Hoffman
EASY-VISION*
television

COLOR SCHOOL
February 1954

Conducted by the HOFFMAN SALES CORP.
OF MISSOURI

N.T.S.C. Committee

On Dec. 18, 1953, the F.C.C. approved a system of color television known as the N.T.S.C. system. N.T.S.C. stands for National Television Systems Committee. The N.T.S.C. Committee was formed to arrive at a system of compatible color. With the assistance of the entire television industry, the Committee eventually presented an acceptable compatible system of color to the F.C.C.

Compatible Television

A compatible system of color is one whereby a transmitted color signal can be received by a black and white receiver and the picture reproduced in black and white. Compatible television further means that a transmitted black and white signal can be received by a color receiver and the picture reproduced in black and white. Compatibility also means that a color receiver will reproduce a color picture if it receives a color signal and will reproduce a black and white picture if it receives a black and white signal.

The present black and white receiver need not be changed in any way to receive the color signal. No special antennas or converters are needed. The color receiver of the N.T.S.C. design automatically switches from a color reproduction of a color signal to a black and white reproduction of a black and white signal. No manual adjustments are required in the switching.

Review of the Black and White Picture Tube

Except for the picture tube, neither black and white or color television would be possible. In the black and white tube, an electron beam is fired from an electron gun and strikes a black phosphor screen. The phosphor glows and emits white light upon being struck by the beam. The beam is scanned across the phosphor in both a horizontal and vertical direction at the same time. The speed of the scanning is such as to give the effect of a completely lighted screen. The video signal paints the black and white picture by simply varying the brightness of the spot as it moves. Maximum beam intensity paints details of white; lesser beam intensities paints shades of gray, and minimum beam intensities paints shades of dark grays or blacks. It is obvious therefore that the black and white signal contains only information of brightness. The black and white tube need only reproduce shades of white.

Some Requirements of the Color Tube

The color tube by comparison with black and white has the seemingly impossible task of reproducing a picture in full color utilizing almost every color in the spectrum. There are at least three types of color tubes available at this writing that will accomplish this end. The most advanced of these tubes at this time is the RCA and we will therefore use the RCA tube in the discussion of N.T.S.C. color.

Most of us remember from school days that various mixtures of three primary colors will produce almost every color in the spectrum. Mixtures of paints differ from mixtures of light sources but again only three primary colors of light are needed to produce the spectrum. The three colors utilized in the RCA tube are green, red, and blue. These colors are painted on the screen of the tube in the form of phosphor dots.

Dot Arrangement - Viewed Outside Tube

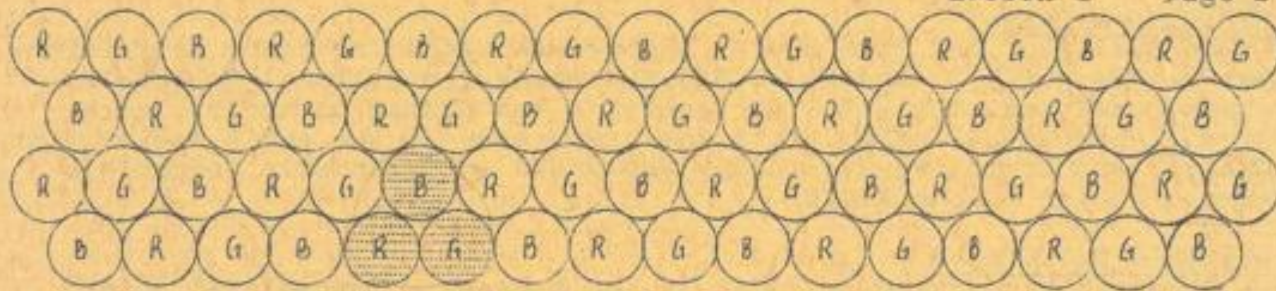


FIG 1

Note in Fig 1 the relationship of the three colors of phosphor dots. This triangle arrangment of the red, blue, and green dots holds true all over the screen of the color tube. The N.T.S.C. system of color requires some 600,000 total dots with 200,000 being red, 200,000 being green, and 200,000 being red. It should be pointed out that none of these dots have any color until they are struck with an electron beam. In other words, each is black until lighted with a beam. This fact is instrumental in the reproduction of a black and white picture on the color screen. Each phosphor dot produces it's respective color when struck with an electron beam.

Three beams of electrons rather than one scan the phosphor dots of the RCA tube. A considerable amount of work is being done on single gun tubes but at the present time, the three beam RCA tube is the most successful. The three beams scan the phosphor dots in the same way and at the same rate as the single beam of the black and white tube. The vertical scan frequency remains at 60 cps and the horizontal frequency at 15,750 cps. The arrangment of the three beams in the RCA tube is such as to allow only one beam to strike the red dots; one beam to strike the green dots; and the third beam strike the blue dots. An off-color picture is reproduced if one or more of the beams strike the wrong dots.

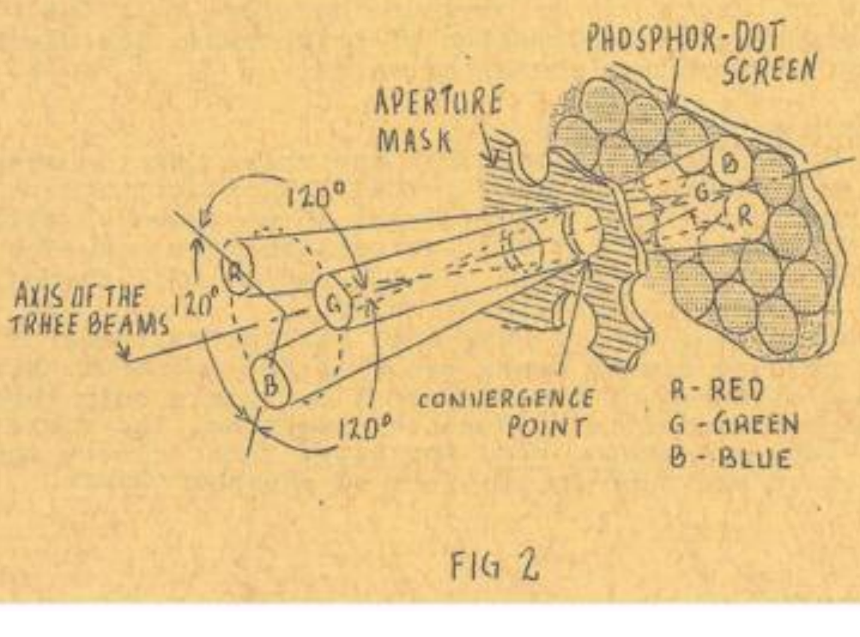


FIG 2

With three beams scanning the phosphor dots, it would be impossible to cause any one of the three beams to strike only one color of phosphor dots without some sort of mask to block the other two beams. Note in Fig 2 that a shadow mask is arranged behind the phosphor dots. This mask is sometimes called an aperture mask since it consists of nothing more or less than a metal plate with a pattern of holes in it. The metal plate is very effective in blocking electron beams. The mask contains 200,000 holes and each hole is positioned such as to allow the three beams to pass through and strike the three dots. There is one hole for each of the triangles of phosphor dots. It is apparent in Fig 2 that the shadow mask insures that the beams strike only their respective phosphor dots. It is also apparent that each of the three beams is assigned one color of phosphor dots.

Note in Fig 2 that the three beams converge at the mask such as to cause the total diameter of the three beams to be equal to the diameter of any of the three. An improper adjustment of any of the three beams might cause only part of one of the beams to pass through the mask hole. Let's assume that the red beam is slightly high with respect to the hole. This being true, only part of the red beam will pass through and light the red phosphor dot. The light intensity from the red dot will be something less than what it should be. Also, with the red beam slightly high, the red beam will strike a portion of the blue phosphor dot generating some blue light. The net result of this condition would be an off-color detail and therefore an off-color picture.

One of the most important jobs of the technician is the job of adjusting convergence. A centering ring or magnet is used on present black and white tubes to position the single beam on the screen. It is not at all important that the black and white beam be exactly positioned on the screen since all the adjustment does is move the picture either horizontally or vertically or both. Three centering mags. are used on the RCA color tube. Each mag. serves to adjust it's beam independent of the other two. Convergence is enjoyed when the three beams are in the proper relationship to each other and pass through the holes in the shadow mask without striking the mask. It is most important that the technician have Fig 2 imprinted in his mind. It is important in many ways other than the understanding and adjustment of convergence.

Some Fundamentals of Color

It has been pointed out that in black and white receivers, we are concerned only with the brightness of a white source of light. In considering colors other than white, we are concerned with factors other than the brightness of the colors. For example, the light from a red phosphor dot has hue, saturation, and brightness. In everyday language, hue means red and saturation means how-red. Considering two sources of red light, one might be a deep red and the other a light red. The brightness of the two light sources may be equal or different. The term brightness refers to the intensity of the red light source just as it does to the white light source from a black and white receiver. Do not confuse the brightness of the red light with either the term hue or the term saturation. A light red source might have either more or less brightness than a deep red source.

FIG 3a

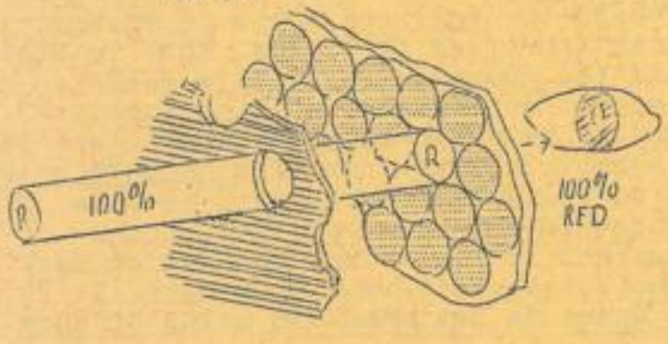
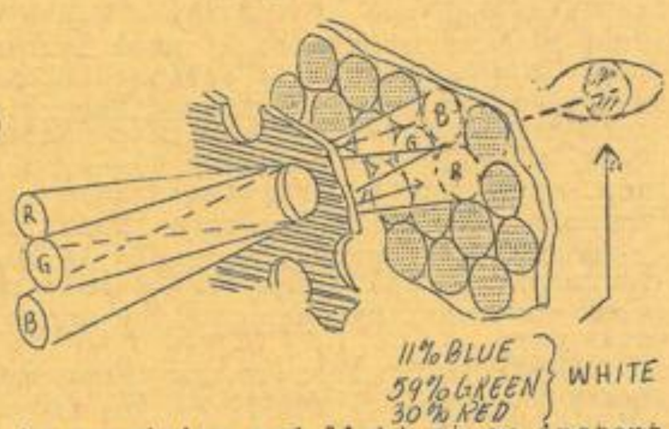


FIG 3b



Consider in Fig 3a that the eye is receiving red light at an instant from a single red phosphor dot of the tube. Obviously the brightness of the light is dependent upon the picture tube red beam intensity. If the red beam intensity was more or less, the brightness of the red light source would be more or less. Under this condition, hue and saturation are not variable but brightness is.

Reproducing a Black and White Picture on Color Tube

Consider in Fig 3b that the eye is receiving light at an instant from a red, green, and blue dot. Since these different colored light sources are so close together, the eye sees only the mixture of the three light sources. The brightness of the three light sources may all be equal or all different depending upon the three beam intensities of the tube. Three primary colors mixed together in the proper proportions will produce a white color. In the above case, if the green light source furnishes 59% of the total light; the red source 30% of the total; and the blue light 11% of the total, the eye will recognize the mixture as white. This is very significant since it explains how the color tube is able to reproduce a black and white picture. Remember, the phosphor dots are black to the eye until struck with a beam of the picture tube.

The question arises now as to the ability of the color tube to reproduce shades of gray (between white and black). Recalling from black and white television that a gray light source is simply a white light source of low intensity, it is apparent that the color tube will reproduce shades of gray. A white light is recognized by the eye anytime that the three primary light sources are mixed together in proportions of 59% green, 30% red, and 11% blue. If the intensity of the total beam is very bright, the eye recognizes a white. If the intensity of the total beam is varied between bright and off, the eye recognizes the shades of grays between white and black. One might consider that when the color tube is producing a black and white picture, each detail of the black and white picture except black (no light) is composed of 59% green, 30% red, and 11% blue light. One might further conclude that the light from the entire black and white picture is composed of these same proportions of green, red, and blue light.

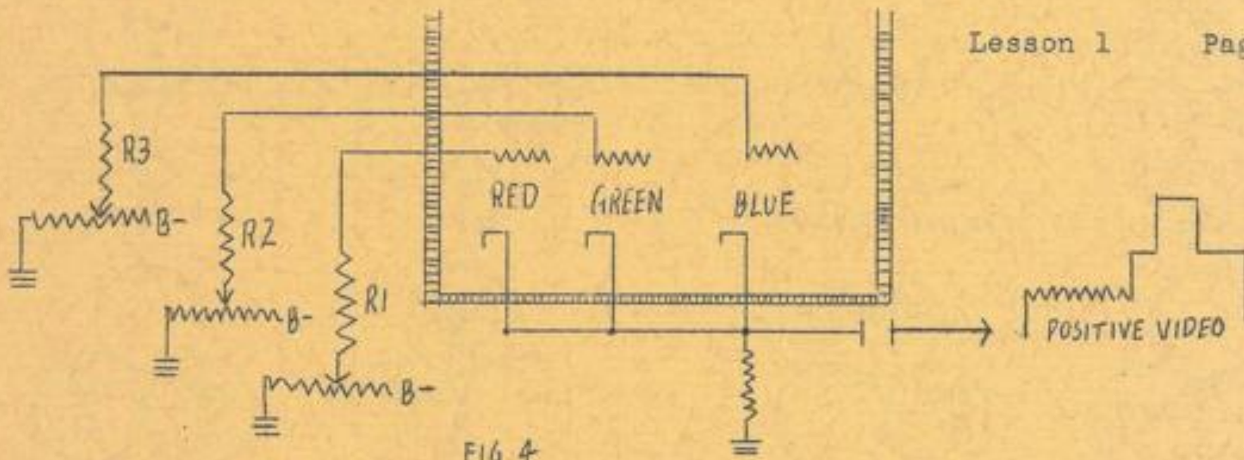


FIG 4

INDIVIDUAL BIASING ARRANGEMENT FOR EACH GUN

Fig 4 illustrates the necessary circuits to enable a color tube to reproduce a black and white picture with a black and white signal. Note that the cathodes of the three color guns are connected together allowing the same video signal to be supplied to each gun. The grids of the three guns return to separate brightness controls allowing individual adjustment of each beam. When the brightness control for the green gun is adjusted to give 59% of the total brightness; the red control to give 30%; and the blue control to give 11%, the reproduced picture will be a black and white picture. The adjustments of these three controls are equally important to the reproduction of a color picture and in either case are the responsibility of the technician.

It is interesting to note that if these controls are misadjusted to allow one color of light to contribute more than it's normal percentage of light, the reproduced picture will indicate this malfunction. If the abnormal light is green, the picture will look slightly green to the eye.

At this point it is apparent that the color tube if properly connected into a black and white receiver could reproduce a black and white picture. This doesn't mean that the same receiver could reproduce a color picture. It does mean however, that a compatible color receiver must have the same type of circuits as a present black and white receiver. The extra circuits involved in a compatible color receiver are only those circuits needed to cause the color tube to reproduce a color picture from a color signal. Henceforth, we will substitute the word monochrome for "black and white" when we are talking about the black and white receiver, signal, picture, or picture tube. For example, the present receiver is a monochrome reciver, operating on a monochrome signal, producing a monochrome picture on a monochrome picture tube.

Reproducing the Color Picture

The most important function of the color tube is to reproduce a color picture rather than a monochrome picture even though it has to do both.

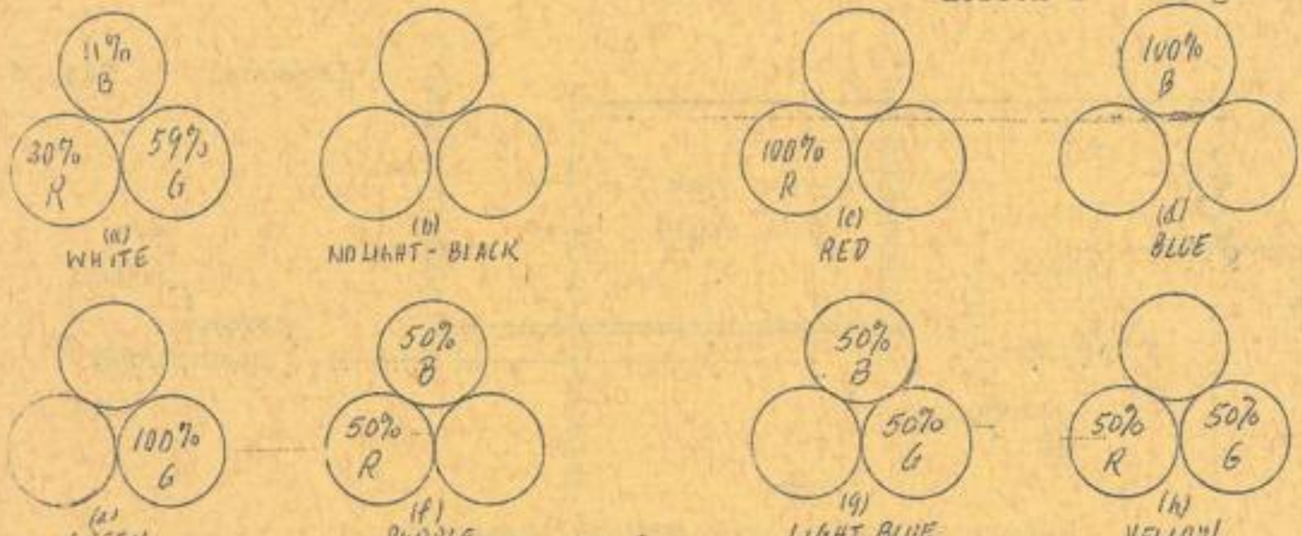


FIG. 5

Fig 5 illustrates six details of different colors made possible with the RCA tube. We have previously discussed the details(a)through(e).Note that in f, the red light and blue light are each contributing 50% of the total. Under this condition, the eye recognizes this mixture as purple. In g, equal proportions of blue and green produce a light blue. Under condition h, the resultant light is yellow.

It becomes obvious at this point that there are practically no limitations on the reproduction of the color spectrum. Any one of the three light sources may contribute from 0 to 100% of the total light. For example, we might have a mixture of light from the three sources of 98% red, 1% blue, and 1% green. Obviously, this detail would have a hue of red. Hue refers to the color. It would not be as deep a red however, as what it would be if the blue and green lights were not present. Note in Fig 5g that equal mixtures of blue and green produces a light blue light. What the eye sees then is a mixture of 2% light blue light and 98% red light. This mixture would result in a detail of red that is just slightly pink.

The ability of the color receiver to reproduce practically the entire color spectrum should make us all very proud of our industry and it's engineering ability. By contrast, commercial printing is done in most cases with less than a half dozen colors. Technicolor movies are produced in most cases with less than half the color spectrum. The television industry could have settled for a system of color utilizing only part of the spectrum but it refused to do so even though higher standards meant higher costs and a great deal more complexity in the system. Costs don't involve technicians too much but complexity does. Try to remember the reason for the complexity and it should help you if you become discouraged with the learning, adjusting, and repairing of the compatible color receiver.

Previously, we discussed a colored light source (other than white, gray, or black) as having hue, saturation, and brightness. Repeating, hue refers to the color (such as red), saturation refers to the density of the color (how-red), and brightness refers to how much light without any consideration of hue or saturation. In our color system, saturation and brightness are the variables. Hue is a variable only because changes in saturation produce different colors or hues. Henceforth, we will concern ourself's with saturation and brightness but not hue.

It is interesting to note that brightness is a variable in both the monochrome and compatible color receivers. The monochrome signal of present monochrome receivers varies only the brightness of details of the scene. The color involved is the single color white (white to black). One might consider that saturation is involved because saturation in this case might mean how-white. One must remember, however, that only brightness is variable in the monochrome receiver and if saturation is considered to vary, it is only because the brightness does. Neither the monochrome tube or color tube requires more than a brightness or monochrome signal to reproduce a monochrome picture.

By contrast, the color tube in order to reproduce a color picture requires a video signal containing two variables. One of these variables is the brightness or monochrome signal as mentioned above. The other variable required of the signal is saturation. The saturation signal obviously serves the function of causing the tube to reproduce the proper details of color at the proper times. Simplifying the discussion, it might be said that the saturation video signal determines the color of a detail of the scene and the brightness or monochrome signal determines how bright the detail is. The industry has chosen to use the word chroma rather than saturation (they mean the same thing). Henceforth, we will refer to saturation as chroma. The saturation video signal path through the receiver will be known as the chrominance path.

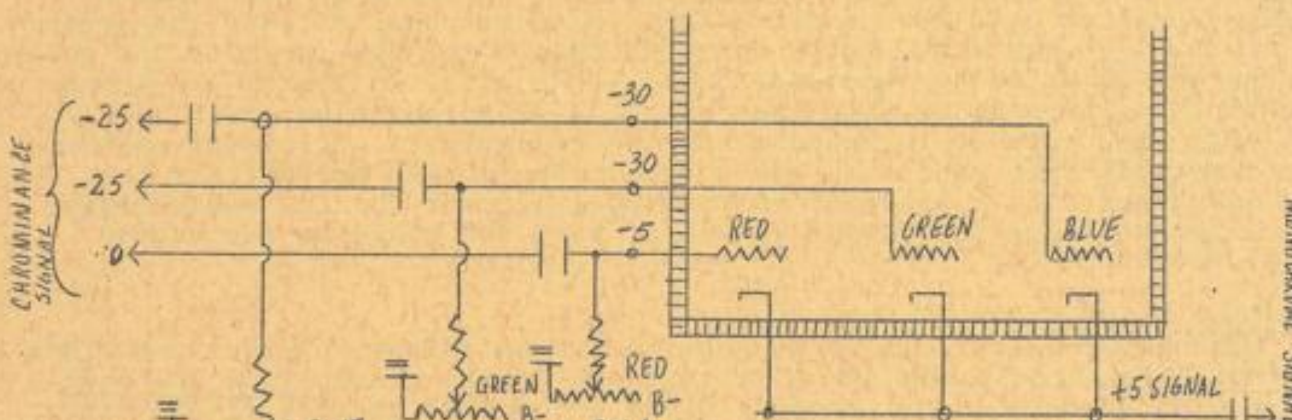


FIG 6
REPRODUCING A PURE RED DETAIL

Fig 6 above illustrates how both the monochrome signal and chrominance signal might be applied to the color tube. The monochrome signal is simply applied to the three cathodes whereby the cathodes are connected in parallel. The chrominance signal is applied to the three grids whereby the grids return individually through grid resistors and brightness controls to ground. A most interesting item reflects itself here for we notice that the chrominance signal is not a single signal but rather a combination of three signals. This should have been suspected since the color tube involves three guns and beams and individual control over each beam or gun must be enjoyed in order to reproduce the color standards that we've been talking about. Since each of the three chrominance signals controls a separate gun, the signals are known as the red chrominance, green chrominance, and blue chrominance signals.

Both the chrominance signal and monochrome signal produce voltage changes between cathode and grid of the three guns and therefore produce changes in intensities of the three beams. Let's consider that only the monochrome signal is present. Under this condition, voltage variations of the monochrome signal will cause the beam intensities of all three beams to vary in exactly the same way. This is exactly what happens when the color receiver is receiving a regular monochrome signal. If the technician has adjusted the brightness controls of the three guns properly, a monochrome picture will be reproduced. Otherwise, the reproduced picture will contain color other than white.

When a station is telecasting a color signal, the picture tube receives both a chrominance and monochrome signal. Let's assume that the color tube cuts off with a 30 volt signal (grid is -30 with respect to cathode). Let's further assume that the station camera at an instant is taking a picture of a pure red detail of the scene and the detail is very bright. Since the monochrome signal is no different in color work than in monochrome work, it will contain a voltage such as to cause high beam currents from the three guns. Since the monochrome signal is being applied to the cathodes, the voltage would be positive. It would be of low amplitude (reduced grid bias causes high beam current). We might give this positive voltage a size of say 5 volts positive. This would mean that each of the guns would have -5 volts on their grids with respect to their cathodes if we don't consider the bias offered by the three separate brightness controls. We won't consider the brightness controls in explaining this point. Under the condition of just the monochrome signal, the tube would produce a bright white detail. Now let's consider the chrominance signal and what voltages must be involved for the tube to reproduce a bright detail of red. If the red detail is to be pure, neither the green gun or blue gun can work. Let's consider then that both the blue and green signals are -25 volts and the red signal is 0 volts. Analyzing the three guns at this instant, we find that both the green and blue grids are -30 (cut off) with respect to cathode and the red grid is -5 (almost maximum beam current). This condition would result in no beam current for the blue and green dots but almost maximum beam current for the red phosphor dot. A bright (high intensity) detail of pure red would be reproduced on the screen.

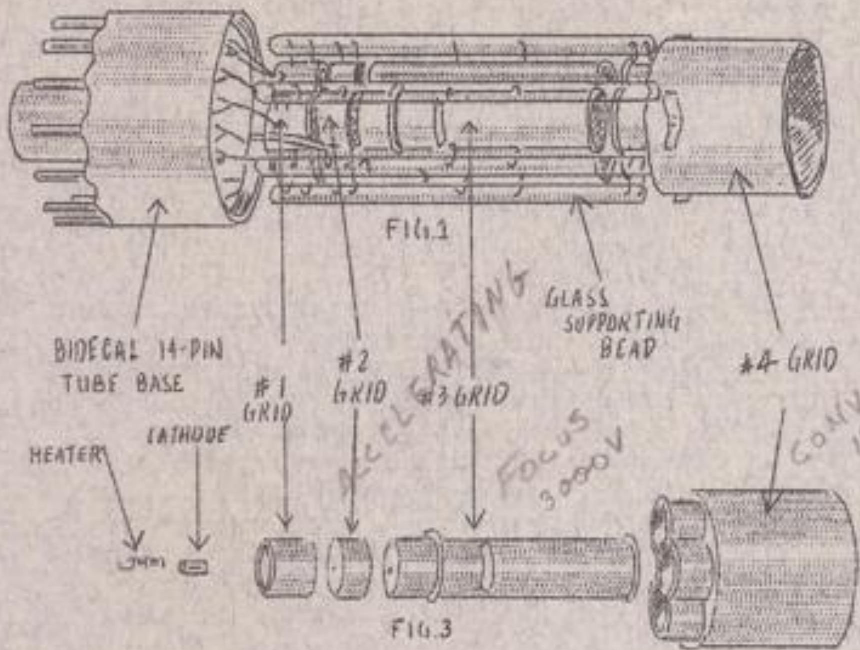
Fidelity of the Color Picture

Monochrome television as we know it has an effective video bandwidth of about 4 Mc. This bandwidth of signal can produce some 8,000,000 monochrome picture details per second. Since a complete picture of 525 lines is completed every 1/30 second, a maximum of some 267,000 details could compose the picture. This is approximatley 500 details per line. Most present receivers have a bandwidth less than 4 Mc and therefore reproduce a picture of less than 500 details per line. Some broadcast stations receive network shows off the coax cable rather than the micro wave system and therefore cannot transmit a 4 Mc picture. The coax system limits the video to some 3.5 Mc. Most of us therefore are more familiar with a picture containing some 400 details per line than we are with 500 per line.

The N.T.S.C. system of color calls for some 400 details per line. Since each color detail might involved all three phosphor dots of red, green, and blue, the tube must be painted with some 1200 details for each of the 525 lines of picture. Due to the triangle arrangment of these dots on the screen, some 800 dots exist in each physical horizontal line across the tube. The present RCA color tube has a horizontal viewing distance of approximately 10 inches. Dividing 10 by 800, we get the diameter of each color dot equal to 1/80 of an inch or .0125 inches. This same diameter is used for the aperture holes in the shadow mask. From this discussion, it is apparent that the reproduced color picture is excellent in detail as well as in color content. As a matter of fact with all things taken into consideration, the color picture is a higher fidelity picture than today's monochrome. This will be pointed out in a later discussion.

Charles Ogilvie
2-24-54

Three-Gun Tube Assembly



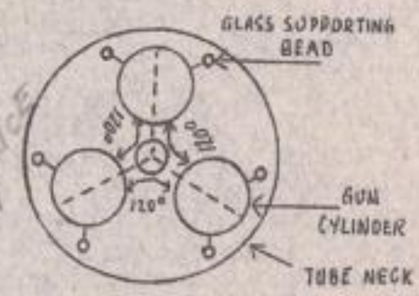


FIG. 2

Focus and Convergence Action

Note in Fig 1 the arrangement of the three electron guns in the neck of the tube. Since each of the guns is as large as the monochrome type, the neck of the tube must be considerably larger to accommodate the three-gun arrangement. Fig 2 shows an end view of the guns with the necessary glass supports. Note the 120 degree spacing of the guns in Fig 2.

The exploded view of one of the guns in Fig 3 illustrates the necessary grids along with the filament and cathode. #1 grid is the control grid while the #2 grid is the screen or accelerating grid. The #1 and #2 grids of each gun are independent of the same grids in the other two guns. The #1 and #2 grids serve the exact same purposes as in the single gun type. That is, the #1 grid serves to control the intensity of the beam while the #2 grid supplies accelerating energy.

The #3 grid in each gun is a focus electrode. These electrodes are independent of each other but are electrically connected together inside the tube. The #4 grid is a single electrode and is common to all three guns. It serves as the convergence electrode for the three guns and their beams.

Approximately 3000 volts is applied to the focus electrodes and some 10,000 volts is applied to the convergence electrode. The potential difference between the focus electrodes and the convergence electrode establishes an electrostatic field which serves to focus the three beams. Focus, you recall, is the action taken to reduce the beam diameter of a gun to a minimum at the point of contact with the phosphor. In this case, focus means to reduce the beam diameter to a minimum at the shadow mask to allow it to pass through an aperture hole and not strike the mask. Striking the mask would result in a loss of electrons for the phosphor resulting in loss of brightness.

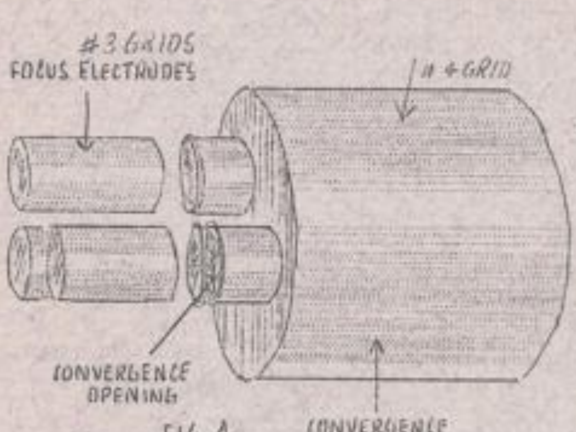


FIG. 4

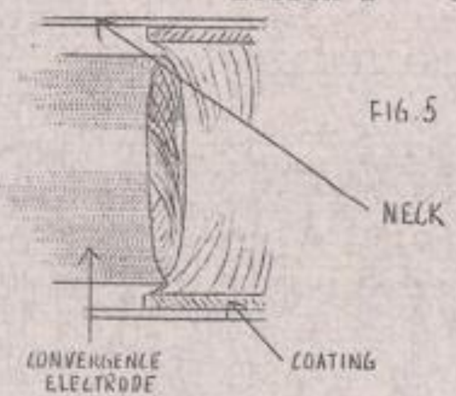


FIG. 5

Note in Fig 4 that the convergence electrode (#4 grid) has a rather peculiar shape. The left end (nearest the focus electrodes) has three individual openings while the right end is completely open and is common to all three beams. Consider the left end first. Each of the focus electrodes is positioned in-line with one of the convergence openings. Individual electrostatic fields are thus established between each focus electrode and corresponding openings in the convergence electrode. All three beams are focused simultaneously by varying the focus electrode voltage with respect to the convergence electrode voltage. This arrangement is practically indentical with a single gun tube except in this case, we are focusing three beams at the same time and with a single control.

This brings us up to convergence. Convergence, you recall, is the action taken to position the three beams with respect to each other such as to cause all three beams to pass through the same aperture hole at the same time. This action takes place as the beams leave the convergence electrode on their way to the mask. Note in Fig 5 that the inside coating of the tube extends back into the neck of the tube just opposite the convergence electrode. This coating along with the shadow mask serves as the plate or high voltage anode for the three guns. The voltage supplied to this anode is approximately 20,000 volts. The potential difference between the plate anode and the convergence electrode establishes an electrostatic field which serves to converge the beams at the shadow mask. The three beams travel exactly parallel to each other until they are acted upon by the convergence field. The exact action of the convergence field is to bend each beam toward each other. This action is sometimes referred to as an electron lense action.

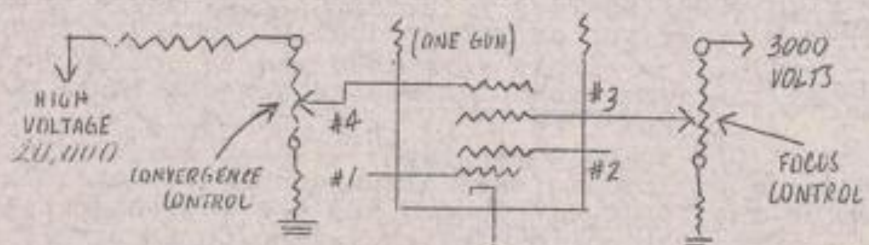


FIG. 6.

The high voltage anode receives a constant 20,000 volts. In order to have control over convergence, the convergence electrode voltage is made variable. On the present RCA tube this voltage needs to be variable from 8,000 to 10,000 volts. Obviously, adjusting the convergence voltage will effect the focus since the focus field will be varied. To off-set this situation, the focus electrodes are connected to a variable source of voltage. This allows the potential difference between the focus electrodes and the convergence electrode to be variable to achieve focus.

The technician has the job of adjusting focus and convergence. It is important for the technician to realize that these adjustments are not completely independent of each other. Adjusting focus will affect convergence slightly and adjusting convergence will affect focus slightly. The technician, therefore, must adjust first one control and then the other until the best condition of both convergence and focus is achieved.

A previous discussion pointed out that the technician has some control over convergence with three separate magnets placed near the neck of the tube. These magnets would not be needed if all tubes were perfect from the standpoint of the three gun structures since the above electrical adjustment of convergence would be sufficient. The magnets only serve to correct malfunctions that are built into a particular tube or that develop in use. Bear in mind too, that these magnets are to adjust each beam with respect to the other two for the purpose of convergence and are not for the purpose of centering the picture. The beam positioning magnets have a very limited control over the individual beams which is all that is needed for correcting convergence.

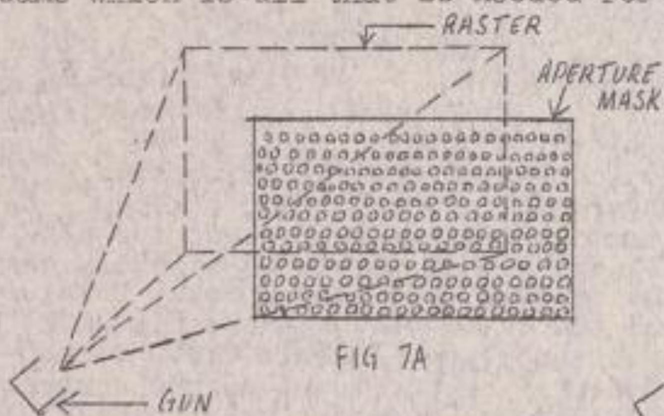


FIG 7A

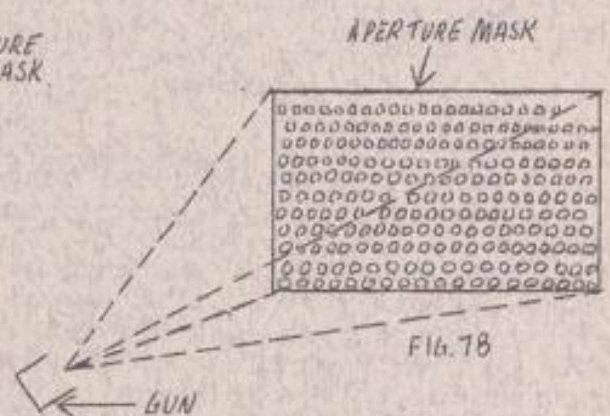


FIG. 7B

Color Purity

So far in our discussion, we haven't considered any control over the total of the three beams. Neither focus or convergence affects the position of the three beams with respect to the shadow mask.

Note in Fig7a that the total beam is not properly positioned with with respect to the mask. This condition, as in monochrome, would result in a non-centered picture. To allow adjustment for this condition, a color purity coil is arranged around the neck of the tube just behind the deflection yoke. This coil is very similiar to the focus coil of monochrome receivers as far as construction and position are concerned. Adjusting the current and position of the coil results in shifting or moving the combined system of beams to achieve a centered picture such as shown in Fig 7b. The location of the purity coil is shown in Fig 8.

The term "color purity" rather than "centering" is used because of the affect the circuit has over the raster. One method of adjusting this circuit is to turn off the blue and green guns and ajust the coil current and physical position of the coil until a pure red raster is achieved at the center of the tube. Various colors other than red will appear on the screen because the color purity adjustment is made by the technician prior to the adjustments of focus and convergence. If perfect focus and convergence were being enjoyed at the time the color purity circuit was adjusted, the **entire** raster would become pure red rather than just the center.

Deflection of the Three Beams and Dynamic Convergence and Focus

The yoke of the three-gun tube is very similiar to the yoke of a single gun tube and has the same purpose. The scanning rate of the system of beams is the same as in monochrome. A pair of coils is used for vertical deflection and a pair is used for horizontal deflection just as in the monochrome receiver. The three beams require a larger areaof uniform field within the neck of the tube. Therefore, the structure of the color yoke differs slightly from the monochrome. The present 15" RCA tube has a deflection angle of 45 degrees. The deflection angle will increase with larger size tubes.

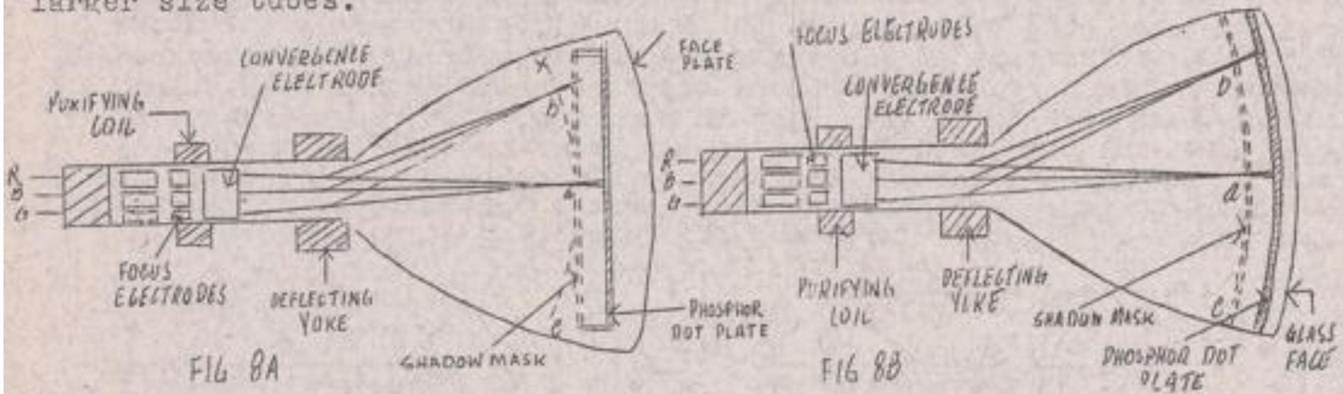
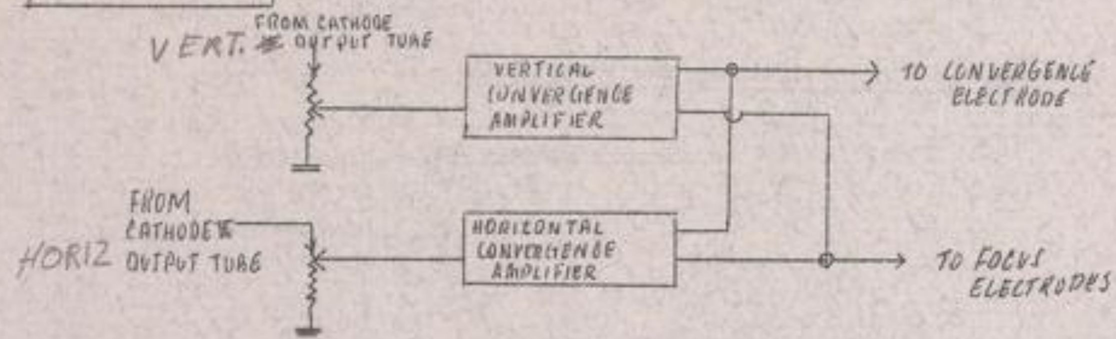


Fig 8a illustrates one of the basic problems of the color tube. Let's assume that we've adjusted convergence at the center of the tube as shown. Note that as the system of beams is deflected, the convergence point does not follow the flat mask. At distances slightly away from (a), the beams are converging at points prior to the mask. This condition becomes more drastic toward the edges of the mask. Fig 8b illustrates the curved mask and screen type tube. In this case, convergence is enjoyed regardless of the position of the beams on the screen. The flat screen, however, seems to be the most accepted type at present. Most people prefer to watch a picture on a flat screen. Also, the construction of the flat screen and mask is much easier than the rounded or curved type. We will, therefore, concern ourselves with the flat screen and it's operation.

Fig 8a further illustrates that the focus of the beams will change as the beams move from (a) toward either (b) or (c). The focus points of the three beams follow the curved line (x) just as the convergence points of the beams do. Until now, we considered convergence and focus at the center of the tube only. We might term our adjustments of focus and convergence at the center of the tube as static convergence and focus adjustments. As the yoke deflects the beams, we become involved with a situation of dynamic focus and convergence as illustrated.

Dynamic convergence and focus is achieved by supplying certain AC voltages to the focus electrodes and to the convergence electrode. These correction voltages must be timed with the horizontal and vertical deflection of the beams to achieve proper correction at the proper time. The result of the proper correction voltage for both the focus electrodes and convergence electrode is proper convergence and focus of the beams regardless of their position with respect to the aperture mask.



The correction voltages for achieving dynamic convergence and focus are taken from the horizontal and vertical sweep circuits. Note above that the vertical correction voltage is taken from the cathode of the vertical output stage and the horizontal correction voltage is taken from the cathode of the horizontal output stage. Until now, we've only considered correcting convergence and focus in a horizontal direction. The problem exists for the vertical direction as well.

The horizontal and vertical correction signals when properly shaped and amplified, provide true focus and convergence over the entire area of the aperture mask. Each amplifier in the above circuit is equipped with an amplitude control. The horizontal amplifier is equipped with a phasing control and the vertical amplifier is equipped with a wave shaping control. These four controls are the responsibility of the technician and when properly adjusted cause perfect focus and convergence for the entire picture.

The best method for adjusting dynamic convergence and focus is one utilizing a dot-pattern generator. A detailed procedure will be given later for these adjustments.

Adjusting a Tilted Picture

Rotating the yoke of a monochrome receiver rotates the picture and thus provides the necessary control over any tilt. If the monochrome tube is not mounted perfectly horizontal, rotation of the yoke allows the necessary correction without physically rotating the tube.

