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FUNDAMENTALS OF COLOR TELEVISION

Part VI The orange-cyan axis. Phase spectrum analysis using I and Q color difference signals.

by P. G. Buttacavoli

In the previous article it was shown that all colors scanned above 500 kc, fall on the straight line axis of $E_R - E_Y$. Recovery of the original color, therefore, is limited since the $E_R - E_Y$ axis extends from a greenish-cyan to a reddish-magenta and all colors, regardless of their original color, will be reproduced at the receiver somewhere between these two colors.

The basic philosophy involving two color reproduction in small areas has been proven experimentally by some of the world's leading color experts. They have found that any color in a small enough area can be matched subjectively at normal viewing distance by mixing only two and not three colors.

What remained then for the NTSC to decide was whether the two colors found on the $E_R - E_Y$ axis provided optimum color reproduction in the smaller areas. Experimentation conducted over the years in two color reproduction has pinpointed the preferred colors in a two color system to be orange and cyan. The Cinecolor process for motion pictures uses the orange-cyan two color system.

Orange-Cyan Axis

The NTSC also chose the preferred orange-cyan axis for color television above 500 kc. With this preferred axis the greatest improvement is seen in the region of small area flesh tones. This is important because the color of flesh is universally recognized, and unnatural flesh tones can readily be detected.

The preferred orange-cyan axis has been called the I axis. This axis represents a color difference signal replacing $E_R - E_Y$. The orange-cyan axis is located 33° away from $E_R - E_Y$. This is shown in figure 1. Figure 2 is a phase spectrum of a typical color bar pattern utilizing the $(E_R - E_Y)$ and $(E_B - E_Y)$ axes.

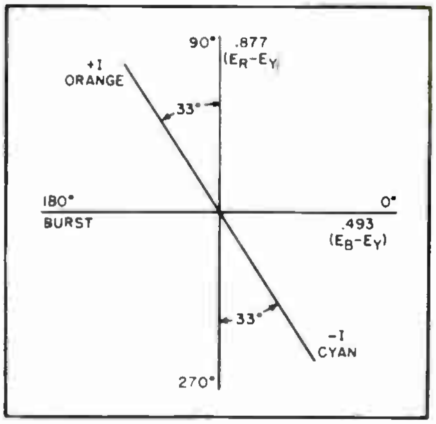

Figure 1. The preferred orange-cyan axis, designated I, is located 33° away from the $E_R - E_Y$ axis.

It must be noted that the preferred I axis has been chosen for best color reproduction *only above* 500 *kc.* The obvious question here is, what becomes of the phase spectrum for colors below 500 kc where the use of the $E_R - E_Y$ and $E_B - E_Y$ axes proved adequate for proper three color reproduction?

The answer is that *nothing* happens to the phase spectrum below 500 kc other than a phase translation of the $E_R - E_Y$ and $E_B - E_Y$ axes to the desired E_I and E_Q axes.

Reference to figure 3A shows the relative amplitude and phase of a resultant chrominance signal below 500 kc after adding the two color difference signals $(E_B - E_Y)$ and $(E_R - E_Y)$. Figure 3B shows the resultant chroma signal resulting from the addition of I and $(E_B - E_Y)$. It becomes apparent that the error in the use of I in this vector addition has changed both the amplitude and phase from the original desired resultant.

We repeat, *nothing* must happen to the original resultant obtained for frequencies below 500 kc. The solution was achieved by establishing another axis for $E_R - E_Y$ displaced 33° from $E_B - E_Y$ and it was identified as the Q axis. This Q axis is exactly 90° out of phase (in quadrature) with I, and is the second color difference signal replacing $E_B - E_Y$. By judicious selection of the individual lengths of I and Q we can recover any color below 500 kc in the *original* amplitude and phase achieved with $E_R - E_Y$ and $E_B - E_Y$. This is basically demonstrated in figure 4.

Phase Spectrum Analysis Using I and Q Signals

Let us prove that our system analysis still holds for color reproduction below 500 kc. We will develop a phase spectrum using I and Q, which should produce the same resultant chroma signals shown in figure 2 using $E_R - E_Y$ and $E_B - E_Y$. Figure 2 represents a detailed phase spectrum showing the individual lengths for $E_R - E_Y$ and $E_B - E_Y$ and the resultant amplitude for each of the saturated colors indicated.

In order to accomplish the foregoing, the lengths of I and Q must be properly proportioned. This was done by assigning the formulas shown in

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figure 5 for both the transmitter and receiver. You will note that both E_I and E_Q could be determined also by using the alternate formulas including $(E_B - E_Y)$ and $(E_R - E_Y)$ in the proportions shown in figure 5A.

At first glance, the formulas may appear as an imposing array of complicated mathematics but working through a few examples will convince you it is simple arithmetic.

Example I — When scanning a saturated red the camera outputs will be:

$E_R = 1$ volt; $E_G = 0$ volts;
$E_B = 0$ volts.

Substituting in the transmitter formulas shown in figure 5A we find:

$$\begin{aligned} E_I &= .60E_R - .28E_G - .32E_B \\ &= .60\ (1) - .28\ (0) - .32\ (0) \\ &= .6 \text{ volts} \end{aligned}$$

$$\begin{aligned} E_Q &= .21E_R - .52E_G + .31E_B \\ &= .21\ (1) - .52\ (0) + .31\ (0) \\ &= .21 \text{ volts} \end{aligned}$$

The resultant chrominance signal is equal to the square root of the sum of the squares, or:

$$\begin{aligned} \text{Resultant} &= \sqrt{(E_I)^2 + (E_Q)^2} \\ &= \sqrt{(.6)^2 + (.21)^2} \\ &= .63 \text{ volts} \end{aligned}$$

The vector analysis is shown in figure 6. As seen, the resultant chrominance signal for red possesses the same amplitude and phase as that shown for red in figure 2 using $E_B - E_Y$ and $E_R - E_Y$.

