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LB-910

CIRCUITS FOR RECEPTION OF NTSC (FEB. 2, 1953) COLOR TELEVISION SIGNALS

RADIO CORPORATION OF AMERICA

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Circuits for Reception of NTSC (Feb. 2, 1953) Color Television Signals

Approved

Stuart Wm Seeley

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Introduction

This bulletin describes the video and color synchronization circuits of a color television receiver intended for use with signals of the type described by the NTSC on Feb. 2, 1953 and reproduced here in the Appendix. The receiver is also suitable for the reception of standard monochrome transmissions. The circuits described here were intended to operate as a part of an integrated receiver. Although r-f, i-f, deflection, sound and power supply circuitry are not described, pertinent data concerning these portions of the receiver are given where the circuits under discussion are dependent thereon.

General Considerations

The portion of the receiver described in this bulletin must perform several functions not encountered in monochrome reception. In addition, of course, there are circuits similar to those used in monochrome receivers which perform functions such as video amplification of the luminance signal.

The video section of a color receiver must include a luminance channel whose function is to amplify the luminance information at the video second detector to a value suitable for application to the matrix circuits.

There must be a chrominance channel the purpose of which is to demodulate the color difference information from the color subcarrier and its associated side bands. Under the present NTSC field-test signal specifications, full advantage of the available bandwidth assigned to chroma information is obtained only by demodulating along two particular phases of color subcarrier called the I and Q axes. The Q information contains frequency components up to about 0.5 Mc. The I information contains frequency components up to about 2 Mc. The I and Q channels should contain filters which reject frequency components above these frequencies to prevent crosstalk. With different bandwidth filters in the I, Q and Y (luminance) channels each of these signals will, in general, experience different amounts of time delay. Accordingly, it is generally necessary to equalize the delay of the three signals.

The tri-color kinescope is a red, green and blue simultaneous display device and thus requires signals representing the red, green and blue information in the composite signal. To obtain R, G, and B signals from I, Q and Y signals a matrix is used. The matrix is an algebraic adder which combines the correct proportions of I, Q and Y to make each of the simultaneous R, G and B signals.

The demodulation of the color subcarrier and its side bands, as mentioned previously, is performed along definite axes or phases. Since the accuracy of these phases will determine the accuracy of the hue and saturation of the color information ultimately applied to the kinescope, there must be information transmitted with the composite signal which establishes a reference phase. This color synchronizing information, referred to as the burst, must be extracted from the composite signal and used to establish a pair of c-w (continuous-wave) signals of phase corresponding to the I and Q axes. These c-w signals are used in a pair of