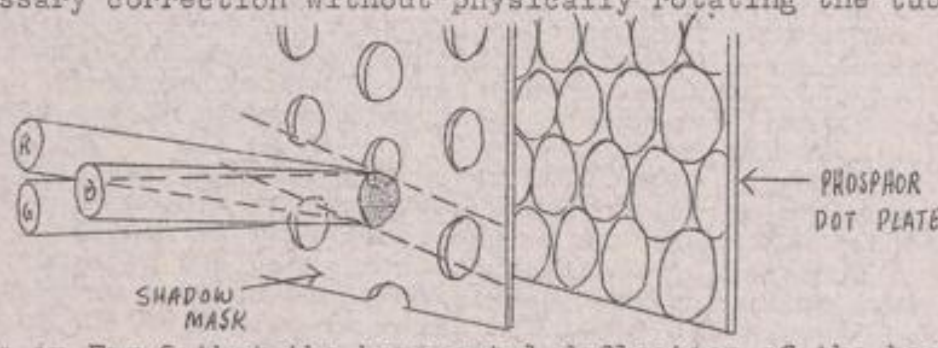


FIG. 9

Note in Fig 9 that the horizontal deflection of the beams isn't parallel with the rows of horizontal holes in the aperture mask. This condition would result in color dilution. This indicates that the yoke cannot be used to correct for any tilt in the picture. Rather, the tube must be mounted perfectly horizontal and the yoke adjusted only to achieve a normal picture without consideration of tilt. The technician must, therefore, exercise more care in adjusting the position of the tube and yoke than what has previously been necessary.

External Comparison of Color and Monochrome Tube

FIG. 10

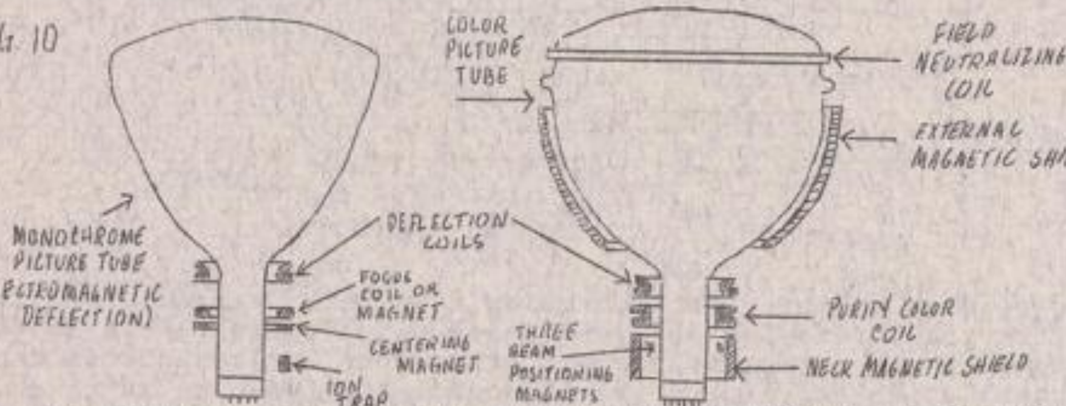


Fig 10 above compares the external components of the monochrome and color tube. Note the external shields about the color tube. These serve to prevent stray fields including the earth's magnetic field from bending the beams out of position. One method of shielding from stray fields is to provide a coil around the tube in the same plane as the picture screen. The field from such a coil cancels the effects of stray fields. The field neutralizing coil arrangement was used on earlier RCA tubes which were part metal. The latest all-glass type does not necessarily require such a coil.

Problems Involving Linearity

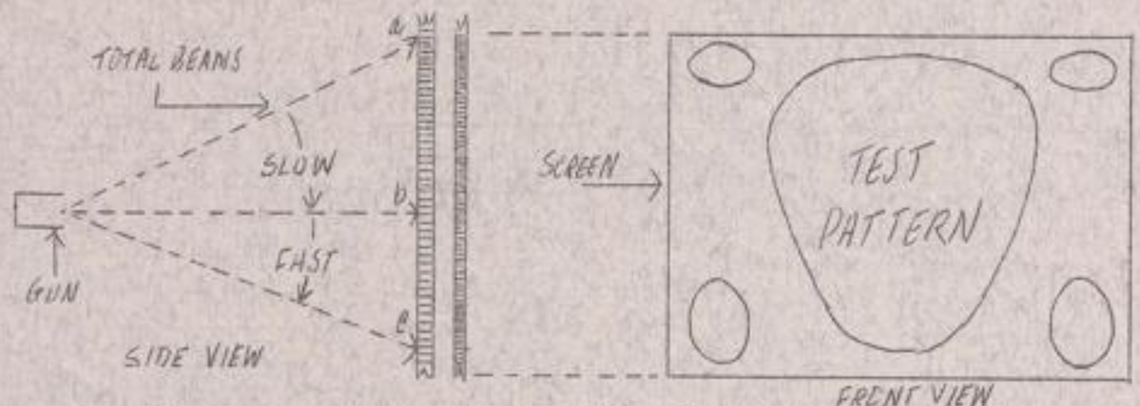
The vertical and horizontal deflection circuits of the color receiver differ very little from a monochrome receiver. The vertical deflection or sweep circuit is provided with a height control and a vertical linearity control. The horizontal sweep circuit is provided with a width control and linearity control. These controls are the responsibility of the technician and the same procedure is used in adjusting them as is used in adjusting the monochrome controls.

The technician must use considerably more care in adjusting vertical linearity and height of the color tube than what has been necessary with the monochrome receiver. Recall from the monochrome receiver that the vertical sweep circuit positions the horizontal scan lines with respect to the phosphor. In the case of the color tube, the vertical sweep circuit positions the horizontal scan of the beams with respect to the aperture mask.

Fig 11 on opposite page illustrates a problem of vertical linearity. Note that the vertical downward sweep of the system of beams is slow from the top of the screen to the center and is fast from the center to the bottom. Considering a test pattern signal, the pattern would assume the shape shown and this condition would be true whether the tube be a monochrome or a color type. The vertical height of the picture is normal since it just fills out the screen.

In addition to the problem of vertical linearity as shown, the color tube would be in trouble to the extent of being out of both dynamic focus and dynamic convergence. Recall that correction voltages are applied to the focus electrodes and the convergence electrode to cause proper focus and convergence over the entire screen. In the case of poor vertical linearity, these voltages are mis-timed and, therefore, cannot correct dynamic focus and convergence in the vertical direction properly.

FIG. 11



Insufficient or too much height offers the color tube a problem very similar to poor vertical linearity. Again, dynamic convergence and dynamic focus is affected resulting in color dilution.

The technician has a rather unusual problem in adjusting vertical linearity and height of the color tube. The horizontal scan lines of the monochrome receiver offer an almost perfect indicator for adjusting vertical linearity and height. The dot pattern of the color receiver rather than a line pattern eliminates any possibility of adjusting for good linearity and height without some sort of linear picture information such as a test pattern. Due to the limited time that test pattern signals are available, the technician will need either a dot pattern generator or a cross-hatch generator. As was stated previously, a dot pattern generator is needed for adjusting convergence and can, therefore, serve as the signal for adjusting linearity and height.

Horizontal Tracking of the Aperture Holes

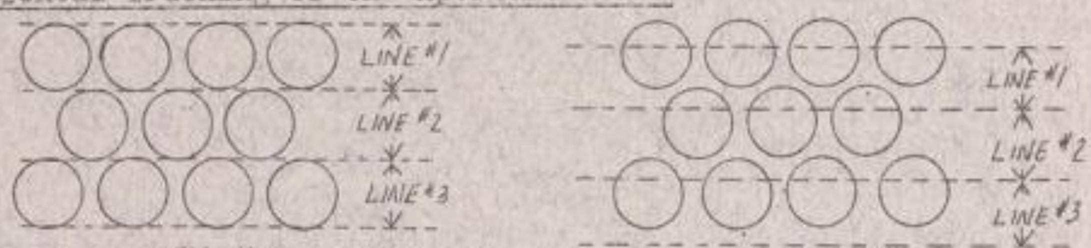


FIG. 12A FIG. 12B

It is interesting to note that the horizontal beam movement across the aperture mask does not necessarily track the centers of the aperture holes. Fig 12a illustrates a small section of the mask showing perfect tracking of the holes by the beams. In Fig 12b, the horizontal beam movement is slightly low compared to the condition of Fig 12a. One might consider that the condition represented by Fig 12a is correct and the condition of Fig 12b incorrect. As matter of fact, either condition is correct. Vertical linearity, height, vertical centering, and color purity are factors that affect the position of the horizontal beam movement with respect to the aperture holes. It would be practically impossible to design a receiver to achieve the condition of Fig 12a. It isn't necessary.

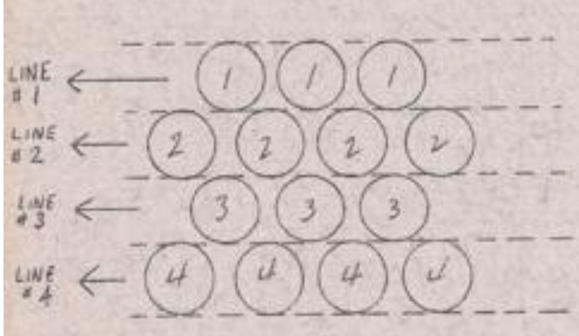


FIG 13A

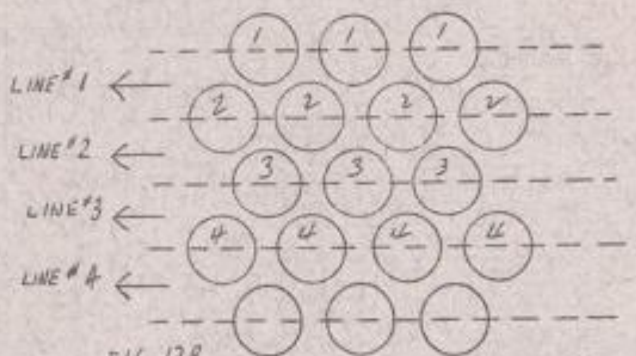


FIG 13B

The beam movement represented by line 1 in 13a above would generate 3 details of the picture. Compare this with line 1 of Fig 13b where the beam is over-lapping two rows of holes. In this case, 7 details would be generated but each would be only half as bright as those in Fig 13 a since only half of the beam is passing through the holes.

Lines 1 and 3 in both Fig's are laid down by the first field and lines 2 and 4 are laid down by the second field. Note that the two fields interlace each other just as in the monochrome receiver. Each field is laid down in 1/60 sec. The eye sees the two fields interlaced together as one picture.

Considering Fig 13a, lines 1 and 3 are laid down during one field and lines 2 and 4 during the next field. Under this condition, the picture details generated by the first field are distinct separate details from those generated by the second field. In Fig 13b, again, lines 1 and 3 represent the first field and lines 2 and 4 represent the second field. Note, however, that line 1 not only generates picture details represented by the #1 holes but also generates picture details represented by the #2 holes. Line two of the second field will also generate picture details represented by the #2 holes. Since the eye sees the total of the two fields, some over-lapping of picture details occur. The position of the horizontal beam movements with respect to the horizontal aperture holes varies depending upon the various circuits that affect the vertical position of the beams.

Horizontal Linearity

When the system of beams move at a constant velocity from right to left (inside the tube), perfect horizontal linearity is enjoyed. This is no different from the same consideration in the monochrome receiver. When the beam velocity is not a constant, the picture is compressed on one side and expanded on the other. In most cases, the technician has both a horizontal linearity control and a horizontal drive control to correct for non-linear horizontal conditions.

Poor horizontal linearity results in a change in the dynamic convergence and focus just as poor vertical linearity does. Again, the technician has to exercise more care in the adjustments than is necessary in the monochrome receiver.

Hoffman EASY-VISION Television

Charles Ogilvie

At this point, a step-by-step adjustment procedure for the color tube would normally be given. However, it appears now that the industry will produce the nineteen inch color tube this year as well as the fifteen inch. Certainly, the larger tube will be the most accepted and will result in a large number of the 1954 color receivers being equipped with it. We have, therefore, chosen to delay a step-by-step procedure until we have the details of the nineteen inch tube.

Another reason for delaying is to allow the manufacturers time to arrive at standard terms for the various controls and circuits.

Review of the Monochrome Signal

FIG 1

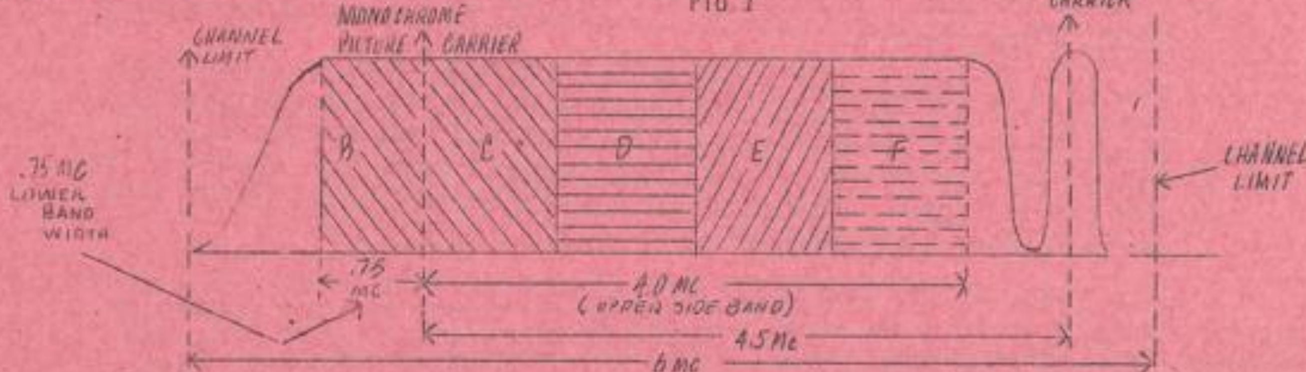


Fig 1 illustrates the transmitted monochrome signal. Note that the total bandwidth is six Mc. The video information is amplitude modulated while the sound information is frequency modulated. Note that a 4 Mc upper sideband is transmitted to conform with the F.C.C.'s requirement of eight million picture details per second. Only .75 Mc of the lower sideband is transmitted. Normally, modulating a carrier with a 4 Mc signal would result in a transmitted signal of 8 Mc. In this case, the station transmitter suppresses 3.25 Mc of the lower sideband to conform with the 6 Mc bandwidth allowed each channel. The intelligence of any signal is contained in either sideband. In the case of radio, both sidebands are transmitted. One sideband helps the other only to the extent of making the transmitted signal more powerful. In the case of television, .75 Mc of the lower sideband is transmitted to provide a more powerful signal at the frequencies that fall within the .75 Mc width.

The lower sideband information is contained in the area B. Since these frequencies are near the picture carrier, they are of low frequency. As far as the picture is concerned, these frequencies represent large areas of the scene. Also, the sync. and blanking information (60 and 15,750 cps) being of low frequency, falls in the area B very near the picture carrier. The station, therefore, transmits more power in the low frequencies than in the high frequencies which aids fringe area reception.

Note areas C, D, E, and F of the upper sideband. Again, C represents large areas of the picture. D represents somewhat smaller areas; E represents rather small areas; and F represents the very fine detail.

The picture and sound carriers are separated by a constant difference of 4.5 Mc. They are completely independent of each other and should be considered as separate signals.

Compatibility Requirements of the Color Signal

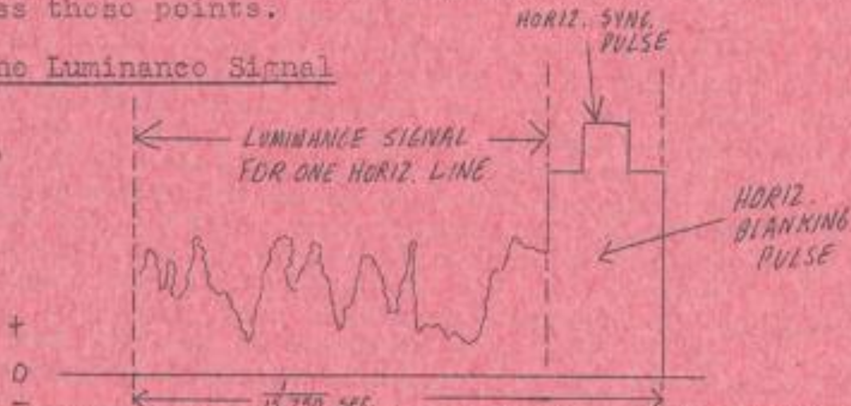
With the composition of the monochrome signal in mind, let's consider the various requirements of a compatible color signal.

1. The color signal must contain the exact type of video as does the monochrome signal. Henceforth, we will refer to this signal as the luminance signal since it contains the intelligence of brightness. The luminance component of the color signal provides normal video operation for the monochrome receiver and supplies the intelligence of luminance or brightness for the color receiver.
2. The color signal must contain a 2 Mc bandwidth of chrominance (color and saturation) information. This intelligence provides full color operation of the color receiver.
3. The chrominance component must not visably interfer with the monochrome picture when the monochrome receiver is receiving a color signal.
4. The color signal must contain the information of sound displaced 4.5 Mc from the luminance carrier. The sound intelligence must be exactly the same as in the monochrome signal.
5. The total bandwidth of the color signal must not exceed 6 Mc.
6. The color signal must contain the information to blank, sync., and interlace the picture.

A most interesting consideration arises at this point. The color signal appears to be 8 Mc wide and yet must occupy a 6 Mc bandwidth. Further, the chrominance signal must not visably interfer with the luminance signal or vice versa. The primary purpose of this lesson is to discuss these points.

Review of the Luminance Signal

FIG 2



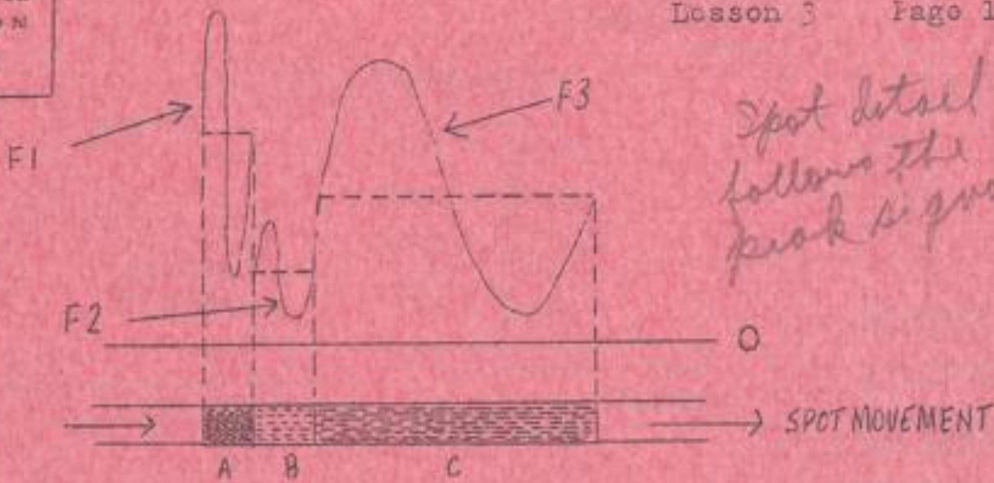
The luminance signal upon being detected in the monochrome receiver appears as shown in Fig 2. The polarity of the signal might be positive as shown or negative depending upon the polarity of the luminance detector.

Applying the above signal to the monochrome tube cathode produces one line of the picture. The signal varies the monochrome grid voltage in a negative direction resulting in variations in the beam current as the beam scans the tube phosphor. As mentioned previously, there may be as many as 500 variations resulting in 500 details in a line. The details are simply details of brightness and may vary from black (no beam) to white depending upon the intensity of the tube beam.

It is important at this point to consider the luminance signal in more detail. The above signal is actually a large group of frequencies that have different amplitudes. The range of frequencies is from 0 to 4 Mc (bandwidth of the luminance signal).

Hoffman EASY-VISION television

FIG 3



Spot detail follows the peak signal

Fig 3 illustrates a small section of the luminance signal. Three frequencies representing three picture details are shown. F1 and F2 are approximately equal in frequency but F1 is of larger amplitude than F2. Note that the frequency of the detail determines the length of the detail while the amplitude determines the intensity or shade of gray. The A and B details are similiar in length but B is more intense or less gray. F3 is a low frequency signal resulting in a long detail. The amplitude is greater than F2 resulting in a more gray detail than B but less than the A detail. The luminance carrier frequency is not illustrated for simplicity purposes and because we are considering the luminance signal after detection.

Note that each of the frequencies have an average amplitude. Due to persistence of vision, the eye recognizes the average brightness of each detail.

Effect of Scanning on Picture Fidelity

As mentioned, the luminance signal may contain all frequencies from 0 to 4 Mc. Let's consider those frequencies that are either even or odd multiples of ½ the horizontal scanning frequency (15,750). ½ (15,750) equals 7,875. Actually, the sum of the even and odd multiples of this frequency covers any bandwidth and in this case, the bandwidth from 0 to 4 Mc.

It is our purpose now to show that the eye does not respond to the odd frequencies but does respond to the even frequencies. Let's first consider even frequencies. For simplicity purposes, we will refer to 15,750 as f and ½ (15,750) as f/2.

Fig 4b shows a few of the even multiple frequencies of f/2. Let's consider that the camera is scanning a horizontal section of the scene that is constant in brightness. During this time, the tube would receive a constant frequency of constant amplitude as shown in Fig 4c. Assuming that the section was 4 picture scanning lines high, we would have the condition as represented in Fig 4a because even multiples of f/2 frequencies complete their cycles in 1/15,750 second. For example, a 15,750 cps signal would complete exactly one cycle in 1/15,750 second (length of scan and retrace) and is an even multiple of f because 2 X f/2 equals f or 15,750 cps. A, B, C, and D represent the first detail of each of the four lines. Because of interlace, details A and C occur 1/15,750 second apart. The same is true of details B and D. B detail occurs 1/60 second (vertical scan frequency) later than detail A. Likewise, detail D occurs 1/60 second later than detail C.

f = 15750 cps

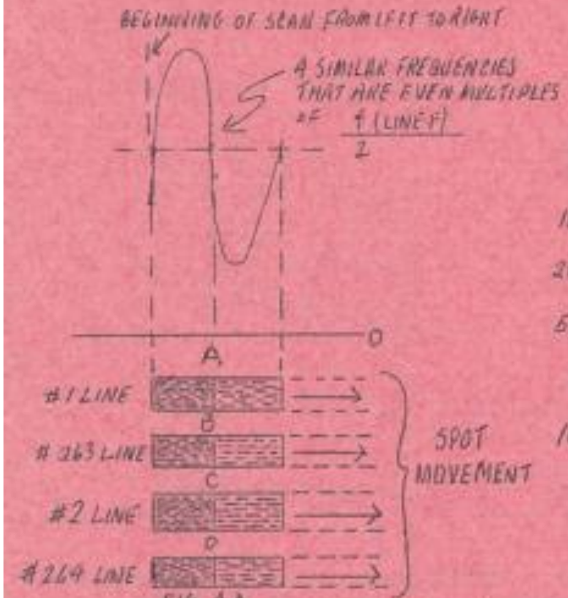


FIG 4A

SOME EVEN MULTIPLES OF $\frac{f}{2}$

$100 \times \frac{f}{2} = 50f$

$200 \times \frac{f}{2} = 100f$

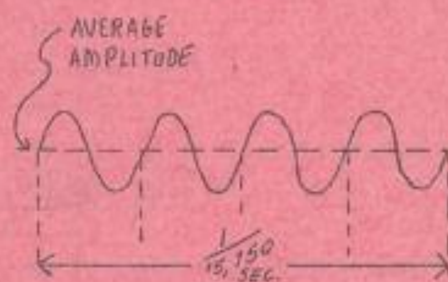
$550 \times \frac{f}{2} = 275f$

$10 \times \frac{f}{2} = 5f$

$1000 \times \frac{f}{2} = 500f$

FIG 4b

FIG. 4c



Note that the brightness of any of the details is not constant from their left end to their right end. The similiar frequencies that are producing the details are varying in amplitude.from left to right causing this condition. Because details A and B are very close together, the eye recognizes the additive brightness of the two details from their left ends to their right ends. In this case, the left and right ends of the two details add together in such a way as to reinforce each other. This condition applies equally to details C and D. This discussion serves as proof that <u>similiar luminance frequencies occuring 1/60 of a second apart that are even multiples of f/2 reinforce each other through out the picture.</u>

Now let's consider those frequencies that are odd multiples of f/2. Again, let's consider only those details that are exactly 1/60 of a second apart.

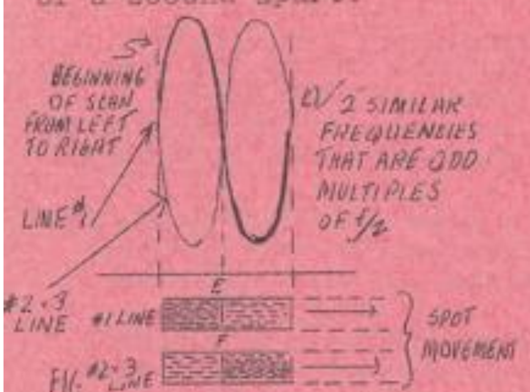


FIG 5a

SOME ODD MULTIPLES OF $\frac{f}{2}$

$101 \times \frac{f}{2} = 55\frac{1}{2}f$

$201 \times \frac{f}{2} = 100\frac{1}{2}f$

$551 \times \frac{f}{2} = 275\frac{1}{2}f$

$11 \times \frac{f}{2} = 5\frac{1}{2}f$

$999 \times \frac{f}{2} = 499\frac{1}{2}f$

FIG.5b

FIG. 5c

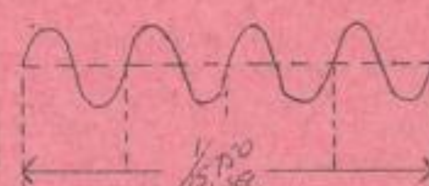


Fig 5c illustrates an odd multiple of f/2. Note that $3\frac{1}{2}$ cycles occur in 1/15,750 of a second rather than some even number of cycles. Let's assume that the Fig 5c signal is the result of the camera sweeping a section of the scene that is of constant brightness. Assuming that the section was 2 or more picture scanning lines high, we would have the condition of Fig 5a. Note the polarity of the # 1 line waveform is reversed to that of the # 263 waveform. These waveforms are 1/60 of a second apart since they appear one above the other on adjacent lines. The odd condition of the waveforms being reversed is a result of the frequency being an odd multipe of f/2. <u>Odd multiple frequencies of f/2 are displaced horizontally ½ cycle on adjacent lines.</u> Note that the polarity of one frequency in Fig 5a cancels the polarity of the other frequency. In this case, the eye sees the additive effect. The effect is zero since one frequency produces the detail E and the other frequency produces the detail F. Note the brightness relationships of each detail from left to right. Note that the E detail is brightner on the right end while the F detail is brighter on the left end. As mentioned, the additive effect is zero to the eye. Detail E is the same picture detail as F since the camera is on the same part of the scene in either case. Recall that the vertical displacement of these details is the result of the monochrome signal supplying interlace information to the receiver's horizontal osicillator.

From the foregoing discussion, we find that the monochrome tube (or color tube) will not reproduce details that are odd multiples of f/2 but does reproduce those that are even multiples of f/2. As matter of fact, the tube doesn't receive odd multiple frequences because the television camera cannot provide them. Odd multiple frequencies cancel out in the camera circuits because of their reverse polarity.

Except for this situation, a 4 Mc bandwidth could provide a picture quality of 16 million details per second rather than 8 million. Perhaps some solution will be found for this condition in the future and allow much more fidelity of pictures.

Since only ½ of the 4 Mc bandwidth contains useful frequencies, one might suspect that these unoccupied sections of the bandwidth may be used for the chrominance intelligence of the color signal. This is true. By properly selecting the chrominance carrier, all frequencies of the chrominance intelligence will be odd multiples of f/2. This situation provides the needed bandwidth for the chrominance intelligence. Further, chrominance information will not interfere visably with the luminance intelligence because the eye cannot recognize odd multiple frequencies of f/2.

"Inter-leaving" the Luminance Signal

FIG 6

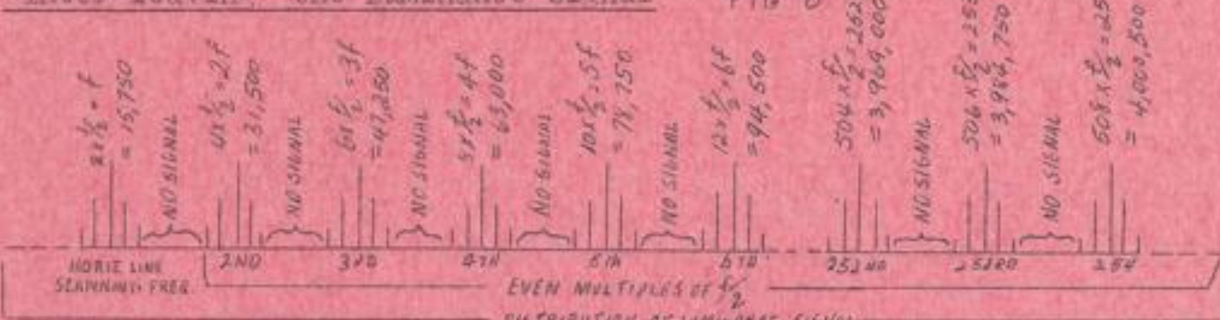


Fig 6 serves to illustrate in block form the distribution of the luminance signal. Even multiples of f/2 are shown. The smaller frequencies near each even multiple of f/2 are the harmonics of that frequency. The total of these frequencies equal 8 million details/second.

Note the spaces where there is no signal. These are the odd multiple frequencies of f/2. As mentioned, these spaces allow the "inter-leaving" of the chrominance signal with the luminance signal.

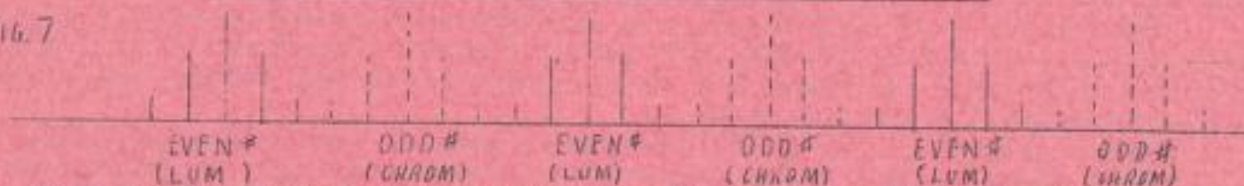
The Chrominance Carrier

Many factors were considered in the selection of the chrominance carrier. Best results were obtained with a 3,579,545 cps frequency. We will refer to this frequency as 3.58 Mc for short. This frequency is 455 X f/2 which setifies the condition for inter-leaving.

The station camera supplies the intelligence of color with the chrominance signal just as it supplies the intelligence of brightness with the luminance signal. We've seen that the luminance intelligence does not include frequencies which are odd multiples of f/2. Likewise, the chrominance intelligence does not include this range of frequencies. It is interesting to note that only odd multiple frequencies of f/2 result from modulating the chrominance carrier with the chrominance intelligence. Remember, the chrominance carrier is an odd number. Also, the chrominance intelligence involves only even numbers. The modulation process is simply the addition of these numbers. The total or difference in any case is an odd number. By comparison, the luminance intelligenge involves, likewise, only even numbers, but is added by modulation to an even numbered carrier. Of course, this results in only even numbers.

DISTRIBUTION OF LUMINANCE AND CHROMINANCE FREQUENCIES

FIG. 7



Note in Fig 7 that the chrominance frequencies fill-in the gaps between the luminance frequencies. This is true for any line of the picture. Remember, however, that the luminance details (even multiples of f/2) reinforce each other while the chrominance details (odd multiples of f/2) cancel out on successive lines of the picture.

FIG. 8

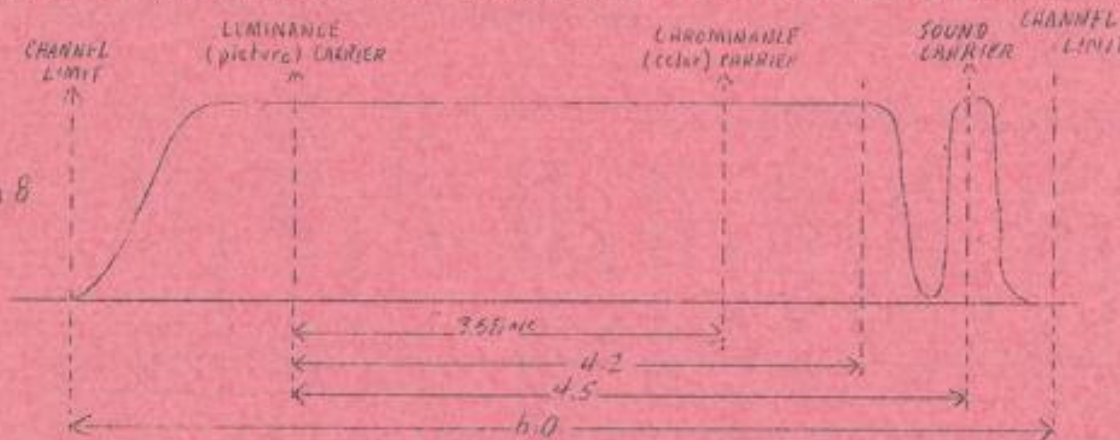


Fig 8 illustrates the position of the chrominance carrier with respect to the luminance carrier and sound carrier. A primary reason for selecting a chrominance carrier frequency of 3.58 Mc was to reduce the possibility of a visable picture beat between it and the sound carrier. The difference between these two frequencies (beat frequency) is an odd multiple of f/2 and such frequencies do not produce visable picture information. Also, the 3.58 Mc position allows maximum spacing of the chrominance carrier from the luminance carrier yet maintains sufficient bandwidth for the chrominance intelligence.

Note in Fig 8 that the useable bandwidth to the right of the luminance carrier has been extended from the normal 4 Mc to 4.2 Mc. This extra .2 Mc serves as the bandwidth for a portion of the upper side band of the chrominance carrier.

FIG. 9

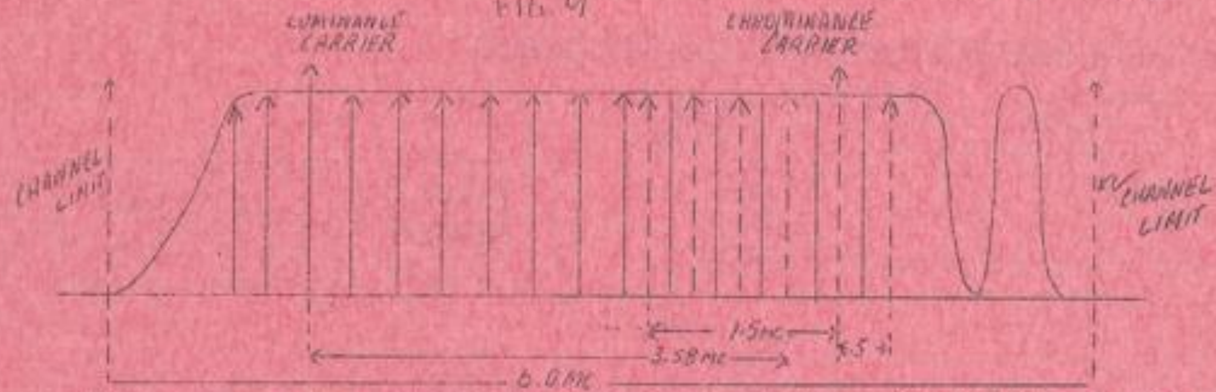


Fig 9 serves to illustrate the approximate bandwidth of the chrominance signal and it's arrangement in the color signal. Note how the chrominance frequencies (dashed lines) inter-leave the luminance frequencies (solid lines). Note that only the lower side band (left of carrier) of chrominance carrier is transmitted complete. A portion of the upper side band is suppressed.

The 1.5 Mc (approximately) lower side band width indicates that the chrominance intelligence is not acting on all details of the picture. In order to do so, it would have to have a band width equal to the luminance signal. Dividing 4 by 1.5, we find that the chrominance signal is acting on approximately 1/3 of the picture details. The luminance signal, therefore, paints approximately 2/3 of the total details without benefit of color (black and white).

It will be shown that the chrominance signal need only affect the picture details that are of relatively large size. These details are the low frequencies of the luminance signal. The higher frequency details of the luminance signal function exactly the same as in the monochrome receiver.

It is apparent from Fig 9 that the color receiver must have more bandwidth than a monochrome type. Also, the technician must be much more aware of the bandwidth requirements. Alignment of the color receiver becomes much more important than before. A loss of bandwidth in the color receiver could result in failure of the color picture.

Requirements of the Color Picture

Most of us, at one time or the other, have observed a "tinted" photograph. In this case, the paint is applied to only the large picture areas. The result is excellent. Obviously, the large areas are in color and the fine detail is black and white. The eye recognizes this type of picture to be equal in fidelity and color to one whereby all details are color details. Of course, the number of details in either case would have to be equal.

The eye cannot perceive fine details of color. The light from fine details of color blend together and result in a shade of white as far as the eye is concerned.

It is not necessary, therefore, that the color picture contain 100% details of color. The color receiver, therefore, does not require a 4 Mc chrominance bandwidth.

Simple Block Diagram Discussion of the Color Receiver

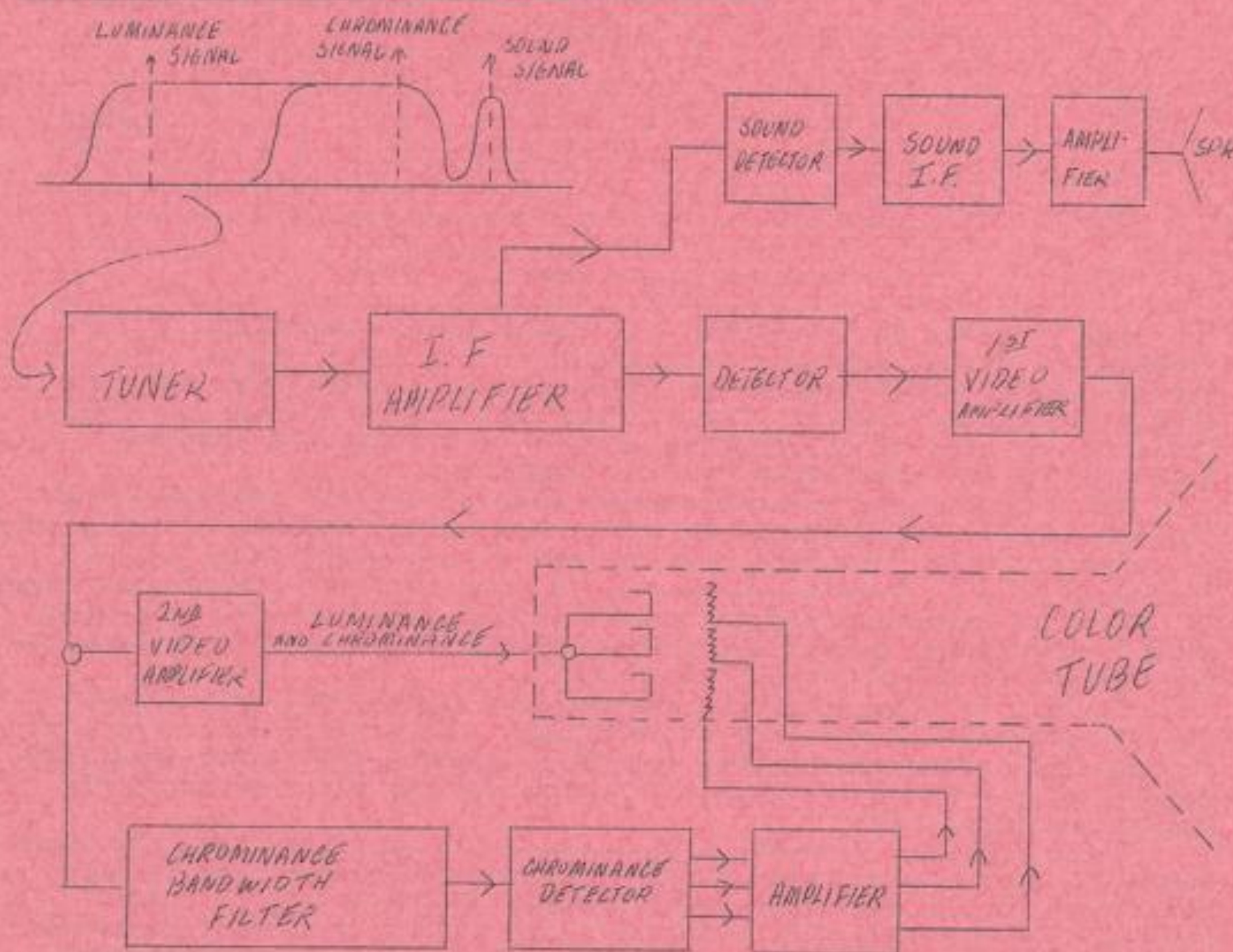


FIG. 10

The luminance path through the color receiver is almost exactly the same as in the monochrome. Note that the sound is picked off a picture I.F. amplifier and is detected with a separate detector. The purpose of this arrangement is to allow more trappage of the sound carrier. Five picture I.F.'s are used in present designs to provide sufficient bandwidth for the color signal. By taking the sound off the 3rd or 4th I.F. stage, extra sound traps can be added to insure a minimum effect from the beats between the sound carrier and the luminance and chrominance carriers.

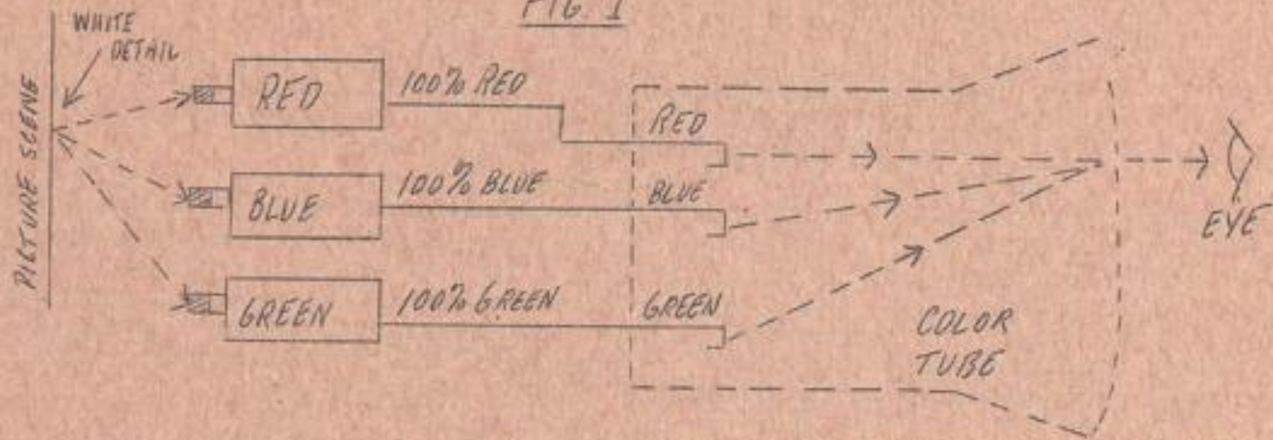
The luminance and chrominance signals, upon being detected, pass directly through two video amplifiers to the picture tube cathodes. Note, however, that a portion of this signal is picked off between the two video amplifiers and directed to a chrominance bandwidth filter. The filter serves to remove that portion of the total bandwidth not involved with the chrominance signal. The chrominance signal is further detected in the chrominance detector. Upon being amplified, the chrominance intelligence passes to the three grids of the color tube.