Example II — When scanning a saturated blue, the camera outputs will be: $E_R=0$ volts; $E_G=0$ volts; $E_B=1$ volt. Substituting in the transmitter formulas shown in figure 5A we find:

$$\begin{aligned} E_I &= .60E_R - .28E_G - .32E_B \\ &= .60\ (0) - .28\ (0) - .32\ (1) \\ &= -.32 \text{ volts} \end{aligned}$$

$$\begin{aligned} E_Q &= .21E_R - .52E_G + .31E_B \\ &= .21\ (0) - .52\ (0) + .31\ (1) \\ &= .31 \text{ volts} \end{aligned}$$

Again results shown in figure 7 are similar to the phase and amplitude of the signal produced in the phase spectrum of figure 2.

Upon making a similar analysis for the remaining primary and complementary colors we obtain the phase spectrum shown in figure 8. As seen, it is identical with respect to phase and amplitude relationships to the phase spectrum shown in figure 2. It will be noted also that —I (303°) is approximately 20° removed from the vector designation for the color cyan. This appears to change the identification of the I axis as orange-cyan, however cyan occupies a large area in the chromaticity diagram and consequently the —I axis is located in the cyan region.

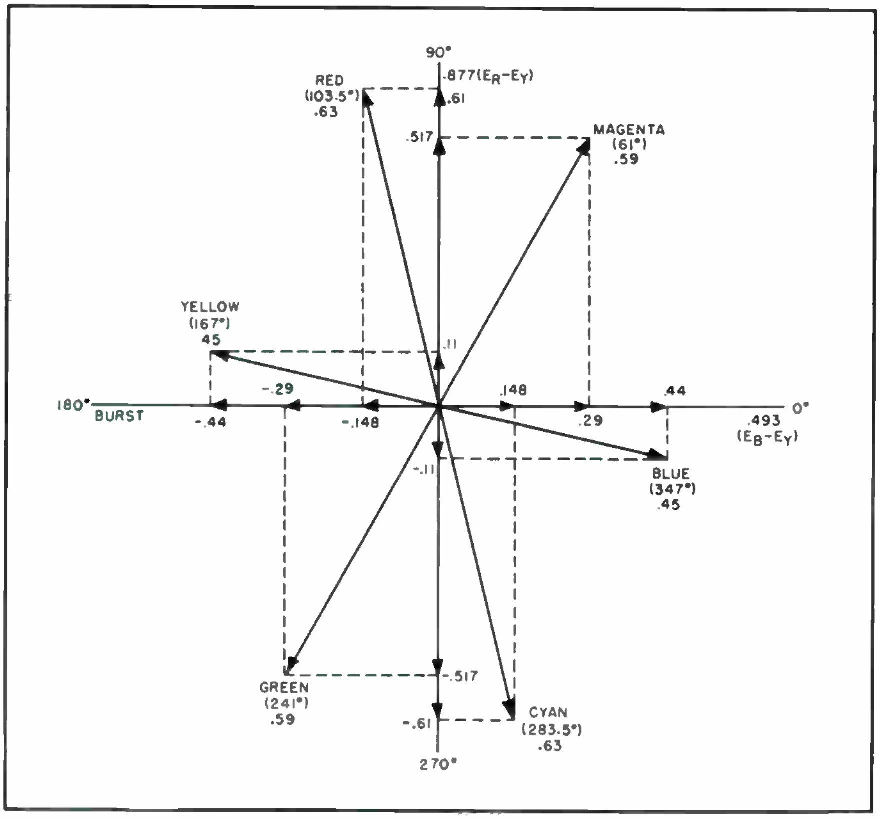


Figure 2. Detailed phase spectrum of a typical color bar pattern (under 500KC) using the $E_R - E_Y$ and $E_B - E_Y$ axes. All angles are referred to 0°.

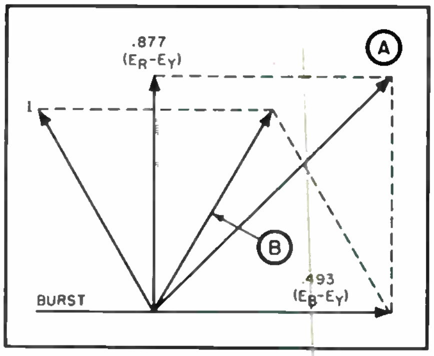


Figure 3. A—Chrominance signal obtained from the addition of $E_R - E_Y$ and $E_B - E_Y$. B — Erroneous chrominance signal obtained by adding E_I with $E_B - E_Y$.

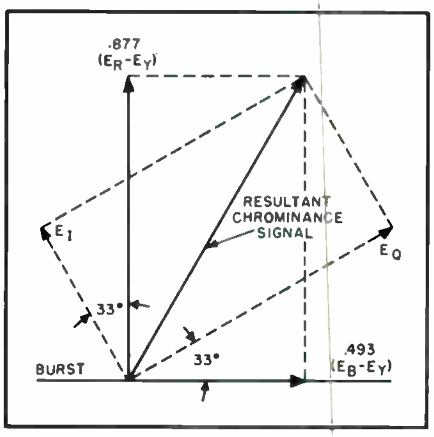


Figure 4. The same resultant chrominance signal is obtained from the addition of E_I and E_Q as is obtained from the addition of $E_R - E_Y$ and $E_B - E_Y$.

Color Reproduction Below 500 KC Using I and Q Signals

There should be no doubt that colors transmitted below 500 kc have not been changed by the use of I and Q.

Briefly, let us investigate the reproduction of colors under these transmission conditions. As shown in figure 5B the detected E_I and E_Q signals plus the brightness signal, E_Y, are fed into the receiver matrix (adder) where the proportions for recovery of the individual primary colors are fixed by the formulas shown.