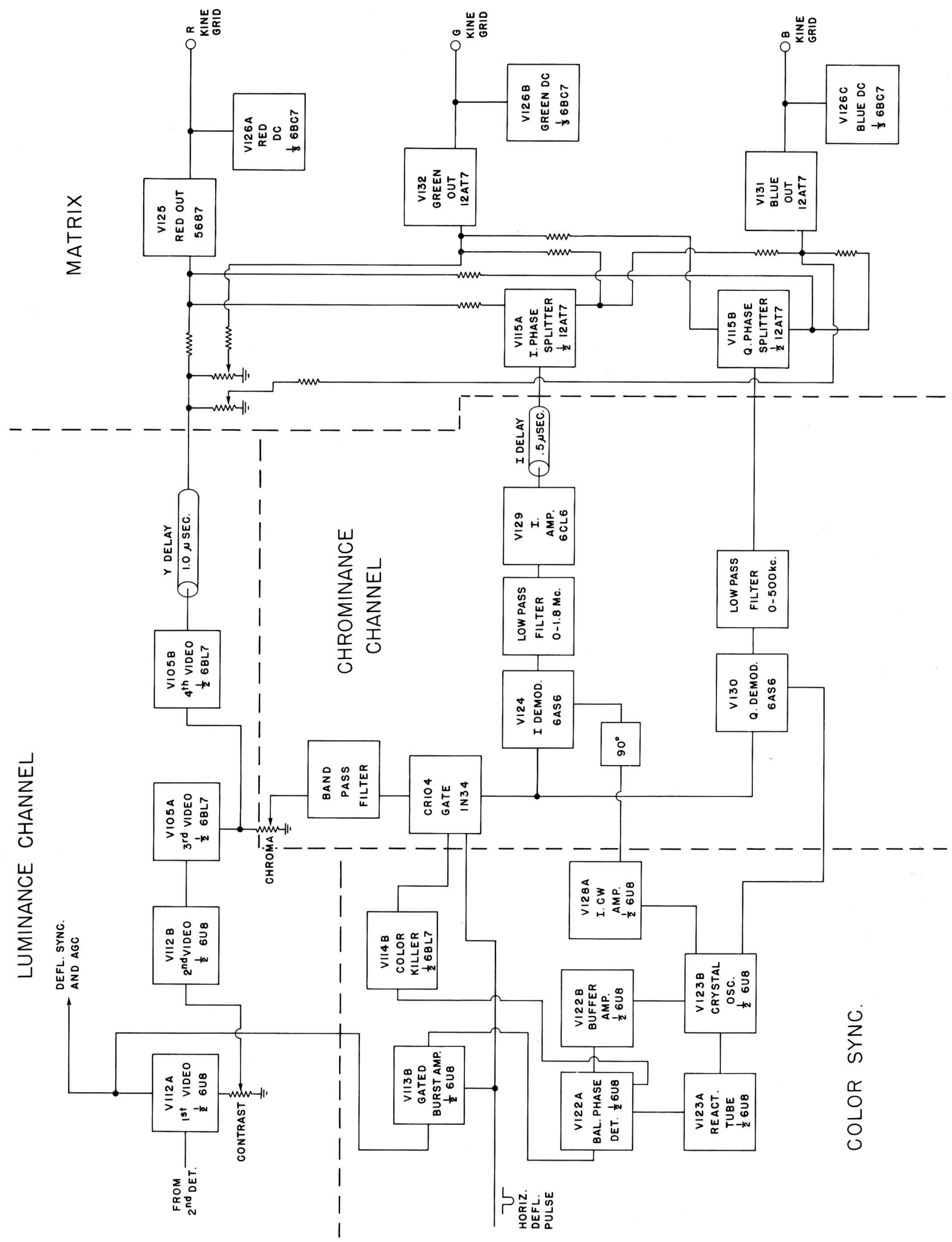


Fig. 1 – Block diagram, video se on of color television receiver.

synchronous detectors whose outputs are the I nd Q signals. The c-w signals may be obtained in a number of different ways. One method is to use a crystal oscillator whose exact frequency is determined by a reactance tube which is in turn controlled by an error signal proportional to the difference in phase between the incoming synchronization information and the oscillator output.

The following discussion will cover these four principal functions, luminance channel, chrominance channel, matrix and color synchronization. The block diagram of Fig. 1 shows the general orientation of these portions of the receiver. Fig. 2 is the schematic diagram.

Video Input Signal

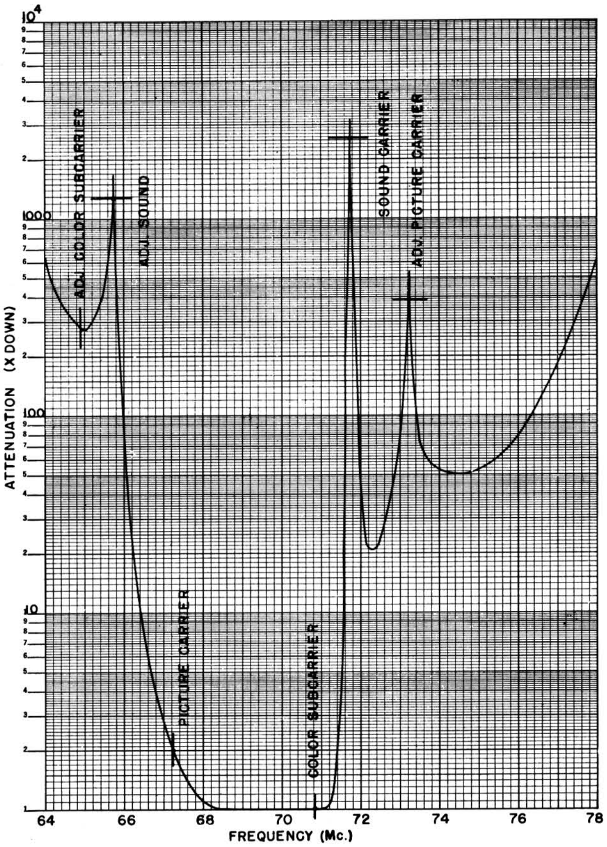


Fig. 3 - Overall rf-if response, channel 4.

