DU MONT
First with the Finest in Television
SERVICE NEWS

Service News

PUBLICATION OF THE TELESET SERVICE DEPARTMENT
ALLEN B. DU MONT LABORATORIES, INC., PATERSON, N. J.

Volume 4 APRIL, 1954 Number 4

FUNDAMENTALS OF COLOR TELEVISION

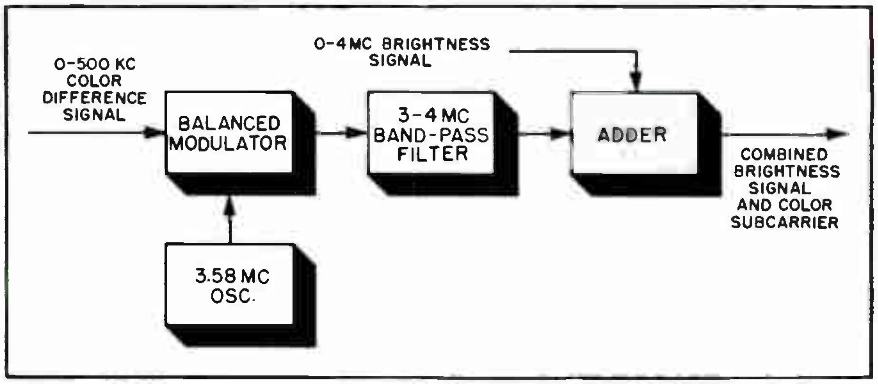
Part IV Formation of the color picture signal. Delay equalization and gamma correction.

by D. Newman & J. J. Roche

In the previous article it was shown that the minimum amount of information which must be transmitted to provide pleasing color pictures consists of a special brightness signal and two color-difference signals. The brightness signal contains video frequency components ranging from zero to approximately 4 mc. The color-difference signals consist of a 0-500 kc signal which provides blue chromaticity information and a 0-1.5 mc signal which provides red chromaticity information.

It might be well to state at this point that in the NTSC color television system the color-difference signals are not transmitted in their original form. Before transmission they are modified, to produce two new signals referred to as I and Q. The formation and purpose of the I and Q signals will be discussed in a later article. For the present we will continue to assume that the red and blue color-difference signals are transmitted, since this simplifies explanation of the techniques used to transmit and recover the chrominance information.

To transmit the complete color television signal within a 6-mc channel, the color-difference signals must share the same channel as the brightness signal. If all three signals were used to simultaneously modulate the video r-f carrier, sideband components of both of the color-difference signals, and the brightness signal, would be present at frequencies within 500 kc of the carrier. At frequencies between 500 kc and 1.5 mc, components of the brightness signal and the wide-band color-difference signal would be present. Interference between the three signals would therefore occur primarily at frequencies below 1.5 mc. Since these frequencies represent the large and intermediate size details in the picture, the interference would be coarse in structure and extremely objectionable.



Figuer 1. Circuits required to insert the narrow band chrominance information in the higher frequency portion of the brightness pass band.

Frequency Multiplexing

If the color-difference signals are shifted to the high-frequency end of the spectrum occupied by the brightness signal, the interference between the signals will produce a much finer and thus less objectionable visible pattern. The technique employed to shift the frequency band occupied by the color-difference signals is referred to as "frequency multiplexing." The circuits required to shift one of the color-difference signals (the narrow-band signal) to the higher frequency end of the brightness pass-band are shown in block diagram form in figure 1.

The narrow-band, blue color-difference signal is applied to a balanced modulator circuit. An oscillator supplies a 3.58-mc signal which is also applied to the balanced modulator. This 3.58-mc signal, referred to as the "subcarrier," is modulated by the 0-500 kc blue color-difference signal. The output of the modulator contains upper and lower sideband components ranging in frequency from approximately 3 mc to 4 mc. A bandpass filter in the output of the balanced modulator attenuates all other frequency components which may be present.

In the balanced modulator circuit the 3.58-mc subcarrier signal is suppressed. In other respects the output of the balanced modulator is similar to that of an ordinary modulator, i.e., it is an amplitude modulated signal with upper and lower sideband pairs for each component in the modulating signal.

A circuit diagram of one type of balanced modulator is shown in figure

DU MONT
SERVICE NEWS

Published Monthly by the
Teleset Service Department

ALLEN B. DU MONT LABORATORIES, INC.
257 SIXTEENTH AVENUE, PATERSON, N. J.

