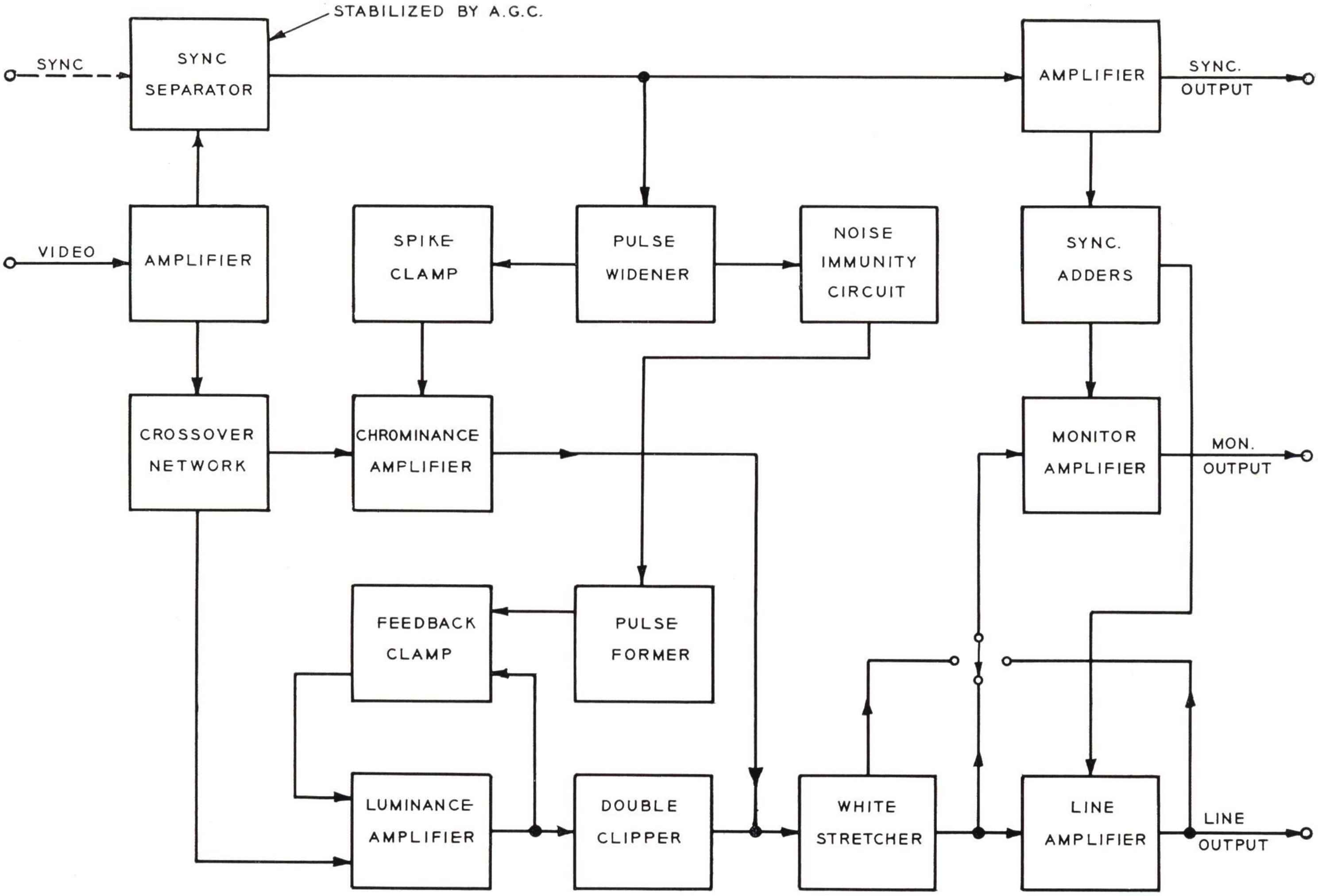
I'd like to offer two basic pieces of advice for avoiding problems with the TA-9: (1) keep in mind that the equipment by necessity is unusually complex, and that it needs and deserves considerably more attention than most other types of equipment; and (2) take the instruction book seriously. The instruction book we provide for the TA-9 is quite comprehensive, and contains virtually all the information you need for operation and maintenance. It is appropriate, however, that we conclude this paper with a few more specific comments concerning the TA-9.

The waveform sketches in Fig. 11 illustrate several of the reasons why a *color* stabilizing amplifier must be considerably more complex than a *monochrome* unit.

One of the features normally required in a stab amp is the ability to re-generate or reshape the synchronizing and blanking pulses. In some cases, it is even required that composite signals be converted to non-composite signals through the complete removal of synchronizing pulses. In a monochrome amplifier, removal of original sync pulses and "clean-up" of the blanking interval is accomplished by a simple clipping operation, which simply "wipes off" everything extending below the blanking level. (Of course, a little bit of "set-up" or pedestal is lost in each such clipping operation.) In a color stab amp, such a simple clipping circuit cannot be used because of the presence of the color synchronizing burst and the "blacker-than-black" excursions of the sub-carrier signal during the transmission of red and blue colors; clipping of these burst and sub-carrier signals would obviously represent intolerable distortion of essential information. Thus, it is necessary in a color unit to employ a "crossover network", or a filter arrangement which separates the chrominance information (centered around 3.6 mc) from the lower-frequency luminance information. The luminance signal alone is then subjected to the clipping operation, while the chrominance information (and the color synchronizing bursts) are handled in a separate but parallel channel.

A simplified block diagram for the TA-9 is shown in Fig. 12. Note that the clipper in this unit is a *double* clipper, indicating that it has the ability to clip the signal at the reference white level (or slightly above) as well as at black level. The white-clipping feature is desirable in cases where signals are marred by impulse noise or excessive highlight "glints", but the same feature can be a source of serious distortion for color signals if inadequate attention is given to proper setting of the WHITE CLIP control. Note that the d-c restoration for the clipping operation is accomplished with a feedback-stabilized clamp; while the unit may have its share of problems, drift in clipping levels is not likely to be one of them. The "white stretcher" which follows the clipper is another potential source of trouble. This feature is essential when the stab amp is used to drive some types of television transmitters, but some operators tend to forget that the white stretch circuit is designed to alter both the differential gain and differential phase characteristics to compensate for distortions in other types of equipment. If the white stretch adjustments are not made carefully with the aid of differential gain and phase test signals, the final result may be worse than no compensation at all.

The fact that the chrominance information is handled in a separate amplifier which bypasses the clipper, represents both an opportunity and a hazard. The *opportunity* is that of adjusting the gain separately in the chrominance channel to compensate for obvious problems in the chrominance level of the incoming signal. The *problem* (and we know from experience that this is a chronic



SIMPLIFIED BLOCK DIAGRAM OF TA-9 STABILIZING AMPLIFIER

FIG. 12

problem) is that operators tend to forget when they have deliberately increased the chroma gain to compensate for a substandard signal, and fail to restore the gain to normal when the abnormal signal condition no longer exists. Our home office people tell me that they have had many telephone calls from customers complaining about excessive noise or "spiking" in the TA-9, and in the great majority of cases the problem turns out to be nothing more than excessive gain in the chrominance channel.

The "spike clamp" associated with the chrominance amplifier is necessary to remove the high-frequency "spikes" associated with the leading and trailing edges of the original sync pulses. These spikes pass through the high-pass section of the cross-over filter, but must not be added back to the signal because the reshaped sync pulses provided by the sync channel (shown across the top of the block diagram) already have a full share of high-frequency information in their edges. The spike clamp circuit should not be particularly troublesome, although it is conceivable that it could introduce some burst distortion if badly out of adjustment. The instruction book has complete information on the function and adjustment of this circuit.

We occasionally hear complaints about low-frequency instability, or a tendency toward "bounce", in the TA-9. In the majority of cases, we find that this problem results from the use of an improper voltage tap on the power transformer, which delivers a-c power both to the heaters and to the built-in bias supply used for the output amplifier stages. If the tap is improperly chosen, the voltage regulator tube in this bias supply may not "fire" reliably, and the resulting instability in the bias voltage becomes evident in the output signal.

Conclusion

We realize that in a brief paper it is not possible to cover all possible sources of difficulty in handling color signals through "master control" facilities, but we hope that these comments prove helpful in your efforts to deliver better color pictures to your broadcast audience.

MICROWAVE RELAYING OF COLOR TV SIGNALS

How to Adjust and Maintain Modern S-T-L Equipment

by JOHN B. BULLOCK
Microwave Engineering
RCA Broadcast and Communications Products Division

A modern TV studio-transmitter link, properly adjusted, should be a very minor contributor to the total distortion in the color picture. The better equipments on the market today are capable of differential gain of less than 5 per cent, differential phase of less than 1 degree, a video frequency response that is flat well out through the required 4½ megacycles, and a vertical rate square wave tilt of well under 1 per cent.

Most of the studio transmitter link equipments employ klystrons. The source of the r-f signal at the transmitter is a klystron which is directly frequency modulated; the receiver is a superheterodyne, usually without any r-f pre-selection, whose local oscillator is also a klystron. The major requirement in maintaining the stability of STL equipment, is in preserving proper adjustment on both these klystrons. The transmitter klystron must be set to oscillate at its assigned frequency, and that frequency must be attained by mechanical and electrical adjustment which will permit the klystron to be modulated linearly. In the receiver, AFC assists in preserving klystron adjustment.

This paper will briefly review a typical STL equipment, pointing out where certain distortions might arise, then follow with a relatively simple procedure for adjusting such an equipment for optimum performance.

A typical STL microwave transmitter is block diagrammed in Fig. 1. Video input is through a modulation level control, generally an attenuator. If sound is to be transmitted, the sound sub-carrier is picked up next and the "combined" video signal is then fed through the pre-emphasis network and on to the transmitter modulator.

It is almost the universal custom to transport sound over the link by frequency modulating the audio on a sub-carrier somewhere in the 6 to 7 megacycle region, and that frequency modulated sub-carrier is then simply added to the video. The addition is made after a 6 mc notch filter. The filter serves both to prevent video inputs at the sub-carrier frequency from going on to the microwave transmitter and to prevent the sound modulator r-f output from going back into the camera equipment. This filter will cause some ringing to the .125 μs sine-squared pulse, however, the .250 μs sine-squared pulse is passed with virtually no distortion.

In RCA's TVM-1 equipment pre-emphasis is an option, however, we urge its use for color transmission. Pre-emphasis (or pre-distortion) is accomplished by a high-pass filter which attenuates the low frequency content of the picture signal by some 8 to 12 db. Unfortunately there is no standardization. At the other end of the microwave link there will be a restorer network, a low-pass filter, which attenuates high frequencies so that, overall, the link is restored to flat video frequency response.