Charles Ogilvie 3-9-54

Color Signal Development

Previously, we've considered the bandwidth requirements of the color signal as well as the luminance portion of the signal. We haven't, however, considered the chrominance portion. Further, we need to consider the generation of the color signal by the transmitter. ..

FIG. 1



The three cameras in Fig 1 are regular monochrome type with one exception. A red filter is positioned in front of the camera designated red. Likewise, blue and green filters are used for the blue and green cameras. A filter has the property of allowing only that color of light to pass through that corresponds with the tint of the filter. All other colors of light are thus removed. Each camera, therefore, receives only one color of light and thus produces electrical intelligence that represents that color.

The physical arrangement of the cameras is such as to cause all three to be simultaneously focused on a detail of the scene. For an example, let's consider that the cameras are focused on a detail of pure white. The voltage output of the red camera is proportional to the amount of red light being reflected off the white detail of the scene. The voltage output of the blue and green cameras is proportional to the blue and green light being reflected off the white detail of the scene. Let's further consider that the voltage outputs of the red, blue, and green cameras are connected to the red, blue, and green grids of a color tube. The simultaneous action of the color tube beams on their phosphor dots of red, blue, and green results in the eye receiving and reacting to the mixture of light from the color dots. It might seem that the eye recognizes the mixture as white. This isn't true because the mixture of light to the eye isn't 30% red, 11% blue, and 59% green. Only this mixture will be recognized as white.

It can be said that the color cameras are linear devices and produce voltages that represent the red, blue, and green light of a detail of the scene. The eyé, however, is not a linear device. Note the response curve of the average eye in Fig 2. The curve peaks on green and falls off toward violet and red. This means that the eye reacts much more to the green in white light than it does to the other colors. Further, it reacts to the yellow, orange, and red part of the spectrum

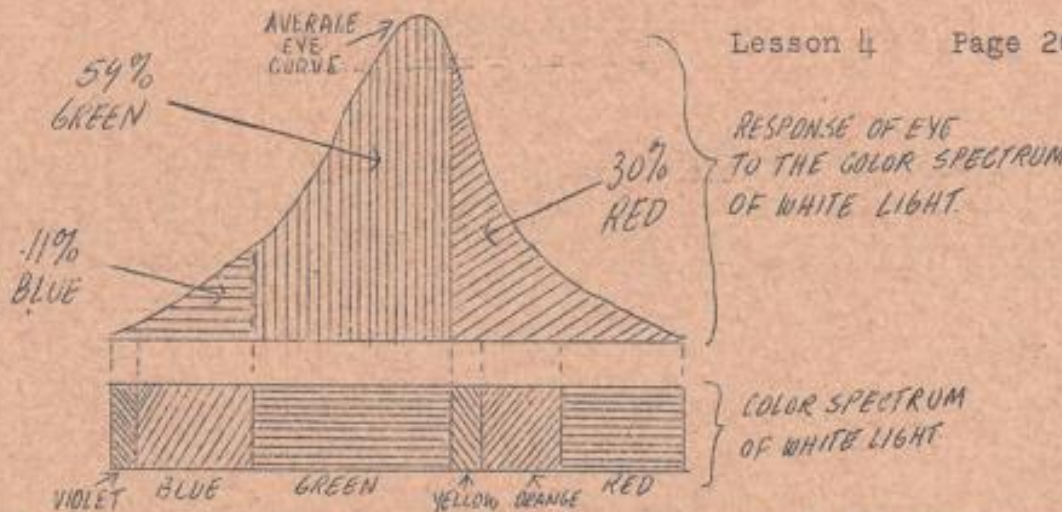


FIG. 2

more than the violet and blue part. The shaded areas of the eye curve indicate that the eye sees 30% red, 11% blue, and 59% green when it is focused on a white light source. In order to correct for the non-linear response of the eye, the camera output voltages must be modified such as to cause the red output voltage to represent 30% of the total voltage; the blue output voltage to represent 11% of the total, and the green output voltage to represent 59% of the total.

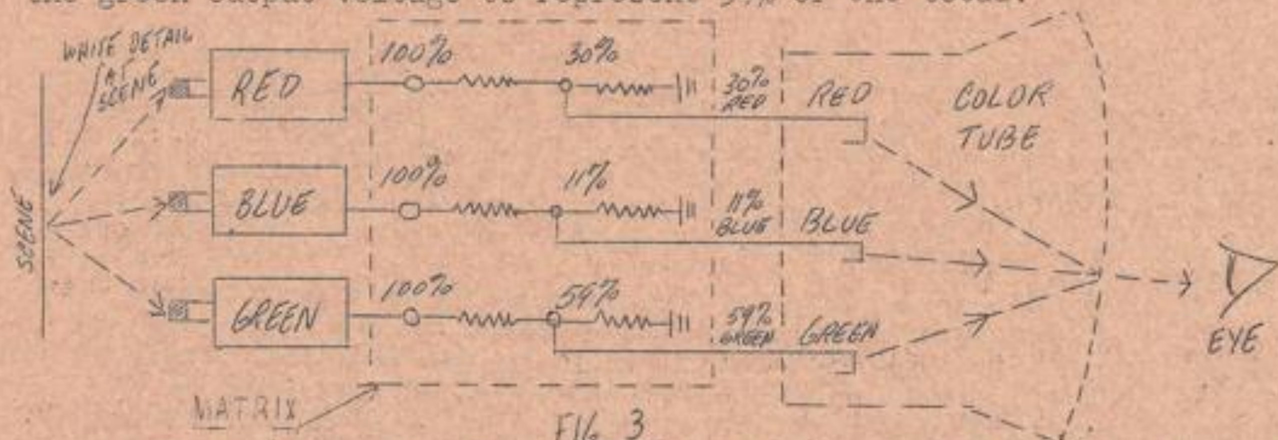


FIG 3

Note the "matrix" unit in Fig 3. This simple unit serves to divide the camera output voltages to achieve the necessary values. Let's consider the matrix connected to the color tube as shown. In this case, the simultaneous action of the color tube beams on their phosphor dots results in the eye receiving and reacting to a mixture of light containing 30% red, 11% blue, and 59% green. The eye would see a white detail corresponding with the white detail that the cameras are focused on. Also, the brightness that the eye receives corresponds with the brightness of the picture detail. If at the next instant of time, the cameras are focused on a detail of white having less brightness, the matrix output voltages would be less but the ratio of red, blue, and green voltages continues to be 30%, 11%, and 59%. Obviously, the matrix unit provides the color tube with the intelligence of brightness.

If we consider the cameras above to be focused on a green picture detail, it is apparent that the voltage output of the green camera will be proportional to the brightness of the detail. Also, there will be no output from either the red camera or blue camera. The green gun of the color tube will function to produce light from a green phosphor dot. The amount of light (brightness of the picture detail) is proportional to the brightness of the same detail of the scene.

The color system in Fig 3 would function very well but is not a practical system. Each of the three colors would require a bandwidth of 4 Mc resulting in a total video bandwidth of 12 Mc.

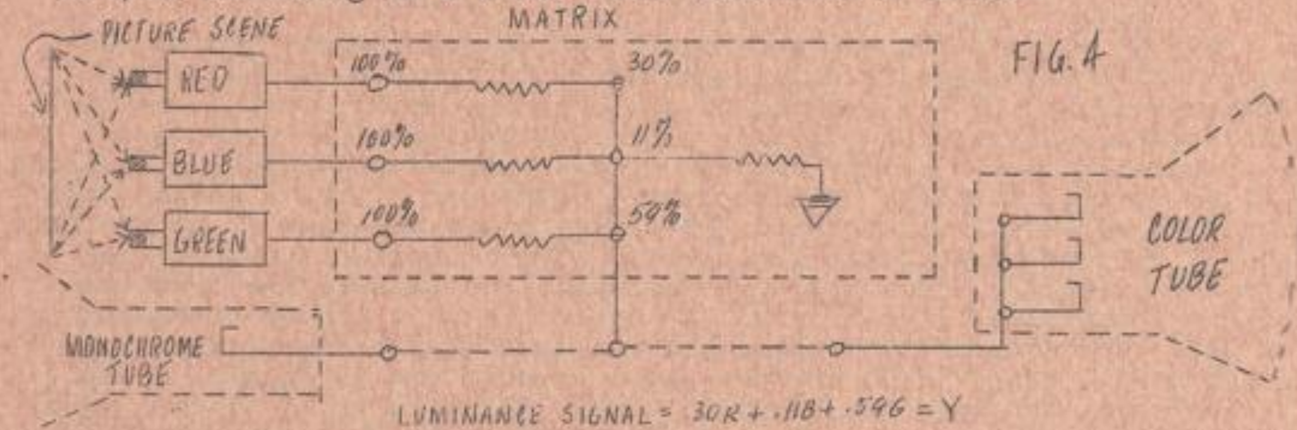


FIG. 4

A primary requirement of the color signal is that it must contain the intelligence of luminance. The foregoing discussion has shown that the matrix unit can supply this information. Fig 4 shows the necessary connections. With these connections, the matrix output signal is equal to 30% of the voltage from the red camera plus 11% of the voltage from the blue camera plus 59% of the voltage from the green camera. This signal is the luminance (brightness) signal and is, therefore, exactly the same as the luminance intelligence of the monochrome signal.

The luminance portion of the color signal is referred to as the "Y" signal. Fig 4 illustrates that the Y signal may be supplied to either a color tube or a monochrome tube for reproduction of a monochrome picture. The expression for the luminance signal is:

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

WHERE Y = LUMINANCE SIGNAL
R = VOLTAGE FROM RED CAMERA
G = VOLTAGE FROM GREEN CAMERA
B = VOLTAGE FROM BLUE CAMERA

The video information of the color signal must contain the intelligence of hue (color-blue) and saturation (how blue) in addition to the luminance intelligence. Fundamentally, the chrominance part of the total color signal must contain intelligence from each of the three cameras. In order for this intelligence to represent hue and saturation but not brightness, the brightness (luminance) component must be removed. Remember, for compatibility purposes, we arrived at a luminance signal which has no intelligence of color.

MATRIX—
ADDER.

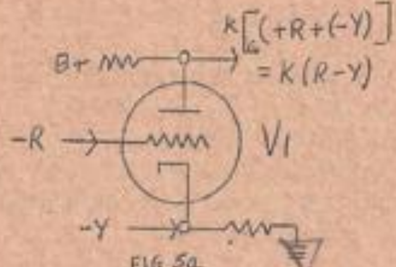


FIG 5a

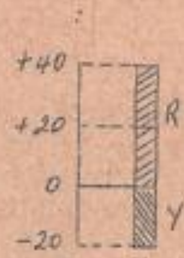


FIG 5b

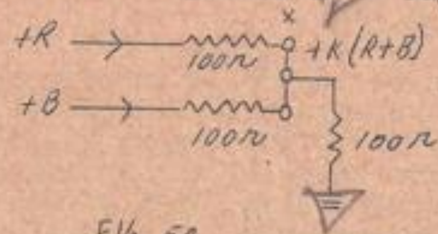


FIG. 5c

Fig 5a illustrates how one signal can be subtracted from another. The red signal voltage is being applied to the grid of V1 while the luminance signal (Y) is applied to the cathode. Recall that a positive grid signal appears as a negative signal at the plate or vice versa. Also recall that a positive cathode signal appears negative at the grid and, therefore, positive at the plate or vice versa. Let's assume that both the red signal voltage and the Y signal are negative at an instant. Under this condition, the plate circuit would contain a positive red signal voltage (R) and a negative luminance (Y) signal. The equation for the total plate signal is K(R-Y) where "K" is a number representing the gain (or loss) of the stage. Let's assume that the amplification factor of the stage is 10 and the input signals are -R equals -4 and -Y equals -2. The equation becomes 10(4-2) equal 20 volts of red signal with the intelligence of luminance eliminated. Fig 5b illustrates the plate signal in block form.

Fig 5c shows how one signal may be added to another by means of resistors. Let's assume that R equals 10 and B equals 20 where R and B are the instantaneous voltages of the red and blue cameras. For simplicity, we are showing the three resistors to be 100 ohms each. Each of the two voltages would be divided equally at point X. In this case, K is ½ or .50. The equation becomes .5(10 plus 20) equal 15 volts of red plus blue signal. This type of "adder" results in a loss of signal but is effective from the standpoint of adding the signals. A resistance device can add signals but cannot subtract.

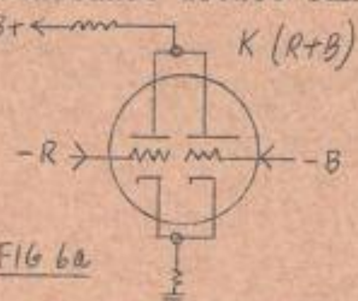


FIG 6a

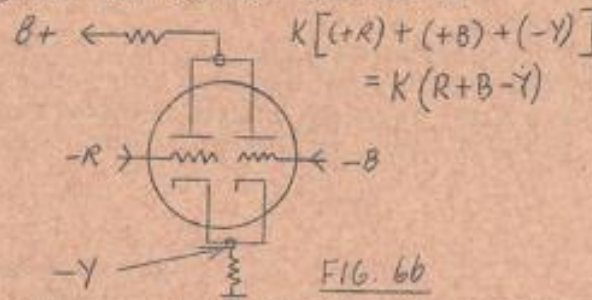


FIG. 6b

Fig 6a illustrates the addition of two signals in a stage. In this example, we have twin triodes with paralleled plates and cathodes. The two negative signals appear in a positive polarity form in the plate circuit and are additive.

Fig 6b illustrates the addition of two signals and the subtraction of one. All three signals add together in the plate circuit. The polarity of the R and B signals reverse between grid and plate but the Y signal doesn't. This means that the R and B signals add in the plate circuit and the Y signal subtracts from both of them. Summing up, we can say that cathode signals subtract from grid signals.

It is interesting to note that signals can be added or subtracted quite easily even in simple devices. However, once they are added or subtracted, it is a most difficult job to separate them.

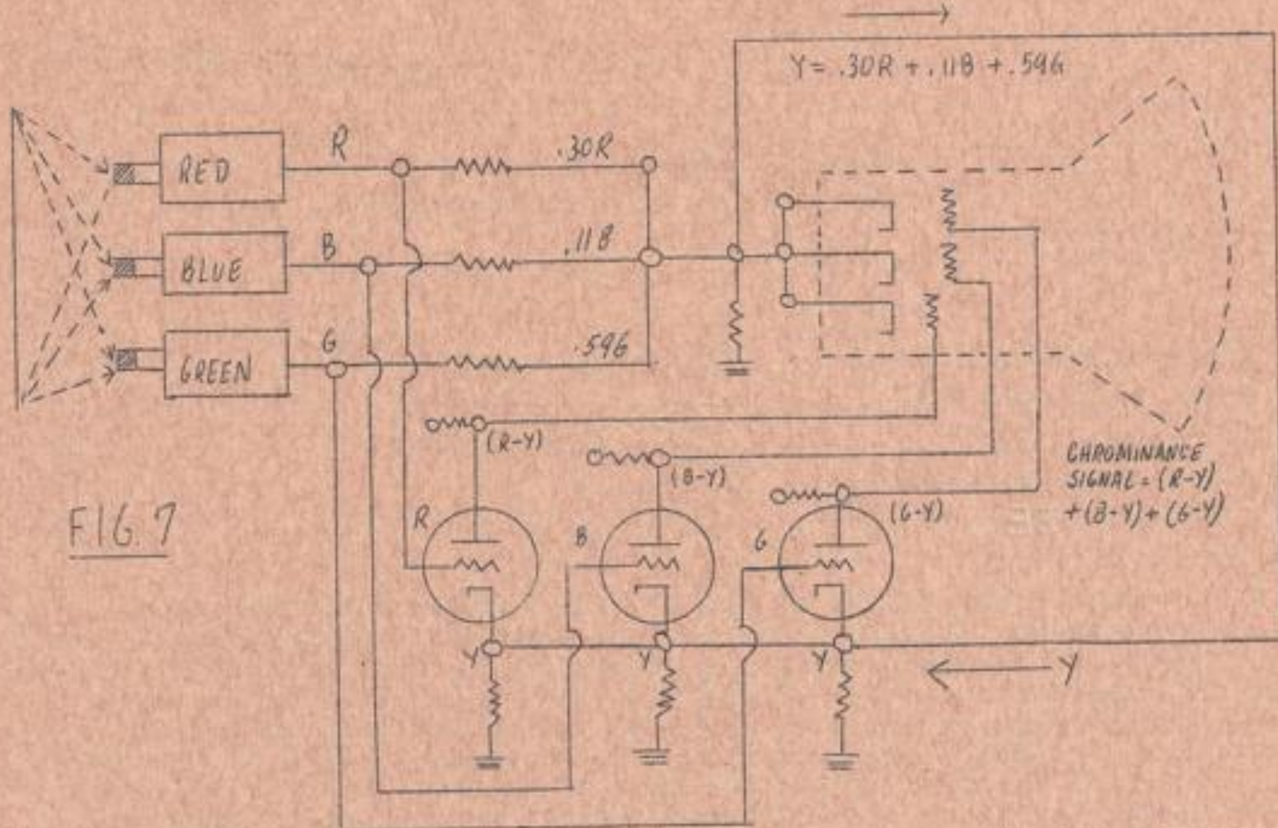
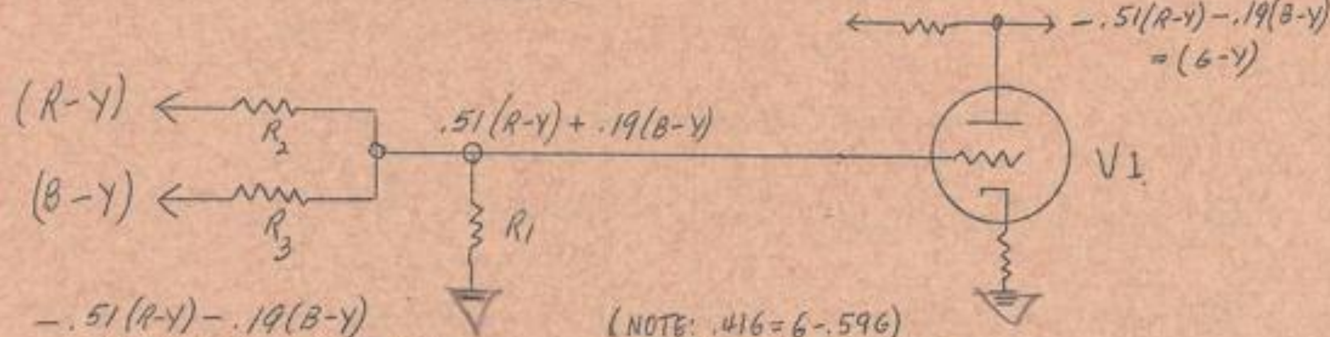


FIG 7

Fig 7 is an example of a complete (closed circuit) color system. Again, the camera output signals are mixed in a matrix unit to generate Y, the luminance signal. Note the three vacuum-tube stages wired as signal mixers or "adders". A camera output signal feeds each grid. The three cathodes are connected in parallel and receives the Y signal. From the foregoing discussion, the plate signal is equal to the grid signal minus the cathode signal discounting any gain or loss in the stage. The plate circuits, therefore, will contain the signals of R-Y, B-Y, and G-Y. This means that the output of each stage contains the intelligence of color but does not contain intelligence of brightness. Thus, the grids of the color tube are receiving chrominance signals and the cathodes are receiving the luminance signal. This type of color system would function very well and is a compatible system. That is, the total color signal involves a separate luminance signal that would allow normal operation of a monochrome receiver. From a consideration of bandwidth, the system isn't practical. Recall that the chrominance signal requires a 2 Mc bandwidth. In the above system, a 2 Mc bandwidth would be required for each of the three color signals for a total of 6 Mc. Our purpose now is to arrive at a solution to this bandwidth problem.

Let's consider adding the R-Y signal with the B-Y signal. Obviously, the resultant signal will contain the intelligence of the red and blue colors but no intelligence of luminance. Fig 8 illustrates the addition.

FIG. 8



$-.51(R-Y) - .19(B-Y)$
$= -.51R + .51Y - .19B + .19Y$
$= -.51R + .70Y - .19B$
(NOTE: $Y = .30R + .11B + .59G$)
$= -.51R + .21R + .8B + .41G - .19B$
$= -.30R - .11B + .41G$

(NOTE: $.41G = G - .59G$)
$= -.30R - .11B - .59G + G$
$= -(.30R + .11B + .59G) + G$
$= -Y + G$
$= G - Y$

By selecting certain values of R1, R2, and R3, (R-Y) can be added to (B-Y) to equal .51(R-Y) plus .19(B-Y). Further, the polarity of this signal can be reversed with a vacuum tube stage. Note in Fig 8 that the signal appears as -.51(R-Y) - .19(B-Y) in the plate circuit of V1. For simplicity sake, we are discounting any gain or loss in the vacuum tube stage. Obviously, if the stage has a gain of 10, the total equation would be multiplied by this figure. In any case, there is no change in the ratio of the red signal to the blue or vice versa. Both signals are increased the same amount.

There is a particular amount of significance attached to the equation -.51(R-Y) -.19(B-Y). Note the mathematics below the above circuit. By substituting for Y (Y equals .30R plus .11B plus .59G) in the equation, it is found to be equal to (G-Y). (G-Y), of course, is the signal from the green camera with the component of brightness (Y) removed. Since (G-Y) can be derived from the (R-Y) plus (B-Y) signal, it becomes apparent that the transmitter need only transmit the proper ratios of (R-Y) and (B-Y) signals as the chrominance intelligence. The (G-Y) signal can be derived from the chrominance signal at the receiver if the proper matrix circuit is utilized.

It might appear that the -.51(R-Y) - .19(B-Y) equals (G-Y) signal is enough intelligence to serve as the complete chrominance signal since the variables of (R-Y), (B-Y), and (G-Y) are all included. In order for these variables to cause proper operation of the color tube, they must be separated from each other and individual applied to the red, blue, and green guns. Such a separation cannot be executed by any means. Actually, the signal represents only the intelligence of (G-Y) as proven above even though it is expressed in terms of (R-Y) and (B-Y).

With the foregoing discussion in mind, let's consider the possibility of the chrominance intelligence being transmitted as two differnt signals with each containing (R-Y) and (B-Y) but not (G-Y).

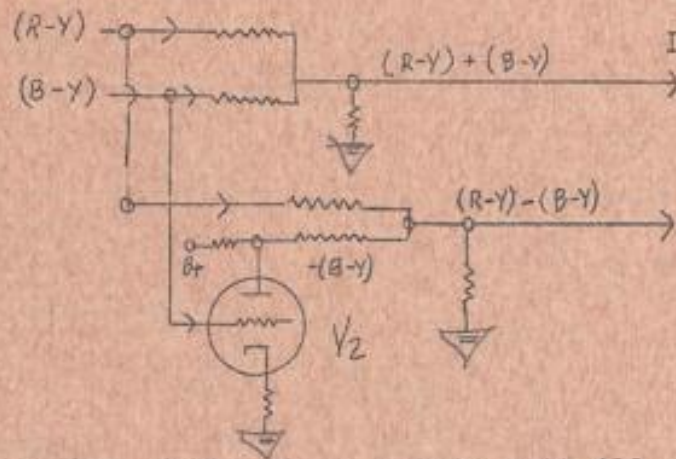
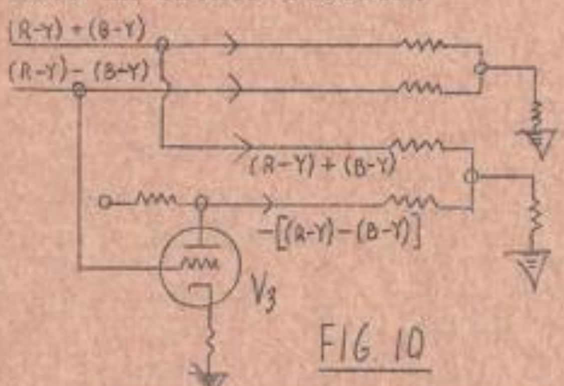


FIG. 9

The top section of the above matrix unit illustrates the addition of (R-Y)and (B-Y) in a resistance circuit such as to produce a total signal of (R-Y) plus (B-Y). The lower section illustrates a similar addition except that the (B-Y) signal is inverted with respect to (R-Y) by means of V2. The output of the lower section is (R-Y) - (B-Y). For simplicity sake only, we aren't considering any gain or loss in either section.

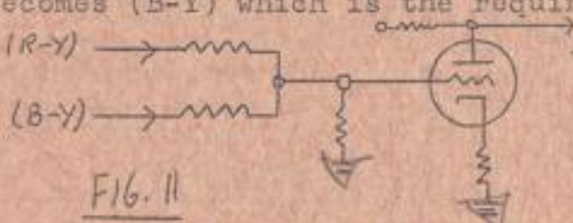


$$\begin{cases} = (R-Y) + (B-Y) + (R-Y) - (B-Y) \\ = R-Y + B-Y + R-Y - B+Y \\ = 2R - 2Y \\ = 2(R-Y) = \text{RED SIGNAL} \end{cases}$$

$$\begin{cases} = (R-Y) + (B-Y) - (R-Y) + (B-Y) \\ = R-Y + B-Y - R+Y + B-Y \\ = 2B - 2Y \\ = 2(B-Y) = \text{BLUE SIGNAL} \end{cases}$$

FIG. 10

Fig 10 shows the application of the two signals of Fig 9 to another matrix unit. The top section illustrates the addition of the two signals to produce a signal equal to 2(R-Y). The (2) can be disregarded since we aren't considering gain or loss in any of the matrix units. The lower section illustrates the addition of the two signals with the (R-Y) - (B-Y) signal inverted by means of V3. The lower unit produces a signal equal to 2(B-Y). Disregarding the (2), the signal becomes (B-Y) which is the required signal for the blue gun of the tube.



$$-.51(R-Y) - .19(B-Y)$$
$$= (G-Y) = \text{GREEN SIGNAL}$$

FIG. 11

It was proven in a foregoing discussion that (G-Y) could be derived by properly adding (R-Y) and (B-Y) with a matrix unit. Fig 11 illustrates this unit (Fig 11 is same as Fig 8). (G-Y) is the green signal required of the green picture tube gun.

N

$I = .28G - .60R - .32B$

$Q = .52G + .21R + .31B$

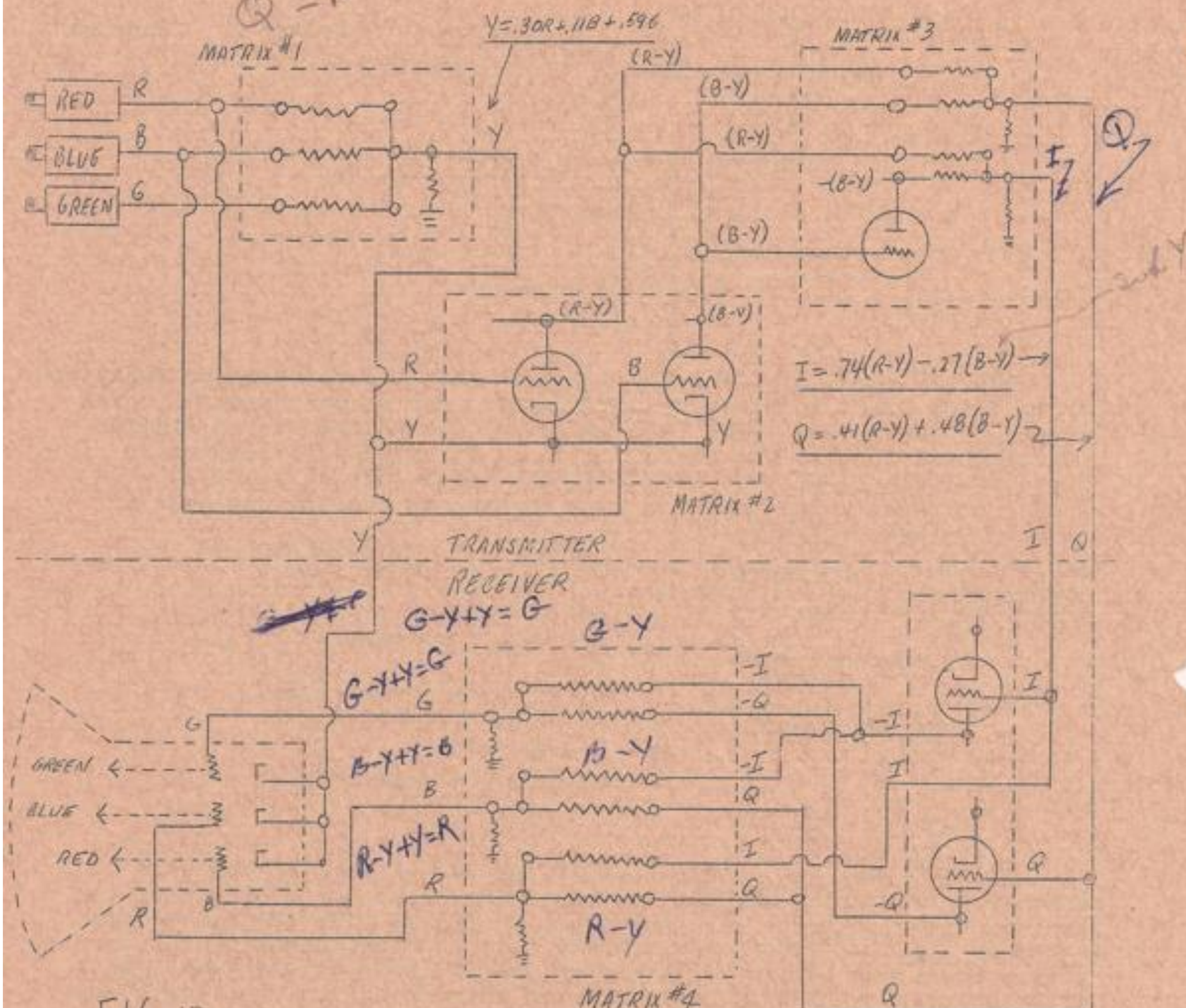


FIG 12

Fig 12 illustrates the complete color system (closed circuit) that has been described. Matrix unit #1 adds R, B, and G to produce the luminance signal Y. Matrix unit #2 adds R and B to produce equal amplitudes of (R-Y) and (B-Y) signals. Matrix #3 adds these signals to produce (R-Y) plus (B-Y) and (R-Y) - (B-Y) signals. Note that matrix #3 produces unequal amplitudes of (R-Y) and (B-Y) components.

The output signals of matrix #3 are specifically referred to as the "I" and "Q" signals. The specific values of these two signals were arrived at by the N.T.S.C. committee. The I and Q signals represent the chrominance intelligence.

The I and Q signals are inverted in the receiver as shown. Matrix #4 of the receiver adds -I and -Q to produce G; adds -I and Q to produce B; and adds I and Q to produce R.

Charles Ogilvie

Modulation and Detection of the Color Signal

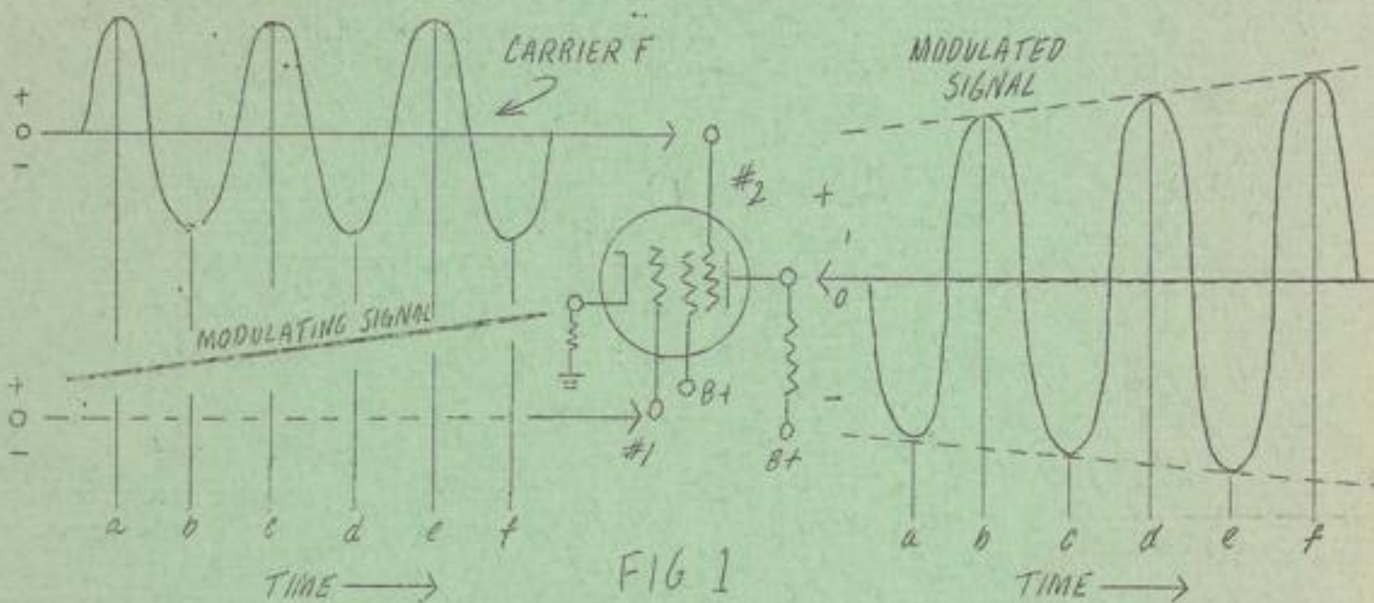


FIG 1

It is helpful at this point to review amplitude modulation. Fig. 1 illustrates the modulation of a carrier frequency with a signal. In this case, the carrier frequency is applied to the suppressor grid #2 and the signal is applied to the control grid #1.

The modulation process simply involves the variation of the carrier voltage peaks with the signal. Consider that the signal determines the gain of the stage from instant-to-instant causing changes in amplitude of the carrier voltage peaks.

The carrier frequency is usually several times higher than the highest signal frequency. In the above example, the carrier frequency goes through three cycles while the signal goes through on a small part of one cycle.

Note that the signal is increasing in a positive direction from time a to time f resulting in an increase in stage gain from time a to time f. This results in the carrier voltage peaks being increased in amplitude at the plate during this time. The intelligence of the signal is represented by either the negative or positive peaks of the plate voltage. Note that a line drawn through either the positive peaks or negative peaks is identical with the input signal except that one line represents a positive condition of the signal and the other represents a negative condition.

The signal at the plate is referred to as a modulated signal. Note that instantaneously the modulated signal is not zero but the average condition of it is.

An important consideration of the amplitude modulation process is the realization that the intelligence of the input signal is not completely represented on the peaks of the modulated signal. Notice that the input signal is a continuous waveform while the modulated signal has sizeable gaps between peaks. Further, notice that the positive polarity of the modulated signal represents the signal at times b, d, and f while the negative polarity of the modulated signal represents the signal at times a, c, and e. This condition would seem to indicate that some distortion would result from the process. The amount is negligible if the carrier frequency is high enough with respect to the modulating signal.

Since the average value of the modulated signal is zero, it must be detected (rectified) before any use can be made of it. Note in

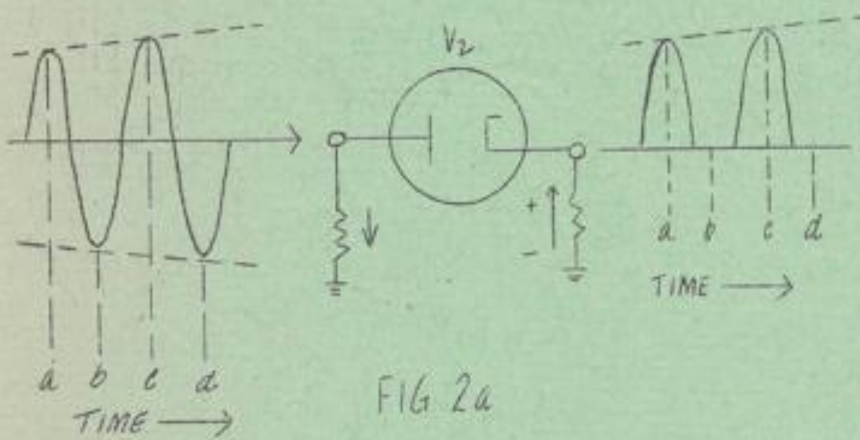


FIG 2a

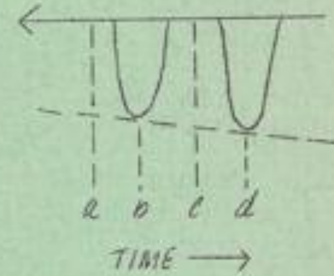


FIG. 2b

Fig 2a that the modulated signal is connected to the plate of a diode with the cathode of the tube returning to ground through a resistor. This arrangement allows the tube to conduct on the positive pulses of the modulated signal but not on the negative pulses. By reversing the plate and cathode connections of V2, the detected output would appear as indicated by Fig 2b.

It is interesting to note that the modulator described continues to function with the carrier frequency if the modulating signal is disconnected. In this case, the output would be the carrier frequency less modulation. The amplitude of the positive and negative peaks would not vary and would be equal. Detection of such a signal results in either positive or negative pulses of equal amplitude. Because of their high frequency, these pulses do not represent any audible or visible intelligence.

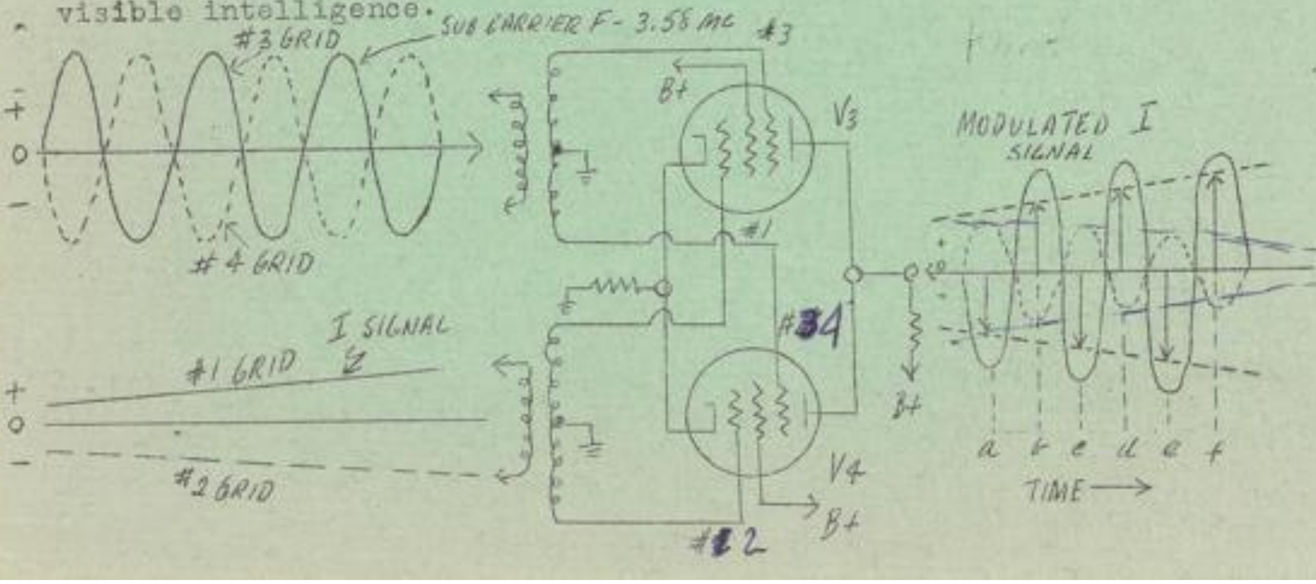


Fig 3 illustrates a balanced type modulator and is the type used to modulate both the I and Q chrominance signals. As previously discussed, the chrominance carrier frequency is approximately 3.58 Mc and is referred to as the subcarrier frequency.

For this discussion, let's consider that the modulating signal is the I signal and has a waveform from time a to time f as shown. Note that the I transformer causes the in-phase component of the I signal to appear at the #1 grid of V3 and causes the 180 degree out-of-phase component to appear at the #2 grid of V4. Note that the subcarrier transformer causes the in-phase component of the subcarrier to appear at the #3 grid of V3 and causes the 180 degree out-of-phase component to appear at the #4 grid of V4. The in-phase subcarrier is represented by a solid line and the out-of-phase component is represented by a dashed line. The same is true of the I signal.

From time a to time b, V3 receives an increasing positive I signal resulting in the in-phase subcarrier voltage being produced at the plate as shown by the solid line waveform. Note the 180 degree phase reversal in the voltage as it goes from grid to plate. During this same time, V4 receives an increasing negative I signal resulting in the 180 degree out-of-phase subcarrier voltage being produced at the plate as shown by the dashed waveform. Note again the phase reversal from grid to plate.

The resultant voltage peaks for times a, b, c, d, e, and f are illustrated with solid arrows. We will refer to these resultant voltage peaks as pulses. By connecting dashed lines through them, it is apparent that they represent the intelligence of I. Again, as was true with the unbalanced type of modulator described previously, the intelligence of the signal is represented by either the positive pulses or the negative pulses. The resultant waveform at the modulator plate is of sine wave type connecting the peaks of the pulses. We will continue to show the resultant modulated signal as pulses for simplicity purposes.

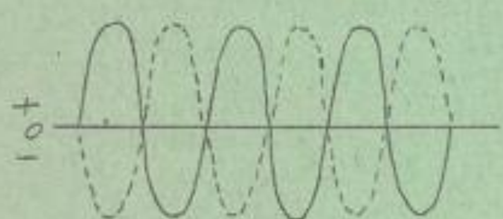


FIG 4a

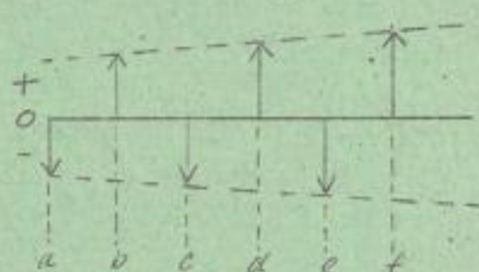


FIG 4b

Fig 4a explains a most significant fact about the balanced type of modulator. Without a modulating signal, the plate waveform appears as shown in Fig 4a. Since the positive peaks are equal in amplitude to the negative peaks and one is out-of-phase with the other by 180 degrees, the output is zero. As a matter of fact, instantaneous, the output is always zero without a modulating signal since any positive output is cancelled by an equal output of negative. This means that without a modulating signal, there is no carrier or subcarrier output from the modulator.

Fig 4b illustrates the modulator output considering the output as pulses of both negative and positive voltages.