Joseph Hatchwell.................SERVICE MANAGER
Joseph J. Roche...EDITOR

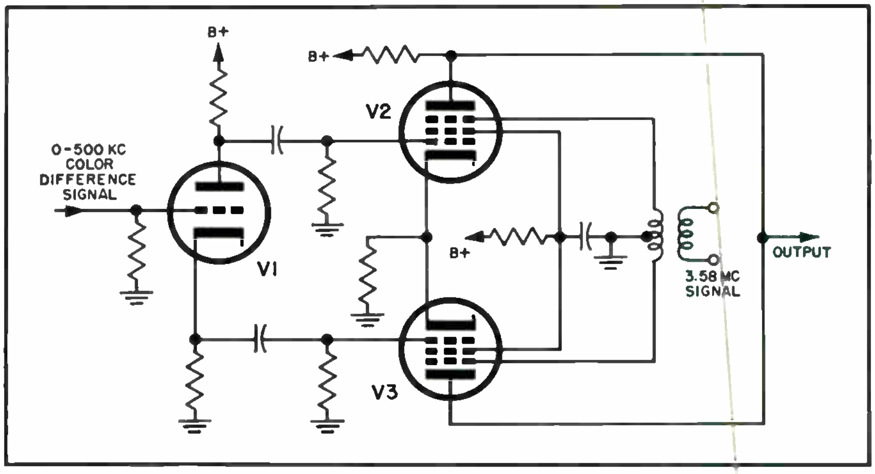


Figure 2. Circuit diagram of a balanced modulator.

2. Let us examine what happens when either the color-difference signal or the 3.58-mc subcarrier is applied separately.

The color-difference signal is applied to the grid of a triode phase splitter (V1). The balanced modulator consists of two pentodes (V2 and V3). The out-of-phase signal voltages provided by the phase splitter (V1) are applied to the control grids of the modulator tubes. These two signals are of equal amplitude but opposite polarity. Thus the color-difference signal appears as a negative going signal at the grid of one modulator tube, and as a positive going signal at the grid of the other tube. Since the amplitudes of these signals are equal, the reduction in current produced in the tube to which the negative going signal is applied, is equal to the increase in current in the tube to which the positive going signal is applied.

The plates of the balanced modulator tubes are tied together, and as a result the changes in plate voltage, produced by the out-of-phase color-difference signals, cancel. Thus the color-difference signal does not appear in the output of the balanced modulator.

The 3.58-mc subcarrier oscillator signal is applied to the suppressor grids of the modulator tubes (V2 and V3) through a transformer. The signals on the suppressor grids are equal in amplitude but opposite in polarity. In the absence of the color-difference signals at the control grids, the subcarrier signal produces equal, but opposite, voltage variations at the plates of the modulator tubes. Since the plates are connected together these voltage variations cancel and the 3.58-mc subcarrier does not appear in the output of the balanced modulator.

When the 0-500 kc color-difference signal and the 3.58-mc subcarrier are applied to the balanced modulator

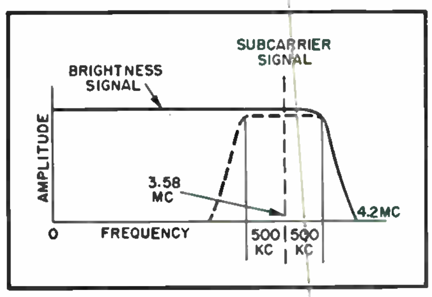


Figure 3. Frequency bands occupied by the brightness and chrominance information at output of adder circuit. Only the narrow-band chrominance component is shown.

simultaneously, the unbalance in the tubes produced by the 0-500 kc signal, causes a larger 3.58-mc signal to appear at the plate of one modulator tube than at the other. Consequently, the 3.58-mc signal is no longer completely cancelled and appears in the output of the modulator. The amplitude of the modulator output varies in

