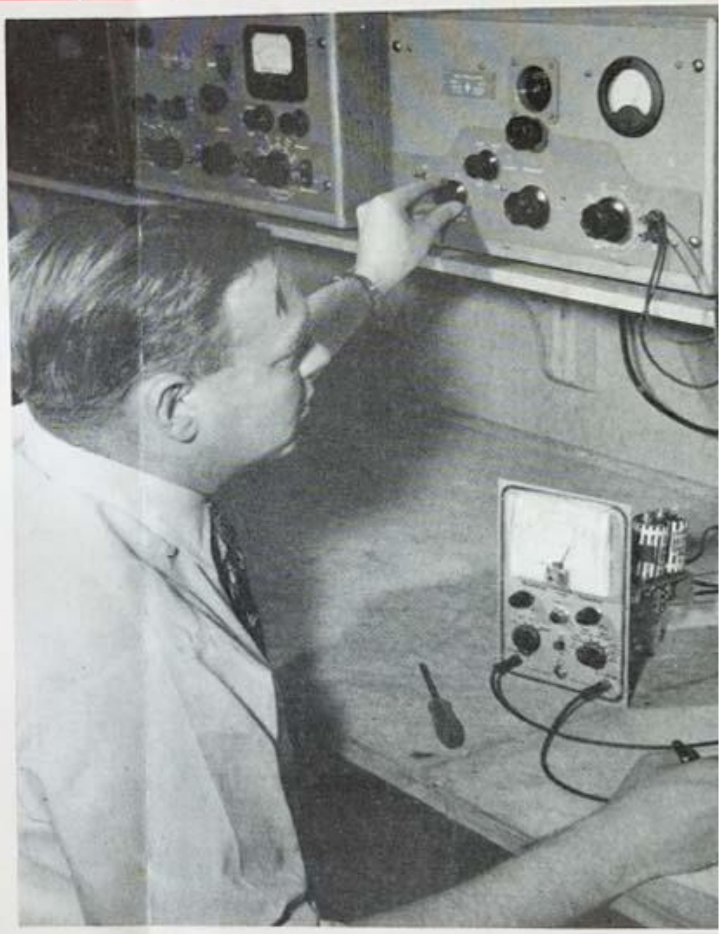
RADIO and TELEVISION maintenance



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SEPTEMBER 1950

New Developments

The Latest Entry in the Race for the Big Prize — General Electric Company's

FREQUENCY-INTERLACE COLOR TELEVISION SYSTEM

By R. B. DOME

Electrical Consultant, Receiver Division, General Electric Co.

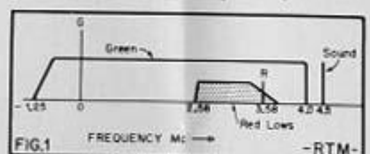
Ed. Note: *The following analysis of the new General Electric color television system is taken from the company's report on the system to the FCC. What effect the commission's tentative proposal to accept the CBS mechanical color system will have, remains to be seen.*

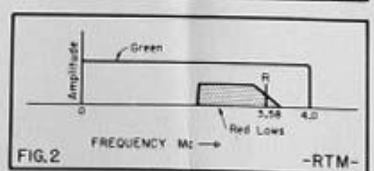
ANY system for transmission and reception in natural color by television in the same bandwidth as is employed in a monochrome system must somehow transmit up to three times as much information as is contained in the monochrome channel. This is based upon the assumptions that three primary colors are employed and that substantially the same overall picture definition or detail is to result at the receiver.

Since there are three messages to be transmitted, some method of multiplexing must be devised if the objective is to be realized. Theer are in general only two means available for multiplexing: time division and frequency division. In a time division multiplex system, only one message is dealt with at any instant.

The longest interval of time devoted to one color may be as long as one complete field of scanning. An intermediate interval corresponding to the length of time required to transmit one scanning line would be the next logical switching interval. Finally, a very rapid switching may be used wherein only a small portion of a line (such as a dot) forms the switching interval. Each of these systems has its own attendant problems in color TV. In general all of these systems require a total elapsed time of two to three times the time required to transmit a monochrome picture of equal definition.