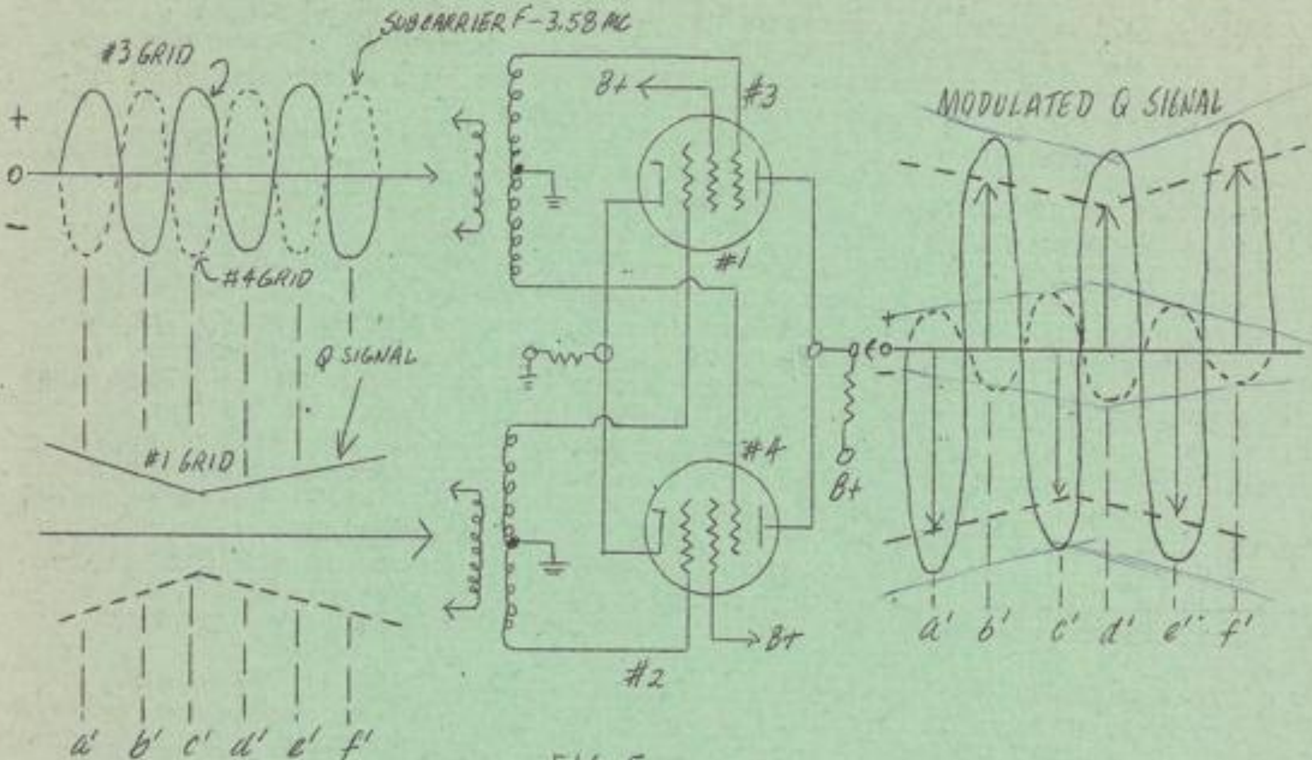


FIG. 5

Fig 5 illustrates the action of the balanced modulator with the modulating signal shown. This illustration is to point out how the modulator functions with a different modulating signal. In this case, we are considering that the modulating signal is the chrominance signal Q. Again, we are representing the modulated output signal as a series of pulses for simplicity.

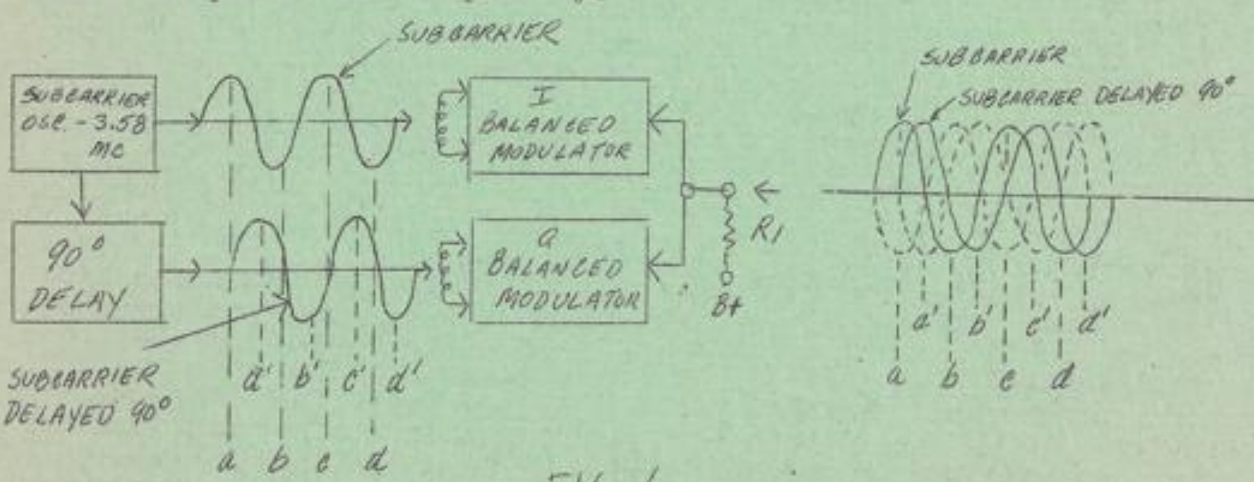


FIG. 6

Until now we have considered the chrominance subcarrier as being a single carrier frequency of 3.58 Mc. **Note in Fig 6 that** the I modulator receives the 3.58 Mc subcarrier frequency directly from the transmitter's subcarrier oscillator while the Q modulator receives the 3.58 Mc subcarrier frequency delayed 90 degrees. In this example, we aren't considering the I and Q modulating signals.

Consider that the plates of the I modulator are connected directly to the plates of the Q modulator resulting in an addition of the two outputs across the resistor R1. Note again, that the output is zero without modulating signals. Instantaneously, any positive voltage output is cancelled by an equal amount of negative output.

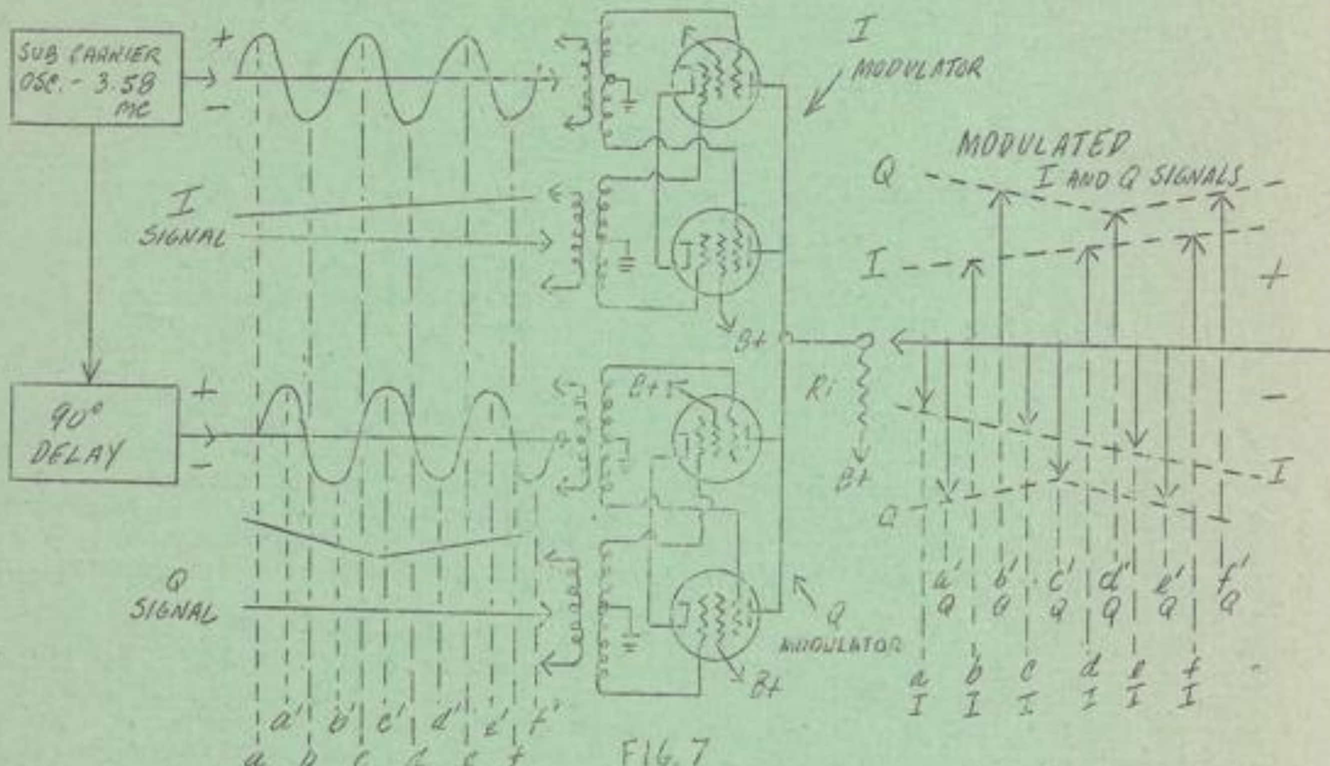


FIG. 7

Fig 7 illustrates the I and Q modulators operating with I and Q signals. For simplicity, we are using the same I and Q signals that were illustrated in Fig's 3 and 5. Note the mixing of the two signals accomplished by paralleling the plates of the two modulators.

Note the 90 degree lag in the subcarrier feeding the Q modulator caused by a delay circuit. The in-phase subcarrier feeds the I modulator. The outputs of the two modulators are the same as previously described except that they are 90 degrees out-of-phase with each other. The Q pulses lag the I pulses by 90 degrees because the Q subcarrier lags the I subcarrier by 90 degrees.

It is most important to realize the equal 90 degree spacing of the I and Q signal pulses. This arrangement allows separation of the two signals in the receiver as we will see. A continuous line drawn from left to right through successive peaks of the pulses would represent the resultant signal. Since the resultant is of little importance to our discussion, we will continue to show the individual I and Q pulses.

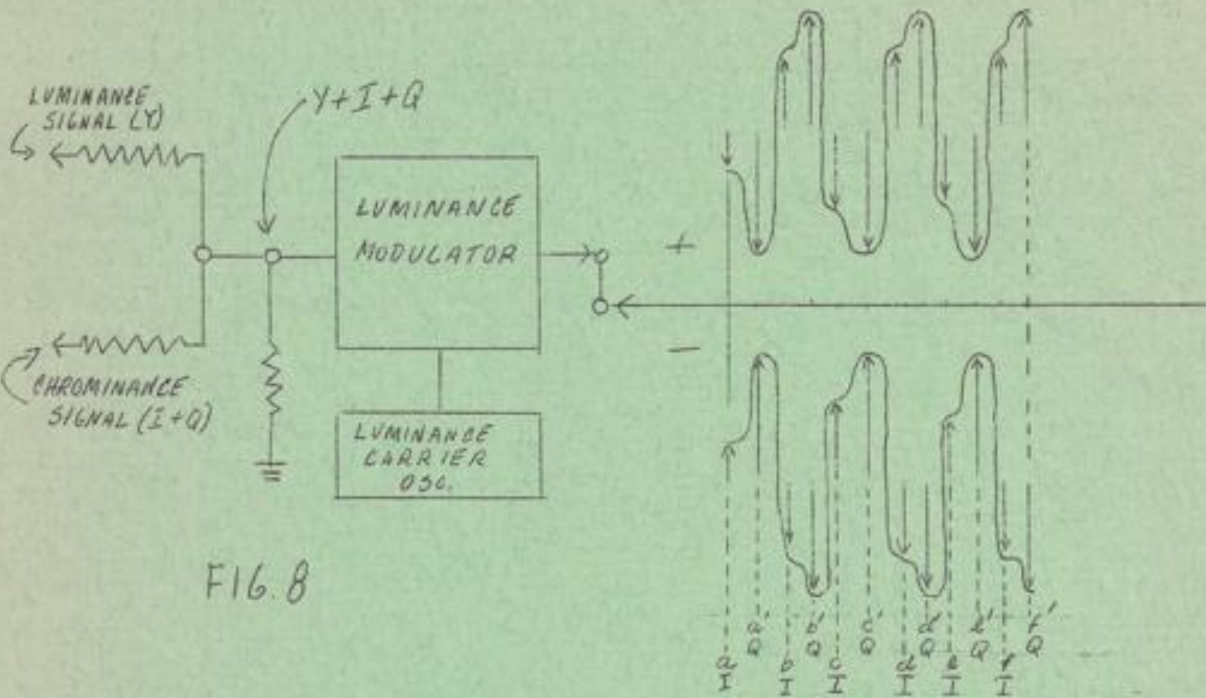


FIG. 8

The chrominance signals I and Q are added to the liminance signal Y and fed to the luminance modulator. This modulator is the regular luminance (video) modulator used in monochrome (black and white) transmitters. The output of the modulator is luminance and chrominance intelligence in modulated form.

The modulated waveform shown in Fig 8 represents the I and Q chrominance signals that we've been discussing. To simplify the drawing, the luminance signal is not shown. Recall that the chrominance signal appears at places not occupied by the luminance signal. The modulated signal envelope shows the variation of the luminance carrier peaks with the chrominance signals I and Q. It is interesting to note that each I and Q pulse is represented in both the positive modulated waveform and in the negative modulated waveform.

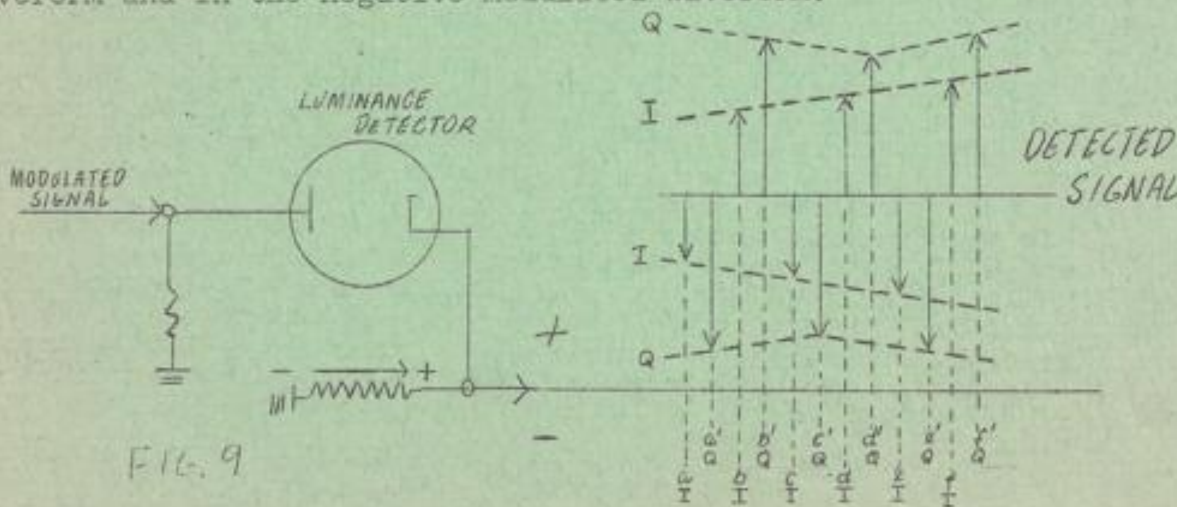


FIG. 9

Fig 9 shows the detection of the chrominance signal with the regular luminance detector. The detector is arranged to cause the detected output to be in a positive direction. Obviously, the detector might be arranged to produce either polarity of the detected signal. The output of the detector contains the luminance signal as well as the chrominance. We are disregarding the luminance signal for this discussion.

Note that the detected chrominance signal is exactly the same as the combined output of the I and Q modulators except that all pulses of I and Q are represented above the zero axis in a positive direction. This change in the zero axis of the signal does not affect the intelligence of the signal. We aren't showing the luminance carrier frequencies that support the I and Q pulses. A continuous line drawn from left to right through successive peaks of the pulses would represent the resultant signal.

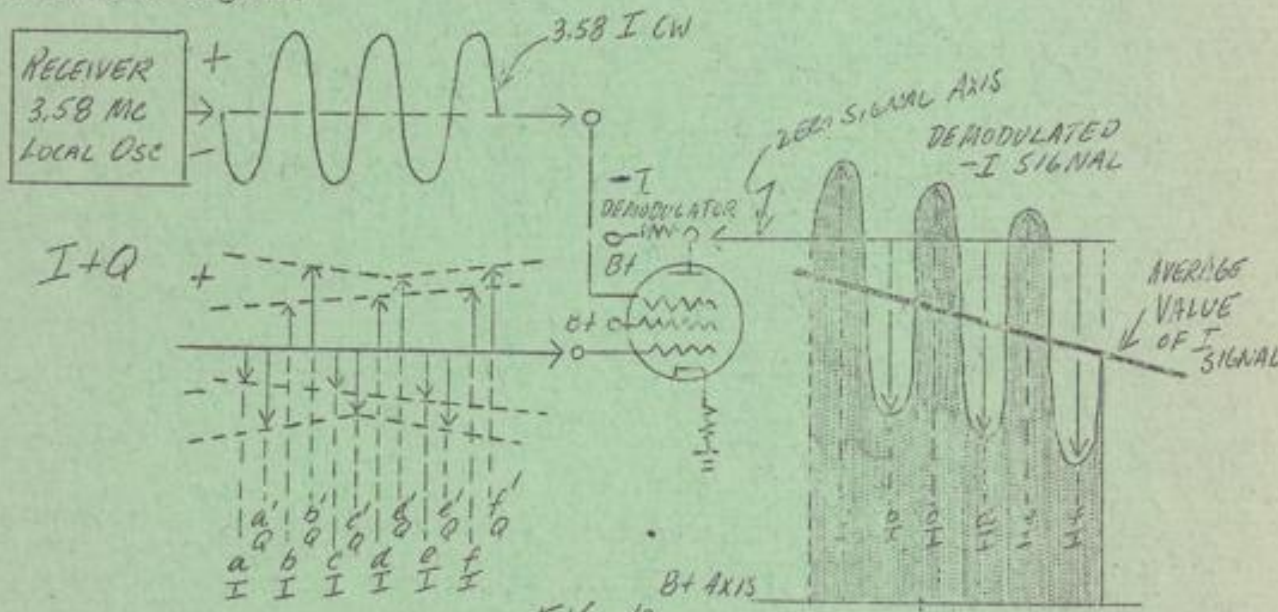


FIG. 10

Fig 10 shows the separation of the I signal from the Q signal with a synchronous type detector referred to as the I demodulator. The control grid of the stage is supplied with the luminance detector output containing the I and Q signals. Because the total signal passes through a resistance coupled amplifier before reaching the I modulator, we are showing a zero axis through the center of the I and Q signals.

A local oscillator in the receiver supplies a 3.58 Mc waveform to the suppressor grid. The oscillator is controlled frequency-wise and phase-wise with special sync. information riding on top of the horizontal blanking pulses. A complete discussion of the control of the 3.58 Mc oscillator will follow later.

The oscillator output is controlled such as to be in-phase with the I pulses of the I plus Q signal. The in-phase output of the oscillator is called the I CW signal. Note above that the peaks of the I CW signal coincide exactly with the I pulses. Further note that the I CW waveform goes through zero at the times of the Q pulses. This results in the I demodulator stage reacting essentially to the I pulses and producing plate information primarily as a function of I. A small amount of Q signal does appear at the plate but for all practical purposes is cancelled out because the average value of it is zero.

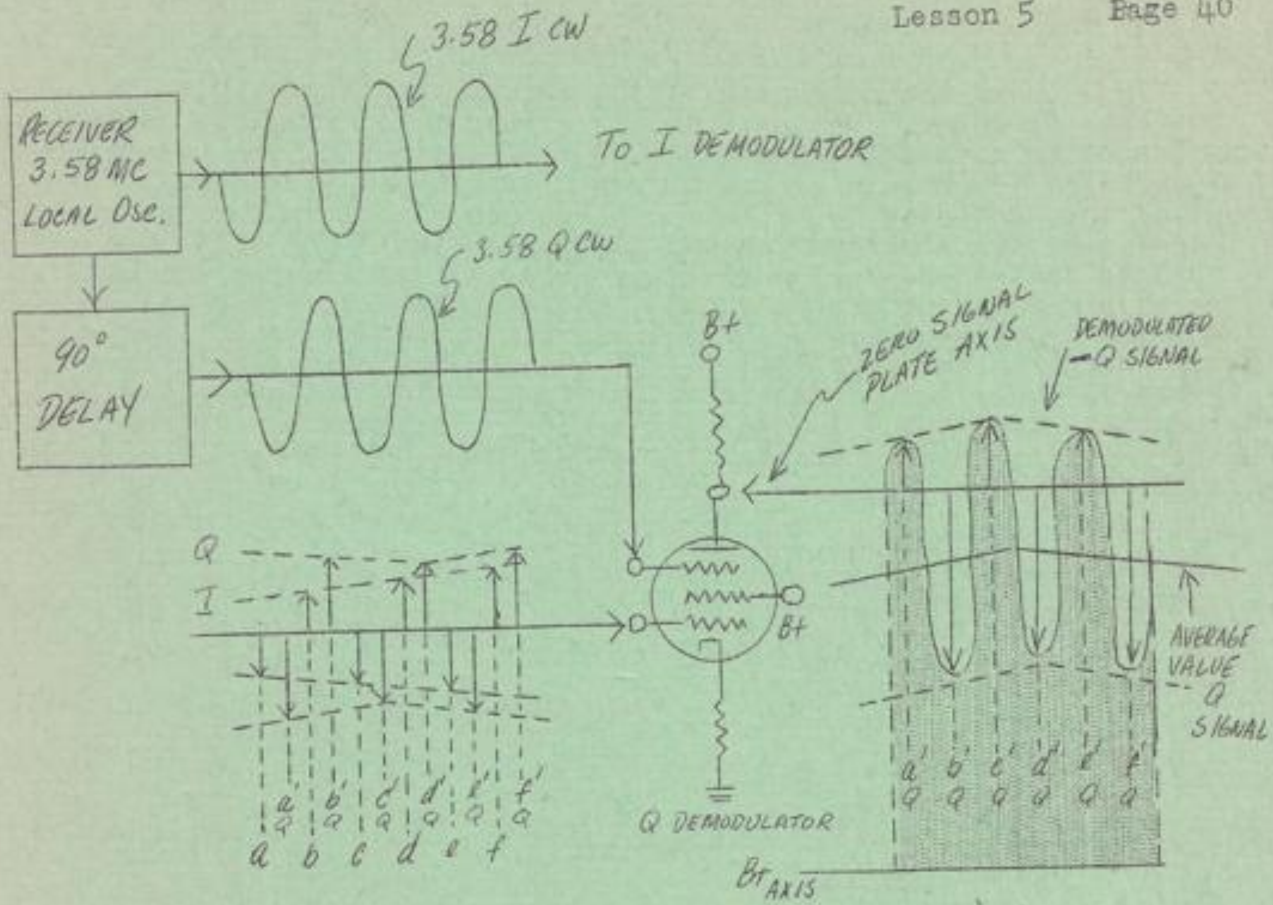


FIG 11

Note in Fig 11 that the receiver's local oscillator is arranged to produce a 3.58 Q CW signal delayed 90 degrees with respect to the I CW signal. This signal is applied to the suppressor grid of a stage called the Q demodulator. The control grids of both the Q demodulator and I demodulator are connected together resulting in the Q demodulator control grid receiving the same signal as was explained for the I stage.

Note that the peaks of the Q CW signal coincide with the Q pulses while the zero values coincides with the I pulses. This results in the Q demodulator stage reacting essentially to the Q pulses and producing information primarily as a function of Q. Some I information shows up at the plate but cancels because the average value of it is zero.

It is important to note the exact conditions of the plate circuit to understand that the intelligence of Q is represented. We are showing a B plus axis to explain how the peaks of the Q waveform varies with respect to it. We are also showing how the Q waveform varies about the zero signal axis. The zero signal axis represents the plate voltage under a zero in-put signal condition. The intelligence of Q is represented on the peaks of the pulses above the zero signal axis as well as the peaks below the zero signal axis. Note that we are showing the average of this waveform. Actually, the average value is the intelligence of Q. The picture tube responds to the average value rather than the actual waveform. Note that the average value is identical with the Q signal we started with, except that it is negative. Refer back to Fig 10 and note that the demodulated I signal is negative at the demodulator plate compared with the beginning I signal.

Charles Ogilvie

I Demodulator

Cancellation of Q in I Demodulator

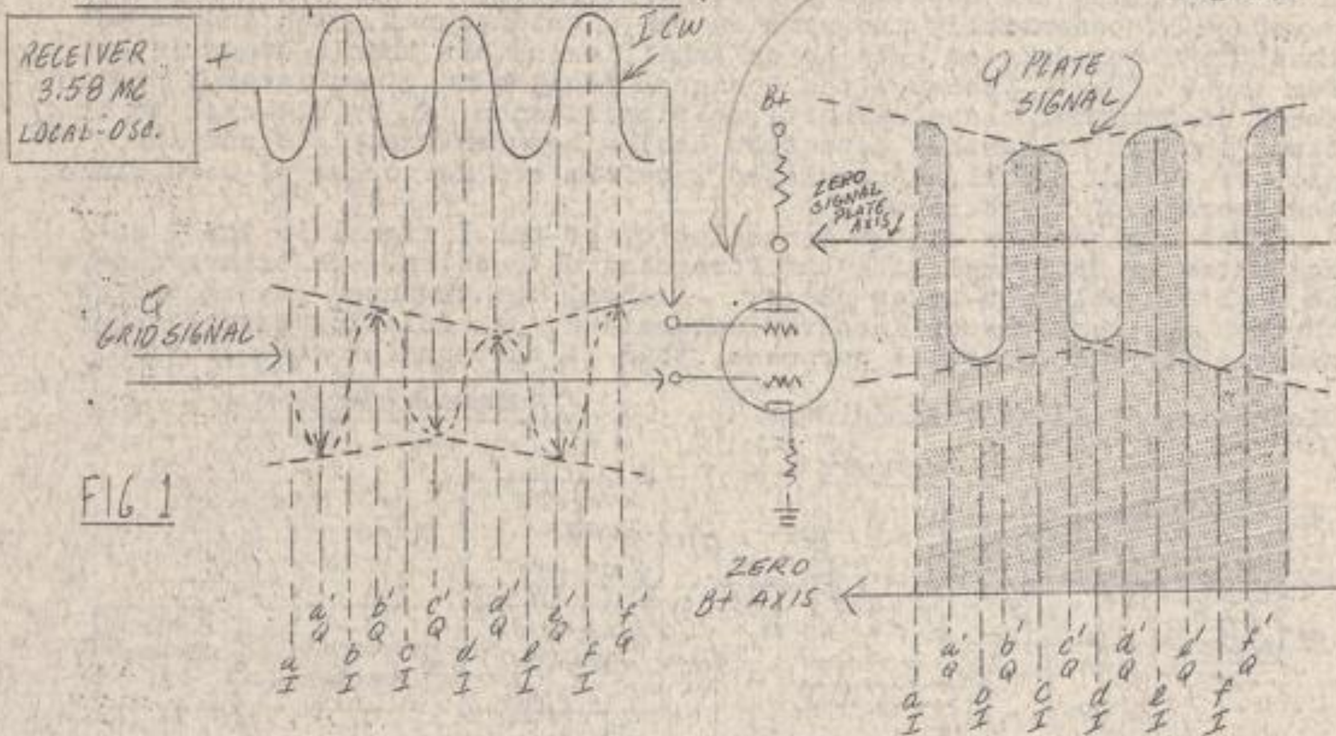


FIG 1

Fig 1 serves to show the effective cancellation of the Q signal as it passes through the I demodulator. As explained previously, the in-phase I CW signal connects to the suppressor and the luminance detector output of I and Q connects to the grids of both the I and Q demodulators. For simplicity, the I signal isn't being considered in Fig 1. Again, the waveform of the Q signal at the grid is represented by pulses. However, in this case, the actual waveform of Q is shown since there is significance associated with the waveform.

The same shape of Q signal previously discussed is being considered. Because of the 90 degree lag of the Q waveform with respect to the I CW signal, the I CW waveform passes through zero voltage at the times the Q waveform peaks. Note from times a to b that the Q signal completes a negative ½ cycle while the I CW signal goes from a maximum negative to a maximum positive. As shown, the plate voltage swings from a positive condition to a negative condition with respect to the zero signal plate axis. The amplitude of the positive and negative swing is equal because the Q grid voltage results in tube gains which are equal for both the positive swing and the negative swing.

From times b to c, the Q signal completes a positive ½ cycle while the I CW signal goes from a maximum positive to a maximum negative. This results in the plate swing from a negative to a positive. Again, the positive and negative swing of the plate voltage is equal because the Q grid voltage produces tube gains which are equal for both swings. The plate swing from time b to time c is of less amplitude than from time a to time b because the Q waveform is of less amplitude.

Note the plate waveform for the time a to f'. Note that a line connecting the plate positive peaks remains equal and opposite to a line connecting the negative peaks. As a matter of fact, the plate waveform is essentially the same as the Q grid signal which indicates that the I demodulator acts as an amplifier rather than a demodulator for the Q signal. Because the Q signal remains in a modulated state in the I demodulator plate circuit, no significance can be attached to it since there is no further detector action between the plate and the picture tube. Recall, a modulated waveform can do no useful work since the average of it is zero.

The explanation of the cancellation of the I signal in the Q demodulator is identical with the foregoing discussion. In either case, no real cancellation takes place. Rather, the unwanted signal passes through the demodulator involved without any demodulation action taken place. For all practical purposes, this is the same as cancellation.

Discussion of I and Q Bandwidths

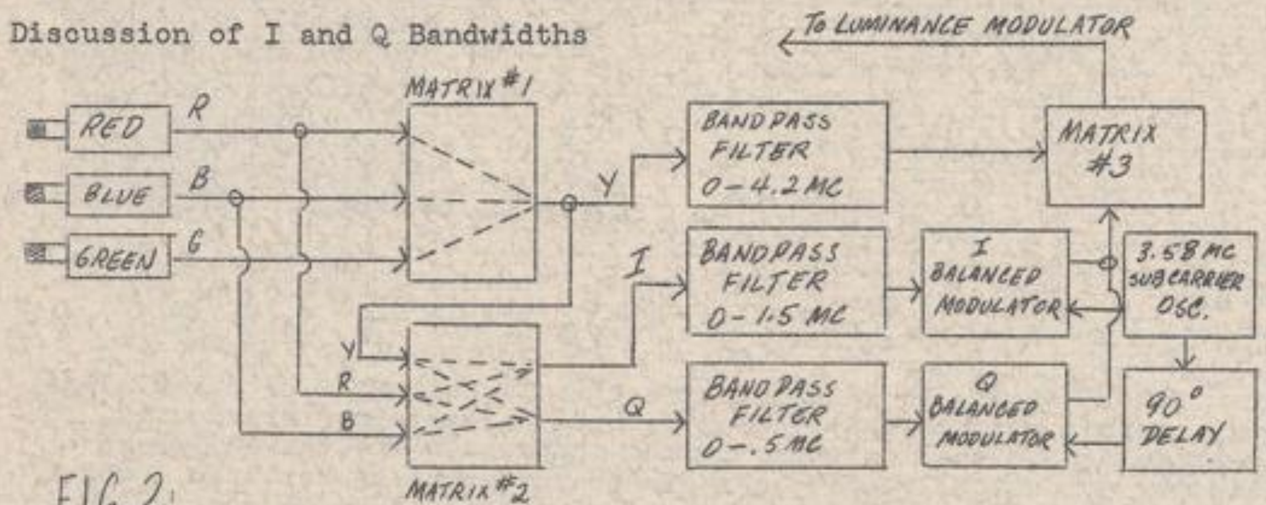
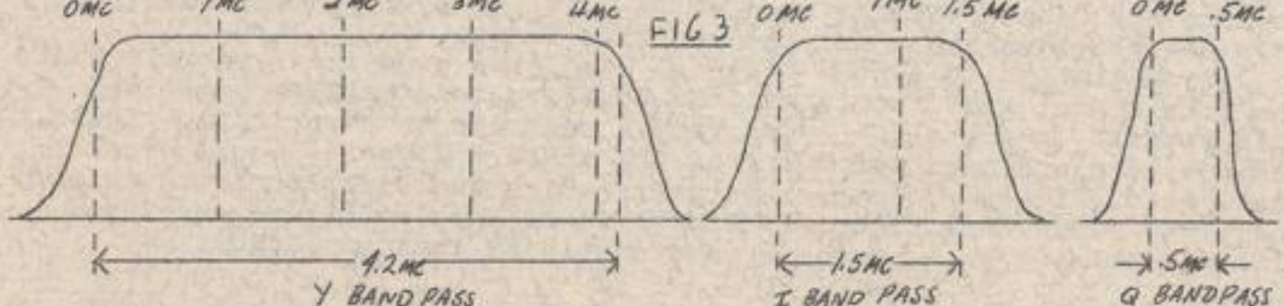


FIG. 2

In previous considerations of the transmitter, no specific bandwidths were established for the Y, I, and Q signals. Fig 2 shows the three color cameras generating the R, B, and G signals. Matrix #1 adds these signals properly to produce the luminance signal Y. Matrix #2 adds the R, B, and Y signals to produce the chrominance signals I and Q. At this point, the Y, I, and Q signals feed individual bandpass filter circuits. The Y bandpass is established at 4.2 Mc; the I bandpass at 1.5 Mc; and the Q bandpass at .5 Mc as shown in Fig 3.

FIG 3



Note in Fig 3 how the I bandpass appears with respect to the Q bandpass prior to modulating the 3.58Mc subcarriers. Low video frequencies from 0 to .5 Mc appear as Y, I, and Q signals. This range of frequencies represents the large color areas of the scene. Thus, any large area of the scene will be reproduced on the picture tube in true color. Recall that the picture tube requires both I and Q signals to reproduce a given color of the color spectrum.

Medium video frequencies from .5 Mc to 1.5Mc appear as I and Y signals only. Obviously, the reproduced picture details representing these frequencies will not be in true color. This limitation of the color signal is permissible because the human eye cannot perceive true color for the range of picture details represented by the .5 Mc to 1.5 Mc range of frequencies.

Video frequencies from 1.5 Mc to 4.2 Mc appear as Y or luminance signals only. The reproduced picture details representing these frequencies have no color except the range from black to white. This limitation of the color signal is permissible because the human eye cannot perceive color except black and white for the range of picture details represented by the 1.5 Mc to 4.2 Mc range of frequencies.

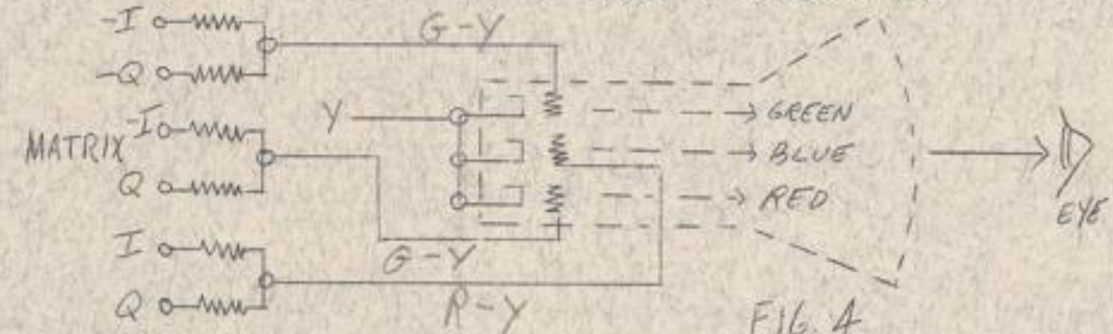


FIG. 4

Time	Signal Q	Signal I	Bias of Guns Green Grid	Red Grid	Blue Grid	Resultant Color
a		0	0	0	0	White
b		1	-1	-1	+1	Light green and red plus blue
c		10	-10	-10	+10	Very light green & red plus deep blue
d		-1	+1	+1	-1	Green & red plus light blue
e		-10	10	10	-10	Deep green & red plus very light blue
f	0		0	0	0	White
g	1		-1	1	1	Light green plus red & blue
h	10		-10	+10	+10	Very light green plus deep red & blue
i	-1		+1	-1	-1	Green plus light red & blue
j	-10		+10	-10	-10	Deep green plus very light red & blue

In order to better understand the color range of the I and Q signals, it is helpful to study the action of the color tube under specific conditions of I and Q voltages. Fig 4 illustrates a picture tube circuit where the I and Q signals are connected to the grids of the tube while the Y signal is connected to the three cathodes. Since the luminance signal Y supplies only the brightness information, it can be disregarded in studying the individual color ranges of I and Q.

For the purpose of simplicity, the chart in Fig 4 considers instants of time when either an I or a Q signal exist but not both. From a previous discussion, an I signal is present anytime that a Q signal is present. However, no Q signal is present at an instant of time if the I signal has a frequency higher than .5 Mc. This fact does not prevent individual considerations of I and Q color range.

At instants of time when the video signal represents black and white detail of the scene and considering that the frequencies involved fall within the I and Q bandpass, the I and Q signals are equal to zero. Recall that the equations for the I and Q signals are:

$$I = .74(R-Y) - .27(B-Y)$$
$$Q = .41(R-Y) + .48(B-Y)$$

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

$$I = -.28G + .60R - .32B$$
$$Q = -.52G + .21R + .31B$$

The camera output voltages R, B, and G are all the same amplitude and polarity when a video frequency represents some shade of white of the scene. Thus, the above equations for I and Q are equal to zero at such instants and do not influence the picture tube. Time a and time f on the chart indicate two such instants.

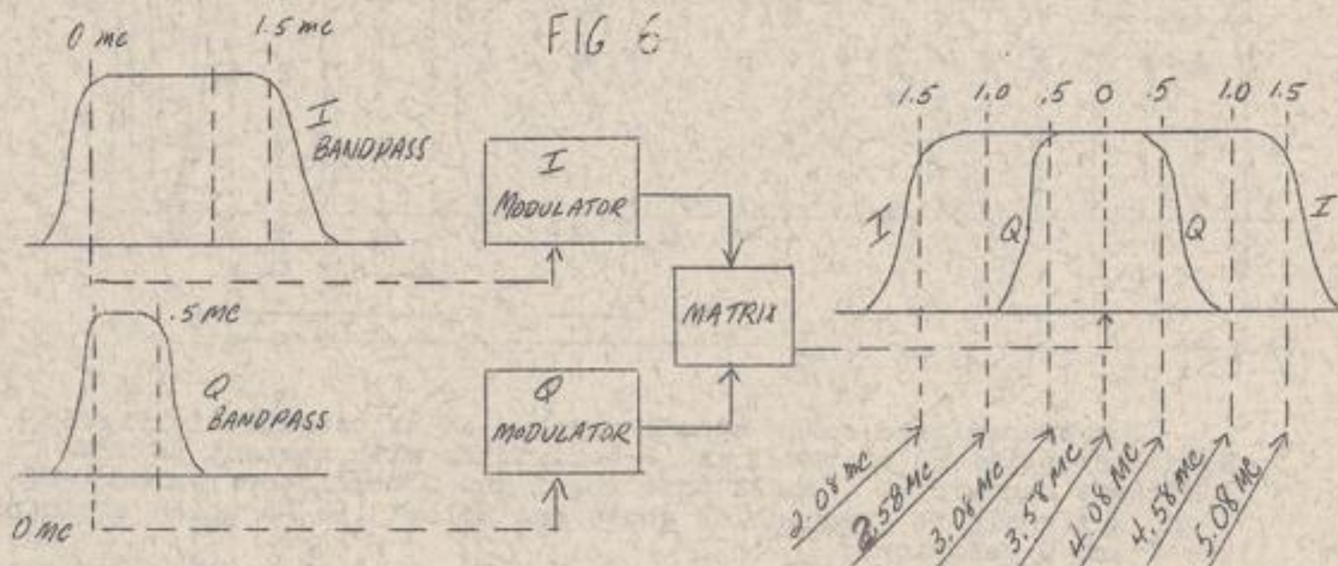
Study of the chart for I voltages of 1,10,-1,and -10 indicates the color range of the I signal to be from green-red to blue. Study of the chart for Q voltages of 1, 10, -1, and -10 indicates the color range of the Q signal to be from green to red-blue.

FIG 5

The I and Q color range is illustrated in Fig 5. The color spectrum is shown as a color wheel to better illustrate the ranges of the signals. The color wheel indicates that a blue-red color or hue is called magenta. Thus, the range of the Q signal is from magenta to green and the I range is from orange (green-red) to blue.

Specifically, the I bandpass was selected because the human eye can perceive details of color or hue from orange to blue of a size determined by video frequencies from .5 Mc to 1.5 Mc. Note in Fig 5 how the I and Q ranges overlap each other to reproduce the entire color spectrum. It is obvious that I and Q signals below .5 Mc mix together in the receiver's matrix to produce any color in the spectrum.

FIG 6



Upon modulation of the two 3.58 Mc subcarriers, the modulated I and Q signals appear as shown above. An upper and lower sideband of frequencies is generated for both the I and Q signals as a result of the modulation process. Since the modulated frequency (subcarrier) is 3.58 Mc in either case, the upper and lower sidebands of I and Q appear on either side of 3.58 Mc.

The range of I and Q intelligence is shown above the modulated waveforms. The frequencies representing the I and Q intelligence are shown below the modulated waveforms.

FIG 7

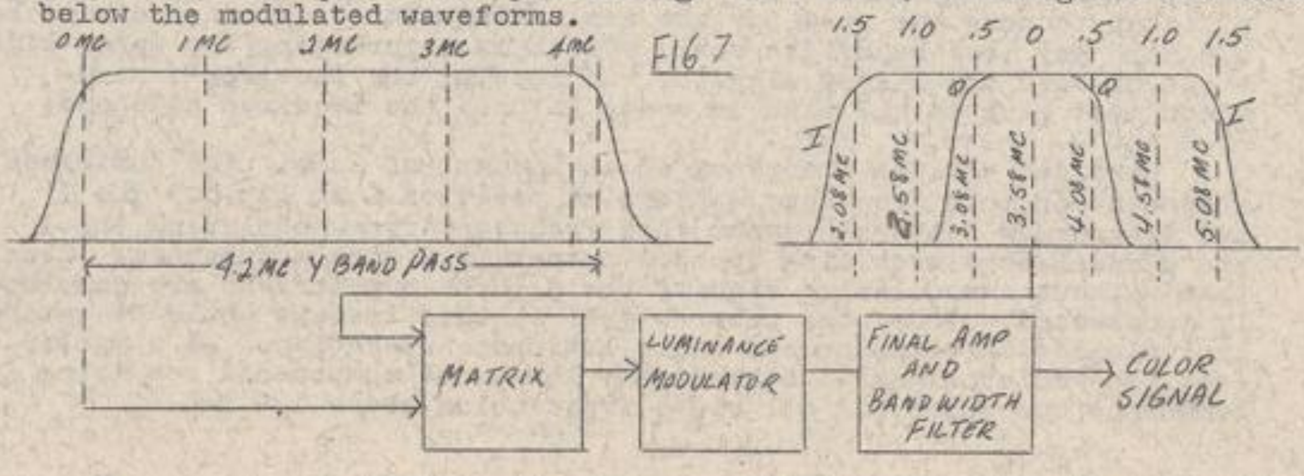
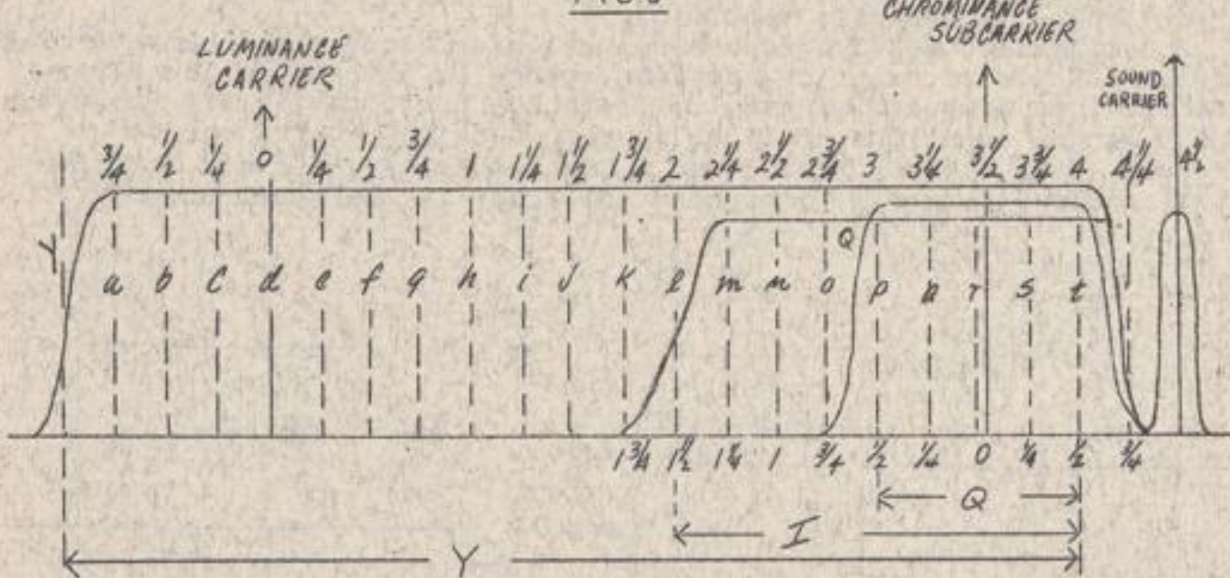


Fig 7 shows the addition of the I and Q modulated signals to the luminance signal Y in a matrix section. The output of the matrix serves as the modulating signal for the luminance carrier frequency. The luminance bandwidth filter serves to establish the required limits of the transmitted color signal.