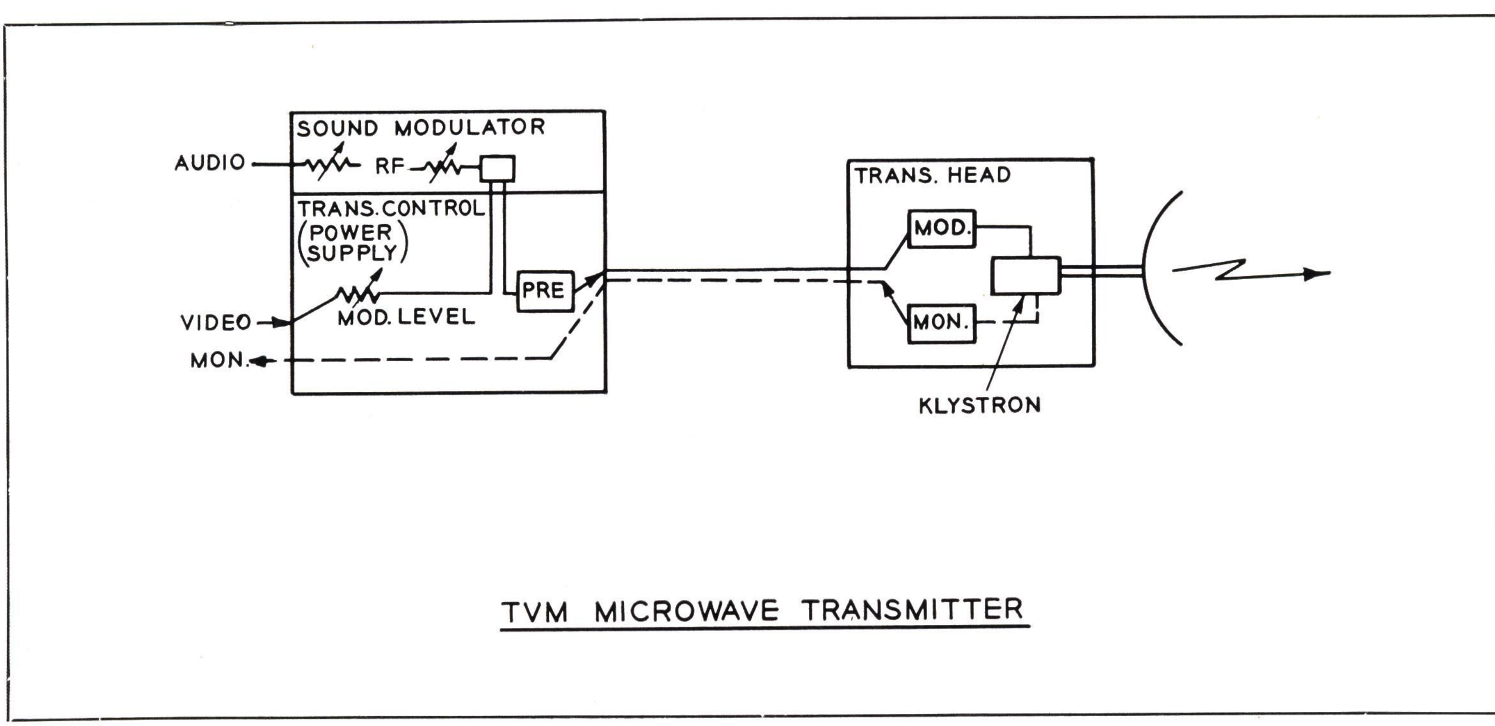


FIG. 1

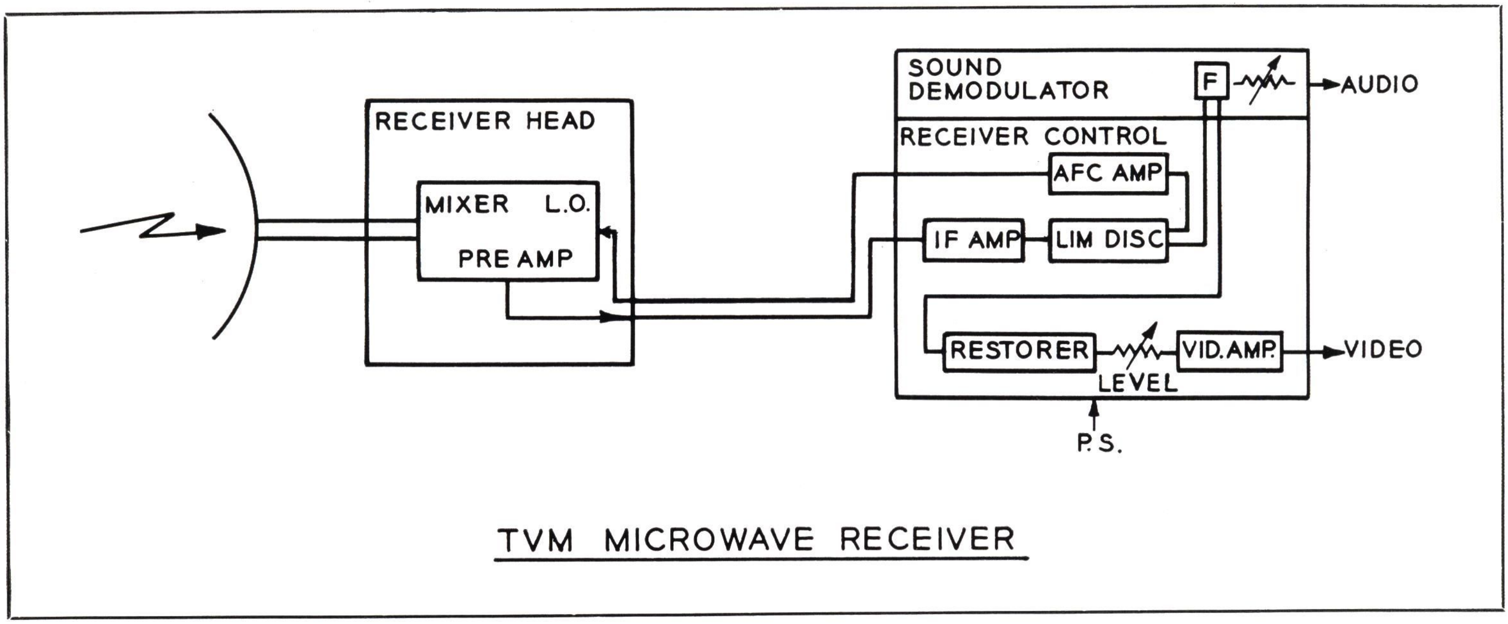


FIG. 2

After pre-emphasis, the video signal goes to the active part of the equipment, the transmitter head. There a video amplifier, called the transmitter modulator, will amplify the signal to a sufficient level to directly frequency modulate the klystron. The transmitter head will be discussed in more detail later in this paper.

In the RCA TVM-1 equipment there is also an optional monitoring feature which detects video from the outgoing signal by means of a tunable discriminator. The detected video is then amplified and fed back to the control unit for observation.

At the other end of the link is the receiver. A typical receiver is diagrammed in Fig. 2. In the RCA TVM-1, the receiver head contains mixer, local oscillator, and four stages of IF preamplification. After the preamp, the IF signal is further amplified in the main i-f amplifier, then fed to limiter and discriminator. Following the discriminator, the signal is again video, and if a sound sub-carrier is used, it is picked off at this point. Next is a sub-carrier notch filter, similar to but not necessarily identical to the one in the sound modulator. Its function is to exclude sound sub-carrier from the video channel outputs.

Following the sound sub-carrier pick-off the video passes through the restorer network then on to video level control and video output amplifier. The restorer is a low-pass filter, and for this reason the sound sub-carrier is picked off prior to this network.

Pre-emphasis of the Video Signal

Figures 3 through 6 deal with the subject of pre-emphasis. Figure 3 shows what happens to the stair-step signal when it goes through the 8 db pre-emphasis network used in the RCA TVM-1 equipment. Notice that the net effect of the network is to "squash" the signal; to reduce its peak-to-peak amplitude. If one thinks in terms of the excursion of plate currents in video amplifiers, obviously there will be less distortion to a signal which is reduced in amplitude compared to one which is not. The purpose of pre-emphasis is to reduce differential phase and differential gain, and it does this by reducing the excursions of plate currents in video amplifiers and the frequency deviation in r-f and i-f areas.

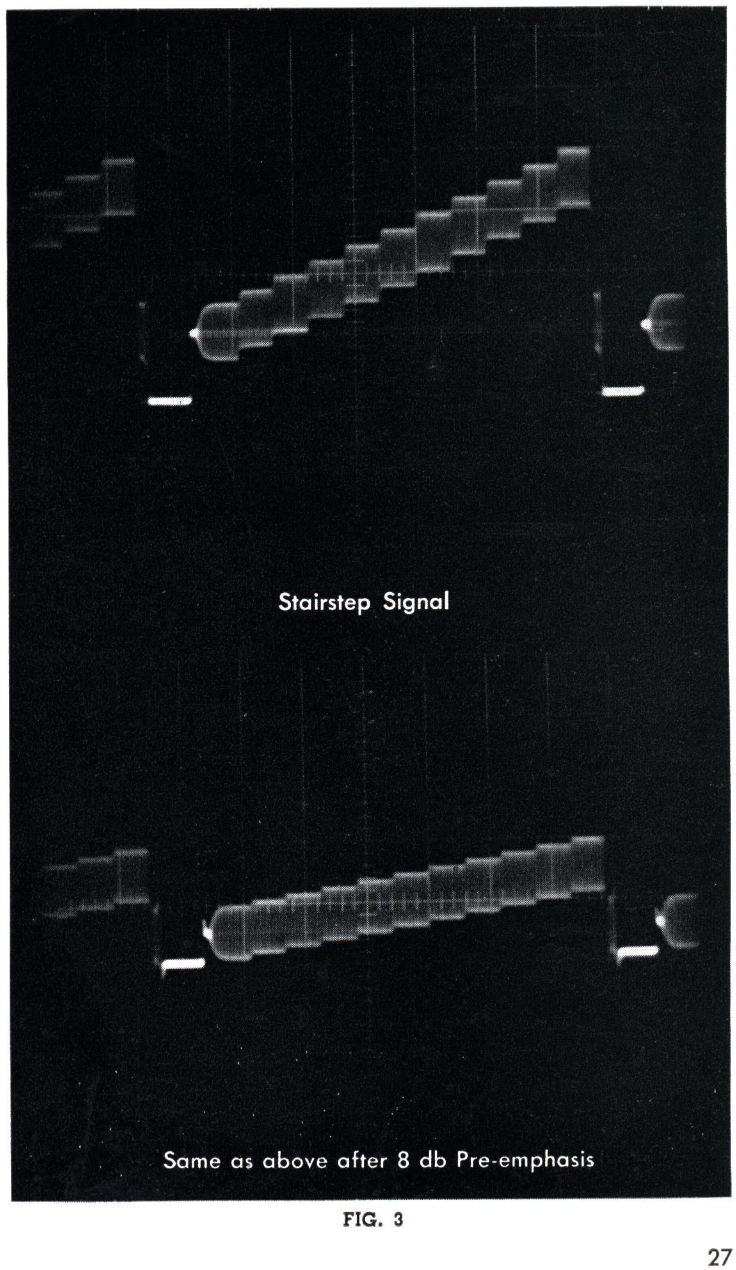
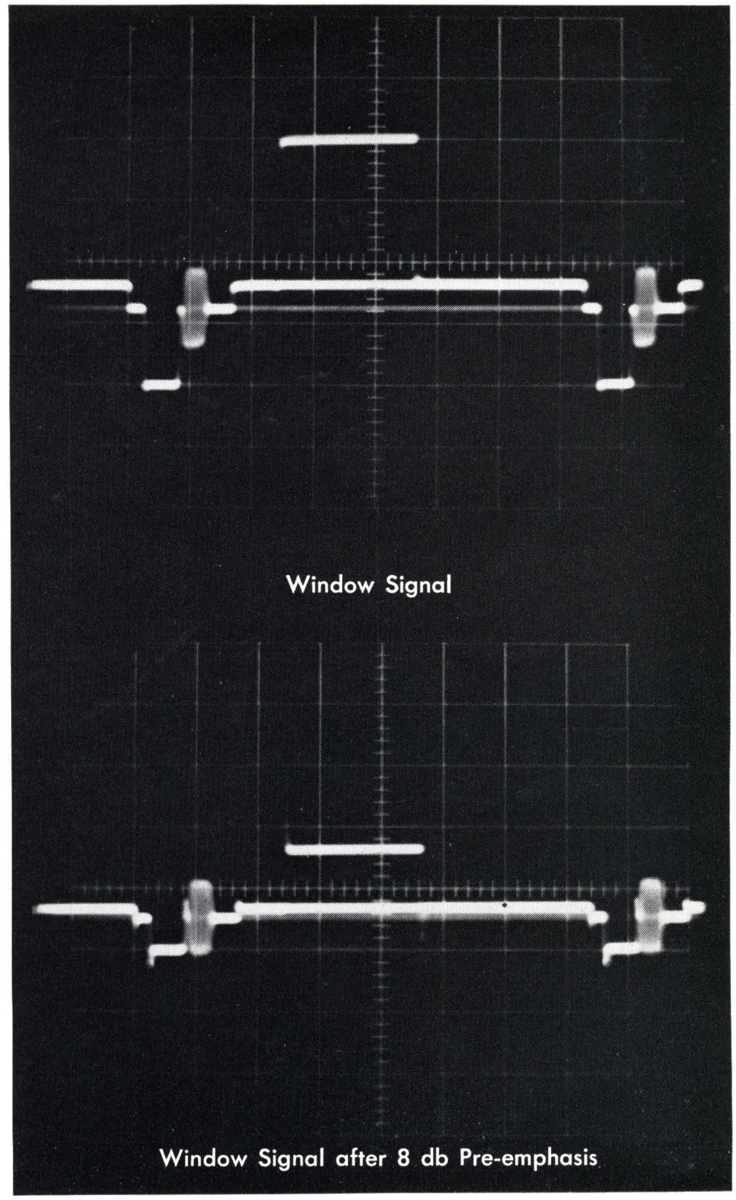


FIG. 3

One might ask why differential phase and gain reduction could not be accomplished by simply reducing the deviation of the transmitter rather than using fancy networks. The answer is that by dropping the deviation via the pre-emphasis network, nothing is sacrificed in signal-to-noise ratio. In an FM system, the noise output of the receiver rises with frequency, hence the restorer network, being a low-pass filter, attenuates noise more than it does signal. This compensates for the fact that deviation was reduced and results in an improvement in differential phase and gain without any sacrifice in signal-to-noise ratio.

Figure 4 shows the multi-burst signal plus sound sub-carrier before and after pre-emphasis. Recalling that the pre-emphasis network is a high-pass filter we note in this photograph that the "squashing down" of the signal is not near so apparent. The highest frequency (4.2 mc) burst here comes through very nearly with no attenuation, as does the sound sub-carrier (6.8 mc).

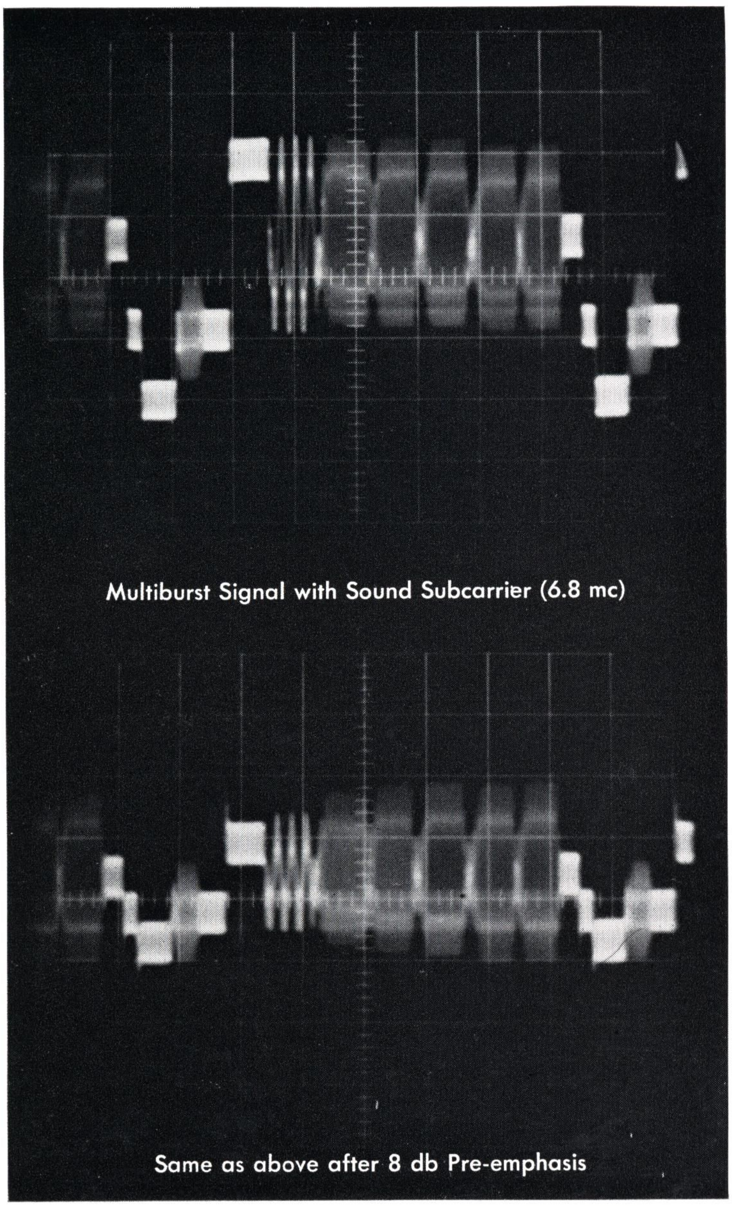
If one were to scale the portions of any of these signals that are basically the 15 kc rate information, like the shift from blanking to white level, one would find this amplitude reduced almost exactly 8 db, the amount of the pre-emphasis. The sync excursion would be another example of this.



