**Hoffman**
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# COLOR
# LECTURE
# NOTES

$1.00

# FOREWORD

In December, 1953, a new set of standards for color television transmission was approved by the FCC. This set of standards is known as the NTSC System. NTSC are the initials of the National Television Standards Committee. This committee is a group formed of the various engineers and scientists employed by radio and television manufacturers throughout the country. A new set of standards is a result of their combined efforts to set up a system which would not only be capable of reproducing color of a very high quality, but would also be able to meet all the requirements for a compatible system.

In conjunction with a training program on color television, we have compiled a series of notes on the material covered in our lectures. They have been bound into book form and will present the major points of the system. This book is not meant as a complete text on the subject but as a discussion which will cover the basic principles and method of operation of the NTSC color system.

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National Service Manager
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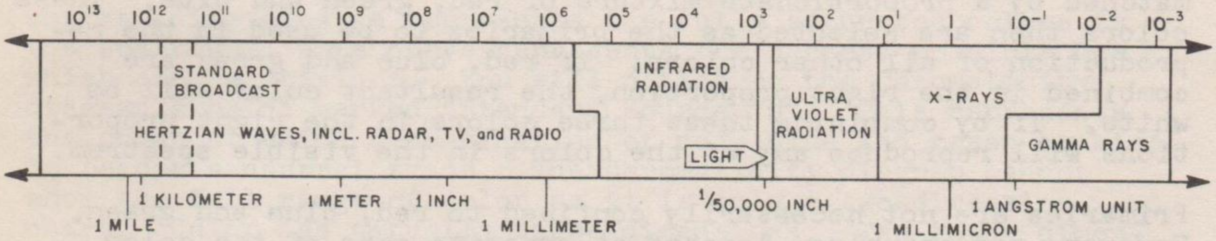
February 1, 1954

# CHAPTER I

## "BASIC COLOR PRINCIPLES"

Light is a form of radiant energy which travels with regular wave motions. The speed at which the energy travels is 186,000 miles per second in air or the same speed as radio waves. Light differs only from radio waves in frequency. The portion of the spectrum which the light waves occupy is above that of the radio waves and is located between the infra-red radiation spectrum and the ultra-violet radiation spectrum.



The Radiant Energy Frequency Spectrum

The wavelength of light is measured in milli microns (one billionth of a meter) and is designated by the symbol "mu". The light range covers the frequency range of 400 to 700 mu's. Below 400 mu's are the ultra-violet rays and above 700 mu's are the infra-red rays. In the range between 400 and 700 milli microns, each frequency represents a different color within the visible range, and when all the frequencies are present in the proper proportions we see the combination as white light. The proof of this fact is shown when the color makeup of white light is separated. When we direct a beam of white light through a prism onto a curved surface we get a distinct separation of all the colors within the light spectrum. When the color spectrum is viewed in this way we can see the range of visible colors.

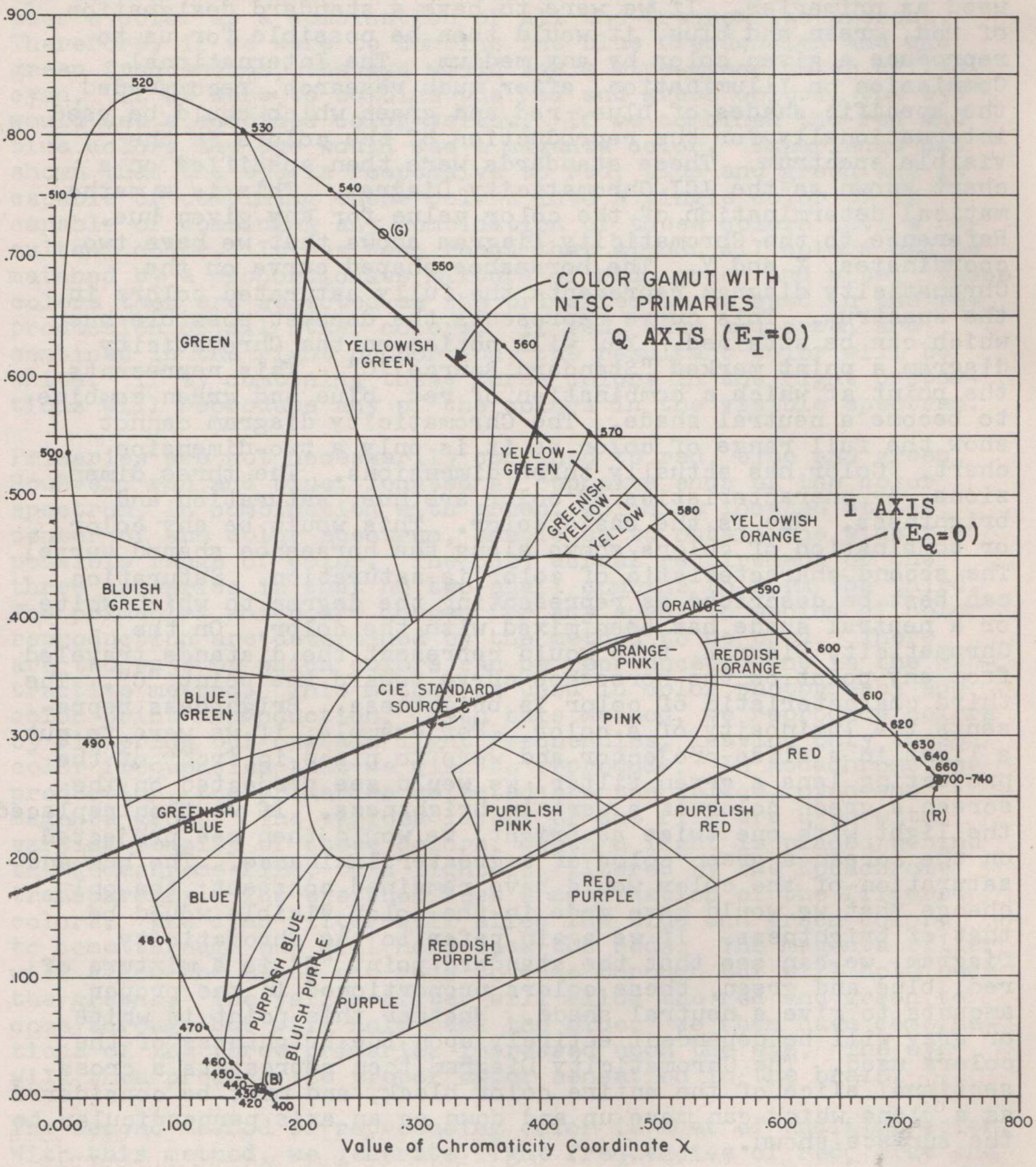
The principal colors which stand out are the blues, blue-greens, greens, yellows and reds, and these appear in that order in the spectrum. The blues represent the highest frequencies and the reds the lowest. The sensitivity of the eye is such that it sees the colors in the approximate center range of the spectrum more clearly than the colors at either end, and these colors appear to have more brightness than either the reds or blues. The eye does not see colors as individual frequencies or colors but sees a color as a combination of all the frequencies present. Therefore, if we were to combine the blue frequencies and the green frequencies, the eye would see a blue-green color called cyan. If we were to combine the red and green colors, the eye would see a combined color yellow. If we combined the red and blue colors the eye would see a magenta color. Experience has shown that the eye is responsive to red, blue and green and is capable of combining these colors into a single color or is capable of combining any combination of these colors into a resultant color. It has been found that almost all colors can be matched by a proportionate mixture of red, green and blue. These colors then are selected as the primaries to be used in the reproduction of all other colors. If red, blue and green are combined in the right proportion, the resultant color will be white. If by combining these three colors in the right proportions will reproduce any of the colors in the visible spectrum.

Primaries are not necessarily confined to red, blue and green. However, red and blue, located at opposite ends of the color spectrum, in combination with green, which is located at the center of the color spectrum, enable us to obtain the widest possible range of color. The only actual requirement of the three primaries is that no two shall combine to form the third. The primaries which are chosen for any specific medium of color reproduction are determined by the method to be used. There are two ways by which colors can be reproduced. One is the subtractive method. This method is used in color photography and color print reproduction. With this method, we reproduce colors by filtering out certain light frequencies, leaving only those color frequencies that we wish to reproduce. In Kodachrome reproduction, the primaries selected are the yellow, cyan and magenta group. The various layers of the film are dyed with varying density of these colors. When a light is placed behind the Kodachrome film, this light is filtered by the Kodachrome transparency. The eye then sees a combination of the filtered colors. The cyan filter will allow the blue and green colors to come through but will hold back the reds. The magenta filter will allow the blues and reds to come through but will hold back the greens. The yellow filter will allow the red and green to come through but will hold back the blue. We then have combinations of the three primaries impressed upon the eye. The eye will then produce the proper color sensation in the brain.

The second method of reproducing color is that of additive color. With this method, we generate light frequencies of red, blue and green. By proportioning the amount of each frequency generated, we can reproduce any color within the visible spectrum. It is the additive method that is used to reproduce the colors in color television. In this system we ignite phosphors of red, blue and green colors to the intensity necessary to reproduce any desired color.

There are many degrees of red, blue and green which could be used as primaries. If we were to have a standard designation of red, green and blue, it would then be possible for us to reproduce a given color by any medium. The International Commission on Illumination, after much research, recommended the specific shades of blue, red and green which could be used internationally for the reproduction of the colors in the visible spectrum. These standards were then specified on a chart known as the ICI Chromaticity Diagram. This is a mathematical determination of the color value for any given hue. Reference to the Chromaticity Diagram shows that we have two coordinates, X and Y. The horseshoe shaped curve on the Chromaticity diagram represents the fully saturated colors in the spectrum. This curve represents the deepest possible hue which can be attained. You will notice on the Chromaticity diagram a point marked "Standard Source "C". This represents the point at which a combination of red, blue and green combine to become a neutral shade. The Chromaticity diagram cannot show the full range of color as it is only a two-dimension chart. Color has actually three dimensions. The three dimensions, or characteristics of color are hue, saturation and brightness. Hue is the basic color. This would be any color or combination of colors shown along the horseshoe shaped curve. The second characteristic of color is saturation. Saturation can best be described as representing the degree to which white or a neutral shade has been mixed with the color. On the Chromaticity Diagram, this would represent the distance traveled from any point on the horseshoe curve toward the point "C". The third characteristic of color is brightness. Brightness represents the luminosity of a color. For example, if we were to put a light in a slide projector and were to place in front of the projecting lens a green filter, we would see projected on the screen a green color of a certain brightness. If we then replaced the light with one twice as bright, we would then see projected on the screen a green color of a greater luminance. The hue and saturation of the color would have remained constant; the only change that we would have made in the color visible would be that of brightness. If we again refer to the Chromaticity Diagram, we can see that the standard point "C" is a mixture of red, blue and green, these colors proportioned in the proper amounts to give a neutral shade. Whether this point is white or gray will be dependent entirely upon the brightness of the colors used. The Chromaticity Diagram then represents a cross-sectional slice of the entire color block, and must be considered as a plane which can move up and down on an axis perpendicular to the surface shown.

The degree of purity of color represented by the horseshoe curve is one which we cannot reproduce by any of the present known methods. This however is no great handicap in color reproduction,



CHROMATICITY DIAGRAM

as colors of this degree of saturation very seldom, if ever, exist in nature. The color range that can be covered by color television is that shown within the triangle. This is approximately twice the color area that can be covered by printers inks or by color films.

The proportions of the primaries which appear at the points of the triangle required to reproduce the neutral shade represented by point "C" are 59% green, 30% red and 11% blue. The points along the triangle represent the colors in the spectrum in the purest form in which they can be reproduced in color television. We refer then to these points as the 100% saturated color.

If we mix white with the red primary, we will produce a shade known as pink. In this we have not changed the hue of the color red, but we have reduced its density, and it would be represented by a point approximately midway between the point red and the point "C". If this point fell at half the distance between "red" and "C", we would consider the red hue to be 50% saturated. As more white were added and the shade moved closer to "C" we consider the shade as a less than 50% saturated. When sufficient white had been added that the shade reached the point "C", then we would consider the shade to be zero saturated. Therefore, a color which is 0% saturated is a neutral shade and has no chrominance or color characteristic. A hue which is in its purest form is 100% saturated.

We state that the three basic primaries are red, blue and green, and that these colors were selected because we could reproduce almost every color in the visible spectrum by combining these colors. This is not quite true, as we cannot reproduce the violets which are in a frequency range above the blues. This however is not important as the eye will combine red and blue to give a shade of purple which the eye will interpret as violet. One other point should be kept in mind and that is that we do not need to use the primaries directly to reproduce the colors within the triangle. We can, for example, combine green with red and produce yellow. The proper proportion of yellow and blue will produce white. By reducing the amount of blue, we can produce a light yellow or a yellow which is not fully saturated. If we combine blue and red, we produce a color known as magenta. By using combinations of these three colors, yellow, cyan and magenta, we can produce the majority of colors within the spectrum. However, we could not reproduce as wide a range of colors as would be possible by using three primary bases. We could however use four points along the triangle and with variations of these points produce a greater percentage of color. If we were to pick the point greenish-blue and reddish-orange, and if we were to use this range of color as one group, and if were to use a reddish-purple and a yellow-green and use the group of colors along a line connecting these two points, it would be possible for us to reproduce most of the colors within the triangle.

Due to reaction of the eye to variations in hue and brightness over the color range, we can in many cases use a smaller range of colors to produce a satisfactory color picture. The eye does not have a uniform sensitivity to color. The eye sees colors in the greenish-yellow range as having maximum brightness for a given color intensity. It then moves toward the reds and will see the red group as the next brightest. The effect of this characteristic of the eye is that we lose the ability to distinguish blues as the area of the color is reduced. If we were to take a surface covered with squares of blue, cyan, green, yellow, red and magenta and, if these colors were of equal luminance or intensity, we would see these colors as separate colors providing the area of each square were fairly large. If we were to move away from this chart, we would notice several things appear to happen. First, we would find that we could no longer distinguish the blues. The affect is that the blues tend to lose their blue and become indistinguishable from gray of the same relative brightness. Colors which contain no blue seem to pick up blue. The next affect that would be noticeable is that we could no longer distinguish yellow. The yellow area would be indistinguishable from a gray of equal brightness. At this point, it would also be difficult to distinguish brown from crimson, and blue from green. However, we would still be able to distinguish red from blue-green. A further reduction of the area would result in reds becoming indistinguishable from grays of equal brightness, and as we continued to move away from the chart, the blue-greens would become indistinguishable from neutral shades of equal brightness. The point that must be remembered is that although we lose the ability to distinguish a color as such from a neutral gray, we do not lose the ability to distinguish the relative brightness of one area from another until a much greater reduction of the surface takes place.

We take advantage of this characteristic of the eye in the reproduction of color television. The larger areas are produced in their proper hue. The smaller areas are reproduced only in two color ranges, the magenta-orange red range, and the fine detail need be reproduced only in black and white.