From the economic standpoint, time division multiplex is not too attractive. The receiver must be equipped with suitable gating apparatus to switch the incoming information into the correct reproducing channels. Means must also be provided for identifying which of the three colors is being transmitted at any given instant so that at a given instant the correct color is reproduced.





Graphs of the frequency-division setup in the three-color channel, with red signal sandwiched in among harmonics of the basic green signal. Detailed representation of division in the vicinity of the red subcarrier is shown in Fig. 3.

Frequency Division Multiplex

An examination of frequency division multiplex shows that if the bandwidth available for the television signals is divided into three equal segments, one for each message (or color), the rate of transmission of the entire information would have to be slowed

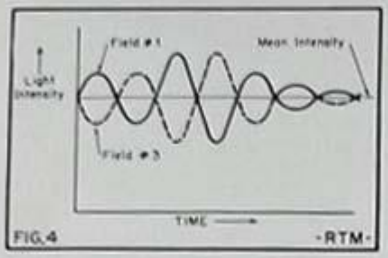


FIG.4 -RTM-

down to one-third that used in monochrome. This could be done, but the flicker problem would become large.

A way of transmitting the three messages simultaneously, in the same frequency spectrum, forms the basis of the system called the "Frequency Interlace Color Television System."

Nature of Frequency Interlace

As the name Frequency Interlace implies, the frequencies employed by the three messages are sandwiched so as to be non-interfering. This can be done in scanned information systems such as television, because the video frequencies associated with a television signal are "bunched" around harmonics of the line frequency. A large part of the available spectrum, then, is unused. It is estimated that about 46% of the space between harmonics is not occupied.

Suppose the video frequency bandwidth available is 4 megacycles, and that scanning frequencies compatible with monochrome television are to be used, namely, a vertical or field frequency of 60 per second, and a line rate of 15750 per second. This results in the standard 525 line system employing two-fold interlace.

At the camera, the composite picture to be televised is split by electro-optical means into three separate groups of signals associated with the three primary colors. Each channel may contain frequencies extending up to 4 Mc. The signals associated with the color green may be regarded as basic. They may be used to modulate the picture carrier in the same way as in a monochrome transmitter. Since the line frequency is 15,750 cps, the sideband energy is chiefly bunched at frequencies spaced from the carrier by 15,750 cps, 31,500 cps, 47,250 cps, etc., out to 4 Mc. The spaces between these harmonics are reserved for the two remaining colors.

Green and Red Interlace

The video frequencies of the second color, red, may be used to modulate a

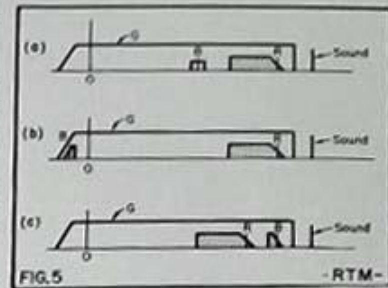


FIG.5 -RTM-

subcarrier. This subcarrier frequency is selected to lie exactly halfway between two harmonics of the line frequency (at an odd multiple of half the line frequency). A frequency of 3,583,125 cps, which is the 455th multiple of 7,875 cps, may be selected. This subcarrier is modulated with video signals of the red channel, and the modulated wave is superimposed on the green channel signals. The entire red spectrum is not used as modulating frequencies. Acceptable color reproduction may be obtained by identifying only the lower video frequencies with their respective colors. The higher frequencies may be transmitted either by green alone or by the principle of "mixed

