Video Signals and Circuits Part 2

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In the first part of this article the basic signal structure of a TV signal was discussed, and how a color video signal is structured. Recalling the luminance part or Y signal as it is called, the Y signal corresponding to luminance is made up of three components corresponding to the red, green, and blue wavelengths present in the scene as follows:

Luminance (Vy) or Y component = 0.30 Vr + 0.59 Vg + 0.11 Vb

The three color video signal components are called Vr, Vg, and Vb, for red, green, and blue, respectively. As discussed, if this signal were viewed on a monitor, we would see the televised scene as a black and white picture, and indeed, other than the sync information, this is the only part of the video signal needed by a monochrome monitor for a complete picture. However, the color information must be handled so color monitors can receive a full color picture. In order to do this, the three video signals from the separate R, G, and B channels called Vr, Vg, and Vb respectively must be encoded into a signal that can be transmitted as part of the video baseband signal and eventually processed (decoded) by the receiver so as to recover the three original Vr, Vg, and Vb signals. These channels contain the levels of the three primaries, and if each were viewed separately, the scene would be in black and white with luminances corresponding to the levels of the individual primaries. This is what you would see viewing the scene through strongly colored glass filters in red, green, or blue, respectively. Viewed through a red filter, trees and sky would appear dark while a red apple would appear very light. A blue filter would show the apple as very dark and the sky very light. The green filter would show the trees as light, with the apple very dark, and so on.

The three primaries are combined in matrix circuits to form two signals, the I and Q signals, standing for in-phase and quadrature signals, respectively. The human eye is not perfect in resolving fine color details. It is better, for example, at resolving orange and cyan fine details than green and purple details. The I signal is roughly orange-cyan and the Q signal is roughly green-purple. A transmission bandwidth of 3.2 MHz is used for the luminance (Y) signal, which is the black and white (B/W) component. However, a 1.5 MHz bandwidth is sufficient for the I signal and only 0.5 MHz is needed for the Q signal. This allows conservation of bandwidth by taking into consideration the natural visual limitations of the human eye. The limitations of human vision were carefully considered in the original development of the NTSC color TV system. The Y signal is bandlimited to 3.2 MHz instead of the full 4 MHz usually used for monochrome, so as to reduce interaction with the color signal at 3.58 MHz. Here is one reason for the apparently greater sharpness of a monochrome image over a color image, but other factors and limitations in the NTSC color system tend to reduce maximum available resolution slightly. One factor is the need for a tricolor video camera chip, and also a tricolor picture tube or LCD display. However, the presence of color, for most people, more than makes up for the rather small loss in

picture sharpness. The exact frequency of 3.579545 MHz (Abbreviated to 3.58 MHz for simplicity) was chosen to place spectrum components of the color and luminance components in such a relationship as to minimize interference, and the details of how this was chosen will not be presented here. Basically, the luminance or Y signal has its components clustered around the 15.73426 kHz intervals which are the harmonics of the horizontal scanning frequency. The 3.579545 color frequency is 227.5 times this frequency. The color signal will therefore have its components exactly midway between the luminance components, as they will be clustered around frequencies spaced 15.73426 kHz from 3.579545 MHz. This is called frequency interleaving, and reduces interchannel interference. Interested readers should consult a book on color television engineering for details on this subject.

The I and Q signals are derived from the R,G,and B signals by video matrixing circuits as follows:

$$I = 0.60R - 0.52G - 0.32B$$

$$Q = 0.21R - 0.52G + 0.31B$$

These signals are applied to two separate balanced modulators that are fed with the subcarrier reference signal frequency of 3.58 MHz. The phase of the I or in-phase signal is set at 57 degrees from the reference phase, which is that of the burst signal (0 degrees). The Q or quadrature signal is set at 90 degrees from the I signal, so we have two signal channels separated by 90 degrees, in quadrature. These two signals from the modulators are summed and form the chrominance or C signal. The C signal is the phasor sum of I and Q, which is the square root of the sum of the squares of the I and Q signals. Mathematically:

$$C = \sqrt{(I^2 + Q^2)}$$

This signal is the chrominance or color difference signal that is finally transmitted along with the Y signal. See the color wheel in Fig 1 for details, and the spectral diagram in Fig 2 for frequency relationships. Fig 3 is a block diagram of a color TV transmitter system.