Window Signal

Window Signal after 8 db Pre-emphasis

FIG. 5



Multiburst Signal with Sound Subcarrier (6.8 mc)

Same as above after 8 db Pre-emphasis

FIG. 4

Figure 5 shows a window signal. The window signal in the absence of any sine-squared pulse contains very little in frequency above say 20 times the basic 15 kc rate, and so is reduced in amplitude almost exactly 2½ to 1, or 8 db. As seen, the color burst is hardly attenuated at all.

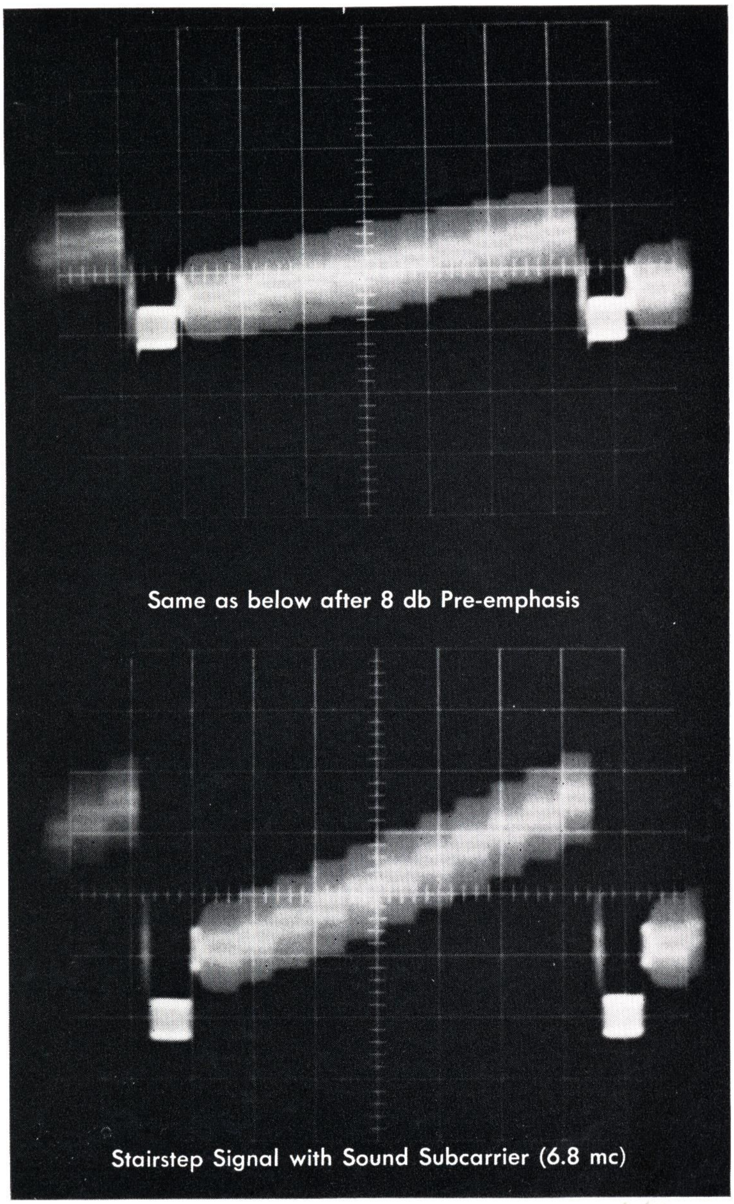
Finally, Fig. 6 shows the staircase signal in the presence of a sound sub-carrier. The sound sub-carrier in the TVM-1 equipment is at 6.8 megacycles. It is generally operated at about 10 or 15 per cent of the overall picture amplitude. The sound sub-carrier amplitude can be measured in the sync interval in Fig. 6. During the picture interval both color and sound sub-carriers are present and their addition makes up the "fuzzy" line pattern. Any non-linearity in the microwave equipment will result in inter-modulation products between these two sub-carriers and a visible "beat" between them. However, if the microwave is linear both in phase and amplitude, that is if differential phase and gain are held within the required limit, then there will be no intermodulation between these two sub-carriers.

Transmitter Considerations

The transmitter head, the really active part of the transmitter is diagrammed in Fig. 7. The heart of this unit is the klystron, which generates the r-f signal. The klystron is directly modulated by the video signal from the modulator amplifier.

The input video signal, after amplification, is fed directly to the klystron repeller electrode. There, added to the d-c tuning voltage, it causes the klystron frequency to be deviated the required amount and in accordance with video waveform. In the TVM-1 the peak-to-peak deviation used is 6 mc (with pre-emphasis this is reduced). The typical VA-222 klystron is deviated 6 mc peak-to-peak by 15 volts of peak-to-peak video on its repeller electrode. The amplitude of video required to deviate the klystron 6 mc depends on the modulation sensitivity of the klystron, and this modulation sensitivity can vary as much as 2 to 1. The actual range of modulation sensitivity for the VA-222 is 225 kc/volt to 525 kc/volt. This means that to produce 6 mc deviation may require as little as 11.4 volts or as much as 21.8 volts. An important point to be noted here is that whenever the klystron is changed, the transmitter deviation should be checked and reset.

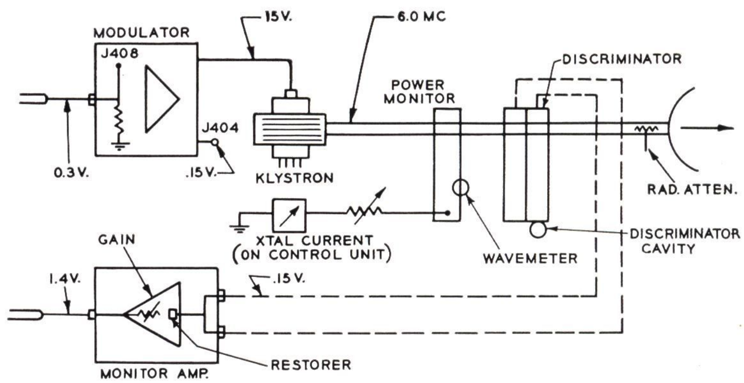
Regulated voltages are supplied to the klystron. Klystron stability can be no better than the stability of these regulators, so a periodic check is recommended. At least one point of maintenance is worth noting. Regulation may be accomplished by two or more regulator tubes in parallel. These tubes should at all times share the load current equally, say within ±20 per cent. If one tube should fail, the other will assume the full load and the regulated voltage may not change but the life of the remaining tube will be seriously shortened. Sharing of current is easily checked by noting the drops across the regulator cathode resistors.



Same as below after 8 db Pre-emphasis

Stairstep Signal with Sound Subcarrier (6.8 mc)

FIG. 6



TVM TRANSMITTER HEAD
VIDEO LEVELS (W/O PRE-EMPHASIS)

FIG. 7

In the r-f plumbing of any of the STL equipments is a power monitor. The power monitor is a directional coupler which samples some of the outgoing r-f energy, and brings it past a wavemeter to a crystal detector. The d-c output of the detector is displayed on the control unit on the panel meter. The first rough adjustment when a new klystron is installed is to adjust its d-c repeller voltage for maximum power output from the klystron. The crystal current meter reading is a display of power output.

The dotted lines in Fig. 7 show the video monitoring accessory that is available for the TVM-1. Video is detected by a tunable discriminator which must of course be tuned to the outgoing r-f signal. The detected video is amplified and fed back to the transmitter control unit for observation.

The basic modulator amplifier schematic of the TVM-1 is shown in Fig. 8. In any of the STL equipments one would find an equivalent. The low level video comes in at J401 and feeds a conventional video amplifier whose output is then added to the d-c repeller voltage supplied to the klystron. Two "touch-up" adjustments are provided in this unit. Similar adjustments will be found in the video amplifier at the receiver. These are high frequency peaking and low frequency TILT controls. The former are adjusted using a multi-burst or video sweep for test signal, the latter using the window signal. In practice the TILT control can be adjusted using any signal that contains vertical sync by observing at vertical rate and removing any apparent tilt in the sync interval.

When tracing a video signal through an amplifier such as this two precautions should be heeded: 1. Do not load the test point with too much cable capacity, thus low impedance points are best; 2. Observe *outside* of any feedback loop. Two excellent monitoring points are provided in the schematic of Fig. 8, J408 and J404.

In Fig. 9, the modulation process is described. The two characteristic curves show klystron frequency and klystron power output as a function of repeller voltage. Sine wave modulation is shown. The sine wave at (c) in Fig. 9 would be about 15 volts peak-to-peak and this is added to an approximate 300 volt negative repeller voltage. As a result the repeller voltage is swung plus/minus 7½ volts and this swings the klystron frequency plus/minus 3 megacycles if the repeller voltage has been adjusted so that the deviation is in the linear center region of the frequency characteristic. It is important in adjusting the klystron to set the repeller voltage so that deviation is in the linear region of this modulation characteristic. The region is quite broad in the VA-222 series.

In the center of the linear modulation region, the slope of the modulation characteristic is minimum, i.e., a given modulating voltage will produce the *least* frequency deviation. This will be the method of locating this linear modulation region. By design of the klystron, this region very nearly centers at the repeller voltage which produces maximum r-f power output from the klystron.

Waveforms (d) and (e), projected off the power characteristic show the variation of power fed to the power monitor crystal with and without the wavemeter tuned to center frequency. It can be seen that as the frequency goes through one cycle of deviation, the power will go through two cycles, thus giving the "120 cycle" pattern shown in (d). If the wavemeter is present, energy is absorbed each time the frequency swings through the wavemeter resonance, and the absorption of some of the r-f energy produces the pips shown in (e).

The modulation process is further illustrated in Fig. 10. This shows with a video signal what happens if the repeller voltage is not set for operation on the linear part of the modulation characteristic. In this case equal modulating voltage above and below the d-c repeller voltages produces unequal frequency deviation above and below center frequency. The result as indicated is a "stretching" of the deviation in the white direction compared to that in the black direction. Thus with a klystron off center as shown in Fig. 10, video from the receiver would have whites stretched. If the klystron was off center in the other direction, sync would be stretched by the modulation process. The repeller voltage adjustment here is quite broad between stretched sync on one extreme and stretched white on the other.

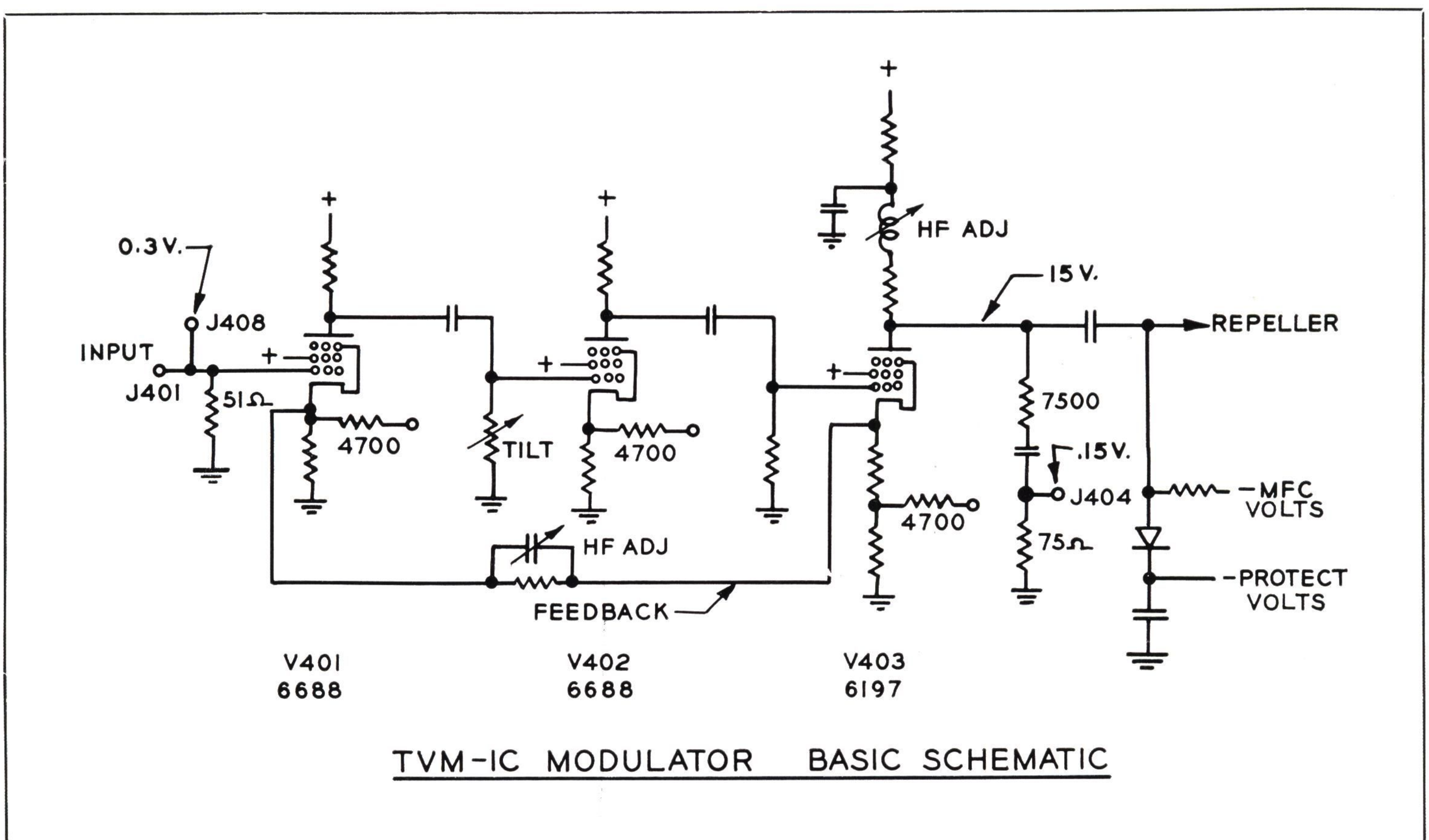


FIG. 8

TVM-1 MODULATION PROCESS

(Correct Adjustment)

