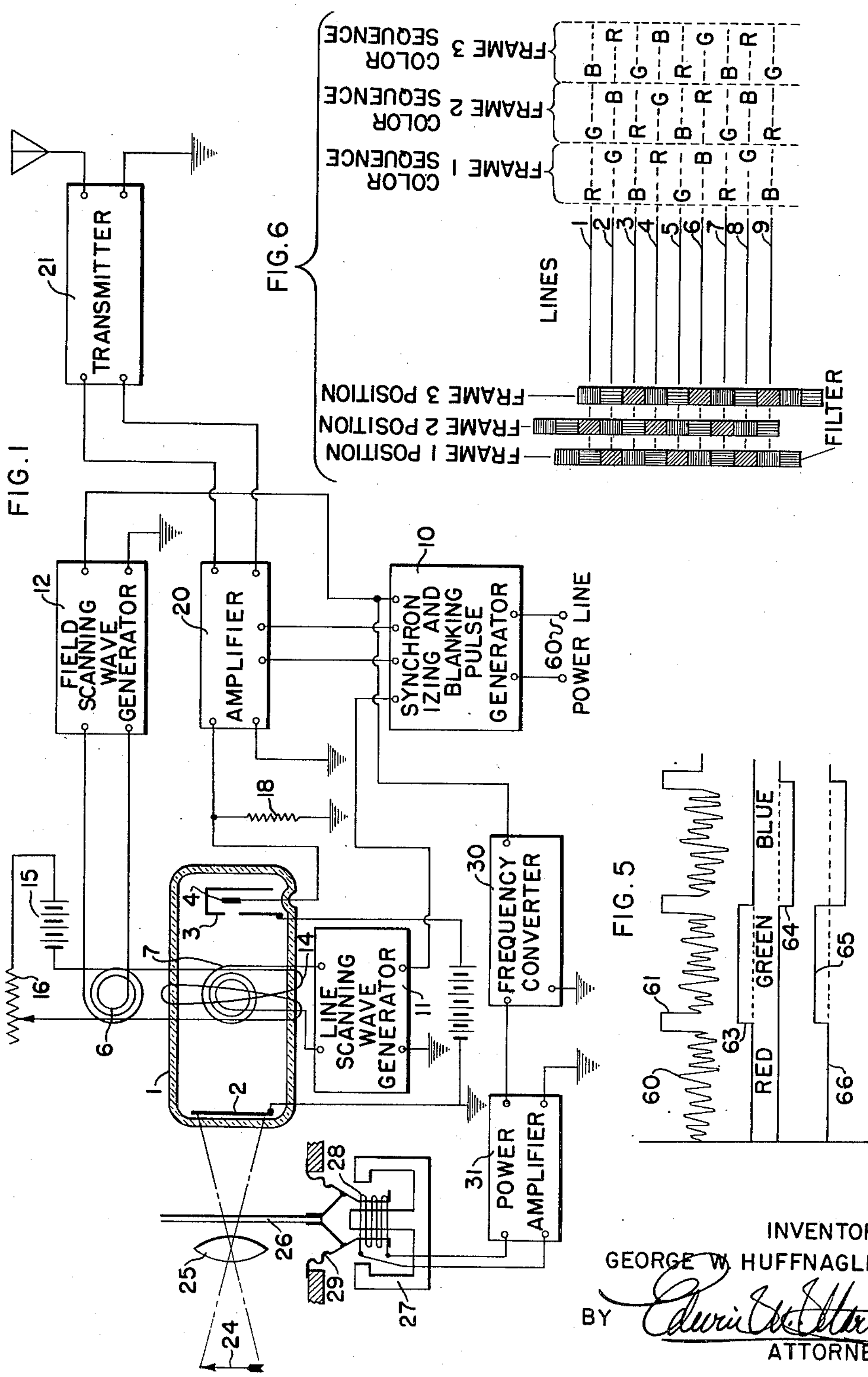
Nov. 27, 1945. G. W. HUFFNAGLE 2,389,979