When scanning a saturated red, at the transmitter the values are:

$$E_I = .6 \text{ volts}$$
$$E_Q = .21 \text{ volts}$$
$$\begin{aligned} E_Y &= .59\ E_G + .30\ E_R + .11\ E_B \\ &= .59\ (0) + .30\ (1) + .11\ (0) \\ &= .3 \text{ volts} \end{aligned}$$

Substituting in the receiver formulas shown in figure 5B we find:

$$\begin{aligned} E_R &= .63E_Q + 1.00E_Y + .96\ E_I \\ &= .63(.21) + 1(.3) + .96(.6) \\ &= .13 + .3 + .57 \\ &= 1 \text{ volt} \end{aligned}$$

$$\begin{aligned} E_G &= -.64E_Q + 1.00E_Y - .28E_I \\ &= -.64(.21) + 1(.3) - .28(.6) \\ &= -.13 + .3 - .17 \\ &= 0 \text{ volts} \end{aligned}$$

$$\begin{aligned} E_B &= 1.72E_Q + 1.00E_Y - 1.11E_I \\ &= 1.72(.21) + 1(.3) - 1.11(.6) \\ &= .36 + .3 - .66 \\ &= 0 \text{ volts} \end{aligned}$$

As shown, the receiver recovers only the color transmitted, i.e., only red is reproduced since the other primary colors produce zero drive to the CRT.

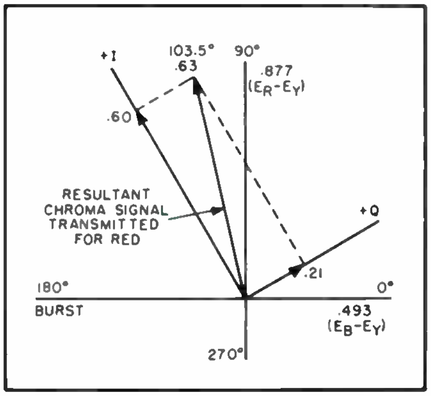


Figure 6. The resultant chroma signal for red is obtained by the addition of $.6E_I$ and $.21E_Q$.

By a similar analysis, the remaining primary and complementary colors are recovered in the receiver. The reader should attempt this analysis using the formulas shown in figure 5, and the techniques set forth in this article. It must be remembered that with proper recovery of the individual colors, the values for E_R, E_G, and E_B will be identical to the camera values for E_R, E_G and E_B as shown in Table I of the previous issue.

Summary

Color reproduction above 500 kc becomes a two color process. In order to realize the best two color reproduction, the orange-cyan axis has been chosen. This new axis designated I, is located 33° away from $E_R - E_Y$. In order to retain color reproduction below 500 kc another axis, called Q (quadrature) was fixed exactly 90° out of phase with I (and 33° away from $E_B - E_Y$). *E_I and E_Q are the actual transmitted color difference signals standardized by the FCC.* Transmission and reproduction of colors below 500 kc using E_I and E_Q are identical to the system analysis using $E_B - E_Y$ and $E_R - E_Y$. The only basic differences are the specific proportions required for E_I and E_Q (because of the 33° phase shift) resulting in the formulas appearing in figure 5. The modulation and demodulation processes described earlier in conjunction with $(E_B - E_Y)$ and $(E_R - E_Y)$ still hold for E_I and E_Q. Simply substitute E_I for $(E_R - E_Y)$ and E_Q for $(E_B - E_Y)$.

An interesting point to note here is that although I and Q are transmitted, the alternate formulas of figure 5A show that they can be expressed as specific proportions of $E_R - E_Y$ and $E_B - E_Y$. Consequently, the receiver may detect along the $E_B - E_Y$ and $E_R - E_Y$ axes. In so doing the bandwidth from both detectors in the receiver must be limited to approximately 500 kc because some I (wideband) information would be contained in both $E_R - E_Y$ and $E_B - E_Y$ outputs resulting in crosstalk.

The relative position of I and Q as compared to B-Y and R-Y is shown in the chromaticity diagram of figure 9.

Transmitter Analysis Using I and Q Signals

Let us review a transmitter block diagram using information we have assimilated to date. Referring to figure

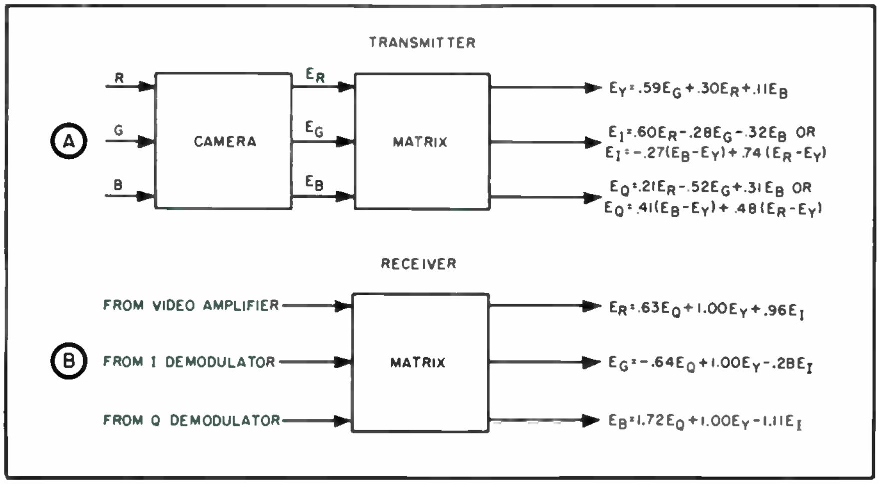


Figure 5. A — Transmitter formulas deriving the values for the brightness signal E_Y, and the color difference signals E_I and E_Q. B — Receiver formulas using the brightness and color difference signals for the reproduction of red, green and blue.

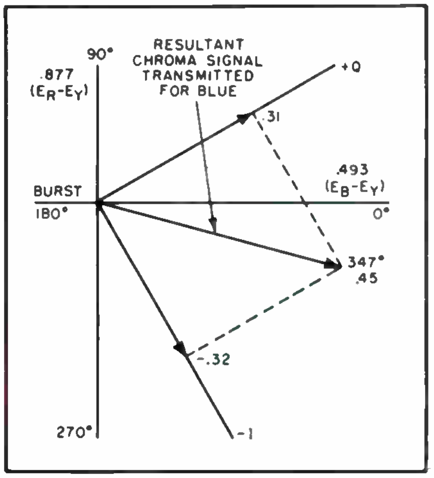


Figure 7. The resultant chroma signal for blue is obtained by the addition of $-.32E_I$ and $.31E_Q$.