FIG 8



The transmitted color signal appears as illustrated in Fig 8. Note the positions of the I and Q bandwidths with respect to the luminance bandwidth. Recall that the I and Q modulators convert the I and Q signals to frequencies above and below 3.58 Mc which explains the I and Q positions.

The range of luminance intelligence is shown above the modulated waveform while the range of I and Q intelligence is shown below the waveform. Note that the upper sideband of I is limited to approximately .5 Mc by the luminance upper sideband filter. Thus, 1.5 Mc of the lower sideband of I is transmitted along with .5 Mc of the lower sideband. Both sidebands of the Q signal are transmitted since each sideband is .5 Mc wide and is not influenced by the luminance sideband filter. The lower luminance sideband filter serves in its usual way to remove all but approximately .75 Mc of the lower sideband. It is significant to note the need for the luminance upper sideband width to be 4.2 Mc. Any less bandwidth would result in suppressing the upper sidebands of both the I andQ signals. Obviously, the receiver's bandwidth must also be 4.2 wide in order to pass the required sidebands of I and Q.

Consider a video frequency at an instant of 2 Mc. The luminance component of this frequency appears at position L in Fig 8. The I and Q bandpass filters prevent this frequency from modulating the I and Q modulators resulting in zero output from both modulators. Recall that without a modulating signal, the 3.58 Mc subcarriers are completely suppressed. Thus, the color signal at this instant would be entirely luminance information and cause luminance operation. As a matter of fact, the color signal contains only luminance components resulting in luminance operation for all video frequencies above 1.5 Mc.

Consider a video frequency at an instant of .5 Mc. The luminance components of this frequency appear at positions B and F. The I and Q components of this frequency appear at positions P and T. Due to the wide separation of these positions in the bandwidth, no possible beat interference can occur.

Upon further inspection of Fig 8, it can be seen than an I or Q signal cannot appear in the total bandwidth at a position where a luminance signal does, thus minimizing possibilities of beats.

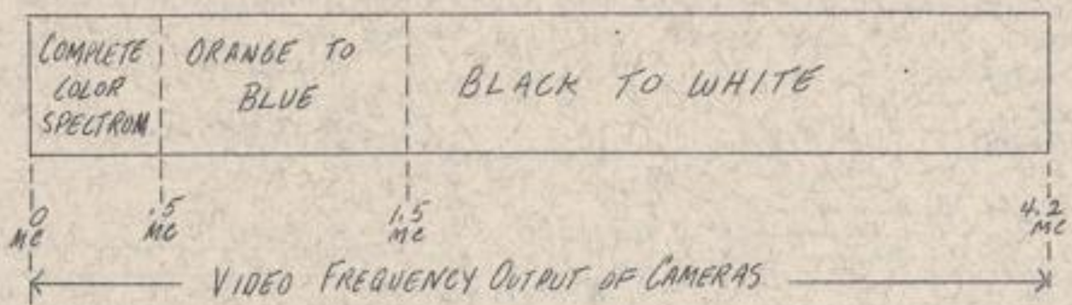


FIG. 9

The block diagram of Fig 9 serves to illustrate that video frequencies from 0 to .5 Mc can produce the complete color spectrum; frequencies from .5 Mc to 1.5 Mc can produce the color spectrum from orange to blue; and frequencies from 1.5 Mc to 4.2 Mc produce only black and white. This is not to say that all video frequencies in the 0 to 1.5 Mc range produce details of color on the picture tube. Remember, only I and Q signals can produce color details, and they don't exist if the cameras are focused on black and white areas of the scene.

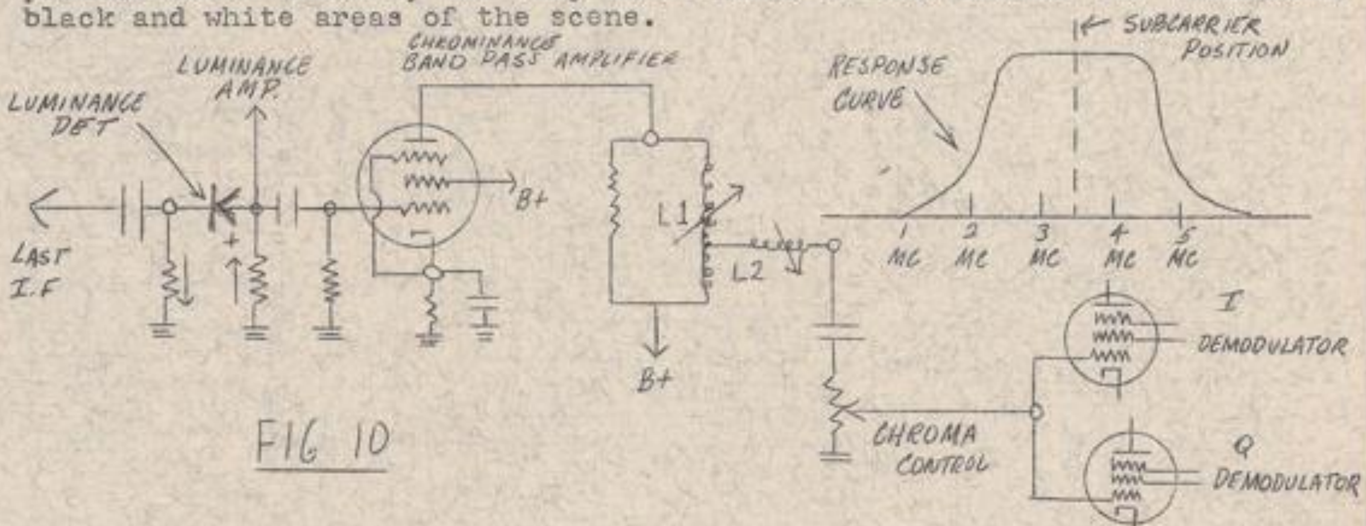


FIG 10

Fig 10 shows the output of the luminance detector feeding the luminance video amplifier and the chrominance bandpass amplifier. The purpose of the chrominance bandpass amplifier is to allow only I and Q signals to pass through the stage while blocking all low frequencies of the Y signal. L1 and L2 are adjustable to achieve the response curve shown. The output signals are applied across a chroma control. This control supplies the I and Q signals to the I and Q demodulators. The chroma control is a front control and provides control over the degree of color in the picture. A full off position of the control kills color operation but does not affect black and white operation. As the control is advanced from an off position toward maximum, the colors in the picture increases from light colors to deep colors.

As stated, the primary purpose of the chrominance bandpass amplifier is to block the low frequency components of the Y signal. Such frequencies would pass through the I and Q demodulators and serve as undesired luminance information for the picture tube. The high frequency components of the Y signal do pass through the demodulators but are filtered out at that point. A later discussion will cover this point in more detail.

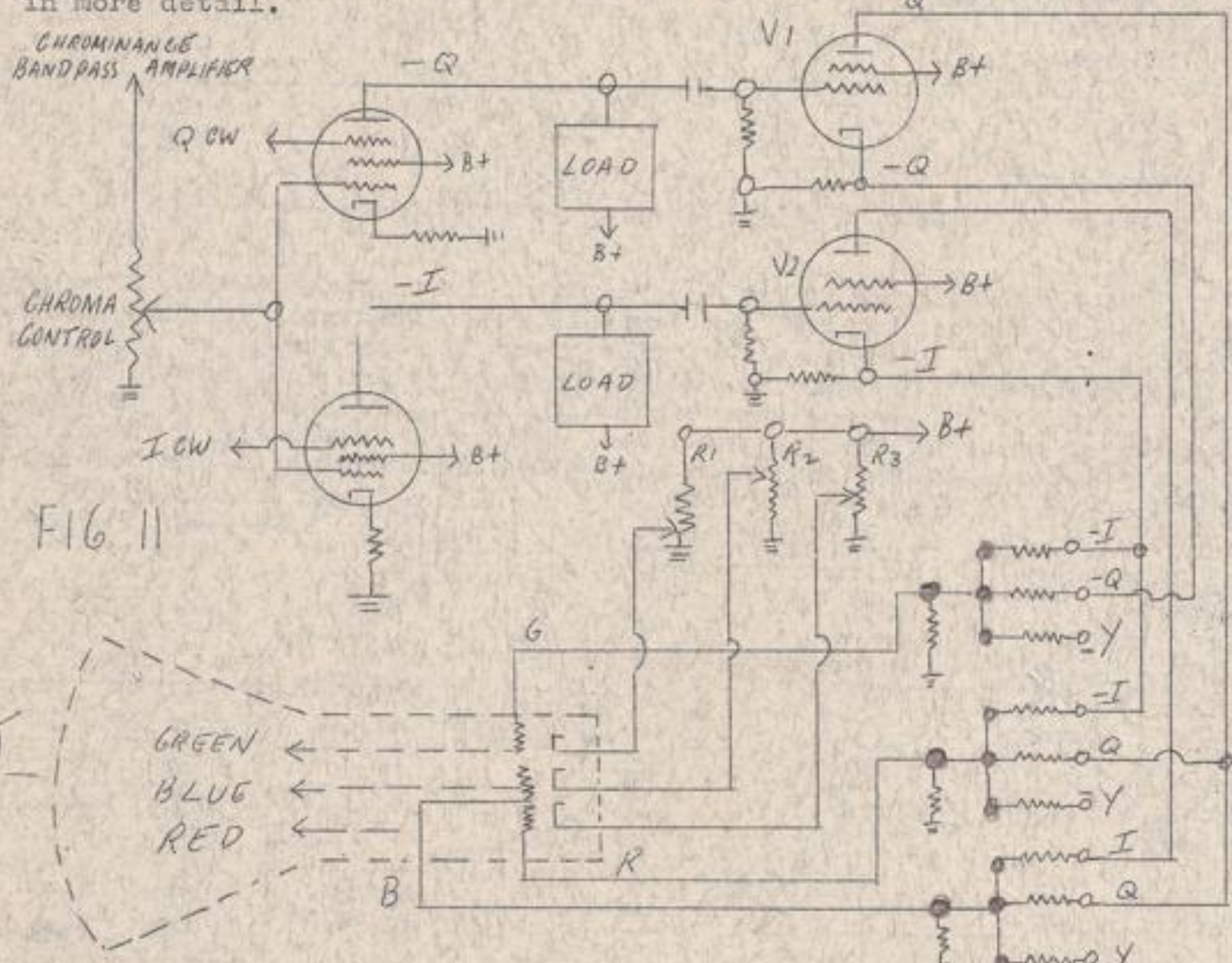


FIG 11

As shown in Fig 11, the I and Q outputs of the two demodulators are connected to phase splitter stages V1 and V2. The phase splitters develop both polarities of the I and Q signals. Recall, the picture tube matrix requires both polarities of the two signals.

In the above example, the Y signal is fed to each section of the matrix to add with the I and Q signals. This addition of the Y signal produces outputs of the matrix sections of G, B, and R. Recall that without the addition of Y, the outputs are G-Y, B-Y, and R-Y. This type of circuit allows the cathodes of the three guns to be connected to individual background controls. These controls (R1, R2, and R3) allow proper bias adjustments for the three guns.

Color Synchronization

It is our purpose now to study the synchronization of the receiver's local 3.58 Mc oscillator which produces the I CW and Q CW signals. Since the very detection of I and Q depends upon the phase of the I CW and Q CW signals, it is clearly evident that the receiver's local 3.58 Mc oscillator must be controlled by a synchronizing signal located in the color signal. In the study of the detection of the I and Q signals, it was pointed out that the I CW and Q CW signals had to coincide almost perfectly with the I and Q modulated signals to achieve detection. Any phase change in the I CW and Q CW signals results in improper I and Q signals and, therefore, picture colors.

FIG 1

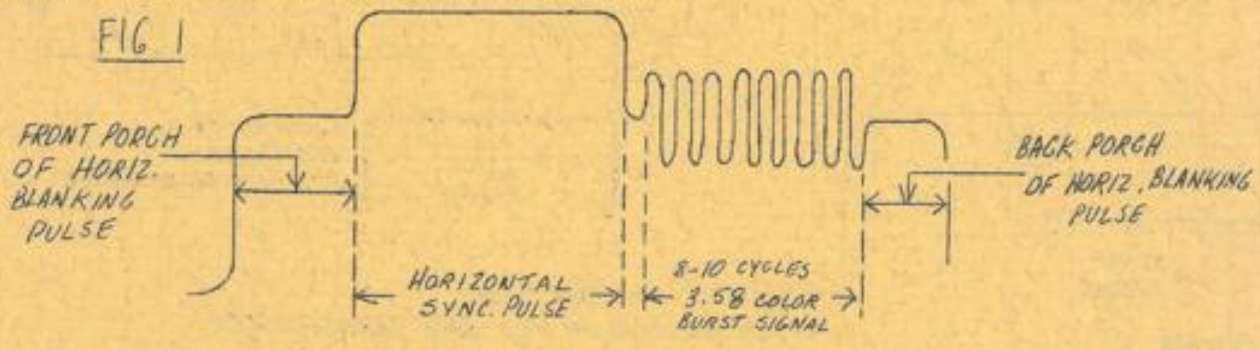
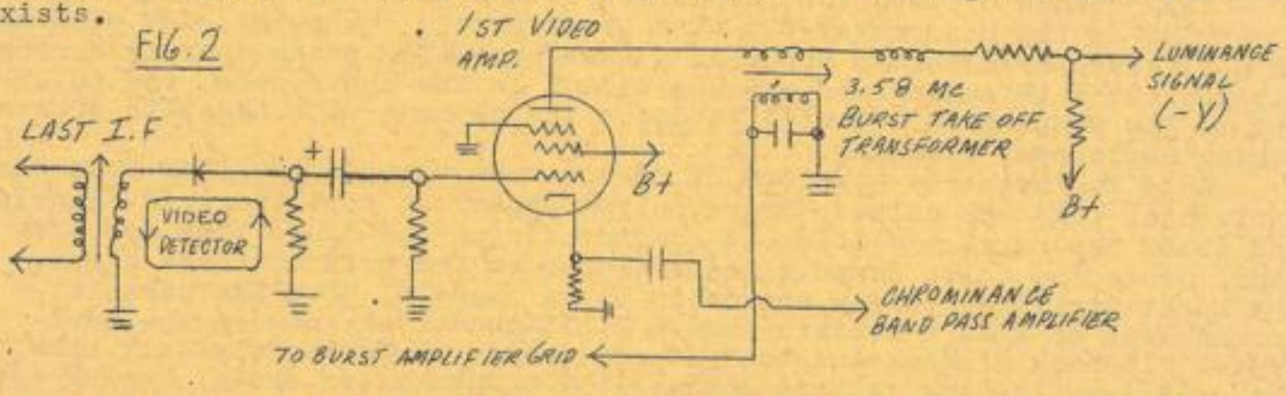


Fig 1 illustrates the location of the color synchronizing signal. This signal is called the color burst and consists of a minimum of 8 cycles of the transmitter's subcarrier oscillator output. Note that the color burst signal is located on the back porch of the horizontal blanking pulse. This location does not disturb the normal operation of the horizontal sync. and blanking pulses. Recall, the horizontal sync. pulse serves to synchronize the receiver's horizontal oscillator, and the horizontal blanking pulse serves to bias the picture tube to cut-off during horizontal retrace of the beam (beams in the case of the color tube). In the case of a monochrome receiver operating with a color signal, the color burst serves no purpose, but presents no problem because the picture tube is operating at cut-off during the time it exists.

FIG. 2



The removal of the color burst from the total signal can be accomplished by placing a 3.58 Mc transformer in the plate circuit of the 1st video amplifier as shown in Fig 2. While such a transformer allows removal of the color burst, it does not prevent other frequencies at and near 3.58 Mc from appearing at it's output. Recall that the 1st video output includes the I and Q signals in a modulated form as well as all other video and synchronizing information in a demodulated form. In order for the color burst to accurately control the receiver's 3.58 Mc oscillator, all other signals at and near 3.58 Mc must be removed.

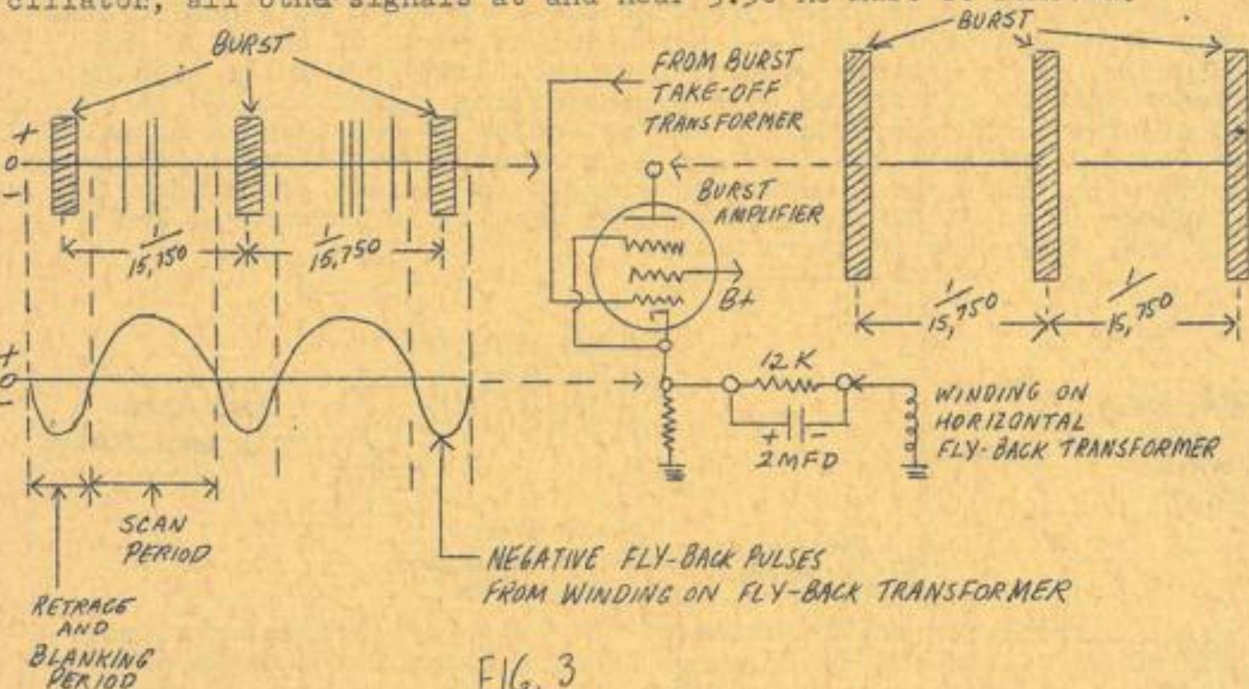


FIG. 3

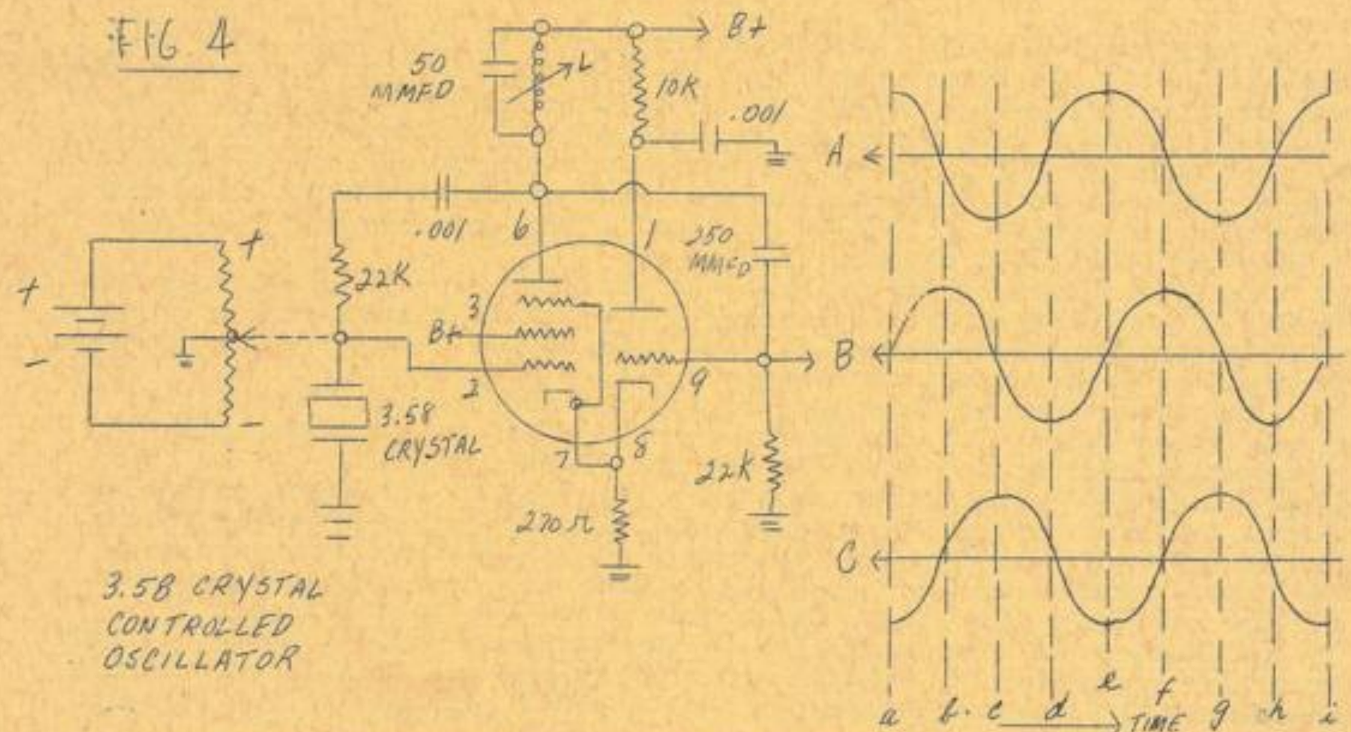
Fig 3 illustrates the output of the burst take-off transformer feeding the grid of a stage called the burst amplifier. More than providing gain, this stage serves to remove all 3.58 Mc signals except the color burst.

Note the input signal to the grid. Because the color burst signals are located on the horizontal blanking pulses, they occur every 1/15,750 second. For simplicity, they are being shown in block form. Other 3.58 Mc signals are shown to exist between the color burst signals.

The cathode of the burst amplifier is fed with negative pulses from a winding on the horizontal fly-back transformer. Reviewing, any winding on a fly-back transformer produces a waveform which peaks sharply during fly-back time (blanking and retrace time). In the above case, the polarity of the winding is selected to drive the cathode with negative pulses during horizontal blanking.

Note the negative waveform of the cathode signal resulting from the horizontal fly-back pulses. These pulses appear as positive grid signals and allow the burst amplifier to conduct during the times they are present. Since the color burst signals appear at the grid at these times, the burst amplifier passes the color burst signals. Note the parallel arrangement of a 12 K resistor and a 2 MFD condenser between the horizontal fly-back winding and the cathode resistor. During fly-back time, the negative fly-back voltage charges the condenser as shown. During scan time, the condenser discharges through the cathode resistor producing a positive cathode voltage. Note the positive waveform of the cathode signal. This voltage appears negative at the grid and results in cutting the tube off. Thus, the burst amplifier is allowed to conduct during blanking time to pass the color burst signals, but is cut-off during scan time to block all other 3.58 Mc signals.

FIG 4



3.58 CRYSTAL CONTROLLED OSCILLATOR

Since the purpose of the color burst signal is to control the frequency and phase of the I CW and Q CW signals, it is helpful at this point to study at least one type of 3.58 Mc oscillator circuit. Fig 4 illustrates an oscillator circuit very similar to the multivibrator types used in some present horizontal and vertical sweep oscillator circuits.

The tube is a 6U8 and contains a triode and a pentode section. For simplicity, consider the feed-back loop between pin 6 and pin 2 of the pentode section to be disconnected. Further, consider the 3.58 Mc crystal disconnected from pin 2, and pin 2 grounded. The resultant circuit is practically indentical with a multivibrator type oscillator. Note, however, that the output is taken from the grid of the 2nd section rather than from the plate. The plate output is grounded with a .001 condenser. By selecting the proper values (shown above), the oscillator generates a sine wave output at a frequency near 3.58 Mc. Note the ringing circuit in the plate of the pentode section. This circuit is resonant at 3.58 Mc and is manually adjustable as indicated.

To increase the stability of the oscillator near 3.58 Mc, a 3.58 crystal is added from the grid of the pentode section to ground. Crystal excitation energy is supplied by the feed-back loop from the plate of the pentode section. This arrangement practically insures that the oscillator will not drift.

The next consideration of the oscillator is its ability to be controlled. Reviewing, a standard multivibrator increases its frequency when its control grid is supplied a negative DC voltage, and decreases its frequency when supplied with a positive DC voltage. The above oscillator has this same ability to be controlled.

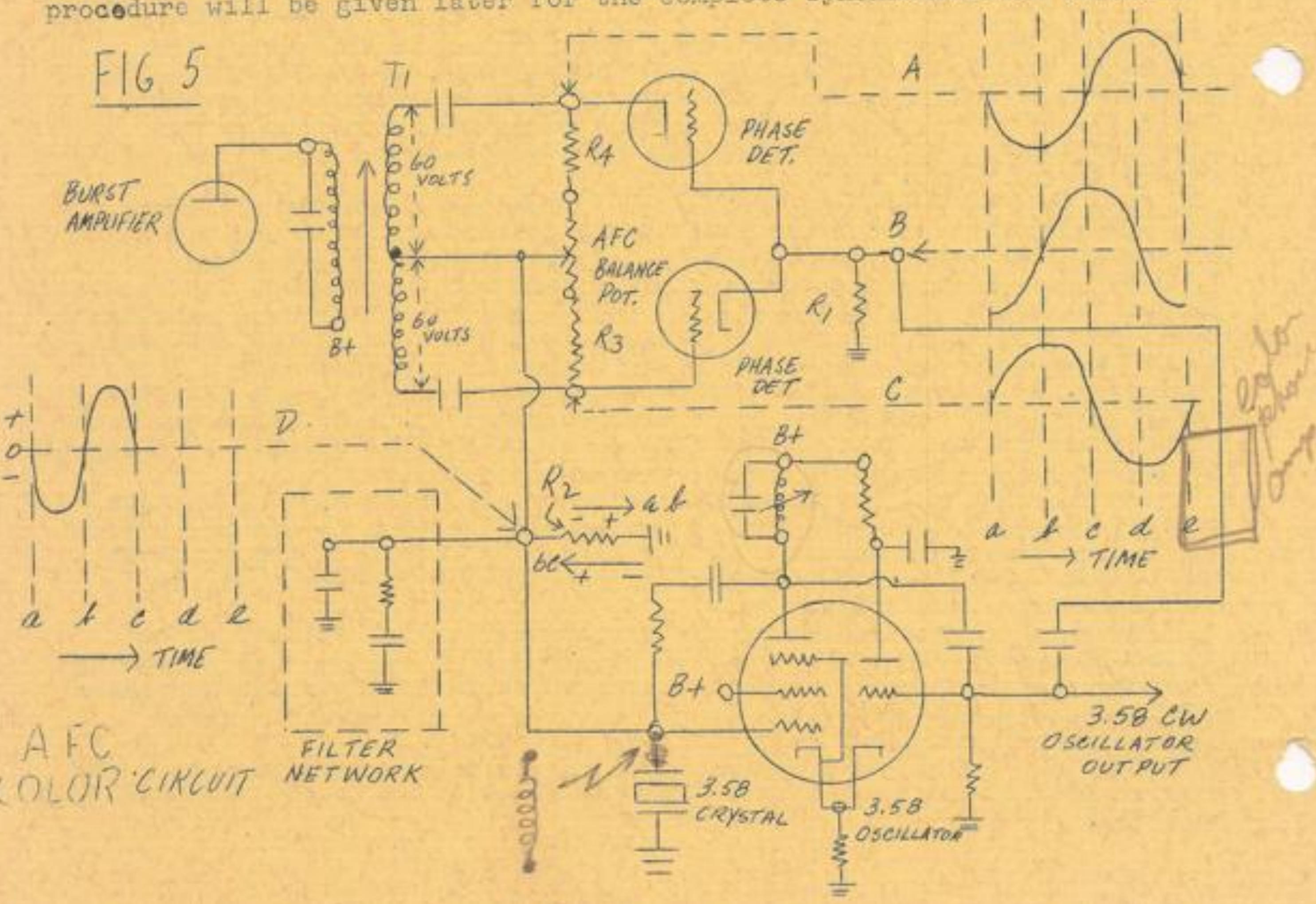
Note the battery and center-tapped potentiometer arrangement in the control grid of the oscillator. With the movable arm at the center-tapped position, no voltage is picked off for the control grid. Let's assume that this results in the oscillator producing the 3.58 Mc waveform shown at B. Moving the arm slightly upward drives the control grid with a small positive DC voltage resulting in a decrease in oscillator frequency. If the control voltage is very small, the oscillator output change will be a phase change rather than a frequency change. The oscillator output for this condition is shown at C. The C waveform is the same frequency as the B waveform, but is 90 degrees delayed.

The A waveform of Fig 4 shows the oscillator output under the condition of the control grid receiving a very small negative DC voltage equal to the positive voltage already considered. Note that the waveform is advanced 90 degrees with respect to the B waveform.

The advantages of this type oscillator circuit are:first, it is very stable; second, it can easily be controlled with DC correction voltages; third, it is simple to adjust; fourth, it will pull in from a frequency 1000 cycles away from the frequency of the synchronization signal and lock almost instantaneously; fifth, the plate supply voltage may be varied from 210 to 320 volts without affecting synchronization and with a phase error not exceeding 12 degrees; and sixth, the output voltage may be as high as 20 volts peak depending on the load.

Adjustment of the oscillator simply involves grounding the control grid, and adjusting the ringing coil for synchronization. A more detail procedure will be given later for the complete synchronization circuit.

FIG 5



AFC COLOR CIRCUIT

Fig 5 illustrates a balanced type of color AFC (automatic frequency control) circuit controlling the 3.58 Mc CW oscillator. The burst amplifier plate transformer (T1) has a high impedance primary tuned to 3.58 Mc with a bifilar secondary tightly coupled to the primary for high gain. Under normal color operation, the output of the center-tapped secondary winding is 120 volts. Sixty volts of one polarity drives the cathode of the upper phase detector, and 60 volts of the opposite polarity drives the lower phase detector. The phase detector tubes are really triode tubes, but in each case the plates are connected to ground through suitable resistors and serve as shields for the grid to cathode sections. Because the plates do not function electrically, they are not shown. In this case, the grids serve as plates and the plates serve to shield the cathodes and grids.

The upper grid and lower cathode are connected in parallel and return to ground through R1. Note that the oscillator CW output feeds the paralleled point of the two detectors.

The waveforms A and C represent one cycle of the color burst signal during the time a to e. Waveform B represents the oscillator CW output during the same time. As will be shown, these waveforms represent a condition whereby the 3.58 CW oscillator is in proper phase and frequency with respect to the color burst control signal.

From time a to time b, the upper detector cathode receives a negative color burst signal while the grid receives a negative CW signal. These voltages prevent conduction of the upper detector. The lower detector grid receives a positive color burst signal while the cathode receives a negative CW signal. These voltages cause the lower detector to conduct. The current flow path is from ground through R1, detector, R3, AFC balancing potentiometer, and R2 to ground. The voltage developed across R2 serves as the control voltage for the 3.58 Mc CW oscillator. The waveform generated across R2 is shown at D. Note that from time a to time b, the waveform is negative.

From time b to time c, the upper detector cathode receives a negative burst signal while the grid receives a positive CW signal. Also, the lower detector grid receives a positive burst signal while the cathode receives a positive CW signal. These voltages prevent conduction of the lower detector, and allow conduction of the upper detector. The current flow is from ground through R2, AFC balancing potentiometer, R4, detector, and R1. The voltage developed across R2 during the time b to c is positive as shown at D.

Note that the average of the waveform at D from time a to time c is zero. As a result, it affects no change in phase or frequency of the 3.58 Mc CW oscillator.

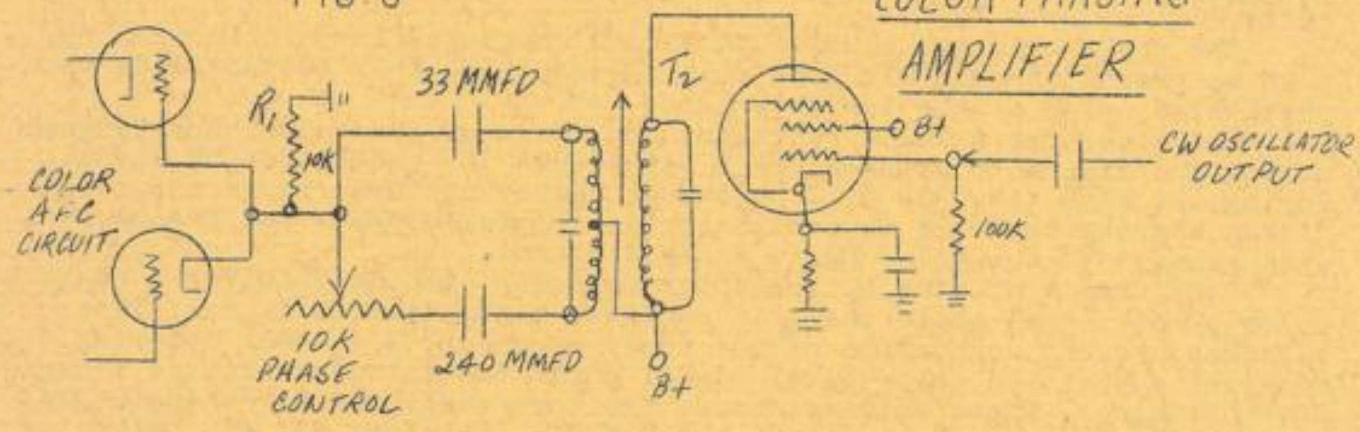
From time c to time e, the voltages applied to the detectors are such as to prevent conduction of either tube resulting in zero voltage across R1. The AFC balancing potentiometer serves to correct for any unbalance in the two detector stages that might result from changes in tubes or parts.

If the CW oscillator tends to decrease in frequency (phase shift), the CW waveform appearing at B would be slightly to the right (phase shift) of the one shown. This would result in the lower detector conducting more than the upper one producing an average value of negative voltage during the cycle. This negative control voltage serves to increase the CW oscillator frequency (phase) to the exact in-phase condition shown at B.

If the CW oscillator tends to increase in frequency (phase shift), the CW waveform appearing at B would be slightly to the left (phase shift) of the one shown. This would result in the upper detector conducting more than the lower one producing an average value of positive voltage during the cycle. This positive control voltage serves to decrease the CW oscillator frequency (phase) to the exact in-phase condition shown at B.

Any noise or unwanted signals present in the color burst signal are filtered out by the action of the AFC circuit plus the filter network from grid to ground of the CW oscillator. This network also serves to slow down the action of the AFC circuit thus preventing oscillator hunting.

FIG. 6 COLOR PHASING AMPLIFIER



In the previous discussion, a portion of the CW oscillator output was considered to be connected directly to the color AFC circuit. Actually, the CW output passes through a stage called the color phasing amplifier before reaching the color AFC circuit.

The purpose of the color phasing amplifier is two-fold. First, it serves to amplify the CW signal to a level required by the AFC circuit; second, it provides full phase control over the CW signal feeding the AFC circuit. The plate transformer is tuned to 3.58 Mc with the secondary center-tapped and connected to B plus. The center-tapped arrangement allows the secondary winding to provide two CW signals that are 180 degrees out of phase with each other. The top signal connects through a 33 MMFD condenser to R1. The lower signal connects through a 240 MMFD condenser and the 10 K phase control to R1. When the phase control is adjusted for zero resistance, the lower CW signal leads the upper CW signal across R1 because the lower coupling condenser is larger than the upper one. When the phase control is adjusted for maximum resistance (10 K), the upper CW signal leads the lower CW signal across R1 because of the lag introduced in the lower path by the phase control. This arrangement allows the control full 360 degree phase control over the CW signal. Since the CW signal originates the I CW and Q CW signals, the control provides 360 degree phase control of these signals. Because the I CW and Q CW signals determine the color of the details of the picture, full color control is enjoyed by the phase control. Because of its importance, the phase control is a front control.

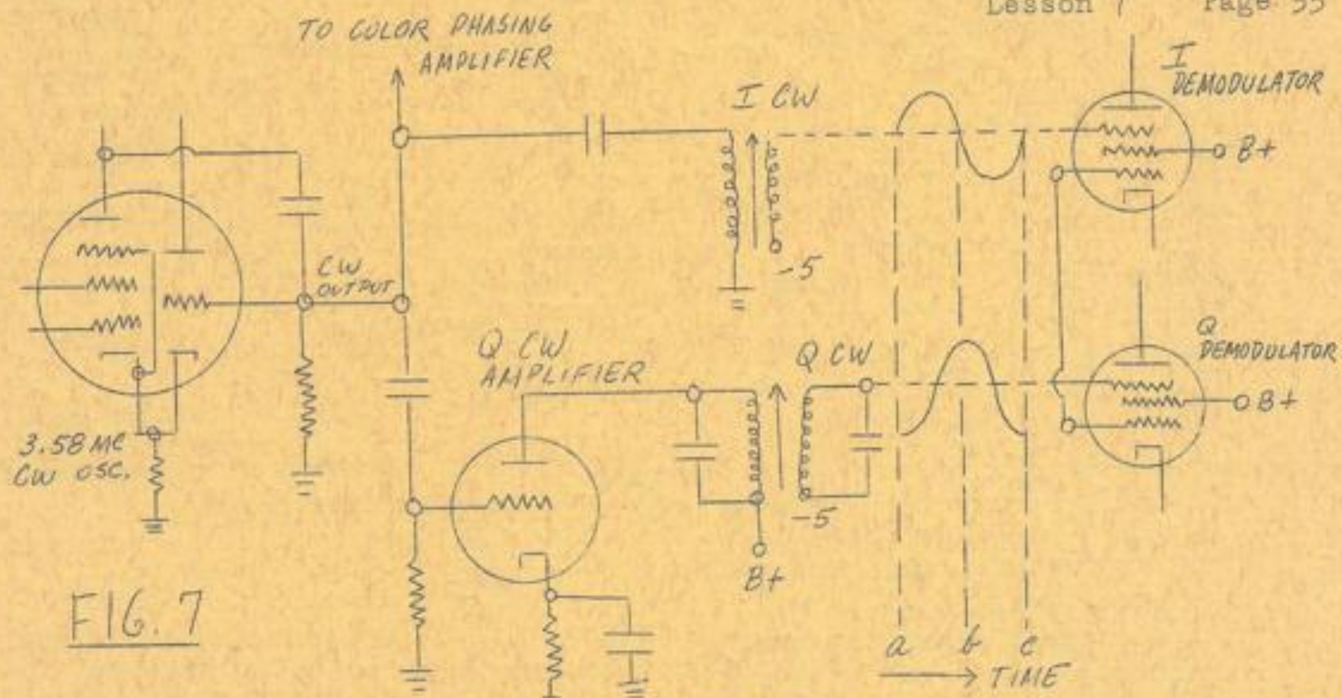


FIG. 7

Fig 7 shows the origination of the I CW and Q CW signals from the 3.58 Mc CW signal. The upper circuit shows the CW signal driving an untuned I CW transformer. The secondary winding produces the I CW signal which, because of the untuned transformer action, is 180 degrees out of phase with the CW signal. Note the I CW waveform feeding the suppressor grid of the I demodulator.

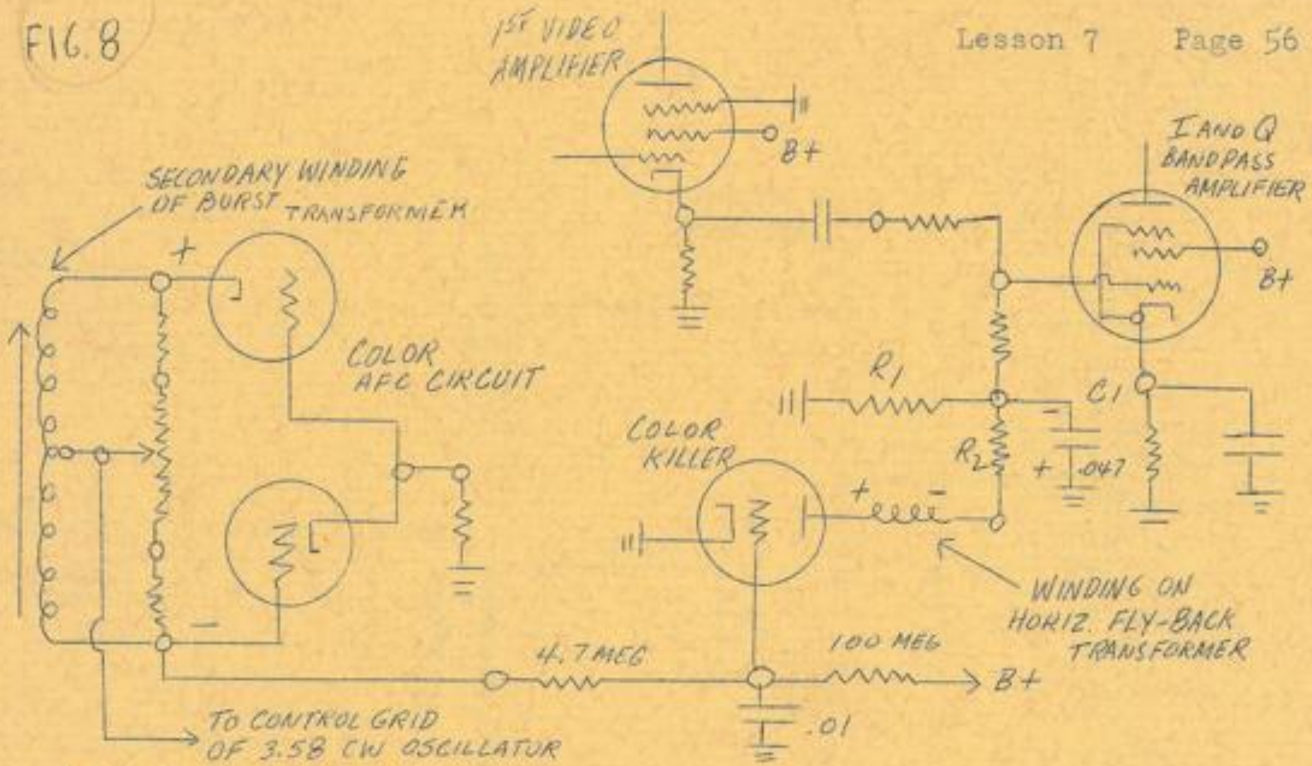
The lower circuit shows the CW signal driving a Q CW amplifier stage. Because of the 180 degree phase shift between grid and plate, the signal input to the Q CW transformer is 180 degrees out of phase with the CW signal. Note that the Q CW transformer is a tuned transformer. A tuned transformer has the characteristic of shifting phase by 90 degrees rather than 180 degrees. As a result, the Q CW signal produced at the output of the Q CW transformer is out of phase with the I CW signal by only 90 degrees. Note the 90 degrees lag in the Q CW waveform compared with the I CW. Components are selected for the Q CW amplifier to insure that the Q CW amplitude does not exceed the I CW amplitude.