COLOR TELEVISION SYSTEM

Filed April 14, 1942 2 Sheets-Sheet 1



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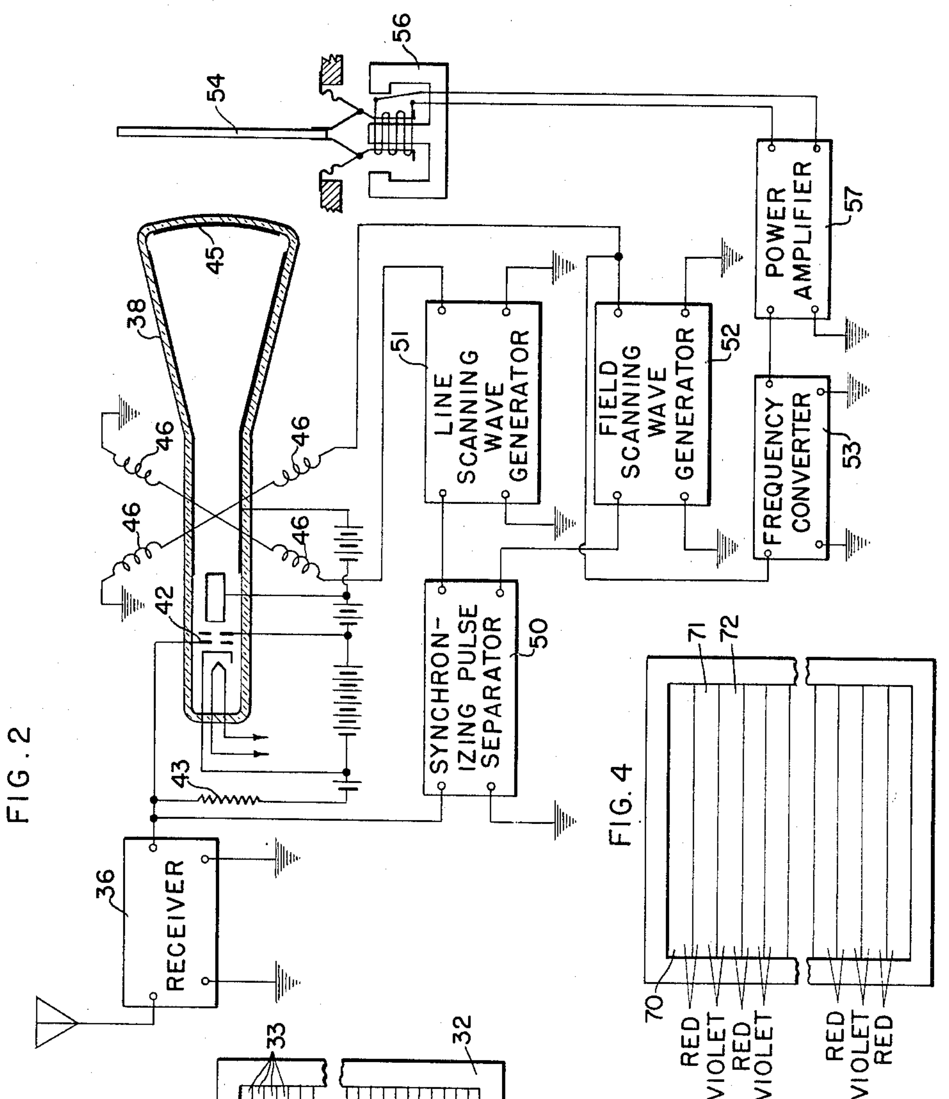

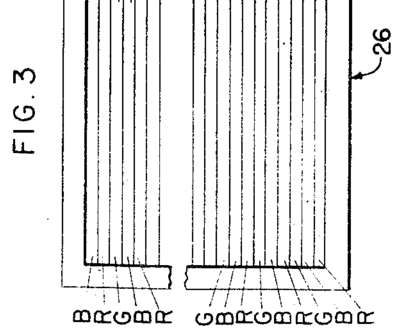

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COLOR TELEVISION SYSTEM

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9 Claims. (Cl. 178—5.2)

This invention relates to television systems and more particularly to television systems adapted to transmit and reproduce images in natural colors.