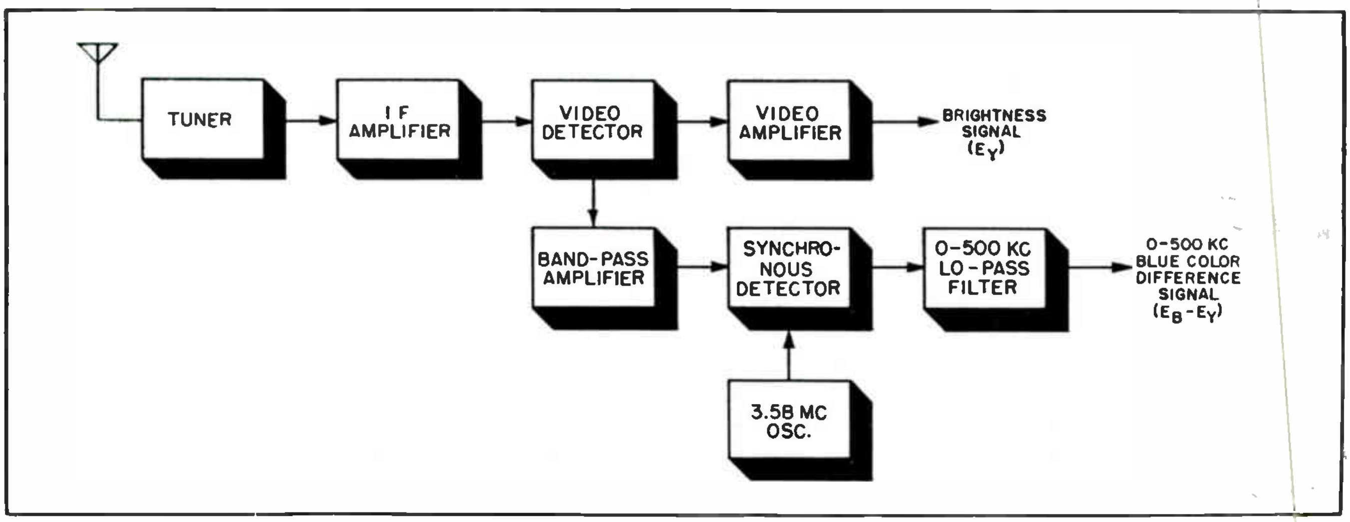


Figure 4. Receiver circuits required to recover the brightness and blue color-difference signals.

accordance with the amplitude of the color-difference signal. The unmodulated portion of the 3.58-mc signal is always cancelled and only the modulation sidebands are present in the modulator output.

The brightness signal is combined with the subcarrier sidebands in an adder circuit. The adder is simply a linear mixing circuit which combines the two signals without distortion. The frequency components in the output of the adder are shown in figure 3. Note that the subcarrier signal consists of sideband components extending approximately 500 kc above and below 3.58 mc.

The combined brightness and subcarrier signals may now be treated in essentially the same way as an ordinary black-and-white video signal, and may be transmitted in the usual manner. In the receiver special circuits are required to separate the two components of the signal.

Separating the Brightness and Subcarrier Signals

The receiver circuits required to detect and separate the brightness and color subcarrier signals are shown in block diagram form in figure 4. The tuner, video i-f amplifier and video detector circuits are essentially the same as those in a black-and-white receiver.

The composite brightness and subcarrier signal is detected in the usual manner, and appears in the output of the video detector as frequency components between 0 and 4.2 mc. This signal is fed to the video amplifier where some attenuation is provided above 3.58 mc to reduce the amplitude of the subcarrier sideband components. The output of the video amplifier is the brightness signal. This signal still contains some of the subcarrier side-band energy. However, its effects on the reproduced image are negligible as a result of the application of several techniques which will be discussed later.

The composite signal is also applied to a 3 to 4.2 mc band-pass amplifier which removes all components of the brightness signal below 3 mc, and passes all the sideband components of the subcarrier signal.

The subcarrier is next applied to a special type of detector circuit referred to as a synchronous detector. A 3.58-mc signal, of exactly the same phase as the original 3.58-mc signal employed in the transmitter is also applied to the synchronous detector. In the detector circuit the chrominance subcarrier and the 3.58-mc reference signal act on the electron stream, producing the original 0-500 kc blue color-difference signal. A low-pass filter at the output of the synchronous detector attenuates all undesired frequency components above 500 kc that appear in the detector output.

It should be noted that those frequency components of the brightness signal which fall within the pass-band of the chrominance circuits appear in the output of the synchronous detector. This represents a source of interference within the system and steps must be taken to minimize its effects. The techniques employed will be discussed in a later article.

The wide-band color-difference signal still remains to be transmitted. This signal is handled in much the same way as the narrow-band color-difference signal. As shown in figure 5, it is fed to a low-pass filter which