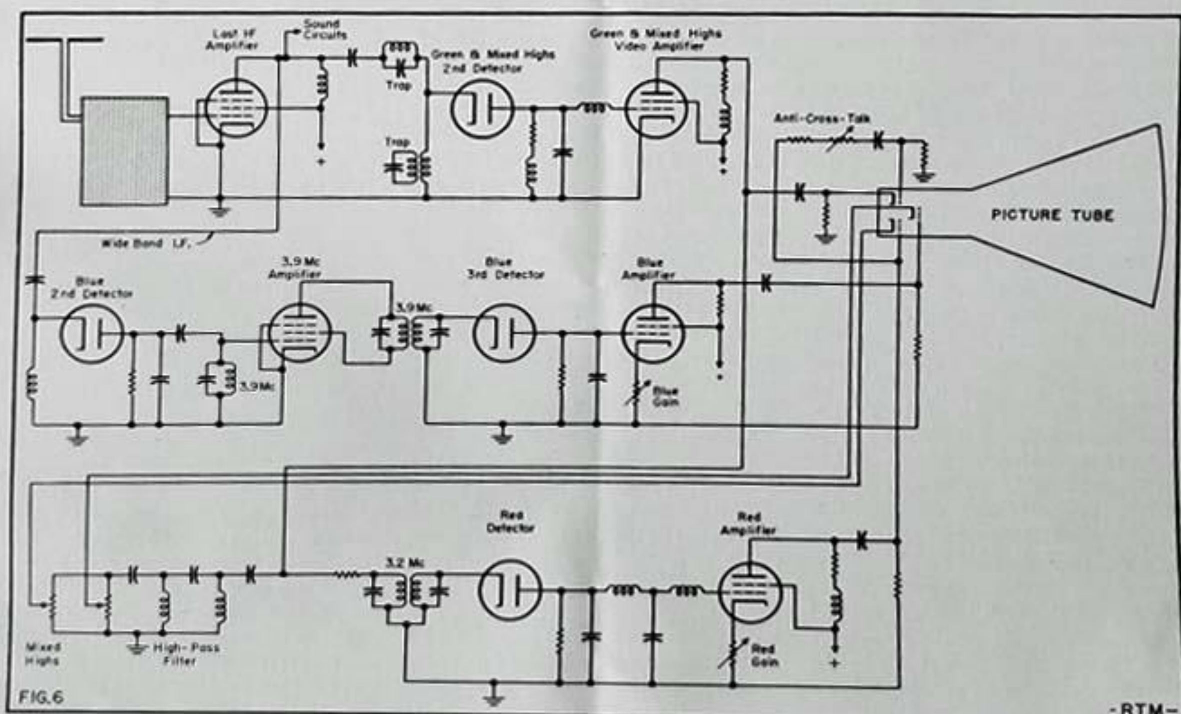


FIG.6 -RTM-

Schematic diagram of color section of simple receiver. As shown here, receiver employs six sets of tube elements in addition to those in black-and-white receivers. Combination tube types might reduce the number of actual envelopes to three. Extra functions which might be required are DC restorers and AGC's, which are not included in this diagram.

highs." Good reproduction will be obtained if red is transmitted as red out to only 1 Mc. Vestigial side-band transmission of the red signal is also used. The spectrum of the combined green and red signals is shown in Fig. 1. This signal may be received by a conventional monochrome receiver insofar as the RF, IF, and second detector are concerned. The video frequency spectrum at the second detector would then be as shown in Fig. 2.

A detailed view of the frequency spectrum in the vicinity of the red subcarrier is shown in Fig. 3.

Separation of Signals

It is necessary now to provide a means at the receiver for separating the signals. Fortunately, a natural filter is the human eye. The satisfactory operation of this system depends largely on "persistence of vision." Any one line of the green television picture will be modulated in intensity at the rate of the red subcarrier, but two fields later in time, in 1/30 of a second. The modulation effect is thus 180° out of phase with the modulation of the first field. Thus a lighter "dot" on field No. 1 will appear as a darker "dot" on field No. 3 and vice versa. In the eye, the illumination tends to average out to a medium background.