Various television systems have been proposed in the past for the transmission of optical images and their reproduction in natural colors but these systems have required, in most instances, duplication of apparatus at the transmitting and receiving ends together with multiple channel transmission systems, the number of channels depending upon the number of primary colors to be transmitted and reproduced. For instance, it has been proposed to transmit color images by providing separate transmitting apparatus for each of three or more primary colors, each transmitter feeding signals into a separate channel and each channel being connected to individual receiving and reproducing apparatus. At the receiving end in such systems each receiver reproduces an optical image representative of a primary color in the transmitted picture and these optical images are combined to produce a natural color picture. Obviously, such systems require expensive apparatus together with complicated control devices.

Another general type of system for transmitting color pictures involves the use of revolving color discs whereby successive frames of the picture are scanned to obtain electrical signals representative of a primary color in the image. In such systems, the signal train in the output of the television transmitter includes a succession of signals representative of each color in the transmitted picture. At the receiving end a second color disc is provided for converting and combining optical images representative of the primary colors into a single image representative of the original optical image. Such systems require special and critical synchronizing apparatus and special driving motors for the color discs. In addition, the color discs require special materials for color filters which are capable of sustaining the mechanical stress resulting from the rotation of the discs. Furthermore, the filter elements must be of the proper configuration accurately to expose successive frames to a single color. The manufacturing problems and processes involved here are necessarily complicated and expensive.

The primary object of the present invention is to provide a novel method of and apparatus for color television which are relatively simple and whereby a high quality of transmission and reproduction is obtained.

Another object of this invention is to provide a novel color television system which requires only simple and non-critical synchronizing apparatus and adjustment.

A further object of this invention is to provide a color television system characterized by a minimum of color flicker in its reproduced pictures.

A still further object of this invention is to provide a simplified construction of a color filter and a simplified construction of driving means therefor.

In accordance with this invention, there is provided a color television system comprising a conventional electronic picture transmission and reproducing apparatus. This apparatus is controlled by means of a conventional synchronizing pulse generating apparatus together with conventional line-scanning and field-scanning control circuits. The transmission of color is accomplished by providing a color filter between the object to be transmitted and an electro-optical transmitting tube. This filter comprises a plurality of sections each of which includes linear color filters capable of passing a number of primary colors or, if desired, the entire spectrum. Each linear filter element is substantially equivalent in length to that of a scanning line of the photosensitive cathode of the dissector tube and each linear filter element is preferably equivalent in width to that of a scanning line on the photosensitive cathode.

There is also provided a similar filter in such optical relation to the receiving apparatus that the black and white image in the receiver may be viewed through the color filter. These filters may be oscillated in a vertical plane by a suitable prime mover such as is provided in electro-dynamic loud speakers, the actuating element being a small coil in a magnetic field. The filters are driven in synchronism from a synchronizing pulse generator at a suitable frequency to analyze the color combination in each line of the optical image. Thus, the transmitter converts a series of elemental areas of the optical image into a train of signals representing the primary colors present on the elemental picture areas and the receiver reproduces an optical image in black and white representative of the intensity of the primary color on each elemental area of the transmitted picture. When the black and white image is viewed at the receiver through the color filter oscillating in synchronism with the transmitting filter, the black and white image becomes converted into a natural color image.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings,

Fig. 1 is a diagram of the preferred embodiment of a color television transmitter;

Fig. 2 is a diagram of the preferred embodiment of a color television receiver;

Fig. 3 is a plan view of the color filter shown in Figs. 1 and 2;

Fig. 4 is a plan view of a modification of the filter shown in Fig. 3;

Fig. 5 is a graph of the control voltage in the input of the power amplifiers shown in Figs. 1 and 2; and

Fig. 6 is a diagram illustrating the sequence of operation of the filters shown in Figs. 1, 2, 3 and 4.

In accordance with this invention, there is provided, as shown in Fig. 1 of the drawings, a dissector tube 1 including a photosensitive cathode 2, an anode 3 and collector 4, together with vertical and horizontal deflecting coils 6 and 7. The deflection of the electron image created by cathode 2 is controlled in a known manner from a synchronizing and blanking impulse generator 10, together with a line-scanning wave generator 11 and field-scanning wave generator 12. The electron image is focused by means of focusing coil 14, battery 15 and potentiometer 16.

The collector 4 of dissector 1 is connected to output resistor 18 and amplifier 20 which amplifies and combines the picture signals from the dissector 1 and the synchronizing signals from generator 10 and feeds the combined signals to transmitter 21.