Color Synchronizating Adjustments

1. Advance chroma control until color is present in picture.
2. Adjust phase control to the center of its range.
3. Ground the paralleled grid and cathode connection of the AFC phase detectors. With a VTVM connected to the control grid of the CW oscillator, adjust the AFC balancing potentiometer until the VTVM indicates zero. Remove ground.
4. Ground the control grid of the CW oscillator. Adjust the ringing coil of the oscillator for approximately synchronizating. Remove ground.
5. Adjust phase control for normal flesh colors.
6. Adjust chroma control for most pleasing brilliance of colors.

The symptom for out-of-color-sync. is one whereby the picture colors appear as horizontal bars rather than color sections of the

FIG 8



Color Killer Circuit

Fig 8 shows the circuits involved to block the I and Q signals through the I and Q bandpass amplifier when the color receiver is operating with a black and white transmission. Under conditions of a black and white transmission, the input to the bandpass amplifier is the luminance signal. Unless blocked, this signal would pass through the bandpass amplifier and subsequent circuits and produce interference in the black and white picture.

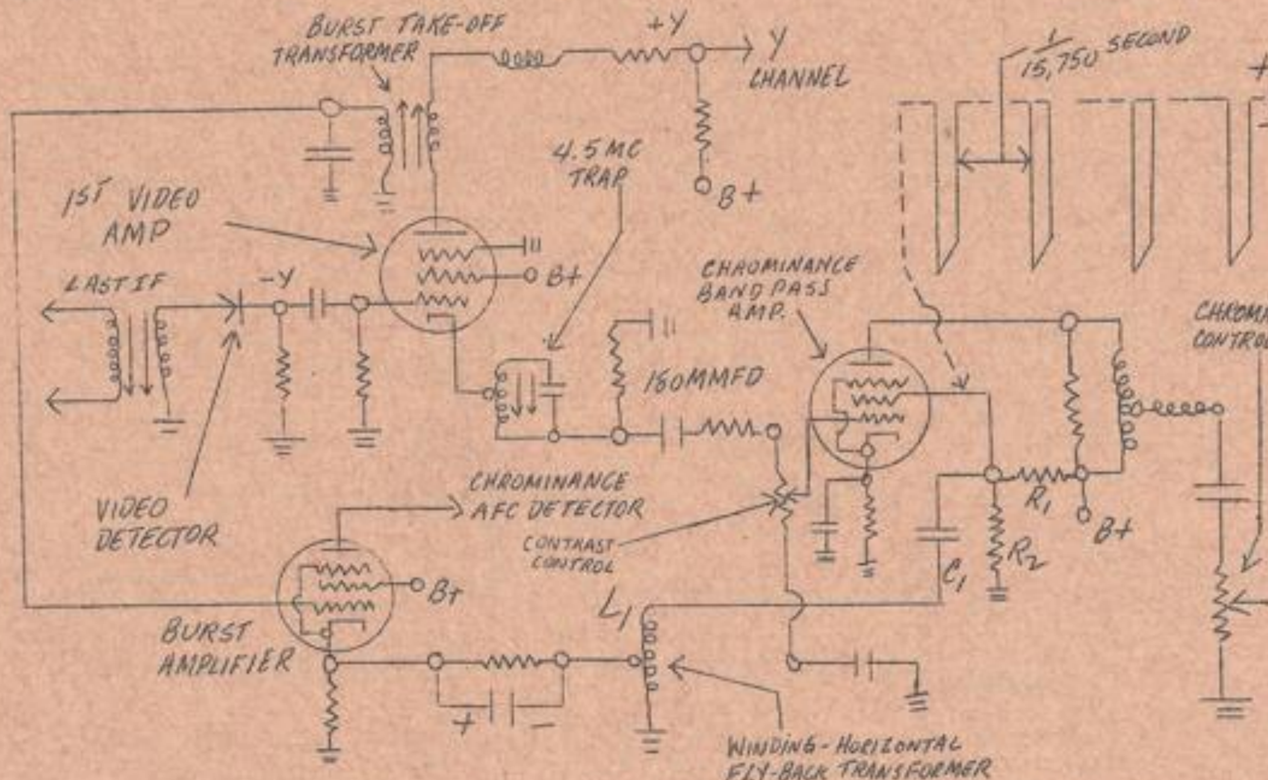
Note that the grid of the bandpass amplifier returns to ground through R1 which also serves as part of the plate circuit of a stage called the color killer. A winding off the horizontal fly-back transformer is arranged in series with the plate of the color killer stage and supplies plate voltage. The grid of the stage connects to B plus through a 100 meg. ohm resistor and to the negative leg of the color AFC circuit through a 4.7 meg. resistor.

When operating with a black and white signal, no color burst is present to generate voltage in the AFC circuit. Thus, the grid of the color killer is biased with a positive voltage from the B plus supply through the 100 meg. ohm resistor. During the time the plate winding is supplying positive voltage to the killer tube plate, the tube conducts through R2 and R1 to ground. The developed negative voltage at the junction of R1 and R2 charges C1 with a negative voltage with respect to ground. The discharging of C1 through R1 produces sufficient negative bias voltage for the bandpass amplifier to maintain it at cut-off. C1 is charged during horizontal blanking because the color killer fly-back winding is supplying positive plate voltage during this time. At all other times, it discharges through R1, maintaining the bandpass amplifier at cut-off.

When operating with a color signal, the color burst causes the AFC circuit to function and an average negative voltage appears at the grid of the lower phase detector. This voltage over-comes the positive bias on the killer tube grid and results in cutting-off the tube. Without conduction of the killer tube, no negative bias is developed to cut-off the I and Q bandpass amplifier resulting in normal I and Q operation.

6AR8
New tube
For I & Q Demodulator

FIG 1



In a previous discussion, it was pointed out that the chrominance bandpass amplifier serves to remove the low frequency components of the Y signal. In order to insure that the horizontal blanking and sync. information is blocked in the bandpass amplifier, a special circuit is arranged to bias the bandpass amplifier screen grid to cut-off during horizontal retrace. Note in Fig 1 that a 15,750 cps keying pulse is taken from a winding on the horizontal fly-back transformer and connected through C1 to the screen grid of the band-pass amplifier. Because these pulses occur during horizontal blanking and are negative, the chrominance band-pass amplifier is biased to cut-off and does not pass the horizontal blanking and sync. information that is present at its grid. The keying voltage wave-form is shown at the upper right of Fig 1.

If the horizontal blanking and sync. information was allowed to pass through the chrominance band-pass amplifier, it would pass through the I and Q demodulators and eventually reach the picture tube grids. Because the color burst is located on the back porch of the horizontal blanking pulse, it would also pass through the circuits and reach the picture tube grids. The horizontal blanking and sync. information does not effect the picture because the picture tube beams are cut-off during blanking. The 3.58 Mc color burst, however, might cause a malfunction of the D.C. restorers located at the picture tube grids.

As previously mentioned, the chrominance burst amplifier is supplied a 15, 750 cps keying pulse to allow it to conduct during horizontal blanking and thus pass the color burst signal. Note in Fig 1 that L1 supplies the necessary keying pulses for both the chrominance burst amplifier and the band-pass amplifier. Reviewing, the burst amplifier conducts during horizontal blanking, passing the color burst signal to the chrominance AFC detector, but is blocked at all other times, preventing any information except the burst to be present in the plate circuit.

Note the 4.5 Mc sound trap in the cathode of the 1st video amplifier. This trap serves to insure that no sound information passes into the chrominance channel. If it did, a 900 KC beat would occur between the 3.58 Mc chrominance components and the 4.5 Mc sound carrier resulting in an annoying 900 KC beat pattern in the picture.

I and Q Bandpass Filters and Inverters

FIG 2

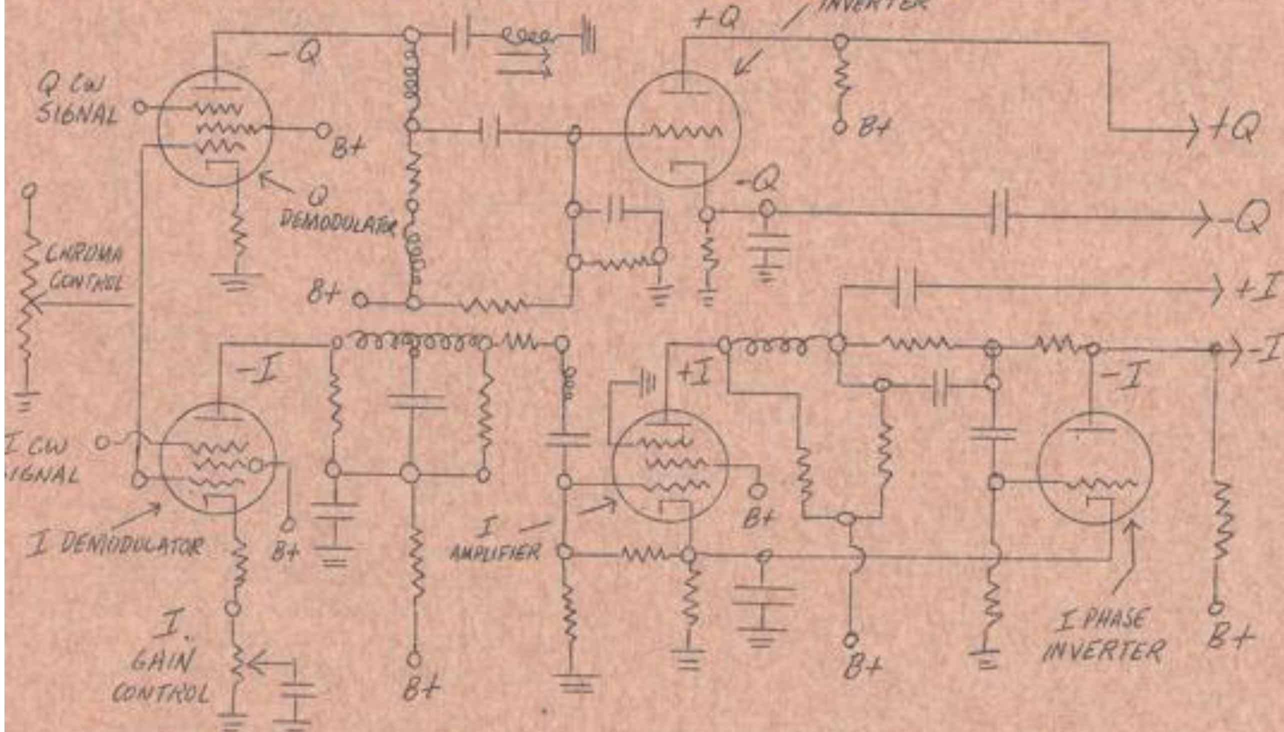


Fig 2 illustrates the bandpass filters and inverters for the I and Q signals between the demodulators and the receiver's matrix section. Note the I gain control in the I demodulator cathode. This control serves to balance the I and Q signals at the input of the matrix. Remember, the I and Q signals bear definite relationships to each other. Reviewing, the I and Q equations are:

$$I = -.28G + .60R - .32B$$
$$Q = -.52G + .21R + .31B$$

Considering an instant of time when the camera outputs are B equals 0,
R equals 10, and G equals 0, the equations reduce to I equals 6 volts and
Q equals 2.1 volts. Because at this instant I is approximately three times
the value of Q, it is apparent that the I signal voltage at the output of
the circuits in Fig 2 should be approximately three times the Q voltage
output. Otherwise, picture details will not be in true color. Thus, the
I gain control serves to equalize the gain between the inputs to the dem-
odulators and the inputs to the matrix section.

Because the Q signal range is from 0 to .5 Mc, a filter is arranged
between the Q demodulator and Q phase inverter to remove all frequencies
except those in the Q range. As previously discussed, the I signal passes
through the Q demodulator but is not demodulated and is of no consequence.
Luminance signals, however, are in a demodulated state upon reaching the
I and Q demodulators. Fortunately, the demodulators serve as modulators in
this case, and produce out-put luminance information in a modulated state.
Modulated signals at these points in the circuit have no meaning because
no further detection or demodulation takes place. Actually, some small
amount of demodulated I and luminance signals do appear in the Q demodu-
lator plate circuit because the process isn't perfect. The Q filter eli-
minates all such information above .5 Mc in frequency.

Because the I signal range is from 0 to 1.5 Mc, a filter is provided
between the I demodulator and I amplifier to remove all frequencies except
those in the I range. Modulated luminance and Q signals are present in the
plate circuit of the I demodulator for the same reasons as explained
above. In the case of the small amount of luminance components that appear
in a demodulated condition, the 0 to 1.5 Mc I filter eliminates all such
information above 1.5 Mc in frequency. Obviously, the I filter cannot act
on demodulated Q components because the Q range is less than the I filter.
In addition to serving as filters, the I and Q demodulator plate circuits
are properly compensated to provide essentially flat voltage output for
the two frequency ranges involved. In other words the Q filter circuit
provides a flat voltage output through the frequency range of 0 to .5 Mc,
and the I filter circuit provides a flat voltage output through the fre-
quency range of 0 to 1.5 Mc.

The I and Q outputs from the two filters are not in the proper re-
lationship to each other. This happens because the I filter antenuates
its signal much more than the Q filter does. In order to compensate for
this condition, an extra amplifier is provided in the I signal path. Note
in Fig 1 that the I input to this amplifier is negative. Because of the
180 phase reversal in the I amplifier stage, the signal appears as a posi
tive signal at the plate. Since both polarities of the I signal are re-
quired by the receiver's matrix section, a phase inverter stage is couple
to the I amplifier to provide a negative I signal. The positive I signal
is taken from the plate of the I amplifier, and the negative I signal is
taken from the plate of the I phase inverter.

The negative Q signal is connected to the grid of the Q phase inver-
ter stage. The positive Q signal is taken from the plate and the nega-
tive Q signal is taken from the cathode. The receiver's matrix requires
both polarities of the Q signal as well as the I signal.

From a consideration of trouble shooting, it is significant to note that the two signal paths shown in Fig 2 are the only place in the receiver where I and Q appear as distinct separate signals. A trouble in either of these circuits changes the relationship of the two signals to each other and would affect an improper color picture. It is interesting to note that if the I phase inverter stage failed, the receiver's matrix would receiver the positive value of I but not the negative value. Again, this would result in an improper color picture.

FIG 3

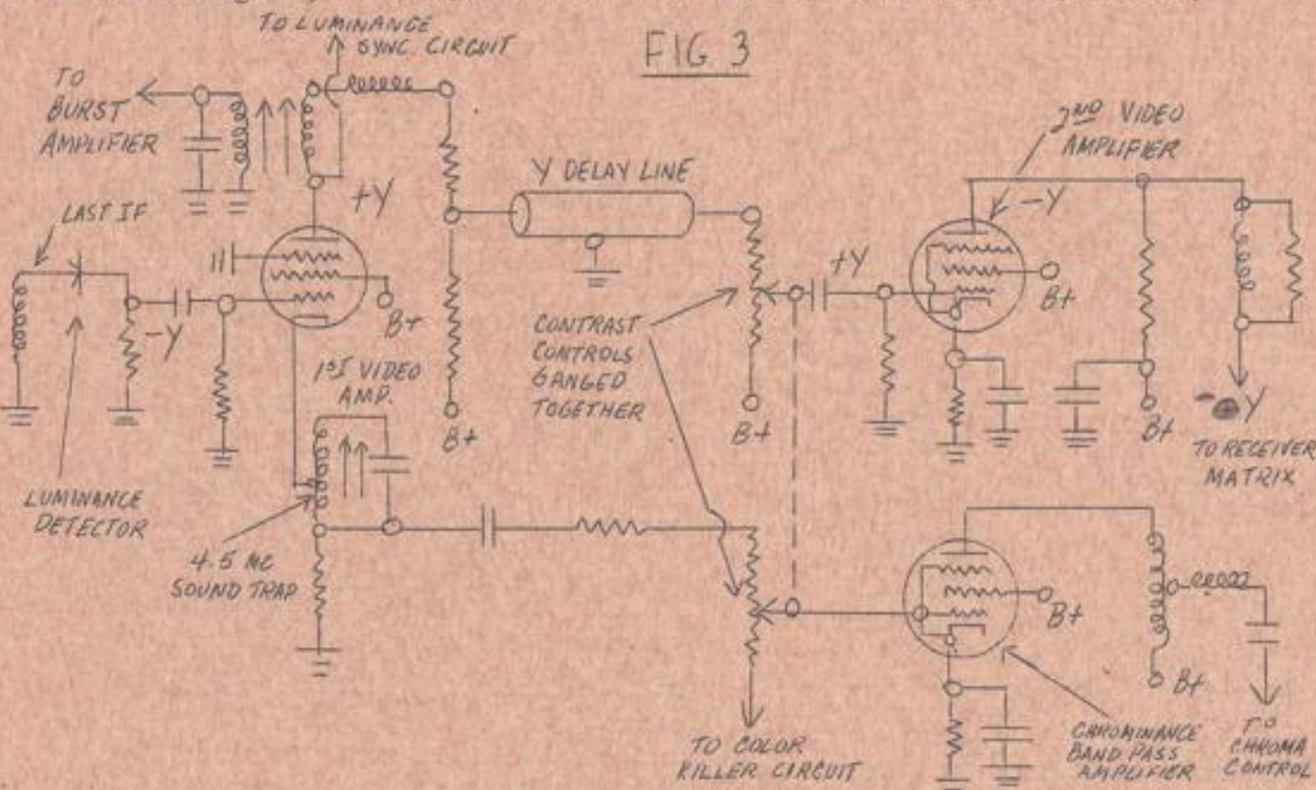


Fig 3 shows the 1st and 2nd video amplifier stages along with the chrominance bandpass amplifier. In this circuit, the luminance detector is arranged to provide a positive Y signal to the 1st video amplifier. Thus, the output of the 1st video amplifier is negative, and the output of the 2nd video amplifier is positive, which is the required polarity of Y voltage at the receiver's matrix.

Note the Y delay line between the 1st and 2nd video amplifiers. The delay line serves the purpose of delaying the Y signal with respect to the I and Q signals sufficiently to cause all three signals to reach the receiver's matrix at the same time. For all practical purposes, it can be considered that the luminance and chrominance signals divide in the 1st video amplifier. From this point, the luminance path to the matrix is much shorter than the chrominance path. Without a delay line, the luminance signal would arrived at the receiver's matrix prior to the chrominance signals I and Q. This would cause improper additions of I, Q, and Y and result in a poorly reproduced color picture. One way of looking at this situation is to consider that the Y signal paints the black and white picture and the I and Q signals paint the color picture.

Without a proper delay in the Y signal path, the color picture would be shifted slightly to the right of the black and white picture because the beam scanning is from left to right facing the picture tube.

The Y delay line is a simple piece of coax cable cut to the proper length. The length varies with different receivers, but in most cases will be 12 to 14 inches long. The shield of the coax is grounded to prevent pick-up and radiation.

Note the two contrast controls. They are ganged together to maintain the proper relationships of luminance and chrominance signals at the inputs to the 2nd video amplifier and chrominance bandpass amplifier stages. In some cases, these controls will be called picture controls rather than contrast controls since one effects the intensity of the picture and the other effects the intensity of color of the picture. Due to their importance, a single knob is arranged on the front of t he receiver to provide front control adjustments.

Note that the color burst signal is taken from the plate of the 1st video amplifier. This eliminates any possibility of the contrast controls effecting color synchronizing since the position of the controls does not effect the amplitude of the color burst signal. Likewise, and for the same reason, the luminance sync. information is taken from the 1st video amplifier.

Since the 1st and 2nd video amplifiers must pass the 0 to 4.2 Mc luminance signal, frequency compensating circuits are provided in the amplifier plate circuits to insure the proper response through this range. Note that the luminance detector, 1st video amplifier, and 2nd video amplifier are directly (D.C.) coupled. Such coupling insures good frequency response. At present, some consideration is being given to a luminance video amplifier response that is flat to approximately 3.0 Mc with attenuation at this point up to 4.2 Mc. Such response allows attenuation of the chrominance subcarrier of 3.58 Mc. The picture effect of the subcarrier is a 3.58 Mc dot pattern. While the effect of the subcarrier is not too noticeable, it is felt that some attenuation at and near this frequency will result in the best picture compromise. Complete attenuation above 3.0 Mc would be most undesirable because of the loss in picture fidelity.

FIG 4

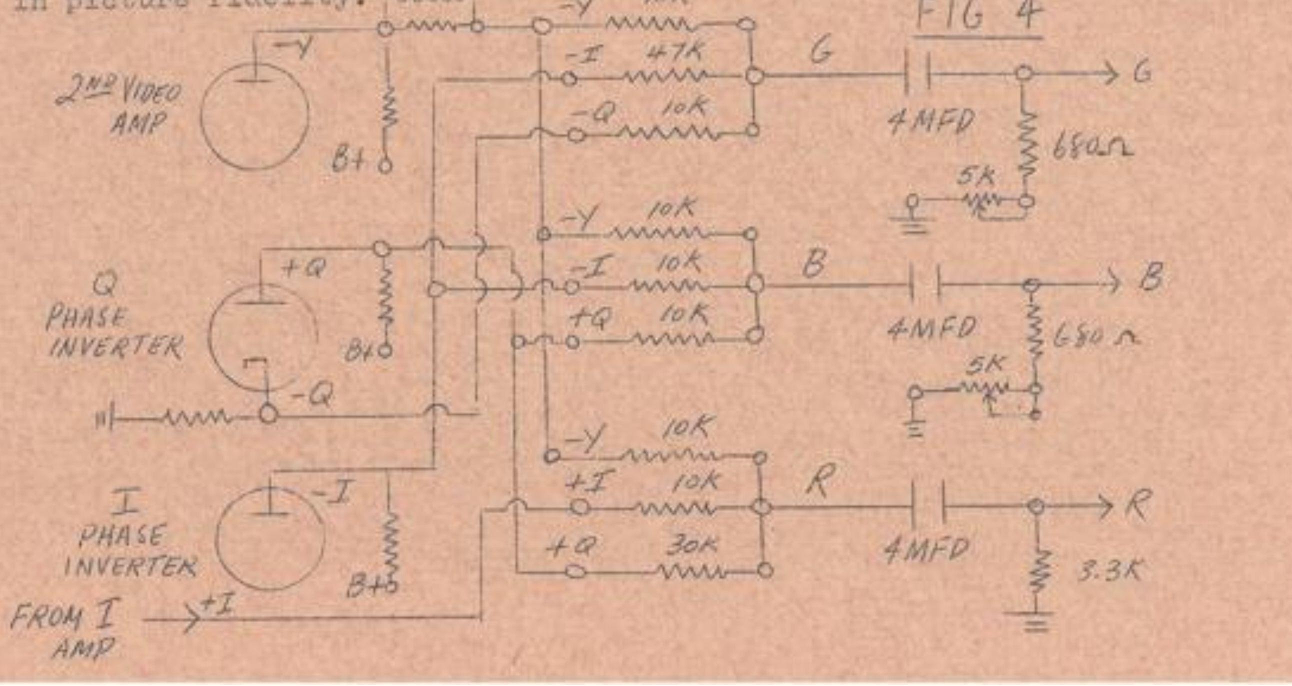


Fig 4 shows the outputs of the 2nd video amplifier, Q phase inverter, I phase inverter, and I amplifier feeding the receiver's matrix unit. The top unit adds -Y, -I, and -Q properly to produce the signal G. Remember, G corresponds with the voltage output of the green transmitter camera. The middle section adds Y, -I, and Q properly to produce B. B corresponds with the voltage output of the blue transmitter camera. The lower section adds -Y, I, and Q properly to produce the signal R. R corresponds with the voltage output of the red transmitter camera.

Note the 4 MFD condensers in each leg of the matrix sections. These condensers serve to remove the D.C. component existing in some of the input signals. Gain controls are incorporated in the green and blue matrix sections. Again, as in the case of the I, Q, and Y signals, the B, G, and R signals bear definite relationships to each-other. Reviewing, if the cameras are focused on a white detail of the picture scene, the camera outputs are equal to each other and to Y. In other words, if the blue camera output focused on a white detail is one volt, the green and red outputs will also be one volt. Y is also equal to one volt as shown below.

$$B = G = R = \text{ONE VOLT}$$
$$Y = .30R + .59G + .11B$$
$$Y = .3 + .59 + .11 = \text{ONE VOLT}$$

Because of the gain in the receiver, let's assume that Y is 10 volts at the input to the matrix section shown in Fig 4. In the red matrix section, this voltage would divide across a 10 K and 3.3 K resistor. For simplicity, we aren't considering any effect from the 4 MFD condenser. The R signal that would appear across the 3.3 K resistor would be approximately $\frac{1}{4}$ of the input voltage or about 2.5 volts. The G and B gain controls are 5 K each and are in series with 680 ohm resistors. Obviously, this resistance in either case could be set at 3.3 K equal to the R leg. If so, the G and B matrix output voltages would be equal to approximately 2.5 volts equal to R. With equal values of B, G, and R at the output of the matrix sections, and with equal gain from these points to the picture tube grids, each grid would be driven with the same amount of voltage. This condition would cause the beam currents of the three guns to change proportional to each other. Remember that without a signal, the three guns are adjusted to produce light outputs from the three phosphor dots of 30% red, 59% green, and 11% blue. It might seem that equal increases or decreases in the three beam currents caused by equal values of R, B, and G signals would continue to result in light outputs from the phosphor dots of 30% red, 59% green, and 11% blue. This would be true if the efficiency of the three colors of phosphor dots were equal. Actually, the blue and green phosphor dots are almost equal in efficiency, but the red phosphor dots are very inefficient by comparison. In order to correct for this nonlinearity in the phosphor dots, gain controls are provided in the green and blue matrix sections allowing a reduction in the G and B signals by comparison with the R signal. Note that no control is provided in the R section allowing the full voltage to be applied to the next stage.

In the case of the receiver we are discussing, the G and B signals are properly corrected with respect to the R signal at the output of the matrix section.

This correction could be built into the R, G, and B amplifier circuits that follow the matrix sections. Fig 5 shows the R, G, and B amplifiers. Because the G and B correction is provided at the output of the G and B matrix sections, the amplifiers shown have equal gain.

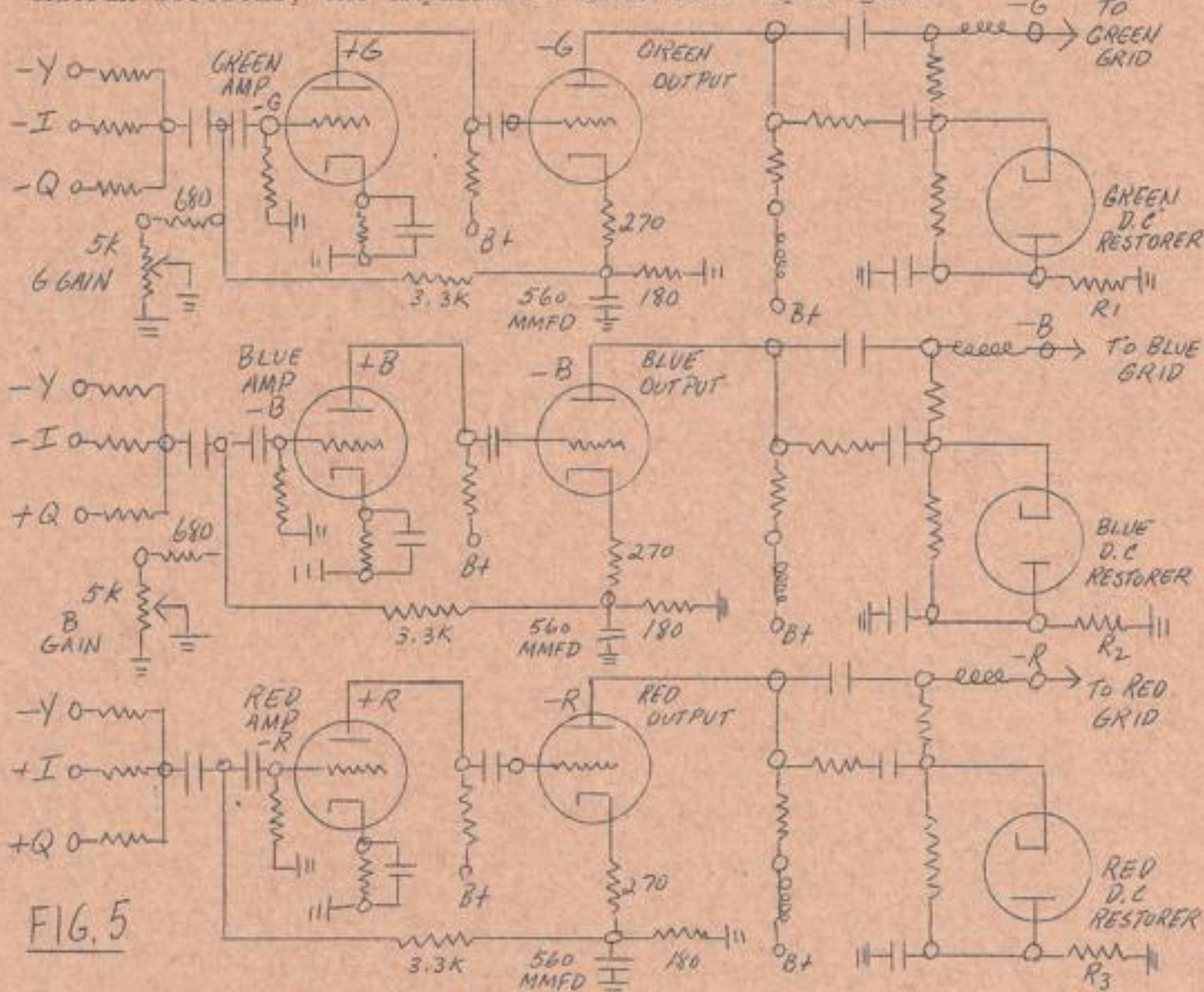


FIG. 5

The R, G, and B amplifiers consist of two amplifier stages in cascade. These amplifiers serve to provide sufficient R, G, and B drive voltage for the picture tube grids. Recall that the matrix unit lowers the various signals by some 75%. Since the amplifiers must pass video frequencies from 0 to 4.2 Mc, it is necessary to incorporate high frequency compensation. This is accomplished in the cathode circuits of the output tubes. Note that the cathode resistance of each tube is divided and the lower half is bypassed to ground with a 560 MMFD condenser. All high frequency information will be bypassed to ground and the low frequency information will cause some degeneration to the signal in the grid circuit. Note that the bypassed resistor in each cathode circuit connects back to the grid of each input amplifier through 3.3 K resistors. Reviewing, degeneration is the effect caused by coupling part of the output of a stage back to the input of a preceeding stage such that a portion of the input signal is "bucked out" (opposite voltages). In this case, only low frequency signal voltage is coupled back to the input stages resulting in a partial cancellation of the input low frequency video signals.

Thus, the input video signal is made non-linear with the high frequencies having more amplitude than the lower frequencies. The two amplifier stages in each section are non-linear to the extent that they provide more gain on low frequencies than high frequencies due to the grid to cathode capacity of the tubes. Such inherent capacity acts as a partial short circuit for high frequency signals. The degeneration voltage is selected to cause the R, B, and G output voltages to be equal through the video range of 0 to 4.2 Mc.

Note in Fig 5 that the matrix sections produce negative values of R, B, and G signals. These signals are considered to be negative because each one contains negative sync and blanking information. Note that the matrix sections receive negative Y signals. The output of the 1st stage of each amplifier is positive, and the output of the final stage is negative which is the required polarity of signal for the picture tube grids.

The oscilloscope is an ideal instrument for trouble shooting the R, B, and G amplifier circuits. Because of the presence of the luminance blanking and sync information, the amplitude of the signals can be checked and compared any place in the three circuits.

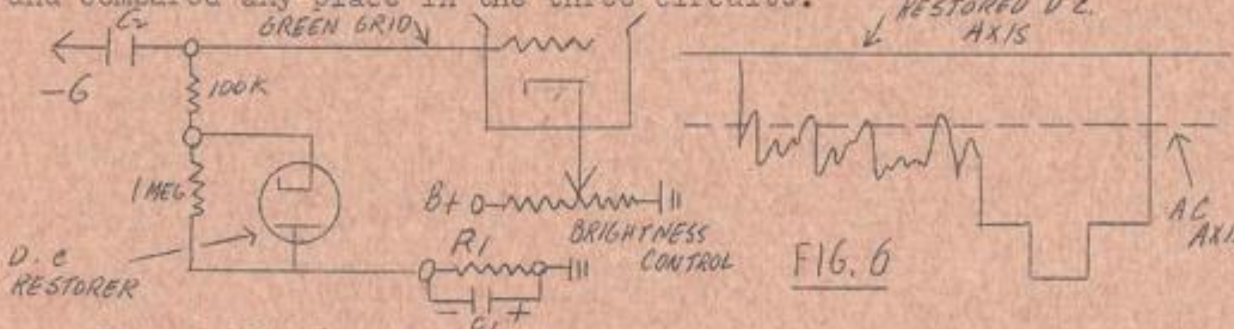


FIG. 6

Note in Fig 5 that the output of each of the amplifiers is capacity coupled to the picture tube grids. Because of such coupling, D.C. restorer circuits are required to restore a D.C. axis for the signals as they appear at the picture tube grids.

Fig 6 serves to review D.C. restoration. C2 couples the - G signal to the green picture tube grid. Because of the condenser action, the G signal is presented to the green grid about an axis equal to the average value of the signal for a period of time. This axis is referred to as an A.C. axis and is illustrated above. Since this axis always represents the average of the signal, it will shift up and down from instant to instant with respect to the blanking pulse as the picture scene changes. The average grid bias, therefore, will be varying from instant to instant producing a picture flicker. To prevent this condition, a D.C. restorer circuit as shown in Fig 6 is added in the grid circuit to restore a D.C. axis. Note that the green grid returns to ground through a 100 K, 1 meg, andR1. A diode tube is paralleled with the 1 meg. resistor and R1 is paralleled with a condenser (C1). The diode tube polarity is arranged to conduct on negative voltage but not on positive voltage. The output of the coupling condenser C2 is both negative and positive. The greatest amplitude of signal voltage is the sync pulse and it is negative which is the proper polarity of voltage to cause conduction of the diode. The heavy conduction of the diode during sync pulse time results in C1 being charged to a value representing the amplitude of the pulse. The charge in the condenser is such as to maintain a negative bias on the grid during picture scan time. With such circuits, the picture tube grids are maintained at constant negative values because the sync amplitude is constant.

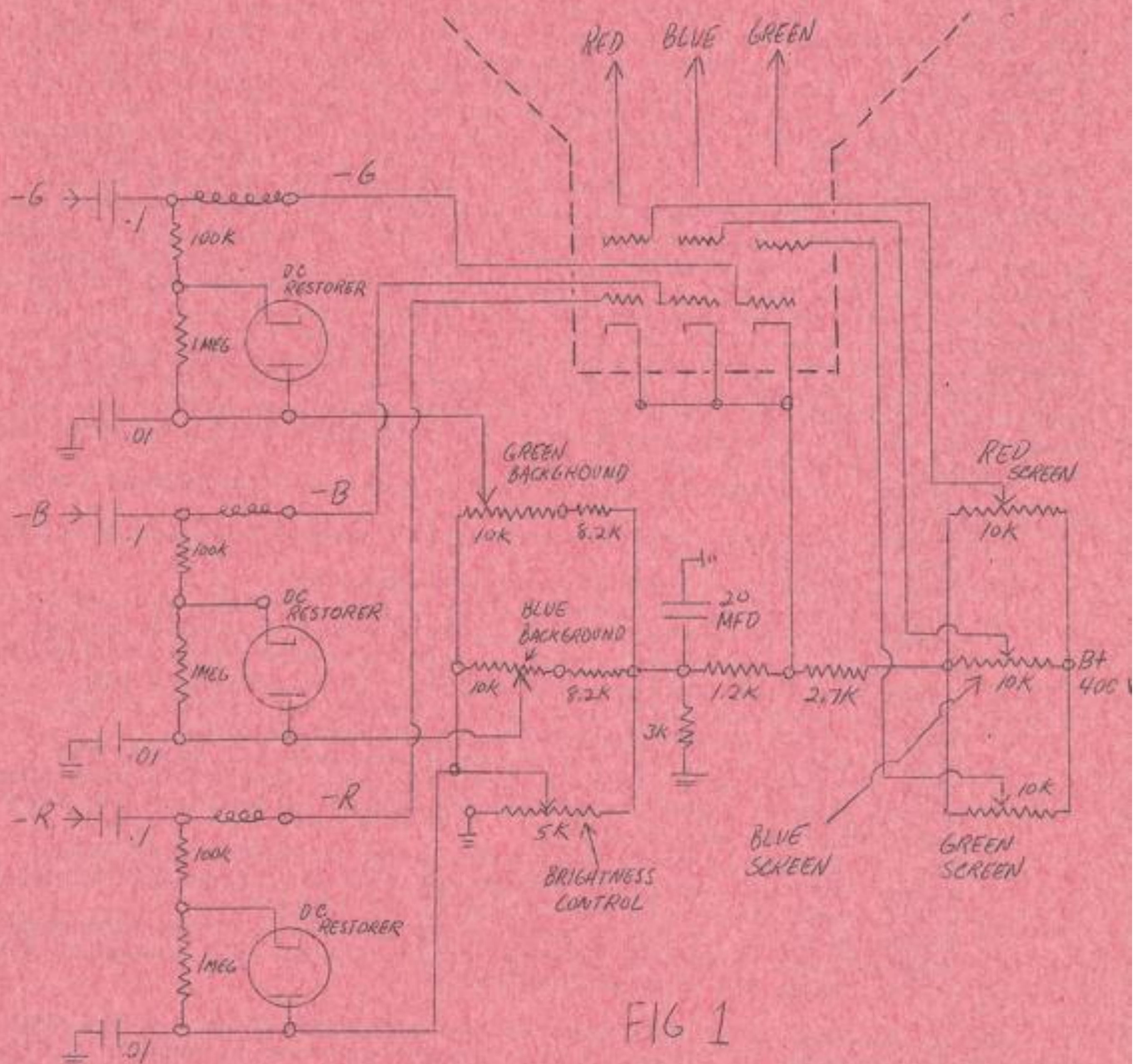


FIG 1

Fig 1 shows the circuit arrangement for the green and blue background controls, brightness control, and red, blue and green screen controls. The screen controls are used to adjust for a white raster (without modulation) and the background controls are used to adjust for normal black and white picture operation. The brightness control is arranged to increase and decrease the picture brightness without effecting the color of the picture.

In order to become acquainted with the various controls, it is helpful to study the circuit. Note on the right side of Fig 1 that some 400 volts is applied to one end of the red, blue, and green screen controls in parallel. The opposite end of the controls returns to ground through resistors of 2.7 K, 1.2 K, and 3K. The three cathodes of the picture tube are connected together and return to the junction of the 2.7 K and 1.2 K resistors. This arrangement allows the red, blue, and green screen voltages to be adjusted individually to achieve the condition of a white raster. Remember, the beam currents must be adjusted such that the red, blue, and green light outputs appear as white to the eye.

Previously the D.C. restorer for each picture tube gun was shown as returning to ground. To provide individual grid bias control over the three guns, the red, blue, and green D.C. restorers are returned to the green background, blue background, and brightness controls respectively.

The brightness control connects across the 3 K resistor which serves as the lower leg of the screen control circuit. Varying the brightness control varies the voltage across the green and blue background controls. Also, it directly determines the red grid bias because the red D.C. restorer connects directly to the arm of the brightness control. This arrangement allows the green and blue grids to be adjusted individually with respect to the red grid to achieve normal black and white picture operation. Further, it causes the brightness control to affect the necessary bias change on each grid to vary the brightness of the picture without changing the color of the picture.

The proper procedure for adjusting the screen and background controls is as follows:

1. Without a signal, turn the chroma and contrast controls to a minimum position.
2. Turn brightness control to a maximum position.
3. Adjust the red screen control, blue screen control, and green screen control individually to achieve a low brightness white. The color of the white should be about the same white produced by a low brightness setting on a standard black and white tube.
4. Turn the contrast control to approximately the middle of its range. Leave brightness control at maximum setting.
5. With a signal of either a station or bar pattern, adjust the blue and green gain controls until the high brightness high lights in the picture appear about the same color of white as the white established in step 3 above.
6. Turn brightness control down until a dim picture is achieved. Adjust the blue and green background controls to achieve an equal white condition of the low lights of the picture.
7. Repeat steps 4, 5, and 6 until white is made to track from high lights (high intensity details) to low lights (low intensity details) using the contrast control.

It is interesting to note that if the emmission of one of the guns changes with respect to the other two, corrections can be made to off-set the condition within certain limits. Changing the picture tube will necessitate readjusting the screen and background controls as well as all other picture tube adjustments.

Due to the complexity of the grid and screen circuits, the technician will often times be fooled into changing the picture tube when the trouble is in one of the grid or screen circuits. Considerable more thought will have to be given to these circuits than what has been given their counterparts in the monochrome receiver.

I.F. Alignment of the Color Receiver

At the present state of the art, the c olor receiver incorporates five video I.F. stages. This number of stages is necessary to achieve the necessary gain and waveshape. Different from the monochrome receiver, little tolerance is allowed in the I.F. waveshape construction.