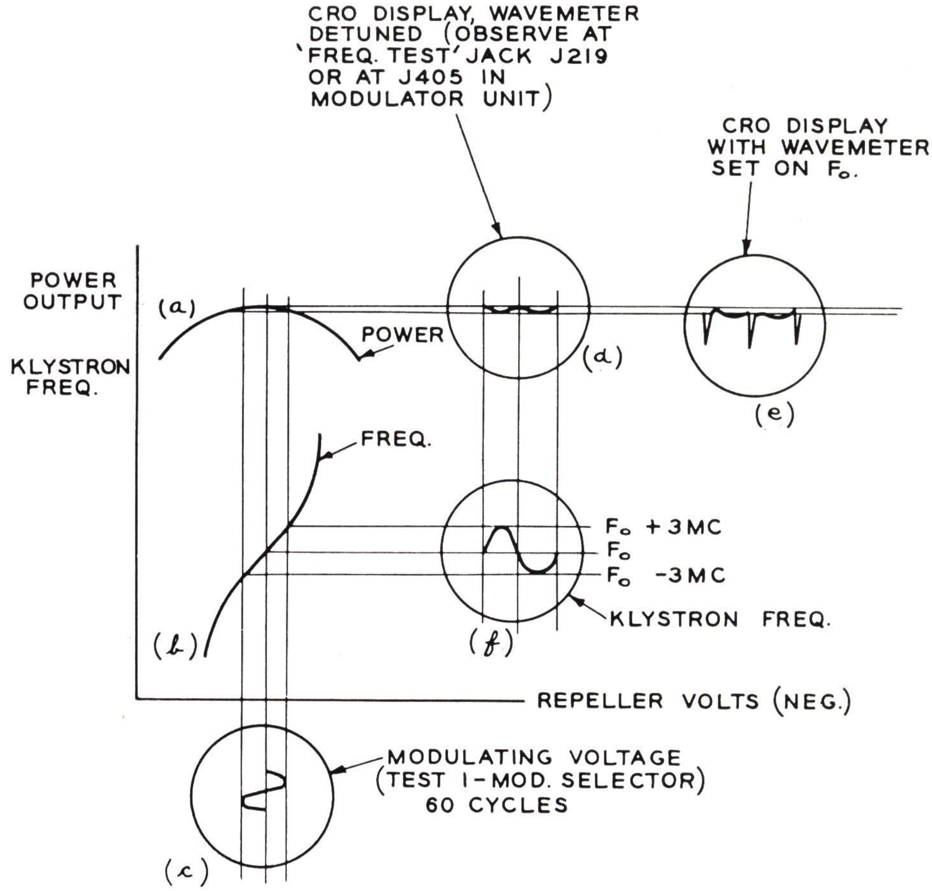


FIG. 9

TVM-I MODULATION PROCESS

(Incorrect Adjustment)

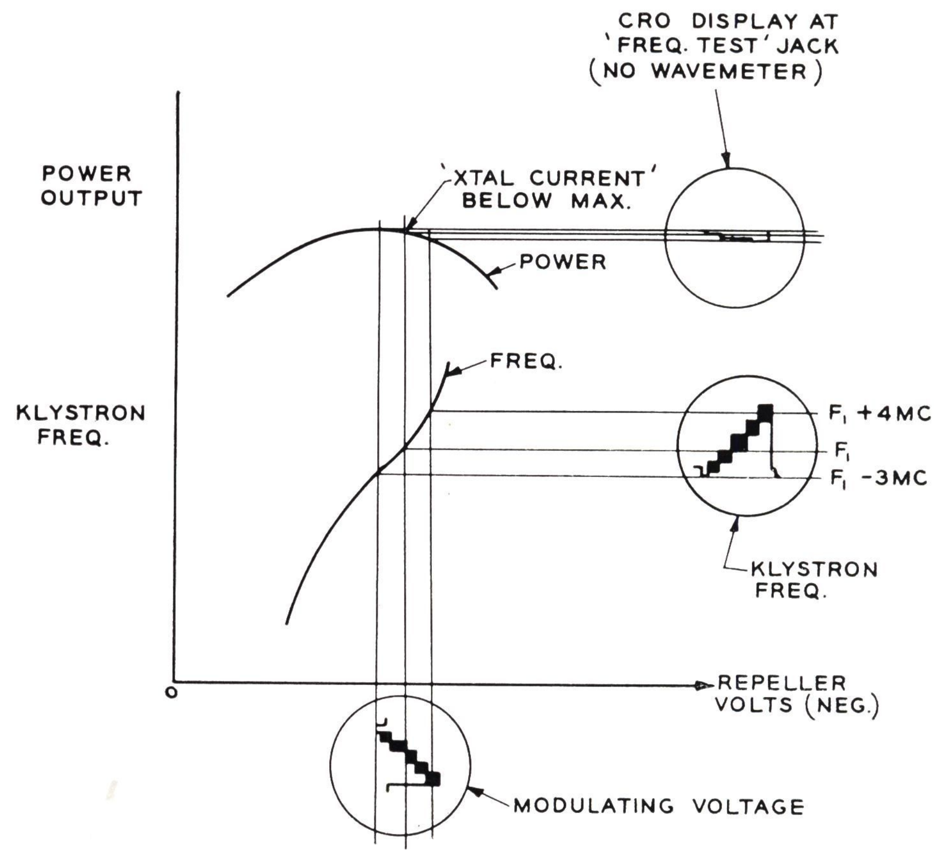


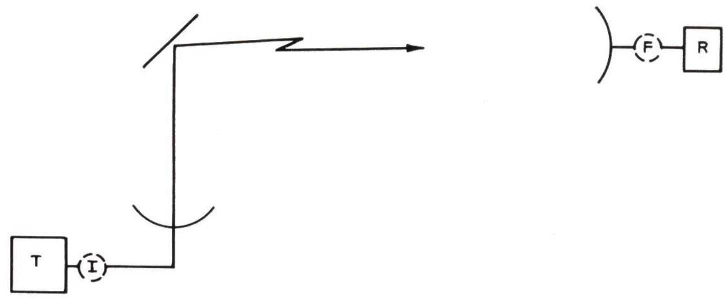
FIG. 10

R-f Feed Line Considerations

Figure 11 illustrates a typical STL path, and serves to bring several points to mind. One is that to be linearly modulated the klystron must work into a constant fixed load as its frequency is deviated. The characteristics depicted in Figs. 9 and 10 assume this. If the waveguide run to the antenna exceeds 10 to 15 feet, then reflections from bends and joints in the waveguide, and from the terminating antenna feed make it difficult to maintain this load within the required limits. In such cases a ferrite isolator should be installed at the transmitter output.

The r-f signal proceeds to the receiver by way of a passive reflector. We will assume that adequate path clearance is provided, and that antenna orientation is correct as determined by the calculated amount of r-f signal being delivered to the receiver, or by the measured video S/N ratio at the receiver output. Path problems are somewhat outside the scope of this paper.

Figure 11 shows a waveguide filter ahead of the microwave receiver. Such a filter is often employed where there is danger of adjacent channel interference, image interference, or where two or more r-f signals are on the same antenna. If any sort of r-f filter is employed ahead of the receiver, then it is doubly important that the transmitter be kept on its assigned frequency and thus in the middle of the passband of the waveguide filter. Serious differential phase distortion can result if the received signal is off center of the r-f passband.



TYPICAL STL MICROWAVE PATH

FIG. 11

Receiver Considerations

Figure 12 is a diagram of the receiver. The signal from the antenna which in the general case might be 2000, 6000 or 13,000 megacycles, but with 6 megacycles of peak-to-peak deviation, beats against the local oscillator in the mixer to generate the IF. This, still carrying the 6 megacycles peak-to-peak deviation, is

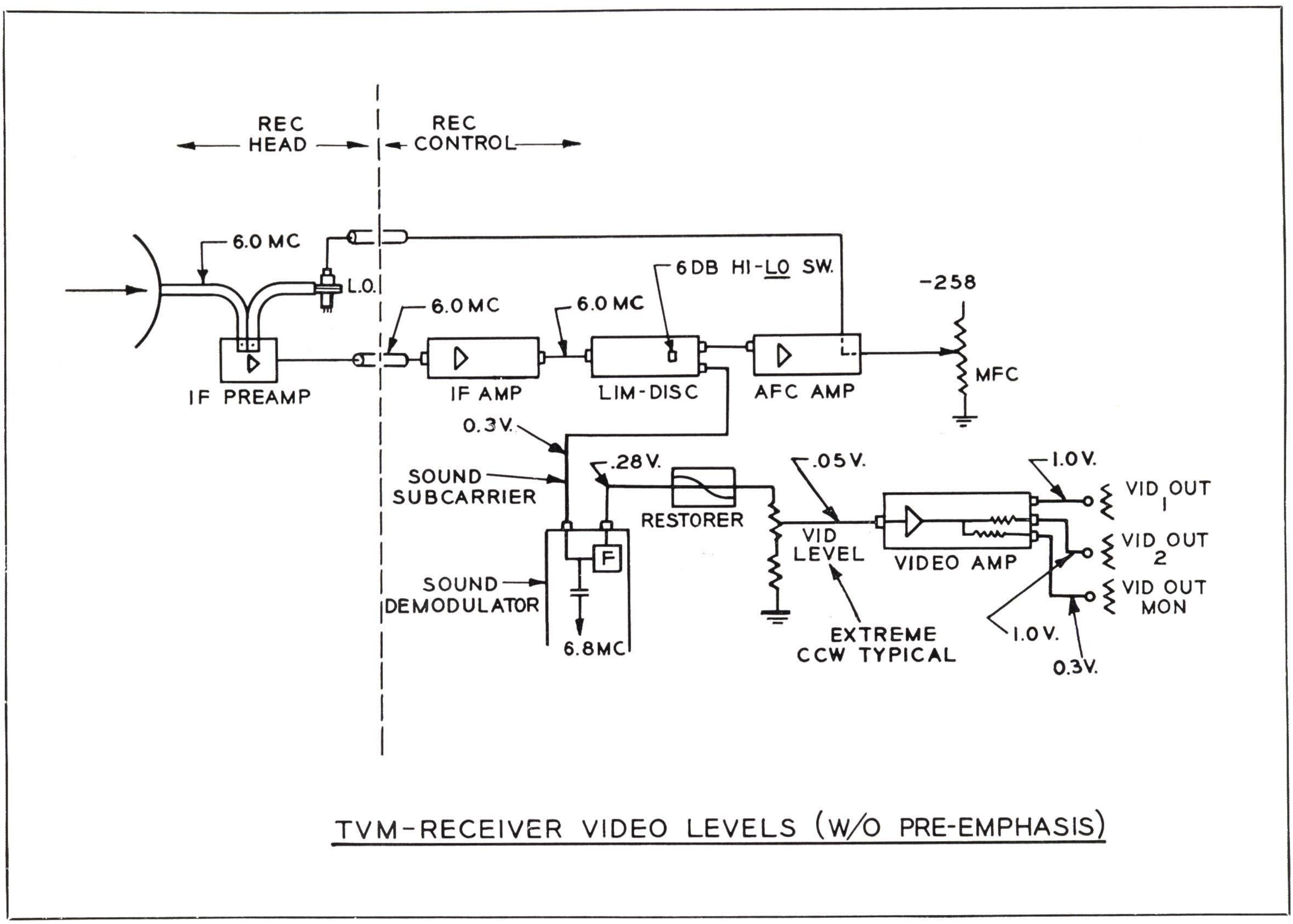
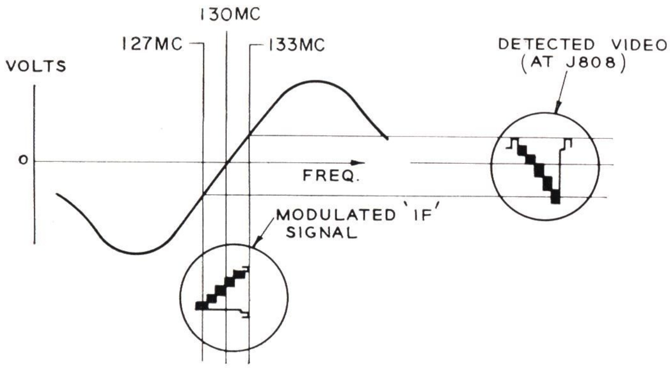
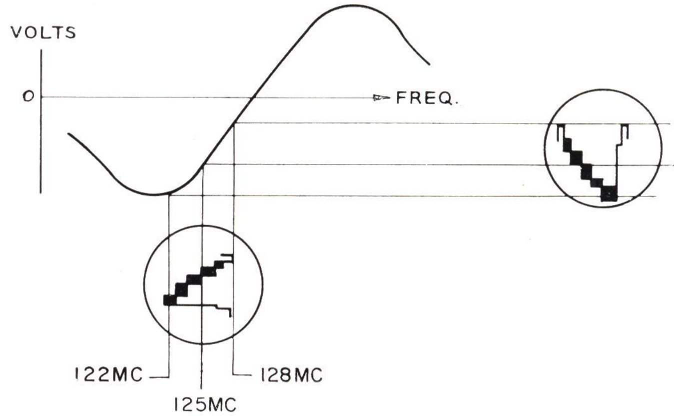


FIG. 12



TVM-I RECEIVER PROPERLY TUNED

FIG. 13



TVM-I RECEIVER IMPROPERLY TUNED

FIG. 14

amplified in the i-f preamp and main i-f amplifier to a level high enough to drive the limiter, and then to drive the discriminator. From the discriminator, there are two useful outputs. One is the video signal, and the other is a d-c signal to be used for AFC. It is very important that AFC hold the tuning of the receiver so that the local oscillator *always* differs from the incoming signal center frequency by exactly the i-f frequency. It will be shown later that the sharpest indicator of receiver tuning is minimum differential phase. AFC will then be set to hold that tuning.