10 we note that the camera changes primary colored light inputs to voltages designated E_R, E_G, and E_B. Next, the signal passes through the Gamma amplifiers which are used to compensate for the non-linear characteristics of the picture tube. The gamma corrected signals are designated by the prime (′) symbol, therefore they are shown as E'_R, E'_G and E'_B. These signals are then fed into a matrix, where the proportions shown in the block "Matrix Settings" are satisfied. The transmitter matrix could take on several forms, i.e., it could be made up of vacuum tube circuitry or it could be made up without vacuum tubes.

The output from the matrix consists of three signals; the Brightness signal identified as E'_Y; a wide band color difference signal (0 — 1.5 mc) designated E'_I; a narrow band color difference signal (0 — 500 kc) designated E'_Q.

The brightness signal, E'_Y is transmitted at full bandwidth (4mc), and is proportioned to take into account the spectral sensitivity of the eye. In color programming it represents the compatible signal that provides excellent black and white pictures on a standard monochrome receiver. Delay equalization is provided to compensate for the difference in bandwidths of E'_Y, E'_I and E'_Q. The reason for this stems from the fact that without correction all three signals would not be in time coincidence, and the result would be poor transient response of the chroma signal which would result in color fringes at the edges of objects. As a result, the NTSC has set a tolerance match of ± 0.05 μsec between these three signals. Transmitters usually incorporate the delay in the matrix and encoder units.

The color difference signals E'_I and E'_Q are limited in bandwidth to take advantage of the physiological characteristics of the human eye.

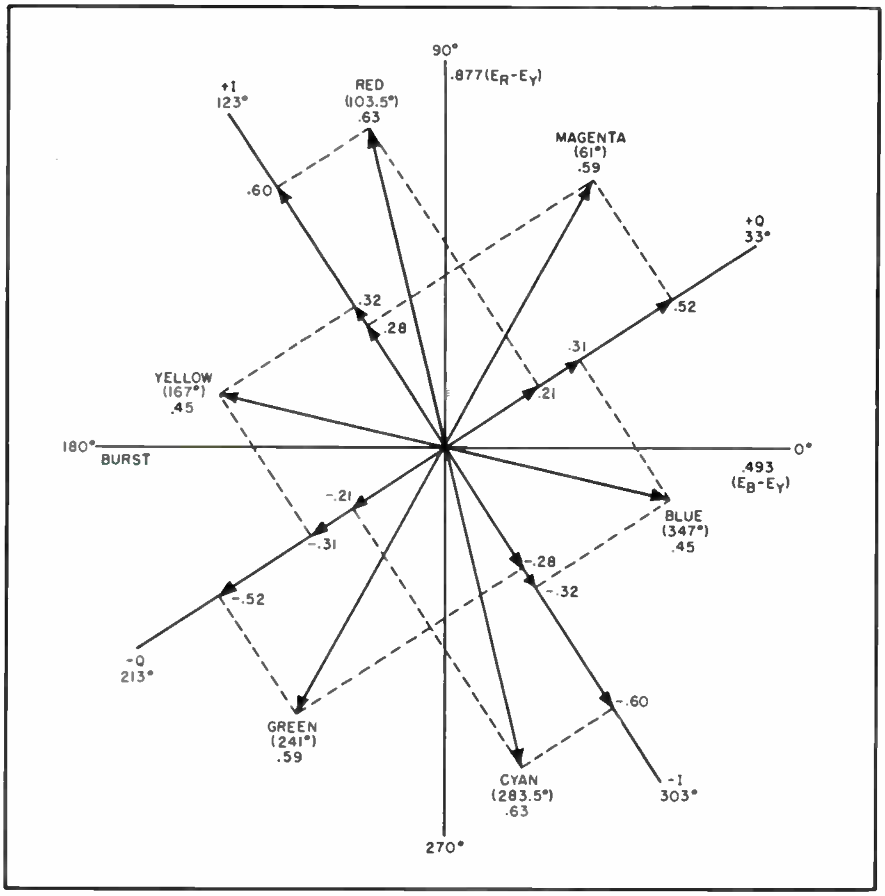


Figure 8. Detailed phase spectrum of a typical color bar pattern (under 500 KC) using the E_I and E_Q color difference signals. Note that the resultant chroma values and the phase angles for the colors indicated are the same as the phase spectrum using E_R — E_Y and E_B — E_Y, shown in figure 2. All angles are referred to 0°.

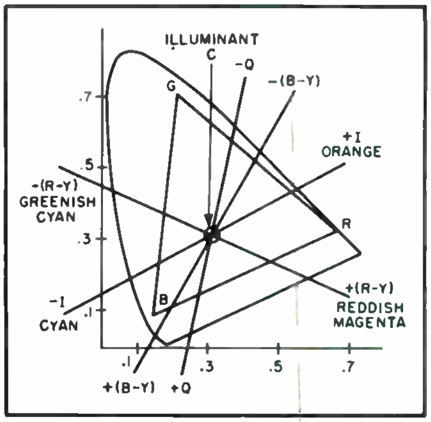


Figure 9. Chromaticity diagram showing the relative positions of (R - Y), (B - Y) and the I and Q axes.

The wide band color difference signal E'_I is nominally referred to as having a bandwidth of 0 — 1.5 mc. Actually the NTSC specification is as follows:

at 1.3 mc less than 2 db down
at 3.6 mc at least 20 db down

In practice we will continue to refer to the nominal value of 1.5 mc. The E'_I signal is fed into a low pass filter which removes all signals above the nominal 1.5 mc, and allows only the desired E'_I signal to be fed into a Balanced Modulator which also receives a subcarrier feed phased in accordance with the designation cos ($\omega t + 33°$). The reader will find this trigonometric relationship used in many texts, and will be used here to accustom the reader to its usage. It merely identifies the exact position of the I axis, as being 33° away from the 90° ($E_R - E_Y$) position. By contrast, the sin ($\omega t + 33°$) locates the Q axis as being 33° from the 0° ($E_B - E_Y$) position.