Fig. 3 shows the overall amplitude vs frequency characteristic of the rf-if system used in this receiver. It should be mentioned that while the sound carrier is attenuated over 60 db with respect to the picture carrier at the second detector, a modified intercarrier sound system is used with sound take-off before the final i-f tuned circuit. Since the last i-f tuned circuit includes most of the attenuation to the sound carrier, this arrangement permits adequate 4.5-Mc beat amplitude to be generated. The level at the video second detector under a-g-c action is about 8.5 volts peak-to-peak for a typical picture.

Luminance Channel

The luminance information passes through V112A, a cathode follower with sound trap, a video amplifier, V112B, another cathode follower, V105A, and another amplifier, V105B. At this point the frequency response is substantially the same as that of a monochrome receiver with some additional attenuation at the color subcarrier frequency. The output of V105B is fed to a delay line to insure time coincidence of all signals at the grids of the adders. The amount of luminance (and chrominance) signal to the green and blue adders is less than to the red adder in order to develop proportionately less kinescope drive for these colors. This is necessitated by unequal phosphor efficiencies in the tri-color kinescope.

Chrominance Channel

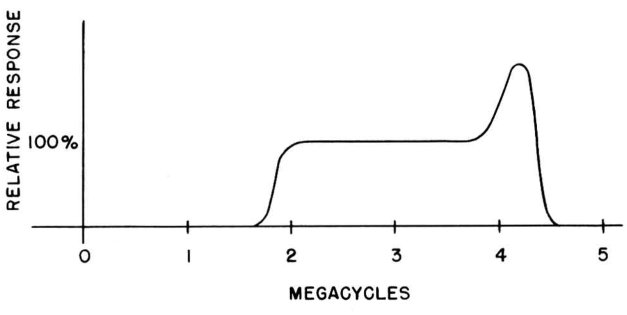
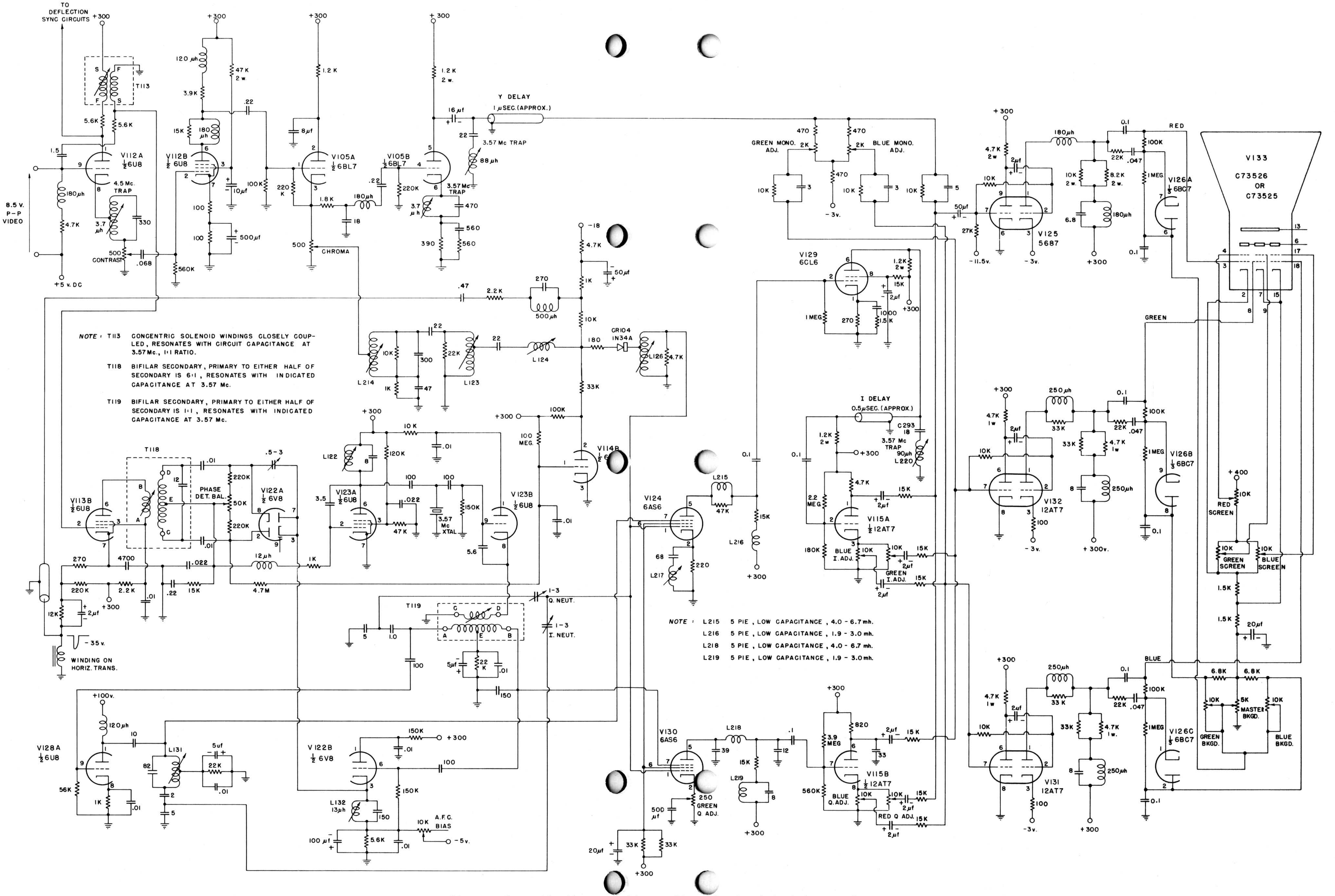