The video output from the discriminator goes first to a filter where the sound sub-carrier is picked off and then the "clean" video signal is fed to the restorer network. This network attenuates high frequencies and thus restores the overall relay system to flatness. As mentioned earlier, it thus also attenuates a great part of the noise and permits the achievement of good signal-to-noise performance along with improved differential phase and gain.

After the restorer the signal passes through a level control, the video amplifier and on to one or more video outputs.

The receiver klystron, like the one in the transmitter, is tuned mechanically by an adjusting screw in a cavity on the tube and electrically by the d-c voltage fed to its repeller. The repeller voltage is derived from a pot across a regulated negative voltage supply. After initial set up is completed this repeller voltage is used to "tune" the klystron, manually by means of the pot, and automatically by means of the output of the AFC amplifier, which is added to the pot voltage as indicated in the diagram.

Any shift in the incoming signal frequency *or* in the local oscillator frequency results in a shift in the IF, and any shift in the IF away from the center of the i-f discriminator characteristic results in a d-c error voltage from the discriminator. This voltage represents an error in tuning. It means that the signal has moved away from the center of the i-f passband. The error voltage is amplified, added to the manual tuning voltage, and fed back to correct the local oscillator frequency to make up for the shift. The action is the same, whether the drift occurred in the transmitter or in the local oscillator, and the result is that the difference frequency or IF comes back to the *center* of the i-f passband.

At this point a few words should be said about i-f responses. We urge that, in the RCA equipment, and probably in other equipment too, the setting of the i-f coils and trimmers *not* be disturbed so long as it is possible to get good overall differential phase, differential gain, and video response through the system. The swept i-f response is an internal inspection of the receiver which is not necessary unless end to end video performance cannot be met. The reason for this attitude is that it is difficult to perform a precise i-f alignment without factory test equipment, and it is also difficult to state how much an i-f response can degrade from the ideal before it will prevent good video performance. Often the excess of tilt or valley or other departure from ideal i-f response in a field test will be as much due to the test setup and test equipment as to the i-f circuitry. For these reasons we emphasize that so long as normal tuning procedures result in good system video performance—leave the IF alone.

When good video performance cannot be obtained, and video areas of the equipment are known to be good, then an i-f sweep may show up i-f troubles and these will generally indicate a *drastic* departure from the ideal passband, rather than simply excess tilt or valley.

When the receiver is *"tuned,"* what we really tune is the local oscillator. We simply adjust the frequency of the local oscillator so that it beats with the incoming signal to produce the correct IF, and if it does produce the correct IF, it will produce a group of signals that is in center of the i-f passband, and in the center of the receiver's discriminator curve. This is illustrated in Fig. 13. When the receiver tuning is varied the group of signals centered in the 127 to 133 mc region is moved up or down in frequency. If the receiver is tuned one way in frequency the group of signals to the discriminator will increase in frequency; if tuning is moved the other way the group will move downward. Too much detuning in either direction results in compression—of sync if detuning moved the i-f signal up in frequency, or of whites if detuning moved the IF lower. The latter case is illustrated by Fig. 14. Proper receiver tuning is obviously in the center of the discriminator characteristic, where neither sync nor white compression results. This linear region will be quite broad as the receiver output is viewed on a CRO.

Differential Phase as A Tuning Indicator

A very *sharp* indicator of the exact center of tuning is available, however, and this is differential phase. When the receiver is tuned "dead center," differential phase will null to a minimum.

Once the receiver has been tuned to the point of minimum differential phase, the discriminator balance control, which shifts the discriminator curve (Fig. 13 or 14) up or down, should be set so that the d-c output from the discriminator at this point of tuning is zero. The AFC system may then be set to hold the discriminator output at 0 d-c.

Video output from the discriminator is pictured as inverted in Figs. 13 and 14, and such is the case in the TVM-1. The video amplifier that follows will invert this video so that the receiver output has proper polarity.

One more point on the receiver tuning: An examination of the noise in the audio channel, the sound sub-carrier channel passing through the microwave *in the presence of video*, will show that a small crosstalk component is present, particularly at the vertical rate. At the point of best tuning, minimum differential phase, this crosstalk or sync buzz, will very nearly null out.

Touch-Up Procedure Restores Optimum Performance

Figure 15 describes a "touch up" procedure which should be applicable to any klystron type equipment. If the steps described are applied in sequence to an already properly installed and operating system, they should provide a method by which optimum performance may be restored at any time. If some fault should exist, these procedures will readily show the area in which it lies.

We suggest that with the TVM-1 equipment, a two months interval is about the right period between inspections. If one waits longer than two months, the distortions that take place due to ageing, AFC drift, trimmers which need readjustment, etc., may become a bit excessive for good color performance.

The tests outlined can be performed with pre-emphasis network in or out. (If the pre-emphasis is in, the restoration network must also be in). If the tests are performed with the networks in, better differential phase and gain can be expected than if they are performed with the networks out.

The tests performed with the networks out are sometimes of value because the networks themselves, due to a fault, can interfere with the flat video frequency response. It is suggested that performance of the equipment be checked once with the networks out, then with the networks in. If tests are performed with the networks out, then when the networks are inserted it will be necessary to raise the receiver (and transmitter monitor) video gains by the amount of the pre-emphasis to recover normal output levels. The differential phase in the TVM-1 equipment should be within 1 degree with the networks in, within 3 degrees with the networks out.

The tests must be performed in the sequence indicated. In the event that a fault is discovered and repaired it would generally be advisable to start again with step 1.

Transmitter Tuning and Adjustment

The first step in the adjustment procedure is given in Fig. 16. The object of this step is to center the transmitter klystron in the linear region of its modulation characteristic and to place it on the assigned frequency. This is accomplished by using the receiver as a deviation indicator to tell when transmitter deviation is minimum for a given video input, and using the transmitter's wavemeter to check transmitter output frequency. The procedure outlined, plus a working knowledge of the equipment should be sufficient for completing this first step.

FIVE-STEP TOUCH-UP PROCEDURE

TVM-1 Equipment Installed and Operating at Normal Levels

ADJUSTMENT	PURPOSE
1. Transmitter Tuning	For linear modulation
2. Receiver Tuning	For min. differential phase
3. High Freq. Response	For flat multiburst
4. Low Freq. Response	For zero tilt
5. S/N Test	To check fade margin

Notes

Perform steps with Pre-emphasis and Restoration either **in** or **out** (See text).

Perform in sequence.

On multi-hop circuits, each receiver serves as signal source for following hop.

Suggested checking interval: two months.

FIG. 15

1. TRANSMITTER TUNING

TRANSMITTER

Input signal: optional; staircase recommended, full level.

Full deviation.

Transmitter AFC off.

(a) Adjust MFC controls for min. p/p video from receiver.

(b) Check transmitter freq.—if required, adjust klystron mech. tuning, and repeat (a).

RECEIVER (NO ADJUSTMENTS)

Operating normally, with signal.

AFC on.

TRANSMITTER MONITOR (IF USED)

(c) Adjust monitor cavity for most linear output from monitor (J218).

(d) Adjust transmitter AFC to hold this tuning.

FIG. 16

When the klystron is found to be within two or three megacycles of the assigned frequency further adjustment should not be made, as this should be adequate both from the licensing standpoint and from the standpoint of any waveguide filters that are used. The MFC adjustment required in this step will be quite broad and will not normally move the transmitter but a few megacycles from the point of maximum power output.

The last two adjustments (under transmitter monitor) apply only to an equipment which has the transmitter monitor. The discriminator in the transmitter must be tuned manually to the klystron frequency. It is tuned via its cavity for most linear output from the monitoring amplifier. Then, if there is any transmitter AFC, it must be adjusted by the routine procedures to hold transmitter tuning with whatever the discriminator d-c output may be at this setting. This d-c should be very near zero, possibly ±0.1v. max.

Receiver Tuning and Adjustment

Figure 17 outlines the second step in the touch-up procedure, receiver tuning. AFC is turned off and the receiver is tuned for minimum differential phase. Then the discriminator balance control is adjusted to give zero d-c volts output from the receiver discriminator at this point of tuning. AFC is then turned on and should hold this tuning. If it does not hold, an AFC adjustment is required. This, in the TVM-1, is the balance adjustment on the AFC amplifier. It is called the modulator balance control and it should be adjusted so that AFC holds this minimum differential phase, zero d-c point of tuning. Next, the differential gain in the receiver output should be checked. If it's excessive, something is wrong and trouble is indicated. Tuning a receiver for best differential phase should inherently produce best differential gain.

Figure 18 shows the stair-step signal and the resulting differential phase display at the output of a TVM-1 receiver obtained using a Telechrome 1004B Test Receiver. The Test Receiver translates the difference in phase shift to the color sub-carrier at the various brightness levels of the staircase into an amplitude. Thus the lower waveform in Fig. 18 indicates difference in phase shift to the color sub-carrier at black and at gray level. At white level the phase shift is again the same as it was at black level. That difference in phase shift, differential phase, can be meas-

2. RECEIVER TUNING

RECEIVER	TRANSMITTER (NO ADJUSTMENTS)
Operating normally, with signal.	Input signal: staircase, full level.
AFC off.	Full deviation.

(a) Adjust MFC for **minimum differential phase.**

(b) Adjust DISCRIM BAL to give **0.0 volt** d-c on cable to AFC amp (J901).

(c) Adjust MOD BAL on AFC amp to hold **min. differential phase** and **0.0 volt** d-c.

(d) Check differential gain. If excessive, repeat transmitter tuning. Check discriminator circuit.

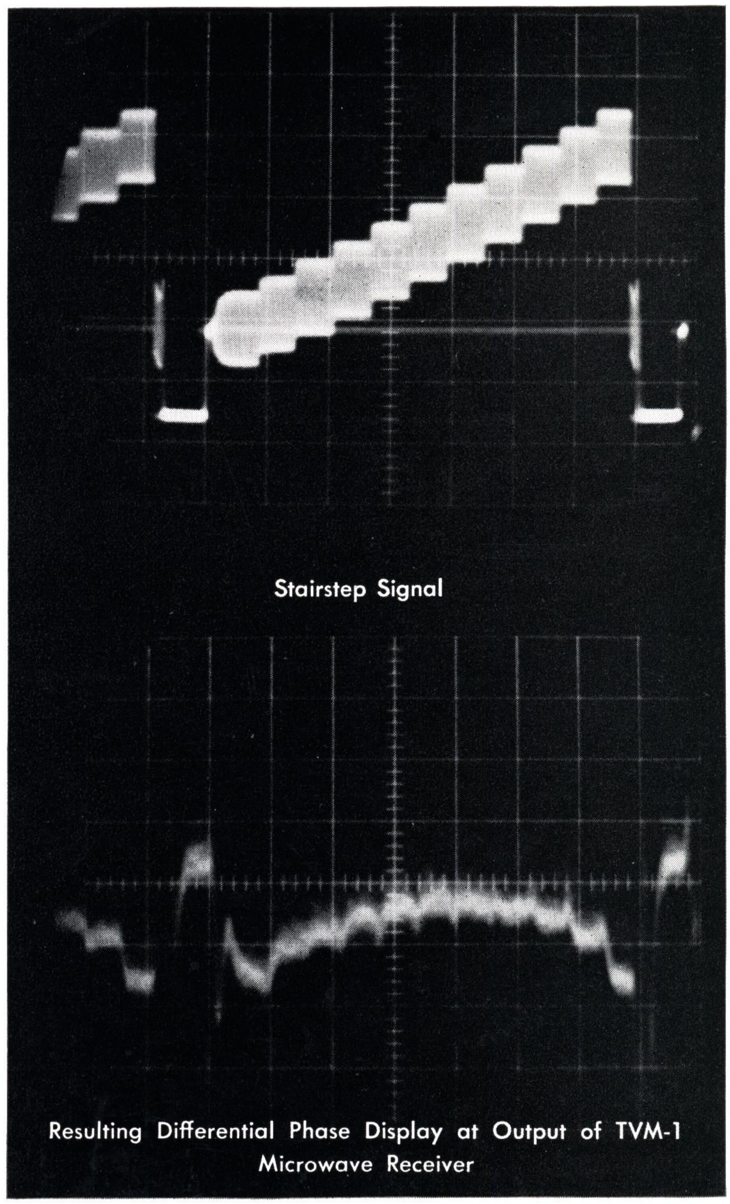
FIG. 17

ured by means of a calibrated knob on the Telechrome unit which varies the location of the marker visible during the sync interval. The marker may be moved up or down on the display. Differential phase can be measured by setting the marker abreast of the lowest point in the display, then jumping it up in one-degree steps until it coincides with the highest point in the display. The differential phase thus measured should barely exceed one degree.