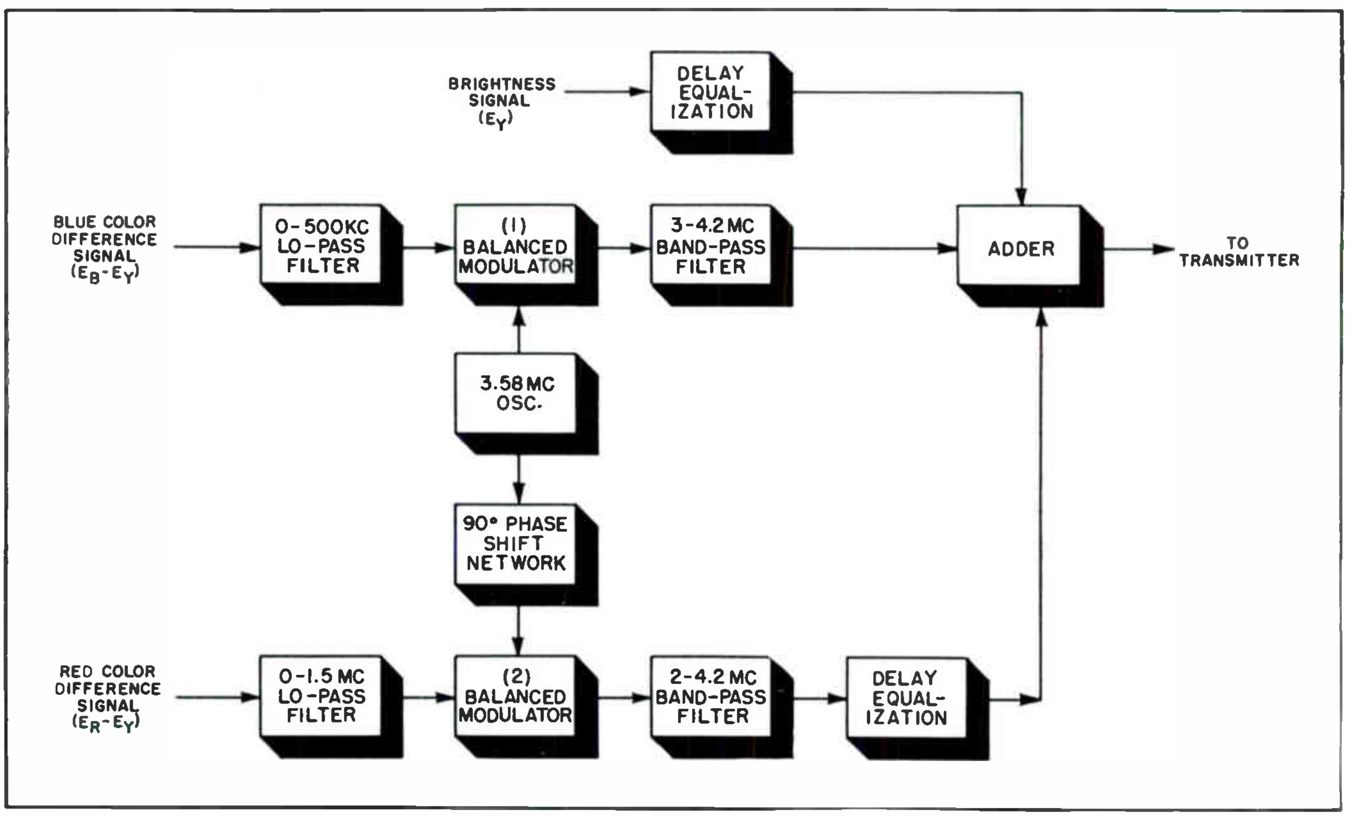


Figure 5. Transmitter circuits used to form a color picture signal from the brightness and red and blue color-difference signals.

attenuates all frequencies above 1.5-mc. The output of the filter is applied to a balanced modulator similar to the one previously described. The 3.58-mc subcarrier signal, fed directly to the balanced modulator (1) which handles the narrow-band color-difference signal, is also applied to a 90° phase-shift network. The output of the network is coupled to the balanced modulator (2) in the wide-band chrominance channel. The output of balanced modulator (2) is then passed through a 2 - 4.2-mc band-pass filter.

The narrow and wide-band subcarrier components are then combined with the brightness signal in an adder circuit. The frequency distribution of the brightness and chrominance information at the output of the adder circuit is shown in figure 6. The brightness signal extends out beyond 4 mc. The chrominance subcarrier is located at approximately 3.58 mc. The sidebands of the narrow-band chrominance component extend approximately 500 kc above and below this frequency. The sidebands of the wide-band chrominance component extend from below 2 mc to approximately 4.2 mc. As indicated a portion of the upper sideband of the wide-band chrominance component is attenuated. This does not result in the loss of information since all of the required information is contained in the lower sideband.

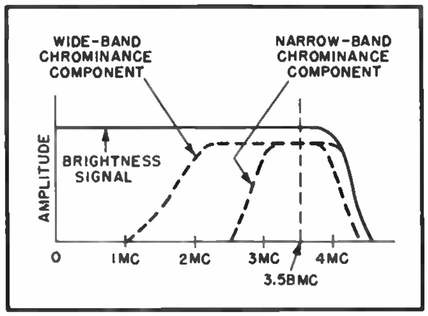


Figure 6. Frequency bands occupied by the brightness and chrominance information in the color picture signal.

Delay Equalization

In passing through the transmitter circuits the brightness and color-difference signals suffer some delay. The delay is greatest in the narrow-band chrominance channel and least in the brightness channel. For proper operation of the system all three signal components must be transmitted in coincidence. This is accomplished by inserting sufficient artificial delay in the brightness and wide-band chrominance channels to make the delays in these channels equal the delay in the narrow-band chrominance channel. In this way the brightness and chrominance signals are delayed equally before they are combined in the adder circuit.

The combined subcarrier signals are referred to as the "chrominance signal." The vector relationships of the components of the chrominance signal are shown in figure 7. The phase relationship of the unmodulated subcarrier signals, which are applied to the balanced modulators, is shown at A. These signals are identical in frequency but are 90° out of phase.

In the balanced modulators sideband pairs are generated for each frequency component of the color-difference signals. The outputs of the balanced modulators are shown at B in figure 7. Although a sideband pair is generated for each component in the modulating signal, for simplicity only one pair has been shown in figure 7B for each of the signals. The 3.58-mc subcarrier signals are suppressed in the balanced modulators and do not appear in their outputs. The subcarrier phase positions are indicated in the figure by dotted lines.