# CHAPTER 2

## "COLOR PICTURE TUBES"

The picture tube used in a color receiver must be capable of reproducing black and white pictures as well as color pictures. From previous discussions, we know that if a picture tube is capable of producing red, blue and green light, we can blend these to produce a black and white picture or they can be blended in such a manner that they will produce any color in the visible spectrum. There are available phosphors which, when ignited by an electron beam, will produce red, green or blue light of the required shade to allow us to reproduce the visible colors. The problem then becomes one of arranging these phosphors in a form which will allow us to reproduce small enough areas of color to insure good reproduction with the fine detail areas. While it is not necessary to reproduce all the colors in the fine detail portions of the picture, we do have to produce monochrome for the fine detail. If we use three colors of light to reproduce the monochrome areas, then the definition of a picture tube would be limited by the smallest possible area that these three light sources would occupy.

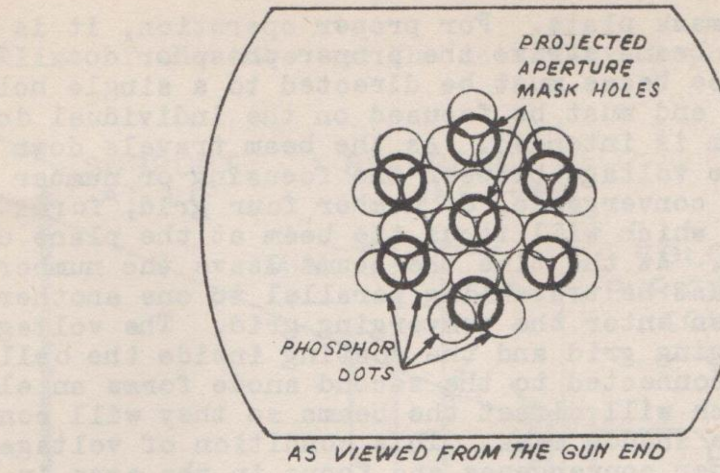
There are, at present, two general methods of arranging the phosphors in the picture tube in order to reproduce the color and black and white. The first method is that of using three very small phosphor dots, each capable of reproducing one of the three primary colors, and the three dots are placed in a triangular pattern in very close proximity of one another. The total area occupied by the three dots would determine the smallest area of definition that we could produce. With present methods, it is possible to place approximately 5,550 dots per square inch on a surface. This would mean that we would have approximately 1,850 definition areas per square inch, as each group of three dots could produce either a black, white or color sensation. Color tubes with phosphor dots of a size which allow this many color areas per square inch, will compare favorably with the definition possible on present black and white television receivers. A 15" black and white color receiver reproducing the intelligence in a video signal of 3.7 megacycles can produce approximately the same number of definition areas. If the black and white receiver were operating on a 4 megacycle bandpass, it would be able to reproduce approximately 2,050 definition areas per square inch. Therefore, a color phosphor plate of 5,550 dots per square inch would be capable of reproducing definition within 10% of that possible on black and white receivers under the most favorable conditions. Phosphor dots of this density will allow an approximate line definition of 350.

The second method of mounting phosphors in a picture tube is that of using strips of phosphor which would extend either in a horizontal or vertical direction. These strips would have to be very narrow and would have to consist of the proper arrangement of phosphors so that each strip would light with the proper color when energized by an electron beam. This method is being used at the present time with phosphor strips approximately ten mills wide. The sequence of color phosphors in this case is green-red-green-blue-green-red. There are twice as many green phosphor strips as either the red or blue. Definition in the direction of the strips can be as good or better than that of the picture tube using the cluster of three phosphor dots. There are two types of color tubes at the present time which can be used for color reproduction and which are available for use. One of these uses the triad grouping of color dots and is of the type developed by RCA. The other tube uses phosphor strips and is known as the Dr. Lawrence or chromatic tube. The two types of tubes will be covered in separate discussions, and the first one to be covered will be the RCA type.

## The Three-gun Shadow Mask Tube -

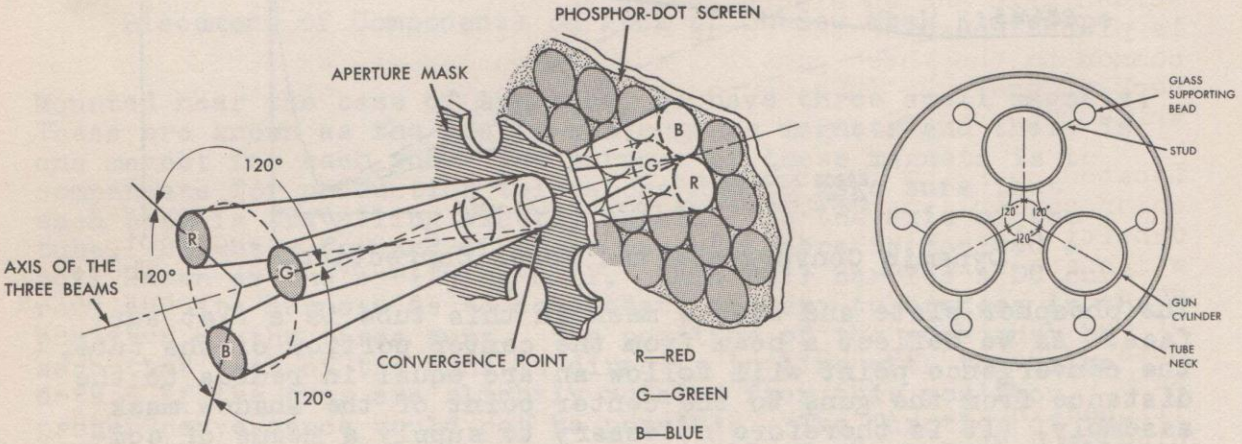
At the present time, the RCA tube of this type appears to be the one which will be used to the greatest extent in the initial stages of color television. This tube contains three identical electron guns, one for each primary color. The guns are mounted parallel to the tube axis and are spaced radially 120° from each other. Each gun has a filament and cathode, a control grid, a screen grid and an electrostatic focus grid. A convergence grid is placed ahead of the focus grid and the convergence grid is common to the three guns. The gun structure is assembled in the neck of the tube in a manner similar to that of the black and white tube.

Located near the front of the bell of the tube is a shadow mask color screen assembly. The color screen consists of a neutral density glass plate, upon which are mounted the phosphor dots which are utlized to reproduce the three primary colors. These dots are circular in shape and are approximately eight-thousandths of an inch in diameter. There are approximately 600,000 phosphor dots deposited on the glass plate. There are approximately 200,000 each of the red, green and blue phosphor dots. The dots are positioned in groups of three, with each group consisting of a red, blue, and green dot. The centers of the dots form an equilateral triangle. In front of the phosphor dots at an approximate spacing of 5/8ths inches, there is placed a shadow mask. This mask is a metal plate containing approximately 200,000 holes and is positioned so that the center of the holes are in line with a point equi-distant from the center of each dot in a group of three.



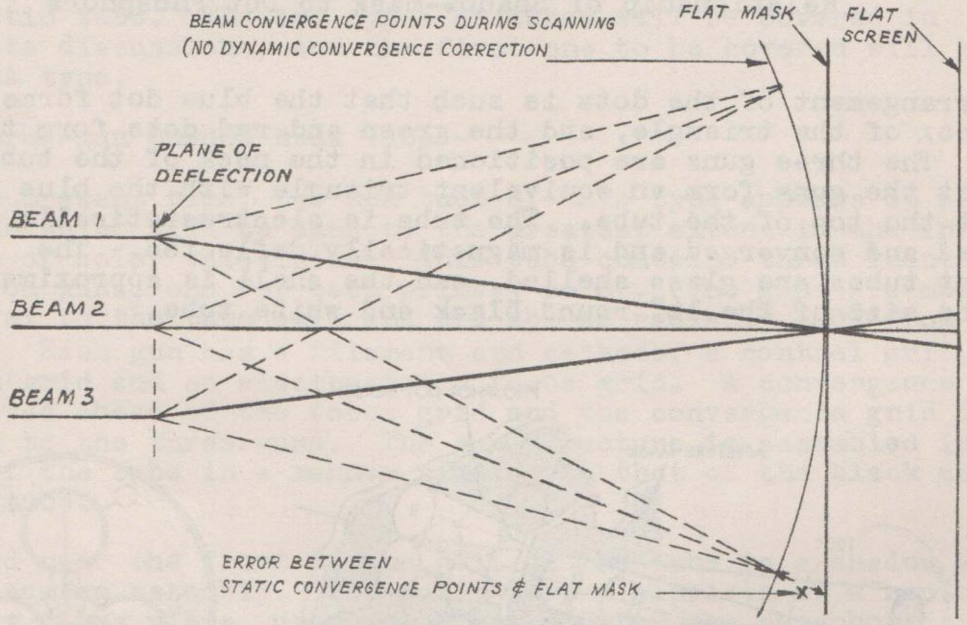
**Relationship of Shadow-mask to Dot Phosphors**

The arrangement of the dots is such that the blue dot forms the apex of the triangle, and the green and red dots form the base. The three guns are positioned in the neck of the tube so that the guns form an equivalent triangle with the blue gun at the top of the tube. The tube is electrostatically focused and converged and is magnetically deflected. The present tubes are glass shelled, and the shell is approximately the size of the 16" round black and white tube.



**Electron Beams, Shadow Mask and Phosphor Screen**

In operation, we feed the blue energy from the signal to the blue gun, the red information to the red gun, and the green information to the green gun. The beams are then directed toward the shadow mask plate. For proper operation, it is necessary that the beams strike the proper phosphor dot. This means that the three beams must be directed to a single hole on the shadow mask and must be focused on the individual dot for which each beam is intended. As the beam travels down its individual gun, the voltage between the focusing or number three grid and the convergence, or number four grid, forms an electrostatic lens which will focus the beam at the plane of the phosphor plate. At the time the beams leave the number three grids they must be travelling parallel to one another. The three beams then enter the converging grid. The voltage between the converging grid and the coating inside the bell of the tube which is connected to the second anode forms an electrostatic lens which will direct the beams so they will converge at the plane of the shadow mask. This condition of voltage will allow for proper convergence and focus in the area in the center of the shadow mask assembly.

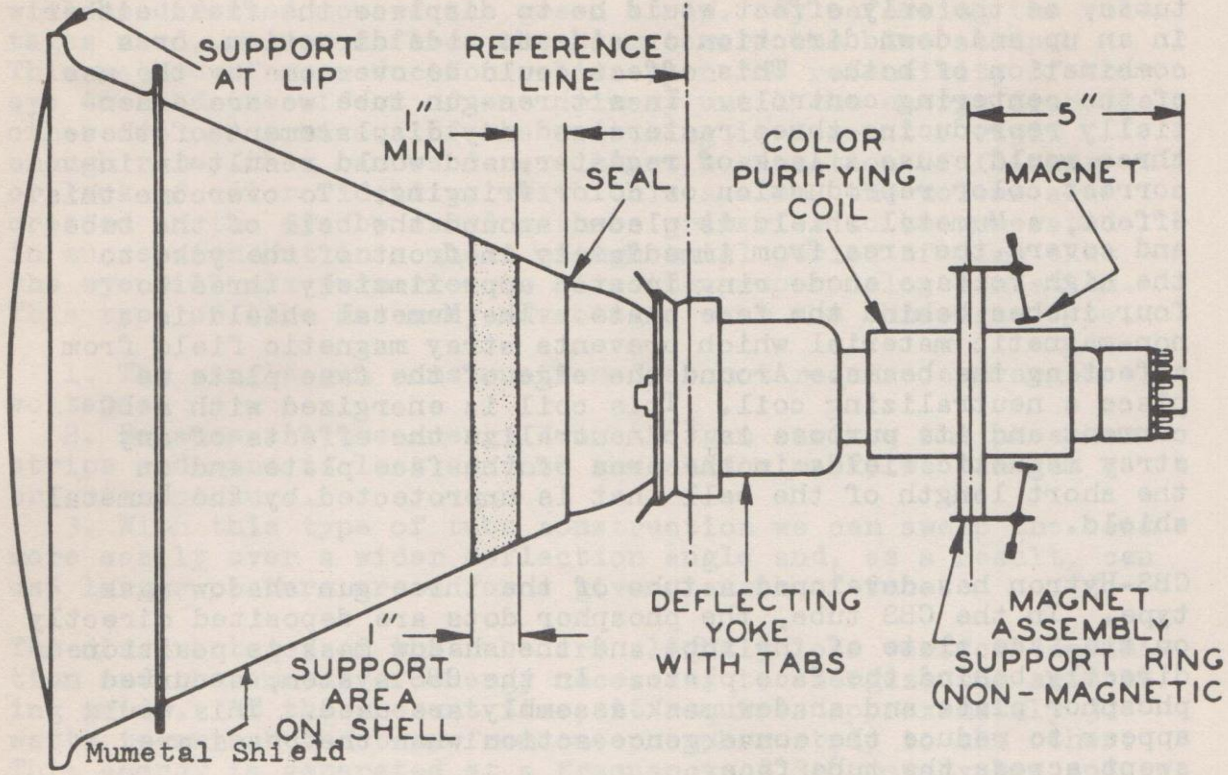


Dynamic Convergence and Focus Correction

The phosphor plate and shadow mask in this tube is a flat surface. As we deflect a beam from the center portion of the tube, the convergence point will follow an arc equal in radius to the distance from the guns to the center point of the shadow mask assembly. It is therefore necessary to supply a means of compensating both the convergence and focus voltages to compensate for this difference in distance. A voltage of proper waveform is supplied in the receiver to accomplish this and is the dynamic convergence voltage.

The components necessary for the operation of a three gun color tube are of necessity more complex than that needed for a black and white tube.

The outline of the tube and the necessary components are as shown.



Placement of Components on Neck of Shadow Mask Kinescope

Mounted near the base of the tube, we have three small magnets. These are known as the static convergence magnets and there is one magnet for each gun. The purpose of these magnets is to compensate for production tolerances and to make sure that each beam is travelling exactly parallel to the axis of the tube. Slightly forward of these magnets there is located a coil known as the purifying coil. This coil carries a DC current and its purpose is to compensate for any tolerances in the position of the three guns. The position of the guns must be such that each of the guns is directly in line with the color dots. If the guns are slightly rotated from this position, proper convergence would not be possible. The function of the purifying coil coil is then to rotate all of the beams equally so that the beam from the blue gun is exactly at the top center of the tube. The next unit mounted on the neck of the tube is that of the deflecting yoke. The function of this yoke is the same as that of the yoke in the black and white tube; however, much greater care must be exercised in its manufacture to maintain uniform fields.