As the microwave receiver is tuned, first CW, then CCW from the correct point, this differential phase display should rock back and forth tilting one way for CW detuning, the other way for CCW. The proper point of receiver tuning is the cusp shaped display shown here; however, it may appear inverted. The polarity of the display is a function of test equipment adjustment—either a "right-side" up saucer or an "upside down" one indicates proper tuning—if accompanied by good differential gain.

Figure 19 continues with receiver adjustment. Receiver tuning has been completed but the high frequency trimmers in the video amplifier which follows the discriminator may require touch-up. If there is excessive roll-off in the high frequency response, more than 1 db at 6 mc, then it may be that the similar trimmer in the transmitter's modulator amplifier needs adjustment. If there is a monitoring unit on the transmitter, then the high frequency trimmers in it should be adjusted at this time. These adjustments are performed using the multi-burst or preferably, the video sweep generator.

Figure 20 shows the same procedure as applied to TILT controls. Here again only a slight touch up is expected to be required, and it is most easily done in the receiver. If tilt is excessive then the modulator TILT must be investigated. And, if there is a monitor, it should be adjusted for zero tilt at this point.



Stairstep Signal

Resulting Differential Phase Display at Output of TVM-1 Microwave Receiver

FIG. 18

Lastly, we suggest a periodic check of signal-to-noise ratio at the output of the microwave link. This has to be done last because the noise that is measured depends on the bandwidth of the receiver, and this is not determined until Step 3 in this procedure is completed.

The measurement of S/N (see Fig. 21) simply consists of operating the transmitter with full deviation and assuring that the peak-to-peak output of the receiver is set at some known level, usually 1 volt. Then the transmitter video input is removed, the sound diplex equipment is turned off, (the sub-carrier is up in the noise region) and the noise is measured. Hum must be excluded from the measurement and the bandwidth of the measment must be known. The S/N ratio may be calculated from these two measurements.

To evaluate this measurement it is necessary to calculate from the transmitter power, waveguide losses, antenna gains, receiver noise figure, etc., what the signal-to-noise ratio *should be* for a particular path. Information on how to do this is given in RCA's TVM-1 instruction book. The measured S/N ratio may be expected to come within 2 db of that calculated via the path information.

The importance of this S/N measurement lies in the fact that most STL links have a fade margin of 20 or 30 db, adequate to go through the fading season without any interruption of service. During the season when there is no fading, the fade margin can disappear due to antenna misalignment, fall-off in power output of the transmitter, degradation of the noise figure of the receiver, etc. These degradations may not be noticed because the resulting noise will be too low to be apparent in the picture. The first warning of lost fade margin will come with the fading season. Then, what was before merely a slight noisy interval may be an outage. A periodic measurement of signal-to-noise ratio will assure that the fade margin has not deteriorated.

3. HIGH FREQ. RESPONSE

RECEIVER

Operating normally, with signal.

AFC on.

(a) Adjust C514 to eliminate roll-off at VID OUTPUT #2 (or #3).

(b) Adjust C522 to eliminate roll-off at VID OUTPUT #1.

TRANSMITTER

Input signal: multiburst

No adjustments unless need is indicated.

TRANSMITTER MONITOR (IF USED)

(c) Adjust monitor C611, C605 to eliminate roll-off at MON OUTPUT.

FIG. 19

4. LOW FREQ. RESPONSE (TILT)

RECEIVER

Operating normally, with signal.

AFC on.

(a) Adjust R506 TILT control for zero tilt.

TRANSMITTER

Input signal: Window

No adjustments unless need is indicated.

TRANSMITTER MONITOR (IF USED)

(b) Adjust R605 TILT control for zero tilt.

FIG. 20

5. S/N MEASUREMENT

RECEIVER

Operating normally, with signal.

AFC on.

(a) Set p/p video output signal at 1.0 volt.

TRANSMITTER

Input signal: optional; full level.

Full deviation.

(b) Terminate transmitter input.
Turn sound diplex modulator off.

(c) Measure noise. Exclude hum. Note bandwidth of measurement.

(d) Calculate S/N: $S/N = 20 \log \frac{1.0}{\text{rms noise volts}}$

FIG. 21

Multi-Hop Systems

Now, one last word for those few STL's which are multi-hop. We suggest that the *first* link be checked first, using the procedure indicated. Then the receiver test equipment may be taken to the next receiver location and the output of the number one link used for the signal source for checking the number two link. This may be repeated for the third and fourth links, and so on.

A reverse procedure, i.e., checking the last link first, then moving the transmitter test equipment to the next station as each link is ok'd might be used. Such a method would in effect use the checked links as a long "cable" to the receiver test equipment. However, this method results in having to make adjustments to a receiver remote from its test equipment and coordination becomes difficult. Most adjustments in these tests are made at the receiver and it is advantageous to have the receiver test equipment at that same location.

Proceeding down the system as recommended takes advantage of such cancelling distortions as may occur, and allows test equipment error to accumulate only once. In "n" *identical* equipment there will be little "cancelling" of distortions, and it is suggested that any deliberate off-setting of one equipment to make up for troubles in another *be avoided*. It is much better to know that each transmitter and receiver is *dead on center* and thus providing the maximum in range for "drift" and "ageing" which of course does take place in even the best of equipments.

GETTING THE COLOR SIGNAL ON-THE-AIR

Adjusting the TV Transmitter for Good Color Signals

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and H. E. SMALL, *Project Engineer*

Transmitter Engineering
RCA Broadcast and Communications
Products Division

FIG. 1

Preceding papers have discussed how to deliver and maintain a high-quality video signal to the transmitter input. Now, the objective is to modulate an r-f carrier with this signal of approximately one volt, peak-to-peak. In most TV transmitters, it is necessary to amplify the video signal to a peak-to-peak value between 200 and 400 volts, and reinsert the d-c component in order to produce a high-power, modulated, r-f signal.

The problems encountered in this process would be relatively simple and straightforward if a double-sideband system were employed. However, in order to conserve space in the frequency spectrum, the FCC adopted the vestigial-sideband system in which approximately three-quarters of the lower sideband is suppressed. Thus, video frequencies below 1.25 mc are transmitted at twice the amplitude of the frequencies above 1.25 mc but the receiver has a complementary amplitude response. Hence, the amplitude response of the overall system is essentially flat.

All of the available bandwidth allocated for a TV channel must be utilized for the transmission of a color-TV signal or a high-quality monochrome signal. In order to maintain the necessary bandwidth, while at the same time meeting FCC specifications on out-of-band radiation, it is necessary to use sharp cut-off filters to attenuate frequencies which fall outside the channel. The lower sideband is attenuated by a vestigial sideband filter while a video low-pass filter is used to prevent modulation by frequencies above 4.2 mc. The problems encountered as a result of this sideband shaping will be discussed later.

The Four Transmitter Parameters

There are four basic parameters of a TV transmitter which require careful attention to insure the transmission of a good-quality color signal. These are:

1. Bandwidth (or amplitude response)
2. Differential Gain (or linearity)
3. Differential Phase
4. Envelope Delay (or delay distortion)

Bandwidth

To assure proper hue and saturation values, the amplitude response should be maintained as flat as possible out to 4.18 mc, since the color information is contained in the frequency spectrum between 2.1 and 4.18 mc. Variations in amplitude response with changes in brightness level should also be observed to ascertain that there are no drastic changes which would give false saturation values at different degrees of luminance.

When adjusting the transmitter for proper bandwidth, it is recommended that the Type BW-5 Sideband Response Analyzer, shown in Fig. 1, be used. The BW-5 greatly facilitates the adjustment by separating the sidebands and providing an oscilloscope presentation of the overall bandwidth as shown in Fig. 2.

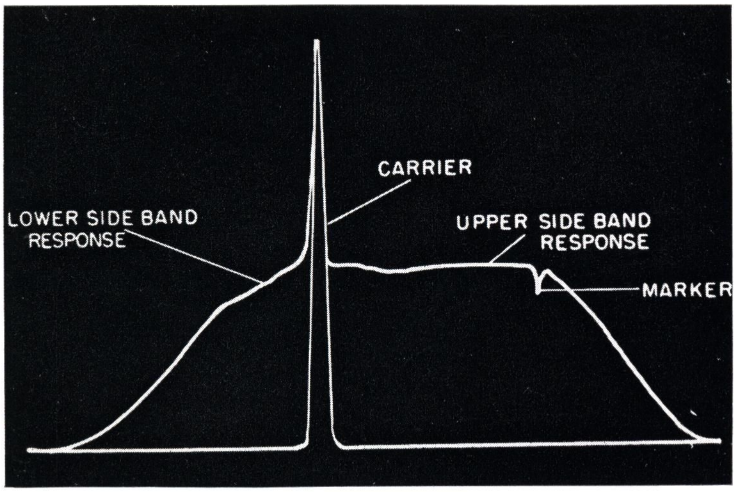

FIG. 2

The multiburst signal, illustrated in Fig. 3, provides a convenient method for making daily checks on the transmitter's bandwidth; however, as explained later, it should not be used for the purpose of making adjustments to the transmitter.

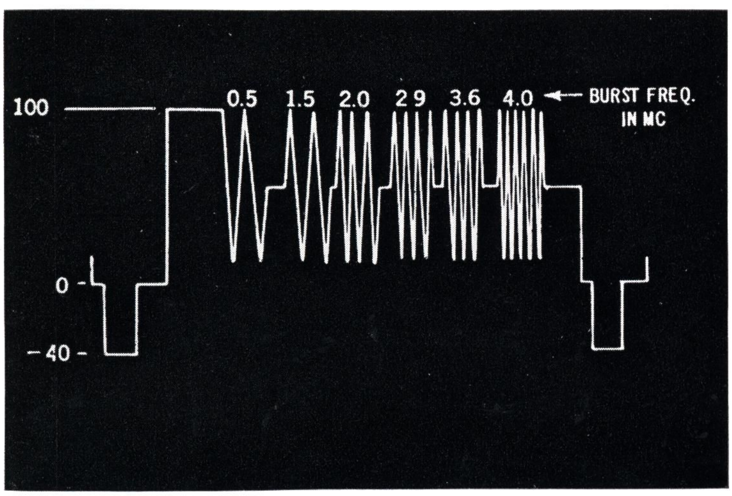

FIG. 3

Bandwidth Adjustment

During initial tune-up, the transmitter should be terminated in a suitable dummy load, with the vestigial sideband filter out of the circuit. The video-sweep from the BW-5 should be fed directly into the modulator, by-passing all input equipment ahead of the modulator.

Typical BW-5 presentations under these conditions are shown in Figs. 4a and 4b. The marker is at 4.2 mc. Figure 4a is typical

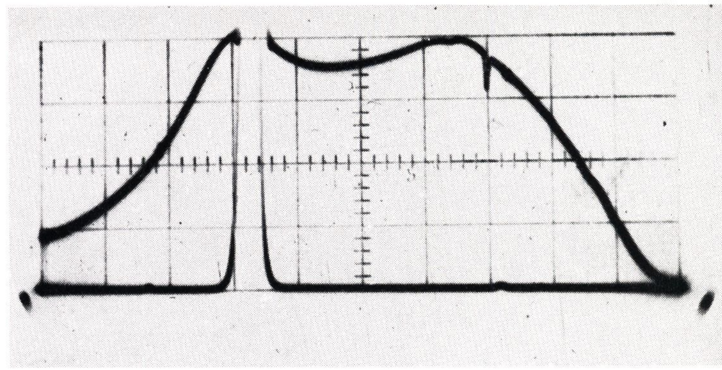

FIG. 4a

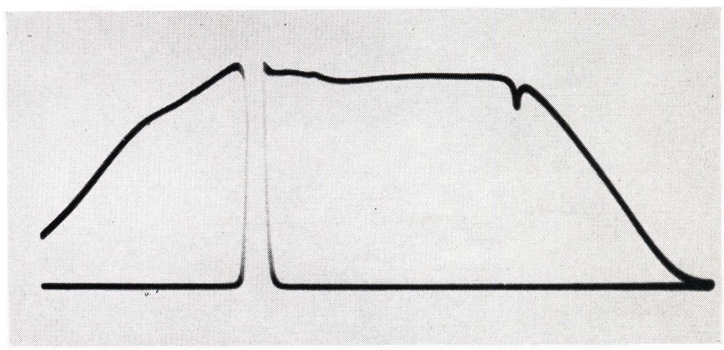

FIG. 4b

of the older transmitters; while better upper sideband response as shown in Fig. 4b is characteristic of new transmitters.

If the transmitter contains more than one broadbanded stage, each stage must be tuned for a flat response into the dummy load. Peaking one stage to compensate for a deficiency in another —commonly known as "stagger" tuning—is one of the main causes of excessive variation in response with changes in brightness. Another common cause is poor impedance-match between stages; the input of each linear amplifier should be adjusted for the best possible match.

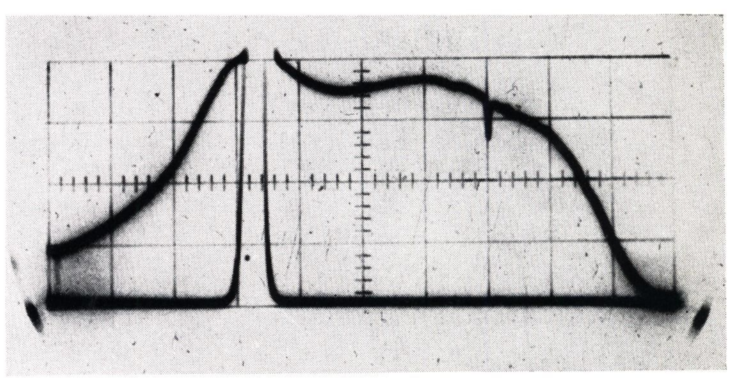

FIG. 5

After the transmitter has been tuned directly into the dummy load, the response of the vestigial-sideband filter can be checked by feeding the output of the transmitter into the filter with the filter terminated in the dummy load. Figure 5 shows the response at the input to the sideband filter. Note that there is only a slight drop-off of the high frequencies as compared to Fig. 4 which indicates that the sideband filter presents a reasonably good termination across the pass-band. The response characteristic at a point following the sideband filter is shown in Fig. 6. Note the sharp cutoff of the lower sideband with no appreciable change in the upper sideband response.