It will be recalled that the Balanced Modulator suppresses the subcarrier proper and allows only sideband information of the color difference signal to pass. The subcarrier is suppressed to minimize interference. This is particularly important when scanning white or low amplitude (saturation) signals. Under these conditions, if conventional modulators were used the subcarrier would always be present, and beats would be more prevalent. In the NTSC operation *white* is reproduced only with the E'_Y signal, the color difference signals are reduced to zero, consequently there is no output from the color difference channels.

In our analysis of the E'_Q signal we

have noted that the narrow band E'_Q color difference signal is nominally referred to as having a bandwith of 0-500 kc, actually the NTSC specification is as follows:

at 400 kc less than 2 db down
at 500 kc less than 6 db down
at 600 kc at least 6 db down

In practice we will continue to refer to the nominal value of 500 kc. The E'_Q signal is fed into a 0—500 kc low pass filter and then into a balanced modulator along with a subcarrier signal phased in accordance with sin $(\omega t + 33°)$. The function of the balanced modulator is similar to the E'_I channel and only sideband information is passed, the subcarrier is suppressed.

The resultant sideband information from both E'_Q and E'_I are added, and the resultant of this vector addition represents a specific phase and amplitude of the color actually being transmitted as covered in our phase spectrum analysis discussed earlier in this article.

To illustrate again, using the block diagram of figure 10 we will scan a saturated yellow:

Yellow is obtained by mixing green and red, so that the camera outputs will be:

$E_R = 1$ volt; $E_G = 1$ volt;
$E_B = 0$ volts.

The output from the Gamma amplifier will be:

$E'_R = 1$ volt; $E'_G = 1$ volt;
$E'_B = 0$ volts.

Substituting these values in the Brightness Formula, we find:

$E'_Y = .89$ volts

Substituting in the E'_I Formula, we find:

$E'_I = 0.32$ volts (Input to "Adder")

Substituting in the E'_Q Formula we find:

$E'_Q = -0.31$ volts (Input to "Adder")

The output from the "Adder" block will be:

$$\text{Resultant} = \sqrt{(0.32)^2 + (-0.31)^2} = .45 \text{ volts}$$

Therefore, the color yellow produces a resultant chrominance value of .45 volts at an angle of 167° as shown in figure 8.

This chrominance signal is then added to the E'_Y signal (see figure 10) in the output amplifier, and the composite signal represents the actual *transmitted* signal for the color yellow. It must be remembered that a color can be fully identified only by the properties of hue, saturation and brightness. The resultant chrominance signal contains only the hue and saturation information; the hue corresponds to the angle and the saturation to the amplitude (length) of the vector in the phase spectrum analysis.

Actually, it would be incorrect to refer to a color as such, unless all three properties are identified. Where only hue and saturation are present, we usually identify it as chrominance (or chroma) information. The chrominance channel in a transmitter (or receiver) involves those functions which are devoid of brightness information. When brightness information is added to the chroma signal it may then be referred to as a color.

Therefore the total transmitted color signal may be expressed as:

Color Signal = Brightness + Chrominance or in formula form:

$$E'_M = E'_Y + [E'_Q \sin(\omega t + 33°) + E'_I \cos(\omega t + 33°)]$$

Receiver Analysis Using I and Q Signals

The receiver signal circuits as shown in figure 11 are similar to a monochrome receiver, and provide a common signal path for the composite color signal. The video amplifier (in this case) serves as the takeoff point for the brightness and chrominance information. Basically, the receiver function is opposite to that of the transmitter. At the transmitter the chroma and brightness signals were combined to form a composite signal. In the receiver the chroma information is separated from the brightness component, and then the individual E'_I and E'_Q color difference signals are de-

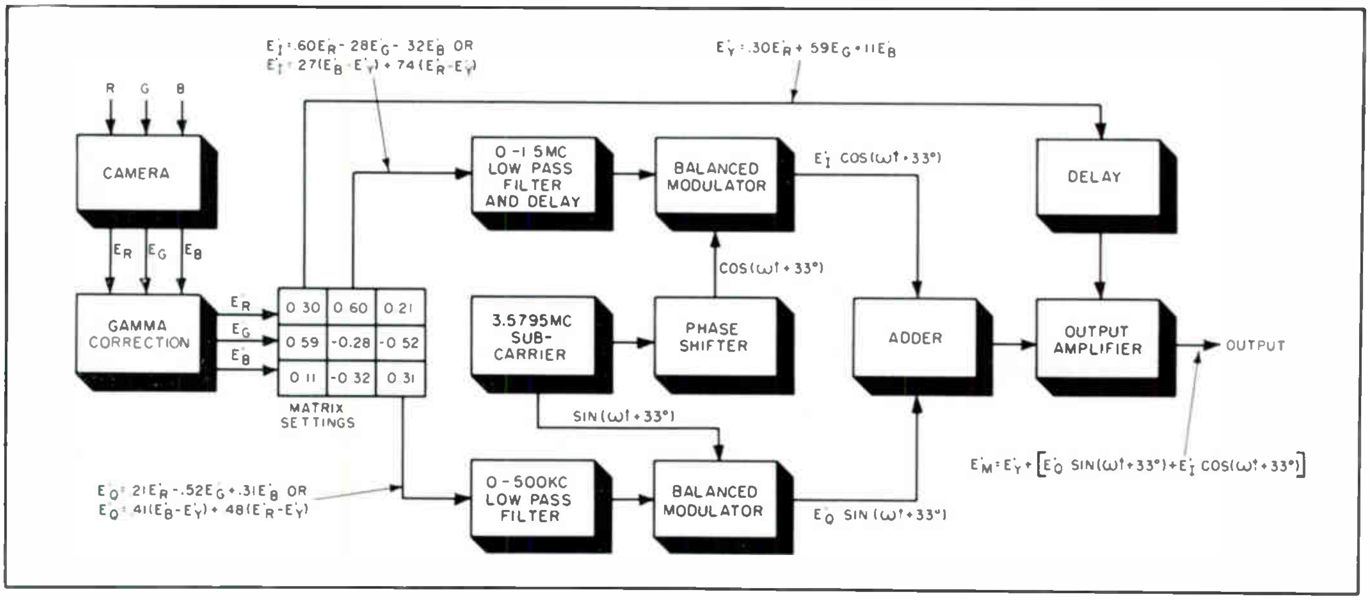


Figure 10. Block diagram of a color transmitter showing how colored lights are changed to brightness and chrominance information required in the formation of a color signal.

