A BRIGHTNESS ENHANCED COLOR RECEIVER EMPLOYING
AUTOMATIC DECODING IN THE CHROMATRON

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Summary

This paper describes a prototype color receiver utilizing a unique method of decoding the NTSC transmitted color television signal.

The new decoding method, termed "quadramatic", takes advantage of the inherent capability of the CHROMATRON[1], or Lawrence single-gun color tube, to produce a color picture of high brightness. Basically a gate-off pulse is used with quadramatic decoding instead of using a gate-on pulse, with attendant space-charge blow-up, as in former self decoding methods. Highlight brightness of 40-60 foot-lamberts with good resolution has been obtained with a 22" rectangular CHROMATRON tube.

CHROMATRON Operation

The single electron gun tricolor CHROMATRON employs sets of colored phosphor strips for the light emitting screen, (Fig. 1). A color selector grid of alternately connected wires is arranged parallel to the phosphor strips.

A potential difference of proper magnitude applied to the color selector grid will deflect the electron beam to the phosphor strip aligned with the positive grid wire. As shown in Fig. 2a, the potential difference between adjacent wires is zero and the blue center phosphor is selected. In Fig. 2b, the set of wires electron optically aligned with the red strip is made positive and the red phosphor is selected. Similarly the green strip is selected when the set of wires over the green strips is made positive. Color selection is independent of scanning pattern, orientation, position of the beam, or video modulation.

Post deflection focusing, PDF, is utilized to obtain an electron beam spot size smaller than a phosphor strip width. This provides ample tube assembly tolerance. PDF is obtained by applying a post deflection acceleration voltage to the phosphor screen relative to the switching grids; in this case 18 KV, (Fig. 2).

NTSC Color Signal

The NTSC color signal consists of a high-resolution luminance component for black-and-white compatibility and a limited resolution two-phase quadrature-modulated chrominance component, (Fig. 3).

For color signal components with frequencies of less than 0.5 mc, the I and Q components are both present and the signal in terms of the color difference components is:

$$E_m = E_Y + 1/1.14 \left[(E_R - E_Y) \operatorname{Cos} \omega t + 1/1.78 (E_B - E_Y) \operatorname{Sin} \omega t\right]$$

The chrominance difference signals $(E_R - E_Y)$ and $(E_B - E_Y)$ are reduced in amplitude to 87.7 percent and 49.3 percent, respectively, to prevent excessive over-modulation of the transmitter. The luminance signal is not reduced in amplitude, otherwise compatibility would be affected.

Quadramatic Decoding

The one-gun CHROMATRON has a color-selector-grid interelectrode capacitance of about 3000 uuf. While square-wave switching can be used for low-frequency color-switching applications, an external inductance resonated with the grid capacity is used to provide the 3.58 mc sine-wave switching employed in quadramatic decoding. The effective Q of the resonant switching circuit is high so that a power saving of about 100 is effected by using real power rather than reactive power.

The sine-wave switching causes the beam to oscillate back and forth over the red, blue, and green phosphor strips as raster scanning action takes place. When this frequency is chosen equal to the NTSC subcarrier frequency, a low-visibility interlaced dot pattern results.

The highlight brightness of the one-gun CHROMATRON can be increased substantially by increasing the gating duty factor of the electron beam to unity. The quadramatic decoding technique approaches this criterion more closely than other decoding techniques previously utilized. The NTSC signal phase sequence, (ref. Fig. 3) is red, blue, green; and repeats at a 3.58 mc rate. Decoding of the NTSC signal in the one-gun CHROMATRON is accomplished by choosing 3.58 mc as the color switching frequency and applying the NTSC video signal to the beam intensity control grid. The R-Y and B-Y vectors are separated in phase by 90°, and G-Y and B-Y vectors are separated by about 124°. If the color difference vectors are superimposed on a diagram showing the phosphor strip sequence for a CHROMATRON with blue as the double resolution color, it is observed that the NTSC color signal difference vectors and a double blue CHROMATRON phosphor strip sequence match very closely, (ref. Fig. 4).

It will be noticed from Fig. 4 that any yellow video information present in the transmitted scene occurs at the time the electron beam is crossing the blue-emitting phosphor strip for the second time; therefore, the electron beam is gated "off" for approximately 36° during the second blue crossing to eliminate the unwanted blue during a yellow hue presentation. This gate off pulse is known as the "anti-blue" or "knock-out" pulse and compared to other decoding techniques permits approximately 90% (i.e., 100 - [36/360 x 100%]) utilization of the electron beam.