The effect of the earth's magnetic field must be taken into consideration in the operation of a three gun tube. These fields do not cause any particular problem in black and white tubes, as the only effect would be to displace the field either in an up and down direction or side to side direction, or a combination of both. This effect could be overcome by the use of the centering controls. In a three-gun tube we are essentially reproducing three rasters and any displacement of these three would cause a lack of register, and would result in incorrect color reproduction or color fringing. To overcome this effect, a Mumetal shield is placed around the bell of the tube and covers the area from immediately in front of the yoke to the high voltage anode ring located approximately three to four inches behind the face plate. The Mumetal shield is a non-magnetic material which prevents stray magnetic field from affecting the beams. Around the edge of the face plate we place a neutralizing coil. This coil is energized with a DC current and its purpose is to neutralize the effects of any stray magnetic fields in the area of the face plate and on the short length of the bell that is unprotected by the Mumetal shield.

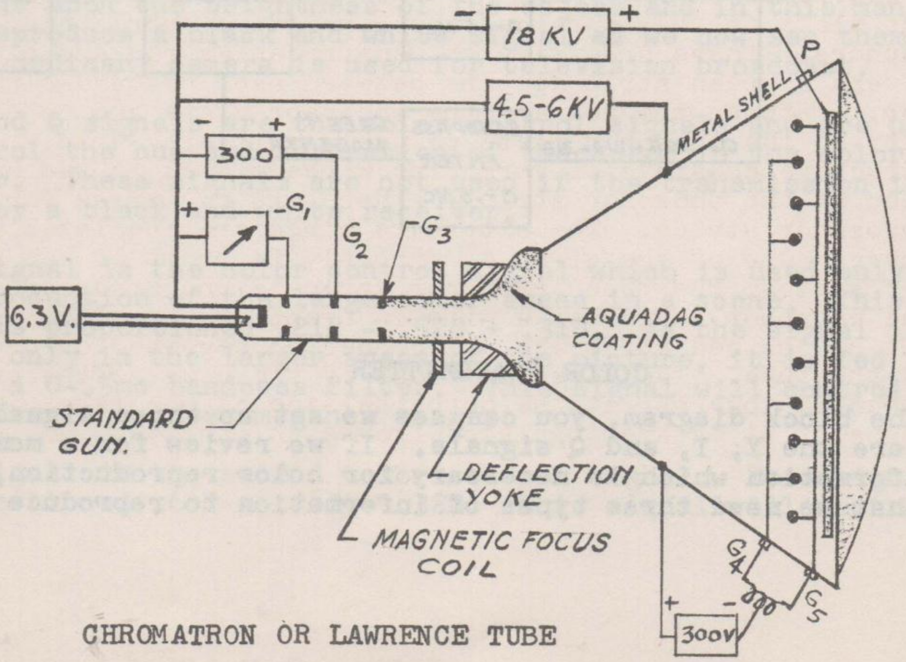
CBS-Hytron has developed a tube of the three gun shadow mask type. In the CBS tube, the phosphor dots are deposited directly on the face plate of the tube and the shadow mask is positioned directly behind the face plate. In the CBS system, a curved phosphor plate and shadow mask assembly are used. This would appear to reduce the convergence action when the beams are swept across the tube face.

The Lawrence or chromatic tube is a single gun type. The method of operation is entirely different from that of the three gun shadow mask type. In the Lawrence tube the gun structure is, in effect, that of a black and white tube in which we have a single source of energy being directed toward the face plate. The face plate on the Lawrence tube consists of horizontal strips of phosphors. There are twice as many green as red and blue strips, and a green strip appears between each red and blue phosphor. Between the gun and the phosphor plate and in close proximity to the phosphor plate we use a switching grid. The grid structure consists of very fine wires placed in the same direction as the phosphor strips. There are two wires for each three phosphor strips. The alternate wires are insulated from the others. One of the wires is directly in front of the red phosphor strips; the green phosphor strip is unobstructed and the blue phosphor strip has a wire in front of it. The wires in front of the red strip are all connected together on one side of the tube. The wires in front of the blue strips are all connected together at the opposite side of the tube. These two groups of wires are insulated from each other.

By applying a positive voltage to one wire, a negative to the other, we can cause the beam to be deflected upward to the red strip. By applying an equal voltage to each grid, the beam will be directed toward the green strip. By refersing the voltages used, we can deflect the beam toward the blue strip. This method of reproduction relies upon the retentivity of the eye to hold the effect of one primary until the energy from the other two can arrive. If the switching is done at a rapid enough rate, this can be done without a sensation of flicker or lack of color fidelity. With this system, the colors are created in the eye by causing three primaries to be generated in succession but in a short enough total period of time that the eye will mix primaries to give the proper color sensation. This type of tube has many advantages over the three-gun type.

1. The single gun construction does not require convergence voltages.
2. Because all the energy from the gun strikes the phosphor strips and none is lost against the shadow mask, we can get a brighter picture.
3. With this type of tube construction we can sweep the beam more easily over a wider deflection angle and, as a result, can use larger picture areas for a given length of tube.

The disadvantages of the tube are slightly less vertical definition and the amount of energy necessary to energize the switching grids. At the present time, it requires approximately 30 watts to switch the beam from one phosphor strip to the other. This energy is generated at a frequency of 3.6 megacycles and it causes a serious radiation problem, as the deflecting grids act as efficient radiating elements. Until this particular problem can be overcome, it appears that the three-gun type of tube, as developed by RCA, offers the most practical immediate solution for color television.



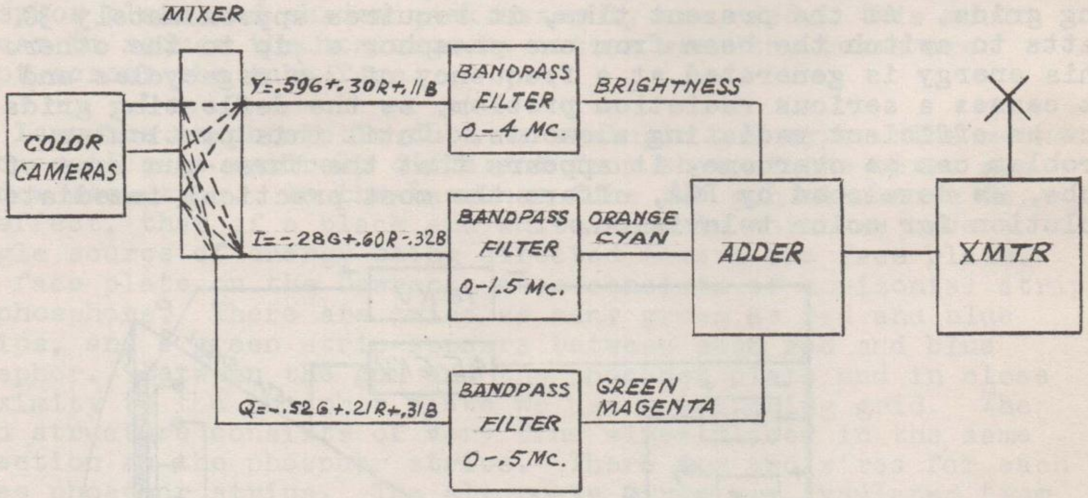
CHROMATRON OR LAWRENCE TUBE

# CHAPTER 3

## "OUTLINE OF COLOR SYSTEM"

We have studied the basic color principles and are acquainted with the requirements of color reproduction. From our knowledge of the color picture tube, we know that the construction of the tube will allow us to reproduce the primaries required to reproduce color. Before making a detailed study of the transmitter signal, and the receiver requirements, it would be an advantage to study a block diagram of the receiver and transmitter.

A color camera contains three pick-up tubes. The scene to be telecast will generate a signal in the pick-up tubes. A filter is placed in front of each camera tube so that each tube will receive only the information representing one primary color. One tube receives only the red information, another the blue, and a thrid the green. The output voltages from these tubes are adjusted to an equal amplitude when the camera is directed at a white surface. The outputs of the three cameras then go to a mixer or matrix. The matrix is a divider and polarity changing device from which we can assemble the signals which we require.



COLOR TRANSMITTER

From the block diagram, you can see we set up three signals. These are the Y, I, and Q signals. If we review for a moment the information which is necessary for color reproduction, we know that we need three types of information to reproduce a color. These are brightness, hue, and saturation. In a color system, we also have to supply a signal which can be used to reproduce a black and white picture of the color scene. This is necessary in order to satisfy the compatability requirement. We will then briefly discuss each of these signals and its function.

The Y, or luminance signal contains the information necessary for black and white picture reproduction on black and white sets, and also contains the brightness information for use in color receivers. This signal consists of a portion of the output of each of the camera tubes. The proportions are .30 red + .59 green + .11 blue. This signal adds up to a total of 1 when the camera is directed against a white scene. The figure 1 in this case represents unity and is not indicative of a value of voltage. When the cameras are directed against a white scene, the amplitude of signal in the Y channel will be equal to that of the signal at the output of each of the camera tubes. This signal will then indicate the brightness of the scene and the output signal from this channel will register differently for colors of different hues, saturation, and brightness. This will satisfy the requirement for a compatible signal. When the camera is directed at a white scene, the signal output will be maximum, and if this signal were impressed on a black and white tube, we would see white reproduced. If the camera were directed at a green scene, there would be no red or blue information in the signal and the black and white tube would produce a shade of grey which would be approximately 60% as bright as the white shade. If the camera were directed successively at a red and a blue scene, we would see shades of grey which would be approximately 30% and 11% as bright as the white. A grey object would reproduce a signal approximately half the amplitude of that produced by a white scene, and a black and white tube would reproduce this as a grey object. This signal will then reproduce a different shade of grey, dependent upon the brightness of the object and in this manner would reproduce a black and white signal as we now see them when an ordinary camera is used for television broadcast.

The I and Q signals are the color control signals and are used to control the hue and saturation of the color in the color receiver. These signals are not used if the transmission is picked by a black and white receiver.

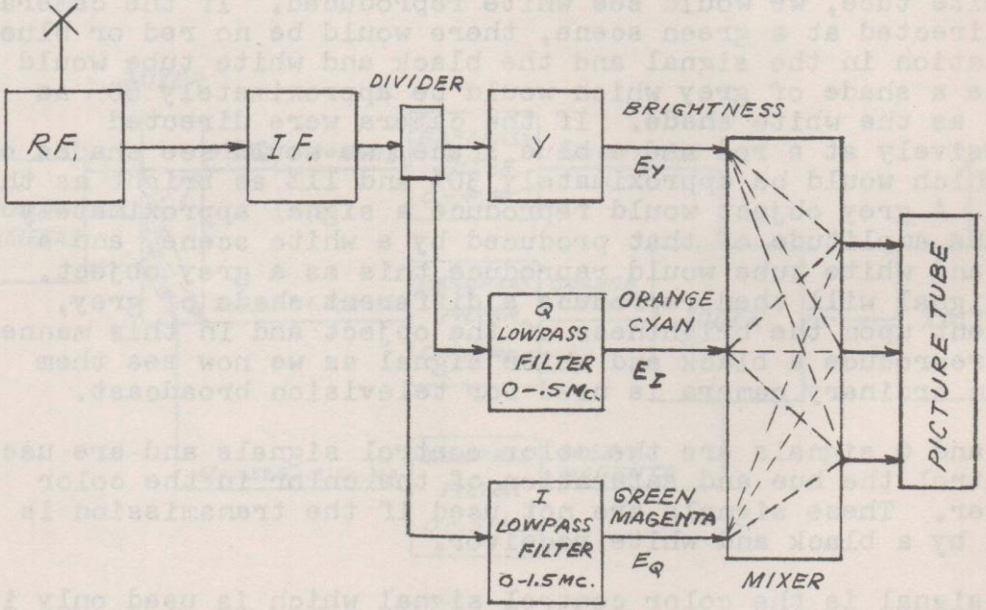
The Q signal is the color control signal which is used only in the reproduction of the large color areas in a scene. This signal is proportioned .21R - .52G + .31B. As the signal is to be used only in the larger areas of the picture, it is fed through a 0-.5mc bandpass filter. This signal will control the colors over the green-magenta range.

The I signal is the second color control signal. This signal is proportioned .60R - .28G - .32B. This signal will control colors over the range of the cyan-orange red group. The I signal is used in conjunction with the Q signal to control the colors in the large areas of the picture and is used by itself to control the colors in the small picture areas. This signal passes through a bandpass filter with range of 0 to 1.5mc.

The three signals Y, Q and I are then combined and used to modulate transmitter output. The manner in which these signals are combined is quite a complex operation and will be covered later.

When the signal is received by a black and white receiver, only the informationcontained in the Y channel will be utilized and the color control information will be cancelled out. The black and white receiver will then reproduce a picture and the viewer will be unaware of the fact that the program is a color transmission unless he has been previously informed.

When the signal is received by a color receiver, all of the information is utilized, the Y signal is used to control the brightness, and the I and Q signals control the hue and saturation of the color.



COLOR RECEIVER

The block diagram of the receiver will show that we have an RF and IF system very similar to that used in black and white receivers. The signal then enters a divider system which separates the three signals. The Y signal goes through a normal type of video circuit and this information is then fed to the three guns of the picture tube. The color control signals are handled by circuits which are additional to those required for black and white. In these circuits the two signals are separated, the Q signal is then fed through a low pass filter of 0-.5mc and the output signal properly proportioned to the picture tube guns. The I signal proceeds through a low pass filter 0-1.5mc and is properly proportioned to the picture tube guns.

The color control information is fed into a chroma control prior to the operation of separating these two signals. If the chroma control is adjusted so that no I and Q information can reach the picture tube, then the color receiver will reproduce a black and white picture. When a black and white picture is being transmitted, the I and Q signals are not reproduced and it is not therefor necessary to reduce the chroma control to a 0 position for black and white reproduction. In normal operation on a color broadcast, the position of the chroma control will determine the amount of color hue which is fed to the picture tube and will as a result determine the degree of saturation reproduced in the colors up to the limits set by the transmitted signal.

# CHAPTER 4

## NATIONAL TELEVISION SYSTEM COMMITTEE
## SIGNAL SPECIFICATION

Approved by Panel 13, July 8, 1953 and
the National Television System Committee
July 21, 1953

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### I. *General Specifications*

#### A. Channel

The color television signal and its accompanying sound signal shall be transmitted within a 6 megacycle channel.

#### B. Picture Signal Frequency

The picture signal carrier, nominally 1.25 Mc above the lower boundary of the channel, shall conform to the frequency assigned by the Federal Communications Commission for the particular station.

#### C. Polarization

The radiated signals shall be horizontally polarized.

#### D. Vestigial Sideband Transmission

Vestigial sideband transmission in accordance with Figure 2 shall be employed.

#### E. Aspect Ratio

The aspect ratio of the scanned image shall be four units horizontally to three units vertically.

#### F. Scanning and Synchronization

1. The color picture signal shall correspond to the scanning of the image at uniform velocities from left to right and from top to bottom with 525 lines per frame interlaced 2:1.