tected separately, and then added to the E'_Y in proper proportions resulting in individual voltages E'_R, E'_G and E'_B which are applied to the picture tube to reproduce the colors of the televised scene.

As shown in figure 11, the composite chroma information is selectively passed by a tuned band pass filter. The chroma frequency band extends from *approximately* 2 to 4.2 mc which includes both E'_Q and E'_I information. Reviewing, it must be remembered that the narrow band E'_Q signal is transmitted double sideband, i.e., it extends approximately 500 kc on either side of the subcarrier frequency of 3.579545 mc whereas the E'_I wideband color difference signal is transmitted vestigial sideband. Thus the lower sideband can extend 1.5 mc, while the upper sideband extends 500 kc.

Restated, we find:

3.579 mc — 1.5 mc = 2.07 mc
(lower sideband)

3.579 mc + .5 mc = 4.079
(upper sideband)

In practice we usually refer to the bandpass as being 2 to 4.2 mc.

The output from the band pass filter is fed into both the I and Q demodulators. The I and Q demodulators must perform the reverse function of the balanced modulators, i.e., they must separate the individual sidebands of E'_I and E'_Q that went into the makeup of the resultant transmitted signal. The detailed analysis of the demodulation process was covered in a previous article, and the reader is referred to it for review. Briefly, in order to accomplish detection the receiver signals must bear exactly the same frequency and phase relationships to the subcarrier at the transmitter. It was shown that the transmitter subcarrier was suppressed, this means that the receiver must supply its own subcarrier of 3.579545 mc in the same phase relationship as the subcarrier at the transmitter. It was shown also that this is accomplished by locking in the receiver a locally generated subcarrier frequency to the transmitter by means of a subcarrier burst carried on the back porch of horizontal blanking.

It will be noted from figure 11 that the subcarrier feeds to both receiver demodulators bear the same identity to the subcarrier inputs to both balanced modulators shown in figure 10.

The outputs from the individual demodulators are fed into their respective low pass filters which remove all information above the upper end of the bandwidths assigned to each as shown in figure 11. Thus both E'_I and E'_Q color difference modulation information is recovered at the receiver and is fed into a matrix, along with the E'_Y brightness signal which was separated from the chroma signal at the video amplifier. As noted "DELAY" is used in the E'_Y and E'_I signals. We had seen that "DELAY" was used also in the transmitter, to provide a composite color signal that was transmitted in time coincidence. Although the signal is transmitted in time coincidence the receiver detects each signal, E'_Y, E'_I, and E'_Q in individual circuits of different bandwidths, consequently the receivers must also introduce delays to effect time coincidence of the recovered color intelligence. In practice, the receiver uses separate delay lines for the E'_Y and E'_I signals. There is no delay assigned to E'_Q because it has the lowest frequency (500 kc), and since time = 1 ÷ freq. it can be seen that the lower the frequency the greater the time involved, i.e., the frequency is inversely proportional to time, consequently both E'_Y and E'_I which are assigned the higher frequencies must be delayed in time to match E'_Q. The analogy used here is basic, actually the formulas are more complex since the delay must be constant for all sig-