FIG 2

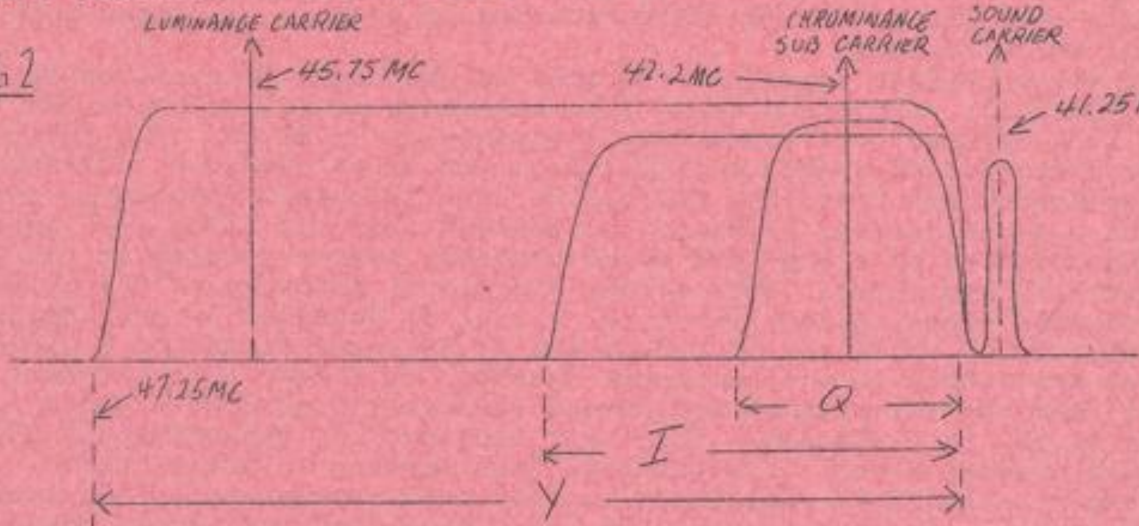


Fig 2 illustrates the condition of the color signal at the output of the converter stage in the tuner. Reviewing, the tuner R.F. section has a very broad response resulting in equal gain on all components of the total signal. The output of the R.F. section beats with the local oscillator signal in the converter stage producing the desired I.F. signal range. In the above case, the I.F. range calls for a luminance I.F. carrier of 45.75 Mc; a sound I.F. carrier of 41.25 Mc; and a chrominance subcarrier of 42.2 Mc. This I.F. range is used by most of todays monochrome manufacturers and from all indications will be used extensively in color receivers.

FIG 3

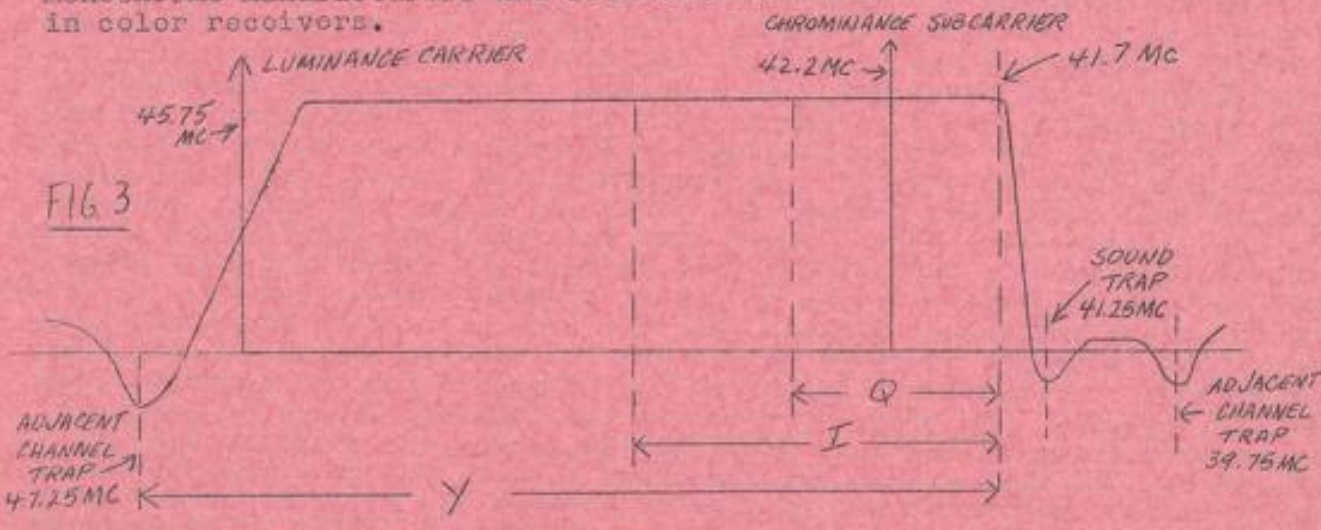


Fig 3 shows an ideal I.F. response curve for the tuner output signal of Fig 2. Note that most of the lower sideband (left of carrier) of the luminance signal is suppressed by the I.F. response curve. This is necessary in order for the I.F. amplifier to pass only a single sideband of the luminance intelligence.

In order for the I.F. amplifier to pass both sidebands of the Q signal, the I.F. curve must extend flat to 41.7 Mc which is the upper limit of the Q signal. The design of the color receiver is such as to demand both sidebands of the Q signal.

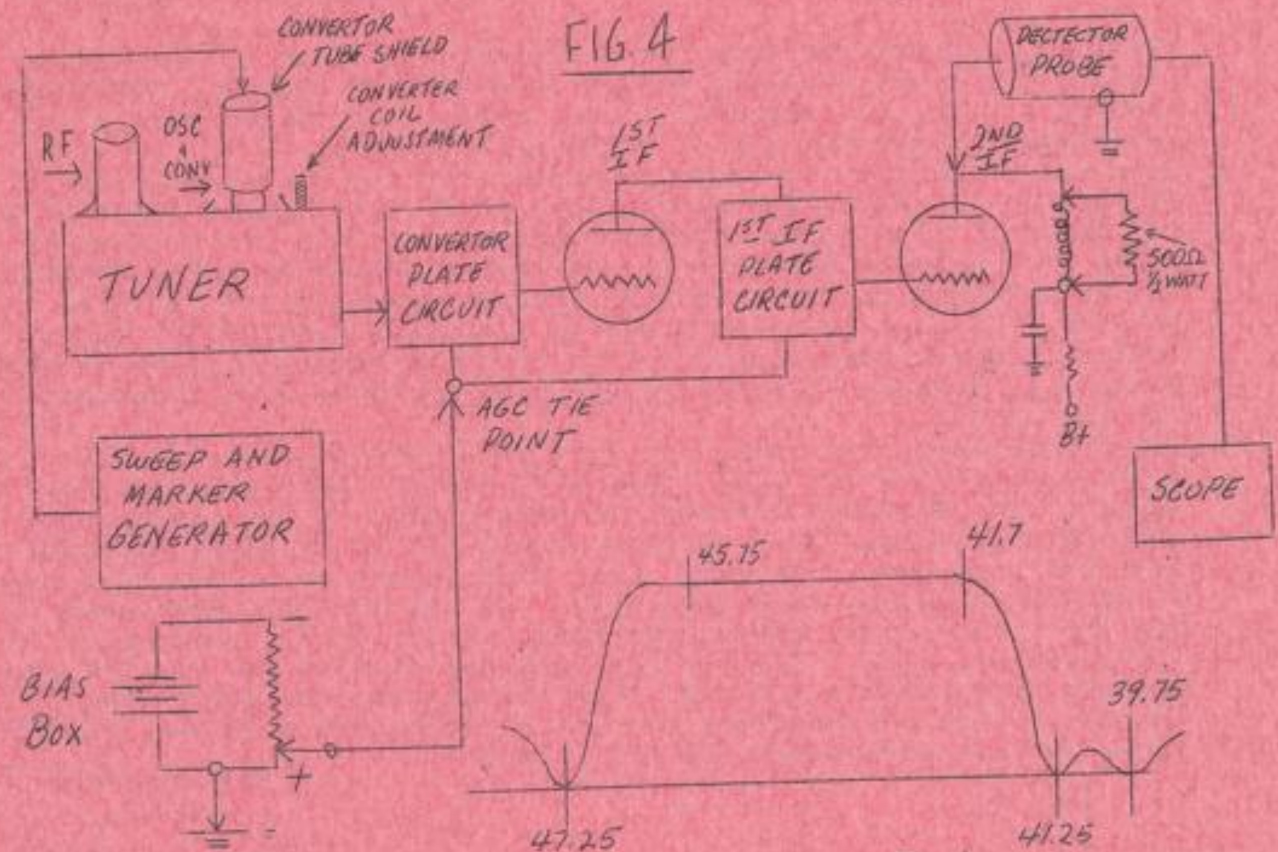
Adjacent channel traps are required at the usual frequencies of 47.25 Mc and 39.75 Mc. Since the sound I.F. frequency is 4.5 Mc below the luminance I.F. carrier, the sound trap frequency is 41.25 Mc. The intercarrier principal of sound is utilized in the color receiver. Different from the monochrome receiver, the 4.5 Mc beat frequency (luminance carrier 45.75 Mc - sound carrier 41.25 Mc) is removed from the fifth I.F. amplifier and detected by a separate sound detector before passing to the 4.5 Mc sound I.F. amplifier. This allows additional trappage of the 41.25 sound carrier signal before the total signal is detected by the luminance detector. It is necessary to reduce the 41.25 sound signal to a minimum value at the output of the luminance detector to insure that the beat between it and the chrominance subcarrier (subcarrier 42.2 Mc - sound carrier 41.25) is a minimum. This beat frequency is approximately 950 Kc and would produce a most objectionable beat pattern in the picture.

Present color I.F. amplifiers include both stagger-tuned and overcoupled stages. In either case, the individual stages are quite broad. The high gain of the system coupled with the number and type of stages involved calls for extreme care and precision during the alignment procedure. It is our purpose now to discuss a general alignment procedure that will serve most receivers.

The required basic equipment includes a sweep generator, marker generator, V.T.V.M., oscilloscope, and a variable source of D.C. voltage, usually referred to as a bias box. To facilitate the alignment, it is most helpful to have individual crystals for the key frequencies. This allows the curve to be marked at two places at the same time making it much easier and quicker to obtain the desired curve.

Before studying the general alignment procedure, it is helpful to review some of the theory involved. The design of any video I.F. system involves arranging a series of I.F. stages in cascade such that each one contributes to the final gain and waveform. Obviously, the bandwidth of each stage must be broad enough to pass the entire video signal. In most cases, however, the individual stages peak more for one range of the video frequencies than for another. By staggering the stages, the final waveform is made quite flat through the necessary range. Actually, successive I.F. stages are staggered such that the resultant waveform of any two successive stages is essentially flat through the video frequency range. This fact is the basis for the alignment procedure that follows. By feeding the sweep and marker signals into the tuner converter stage and looking at the resultant waveform at the 2nd I.F. plate, visual adjustments can be made to achieve the necessary flat response for the converter and 1st I.F. stages. Any traps involved in the distance should be adjusted before proceeding to the next section. By moving the scope to the 4th I.F. plate, two more stages are added and a resultant waveform produced. Again, visual adjustment can be made to achieve the desired curve. In this case, the 2nd and 3rd I.F. stages are involved as far as adjustments are concerned. Again, any traps involved should be adjusted before moving the scope. Finally, the scope can be moved to the luminance detector and the 4th and 5th stages aligned. The detailed procedure follows.

FIG 4



Converter Plate and 1st I.F. Plate Adjustments - Fig 4

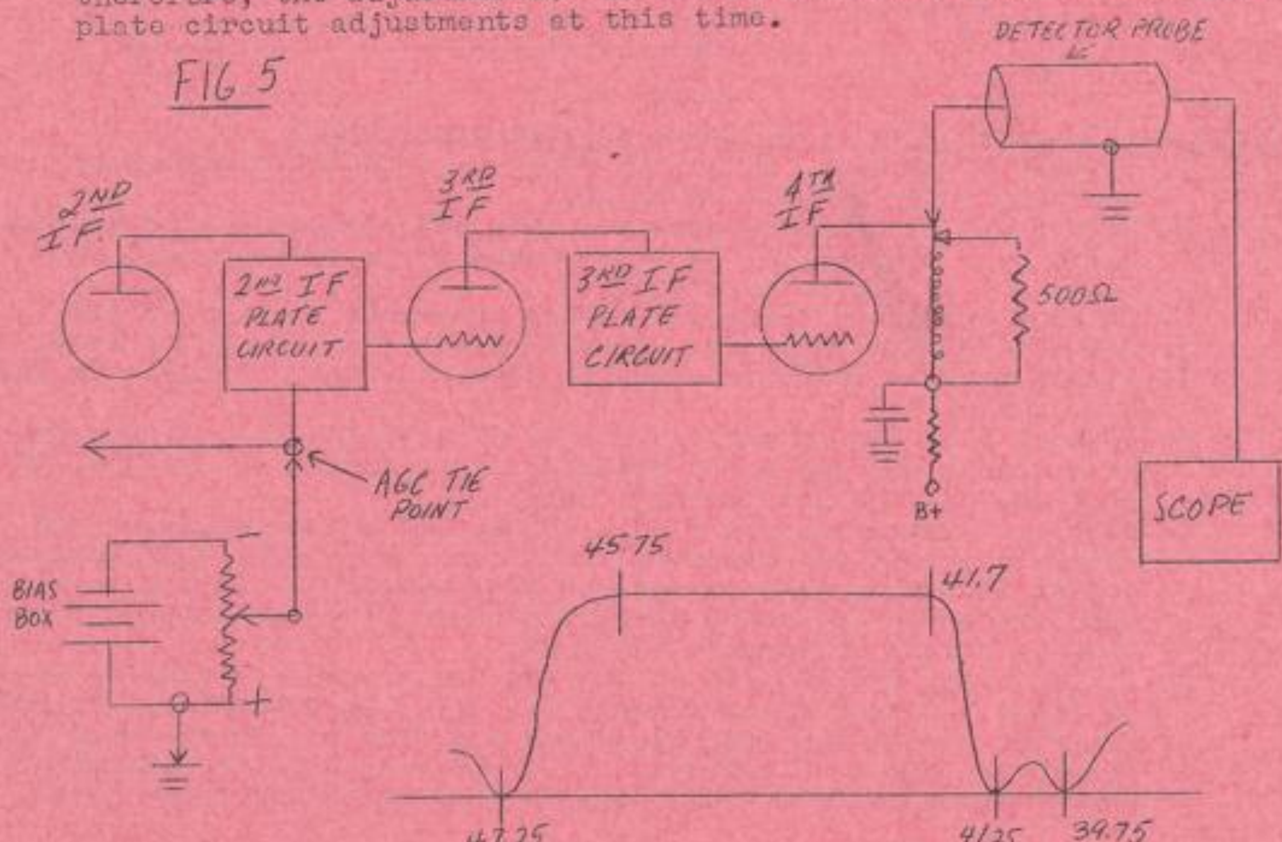
1. Disable tuner osc. If turret type, osc. can be disabled by cracking tuner between channels.
2. Remove shield of converter-osc. tube and squeeze shield together slightly. Slip shield back over tube for a friction fit but don't let it touch the chassis.
3. Connect output of sweep and marker generator to tube shield.
4. Connect 500 ohm resistor - ½ watt across 2nd I.F. plate load.
5. Attach crystal detector probe to scope and connect probe to 2nd I.F. plate.
6. Connect bias box to the A.G.C. bus feeding the I.F. strip such as to cause the bus to be negative with respect to chassis. Adjust the box for zero voltage output.
7. With the marker generator off, adjust the sweep generator and scope to obtain the waveform. With the scope gain near maximum, adjust the sweep gain for proper size waveform. In some cases, both the sweep and scope gains will have to be adjusted for maximum to obtain a readable waveform.
8. If any traps are present in the two stages, they should be adjusted first. Obtain their frequencies from the schematic. Establish a marker pip at the trap frequency and then adjust the trap to reduce the pip to a minimum. A second method is to modulate the marker signal with an audio signal thus producing audio in the

waveform. Adjust the trap for a minimum condition of the audio. If more traps are present, adjust in a similar manner. While adjusting a trap, use whatever scope, sweep, and marker gain is necessary to make the pip or audio more visable.

9. Upon adjusting trap or traps, readjust for the waveform as explained in 7. Establish marker pips at 41.7 Mc (upper limit of Q) and 45.75 Mc (luminance carrier frequency). This can be done by using two marker generators or one marker generator and a crystal. Two marker pips at the same time aren't essential but are most helpful. In case the I.F. range is different from 41.25, the above equivalent frequencies can be found by adding 0.45 Mc to the sound I.F. frequency for one and 4.5 Mc to the sound I.F. frequency for the other.

10. Adjust the converter coil, 1st I.F. grid circuit, and 2nd I.F. plate circuit for the best compromise between gain and flat response. The distance between the marker pips is the significant part of the curve. Both markers should end up an equal distance from the base line. In each case, they should be on the flat part of the curve rather than on a side. Do not tolerate more than 10% dip in the curve between markers. Also, do not compromise bandwidth for gain. The 500 ohm load resistor across the 2nd plate circuit prevents the 2nd I.F. from influencing the curve and, therefore, the adjustments. Do not be concerned with the 2nd I.F. plate circuit adjustments at this time.

FIG 5

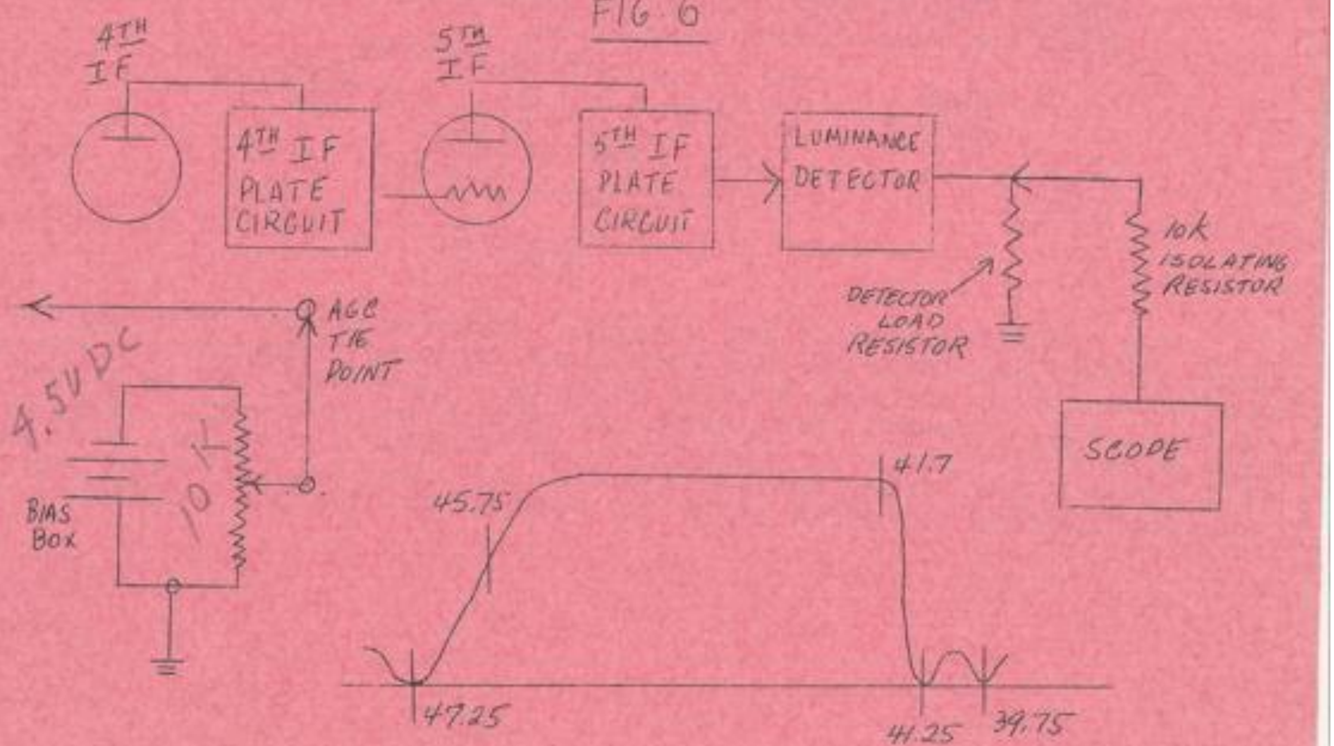


2nd and 3rd I.F. Plate Adjustments - Fig 5

1. Remove 500 ohm padding resistor from 2nd I.F. plate load and connect across the 4th I.F. plate load.
2. Move crystal probe to 4th I.F. plate.
3. With a V.T.V.M. connected to the A.G.C. bus, adjust bias box for a 4 volt output.
4. With the marker generator off, adjust the sweep generator and scope to obtain the waveform. Use just enough sweep signal to produce a clean waveform. Adjust scope gain for proper size waveform. To insure that the sweep signal is not overloading the I.F. amplifier, decrease the sweep gain and note if the waveform retains its shape as it decreases in amplitude. If it does retain its shape, the proper amount of signal is being used. Otherwise, reduce the sweep gain until the point of overload is passed.
5. If any traps are present in the 2nd and 3rd I.F. stages, they should be adjusted as previously explained.
6. Adjust the 2nd and 3rd I.F. transformers for the best compromise between gain and flat response. Again, the distance between the markers is the important part of the curve. Adjust as previously explained.

In some cases, depending upon the circuit, some value of A.G.C. voltage other than 4 volts might be a better value. A good rule of thumb is to measure the A.G.C. bus voltage under normal set operation conditions to establish the amount of bias to use during alignment. In the case of two or more TV stations, select a value equal to the average of the strongest signal A.G.C. voltage and the weakest signal A.G.C. voltage.

FIG 6



4th and 5th I.F. Plate Adjustments - Fig 6

1. Remove 500 ohm padding resistor from 4th I.F. plate load.
2. Remove crystal probe from scope and connect scope directly to luminance detector load resistor. To find this resistor, locate detector and follow output side of it toward ground until a 5600 ohm (approximate) resistor is located. Attach scope to the end of the resistor nearest the detector.
3. With the marker generator off, adjust the sweep generator and scope to obtain the waveform. Use just enough sweep signal to produce a clean waveform. Adjust scope gain for proper size. To insure that the sweep signal is not overloading the I.F. amplifier, decrease the sweep gain and note if the waveform retains its shape as it decreases in amplitude. If it does retain its shape, the proper amount of signal is being used. Otherwise, reduce the sweep gain until the point of overload is passed.
4. If any traps are present in the 4th and 5th I.F. stages, adjust as previously explained.
5. Adjust the 4th and 5th I.F. transformers for the best compromise between gain and ideal waveform. At this point, the scope waveform represents the entire I.F. response. The waveform should be adjusted until the 45.75 marker pip (luminance carrier) appears ½ way on the slope and the 41.7 marker pip (upper limit of Q) appears in the knee. In most cases, adjustments of the 4th and 5th I.F. stages will not produce the ideal curve (shown in Fig 6). After adjusting the 4th and 5th I.F. stages for the best possible waveform, touch-up preceeding stages to accomplish the ideal curve. In the touch-up procedure, move from one I.F. to another. Change only those I.F. adjustments that make the waveform more ideal. Repeat the touch-up procedure two or three times, or until the ideal curve is achieved.

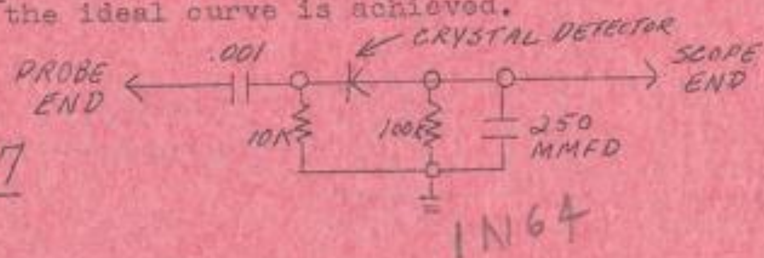


FIG. 7

Fig 7 shows a circuit for a crystal detector probe. This particular probe is very sensitive and has sufficient frequency response for the purpose of alignment and most trouble shooting. Since very few parts are involved, it may be wired into almost any type of probe housing. Due to its high sensitivity, it is an ideal probe for trouble shooting the I.F. path. In a strong signal area, the video out of the tuner may be viewed thus determining whether a trouble is in the tuner or in the I.F. amplifier.

Color Synchronizating Alignment

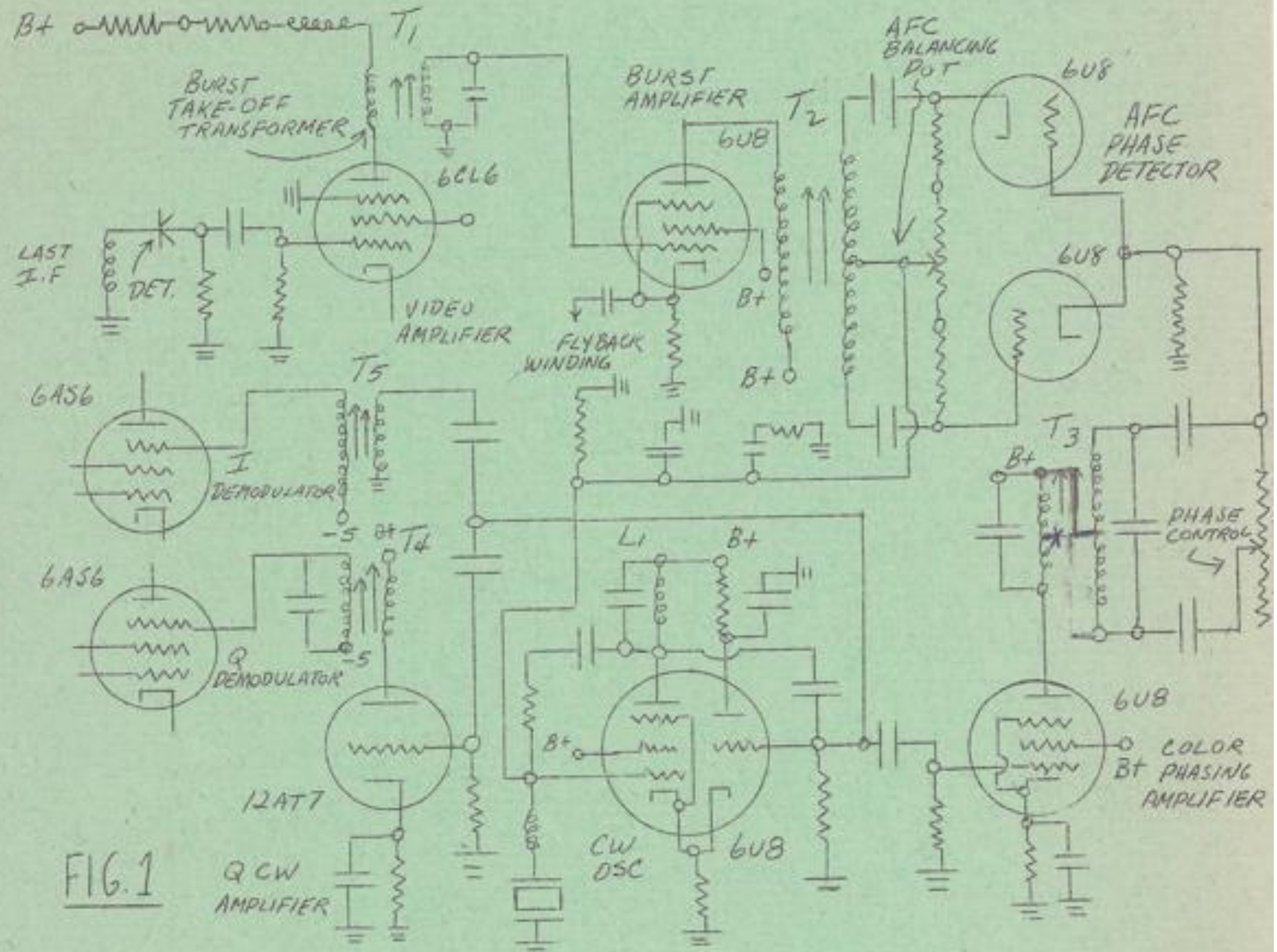


FIG.1

Fig 1 shows the complete synchronizing circuit that was discussed previously in detail. Reviewing, the 3.58 Mc color burst signal is removed from the video signal by means of the color burst transformer T1. Since the color burst take-off transformer is located in the 1st video amplifier plate circuit, it tends to attenuate the video response of the stage in the distance from 3 to 4 Mc. While this limits the high video frequencies of the Y signal, it provides attenuation of the color subcarrier frequency, thus providing a minimum 3.58 beat pattern in the picture.

The color burst transformer feeds the color burst signal to the burst amplifier stage. The burst amplifier stage amplifies the color burst signal but does not pass other 3.58 Mc signals. The cathode of the stage is keyed with horizontal flyback pulses, preventing the stage from conducting except during horizontal blanking, which is the time that the color burst signal is present.

60V

The burst amplifier transformer T2 couples to the color A.F.C. phase detector stage. The secondary winding of T2 produces about 120 volts peak to peak of color burst signal. Since it is center tapped, about volts drives each section of the A.F.C. stage.

The A.F.C. stage is a conventional type of phase detector circuit. It compares the phase of the color burst signal with the CW signal and generates a D.C. correction voltage of the proper polarity to correct the CW oscillator. An A.F.C. balancing potentiometer is arranged in the output side of the stage which serves to balance the two tube circuits of the stage. The output correction voltage is taken from the arm of the balancing potentiometer and applied to the control grid of the CW oscillator.

The CW oscillator is a very stable crystal controlled type of oscillator. It serves to generate the 3.58 Mc CW signal required of the I and Q demodulators. Besides having the ability of being stable, it is easily controlled by the D.C. correction voltage from the A.F.C. stage. Depending upon the load, it produces from fifteen to twenty volts output.

Part of the CW output is coupled to the color phasing amplifier. This amplifier serves to amplify the CW signal before it reaches the A.F.C. stage. Besides amplifying, it provides 360 degree control over the CW phase by means of the phase control.

The bulk of the CW oscillator signal couples through phase shifting stages to the I and Q demodulator stages. The I CW signal is developed by passing the CW signal through a nonresonant transformer T5, producing a phase shift of 180 degrees. The Q CW signal is developed by passing the CW signal through a Q CW amplifier and a resonant plate transformer T4 producing a phase shift of 270 degrees. This results in the I CW signal leading the Q CW signal by 90 degrees which is the required condition for I and Q demodulation.

Due to the high frequency (3.58 Mc) of the two primary signals involved, trouble shooting and alignment of the circuits is rather difficult. At present, most oscilloscopes do not have sufficient frequency response to read a 3.58 Mc signal. Therefore, a method of alignment and trouble shooting must be arrived at that does not require a visual picture of the signals. Different from most of the circuits in the color receiver, the synchronizing circuits are narrow band and high gain. This situation is quite an asset because narrow band circuits are quite easy to trouble shoot and align using a V.T.V.M. As matter of fact, a V.T.V.M. is almost as good an indicator in such circuits as an oscilloscope.

The ideal 3.58 Mc signal to use for alignment of the synchronizing circuit is the color burst signal itself. However, due to the limited number of color telecasts at present, a more practical method is one using a 3.58 Mc signal from a crystal controlled generator. A large number of the crystal controlled marker generators that are in use today do not provide a 3.58 Mc frequency. In lieu of this situation the most practical answer is to crystal control the marker oscillator with an external crystal of 3.58 Mc frequency. Most R.F. and marker generators have an external crystal position and a switch to allow the crystal to control the internal oscillator. Actually, such an arrangement is considerably more accurate than using a generator that generates frequencies through the 3.58 Mc range. Human error always enters into the setting of a dial.

The following is a color synchronizing alignment method that has proven to be successful and practical.

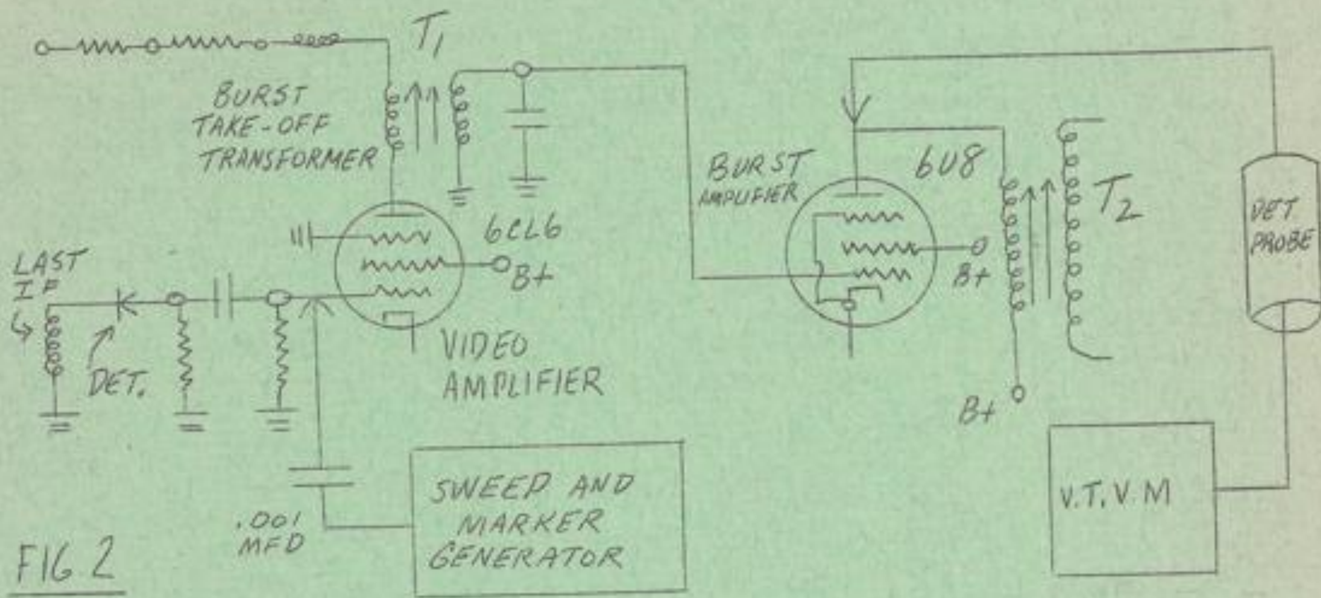


FIG 2

Burst Take-Off Transformer Adjustment - Fig 2

1. Turn tuner to a position where no signals are being received.
2. Connect output of marker generator to control grid of 1st video amplifier through a .001 MFD condenser. Adjust generator for zero output.
3. Attach crystal detector probe to V.T.V.M. and connect probe to plate of burst amplifier stage.
4. If marker generator is combined with a sweep generator, turn off sweep generator. Plug in external 3.58 Mc crystal and turn marker selector switch to external crystal position.
5. If 1st video amplifier is provided with a contrast control, it should be adjusted for one-half to three-fourths maximum gain.
6. Zero the V.T.V.M. and adjust it for a sensitive scale. Turn up marker generator to give a mid scale reading. If V.T.V.M. gives a substantial reading with marker generator off, remove external 3.58 Mc crystal. If reading drops to zero, the marker generator is providing an output even through the gain control is in a minimum position. This does not handicap the procedure. If V.T.V.M. reading does not drop to zero with crystal removed, disconnect keying circuit from cathode of burst amplifier to remove the possibility of the 15,750 cps horizontal signal being amplified and causing an error in the reading. If disconnecting the keying pulse does not reduce the V.T.V.M. reading to zero, the burst amplifier circuit should be checked until the signal is found that is providing the reading. With the keying signal disconnected, no signal should be present in the circuit.
7. Adjust burst take-off transformer T1 for maximum V.T.V.M. reading. If voltmeter goes off scale during the adjustment, reduce marker generator signal.

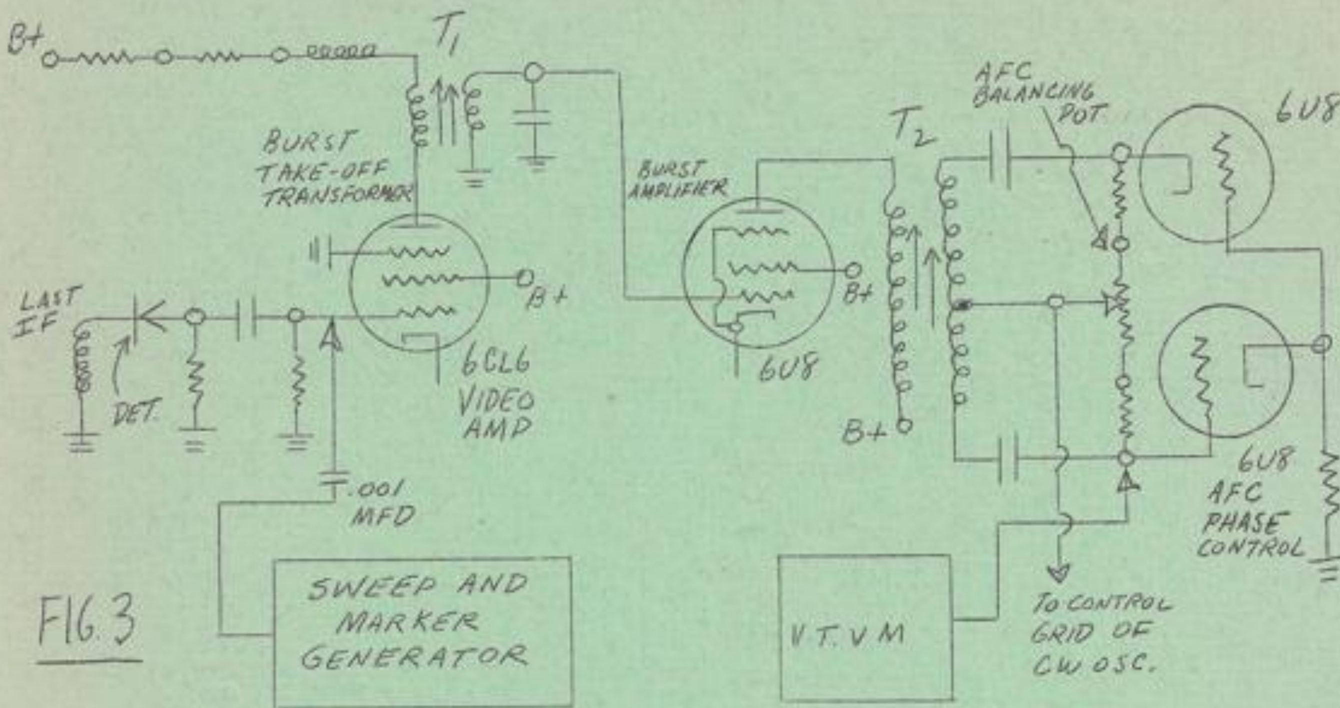


FIG 3

Burst Amplifier Transformer Adjustment - Fig 3

1. Remove crystal probe from voltmeter and connect voltmeter directly to either a cathode or grid of the A.F.C. stage that connects back to the burst amplifier transformer secondary.
2. Remove 3.58 Mc CW oscillator tube from socket.
3. Without changing the marker generator gain control, adjust the voltmeter for the proper scale for a mid scale reading. If voltmeter goes off scale during the adjustment, change the voltmeter to a higher range (lower sensitivity).

For trouble shooting purposes, it is a good idea at this point to move the voltmeter to the opposite tube of the A.F.C. stage and measure the voltage. Obviously, the polarity will be reversed. The two voltages should be approximately the same in amplitude. At this point, the two stages haven't been balanced so a few volts difference can be expected. If little or no voltage exists at one of the two tubes, the stage isn't conducting or isn't receiving signal from the burst amplifier transformer.

Balancing the A.F.C. Phase Detector Stage - Fig 3

1. Remove voltmeter from A.F.C. stage and adjust it so that zero voltage is read at mid scale.
2. Connect the voltmeter to the arm of the balancing potentiometer.
3. Adjust the balancing potentiometer for a zero voltmeter indication. To most accurately balance the stage, the most sensitive voltmeter scale should be used. If the stage cannot be balanced, it should be checked for trouble and the trouble repaired before proceeding to the next step. Without the A.F.C. circuit being balanced, the color synchronizing circuit will not function to synchronize the color picture.

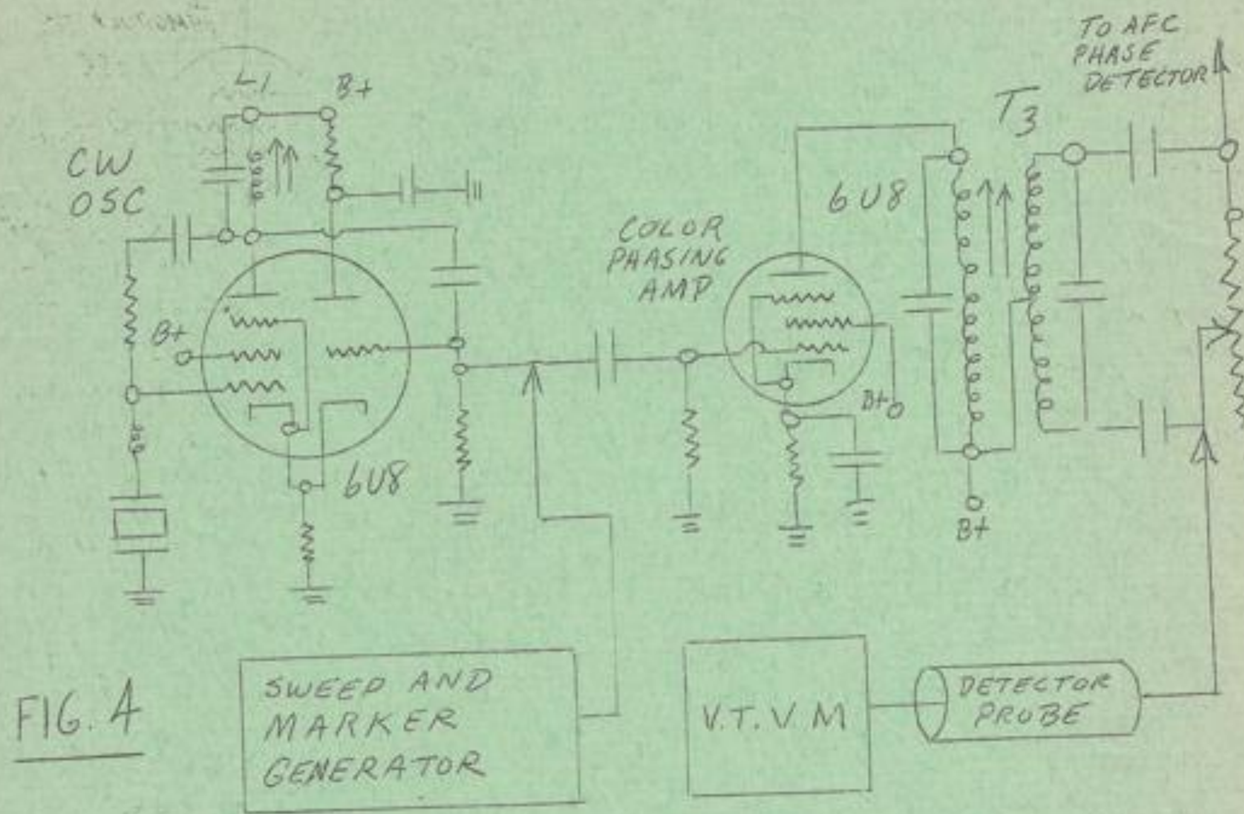
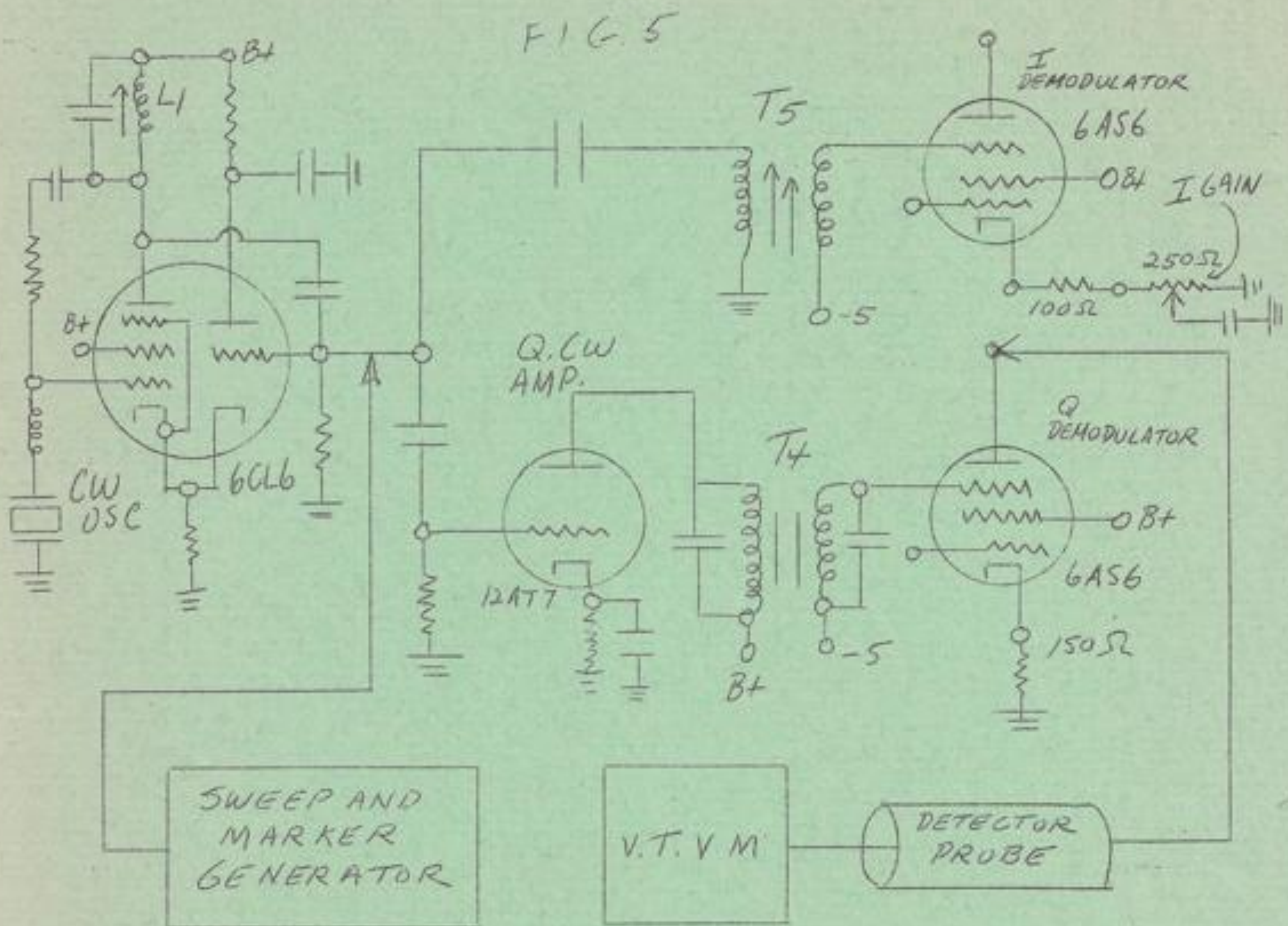


FIG. 4

Color Phasing Amplifier Adjustment - Fig 4

1. Connect marker generator to output point of CW oscillator. As in the previous step, the CW oscillator tube should be out of its socket.
2. Remove voltmeter from arm of balancing potentiometer and re-adjust it for normal zero voltage readings.
3. Attach detector probe to voltmeter and connect probe to output side of either of the two phase condensers.
4. Adjust phase control for the center of its range.
5. With the voltmeter adjusted for its most sensitive scale, increase the marker gain for a mid scale reading if possible.
6. Adjust the color phasing amplifier transformer T3 for maximum voltmeter indication. If voltmeter goes off scale during the adjustment, adjust the voltmeter for a less sensitive scale.