2. The horizontal scanning frequency shall be 2/455 times the color subcarrier frequency; this corresponds nominally to 15,750 cycles per second (with an actual value of 15,734.264 ± 0.047 cycles per second). The vertical scanning frequency is 2/525 times the horizontal scanning frequency: this corresponds nominally to 60 cycles per second (the actual value is 59.94 cycles per second).

3. The color television signal shall consist of color picture signals and synchronizing signals, transmitted successively and in different amplitude ranges except where the chrominance penetrates the synchronizing region, and the burst penetrates the picture region.

NTSC Signal Specification—*continued*

4. The horizontal, vertical, and color synchronizing signals shall be those specified in Figure 1, as modified by vestigial sideband transmission specified in Figure 2 and by the delay characteristic specified in III.B.

G. Out-of-Channel Radiation

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

II. *Sound*

A. Sound Signal Frequency

The frequency of the unmodulated sound carrier shall be 4.5 Mc ± 1000 cycles above the frequency actually in use for the picture carrier.

B. Sound Signal Characteristics

The sound transmission shall be by frequency modulation, with maximum deviation of ± 25 kilocycles, and with pre-emphasis in accordance with a 75 microsecond time constant.

C. Power Ratio

The effective radiated power of the aural-signal transmitter shall be not less than 50 per cent nor more than 70 per cent of the peak power of the visual signal transmitter.

III. *The Complete Color Picture Signal*

A. General Specifications

The color picture signal shall correspond to a luminance (brightness) component transmitted as amplitude modulation of the picture carrier and a simultaneous pair of chrominance (coloring) components transmitted as the amplitude modulation sidebands of a pair of suppressed subcarriers in quadrature having the common frequency relative to the picture carrier of + 3.579545 Mc ± 0.0003 per cent with a maximum rate of change not to exceed 1/10 cycle per sec per sec.

B. Delay Specification

A sine wave, introduced at those terminals of the transmitter which are normally fed the color picture signal, shall produce a radiated signal having an envelope delay, relative to the average envelope delay between 0.05 and 0.20 Mc, of zero microseconds up to a frequency of 3.0 Mc; and then linearly decreasing to 4.18 Mc so as to be equal to −0.17 μsecs at 3.58 Mc. The tolerance on the envelope delay shall be ± 0.05 μsecs at 3.58 Mc. The tolerance shall increase linearly to ± 0.1 μsec, down to 2.1 Mc, and remain at ± 0.1 μsec down to 0.2Mc*. The tolerance shall also increase linearly to ± 0.1 μsec at 4.18 Mc.

C. The Luminance Component

1. An increase in initial light intensity shall correspond to a decrease in the amplitude of the carrier envelope (negative modulation).

2. The blanking level shall be at (75 ± 2.5) per cent of the peak amplitude of the carrier envelope. The reference white (luminance) level shall be (12.5 ± 2.5) per cent of the peak carrier amplitude. The reference black level shall be separated from the blanking level by the setup interval, which shall be (7.5 ± 2.5) per cent of the video range from the blanking level to the reference white level.

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*Tolerances for the interval of 0.0 to 0.2 Mc should not be specified in the present state of the art.

NTSC Signal Specification—*continued*

3. The overall attenuation versus frequency of the luminance signal shall not exceed the value specified by the FCC for black and white transmission.

D. Equation of Complete Color Signal

1. The color picture signal has the following composition:

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

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 reference in the above equation is the phase of the (color burst + 180°), as shown in Figure 3. The burst corresponds to amplitude modulation of a continuous sine wave.

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

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

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 red, green, and blue signals during the scanning of the given picture element.

The gamma corrected voltages $E_R'$, $E_G'$, and $E_B'$ are suitable for a color picture tube having primary colors with 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 |

and having a transfer gradient (gamma exponent) of 2.2** associated with each primary color. The voltages $E_R'$, $E_G'$, and $E_B'$ may be respectively of the form $E_R^{1/\gamma}$, $E_G^{1/\gamma}$, and $E_B^{1/\gamma}$ although other forms may be used with advances in the state of the art.

$E_Q'$ and $E_I'$ are the amplitudes of two orthogonal components of the chrominance signal corresponding respectively to narrow-band and wide-band axes, as specified in paragraph D.5.

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*Forming of the high frequency portion of the monochrome signal in a different manner is permissible and may in fact be desirable in order to improve the sharpness on saturated colors.

**At the present state of the art it is considered inadvisable to set a tolerance on the value of gamma and correspondingly this portion of the specification will not be enforced.

The angular frequency $\omega$ is $2\pi$ times the frequency of the chrominance subcarrier.

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

2. The chrominance signal is so proportioned that it vanishes for the chromaticity of CIE illuminant C ($x = 0.310$, $y = 0.316$).

3. $E_Y'$, $E_Q'$, $E_I'$ and the components of these signals shall match each other in time to 0.05 $\mu$secs.

4. A sine wave of 3.58 Mc introduced at those terminals of the transmitter which are normally fed the color picture signal shall produce a radiated signal having an amplitude, (as measured with a diode on the R.F. transmission line supplying power to the antenna) which is down ($6 \pm 2$) db with respect to a radiated signal produced by a sine wave of 200 kc. In addition, the amplitude of the radiated signal shall not vary by more than ± 2 db between the modulating frequencies of 2.1 and 4.18 Mc.

5. The equivalent bandwidths assigned prior to modulation to the color-difference signals $E_Q'$ and $E_I'$ are given by Table I.

*Table I*

*Q-channel bandwidth*

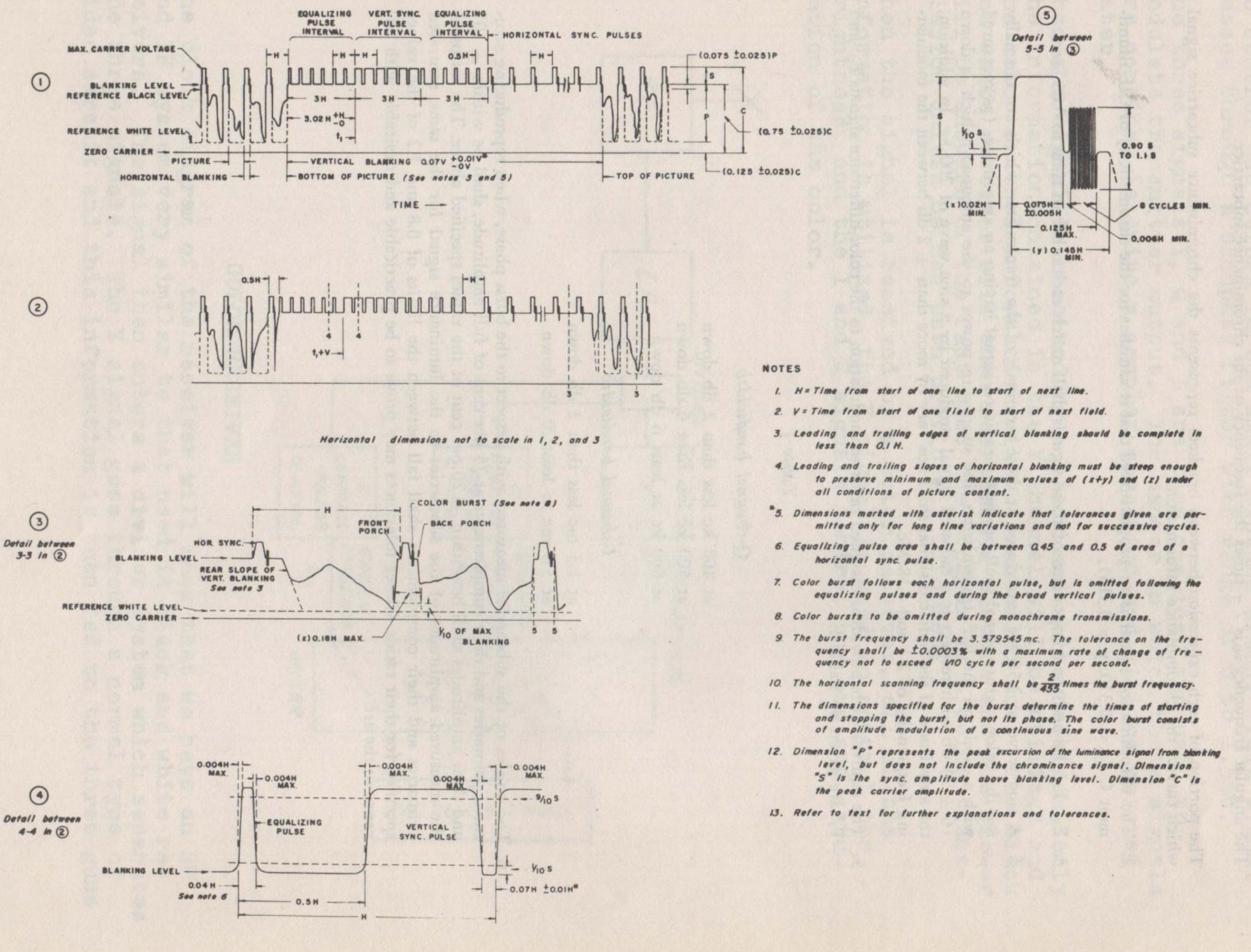
at 400 kc less than 2 db down
at 500 kc less than 6 db down
at 600 kc at least 6 db down

*I-channel bandwidth*

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

6. The angles of the subcarrier measured with respect to the burst phase, when reproducing saturated primaries and their complements at 75 per cent of full amplitude, shall be within ± 10° and their amplitudes shall be within ± 20 per cent of the values specified above. The ratios of the measured amplitudes of the subcarrier to the luminance signal for the same saturated primaries and their complements shall fall between the limits of 0.8 and 1.2 of the values specified for their ratios. Closer tolerances may prove to be practicable and desirable with advance in the art.

# TELEVISION SYNCHRONIZING WAVEFORM



*Horizontal dimensions not to scale in 1, 2, and 3*

**NOTES**

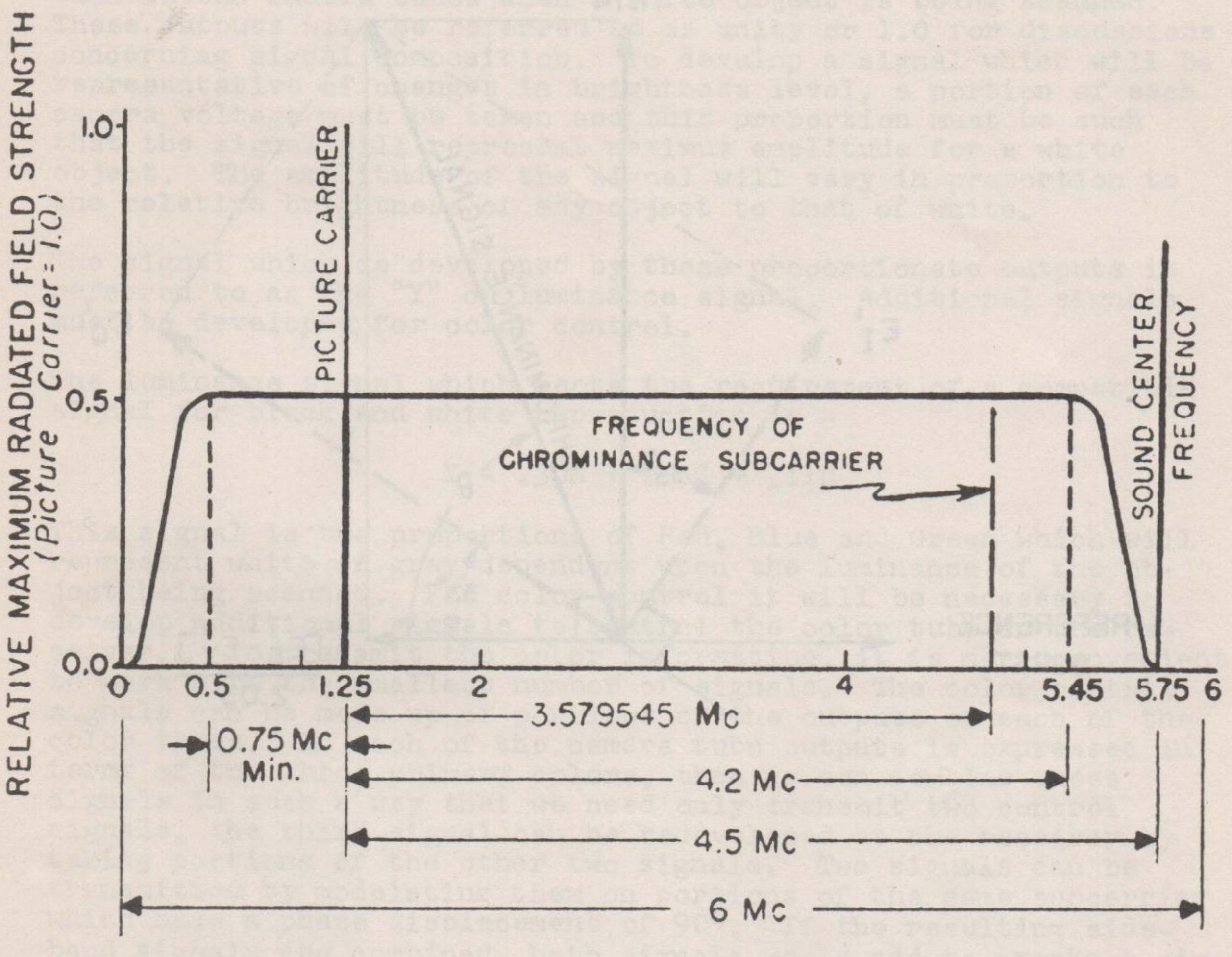
1. *H = Time from start of one line to start of next line.*
2. *V = Time from start of one field to start of next field.*
3. *Leading and trailing edges of vertical blanking should be complete in less than 0.1 H.*
4. *Leading and trailing slopes of horizontal blanking must be steep enough to preserve minimum and maximum values of (x+y) and (z) under all conditions of picture content.*

*5. *Dimensions marked with asterisk indicate that tolerances given are permitted only for long time variations and not for successive cycles.*

6. *Equalizing pulse area shall be between 0.45 and 0.5 of area of a horizontal sync. pulse.*
7. *Color burst follows each horizontal pulse, but is omitted following the equalizing pulses and during the broad vertical pulses.*
8. *Color bursts to be omitted during monochrome transmissions.*
9. *The burst frequency shall be 3.579545 mc. 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.*
10. *The horizontal scanning frequency shall be $\frac{2}{455}$ times the burst frequency.*
11. *The dimensions specified for the burst determine the times of starting and stopping the burst, but not its phase. The color burst consists of amplitude modulation of a continuous sine wave.*
12. *Dimension "P" represents the peak excursion of the luminance signal from blanking level, but does not include the chrominance signal. Dimension "S" is the sync. amplitude above blanking level. Dimension "C" is the peak carrier amplitude.*
13. *Refer to text for further explanations and tolerances.*