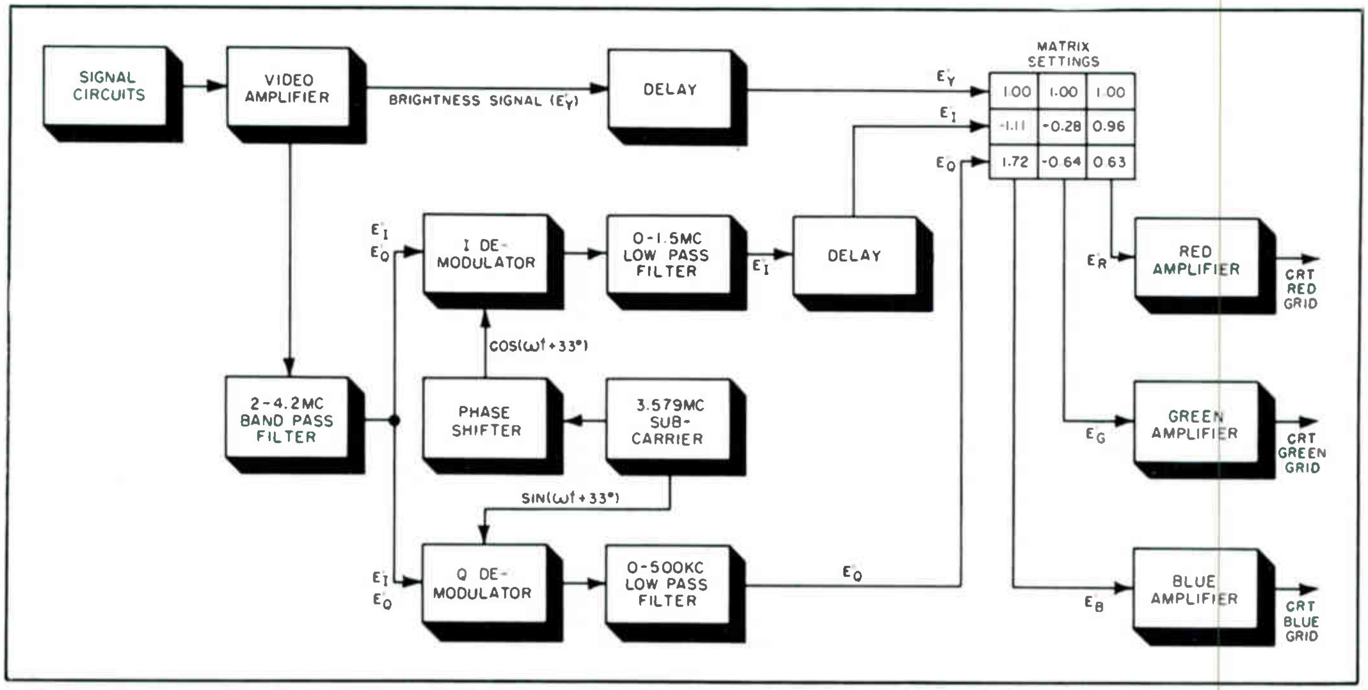


Figure 11. Block diagram of a color receiver showing how the brightness and chrominance information is utilized to reproduce the red, green and blue signals.

nificant frequency components of the signal.

The matrix in a receiver is usually a resistive network which proportions the E'_Y, E'_Q and E'_I signals as shown in the "MATRIX SETTINGS" block. These values were covered previously in this article in figure 5B. In our discussion of the transmitter block diagram we showed the transmitter process when scanning a saturated yellow. We shall take the same color, and show how it is reproduced on the CRT at the receiver.

Assuming our demodulation process is correct we derive E'_I and E'_Q signals which are fed into the receiver matrix. We know that for yellow, $E'_I = 0.32$ volts and $E'_Q = -0.31$ volts. We also know that $E'_Y = .89$ volts. Substituting these values in the matrix proportions at the receiver we find:

$$\begin{aligned} E'_R &= 1.00E'_Y + 0.96E'_I + 0.63E'_Q \\ &= 1.00\,(.89) + 0.96\,(.32) \\ &\qquad + 0.63\,(-.31) \\ &= .89 + .30 - .19 \\ &= 1 \text{ volt} \end{aligned}$$

$$\begin{aligned} E'_G &= 1.00E'_Y - 0.28E'_I - 0.64E'_Q \\ &= 1.00\,(.89) - 0.28\,(.32) \\ &\qquad - 0.64\,(-.31) \\ &= .89 - .08 + .19 \\ &= 1 \text{ volt} \end{aligned}$$

$$\begin{aligned} E'_B &= 1.00E'_Y - 1.11E'_I + 1.72E'_Q \\ &= 1.00\,(.89) - 1.11\,(.32) \\ &\qquad + 1.72\,(-.31) \\ &= .89 - .36 - .53 \\ &= 0 \text{ volts} \end{aligned}$$

As noted, we recover the same voltages as had been present at the output of the Gamma amplifiers in the transmitter. The receiver voltages E'_R, E'_G and E'_B are fed into amplifiers and then into the grids of a three gun CRT. Since there is drive present on only the green and red guns, and no drive on the blue gun the green and red phosphor dots will glow simultaneously to provide an additive mixture of red and green which produces yellow.

In a future article we will discuss waveforms, and signal makeup based on a color bar analysis.

PRODUCTION CHANGES

RA-306, 307

No. 30621025, 3072853

Reason:

Capacitor C263 was changed from a 1KV to a 1600 volt unit to minimize the possibility of breakdown.

Parts Required:

SYMBOL	PART NUMBER	DESCRIPTION
C263	03 139 681	Cap F Pa .01mf 20% 1600 V

The first chassis so modified are:

RA-306	Serial No. 30621025	Coded Run-1
RA-307	Serial No. 3072853	Coded Run-1

No. 30632492, 3078288

Reason:

To eliminate the possibility of damage to the 6AU6 a-g-c amplifier when the high voltage fuse opens, the tube's screen voltage has been changed to the fused side of the +270 volt line.

To reduce tube failure in the horizontal deflection amplifier stage and increase the 6BQ6 tube life.

Procedure:

1. Disconnect the screen of the 6AU6 a-g-c amplifier, from the +270 volt line.
2. Connect a wire from the screen of the a-g-c amplifier to the high voltage fuse at the fused side of the +270 volt line.
3. Change the value of R281 from 4K, 10%, 10W to 5K, 10%, 10W. R281 is the screen resistor of the 6BQ6 horizontal deflection amplifier.

Parts Required:

SYMBOL	PART NUMBER	DESCRIPTION
R281	02 113 070	Res FW 5K, 10%, 10W

The first chassis so modified are:

RA-306	Serial No. 30632492	Coded Run-1
RA-307	Serial No. 3078288	Coded Run-1

No. 30638371, 30710927

Reason:

Wiring changes have been made to the a-g-c amplifier stage, V218, to permit the use of a power transformer with a single 6.3 volt a-c filament winding.

Procedure:

1. Remove the filament leads (designated "Y" on the schematic) from pins 3 and 4 of the 6AU6, a-g-c amplifier. Do not disturb the ground lead connecting to pin 4.
2. Connect a lead between pin 3 of the 6AU6 a-g-c amplifier and pin 2 of the 6W6 audio amplifier.

Parts Required:

SYMBOL	PART NUMBER	DESCRIPTION
T204	20 008 941	Power Transformer (RA-306)
T204	20 008 951	Power Transformer (RA-307)

The first chassis so modified are:

RA-306	Serial No. 30638371	Coded Run-1
RA-307	Serial No. 30710927	Coded Run-1

No. 30641084, 30711528

Reason:

The sound performance was increased by removing resistor R216, 47K, 10%, ½W connected between pin 1 of the 6AU6 sound i-f amplifier and ground. As L208 the sound i-f coil is also wired between pin 1 of the 6AU6 sound i-f amplifier and ground, the Q of the sound i-f coil, is increased when R216 is removed.