This principle is illustrated in Fig. 4 in which are depicted light intensities along a single green line in field No. 1 and in field No. 3. The sine wave is the red sub-carrier. It is shown amplitude modulated by low frequency red picture signals. The approximate visual sensation is shown by the line marked "mean intensity," which corresponds in this case to the desired green signal. The repetition rates involved here are not fast enough to give perfect integration, but the practical result is close to the ideal. The superposition of fields yields twice the number of dots per line as one field alone gives, so that a very fine dot structure results; its fineness is comparable to horizontal scanning line structure and disappears at substantially the same distance away from the picture tube that normal line structure does. Thus although both the red and green signals appear on the green gun, the red is effectively filtered out by the eye and only the green remains.

The information contained in the red camera signal above 1 Mc and up to 4 Mc may be superimposed on the green signal to yield a mixed high signal above 1 Mc.

Addition of Blue Signals

The video frequencies associated with the third color, blue, may be transmitted as modulation on a second subcarrier. As in the case of the red signals, only the lower blue frequencies need be transmitted, so that a comparatively narrow channel should suffice. A blue video band up to 0.2 Mc. may be sufficient. Fig. 5 shows several possible locations for the blue subcarrier. It is not yet known which of these methods will provide the best performance.

As was the case with red and green, the blue signal appearing on the green gun is effectively filtered out by the eye, as are the green signals appearing on the red and blue guns. The blue and red signals, since they do not overlap in frequency, do not exhibit this effect.

High Frequency Components

As stated before, the high video frequencies may be represented by the green channel alone. In order to avoid a greenish tinge to high frequencies the green highs may be taken off the green video channel by the shunt connection of a suitable high pass filter and added to the blue and red guns (as well as by direct connection to the green gun) of the reproducing means to produce black-and-white fine detail. Alternatively, blue and red highs may be added to the green channel at the transmitter and taken off from the green video channel in the receiver to feed the blue and red guns as well as the green gun. The cutoff frequency of the high pass filter would be selected at approximately the cutoff frequency of the red channel low pass filter, or in the example given, at about 1 Mc.

Simplified Receiver

A schematic of the color section of a simple receiver for the reception of the transmission shown in Fig. 5c, is shown in Figure 6. The IF is kept wide band at the plate of the last IF amplifier purposely, so that the blue channel will not be adversely attenuated before it is detected in the blue second detector. Following this detector is an amplifier with tuned circuits centered around the blue subcarrier to remove effects of the sound carrier and the red subcarrier. The blue third detector yields the blue low-frequency video signals, which are amplified and fed to the blue gun grid.

Appropriate sound traps are employed before the green and mixed highs second detector. The output of this detector is amplified and fed to the green gun. Two shunt circuits leading from the plate of the green channel amplifier feed, respectively, the red detector through a 3.2 Mc band-pass circuit and the mixed high filter for addition of mixed highs into the red and blue guns. The 3.2 Mc filter feeds a red signal detector and the output of the detector feeds a red amplifier connected to the red gun.

The receiver as shown here employs 6 sets of tube elements, in addition to those the set receiver would employ if designed for black-and-white pictures. By using available combination type tubes, the actual number of envelopes may be as low as three. The polarity of the detectors may be reversed from those shown to produce the right phase of light intensity, that is a "positive" picture. Alternatively, the picture tube gun connections may be reversed to achieve the same result.

A mathematical analysis of the action of the green second detector shows that some of the red low video frequency modulation will appear as low frequency in the detector output because the system is single sideband. The presence of this low frequency spurious signal in the green channel may cause an undesirable cross-talk effect, making itself evident in a change in hue but not in design. This color shift may be reduced to a small amount by feeding some low-frequency red signals into the green gun, in phase reversal to the cross-talk. Again depending upon the modulation polarity of the red signals, the anti-cross-talk connection may be made either to the cathode or to the grid of the green gun as required. It is shown here connected to the grid of the green gun.