FIGURE I

# IDEALIZED PICTURE TRANSMISSION AMPLITUDE CHARACTERISTIC



Note: Not drawn to scale

Figure 2

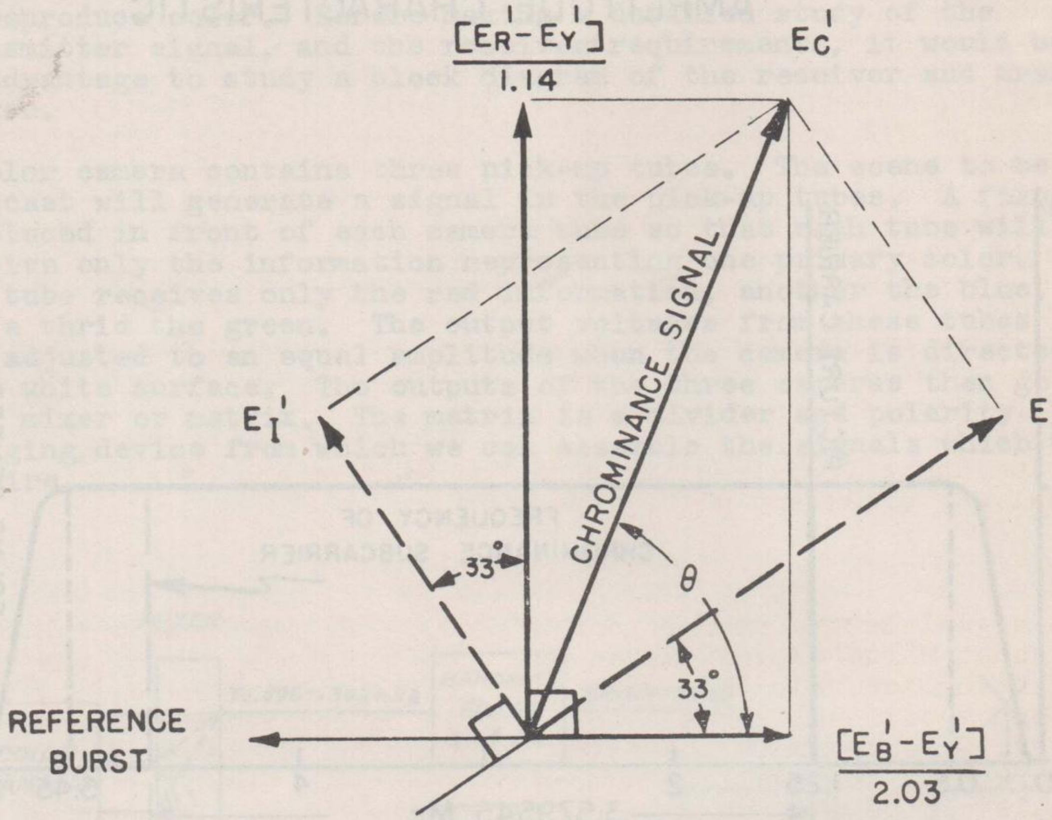

[E'R - E'Y] / 1.14
E'C
E'I
E'Q
CHROMINANCE SIGNAL
33°
θ
33°
REFERENCE BURST
[E'B - E'Y] / 2.03

FIG. 3

# CHAPTER 5

## "THE TRANSMITTER COLOR SIGNAL"

The color camera contains three color pickup tubes. The information at the output of each tube is in the form of a voltage which represents the amount of that color in the portion of the picture being scanned. The camera is adjusted to give equal output at each of the camera tubes when a white object is being scanned. These outputs will be referred to as unity or 1.0 for discussions concerning signal composition. To develop a signal which will be representative of changes in brightness level, a portion of each camera voltage must be taken and this proportion must be such that the signal will represent maximum amplitude for a white object. The amplitude of the signal will vary in proportion to the relative brightness of any object to that of white.

The signal which is developed by these proportionate outputs is referred to as the "Y" or luminance signal. Additional signals must be developed for color control.

The luminance signal which meets the requirement of a compatible signal for black and white reproduction is -

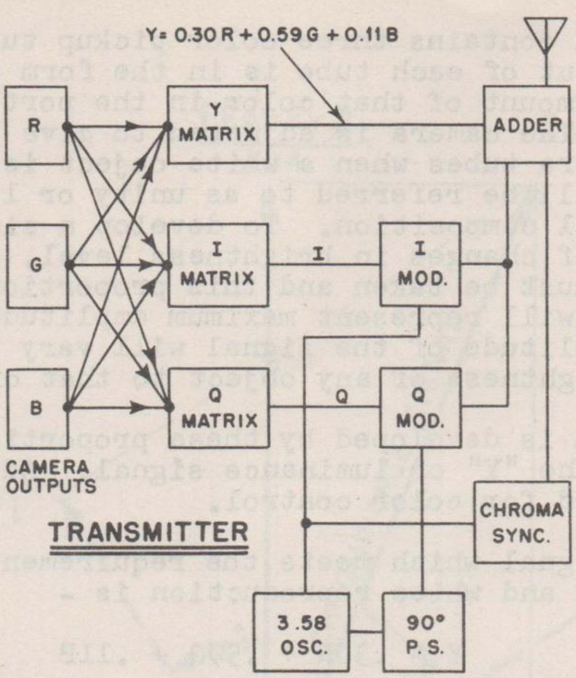
$$Y = .30R + .59G + .11B$$

This signal is the proportions of Red, Blue and Green which will represent white or gray dependent upon the luminance of the object being scanned. For color control it will be necessary to develop additional signals to control the color tube in the receiver. To transmit the color information, it is more convenient to work with the smallest number of signals. The color control signals can be made up of portions of the outputs of each of the color tubes. If each of the camera tube outputs is expressed in terms of the three primary colors, then we can combine these signals in such a way that we need only transmit two control signals, the third signal can be redeveloped at the receiver by taking portions of the other two signals. Two signals can be transmitted by modulating them on portions of the same subcarrier which have a phase displacement of 90°. If the resulting sideband signals are combined, both signals would add to create a signal which would vary in amplitude and phase. This resultant sideband is then used to modulate the picture carrier of the transmitter just as any video signal. Two proportionate amounts of the camera outputs were developed which would satisfy the requirements of being able to produce the three primary colors for full reproduction of color in the large picture areas and for two-color reproduction in the small picture areas. These signals are called the I and Q signals, and their proportions of the camera outputs are -

$$Q \quad - .52G + .21R + .31B$$

$$I \quad - .28G + .60R - .32B$$

The Q signal is transmitted only over a frequency range of 0 - .5 megacycles and the I signal is transmitted over a range of 0 - 1.5 megacycles.



The requirement for the transmission of the Y, I and Q signals would seem to be that of 6 megacycles wide. As this space is not available, further study of the black and white system would have to be made in order to determine how this could be accomplished.

One of the requirements of the color signal is that it must be compatible. This means that the signal must be capable of reproducing a black and white picture on a monochrome set without the need of readjustment or redesign on any of the components. A review of the factors which must be retained for compatible performance shows -

a. The picture and sound signals must be contained within a 6 megacycle frequency allocation.

b. The equalizing and sync pulses for sync control must be retained.

c. The picture carrier frequency shall be 1.25 megacycles from the lower frequency limit of the 6 megacycle allocation.

d. The sound frequency must be 4.5 megacycles above the picture frequency.

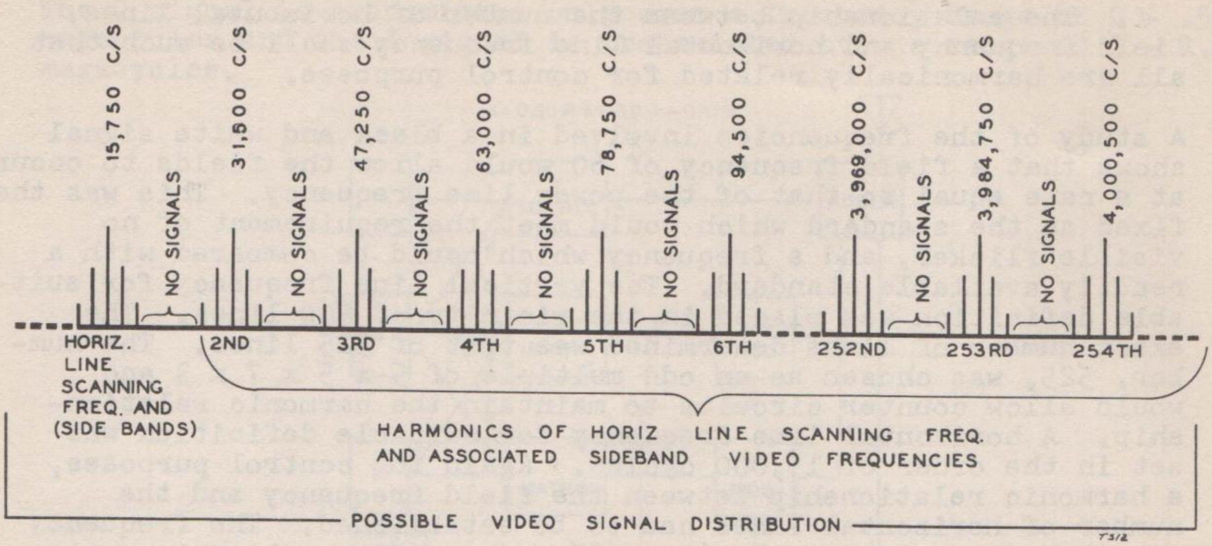
e. The video information should be contained within a 4 megacycle band to minimize interference between video and sound sideband frequencies.

f. The relationship between the number of horizontal lines, field frequency and horizontal line frequency shall be such that all are harmonically related for control purposes.

A study of the frequencies involved in a black and white signal shows that a field frequency of 60 would allow the fields to occur at a rate equal to that of the power line frequency. This was then fixed as the standard which would meet the requirement of no visible flicker, and a frequency which could be compared with a readily available standard. The vertical line frequency for suitable definition was placed in the vicinity of 500 lines. The exact number of lines determined was that of 525 lines. The number, 525, was chosen as an odd multiple of 5 x 5 x 7 x 3 and would allow counter circuits to maintain the harmonic relationship. A horizontal line frequency for suitable definition was set in the order of 15,000 cycles. Again for control purposes, a harmonic relationship between the field frequency and the number of horizontal lines had to be established. The frequency was then determined to be 60 x 525 ÷ 2. This resulted in a line frequency of 15,750 as the horizontal line frequency.

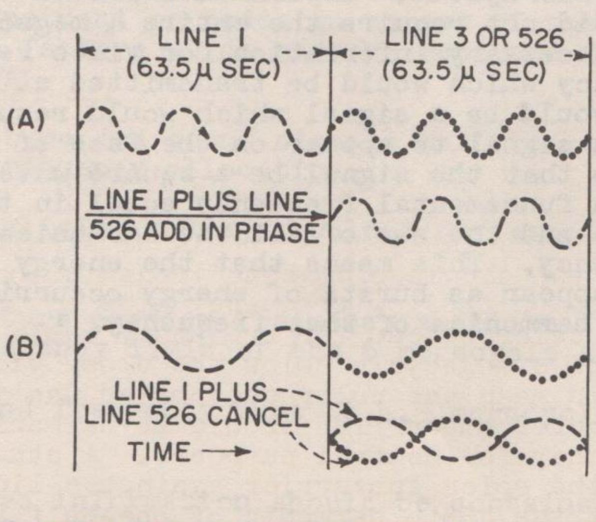
These frequencies could be maintained within very close limits if synchronized with an automatically controlled power line, and the power line could be used as a common sync standard between film transmission and broadcast station sync requirements or as a standard between transmissions originating from two stations. Power companies with automatic regulation can maintain their frequency within .1 CPS. This is equivalent to .16% variation. The sync circuits in a receiver could be designed to handle this range of variation without need of readjustment.

To transmit a color signal within the limits defined for black and white transmission would appear to present an impossible task. The problem was that of transmitting 6 megacycles of information through a 4 megacycle system. Experiments proved that a black and white signal did not require the entire 4 megacycle band to transmit all the necessary information for video reproduction. The lowest frequency which would be transmitted at a line frequency of 15,750 would be a signal which would result in an all white or all black signal to appear on the face of the tube. This would require that the signal be a square wave. A square wave consists of a fundamental frequency equal in time duration to the square wave and the sum of all the harmonics of this fundamental frequency. This means that the energy in a 4 megacycle band would appear as bursts of energy occurring at the line frequency or harmonics of that frequency.



Disposition of Video Information in a Black and White Signal

A further study of the black and white signal showed that the only energy appearing in the video signal which was not a harmonic of the line frequency was random energy. When this energy consisted of frequencies which were odd harmonics of one-half the line frequency, the signals would cancel out on the face of the picture tube in each successive field. A signal which is an odd harmonic of one-half the line frequency would cause a positive signal to appear on the first line of any frame. This energy would appear as a negative signal on the first line of the following frame. The effect on the eye would be that of representing an average change in brightness of zero. The interference or energy appearing at this frequency would not be visible to a viewer.



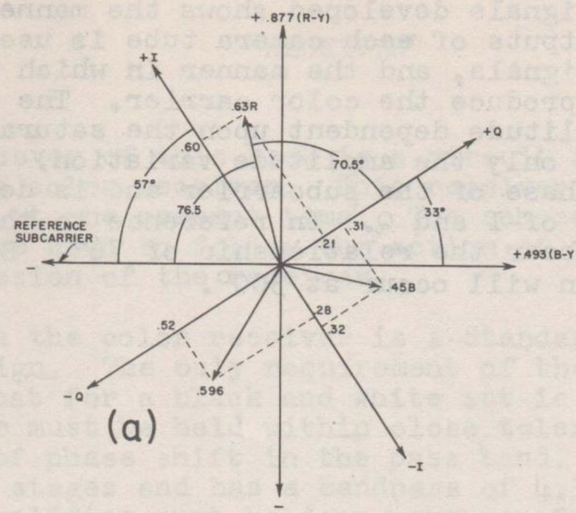
Cancellation of coloring information: (A) even harmonics of half line frequency reinforce each other on successive scanning of same line; (B) odd harmonics cancel out

Discovery of the fact that the energy was contained in bunches at harmonics of the line frequency showed that there was available a considerable amount of unused space in the 4 mc. pass band. It was then evident that these spaces could be used to insert additional information without utilizing additional pass band width. The chrominance or color information could be inserted in the areas between the black and white information and both signals could then be transported within a frequency pass band which would meet the requirement for black and white signals. If this signal were used to modulate a frequency whose harmonics would fall between the harmonics of the line frequency, then the information could be combined with the black and white information without causing interference. The next consideration was that of determining the frequency to be used to accomplish this purpose. Several factors had to be taken into consideration in determining the frequency.