Former decoding methods utilized a "gate-on" pulse to turn the electron beam on when the proper phosphor strip was being crossed. The low duty cycle imposed by color purity considerations required a high peak-to-average ratio of current pulses during the "gate-on" time for a bright display. The resultant space charge dilation of the beam imposed a limit on the resolution capabilities in highlight areas.

Using quadramatic decoding, a highlight brightness of 40-60 foot-lamberts is easily obtained from a rectangular 22-inch CHROMATRON with a 25 KV viewing screen potential.

This method of enhancing brightness by using an increased duty cycle may be compared with a decoding method employing chroma modulated third harmonic gating which was presented at the 1957 National IRE Convention[2].

Prototype Receiver

The circuit of a quadramatic decoding receiver is basically simple and requires fewer tubes than commercially available color receivers.

A developmental quadramatic decoding receiver using 25 tubes was built and demonstrated. A block diagram of this receiver is shown in Fig. 5. It is similar to earlier one-gun CHROMATRON receivers described in the literature[3] with the exception of the decoding method.

Figure 6, the anti-blue, or knockout pulser consists of a high perveance tube in a peaking amplifier circuit. Driving voltage for the pulser is derived from the color selection amplifier. Pulse phasing is adjusted in the pulse generator grid circuit. A diode clips the output pulse backswing. Pulse amplitude at the CHROMATRON cathode is 120 V; pulse width is 70 millimicroseconds. The peaked output pulse contains harmonic frequencies of the 3.58 mc subcarrier, therefore the anti-blue pulser is carefully shielded and all power supply lines to the anti-blue chassis are filtered. The 120 V amplitude pulse is sufficient to gate off the CHROMATRON electron beam for all contrast levels.

The higher brightness in quadramatic decoding displays increases viewing screen current requirements. Shunt regulation of both color selector grid and viewing screen potential is used in the quadramatic high voltage power supply. A corona discharge regulator tube has been used with marked success to stabilize the 25 kilovolt viewing screen potential.

Hue stabilization during warmup is achieved by referencing the subcarrier regenerator from the color selection grid signal rather than the crystal oscillator.

Some errors in chromaticity and brightness exist in quadramatic decoding, as they do in other forms of direct decoding. However, certain normalization functions can be performed upon the NTSC color signal to readjust the color difference coefficients to unity. Complete normalization results if the ratio of chrominance to luminance is set to 1.14 and if the B-Y axis is multiplied by 1.78, (Fig. 3).

The chrominance to luminance ratio can be normalized by increasing "chromaboost". Chromaboost is a coined term applied to amplitude control of the 3.58 mc chrominance video relative to luminance video.

A satisfactory method of accomplishing color hue normalization is to apply a second harmonic of subcarrier frequency to a control grid of the first video amplifier stage. The second harmonic modulating frequency amplitude is chosen so that gain of the first video amplifier stage varies by a factor of 2 in the linear operating range of the tube. A polar representation of amplifier gain shows the locus of the gain vector to be an ellipse; hence, the term elliptical-gain amplifier.

Subjective evaluation of quadramatic decoding displays reveals that rigorous NTSC signal normalizing is not required if phosphor luminous efficiencies and strip widths are properly chosen. In effect, normalization of the viewed color picture is accomplished mechanically within the CHROMATRON. For this case only the conventional color saturation or chromaboost circuit is necessary.

The subject of colorimetric errors resulting from direct application of the NTSC signal to the intensity control grid of a one-gun continuous color sequence display has appeared in the literature.[2,4] These prior graphic presentations utilizing the CIE diagram indicate satisfactory reproduction of critical colors.

Another method of qualitatively treating the subject of reproduced color error is by analysis of beam current distribution on the phosphor area. Beam current on each phosphor strip is plotted for a given transmitted color. For a perfectly accurate reproducing system the total beam current should excite the desired phosphor strip. Fig. 7

indicates the magnitude of color contamination present in red due to excitation of the undesired phosphor strips. (See appendix.) The green phosphor is not excited at all while the blue phosphor excitation comprises less than 2% of the total illumination. Blue has the most contamination of the pure primary colors (Fig. 8). Of the total beam current, 30% flows to the green phosphor strip and 6% flows to the red phosphor strip. However, the blue phosphor used has three times the luminous efficiency of the red or green phosphor. Thus, the effective green contamination is 16% and the red 3% when reproducing blue without hue normalization. Figures 9 and 10 show the beam current waveforms for green and yellow. Figure 11 is the rear view and Figure 12 is the side view of a prototype quadramatic color receiver.