Additional Factors

The simple receiver shown in Fig. 6, while it contains sufficient circuit elements to receive color pictures, does not include two features which may be desirable in a commercial product. These are DC restorers and AGC's. The green AGC and the green restorer are the same as for black-and-white receivers and need not be discussed in detail. The red and blue DC restorers are also conventional.

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AGC for the red and blue channels will probably be needed in a practical receiver to take care of receiver IF response variations due to tuning and effects of AGC on the IF response curve shape.

AGC Signals

Many methods of transmitting reference signals for use by the AGC systems suggest themselves. One of the simplest is that adopted by communication services which employ suppressed carrier channels. This method is to transmit a pilot signal of fixed amplitude which may be continuous except for blanking intervals, but which lies outside the normal communication channel. Thus in the red channel, a continuous unmodulated wave at a frequency of 1.1 megacycles from the red carrier might be used as a pilot frequency. Another pilot frequency 220 Kc from the blue channel carrier could be used for blue AGC. In a practical receiver, it is quite likely that the red and blue signals would maintain their relative magnitudes fairly well, but that the green might change with respect to them depending upon the position of the green carrier along the slope of the IF response characteristic. Therefore a single AGC for the red and blue channels may prove to be adequate. In that case, a pilot frequency could be radiated in the vicinity of 3.65 Mc in the guard band between the blue and red channels, shown in Fig. 5c. The exact frequency for the pilot may be 3.646125 Mc, the 463rd multiple of 7875 cps. This frequency may be generated by subtracting the eighth harmonic of 31,500 cps from 3.898125 Mc. This pilot would then lie 252 Kc below the blue carrier, or 456.75 Kc above the red carrier, in a position where the pilot carrier can be eliminated from the blue and red low frequency signals by the use of suitable traps, and so that its effect on the green picture will be cancelled by the eye.

The pilot AGC signal may be amplified and rectified to obtain AGC-DC control voltage which may be applied to the 3.9 Mc blue signal amplifier as control grid bias. The DC may also be applied to an amplifier which may be inserted in the system shown in Fig. 6 just prior to the red detector. DC delay voltage may be employed on the AGC rectifier to make the output uniform regardless of variations in input. Actually, since the receiver as a whole has its gain controlled by the green channel, it is not likely that extreme ranges in input variations to the red and blue channels would occur.

The DC delay voltage may be made adjustable, so that the serviceman at the time of installation could adjust the control (as well as the individual red and blue gain controls) for best color balance.

Time-Delay Networks

Time-delay networks may be required in the green and red channels to give a resultant overall uniform time-delay equal to the time-delay of the blue low-frequency channel, because the blue channel is the narrowest and therefore will probably have the greatest inherent time-delay.

A block diagram of the color portion of a receiver incorporating some of these fine points is shown in Fig. 7.

This receiver employs the following tube functions, above what is required for a black-and-white television receiver: (a)-1-2.2-3.5 Mc Red IF Amplifier. (b)-1-Red diode detector. (c)-1-0-1 Mc Red Video Amplifier. (d)-1-Red restorer diode. (e)-1-Blue second detector diode. (f)-1-3.6-4.0 Mc Blue IF Amplifier. (g)-1-Blue third detector diode. (h)-1-0-.2 Mc Blue Video Amplifier. (i) -1-Blue restorer. (j)-3.64