It is interesting to note at this point that if either half of the secondary circuit of the color phasing amplifier gets into trouble, the colors of the picture will be effected but not the synchronization. For example, if the lower phase condenser opens up, synchronization would in all probability be maintained but the resultant phase of the I CW and Q CW signals would be incorrect, resulting in improper I and Q signals. In this case, adjusting the phase control would not change the picture colors. If the upper phase condenser should open, the same conditions would be true except that the phase control would make slight changes in the colors.



I CW Transformer and Q CW Transformer Adjustments - Fig 5

1. Move detector probe to plate of Q demodulator.
2. Turn chroma control off (counter clockwise).
3. With the voltmeter adjusted for its most sensitive scale, increase the marker gain for a mid scale reading if possible.
4. Adjust the Q CW amplifier transformer T4 for maximum voltmeter indication.
5. Move detector probe to plate of I demodulator.
6. With the voltmeter adjusted for its most sensitive scale, increase the marker gain for a mid scale reading if possible.
7. Adjust the I CW transformer T5 for maximum voltmeter indication. Due to the fact that the Q demodulator has 150 ohms of cathode resistance and the I demodulator has 350 ohms of cathode resistance with a regenerative type of gain control, it is not to be expected that the measured signal at the I demodulator plate will be equal to the Q demodulator plate signal.

From a consideration of trouble shooting, it would be helpful to parallel the two cathode circuits and adjust the I gain control so that the gain condenser is out of the circuit. Under this condition, the I demodulator plate signal from the marker generator should be equal to the Q demodulator plate signal. Any deviation should be corrected by locating the defective component and replacing it.

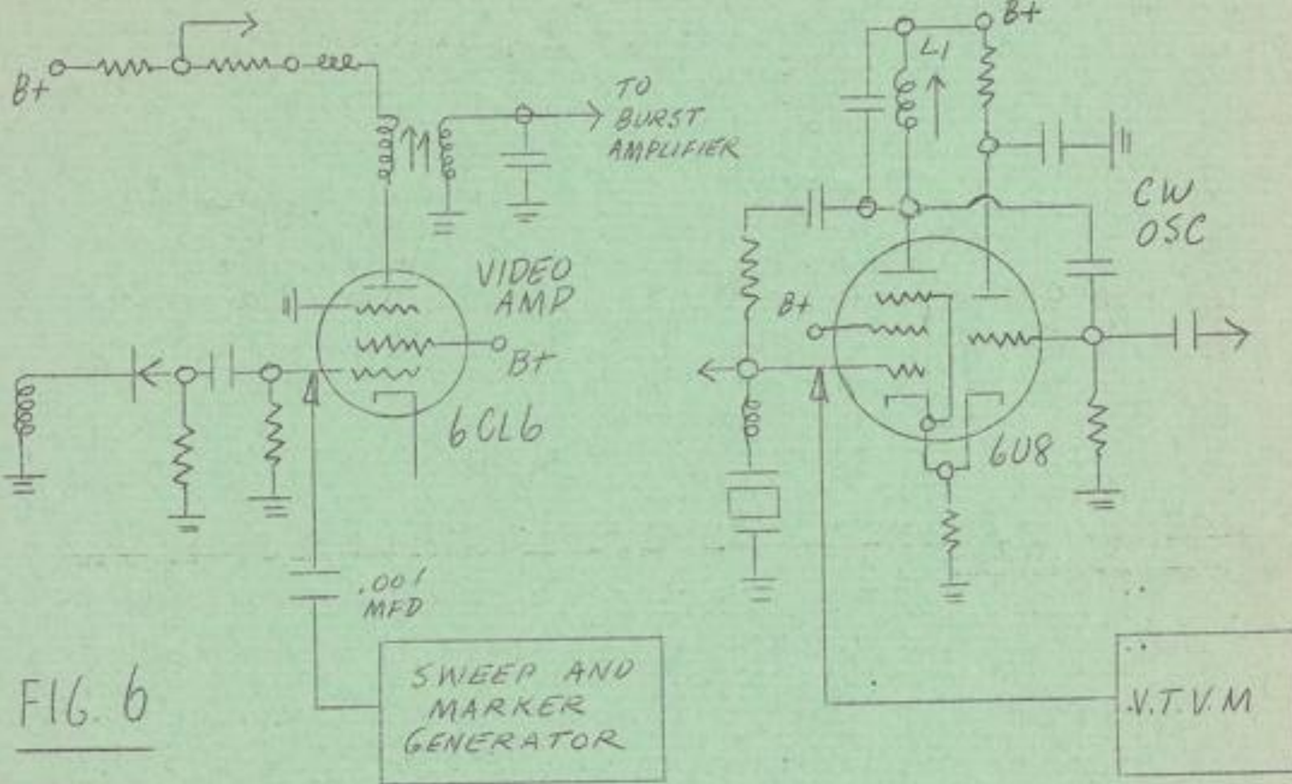
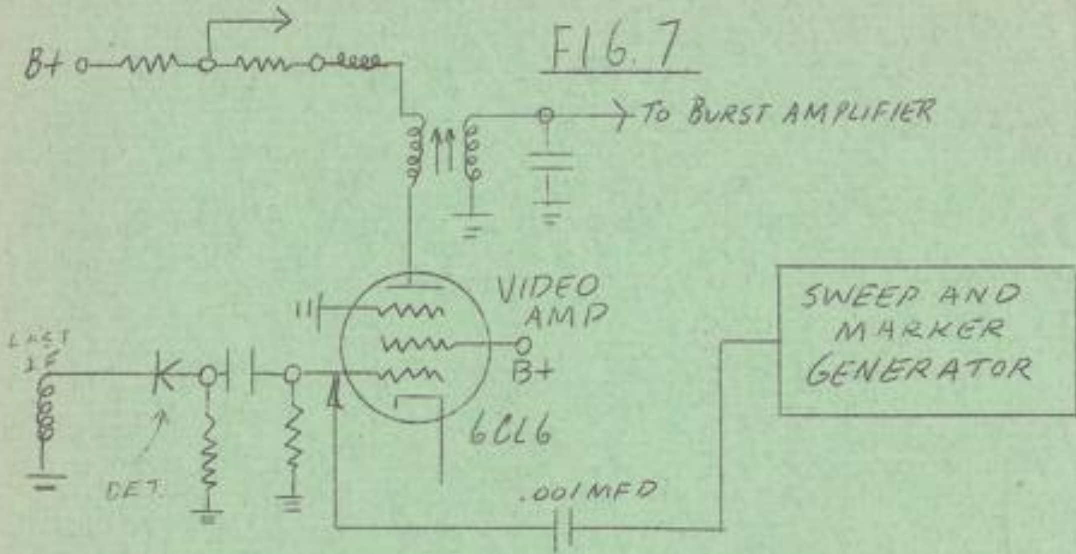


FIG. 6

Adjusting the CW Oscillator for Synchronization with the Marker Generator

1. Move output of marker generator to control grid of 1st video amplifier. Connect generator to grid through a .001 MFD condenser. Adjust generator for zero output.
2. Replace CW oscillator tube in socket and allow four or five minutes for warm up.
3. Remove voltmeter from demodulator stage and adjust it so that zero voltage is read at mid scale. Remove detector probe and attach a .001 MFD condenser. Connect voltmeter to control grid of CW oscillator.
4. Recheck the phase control to insure that it is adjusted for the center of its range.
5. With the voltmeter adjusted for its most sensitive scale, increase the marker output until the voltmeter begins indicating a change in voltage. Without changing the marker signal further adjust the ringing coil L1 of the CW oscillator for a zero voltmeter indication. This adjustment will be quite critical when the proper setting of the coil is reached. The voltmeter will swing either positive or negative with a slight movement of the coil slug. The ringing coil should be adjusted in one direction and then the other to see if the voltmeter positive swing is approximately equal to the negative swing. Under ideal conditions, the two swings should be equal. Try using more marker signal noting the voltmeter to see if the oscillator remains in synchronization. It should stay in synchronization through a wide range of input signal. About the only possibility for synchronization being effected by signal input is the possibility of the A.F.C. stage becoming unbalanced with a signal of more or less strength than the one used in balancing it

FIG. 7



Adjusting the CW Oscillator for Synchronization Visually with the Marker Generator

1. Remove voltmeter from circuit but leave marker generator connected as in previous step.
2. Adjust the picture brightness control so that the raster can be observed.
3. If the CW oscillator is in synchronization, the picture should not contain any video information. Varying the marker gain should give a slight brightness variation. If the oscillator is out of synchronization, the picture will contain video information consisting of horizontal or vertical bars that increase and decrease in intensity with the marker gain. Adjust the CW oscillator ringing coil in the direction to minimize the bars until synchronization is reached. The bars are caused by the I CW and Q CW signals reaching the picture tube grids out of time with the horizontal scanning of the raster. It is interesting to note that by adjusting the CW oscillator slightly away from the synchronization frequency, the bars can be locked in such that they appear as vertical video color bars. Different combinations of the CW oscillator frequency will produce different numbers of vertical bars, and as a matter of fact, different colored bars. Variation of the phase control affects a change in the colors of these bars. It occurs to the writer that a most practical method of trouble shooting can be arrived at for the signal paths between the I and Q demodulators and the picture tube grids by using the color bar signals generated by the CW oscillator being out of synchronization with the marker generator.

Adjusting the CW Oscillator for Synchronization Visually with a Station Color Signal

1. Disconnect all test equipment. Turn off marker generator.
2. Adjust the color receiver for normal black and white operation.
3. Adjust the chroma control for three-fourths of maximum and the phase control for the center of its range.
4. Adjust the CW oscillator ringing coil as explained above.
5. Readjust the phase and chroma controls for the most pleasing color picture.

At the present time, and at this stage of the art, it appears that the technician requires both a dot generator and a bar pattern generator in order to do a good alignment and trouble shooting job. With limited programs and color sets, such equipment is not practical except in a few isolated cases.

In the previous lesson, it was pointed out that a color bar pattern can be generated by feeding a crystal controlled 3.58 Mc signal into the 1st video amplifier grid to serve as the color burst signal and then adjusting the CW color oscillator to a slightly different frequency. It is our purpose now to study this situation further due to the significance attached to it. Perhaps trouble shooting and alignment methods can be arrived at to supplement those utilizing the dot and bar generators.

The following study, adjustments, and trouble shooting considerations should not be made until the receiver's sync. circuit has been aligned and the picture tube adjustments made.

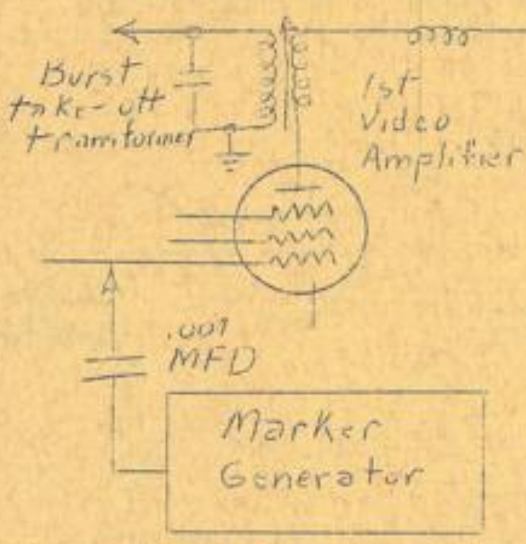


Fig 1

Picture Condition

Generating a Three Bar Color Pattern

1. Turn tuner to a position where no signals are being received.
2. Set marker generator for crystal position and plug in a 3.58 Mc crystal. Connect output of marker generator to control grid of 1st video amplifier through a .001 MFD condenser.
3. Adjust both the chroma and contrast controls for one-half to three-fourths maximum. Adjust brightness control for one-fourth to one-half maximum.
4. Adjust phase control for center of its range.
5. Adjust gain of generator from minimum to obtain visable bars or horizontal lines in the picture. Use just enough signal to get visable results. By chance, the CW oscillator might lock-in on the generator without adjusting it. If no lines or bars appear, adjust the CW oscillator slightly to drive it out of sync. to get a visible pattern.

6. With a visable line or bar pattern on the screen, adjust the CW oscillator slowly to obtain a three bar vertical pattern. This position is the first position that vertical bars can be locked in solidly as the CW oscillator is adjusted away from sync. Depending upon the receiver design and the adjustments of the receiver, the three bars might be any color but usually will be different colors. If the receiver is in good adjustment, the three bars will represent the primary colors red, green, and blue.

The three bar color pattern represents a condition where the CW oscillator is operating 15,750 cps (horizontal line frequency) higher or lower than the color burst signal (marker generator signal). It is conceiveable, but not very likely, that some CW oscillators can not be adjusted away from 3.58 Mc by an amount equal to 15,750 cps. If so, this same condition can be obtained by setting up the marker generator to obtain a variable frequency output and adjusting it rather than the CW oscillator to obtain the three bar picture pattern. The latter method is the most acceptable of the two. Unfortunately, however, most marker generators of the TV type do not tune the 3.58 Mc range. Any R. F. crystal controlled generator that will tune the range and has sufficient output will do very nicely.

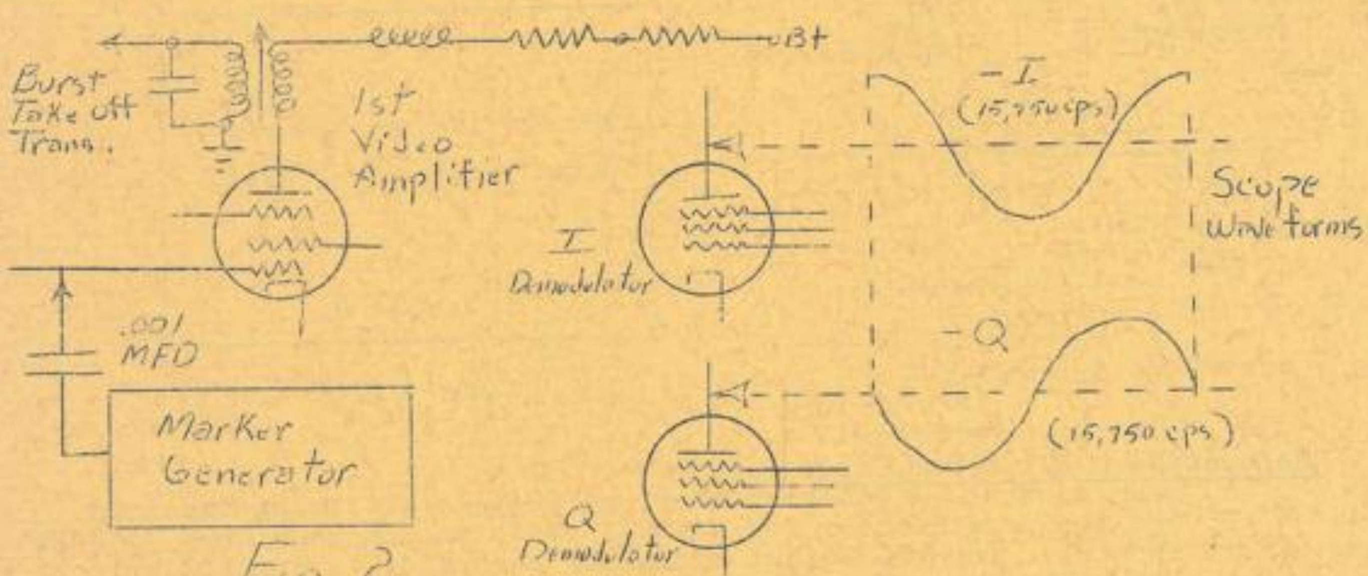


Fig 2

Adjusting for a 90 Degree Phase Shift between the I CW and Q CW signals.

1. Connect the scope to the I demodulator plate. Adjust the scope for internal horizontal sweep and for external sync. Connect external sync. wire to horizontal sweep circuit of receiver. In most cases, a good scope sync. signal can be picked up by clipping the sync. wire to the insulation of the hot wire feeding the horizontal yoke.
2. Adjust the scope's horizontal sweep circuit to obtain a single cycle of the generated color signal. It is most important that the right amount of external sync. signal be

used. When the scope is properly adjusted, the horizontal retrace line of the scope will be essentially straight and the generated sine wave signal will have a minimum amount of distortion.

The waveform at the I demodulator plate represents the demodulated I signal and the waveform at the Q demodulator plate represents the demodulated Q signal. If the color sync. circuit is in exact phase alignment, the I and Q signals will be displaced exactly 90 degrees. In a previous lesson on the color sync. circuit, a method of alignment was presented that accomplishes good results but does not take into account an exact 90 degree phase relationship between the I CW and Q CW signals. Obviously, the generated I CW and Q CW signals must be generated exactly 90 degrees out of phase with each other. Otherwise, improper I and Q demodulation will take place.

The I and Q waveforms of Fig 2 represent the phase of the I CW and Q CW signals. It is a relatively simple job to adjust for correct phase under the conditions of Fig 2. Conversely, it is practically impossible to adjust for correct phase by analyzing the I CW and Q CW signals directly with a scope. Other methods of adjusting for proper phase require either a transmitted color bar pattern or a generated (bar generator) color bar pattern.

3. With the scope connected to the I demodulator plate, adjust the receiver's phase control to accomplish the waveform shown in Fig 2.
4. Move the scope to the Q demodulator plate. Adjust the Q CW transformer slightly to accomplish the Q waveform shown in Fig 2.
5. Move the scope back to the I demodulator plate and adjust the I CW transformer slightly if the waveform is not exactly as shown in Fig. 2.

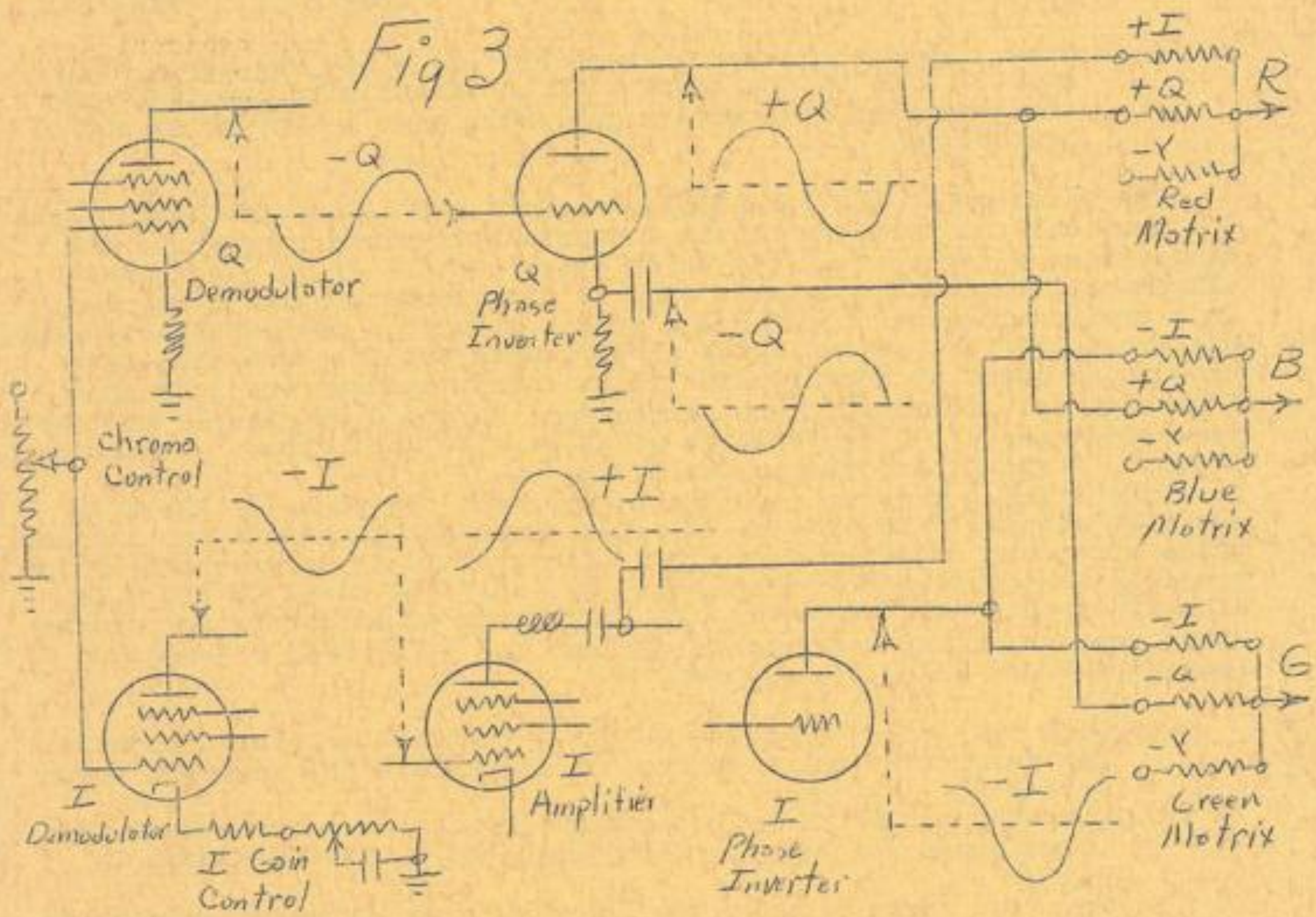
It will be noticed at this point that the three color bars are in the order of blue, red, and green from left to right. It is possible of course that a trouble might exist between the I and Q demodulator plates and the picture tube grids. If so, one or two of the colors might be missing entirely. It is not necessary at this point that the I and Q signals be of the same amplitude.

Adjusting the I Gain Control

1. Move the scope to the Q input side of the green matrix unit (Fig 3 on following page). Adjust the gain of the scope to obtain a waveform either one inch or two inches in height.
2. Move the scope to the I input side of the green matrix unit. Adjust the I gain control to establish the I waveform equal to the Q waveform as measured above.

In addition to the considerations of adjusting the phase of the I and Q signals and making the setting of the I gain control, the particular procedure under study is most significant from the standpoint of trouble shooting. Note in Fig 3 the various positive and negative waveforms of the I and Q signals. Obviously, the scope allows measurement of these signals and thus provides an excellent method of trouble shooting the continuity of these circuits.

Fig 3



It is significant to recall again that when the color receiver is tuned to a color telecast, the demodulated I and Q signals are most difficult to analyze with a scope due to their lack of horizontal and vertical blanking and sync. information. Video signals without reference pulses are confusing to work with.

Fig 4

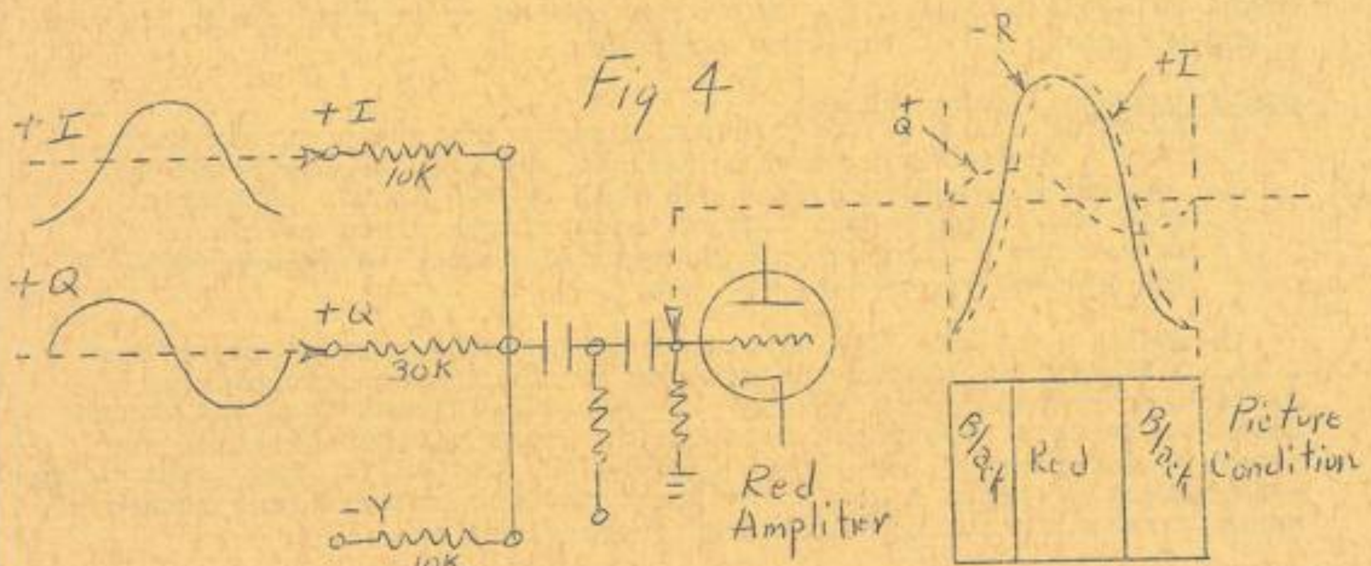


Fig 4 shows the generated I and Q signals as they appear at the input of the red matrix unit. As shown, this unit requires a positive I signal, positive Q signal, and a negative Y signal. Since the I and Q demodulators produce negative signals, they must be reversed in polarity before being presented to the red matrix unit. This is accomplished with the I and Q phase splitters and has been previously explained.

<u>Generating the R Signal</u>

1. Move the scope to the I input resistor of the red matrix unit. The waveform should be as shown in Fig 4. If the three bar pattern falls out of sync. during this set up or any of the others, re-adjust the CW oscillator to obtain the pattern.
2. Move the scope to the Q input resistor and observe the positive Q signal.
3. Move the scope to the grid of the red amplifier tube and observe the negative R signal. The waveform should be similar to the one shown in Fig 4. Reviewing, the R signal at this point is considered to be negative because the Y signal is fed into the three matrix sections in a negative direction.
4. With jumper wires, ground the B and G signals feeding the B and G picture tube grids. Under this condition, the picture will consist of a red vertical bar in the center of the screen with a dark screen on either side of it. This picture condition is illustrated in Fig 4. The R signal waveform shown in Fig 4 appears at the picture tube R grid with the same polarity resulting in the R gun conducting during the positive part of the waveform and being cut off during the negative part. Because the red picture tube beam is sweeping the center one-third of the picture tube during the positive voltage condition, a red vertical bar is generated for the center one-third of the picture.

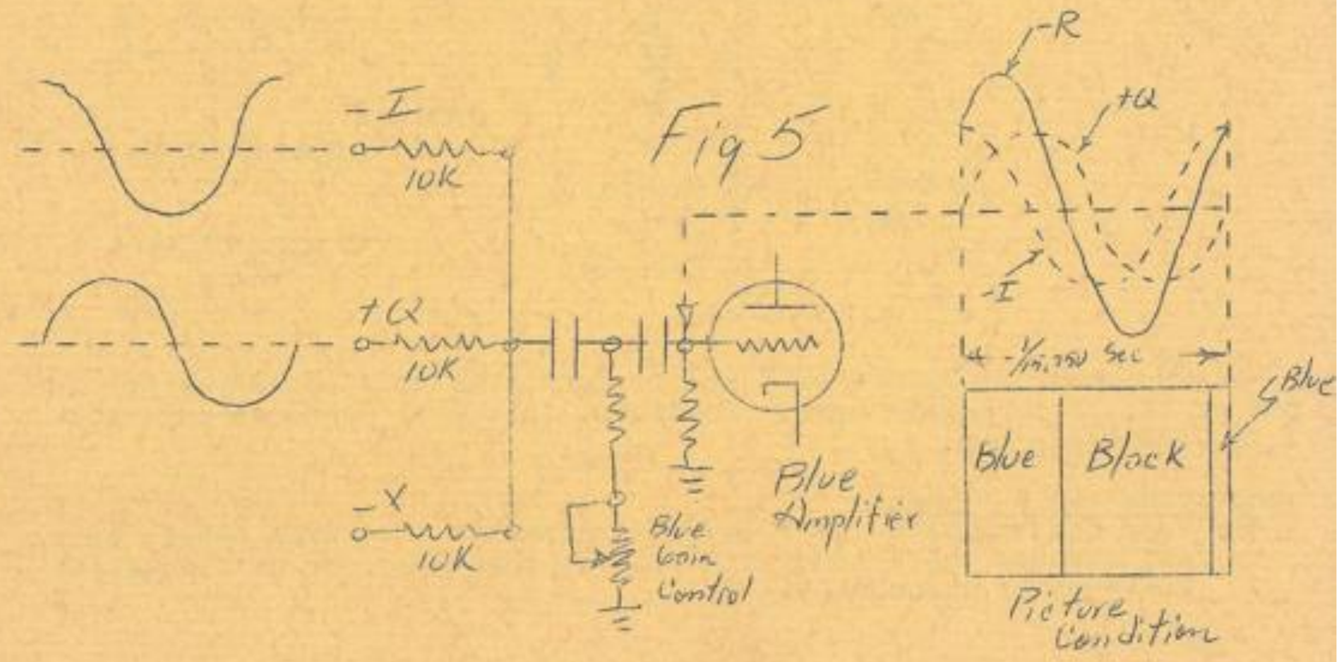


Fig 5 shows the generated I and Q signals as they appear at the input of the blue matrix unit. As shown, this unit requires a positive Q signal, negative I signal, and a negative Y signal.

Generating the B Signal

1. Move the scope to the I input resistor of the blue matrix unit and observe the I input signal. It should appear as a negative I signal as shown in Fig 5.
2. Move the scope to the Q input resistor and observe the Q input signal. It should appear as a positive Q signal as shown in Fig 5.
3. Move the scope to the grid of the blue amplifier tube and observe the negative B signal. The waveform should be similar to the one shown in Fig 5.
4. With jumper wires, ground the R and G signals feeding the R and G picture tube grids. Under this condition, the picture will consist of a wide blue vertical bar on the left side of the screen and a narrow blue vertical bar on the right side of the screen. This picture condition is illustrated in Fig 5. Note the relationship of the B signal waveform to the reproduced picture.

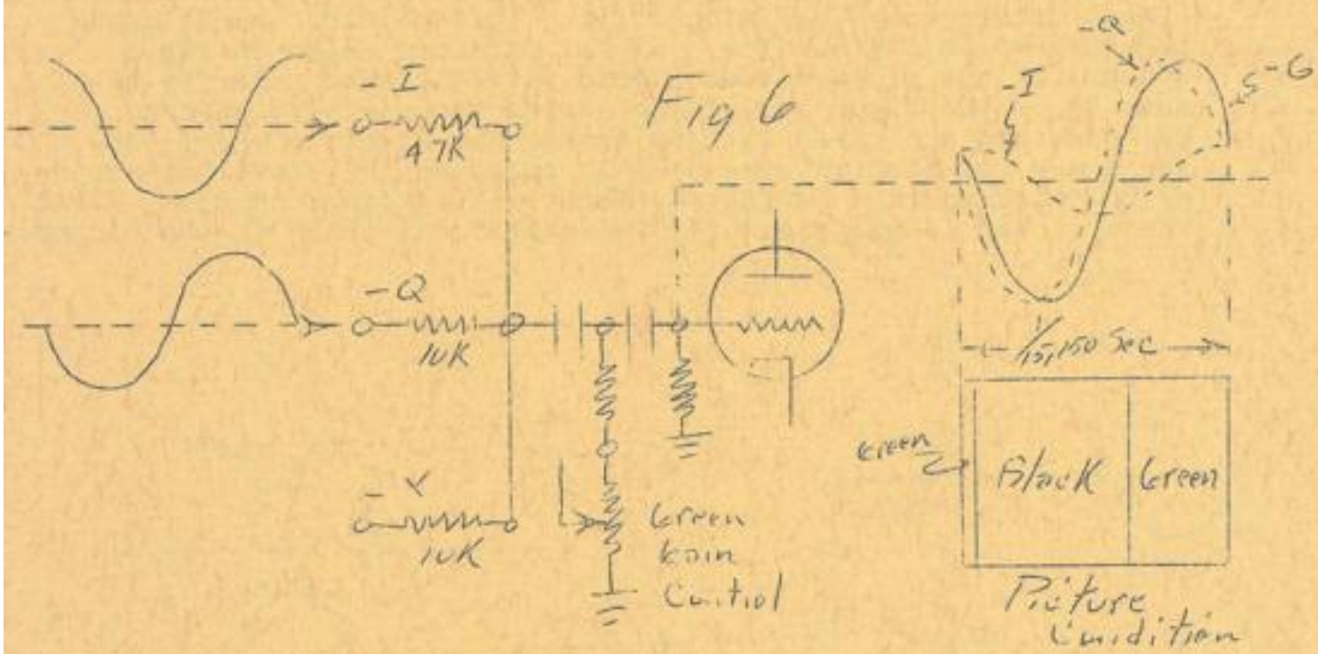


Fig 6 shows the generated I and Q signals as they appear at the input of the green matrix unit. As shown, this unit requires negative I, Q, and Y signals.

Generating the G Signal

1. Move the scope to the I input resistor of the green matrix unit and observe the I input signal. It should appear as a negative I signal as shown in Fig 6.

2. Move the scope to the Q input resistor and observe the Q input signal. It should appear as a negative Q signal as shown in Fig 6.
3. Move the scope to the grid of the green amplifier tube and observe the negative G signal. The waveform should be similar to the one shown in Fig 6.
4. With jumper wires, ground the R and B signals feeding the R and B picture tube grids. Under this condition, the picture will consist of a narrow green vertical bar on the left side of the screen and a wide vertical green bar on the right side of the screen. This picture condition is illustrated in Fig 6. Note the relationship of the G signal waveform to the reproduced picture pattern.

I + Q Signals - Fig 7

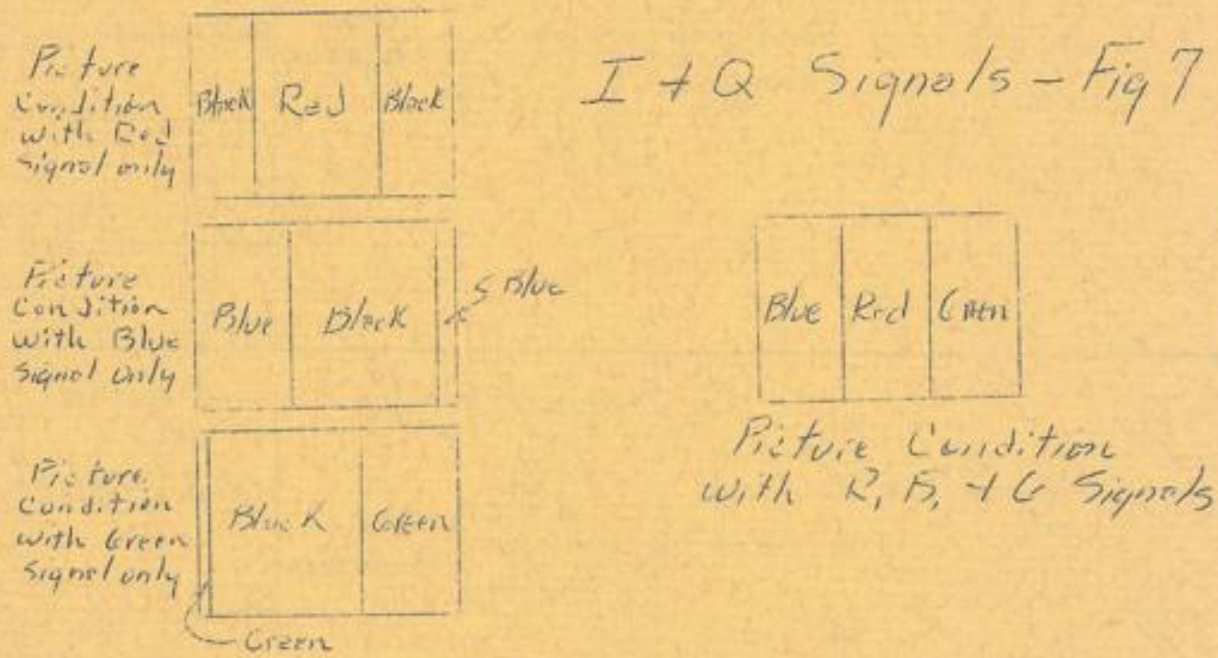


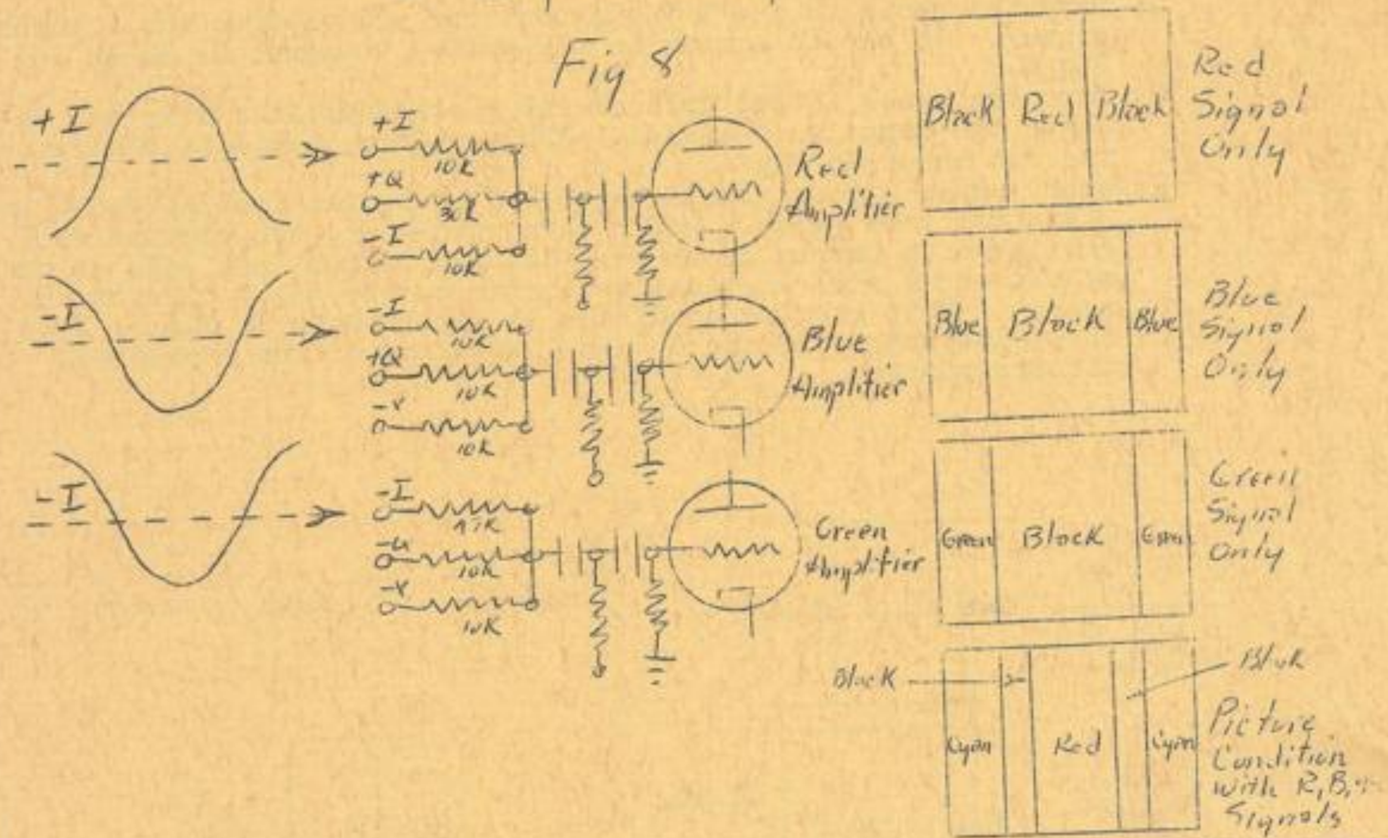
Fig 7 illustrates the three picture conditions that have been under consideration as well as their total effect. This serves to explain the blue, red, and green bar pattern.

Fig 8 on the following page illustrates a condition where the three bar pattern is set up on the screen and then the Q demodulator tube removed from its socket. Obviously, the Q signal is killed allowing only the I signal to drive the R, B, and G amplifiers. Four picture conditions are shown. One with only the R signal, one with only the B signal, one with only the G signal, and one with the R, B, and G, signals. Note that the color range of the I signal is from Red to Cyan.

Fig 9 illustrates a condition with Q existing and I killed. As above, four picture conditions are illustrated for study. Note that the color range of the Q signal is from red to magenta. The color range of the I and Q signals are most important to the technician. With such knowledge, the technician can determine from the picture colors whether I or Q is inoperative.

I Signal Only

Fig 8



Q Signal Only

Fig 9