Fig. 4 - Band-pass filter response.

The color subcarrier and its sidebands are extracted from the composite signal by a band-pass filter following the chroma control in the cathode of V105. The upper-frequency end of this band-pass filter characteristic



NOTE : T113 CONCENTRIC SOLENOID WINDINGS CLOSELY COUPLED, RESONATES WITH CIRCUIT CAPACITANCE AT 3.57 Mc., 1:1 RATIO.

T118 BIFILAR SECONDARY, PRIMARY TO EITHER HALF OF SECONDARY IS 6:1, RESONATES WITH INDICATED CAPACITANCE AT 3.57 Mc.

T119 BIFILAR SECONDARY, PRIMARY TO EITHER HALF OF SECONDARY IS 1:1, RESONATES WITH INDICATED CAPACITANCE AT 3.57 Mc.

NOTE : L215 5 PIE, LOW CAPACITANCE, 4.0 - 6.7 mh.
L216 5 PIE, LOW CAPACITANCE, 1.9 - 3.0 mh.
L218 5 PIE, LOW CAPACITANCE, 4.0 - 6.7 mh.
L219 5 PIE, LOW CAPACITANCE, 1.9 - 3.0 mh.

Fig. 2 - Schematic diagram, video section of color television receiver.

exhibits a peak of about 6 db around 4.1 Mc. This is used in an attempt to compensate somewhat for the i-f attenuation characteristic and thus provide about 500 kc of double-side-band region for the chrominance signals. Fig. 4 shows the band-pass filter response.

The crystal diode CR104 in the band-pass filter serves two functions. Ordinarily it conducts and permits signals to pass to the demodulator grids. However it is keyed off during the horizontal flyback interval to prevent demodulation of the burst. In certain channels a demodulated burst exceeds the height of sync in the adder output and thus causes a color background unbalance due to the d-c restorer clamping on the wrong level. CR104 is also biased off by the color killer, V114B, if the latter tube grid is not held cut-off by the negative d.c. on the phase detector. This action insures no input to the demodulators in the absence of a burst i.e., with monochrome transmissions.