The sidebands of the subcarrier signals combine to form the resultant chrominance signal, as shown in figure 7C. The phase and amplitude of the chrominance signal are determined by the amplitudes of the two subcarrier components from which it is formed.

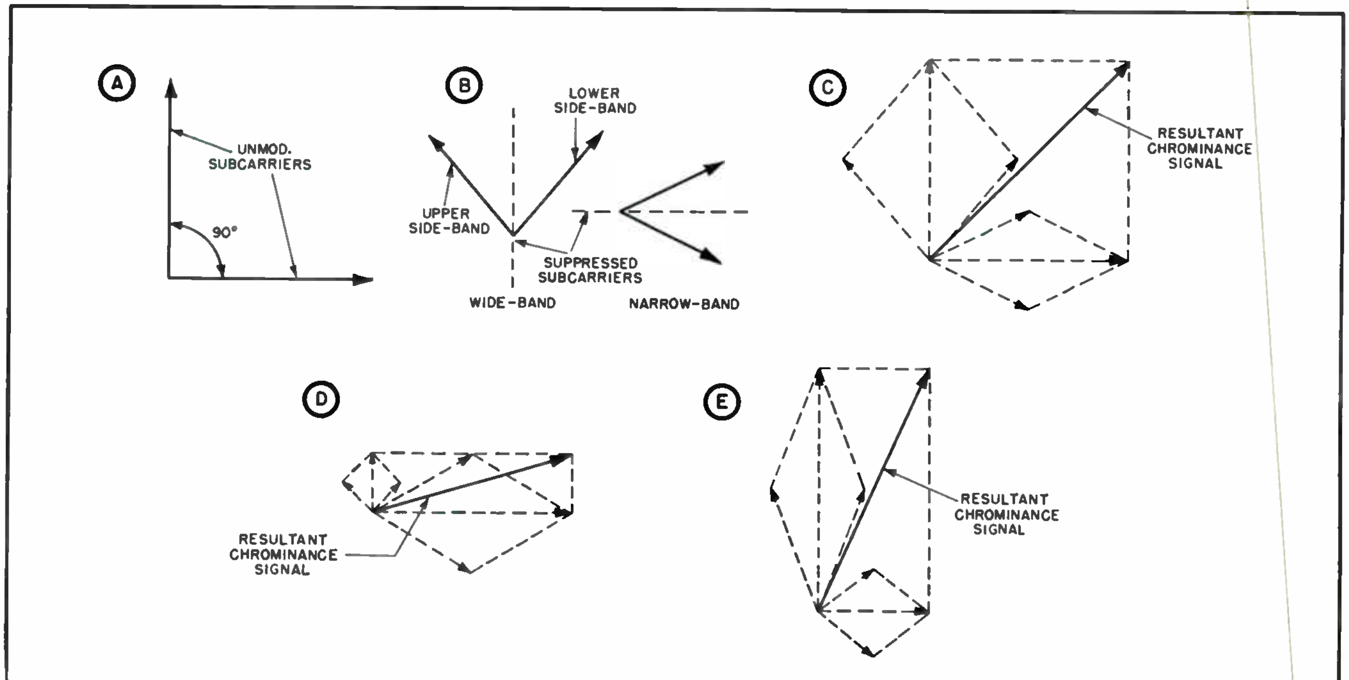


Figure 7. A—Phase relationship of the unmodulated 3.58-mc subcarrier signals. B—Phase relationship of the narrow- and wide-band chrominance signal components at outputs of balanced modulators. C, D and E—Phase and amplitude of the chrominance signal is determined by the amplitudes of the narrow- and wide-band components