In conclusion, the quadramatic decoding technique offers a high brightness color display with a minimum of circuit complexity and alignment adjustments.

Acknowledgment

The principle of quadramatic decoding is a contribution of Professor E. O. Lawrence. A large portion of the material in this paper has been derived from a Litton Electronic Display Laboratory* internal report (EDL 103) prepared by R. Door, J. M. Rosenberg and the author. Credit is due all members of the Litton Electronic Display Laboratory staff, especially G. Morrison and R. Wong for their work on the prototype receivers.

References

1. R. Dressler, "The PDF Chromatron - A Single or Multi-Gun Tri-Color Cathode-Ray Tube", Proc. IRE, Vol. 41, P 851, July 1953.

2. R. Dressler and P. Neuwirth, "Brightness Enhancement Techniques for the Single-Gun Chromatron", IRE National Convention Record, Vol. 5, Part 3, P 220, 1957.

3. J. D. Gow and R. Dorr, "Compatible Color Picture Presentation With the Single-Gun Tri-Color Chromatron", Proc. IRE, Vol. 42, P 308, January 1954.

4. B. D. Loughlin, "Processing of the NTSC Color Signal for One-Gun Sequential Color Displays", Proc. IRE, Vol. 42, P 299, January 1954.

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Appendix

Calculations of beam current waveforms. (Figures 7, 8, 9, 10)

Given:

$$E_m = E_Y + .493\,(E_B - E_Y)\,\text{Sin}\,wt + .877\,(E_R - E_Y)\,\text{Cos}\,wt \qquad (1)$$

$$E_Y = .30\,E_R + .59\,E_G + .11\,E_B \qquad (2)$$

Where E_R, E_G, and E_B are signals derived from the red, green, and blue signal outputs of the camera.

Assumed Conditions:

a. All the beam current is concentrated in an infinitely small spot.

b. Chrominance to luminance ratio set to 1.37.

c. System up to the picture tube is linear.

d. Transfer function of the picture tube is proportional to the 2.2 power.

e. CHROMATRON phosphors balanced for equal energy white with sine-wave color switching.

f. The effect of hue normalization techniques is not included.

Sample Calculation for a Transmitted Saturated Red at an Angle of 13.4°.

a. Let $E_R = 1$; $E_G = 0$; $E_B = 0$

b. Then substituting these values in equation (2) $E_y = .30$.

c. Multiplying chrominance by 1.37 and substituting 13.4° for wt:

$$E_m = .30 + .493 \times 1.37\,|-.3|\,\text{Sin}\,13.4^\circ + .877 \times 1.37\,|.7|\,\text{Cos}\,13.4^\circ$$

$$E_m = 1.163$$

d. Transfer function of the picture tube is assumed to be 2.2,

$$I = kE_g^{\;2.2} \;;\; I = k\,(1.163)^{2.2}$$

$$I = k\,1.394$$

The calculations are similar for any other desired color.