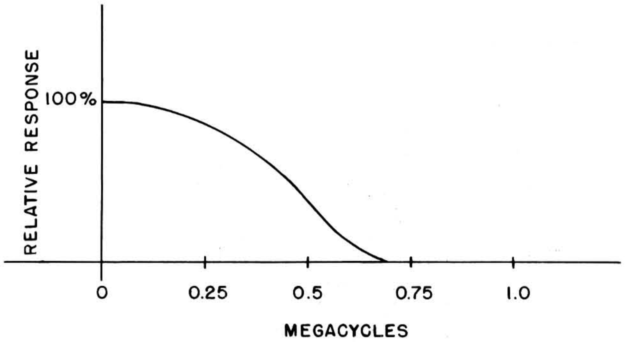


Fig. 5 - Q channel frequency response.

Each of the demodulators has a low-pass filter network in its plate circuit. The amplitude characteristics of the Q and I channels are shown in Figs. 5 and 6 respectively. In the case of the I channel, the response is due to the demodulator cathode circuit, its plate circuit and V129, the I amplifier cathode circuit. The rise in the I frequency response is necessitated by the fact that beyond about 500 kc, the I information is single side band. The additional amplifier, V129, in the I channel is required to feed the low impedance delay line whose delay is equal to the difference in delay between the I and Q low-pass filter circuits. Due to the broader bandwidth of the I channel, a color subcarrier trap, C293 and L220, is used.

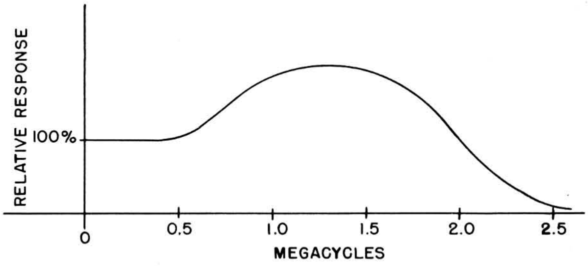


Fig. 6 - I channel frequency response.

Matrix

Since both positive and negative quantities of both I and Q are needed to make the three primary color difference signals, R-Y, B-Y and G-Y, two phase splitters, V115A and V115B, are used. Suitable amounts of plus or minus I and Q and Y (luminance) signal are added resistively in the grid circuits of the adder-output stages V125, V132 and V131. This combination yields the three simultaneous R, G and B signals required at the grids of the tri-color kinescope. DC restoration is performed on each of these signals by the three diodes V126A-B-C.

The background controls are arranged in a partial bridge arrangement so that as the master background control is turned, the proper relation between blue, green and red light output is maintained.

The type 5687 red adder-output tube is used to handle the large drive to the red gun.

Color Sync and Alignment

The two color demodulators each require about 25 volts peak-to-peak of 3.57-Mc c-w sinusoidal signal. The phase of this signal for the Q demodulator should be 147 degrees behind the color synchronizing burst or 33 degrees ahead of the negative burst. The phase for the I demodulator should be 90 degrees ahead of that for the Q. To derive these signals from the burst, an a-f-c circuit is used. 3.57-Mc signals from the second detector are amplified in V112A, the first video amplifier, and are developed across T113 in V112A's plate circuit. The secondary of T113 is connected to the gri of the gated burst amplifier V113B. This tube supplies one of the required signals to the balanced phase detector V122A. The other signal, smaller in amplitude than the burst, comes from the common cathode in V122. The phase detector d-c output is fed to a reactance tube, V123A, which is in shunt with the 3.57-Mc crystal in the oscillator, V123B. The oscillator output is developed across a single-tuned, center-tapped transformer T119. One end of T119 feeds the Q demodulator and a 3.57-Mc cathode follower, V122B. This low-impedance stage of isolation is used as the c-w comparison source for the phase detector. The other side of T119 feeds the I c-w amplifier, V128A. A series-parallel tuned circuit in V128A's plate provides the 90-degree shift required. Neutralization signals for both demodulators are used to cancel out that portion of the c-w signals which is capacitively coupled to the signal grids. The neutralization signal for Q is obtained at the end of T119 opposite the positive Q c-w phase point and that for I is obtained from the end of L131 opposite the positive I c-w phase point.