Note that there are two principal axes in Fig 1. The horizontal axis is called the B-Y axis and contains the burst phase. The vertical axis is called the R-Y axis. The original color signals can be obtained at the receiver by using two or three balanced demodulator or sampling gates fed with CW or pulse signals at 3.58 MHz, that are set at certain phases with respect to the reference signal. This demodulator system will output signals that are the R-Y, G-Y, and B-Y signals. It is not necessary to use three demodulators, as only two can be used, and their outputs matrixed to produce the third signal. G-Y can be derived from B-Y and R-Y. If the phase of the 3.58 reference signals are set at other angles demodulation along other axes can be used. As an example, 102 and 166 degree phases have been used (Called X and Z axes) for

an older vacuum tube demodulator scheme, to derive two other signals called X and Z signals. This scheme allowed use of a matrixing circuit easily implemented with a special vacuum tube to get the original R,G, and B signals directly from the X and Z signals. Any two axes can be used in theory, but practical implementation will determine the axes chosen. With older vacuum tube circuits or discrete transistor cit\rcuitry component count determined this, but with LSI ICs there is no real problem with using three demodulators and other auxiliary circuitry as needed. Note that these demodulated signals are <u>color</u> <u>difference</u> signals, <u>not the original</u> R,G, and B component signals Vr, Vg, and Vb. The color difference signals are given by the following relationships:

(R-Y) = Vr-Vy = 0.70Vr - 0.59Vg - 0.11Vb

(G-Y) = Vg-Vy = -0.30Vr + 0.41Vg - 0.11Vb

(B-Y) = Vb-Vy = -0.30Vr - 0.59Vg + 0.89Vb

After demodulation, if these three signals are individually added to the Y signal, we get the three original components. For example, in the case of the R-Y signal:

(0.30 Vr + 0.59 Vg + 0.11 Vb) + (0.70Vr - 0.59Vg - 0.11Vb) = 1.0 Vr = Vr

(Luminance Signal) + (R-Y Color Difference signal) = Red Signal

This is similarly done for the green and blue. We have now recovered the three original red, green and blue signals (RGB signals). Note that the levels of the three components and their relationships must be kept constant. Video amplifiers should be linear and matched for all three channels. This will ensure proper colors and the availability of a good grey scale picture. The ability to obtain a good B/W image free from any color casts on a color TV set is called grey scale tracking. A good test of a color system, oddly enough, is how well it can accurately produce a good black and white image or test pattern free from visible color. The eye readily detects small deviations from grey, and most near neutral colors are very close to shades of grey in color content. This includes flesh tones as well. Therefore, poor grey scale tracking can throw off neutral colors quite noticeably, with unwanted casts in highlights and shadows.. For example, low blue gain relative to red and green will show up as a picture with brownish highlights and bluish shadows. This effect is called "crossed curves" as the dissimilarity in the channel characteristic curves of output vs input will show up as unwanted color shifts. This effect is often seen in color photography in poorly processed prints from cheap processing laboratories, and occurs from uneven or poorly controlled development of the three color layers in the original color negative. Unfortunately in this case it cannot be corrected in printing, as there are no separate color channel "gain controls".

Note that since the system bandwidth is 3.2 MHz for the luminance signal and less (1.5 MHz approximately) for the color difference signals, the signal delay time through the luminance channel is somewhat less than that of the chrominance signal. Therefore, the luminance component would appear at a time before its corresponding color difference signal. This would cause a misregistration of the colors with the B/W components of the picture. This is corrected by introducing a delay in the luminance channed, so the corresponding signals arrive at the same time.