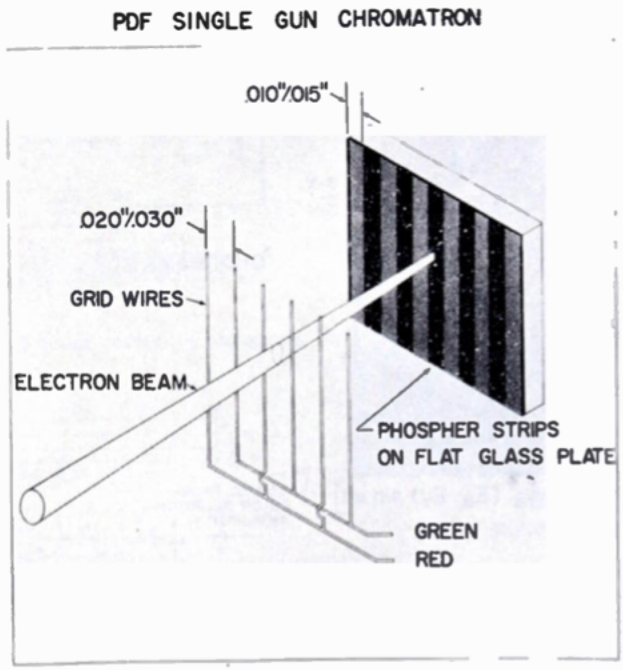


Fig. 1

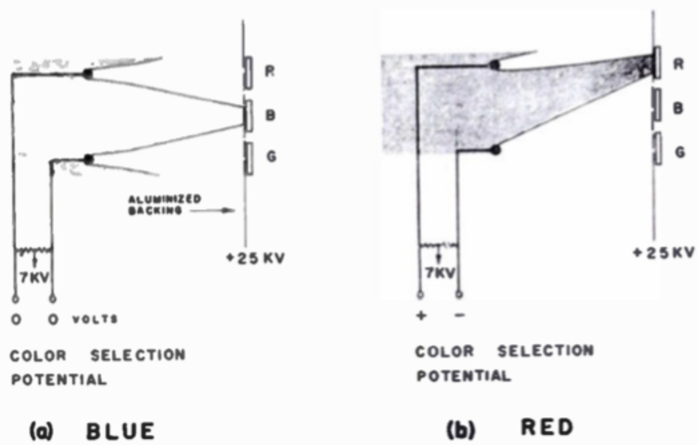
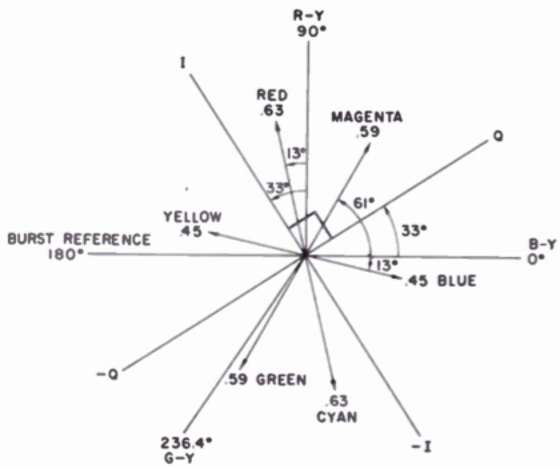


Fig. 2. Color selection in the single-gun CHROMATRON.



$$E_M = E_Y + \frac{1}{1.14}\left[(E_R - E_Y)\cos \omega t + \frac{1}{1.78}(E_B - E_Y)\sin \omega t\right]$$

Fig. 3. Polar diagram showing various phase relationships of the NTSC signal color components.

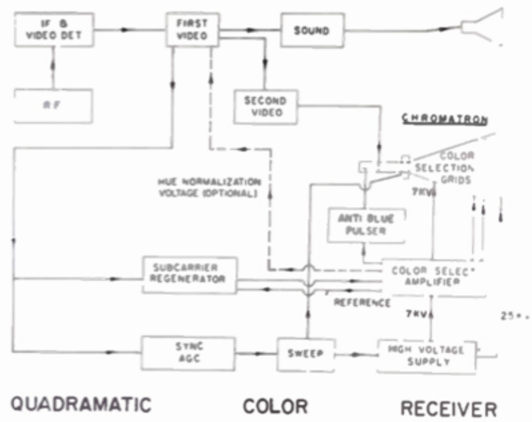


Fig. 5

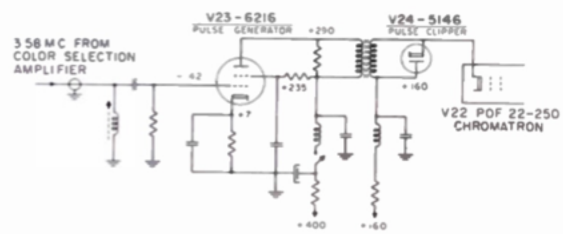


Fig. 6. Schematic anti-blue pulser.

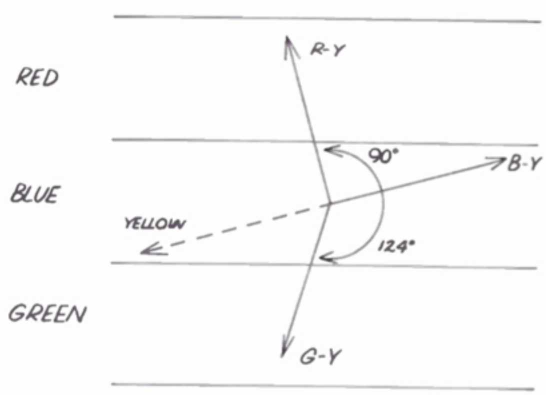


Fig. 4. NTSC color difference vectors superimposed on a double-blue sequence CHROMATRON.