The first step in aligning the color receiver video and color sync circuits is to provide the correct phases of 3.57-Mc c-w signals to the demodulators. T119, the oscillator coil, is peaked for a d-c maximum (about -3.5v) at the center tap of its secondary. L132, the cathode coil of V122B, is peaked with the burst removed by shorting the grid of V113B to ground. About 10 volts d.c. should then obtain at either pin 2 or 8 of the phase detector, V122A. This voltage is measured with respect to the center tap of T118. The voltage between this center tap and ground should be adjusted with the a-f-c bias control for about 3.5 volts d.c. This constitutes the operating bias for the reactance tube, V123A. Both T113 and T118 are peaked for a d-c maximum at either pin 2 or 8 of the phase detector, V122A. From 40 to 60 volts should then be developed at these points. The neutralization capacitor across one of the diodes in V122A is adjusted for minimum c-w feedthrough as observed on either side of T118. With the oscillator out of lock and with burst present, the d-c balance control on the phase detector should be set for 3.5 volts d.c. between the arm of the balance potentiometer and ground. This, of course, means that the phase detector itself is balanced since the a-f-c bias has previously been set to 3.5 volts. Again with burst removed, the reactance tube output tuning coil, L122, should be adjusted for zero beat with the incoming color subcarrier. The presence of the burst should now lock the oscillator at the same frequency as the incoming color subcarrier. To obtain the correct oscillator phase, the Q information should first be removed at the transmitted signal source. T118 is then adjusted for zero output from the Q demodulator. The correct I c-w phase may be set by reinserting the Q information at the signal source and removing the I information. L131 is then adjusted for zero output from the I demodulator. This adjustment should also insure very nearly a maximum d.c. at the L131 tap. This completes the adjustment of the color sync circuits, which, if done correctly, will provide the correct Q and I signals at the demodulator outputs.

Kinescope and Video Adjustment

The final desired R, G and B signals are each obtained by combining appropriate amounts of Q, I and Y (luminance) signal. This combining is done in a compensated resistive matrix at the inputs of each of the adder tubes. These adder stages are, in effect, a part of the matrix network in that their input impedance is relatively low (about 1K).

A saturated color bar pattern is the most desirable pattern to use for set-up of the matrix and kinescope. The kinescope d-c potentials should be set up first. With the chroma and contrast controls at a minimum and the master brightness control at maximum, the red, green and blue screen controls are set for a low-brightness gray. The contrast control is now advanced to introduce normal highlights. These highlight portions of the picture should be adjusted for neutral hue by adjustment of the green and blue monochrome controls. By dropping the brightness level, a gray scale is maintained by adjusting the green and blue background controls. The red matrix is now adjusted for correct output. By advancing the master chroma control and the red +Q control, the desired red bar signal at the red output should be observed. Next the green-Q adjustment and green −I adjustment are set for the desired green bar signal at the green output. The blue +Q and −I controls are set to obtain the desired blue bar signal at the blue output.

With these adjustments completed, there should be three simultaneous signals at the three kinescope grids. The blue and green signals will be approximately equal in amplitude and about 50 per cent of the red signal. A red signal of about 100 volts peak-to-peak is desirable to drive the red gun in the tri-color kinescope when operating with approximately 200 volts on the red screen.

* * *

Appendix

Revised Specifications for Field Test of NTSC Compatible Color Television

Test Specifications - Group I

1. The image is scanned at uniform velocities from left to right and from top to bottom with 525 lines per frame and nominally 60 fields per second, interlaced 2-to-1.

2. The aspect ratio of the image is 4 units horizontally and 3 units vertically.

3. The blanking level is fixed at 75 per cent (±2.5 per cent) of the peak amplitude of the carrier envelope. The maximum white (luminance) level is not more than 15 per cent nor less than 10 per cent of the peak carrier amplitude.