The first chassis so modified are:

RA-306	Serial No. 30641084	Coded Run-1
RA-307	Serial No. 30711528	Coded Run-1

No. 30643047, 30711148

Reason:

To provide fuse protection to the grid circuit of the a-g-c amplifier.

Procedure:

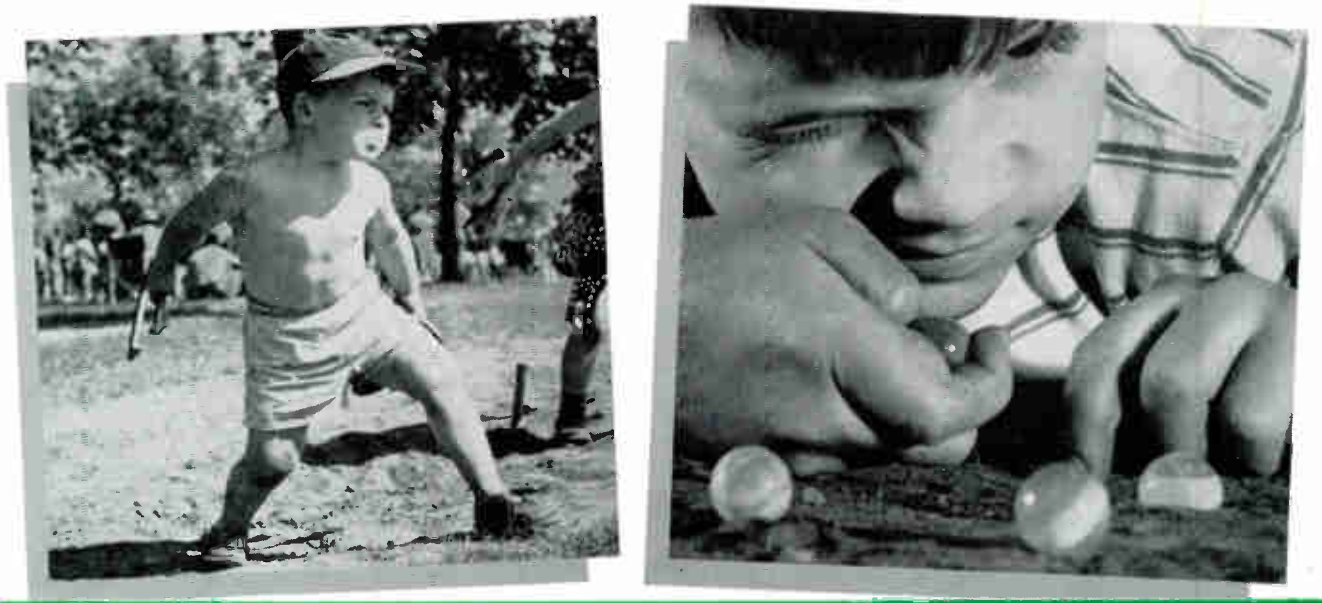
1. Disconnect resistors R225, 68K, 10%, 1W and R221, 7K, 10%, 10W from the +270 volt line. Resistors R221 and R225 are located at terminal board TB-11.
2. Connect the free end of R225 and R221 to the high voltage fuse, F201, at the fused side of the +270 line.
3. Remove F201 the ¼ amp high voltage fuse and replace with a ⅜ amp fuse.

Parts Required:

SYMBOL	PART NUMBER	DESCRIPTION
F201	11 000 730	Fuse ⅜ amp.

The first chassis so modified are:

RA-306	Serial No. 30643047	Coded Run-1
RA-307	Serial No. 30711148	Coded Run-1



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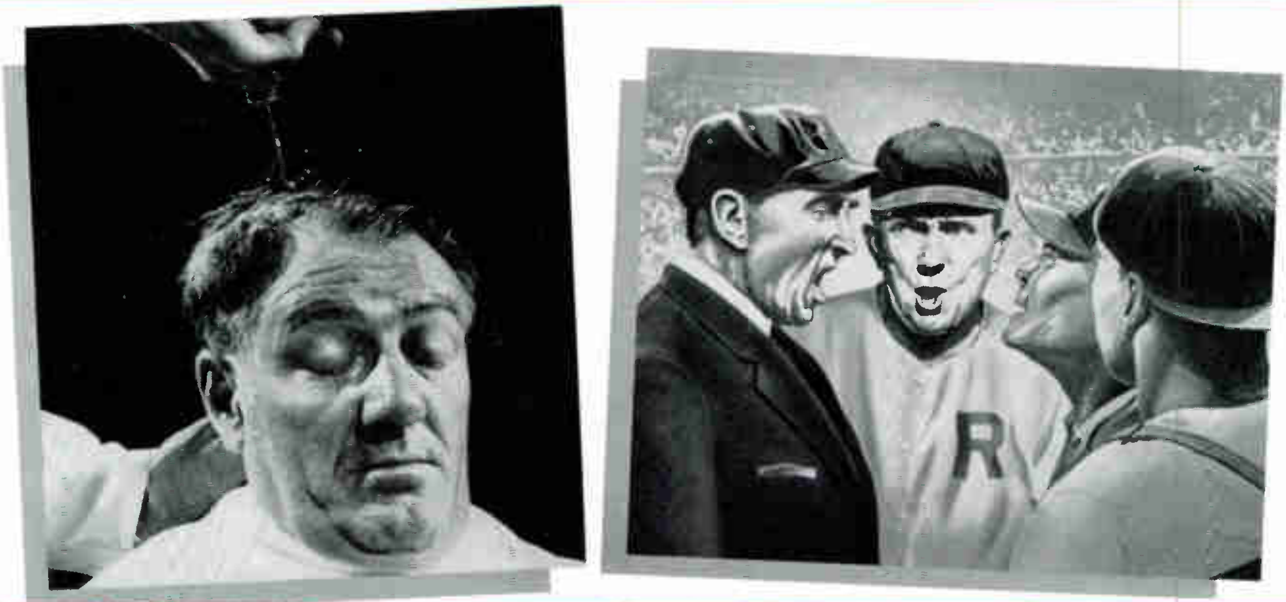

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