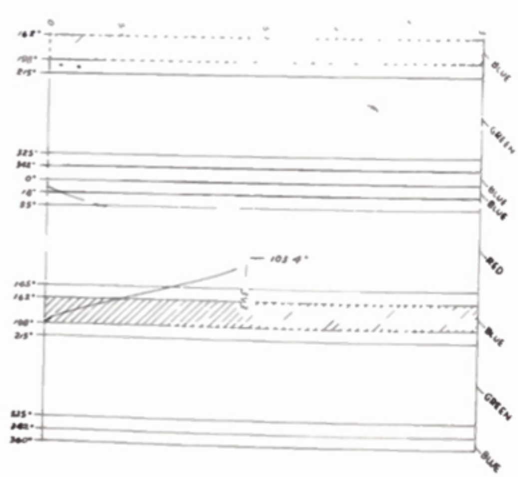


Fig. 7. Quadramatic decoding beam current waveforms.

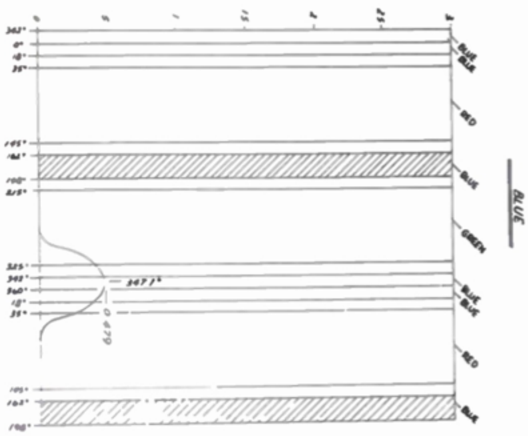


Fig. 8. Quadramatic decoding beam current waveforms.

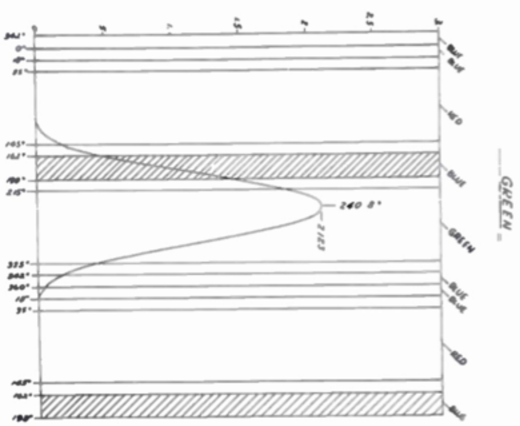


Fig. 9. Quadramatic decoding beam current waveforms.

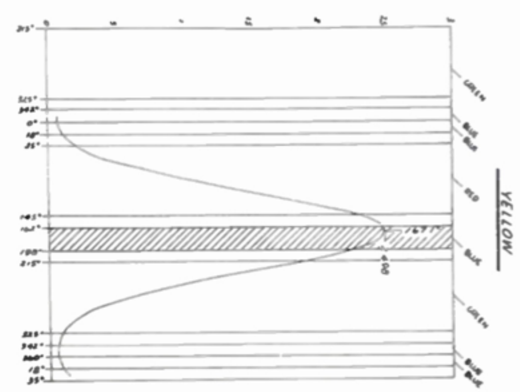


Fig. 10. Quadramatic decoding beam current waveforms.

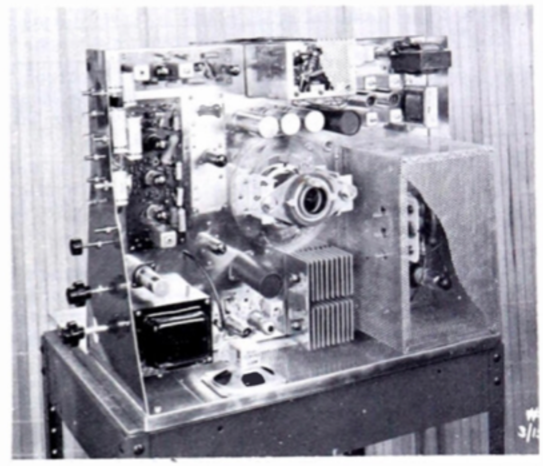


Fig. 11. Rear view quadramatic color receiver.