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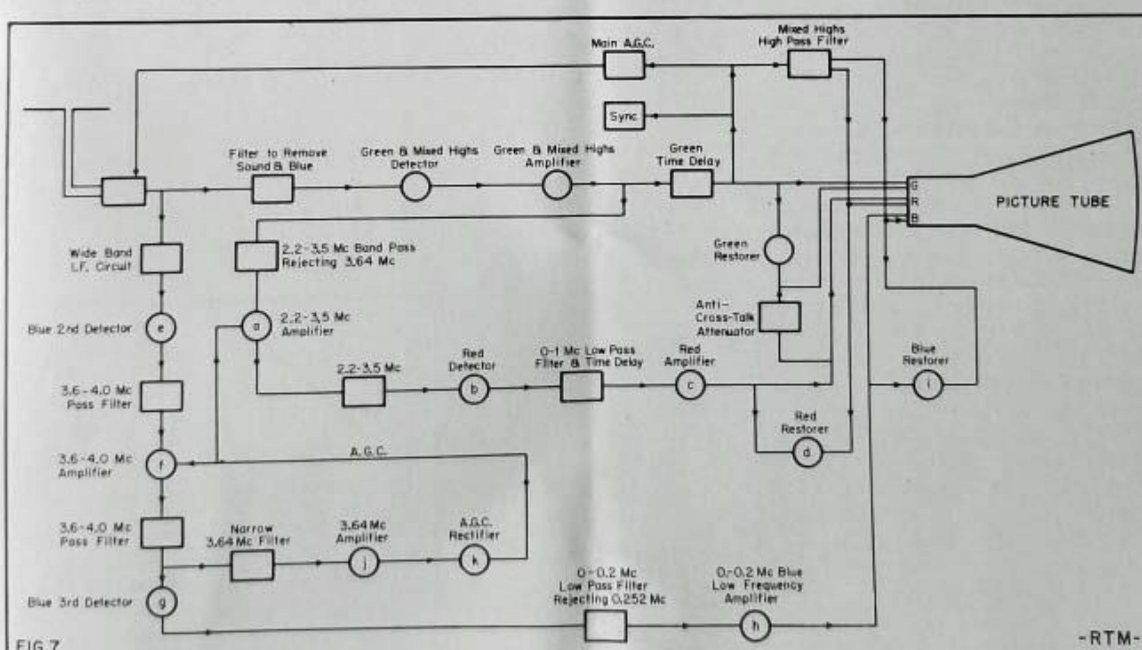

FIG. 7

Block diagram of the color stages in the receiver for the frequency-interlace system. Tube functions, as indicated by lettered circles, are described in the text. Not shown are sweep, sync and other circuits found in conventional black-and-white receivers. System utilizes empty frequency ranges found in present-day TV channels for three-color transmissions.

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Mc AGC carrier amplifier. (k)-1-AGC rectifier diode.

These 11 tube functions can of course be obtained by employing fewer than 11 separate tubes when use is made of suitable double-purpose tubes. Thus approximately 5½ or 6 tubes are needed in addition to the tubes employed in a black-and-white receiver.

Picture Tube Types

The picture tubes which may be employed in the receiver may be any of these forms: (a) Three separate tubes, one for green, one for red, one for blue. (b) A three-gun single tube as demonstrated by RCA. (c) A single gun single tube as demonstrated by RCA.

The first two forms of the transducer, (a) and (b), require no additional apparatus, but the third form would require a circular sweep generator and an auto-sampler, the total number of added tubes possibly being as high as six. For this reason, and for reasons of avoiding the problems attendant to optical registration, form (b) would appear to be the best.

Compatibility

This color system is compatible, in that present black-and-white receivers may be used to receive color transmissions in black-and-white. The green picture would constitute the signal employed in reception. Cross-talk would cause no trouble, because it is geometrically in the same position on the screen as the green signal itself. If the polarity of modulation is chosen carefully, the black-and-white tube might actually be aided by the cross-talk to give lights and shadows even when the green component is weak.

When the color receiver is tuned to a black-and-white transmission, all of the guns may be fed from the main signal. The operator of the receiver may do this manually in low-priced receivers. Switching would be indicated, because the red and blue channels would be dead and the picture would be green. On the other hand, if the receiver were switched for standard black-and-white reception, and a color signal were tuned in, the operator would have no positive signal that the transmission was in color and would have to try the color switch to see if it were in color. On a more expensive receiver, the switching could be accomplished automatically. For example, if the pilot signal at 3.64 Mc is employed, its presence in color transmissions could be used to operate a relay to do the color switching. An absence of the 3.64 Mc signal would fail to close the relay, and the receiver would automatically be set up for black-and-white reproduction.