The reference signal used for demodulation must be exactly at the proper phase or else color shifts in the received picture will be evident. A look at figure 1 will show this, as a shift in (reference) burst phase effectively rotates the color wheel a number of degrees corresponding to the phase error. Burst phase errors may result from transmission paths having unequal delays at different frequencies, caused by unanted phaseshifts. Multipath reception, inadequate bandwidth, incorrect tuning, errors in the system passband characteristics, and defective components all may cause this problem. Most TV receivers have a control that adjusts the phase of the reference by a number of degrees, and this is usually called the tint control. Some receiver designs in the past did adjust or modify the demodulation axes to optimize flesh tints and "human" colors, where the eye is most critical. This was sometimes done automatically depending on color content of the signal by an ATC or automatic tint control, but this scheme did not always work too well. Color saturation is determined by the amplitude of the color difference signals and this is achieved by gain control of the respective circuits. Most receivers have an automatic gain control circuit (Automatic Color Control or ACC) as well as a manual gain control (Chroma control). The reference signal is derived from a local oscillator that is frequency and phase locked to the received burst signal. This is done using a phase locked loop circuit, with the received burst signal as a reference. The 3.58 LO is generally crystal controlled. Very little adjustment in frequency is needed, so a crystal oscillator and varactor or a reactance control is sufficient. All these functions from demodulated video output at the video detector, to the final R, G, and B video outputs are generally handled by one or two multifunction ICs in modern TV receivers and monitors. Audio demodulation and processing is usually included in an LSI IC as well, including tone control, muting, stereo demodulation, as well as SAP (second audio program) demodulation. We have said little about the audio as it is simply a 4.5 MHz FM signal, very similar to commercial 100 MHz FM broadcasting, except for 25 kHz deviation instead of 75 kHz. This subject was previously covered in another column

In receivers with digital features and effects, which today includes all but the really low end models, features such as picture in picture, freeze frame, digital audio controls, on screen displays (and of course remote control functions), LSI ICs and microprocessor circuits handle these functions. These will not be discussed further as they are not essential to the operation of the basic video processing systems. The use of LSI chips and microprocessors with plenty of computing power have made TV receivers and monitors available with capability and features unheard of several

years ago. This could be the subject of several textbooks and therefore cannot be covered here.