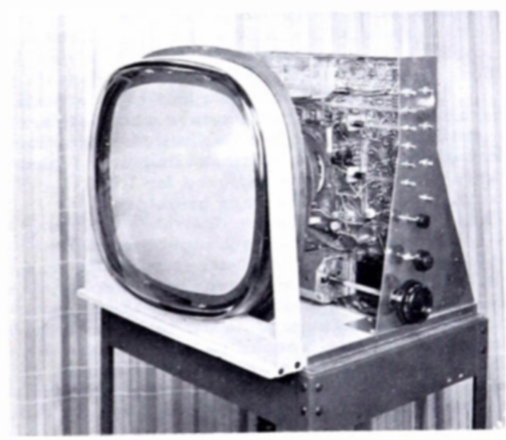


Fig. 12. Side view quadramatic color receiver.

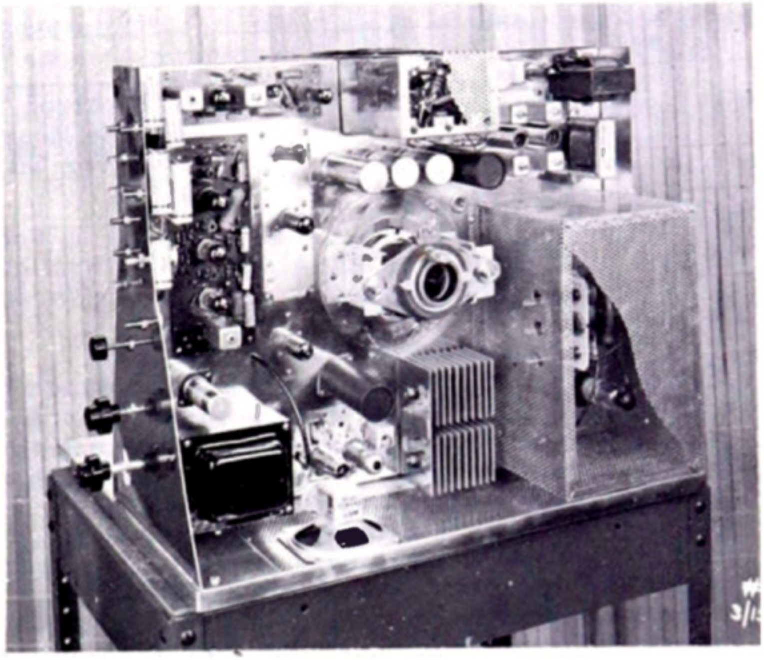


Fig. 11. Rear view quadramatic color receiver.

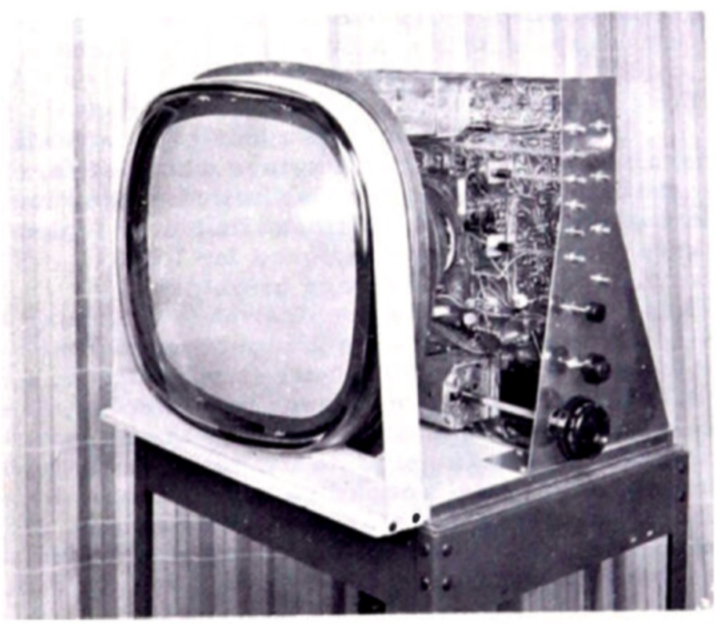


Fig. 12. Side view quadramatic color receiver.