4. The horizontal and vertical synchronizing pulses are those specified in Section 3.682 of Subpart E of Part 3 of the FCC Rules Governing Radio Broadcast Services (as amended April 11, 1952; effective June 2, 1952), modified to provide the color synchronizing signal described in Specification 21 (Group *II* of these specifications).

5. An increase in initial light intensity corresponds to a decrease in the amplitude of the carrier envelope (negative modulation).

6. The television channel occupies a total width of 6 Mc. Vestigial-sideband amplitude-modulation transmission is used for the picture signal in accordance with the FCC Rules cited in Specification 4, above.

7. The sound transmission is by frequency modulation, with maximum deviation ±25 kilocycles, and with pre-emphasis in accordance with a 75-microsecond time constant. The frequency of the unmodulated sound carrier is 4.5 Mc ±1000 cycles above the frequency of the main picture carrier actually in use at the transmitter.

8. The radiated signals are horizontally polarized.

9. The power of the aural-signal transmitter is not less than 50 per cent nor more than 70 per cent of the peak power of the visual-signal transmitter.

Test Specifications - Group II

10. The color picture signal has the following composition:

$$E_m = E_Y' + \{E_Q' \sin(\omega t + 33^\circ) + E_I' \cos(\omega t + 33^\circ)\}$$

where

$$E_Q' = 0.41\,(E_B' - E_Y') + 0.48\,(E_R' - E_Y')$$

$$E_I' = -0.27\,(E_B' - E_Y') + 0.74\,(E_R' - E_Y')$$

$$E_Y' = 0.30\,E_R' + 0.59\,E_G' + 0.11\,E_B'$$

The phase of the color burst is sin (ωt + 180°).

Notes: For color-difference frequencies below 500 kc, the signal can be represented by

$$E_m = E_Y' + \{\frac{1}{1.14}\,[\frac{1}{1.78}\,(E_B' - E_Y') \sin \omega t + (E_R' - E_Y') \cos \omega t]\}$$

In these expressions the symbols have the following significance:

E_m is the total video voltage, corresponding to the scanning of a particular picture element, applied to the modulator of the picture transmitter.

E_Y' is the gamma-corrected voltage of the monochrome (black-and-white) portion of the color picture signal, corresponding to the given picture element.

E_R', E_G', and E_B' are the gamma-corrected voltages corresponding to the red, green, and blue signals intended for the color picture tube, during the scanning of the given picture element.

E_Q' and E_I' are the two gamma-corrected orthogonal components of the chrominance signal corresponding respectively to the narrow-band and wide-band axes.

ω is 2π times the frequency of the chrominance subcarrier. The phase reference of this frequency is the color synchronizing signal (See Specification 21 below) which corresponds to amplitude modulation of a continuous sine wave of the form $\sin(\omega t+180^\circ)$ where t is the time.

The portion of each expression between brackets represents the chrominance subcarrier signal which carries the chrominance information.

It is recommended that field-test receivers incorporate a reserve of 10 db gain in the chrominance channel over the gain required by the above expressions.

11. The primary colors referred to by E_R', E_G', and E_B' have the following chromaticities in the CIE system of specification:

	x	y
Red (R)	0.67	0.33
Green (G)	0.21	0.71
Blue (B)	0.14	0.08

12. The color signal is so proportioned that when the chrominance subcarrier vanishes, the chromaticity reproduced corresponds to Illuminant C ($x = 0.310$, $y = 0.316$).

13. Gamma correction is such that the desired pictorial result shall be obtained on a display device having a transfer gradient (gamma exponent) of 2.75. The equipment used shall be capable of an overall transfer gradient of unity with a display device having a transfer gradient of 2.75. The voltages E_Y', E_R', E_G', E_B', E_Q', and E_I' in the expression of Specification 10, above, refer to the gamma-corrected signals.

14. The color subcarrier frequency is 3.579545 Mc ± 0.0003 per cent with a maximum rate of change not to exceed 1/10 cycle per second per second.

15. The horizontal scanning frequency is 2/455 times the color subcarrier frequency. This corresponds nominally to 15,750 cycles per second (the actual value is 15,734.264 ± 0.047 cycles per second).