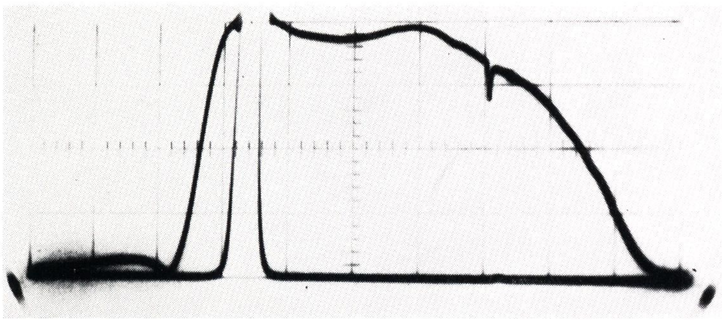

FIG. 6

By inserting the low-pass filter in the input-video line, the overall bandwidth of the transmitter, as shaped to meet FCC specifications, can be observed. Figure 7 displays the usual waveform.

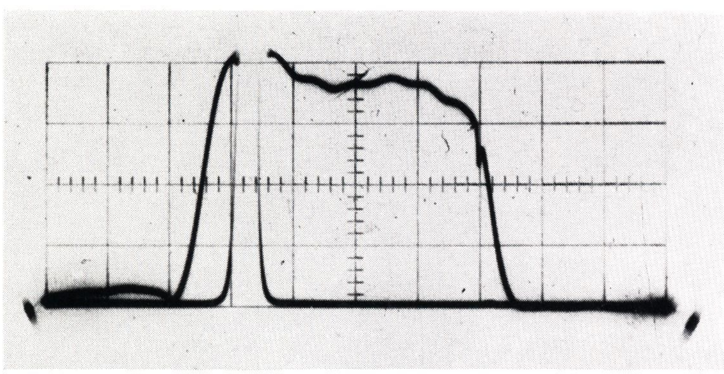

FIG. 7

Differential Gain

Variation of transmitter gain with change of brightness is known as differential gain, or non-linearity of the transfer characteristic of the transmitter. Non-uniform differential gain is a characteristic of grid modulation and grid modulation is used extensively in TV transmitters. The effect of this characteristic is demonstrated graphically in Fig. 8. In color transmission, differential gain produces errors in luminance and saturation in the bright areas of a color picture. Because it is objectionable to the home viewer, this condition must be corrected.

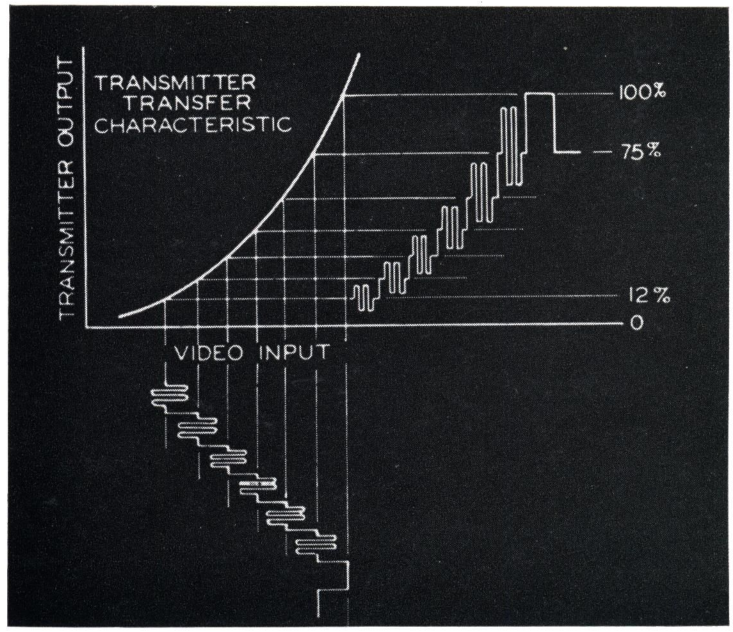

FIG. 8

Correction is accomplished by predistorting the video signal before modulation of the r-f carrier. Most TV transmitters designed within the past seven years have linearity correction circuits included as part of the modulator. For transmitters of earlier design, a stabilizing amplifier containing linearity correction must be used between the video line and the video input to the transmitter.

Differential Gain Adjustment

The most convenient method of measuring and adjusting differential gain is to modulate the transmitter with a stair-step signal that includes a 3.58-mc signal superimposed on each step. The demodulated output of the transmitter is observed on a scope, and the depth of modulation is adjusted (using a chopper to obtain the zero reference) as shown in Fig. 9.

The low-frequency, step-component of the stair-step signal is then removed with a high-pass filter, and the linearity corrector

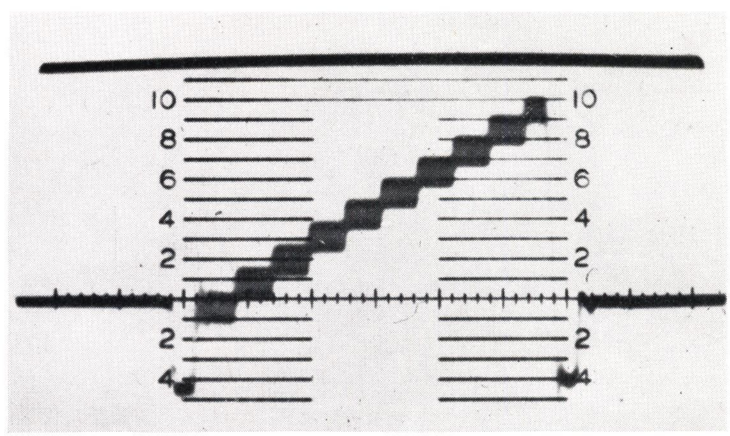

FIG. 9

control adjusted to make each high-frequency component the same amplitude as its neighbor or as close to that value as possible. Figure 10 shows the typical, corrected linearity of a TV transmitter through the high-pass filter. It should be noted that, when linearity adjustments are made, the overall video gain is altered. As a result, it is wise to recheck the depth of modulation frequently while making linearity corrections. After adjustments are completed, all further control of video level should be made ahead of the linearity-correction circuit.

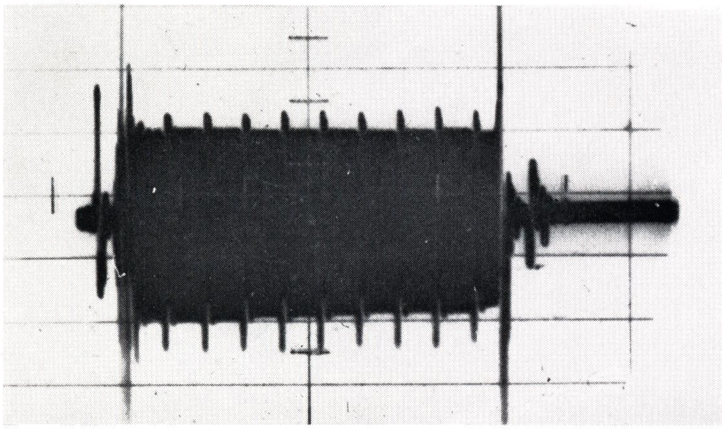

FIG. 10

Differential Phase

Differential phase shift is a term used to describe a change in phase of the color sub-carrier with a change in picture brightness. This type of distortion changes the hue of an object with the intensity of lighting. The most common source of this problem is a change in the plate impedance of an amplifier circuit because of a shift in the operating point of the tube in the amplifier. Two other causes of differential phase shift are: feedback due to improper neutralization and variations of the load into which an amplifier works.

The inherent differential phase shift in most TV transmitters is kept at a point below six degrees by careful selection of tube types used and a circuit design which minimizes the effect. Amplifiers should be checked for proper neutralization in accordance with the transmitter instruction book in order to obtain minimum differential phase shift.

Measuring Differential Phase

Differential phase measurements are made with the same stair-step signal as used for differential gain measurements. A color-signal analyzer or Vectorscope must be used in conjunction with this test signal. The signal should be obtained from a demodulator connected at the output of the sideband filter. It is important that the harmonic filter be ahead of the monitoring point, since the presence of harmonics can give a false reading.

Although the vestigial sideband filter will not introduce differential phase shift, since it is a passive network, it is possible to obtain different measurements before and after the filter. Such a condition indicates the presence of incidental phase modulation in the video signal. The presence of both sidebands would ordinarily result in cancellation of incidental phase modulation; however, with one sideband suppressed the resultant appears as differential phase shift. Unwanted feedback in a video amplifier is often the main cause of incidental phase modulation.

Envelope Delay

The term envelope delay refers to the relative time required for different frequencies within the passband of a transmission system to pass through the system. Unequal delay, or delay distortion, througout the frequency spectrum results in smearing, ringing, and loss of detail in both monochrome and color pictures. In color pictures it can also result in lack of registration between color and luminance parts of the signal as well as distortion of hue and saturation around color edges.

Delay distortion is the result of the sideband shaping mentioned previously. In order to meet the FCC specifications with regard to envelope delay, it is necessary to use envelope-delay equalizers. These equalizers are passive networks that pre-distort the phase characteristics of the video signal before it arrives at the transmitter video input. A low-frequency phase equalizer compensates for the phase distortion introduced by the vestigial sideband filter; while a high-frequency phase equalizer compensates for several factors including phase distortion introduced by the high-frequency cutoff characteristic of the home receiver, the notch diplexer or the filterplexer (if used), and irregularities in the transmitter's high-frequency characteristics. The low-pass filter is ordinarily phase compensated within itself.

Under the standards, each color receiver is required to have its own low-frequency phase compensation; however, the receiver depends on the transmitter for high-frequency phase equalization and therefore correction must be included in the transmitter. Consequently, the transmitter is required to have a pre-distorted phase characteristic in accordance with FCC regulations to complement an assumed typical-receiver-envelope-delay curve.

Measuring Envelope Delay

To accurately measure and adjust the envelope delay of a transmitter, it necessary to use an Envelope Delay Measuring Set such as the RCA Type BW-8A shown in Fig. 11. When measuring the envelope delay of the system, the stabilizing amplifier

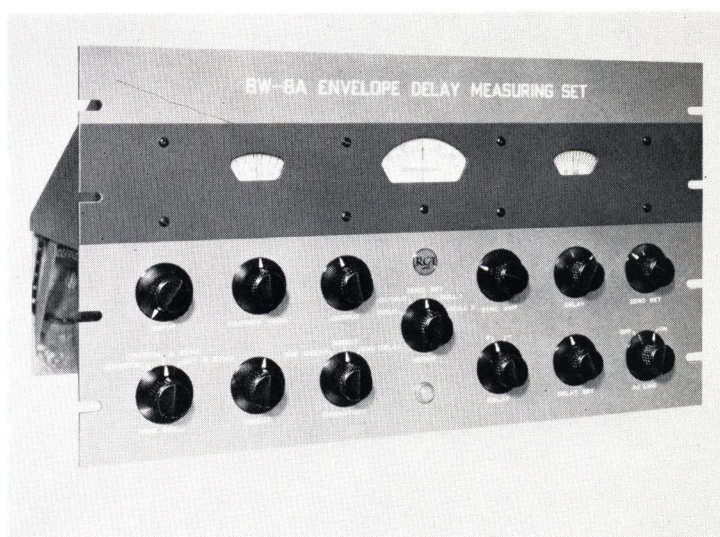

FIG. 11

should *not* be included in the tested system. Due to the nature of the circuitry of a stabilizing amplifier whereby the sync is separated, reshaped and reinserted, it is not possible to measure its envelope delay characteristic with the BW-8A. However, because of its wide bandwidth and flat frequency response, the envelope delay of a stabilizing amplifier is normally very uniform and thus contributes neglible error.

The envelope delay characteristic of the demodulator must be taken into consideration when using the BW-8A to measure the transmitter characteristic. A properly adjusted RCA Type BW-4B Vestigial Sideband Demodulator coupled to the output of the sideband filter will yield fairly reliable measurements. Figure 12 shows an envelope delay curve plotted from data obtained using a BW-8A Envelope Delay Measuring Set and BW-4B Demodulator with the sound notch switched out. The dotted lines represent the FCC limits for positive and negative delay.

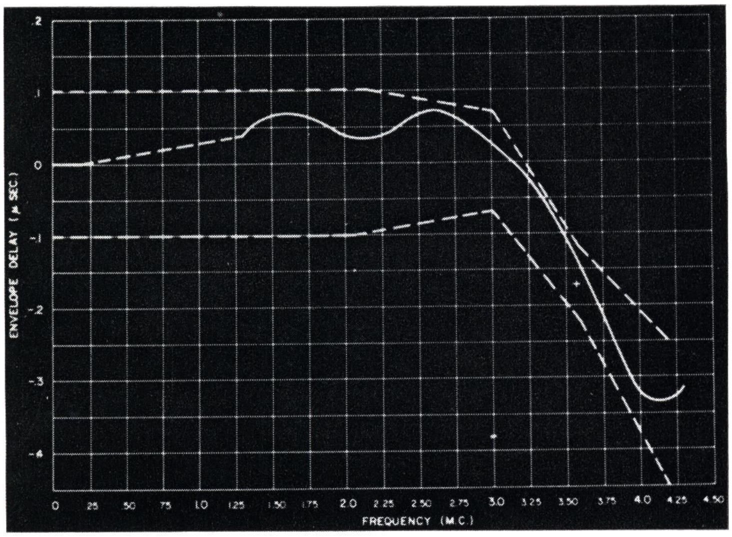

FIG. 12

A diode demodulator can be used to measure the frequency range above 1.4 mc if a correction factor of —0.008 microseconds is applied to all readings obtained in this range. The diode can be used as a check on the BW-4B with the sound notch switched out. Figure 13 shows two curves obtained using a diode demodulator. Curve 1 was taken with no phase equalizers in the circuit, while Curve 2 was taken using the same equalization as used for the curve shown in Fig. 12. (The downward swing at 1.3 mc is due to phase-shifted energy from the lower sideband of the transmitter and should be disregarded.)