The frequency should be maintained at the highest possible value in order to minimize picture degradation caused by the beat frequency resulting from the picture carrier frequency and the color subcarrier frequency. If the subcarrier frequency is made as high as possible, the beat frequency between the color subcarrier and the picture carrier frequency would be high. This would result in a high frequency beat which would cause a very fine beat pattern to appear in the picture and would be the least visible. The higher the subcarrier frequency, the lower beat frequency between the subcarrier and the sound frequency. This pattern would be at a relatively low frequency and would, therefore, be visible in the picture. If the beat pattern between the color subcarrier and the sound carrier could be caused to appear at an odd multiple of the line frequency, this interference pattern could be made to cancel out. The approximate location of the color subcarrier was determined by the space requirements of the color information and the maximum bandpass which could be utilized for video use. It was determined that a bandpass of 4.2 mc. could be used without causing interference between the video information and the side bands of the sound transmission. The requirement for the large color areas was that we be able to transmit a color signal from 0 - .5 mc. The requirement for the smaller color areas was that we be able to transmit information on a 0 - 1.5 mc. range. In order to keep the color subcarrier high it was decided that the low frequency color information could be transmitted with double side band modulation, and the information for the small areas would be single side band transmission. If the single side band transmission were made to place the side band on the low frequency side of the color subcarrier, then the color subcarrier frequency could be placed at approximately .6 of a megacycle below the upper video range of 4.2 mc. This would mean the color subcarrier was in the vicinity of 3.6 mcs. The color subcarrier should be harmonically related to the line frequency for control purposes. A study of the approximate location of the color subcarrier against a line frequency of 15,750 showed that the 455th harmonic of one-half the line frequency gave a number which was easily handled through counter

control equipment, the factors of 455 being 5 x 7 x 13. This calculation showed that one-half the line frequency or 7875 cycles x 455 gave a color subcarrier frequency of 3.583125 mcs. The beat frequency between the color subcarrier and the sound carrier at 4.5 mcs. shows that this frequency would fall at approximately .92 mcs. This beat frequency was to be positioned to fall between the burst of the monochrome information in order that the cancellation effect of the interference beat could be achieved. The closest odd multiple of one-half the line frequency showed that this separation should be .921375 mcs. This separation added to the color subcarrier frequency meant that the sound frequency would be 4.5045 mcs. This meant that the sound frequency would have to be moved 4500 cycles from the present standard. Examination of a number of receivers which had been built showed that this much deviation would result in unsatisfactory performance of receivers now in the field. It was therefore necessary to reduce all the frequencies by the percentage necessary to restore the sound frequency to 4.5 mcs. This percentage is .1%. This resulted in a burst frequency of 3.579545 mcs. In order to retain the harmonic relationship between all the frequencies involved, it meant that the line frequency would now have to be changed and be set at 15,734+ and the vertical scanning frequency at $\frac{2}{525}$ x the horizontal scanning frequency. This means that the field frequency had to be set at 59.94 CPS. This deviation is less than the per cent deviation now encountered in power company regulation. The deviation could then be tolerated, as it would not require modification of any of the vertical or horizontal circuits within present black and white receivers.

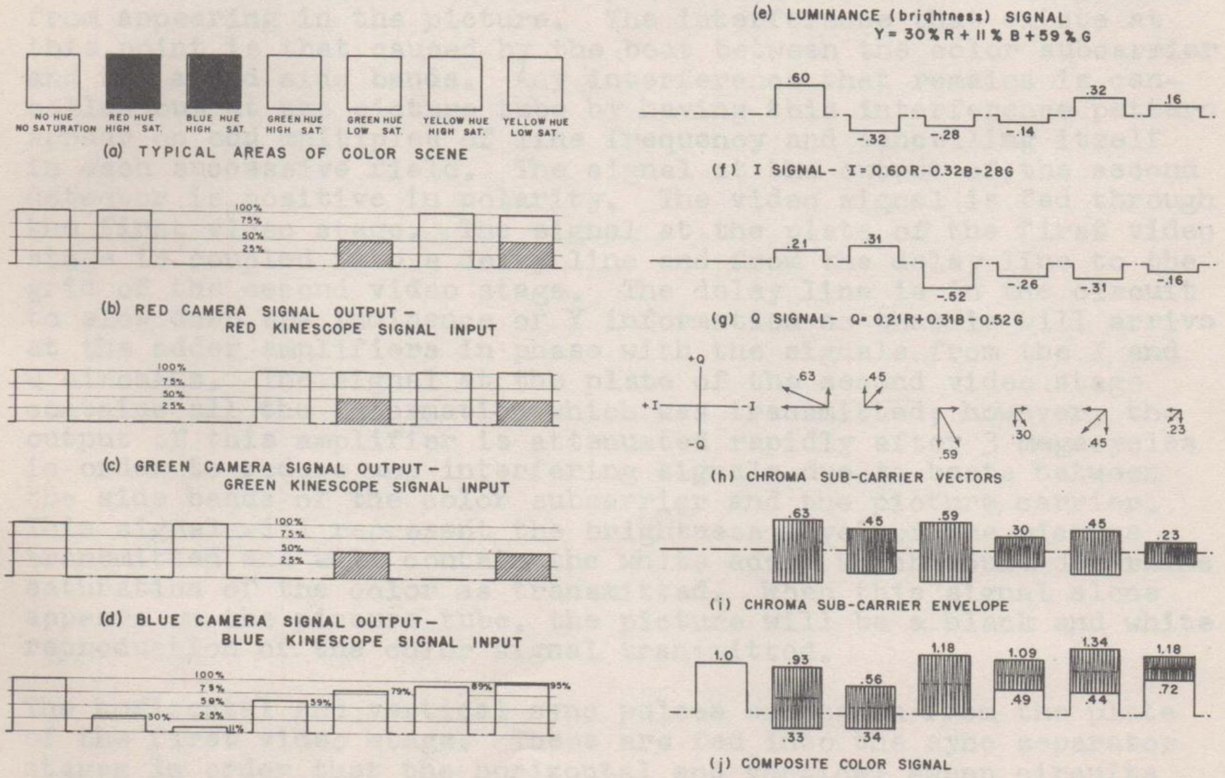
The color control signals are used to modulate the color subcarrier. The two color subcarriers are added vectorially, and the resultant signal will vary in amplitude in direct proportion to the saturation of the colors. The phase of the side bands of the color subcarrier will determine the hue. If this information is to be used to reproduce the correct colors in the receiver, then the signals must be demodulated with a signal which is synchronized with one on the transmitter. A portion of the color subcarrier is transmitted during the blanking time. This signal appears on the back porch of the blanking pulse. The signal consists of 8 to 11 cycles of the subcarrier and its use is to synchronize the decoding circuits in the receiver with the modulator in the transmitter. The reference point throughout the system is the 0° point of the color subcarrier. The phase relationship of the I and Q signals to this point is shown in the following sketch.



(a)

**The signals shown in this vector diagram indicate only phase displacements. They are not displaced in time.**

**The signals developed at the transmitter and their relationship to one another can be shown graphically.**



(a) TYPICAL AREAS OF COLOR SCENE

(b) RED CAMERA SIGNAL OUTPUT – RED KINESCOPE SIGNAL INPUT

(c) GREEN CAMERA SIGNAL OUTPUT – GREEN KINESCOPE SIGNAL INPUT

(d) BLUE CAMERA SIGNAL OUTPUT – BLUE KINESCOPE SIGNAL INPUT

(e) LUMINANCE (brightness) SIGNAL Y = 30% R + 11% B + 59% G

(f) I SIGNAL– I = 0.60R–0.32B–28G

(g) Q SIGNAL– Q = 0.21R+0.31B–0.52G

(h) CHROMA SUB-CARRIER VECTORS

(i) CHROMA SUB-CARRIER ENVELOPE

(j) COMPOSITE COLOR SIGNAL

**Evolution of the Composite Color Signal**

A study of the signals developed shows the manner in which the proportionate outputs of each camera tube is used to develop the Y, I and Q signals, and the manner in which these signals are combined to produce the color carrier. The chroma subcarrier will vary in amplitude dependent upon the saturation of the colors. This charg shows only the amplitude variation. The hue is controlled by the phase of the subcarrier and is dependent upon the relationship of I and Q. In reference to the color bursts, red will always bear the relationship of 76°. Blue will occur at 193° and green will occur at 300°.

# CHAPTER 6

## "RECEIVER"

Inside the back cover of this book is a circuit diagram of the prototype Hoffman color receiver. This receiver represents the circuitry in use at the present time. The schematic in the back of the book can be used to follow the action of the signals during the discussion of the receiver.

The tuner used in the color receiver is a Standard Coil Tuner of conventional design. The only requirement of the tuner that is different than that for a black and white set is that the alignment of the tuner must be held within close tolerance to minimize any possibility of phase shift in the pass band. The IF amplifier consists of five stages and has a bandpass of 4.3 mcs. The alignment of the IF amplifier must be done very carefully in order that phase shift does not occur. If any phase shift occurs in the IF stages, this can cause lack of color balance of the picture tube and incorrect color reproduction. Five stages are necessary in the IF strip in order to insure adequate gain at a wide bandpass. The final stage of the IF amplifier feeds into the video second detector and to the input of the sound amplifiers. The sound is taken off in the final IF stage ahead of the second detector in order to minimize interference between the sound carrier and the color subcarrier and to prevent this interference pattern from appearing in the picture. The interference that exists at this point is that caused by the beat between the color subcarrier and the sound side bands. Any interference that remains is cancelled out at the picture tube by having this interference pattern appear on odd multiples of line frequency and cancelling itself in each successive field. The signal at the output of the second detector is positive in polarity. The video signal is fed through the first video stage. The signal at the plate of the first video stage is coupled into a delay line and from the delay line to the grid of the second video stage. The delay line is in the circuit to slow down the luminance of Y information so that it will arrive at the adder amplifiers in phase with the signals from the I and Q circuits. The signal at the plate of the second video stage contains all the information which was transmitted; however, the output of this amplifier is attenuated rapidly after 3 megacycles in order to reduce any interfering signals due to beats between the side bands of the color subcarrier and the picture carrier. This signal will represent the brightness level of the picture transmitted and will contain the white adder which would determine saturation of the color as transmitted. When this signal alone appears on the picture tube, the picture will be a black and white reproduction of the color signal transmitted.

The horizontal and vertical sync pulses are taken from the plate of the first video stage. These are fed into the sync separator stages in order that the horizontal and vertical sweep circuits can be controlled. The amplitude of the sync pulses are also used to control the gated AGC circuit.

Color control information is taken from the first video stage. The color burst which is located immediately behind horizontal sync pulse is taken from a winding on T114 and supplied to the grid of the burst amplifier. This signal is used to establish the phase relationship between the color subcarrier from the transmitter and a similar oscillator in the receiver. In order to demodulate the color signals, we must have an oscillator in the receiver running at exactly the same frequency as the oscillator at the transmitter. For this we use a crystal control oscillator shown in V131B. It is also necessary that this oscillator be exactly in phase with the transmitter oscillator. A signal is taken from the 3.58 megacycle oscillator and this is fed into the color phasing amplifier. The output of this oscillator is fed to the two halves of the phase detector. The control color burst signal which appears at the grid of the burst amplifier is amplified and coupled to the phase detector through T122. Phase relationship between the color burst signal which appears on the phase detector and the portion of the signal from the receiver oscillator is 90°. When this condition exists, there is no dc difference at the center tap of the secondary T122. However, if the two voltages are at a different phase, a difference in voltage will exist at this point and will change the control grid voltage on V131A, the reactance tube. The reactance tube acts as a variable capacitor and will change the frequency of the receiver oscillator and cause it to speed up or slow down a sufficient amount to be in proper phase with the color burst signal. The color burst amplifier operates only during the time of horizontal blanking. A pulse is taken from the horizontal output transformer T117 and applied to the cathode of this tube. The stage is made inoperative during the rest of the time, to prevent any other signals from affecting the 3.58 megacycle oscillator. The killer tube is used to make the chroma circuits inoperative when no chroma signal is being transmitted. When a black and white signal is being transmitted there will be no color burst signal fed into the burst amplifier. Under this condition, the killer tube would conduct and develop a bias on the grid of the bandpass amplifier sufficient to keep this amplifier at cut-off. When the color burst is present, the killer tube is cut off and the bandpass amplifier can operate.

The chroma signal is taken from the cathode of the first video stage. From there it goes to ghe grid of the bandpass amplifier. This bandpass amplifier is designed to pass only the chroma information and will pass the frequencies between 2.1 megacycles and 4.2 megacycles. This amplifier is cut off during the retrace time. A negative pulse is applied to the screen grid from the horizontal output transformer. If this amplifier were not cut off, the color burst signal would pass through the circuit and might result in yellow retrace lines appearing in the picture tube.

The chroma signal from the output of the bandpass amplifier is fed into the control grids of the Q and I demodulators. From the cathode of the 3.58 megacycle oscillator a signal is taken and supplied to the suppressor grid of the I demodulator. Another signal is taken from the cathode and fed through the quadrature amplifier. This signal is displaced 90° from the oscillator frequency and is supplied to the suppressor grid of the Q demodulator. The demodulators are balanced demodulators and in the output of the Q demodulator will appear the Q information which was inserted at the transmitter plus the I information above .5 megacycles. A bandpass filter is used to cut off all information above .5 of a megacycle and only the Q signal will remain. At the output of the I demodulator only the I information will appear. This is fed through a bandpass amplifier with a range of 0 - 1.5 megacycles. The signal amplitude at this point will only be half the amplitude of the Q signal. This difference is caused by the fact that only one side band of the I information was transmitted. The signal is then amplified and fed to the phase inverter circuit.

The three signals which were generated in the transmitter can now be reproduced and applied to the picture tube adder circuits. The luminance signal is fed in equal amounts to each of the three amplifiers. The I and Q signals are fed in the proper polarity and amplitudes to equal that of the proportions present in the transmitted signal. This is done through the matrixing circuit. The resistors in this circuit are proportioned to give the right amount of each signal.

The adder amplifiers are used to assure that the right amount of signal will appear at the picture tube to compensate for differences in phosphor efficiency. The red phosphor normally requires slightly more drive. Therefore, the green and blue amplifiers are equipped with gain controls so that the outputs of these circuits can be reduced the required amount.

The high voltage circuit of the receiver is designed to maintain a closely regulated second anode voltage. Once the receiver has been set up, a variation in second anode voltage can result in incorrect color reproduction. It is possible for the picture tube to require as much as 800 micro-amps, and the regulation of the supply must be such that the high voltage will remain steady over a range of 0 to 800 micro-amps. High voltage regulator tubes have been developed which will handle the voltages required. The second anode voltage is normally in the vicinity of 19kv.

A voltage is taken from the cathode of the horizontal output tube and this is fed through the transformers T115 and T116. Another voltage is taken from the cathode of the vertical output transformer. This signal is amplified and fed into the primaries of the same two transformers. From the secondaries of these transformers a composite voltage is fed to the picture tube focus elements and to the picture tube convergence elements. These wave forms are shaped and the amplitude adjusted to that necessary to compensate for any convergence errors due to the use of a flat picture surface.