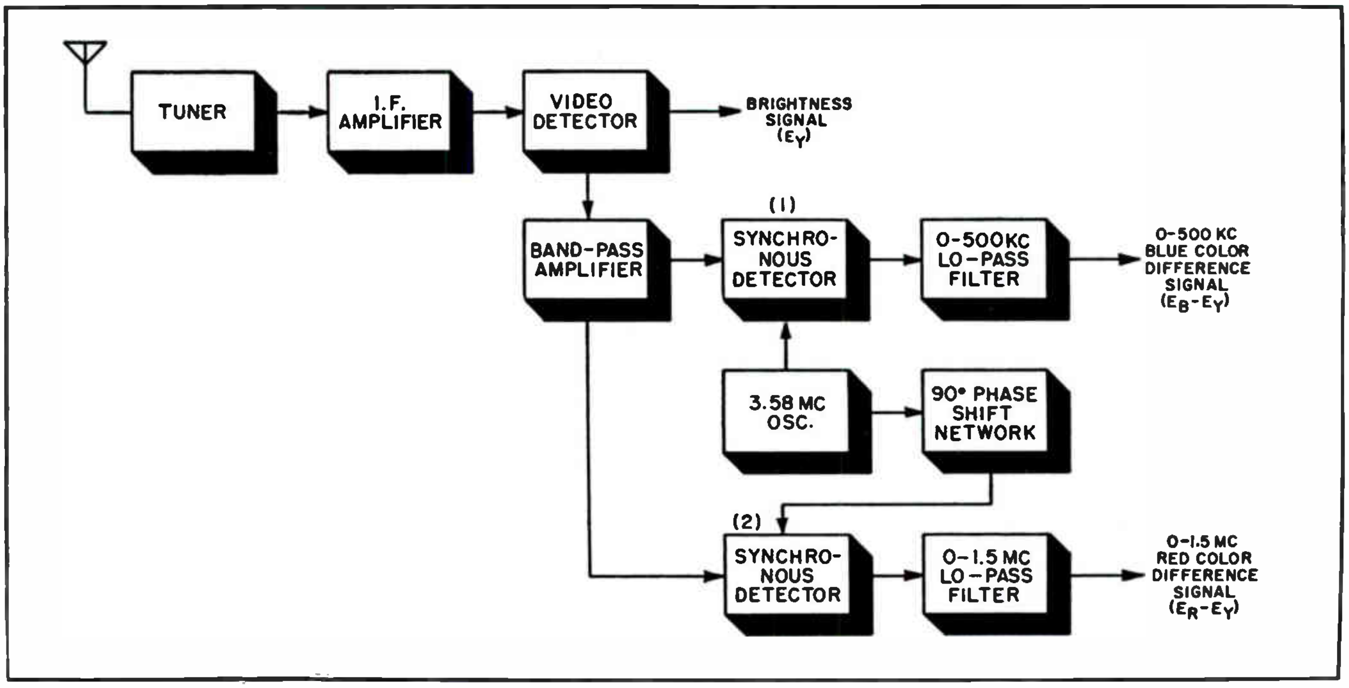


Figure 8. Receiver circuits required to recover the brightness, and the red and blue color-difference signals

When the amplitude of one of the color-difference signals changes, causing the amplitude of its associated chrominance signal component to be reduced, both the amplitude and the phase of the resultant chrominance signal change, as shown in figure 7D. As shown in figure 7E, when the amplitudes of both subcarrier components change, the phase and amplitude of the chrominance signal may change. It should be noted however, that if the amplitudes of both of the chrominance signal components change, the phase of the chrominance signal *will not* change if the proportional relationship between the amplitudes of the two subcarrier components remains the same. This condition occurs when the *saturation* of the televised color changes but its *hue* remains the same.

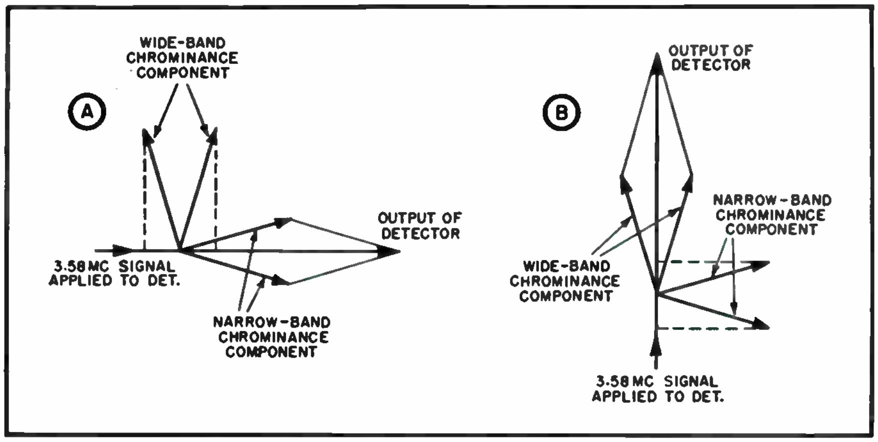
When the *hue* of the color being televised changes and its *saturation* remains the same, the phase of the chrominance signal changes while its amplitude remains constant. The above indicates an important characteristic of the chrominance signal—its phase is determined by the hue of the color being televised, while its amplitude is determined by the saturation of the color.

In the receiver the color-difference signals are recovered using two synchronous detectors. A block diagram of the receiver circuits is shown in figure 8. The color picture signal (consisting of the combined chrominance and brightness signals) at the output of the video detector, is applied to a 2-4.2-mc bandpass amplifier. The output of this amplifier is applied to two separate synchronous detectors.

A 3.58-mc signal is generated in the receiver. This signal is fed directly to synchronous detector (1). The narrow-band color-difference signal is recovered in the output of this detector. The 3.58-mc signal is also applied to a 90° phase-shift network whose output is coupled to a second synchronous detector (2). The wide-band color-difference signal is recovered in the output of detector (2). Undesired frequency components are attenuated by low-pass filters located at the outputs of the detectors.

The action of the synchronous detectors is illustrated by the vectors in figure 9. Although the chrominance signal has but one amplitude and phase at any instant, for simplicity it has been shown in the form of the sideband components of which it is composed.