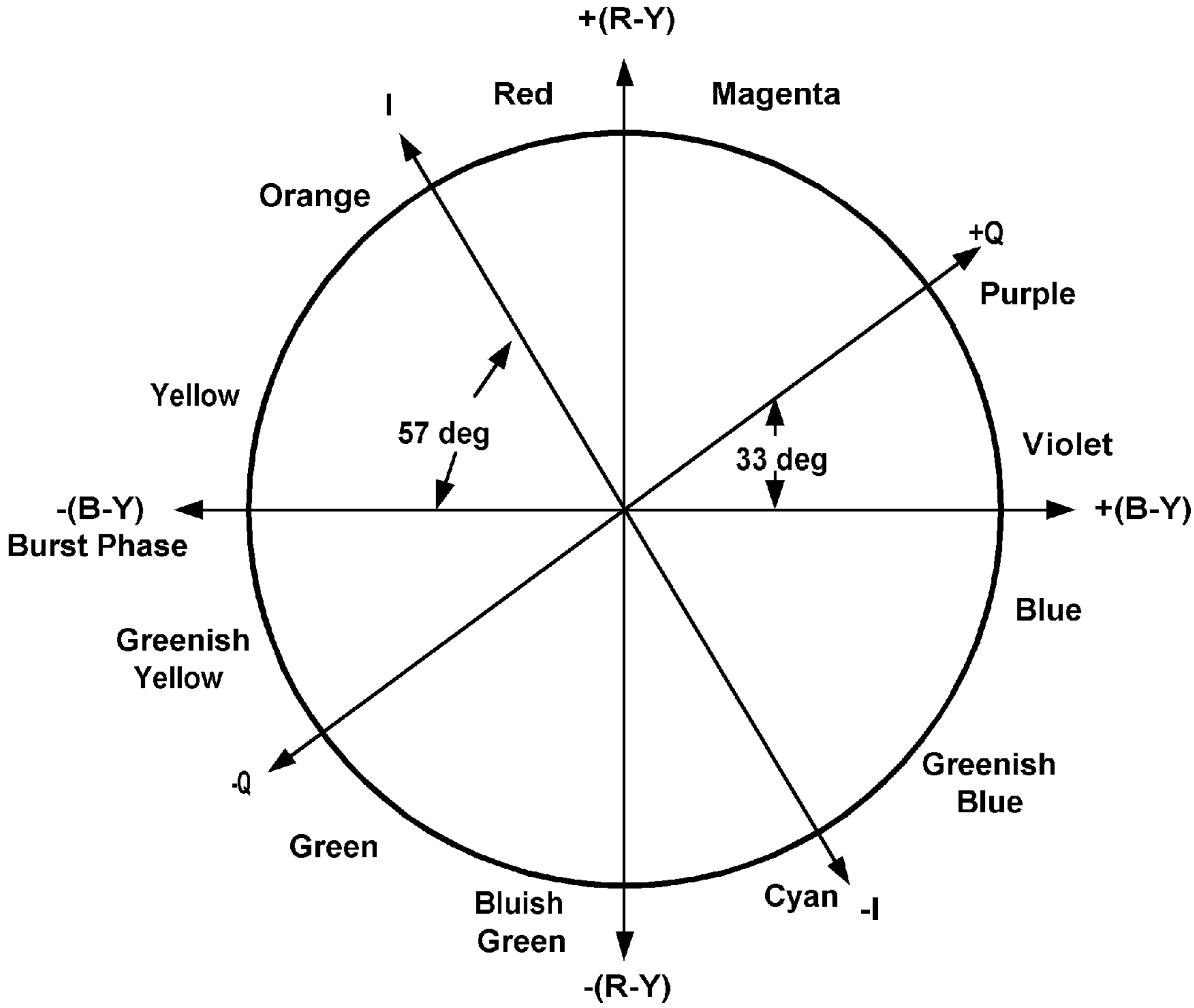

FIG 1 TELEVISION COLOR WHEEL AND COLOR AXES

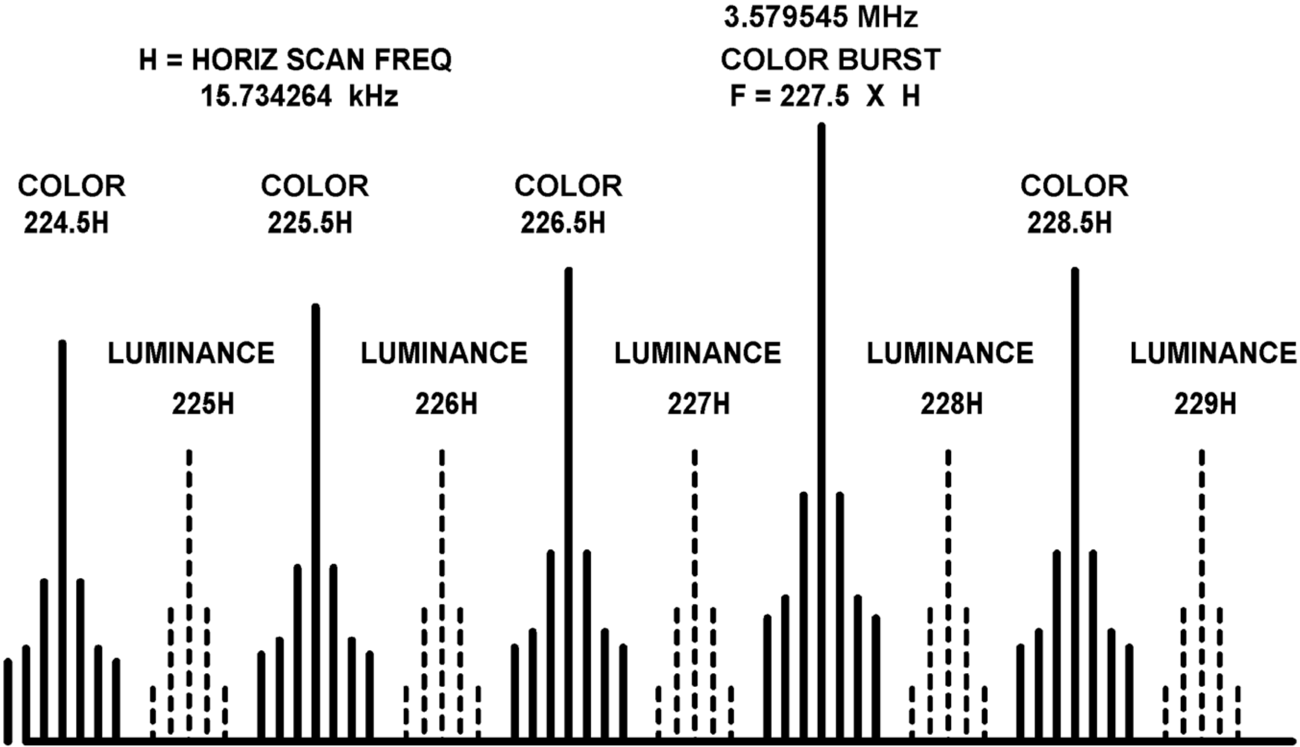