16. The bandwidth assigned to the monochrome signal E_Y' is in accordance with the FCC standard for black-and-white transmissions, as noted in Specification 6 above.

17. The bandwidth assigned prior to modulation to the color-difference signals E_Q' and E_I' is given by Table I.

Table I

Q-channel bandwidth

at 400 kc less than 2 db down

at 500 kc less than 6 db down

at 600 kc at least 6 db down

I-channel bandwidth

at 1.3 Mc less than 2 db down

at 3.6 Mc at least 20 db down

18. E_Y', E_R', E_G', E_B', E_Q', and E_I' are all matched to each other in time to within ±0.05 microseconds. This is a tentative tolerance to be established definitely later.

19. The overall transmission bandwidth assigned to the modulated chrominance subcarrier shall extend to at least 1.5 Mc below the chrominance subcarrier frequency and to at least 0.6 Mc above the chrominance subcarrier frequency, at an attenuation of 2 db.

20. A sinewave, introduced at those terminals of the transmitter which are normally fed the color picture signal, shall produce a radiated signal having an envelope time delay, relative to 0.1 Mc, of zero microseconds up to a frequency of 2.5 Mc; and then linearly decreasing to 4.3 Mc so as to be equal to −0.26 microseconds at 3.579545 Mc. The tolerance on

all these delays shall be ±0.05 microseconds relative to the delay at 0.1 Mc.

21. The color synchronizing signal is that specified in Fig. 1.

22. The field strength measured at any frequency beyond the limits of the assigned channel shall be at least 60 db below the peak carrier level.

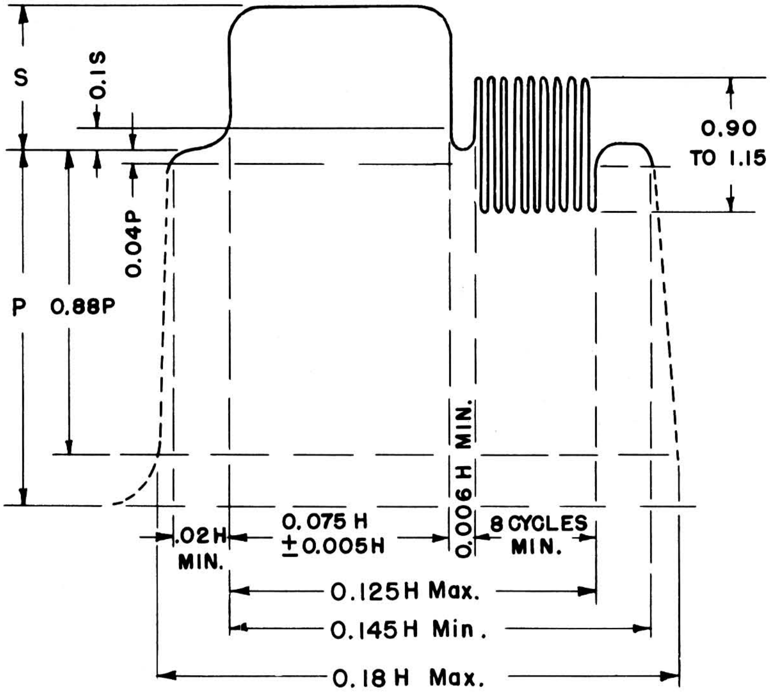


Fig. I of revised specifications for field test of NTSC compatible color television.

NOTES

1. The radiated signal envelope shall correspond to the modulating signal of the above figure, as modified by the transmission characteristics of specification number 6.
2. The burst frequency shall be the frequency specified for the chrominance subcarrier. The tolerance on the frequency shall be ±0.0003% with a maximum rate of change of frequency not to exceed 1/10 cycle per second per second.
3. The horizontal scanning frequency shall be $\frac{2}{455}$ times the burst frequency.
4. Burst follows each horizontal pulse, but is omitted following the equalizing pulses and during the broad vertical pulses.
5. Vertical blanking 0.07 to 0.08v.
6. The dimensions specified for the burst determine the times of starting and stopping the burst, but not its phase.
7. Dimension "P" represents the peak-to-peak excursion of the luminance signal, but does not include the chrominance signal.