Recovery of the narrow-band, blue color-difference signal is shown at A in figure 9. The 3.58-mc reference signal applied to synchronous detector (1) has exactly the same phase as the original subcarrier signal, which was



Figue 9. Vector diagrams showing action of the synchronous detectors.

modulated by the blue color-difference signal in the transmitter. In detector (1) the side-band components produced of the narrow-band chrominance signal component add, causing the blue color-difference signal to appear in its output. As shown in the illustration the sideband components of the wide-band chrominance signal component produce equal but opposite voltages in the output of detector (1) and cancellation occurs.

The action of synchronous detector (2), which is used to recover the red color-difference signal, is shown in figure 9B. In synchronous detector (2) the sidebands of the narrow-band chrominance signal component produce equal but opposite voltages which cancel in the output of the detector. Since the 3.58-mc reference signal applied to detector (2) is in phase with the wide-band component of the chrominance signal, the sidebands of this portion of the signal add, and the red color-difference signal appears in the output of the detector.

The Color Sync Burst

To properly recover the color-difference signals the reference signals applied to the synchronous detectors in the receiver must be of the same frequency and phase, within close tolerances, as the subcarrier signals employed in the transmitter.

To synchronize the reference signals in the receiver with the subcarrier signals in the transmitter, a sync signal is transmitted along with the other components of the color television signal. This sync signal must be transmitted in such a way that it will not interfere with the operation of black-and-white receivers. In the NTSC color TV system the sync signal takes the form of sample bursts of

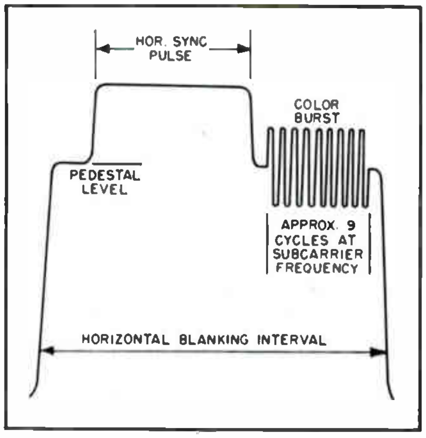


Figure 10. The color sync signal consists of a burst of approximately nine cycles of the subcarrier frequency, transmitted on the back porch of the horizontal blanking pulse.

the 3.58-mc signal from which the subcarrier signals are derived in the transmitter. These bursts are approximately 9 cycles in duration and are repeated at horizontal scanning-rate intervals. The burst is inserted on the back porch of the horizontal blanking pulse, as shown in figure 10. Transmitted in this way, the "color sync burst" occurs when the screen of the receiver is blanked out by the blanking pulse. In addition the burst occurs after the horizontal retrace has begun and thus has no effect on the horizontal sweep.

One way in which the color sync burst can be employed to synchronize the 3.58-mc oscillator in the receiver is shown in figure 11. The color picture signal at the output of the video detector is fed to a burst amplifier. This amplifier is keyed by a pulse obtained from the horizontal sweep circuits of the receiver, and the amplifier conducts only during the burst interval. Thus only the amplified color sync burst appears in the output of the burst amplifier. The amplified burst is fed to a phase detector where it is compared with the 3.58-mc oscillator signal. When the oscillator phase differs from that of the color sync burst, the phase detector develops an error voltage, which is applied to a reactance-tube control circuit to correct the phase of the oscillator output signal.

Gamma Correction

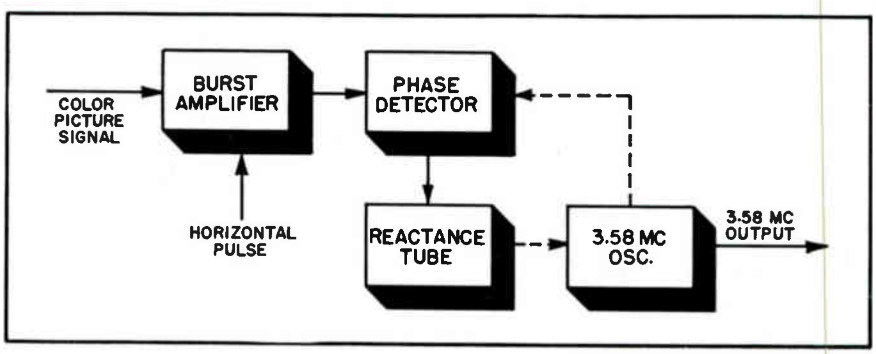
To provide good color reproduction the transfer characteristic (light input vs. light output) of the color television system must be essentially linear. Since some non-linearity is inherent in the components which make up the system some form of correction is required. The compensation provided to eliminate the effects of this non-linearity is referred to as "gamma correction."

The principal non-linear element in the system is the picture tube used in the receiver. The transfer characteristic (screen brightness vs. input voltage) of a typical CRT is similar to that shown in figure 12. Note that a given change in grid voltage does not produce the same change in screen brightness throughout the operating range of the tube. A much greater change in grid voltage is required at high negative grid-bias levels to produce a given change in screen brightness, than is required at low negative grid-bias levels.