FIG 2 SPECTRUM OF TV SIGNAL AROUND 3.58 MHZ SHOWING FREQUENCY INTERLEAVING

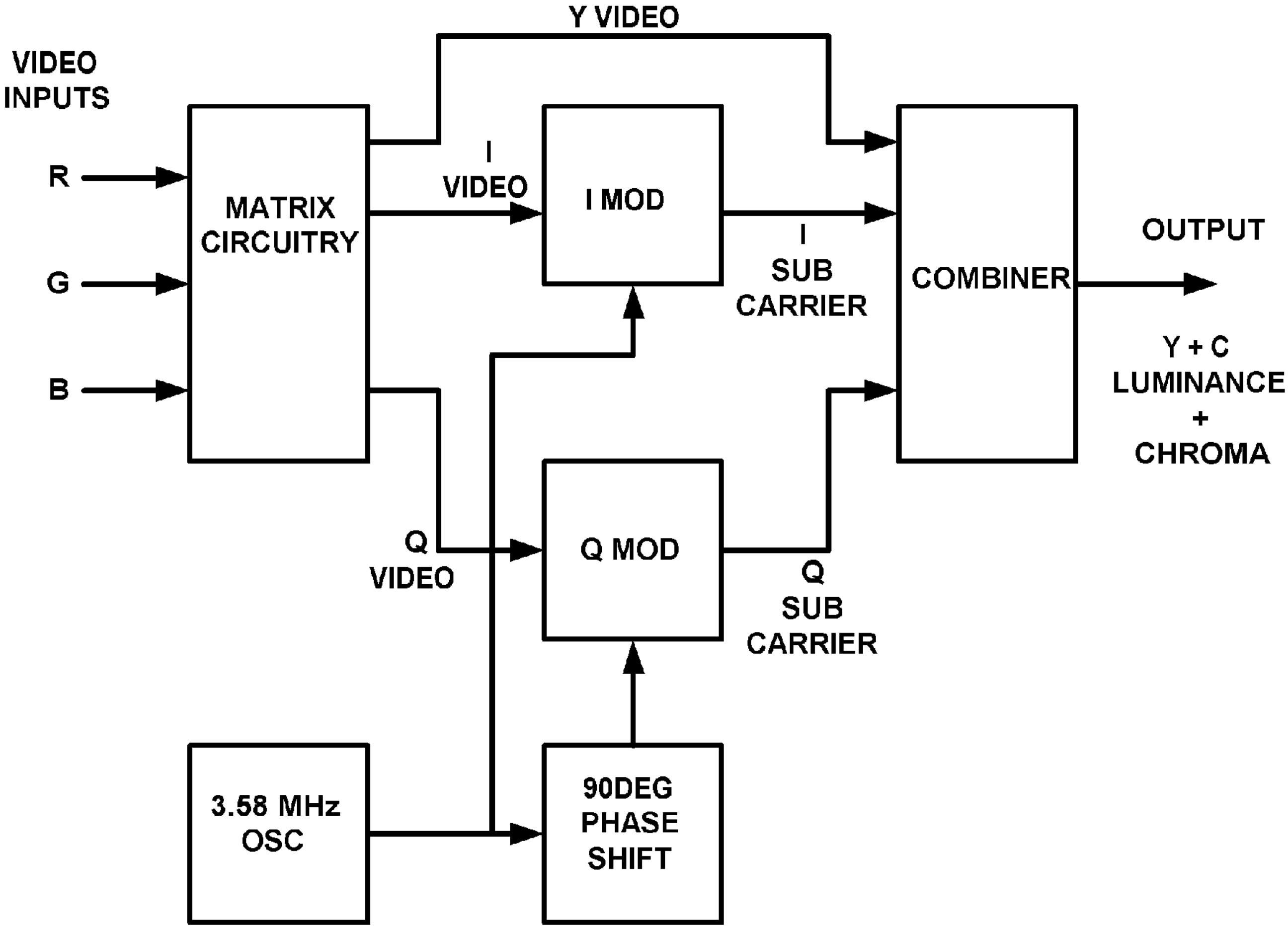