Another Method for Measuring Envelope Delay

A 100-kc square wave can be used as a test signal to check the transmitter's envelope delay characteristic. The square wave should first be observed at the output of the square-wave generator with a 75-ohm termination resistor across the oscilloscope input. This ascertains that the square-wave signal is as it should be under that load. The square wave should then be checked at the transmitter input after passing through all of the video-input equipment, but with all the phase equalizers switched out.

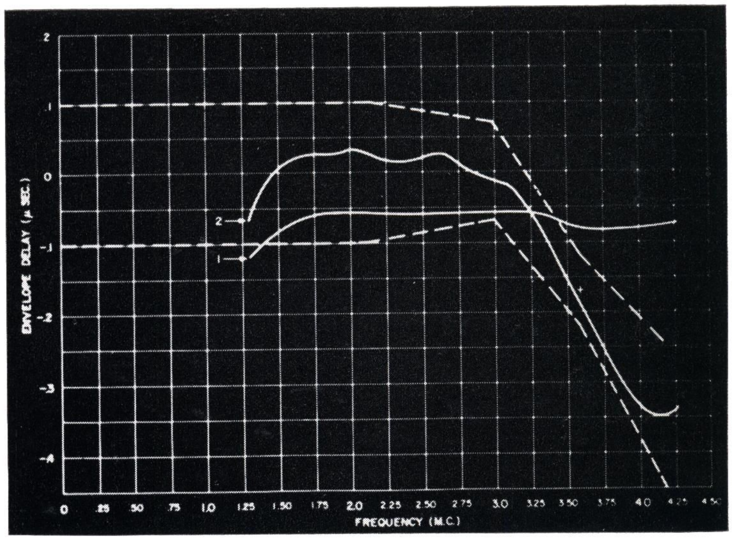

FIG. 13

If the square wave is observed ahead of the low-pass filter or with the filter switched out, a spike-type overshoot appears, as shown in Fig. 14. This spike is caused by a 10-mc (parallel) resonance in the amplitude equalizer. It is removed when the bandwidth is restricted by the low-pass filter as can be seen in Fig. 15. This is the square-wave signal as it appears at the transmitter input.

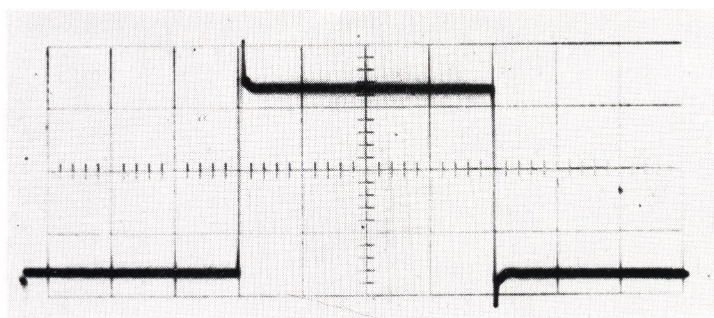

FIG. 14

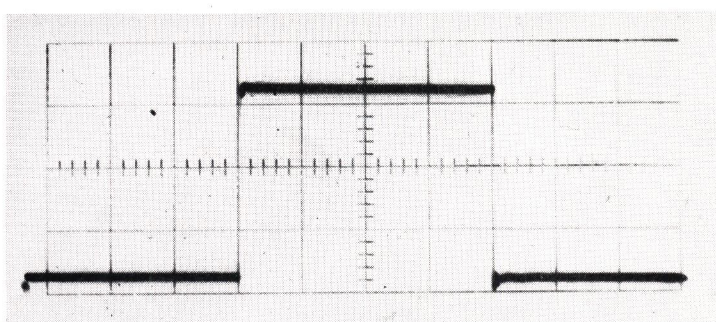

FIG. 15

Figure 16 shows the demodulated square wave as it should appear at a monitoring point following the sideband filter (using a BW-4B Demodulator with the sound notch switched in and with no equalizers connected in the circuit). When the equalizers are inserted and properly adjusted, the ringing will be symmetrical about the vertical transition as exhibited in Fig. 17. The ringing cannot be completely eliminated due to the limited bandwidth of the transmitter and inherent quadrature distortion in the demodulator.

The shape of the square wave will also be affected by the frequency response and linearity of the system, and the phase equalizers will not correct for deficiencies in these areas. Therefore, it is important that all other adjustments be properly made before envelope delay adjustments are even attempted.

When checking the square-wave response at various points in the system, consideration must be given to the equalization inserted ahead of that point, and to which components requiring phase equalization enter into the observation. When using the BW-4B to check the overall system, the sound notch should be switched out, and under these conditions the receiver equalizer should also be switched out. During normal operation both the sound notch and the receiver equalizer should be switched in. Figure 18 shows the effect of the receiver equalization when the demodulator sound notch is out. The anticipatory ringing is the effect of the pre-distortion inserted to compensate for the receiver's sound notch.

Figure 19 shows the 100-kc square wave at the transmitter video input with full equalization applied. The ringing would

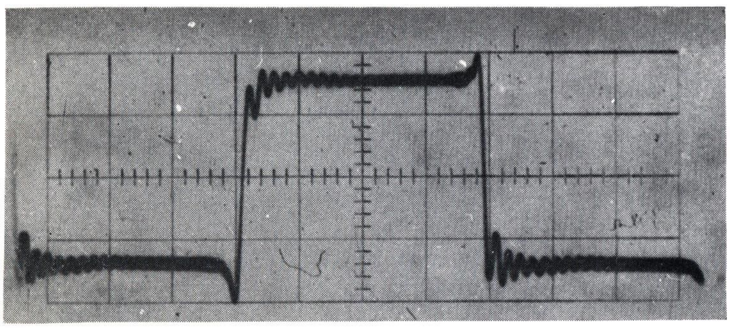

FIG. 16

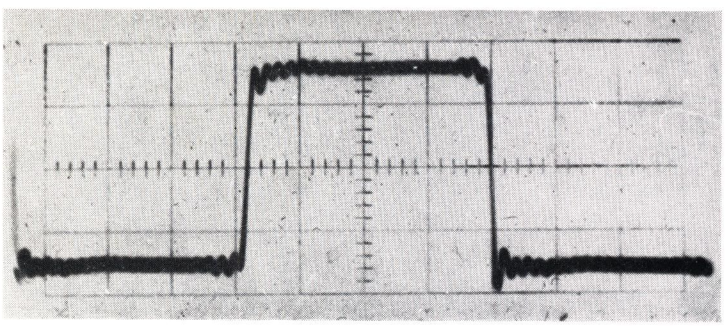

FIG. 17

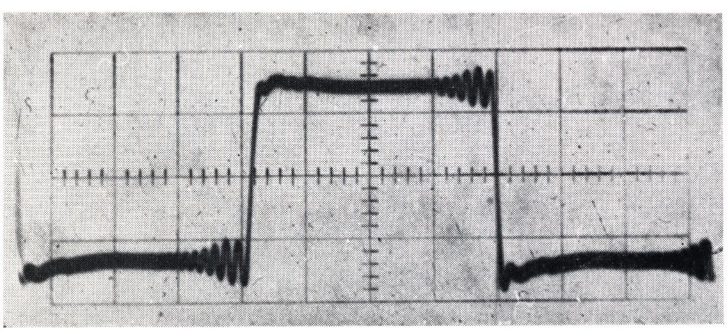

FIG. 18

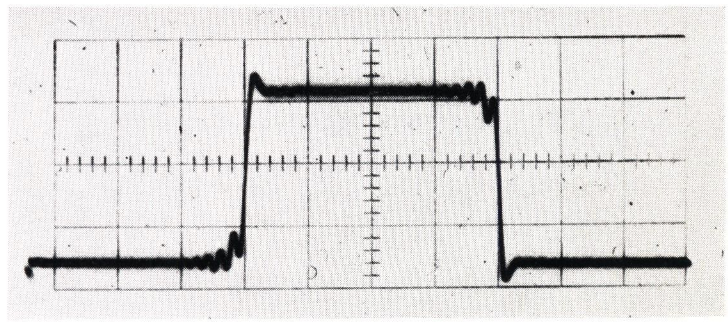

FIG. 19

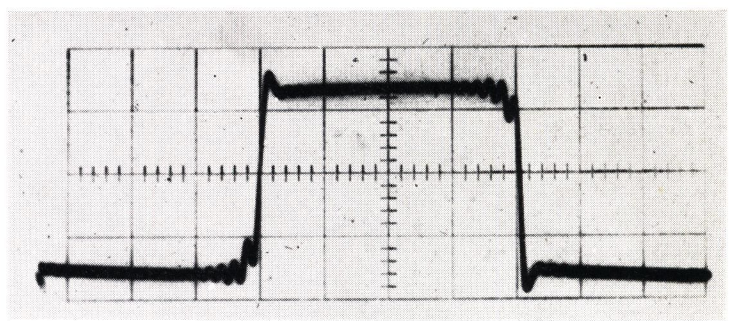

FIG. 20

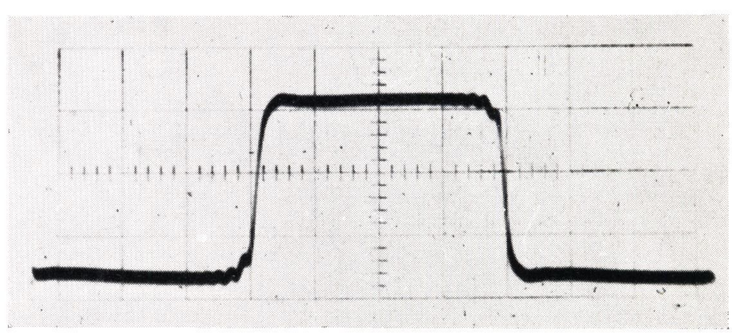

FIG. 21

necessarily be more pronounced if the transmitter feeds a filterplexer or notch diplexer as part of the system, since the notch equalizer would then be in the circuit. Figure 20 shows the same square wave at the output of the modulator, indicating that the modulator needs little or no equalization.

The square wave as presented by a diode demodulator connected ahead of the vestigial sideband filter is shown in Fig. 21. Visible rounding of the corners is due to the 2-to-1 ratio of low-to-high frequencies encountered when using a diode demodulator.

Using Network Test Signals

The TV-test signals commonly employed by the networks can be used to advantage in making periodic checks on transmitter operation. Regular use of these test signals can often help in locating trouble in the system before it becomes serious enough to cause degradation of the transmitted signal.

The multiburst signal is very convenient for checking the amplitude response, since it can be fed through the entire system without disabling the clamp circuits or changing the operating point of the modulated amplifier. However, as mentioned earlier, the multiburst signal should *not* be used for making adjustments to the transmitter, since it only spot checks a few frequencies and gives no indication of excessive bandwidth or irregularities between these frequencies.

The stair-step signal serves to indicate changes in differential gain which, in turn, indicates a change in linearity-corrector gain or that of one of the following stages. Use of a Vectorscope allows monitoring of differential phase with the stair-step signal.

The white window test signal places a critical test on the transmitter and readily shows up smearing and ringing due to phase errors, in addition to faulty clamping and antenna reflections.

Cautions

When observing any test signal at any point in the transmitter system from the stabilizing amplifier to the antenna, evaluation is complicated by the need-to-know whether pre-distortion of the "video" is used and how it effects the signal under observation. If the observed signal is demodulated, the characteristics of the demodulator and its location in the system must be considered.

It is recommended that a diode demodulator be used with the BW-8A for quantitative measurements such as differential gain, differential phase shift, and envelope delay. The BW-4B vestigial sideband demodulator replaces the diode for qualitative observations of test signals such as multiburst, white window, and square-wave analysis of envelope delay. The BW-4B is ideal for air-signal picture monitoring of both monochrome and color transmissions when connected to the appropriate picture monitor.

Summary

The requirements of a TV transmitter for transmission of a good color-TV signal are not much different from those required for a high-quality monochrome signal. However, slight maladjustments can result in serious degradation of color-picture quality while the monochrome-picture quality will still be acceptable. So, when operating with color, transmitter adjustments must be carefully made and maintained or picture quality suffers noticeably.

Adequate test equipment should be on hand for proper adjustment of the parameters just discussed, and the personnel who use the test equipment should be thoroughly versed in its proper operation. It is most important that this test equipment be given good care and be well maintained. A regular maintenance schedule on all equipment, including test and monitoring equipment, should be set up and rigidly followed.

Most TV transmitters presently in operation are capable of transmitting a good color signal if they have been well maintained. All RCA transmitters have been type accepted for color by the FCC, and kits for any modifications required to meet color specifications have been supplied. Older transmitters require a color-stabilizing amplifier for linearity correction, and all transmitters require phase equalizers in order to meet color specifications.

Once the transmitter has been properly adjusted for color operation, it is not at all difficult to keep it that way as long as adjustments are not attempted by personnel who do not thoroughly understand what they are doing. A well-planned maintenance program with adequate test equipment and training of personnel enables any TV station to keep a good color signal on the air.

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