The non-linear characteristic of the system can be compensated for by passing the red, green, and blue color signals through special amplifiers.

These amplifiers are adjusted to provide non-linear transfer characteristics which are approximately inverse that of the balance of the system. In figure 13 the transfer characteristic of the system without gamma correction is indicated by curve A. The transfer

Figure 11. Block diagram showing one way in which the color sync burst can be used to control the source of the subcarrier reference signals in a color receiver.



characteristic of a gamma-correction amplifier which will compensate for the balance of the system is indicated by curve B. The resultant transfer characteristic of the system with gamma correction is shown by curve C. Note that the resultant overall characteristic of the system is essentially linear. The curves in figure 13 have been idealized to illustrate the purpose of gamma correction.

In the next issue the chrominance subcarrier and the purpose and formation of the I and Q signals will be discussed.

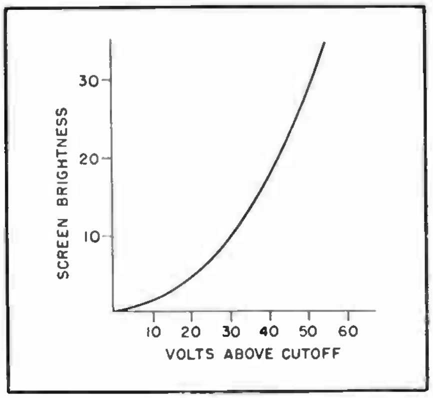


Figure 12. Transfer characteristic of a typical CRT, showing its inherent non-linear response.

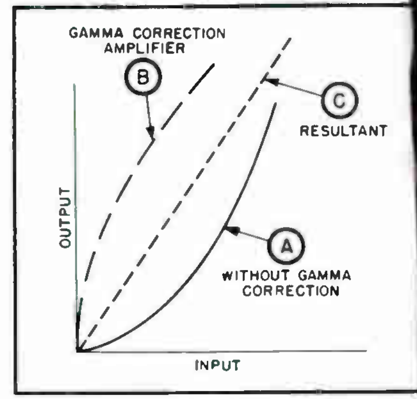


Figure 13. Idealized curves illustratin the result of gamma correction on re sponse of the system.

TROUBLESHOOTING HINTS

Teleset: RA-119A

Symptom: Excessive blooming when the Brightness control is turned fully clockwise. As the control is turned the size increases while the brightness decreases, giving a very dim picture.

A check of the high voltage Regulator control (R307), reveals that the glow in the VR75 regulator tube (V308) disappears when R307 is rotated clockwise.

Probable Fault: R325 (25K, 10W), the resistor connected between B+ and the suppressor and cathode of the 6SJ7 control amplifier tube (V302) and the VR75 regulator, is open.

Remedy: Replace R325, reset the Regulator control, R307, and readjust the ion-trap magnet.

Teleset: RA-306/307

Symptom: White elements in picture have trailing blacks, and black elements have trailing whites, as shown in figure T-1, giving appearance of improper video i-f alignment.

Probable Fault: R218 (33 ohms, 10%, ½W), the cathode resistor of the video amplifier (V204), has increased in value.

Teleset: RA-306/307

Symptom: Heavy streaking noise in the picture accompanied by slight smear, as shown in figure T-2.

Probable Fault: L203, the peaking coil in the grid circuit of the video amplifier (V204), is open.

Figure T-1. The test pattern shown above exhibits the effects of trailing blacks and whites upon the picture. Although this condition can be the result of an improper video i-f alignment, the above was due to a defective component in the video amplifier.

Figure T-2. Slight picture smear accompanied by heavy streaking noise visible at the vertical wedges of the test pattern. This condition was caused by a defective component in the grid circuit of the video amplifier.

customers enjoy "PROFESSIONAL TREATMENT"

In television service as in any profession, whether it be barber or doctor, the client places great emphasis on the way you go about your business. Professional treatment of the customer creates confidence in your service and ultimately results in his satisfaction.

One way to insure this customer good will in TV service is to combine top-quality materials with your skilled, technical, workmanship. With dependable products, you can eliminate costly call-backs and build a reputation for quality service.

You can depend on Du Mont quality picture tubes to do more for your service.

Photo by Joe Clark, H. B. S. S. from Friends Magazine and Photography Magazine.

* TRADE MARK

Replacement Sales Cathode-ray Tube Division

ALLEN B. DU MONT LABORATORIES, INC.

750 Bloomfield Avenue, Clifton, N. J.

PIONEER IN BIG PICTURE TUBES • ORIGINATOR OF THE FAMOUS BENT-GUN AND SELFOCUS
LEADER IN HIGH-RESOLUTION • MAJOR SUPPLIER TO MOST FINE TELEVISION RECEIVER MANUFACTURERS