FIG 3 COLOR TV SIGNAL GENERATION

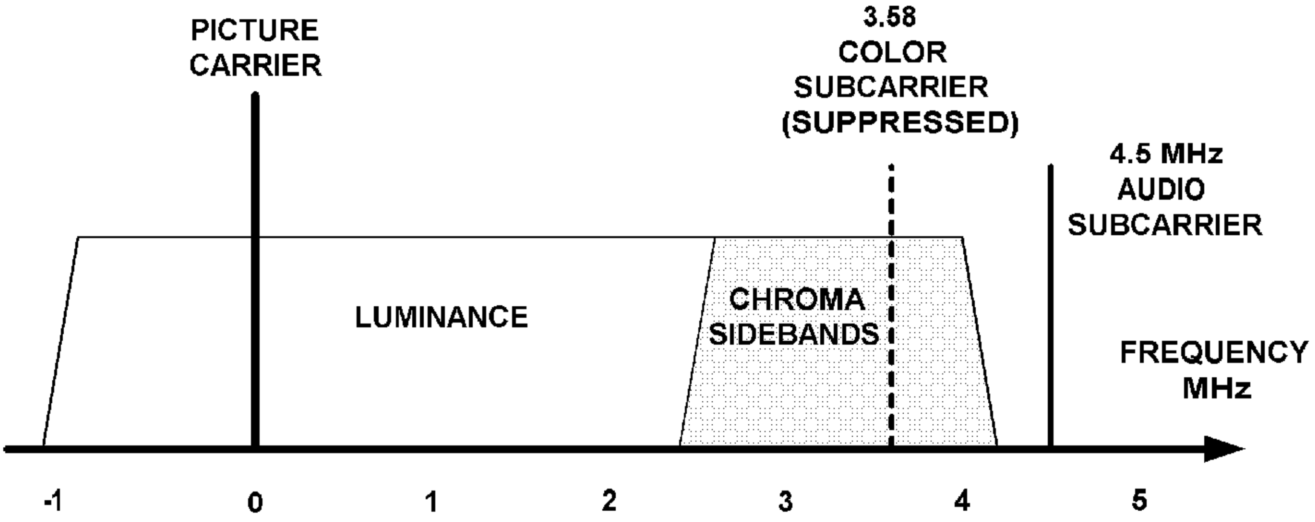

FIG 4 SPECTRUM OF NTSC COLOR TELEVISION SIGNAL