The setup of the picture tube will differ with various receivers. The general order in which the adjustments are made after the tube has been physically mounted in the receiver is first, the linearity and size adjustments are made. This is done with the chroma control in an "off" position. Next, the high voltage is adjusted. This is done to maintain a constant voltage with both minimum and maximum settings of the brightness control. The purity adjustments are made followed by adjustments of the red, blue and green screen voltages. The convergence adjustment is the next in order and it is necessary to use a dot generator for this adjustment. The dot generator allows you to reproduce white dots on the face of the tube and these can be separated to show the three primary colors. The static dc and vertical and horizontal dynamic convergences are adjusted using the dot generator. The next adjustment is that of adjusting the screen to a white surface. The adder amplifiers are then adjusted to give the correct highlights. The background control is adjusted to give the correct reproduction of low light levels.

# GLOSSARY Of Color Television Terms

**Aperture Plate** — Refer to Shadow Mask.

**Brightness** — The attribute of visual perception in accordance with which an area appears to emit more or less light, ranging from black to maximum white.

**Brightness Signal** — That part of the composite color signal wave which has the major control of the luminance of the color picture, and which controls the luminance of the picture produced by a conventional black and white receiver.

**Burst** — A synchronizing signal composed of eight (8) cycles of color subcarrier frequency (added to the horizontal blanking pedestal) for synchronizing the color carrier oscillator in the color receiver with the color carrier oscillator at the transmitter.

**Chroma** — The characterization of a color quality without reference to its brilliance or hue (saturation only)

**Chrominance** — Reference to color quality without reference to its brilliance (hue and saturation)

**Chrominance Signal** — The sidebands of the modulated color subcarrier which are added to the black and white signal to convey color information.

**CIE** — Committee Internationale d'Eclairage (French: International Commission of Illumination)

**Color Edging** — Spurious color at the boundaries of differently colored areas in the picture.

**Color Gamut** — A restricted range of hues and saturations in the color spectrum.

**Colorimetry** — The study of color.

**Color Subcarrier** — The carrier whose modulation sidebands are added to the black and white signal to convey color information.

**Color Sync Signal** — See Burst.

**Color Transmission** — In television the transmission of a signal wave for controlling both the luminance and chrominance values in a picture.

**Compatibility** — The nature of a color television system which permits normal black and white reception of the color transmission by typical unaltered black and white receivers designed for standard black and white reception.

**Composite Color Signal** — The color signal, including blanking, luminance and chrominance intelligence, and all synchronizing signals.

**Constant Luminance Transmission** — A method of color transmission in which the chrominance signal controls the chromaticity of the produced image without affecting the luminance, the luminance being controlled by the brightness signal.

**Convergence** — The meeting and crossover of the three electron beams of the tri-color kinescope at a common point on the shadow mask.

**Crosstalk** — Distortion of a desired signal caused by the presence of an undesired signal. In color television this might be caused by reaction between the chrominance signal and the high frequency brightness signal.

**D.C. Convergence** — The correction necessary to adjust the paths of the three electron beams in a tri-color kinescope so that they meet at a common point at the center of the shadow mask.

**Demodulation** — The process by which the original intelligence is obtained from a modulated radio wave.

**Dynamic Convergence** — The correction necessary to adjust the paths of the three electron beams in a tri-color kinescope so that they meet at a common point as they are deflected over the entire area of the shadow mask.

**Hue** — May be defined as *Dominant Wavelength.* The attribute of colors that permits them to be separated into groups designated by such terms as red, green, blue, yellow, purple, and etc. The word *color* is often considered synonymous with *hue*.

**ICI** — International Commission of Illumination.

**I Phase** — A carrier phase separated by 57° from the color subcarrier (sometimes referred to as the in-phase carrier).

ICW – A 3.58 MC continuous wave signal having I phase. Generally restricted to reference to the receiver local oscillator (3.58 MC) and associated circuits.

I SIGNAL – The sidebands produced by modulating the I phase carrier. The modulating signal is defined by NTSC standards as: $I = 0.60R - 0.28G - 0.32B$.

LUMINANCE – Standardized brightness.

LUMINANCE SIGNAL – Refer to Brightness Signal.

MATRIX – A device consisting of an array of components whose values are so chosen that selected percentages of input signals are combined to form the desired output signal.

MU-METAL SHIELD – A high permeability metal shield placed around the bell of the tri-color kinescope to prevent stray magnetic fields from disrupting the paths of the electrons beams.

NTSC – National Television System Committee.

PHOSPHOR SCREEN – An integral part of the tri-color kinescope: a glass plate having deposited upon one surface an orderly array of small phosphor dots which, upon electron bombardment in correct sequence and intensity, will produce the visible effects of television.

PHOSPHOR TRIO – Closely spaced phosphor dots, arranged in triangular groups accurately deposited in interlaced positions on the phosphor screen of the tri-color kinescope. Each trio consists of a green-emitting dot, a red-emitting dot and a blue-emitting dot.

PURITY – Complete saturation, freedom from white.

Q PHASE – A color television signal carrier phase separated by 147° from the color subcarrier (sometimes referred to as the quadrature carrier).

Q SIGNAL – The sidebands produced by modulating the Q phase carrier. The modulating signal is defined by NTSC standards as: $Q = 0.21R - 0.52G + 0.31\,B$.

QCW – A 3.58 MC continuous wave signal having Q phase. Generally restricted to reference to the receiver local oscillator (3.58 MC) and associated circuits.

REACTANCE TUBE – Generally a pentode type – in principle, a variable reactance may be produced at the plate of the tube by varying DC bias on the grid. The type of reactance (inductive or capacitive) produced at the plate is dependent upon the signal bias applied from grid to cathode (capacitive voltage at the cathode produces inductive reactance at the plate).

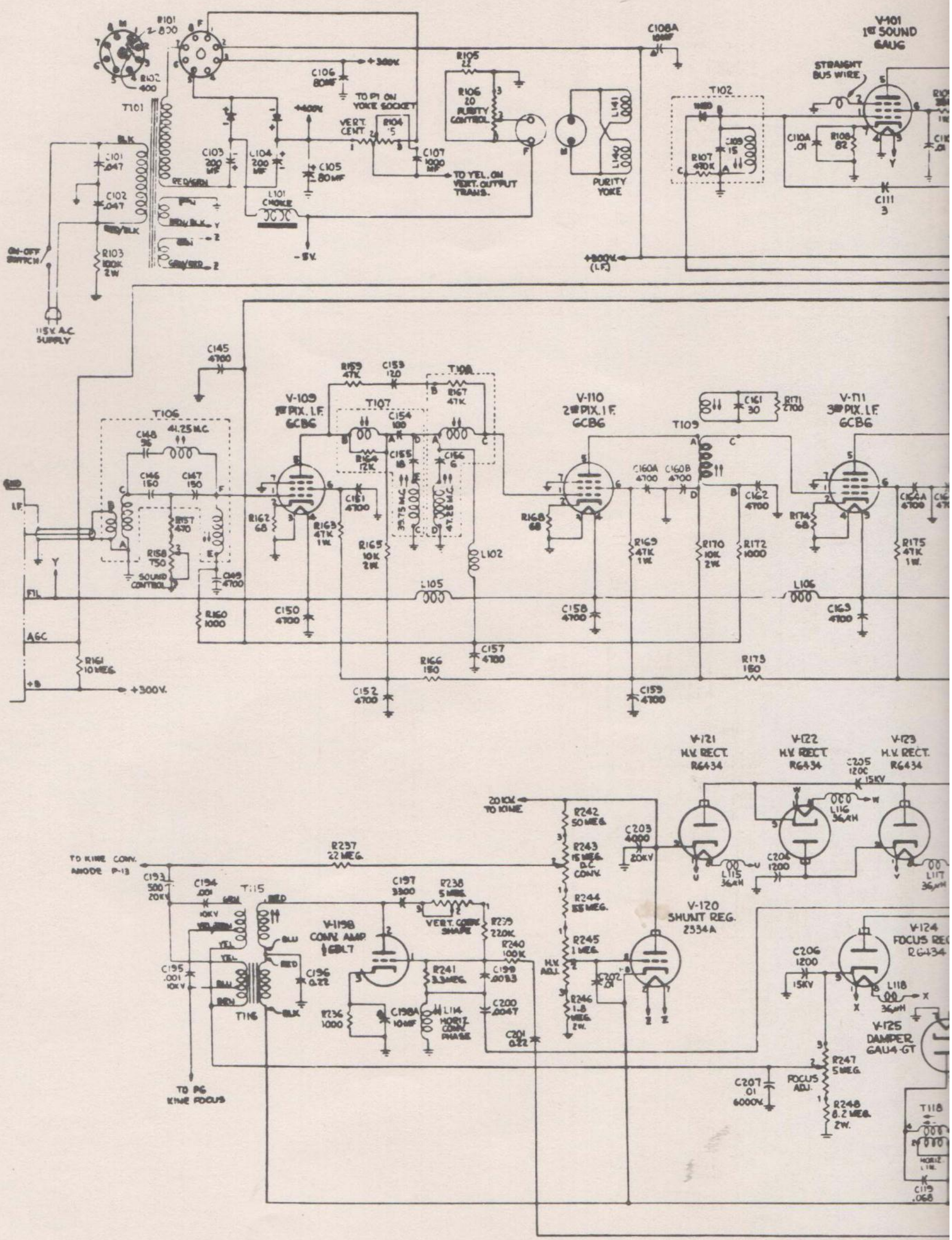
SATURATION – The "vividness" of a color described by such terms as pale, deep, pastel, vivid and etc. May be defined as *chromatic purity*.

SHADOW MASK – A metal mask directly behind the phosphor screen in a tri-color kinescope having openings through which the phosphor trios of the screen are bombarded by electron beams.

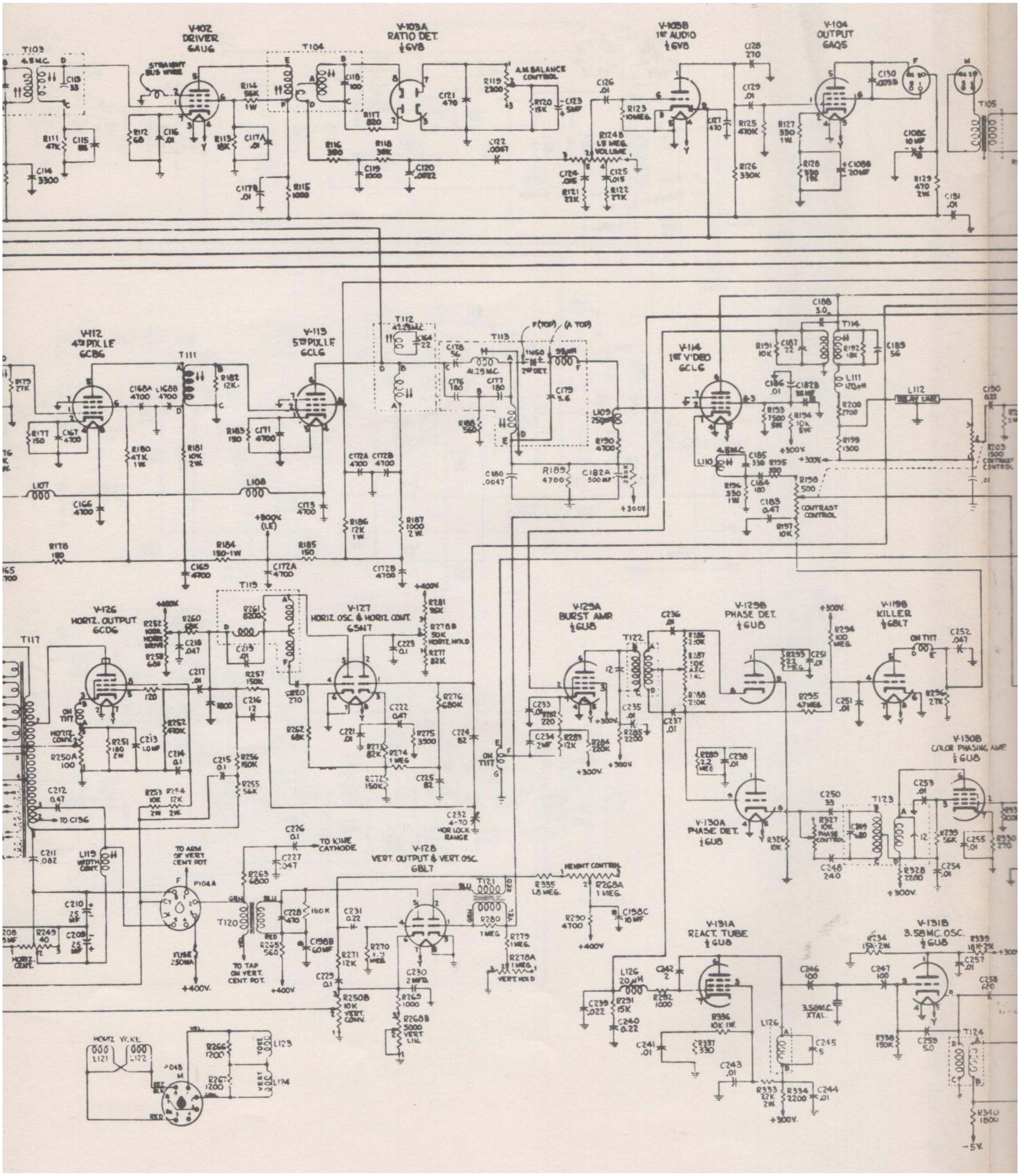
SYNCHRONOUS DETECTION – A phase sensitive process of detecting amplitude variations of a single phase from a multi-phase modulated carrier.

V.S.W.R. – Voltage Standing Wave Ratio.

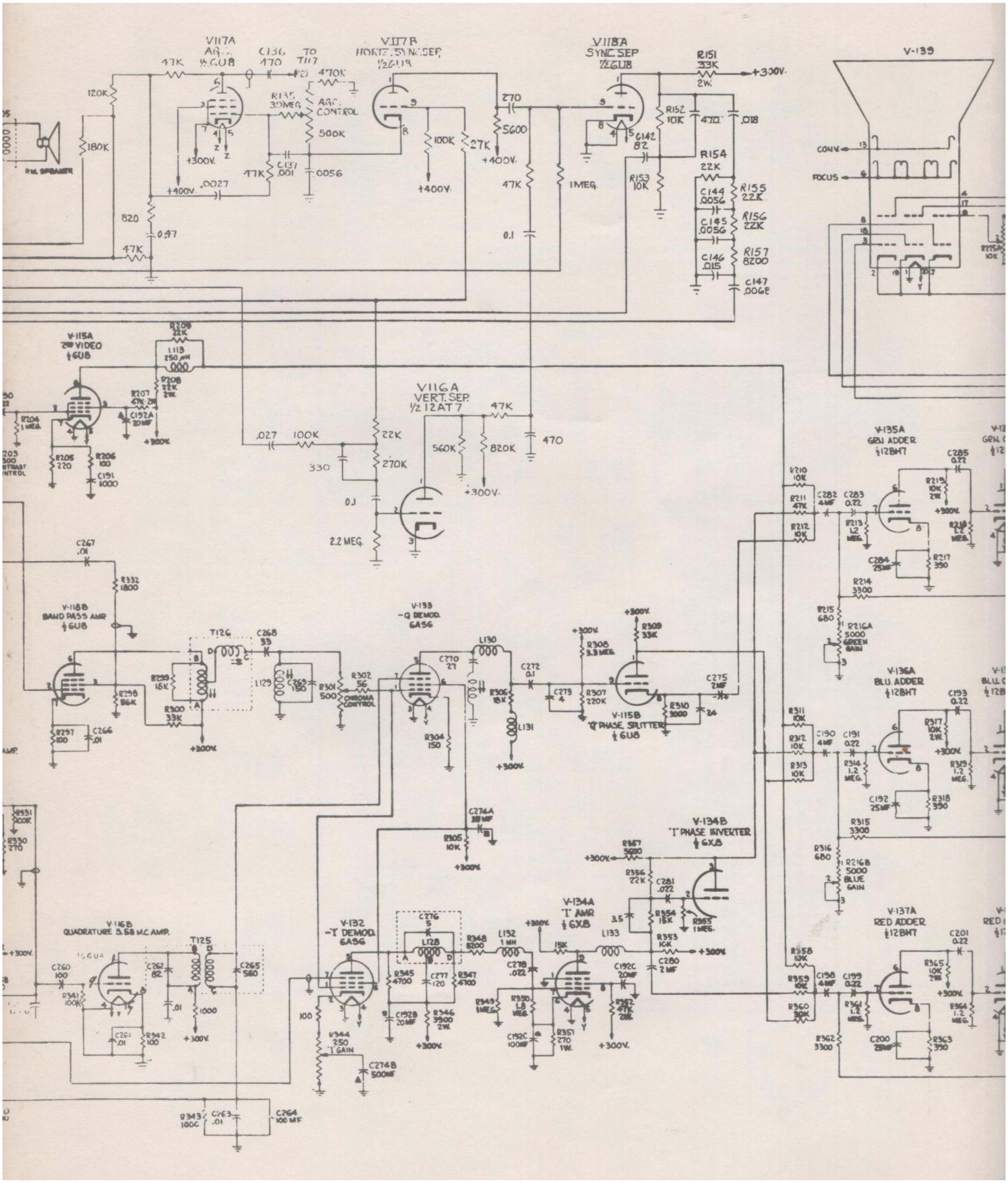
Y SIGNAL – Refer to Brightness Signal.



R101 2-800
R102 400
T101
BLK
C101 .047
C102 .047
RED/GRN
RED/BLK
ON-OFF SWITCH
R103 100K 2W
115V. A.C. SUPPLY
C103 200 MF
L104 200 MF
L101 CHOKE
-5V.
C106 80MF
+300V.
+400V.
TO P1 ON YOKE SOCKET
VERT. CENT.
R104 15
C105 80MF
C107 1000 MF
TO YEL. ON VERT. OUTPUT TRANS.
R105 22
R106 20 PURITY CONTROL
L141
L142
PURITY YOKE
C108A 100MF
+300V. (LF.)
T102
R107 470K
C109 15
C110A .01
R108 82
C111 3
STRAIGHT BUS WIRE
V-101 1ST SOUND 6AU6
C145 4700
T106
C148 56
41.25 M.C.
C146 150
C147 150
R157 470
R158 750 SOUND CONTROL
C149 4700
R160 1000
I.F.
FIL.
AGC
R161 10 MEG.
+B
+300V.
V-109 1ST PIX. I.F. 6CB6
R162 68
C150 4700
R159 47K
C153 120
T107
C154 100
R164 12K
C155 18
39.75 M.C.
C151 4700
R163 47K 1W.
R165 10K 2W.
C152 4700
R166 150
T108
R167 47K
C156 6
47.25 M.C.
L102
L105
C157 4700
V-110 2ND PIX. I.F. 6CB6
R168 68
C158 4700
C160A 4700
C160B 4700
R169 47K 1W.
C159 4700
T109
C161 30
R171 2700
R170 10K 2W.
R172 1000
C162 4700
R173 150
L106
V-111 3RD PIX. I.F. 6CB6
R174 68
C163 4700
C164A 4700
R175 47K 1W.
V-121 H.V. RECT. R6434
V-122 H.V. RECT. R6434
V-123 H.V. RECT. R6434
C205 1200 15KV
L116 36μH
L115 36μH
L117 36μH
C204 1200
20KV. TO KINE
R242 50 MEG.
C203 4000 20KV
R243 15 MEG. D.C. CONV.
R244 55 MEG.
R245 1 MEG. H.V. ADJ.
R246 1.8 MEG. 2W.
V-120 SHUNT REG. 2334A
C202 .01
TO KINE CONV. ANODE P-13
R237 22 MEG.
C193 500 20KV
C194 .001 10KV
T115
C197 3300
R238 5 MEG. VERT. CONV. SHAPE
R239 220K
R240 100K
V-115B CONV. AMP. ½6BL7
C196 0.22
C195 .001 10KV
T116
R241 3.3MEG.
C199 .0033
C200 .0047
L114 HORIZ. CONV. PHASE
C198A 10MF
R236 1000
C201 0.22
TO P6 KINE FOCUS
C206 1200 15KV
V-124 FOCUS REC R6434
L118 36μH
V-125 DAMPER 6AU4-GT
R247 5 MEG FOCUS ADJ.
R248 8.2 MEG. 2W.
C207 .01 6000V.
T118 HORIZ. LIN.
C119 .068

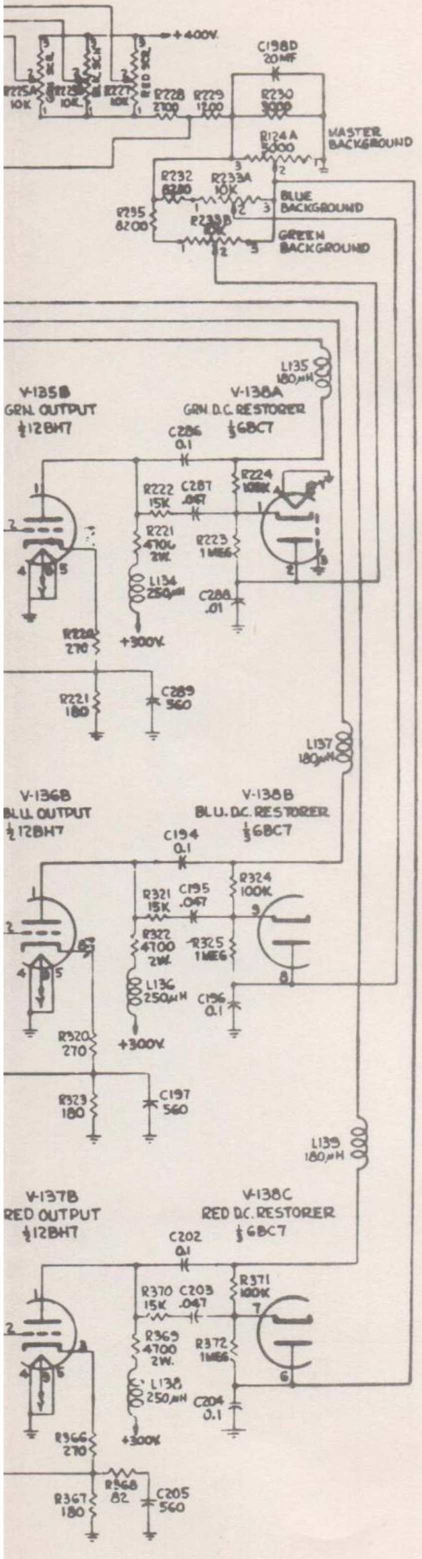


T103
4.5M.C.
V-102
DRIVER
6AU6
STRAIGHT BUS WIRE
T104
V-103A
RATIO DET.
½6V8
AMBALANCE CONTROL
V-103B
1ST AUDIO
½6V8
V-104
OUTPUT
6AQ5
T105
R124B
1.8 MEG.
VOLUME
V-112
4TH PIX I.F.
6CB6
T111
V-113
5TH PIX I.F.
6CL6
T112
42.25M.C.
T113
41.25 M.C.
1N60
2ND DET.
F (TOP)
(A TOP)
+300V. (LE)
V-114
1ST VIDEO
6CL6
T114
L112
DELAY LINE
4.5M.C.
R203
1500
CONTRAST CONTROL
R198
500
CONTRAST CONTROL
T117
V-126
HORIZ. OUTPUT
6CD6
HORIZ. CONV.
T119
V-127
HORIZ. OSC. & HORIZ. CONT.
6SN7
R278B
50K
HORIZ. HOLD
C232
4-70
HOR LOCK RANGE
V-129A
BURST AMP.
½6U8
T122
V-129B
PHASE DET.
½6U8
V-119B
KILLER
½6BL7
V-130B
COLOR PHASING AMP.
½6U8
V-130A
PHASE DET.
½6U8
T123
R327
10K
PHASE CONTROL
L119
WIDTH CONT.
TO C136
TO ARM OF VERT. CENT. POT
P104A
FUSE
250MA
TO KINE CATHODE
V-128
VERT. OUTPUT & VERT. OSC.
6BL7
T121
T120
TO TAP ON VERT. CENT. POT.
HEIGHT CONTROL
R268A
1 MEG.
R278A
1 MEG.
VERT HOLD
HORIZ. CENT.
R250B
10K
VERT. CONV.
R268B
5000
VERT. LIN.
+400V.
+300V.
V-131A
REACT. TUBE
½6U8
L126
3.58M.C.
XTAL.
V-131B
3.58 M.C. OSC.
½6U8
T124
R340
1800
-5V.
HORIZ. YOKE
L121
L122
P04B
YOKE
VERT
L123
L124



V117A
AGC
½ 6U8
C136
470
TO
T117
470K
120K
47K
180K
P.M. SPEAKER
R135
3.3 MEG
AGC. CONTROL
500K
+300V.
C137
.001
.0056
+400V.
.0027
47K
820
0.47
V117B
HORIZ. SYNC. SEP.
½ 6U8
100K
27K
+400V.
270
5600
47K
0.1
1MEG.
V118A
SYNC. SEP
½ 6U8
R151
33K
2W.
+300V.
R152
10K
470
.018
C142
82
R153
10K
R154
22K
C144
.0056
R155
22K
C145
.0056
R156
22K
C146
.015
R157
8200
C147
.0068
V-139
CONV.
FOCUS
R225A
10K
V-115A
2ND VIDEO
½ 6U8
R209
22K
L113
250 µH
R208
22K
2W.
R207
47K
C192A
20MF
R204
1 MEG.
R205
220
R206
100
C191
1000
R203
500
CONTRAST CONTROL
+300V.
V116A
VERT. SEP.
½ 12AT7
47K
560K
820K
470
.027
100K
22K
330
270K
0.1
2.2 MEG.
+300V.
V-135A
GRN ADDER
½ 12BH7
C285
0.22
R210
10K
R211
47K
R212
10K
C282
4MF
C283
0.22
R213
1.2 MEG.
R219
10K
2W.
R218
1.2 MEG.
C284
25MF
R217
390
R214
3300
R215
680
R216A
5000
GREEN GAIN
C267
.01
R332
1800
V-118B
BAND PASS AMP
½ 6U8
T126
C268
33
R299
15K
L129
C269
150
R301
500
CHROMA CONTROL
R302
56
R298
56K
R300
33K
R297
100
C266
.01
+300V.
V-133
-Q DEMOD.
6AS6
C270
27
L130
R306
18K
L131
R304
150
C272
0.1
C273
4
R308
3.3 MEG.
R307
220K
R309
33K
V-115B
'Q' PHASE SPLITTER
½ 6U8
R310
3000
C275
2MF
24
V-136A
BLU. ADDER
½ 12BH7
C193
0.22
R311
10K
R312
10K
R313
10K
C190
4MF
C191
0.22
R314
1.2 MEG.
R317
10K
2W.
R319
1.2 MEG.
C192
25MF
R318
390
R315
3300
R316
680
R216B
5000
BLUE GAIN
R331
100K
R330
270
C274A
25MF
R305
10K
+300V.
V-134B
'I' PHASE INVERTER
½ 6X8
R357
5600
R356
22K
C281
.022
R354
15K
R355
1MEG.
3.5
V-116B
QUADRATURE 3.58 MC AMP.
½ 6U8
T125
C260
100
C262
82
C265
560
R341
100K
.01
1000
C261
.01
R342
100
+300V.
V-132
-'I' DEMOD.
6AS6
C276
5
L128
R348
8200
L132
1 MH
R345
4700
C277
120
R347
4700
C192B
20MF
R346
3900
2W.
100
R344
250
'I' GAIN
C274B
500MF
V-134A
'I' AMP.
½ 6X8
L133
15K
R353
10K
C280
2MF
C278
.022
R349
1MEG.
R350
1.8 MEG.
C192C
20MF
R352
47K
2W.
C192C
100MF
R351
270
1W.
+300V.
V-137A
RED ADDER
½ 12BH7
C201
0.22
R358
10K
R359
10K
R360
10K
C198
4MF
C199
0.22
R361
1.2 MEG.
R365
10K
2W.
R364
1.2 MEG.
C200
25MF
R363
390
R362
3300
R343
1000
C263
.01
C264
100 MF

7


+400V.
C198D
20MF
R225A
10K
R226
10K
R227
10K
RED SCR.
R228
2700
R229
1200
R230
3000
R124A
5000
MASTER BACKGROUND
R232
8200
R233A
10K
BLUE BACKGROUND
R235
8200
R233B
10K
GREEN BACKGROUND
L135
180μH
V-135B
GRN. OUTPUT
½12BH7
V-138A
GRN. D.C. RESTORER
⅓6BC7
C286
0.1
R222
15K
C287
.047
R224
100K
R221
4700
2W.
R223
1MEG
L134
250μH
C288
.01
+300V.
R220
270
R221
180
C289
560
L137
180μH
V-136B
BLU. OUTPUT
½12BH7
V-138B
BLU. D.C. RESTORER
⅓6BC7
C194
0.1
R321
15K
C195
.047
R324
100K
R322
4700
2W.
R325
1MEG
L136
250μH
C196
0.1
+300V.
R320
270
R323
180
C197
560
L139
180μH
V-137B
RED OUTPUT
½12BH7
V-138C
RED D.C. RESTORER
⅓6BC7
C202
0.1
R370
15K
C203
.047
R371
100K
R369
4700
2W.
R372
1MEG
L138
250μH
C204
0.1
+300V.
R366
270
R368
82
R367
180
C205
560