For the purpose of transmitting signals representative of the natural colors in the image 24, there is provided optical system 25 and a color filter 26. Color filter 26 is oscillated in a vertical plane by an electromagnetic driving means consisting of a permanent magnet 27, a driving coil 28 supported in the air gap thereof on a flexible member 29. Power is supplied to the driving coil 28 from the synchronizing pulse generator 10 through frequency converter 30 and amplifier 31. Converter 30 may be of any conventional type, an example of which is illustrated and explained at pages 129–136 of "Measurements in Radio Engineering" by F. E. Terman, 1935, McGraw-Hill Book Company, Inc.

Filter 26 comprises a rectangular supporting frame 32, together with linear color filter elements 33 which are disposed horizontally thereof. As indicated in Fig. 3, the first or top linear element 33 is a blue filter, the next is red, the third is green, the fourth is blue, and so on. The red, green and blue elements comprise a section of the area of the filter 26 and it includes a number of similar sections of linear filter elements sufficient to intercept all light incident on screen 2. Such a filter may be constructed by assembling an arrangement of colored strips on a large frame having dimensions of the order of 4 feet and 3 feet, the colors of each strip being chosen to obtain the desired arrangement necessary for a color filter, for instance, a succession of red, green and blue colors. The strips should correspond in number to the number of lines to be scanned, for example, 343. After arranging the strips as described hereinbefore, the assembly of colors may be photographed on color sensitive film to obtain a reduced reproduction of the linear color elements whereby the film may at least include 343 linear color filter elements of whatever dimensions may be desired. Since the filter reiterates, as will be described, it must include additional elements, for instance, a blue element at the top and a red element at the bottom. The filter may then be supported on the frame 32, as shown in Fig. 3.

Fig. 2 of the drawings illustrates a receiving system comprising radio receiver 36 and cathode ray tube 38. The cathode ray tube includes an electron gun 40, together with a suitable source of potential for producing a cathode ray. Control electrode 42 is connected to the output of receiver 36 across resistor 43. The electron beam is deflected to scan fluorescent screen 45 by means of deflecting coils 46. The cathode ray beam is deflected in accordance with synchronizing signals received in receiver 36 and separated in the synchronizing pulse separator 50, the output of which controls line-scanning wave generator 51 and field-scanning wave generator 52.

The receiving color filter 54 is disposed within optical range of fluorescent screen 45 of the tube 38, and is oscillated in a vertical plane by means of the electromagnetic actuating means 56 which is connected to a power amplifier 57 driven from field-scanning wave generator 52 and frequency converter 53, this converter being similar to converter 30 at the transmitter.

For explaining the mode of operation, reference may be had to Figs. 1, 5 and 6 of the drawings.

Fig. 5 of the drawings illustrates, by way of example, the form of controlling potentials suitable for controlling filters 32 and 54, together with the relation of those potentials to the television signal in its transmitted form. The television signal is conventional in that it includes picture signals 60 and frame-synchronizing signals 61. The control voltage is illustrated at 65 and is the sum of voltages 63 and 64. Portion 66 is of zero potential and extends over a full frame period to its termination at any time during the intervals occupied by the frame synchronizing pulse 61. At this time, the voltage increases in a positive direction and continues at a constant value through the next frame period to a point within the period of the next synchronizing pulse. At this time, the control potential is decreased to a negative value equal in amplitude to the previous positive amplitude. This portion of the control signal continues through the third frame period and during the next frame synchronizing pulse increases to zero to complete a cycle. As mentioned before, this pulse consists of the components 63 and 64 in combination. These components are combined in frequency converters 30 and 53, as will be described hereafter.

Fig. 6 illustrates the sequence of operation of filters 26 and 54. For purposes of illustration, it will be assumed that the television transmitter, illustrated in Fig. 1 commences its operation and filter 26 is in its normal or rest position, as shown in Fig. 1, and in Fig. 6 as a "frame 1" position. Fig. 6 also illustrates the "frame 2" position and the "frame 3" position of filters 26 and 54. Fig. 6 also illustrates the first nine lines to be scanned from top to bottom of the image together with their relation to the frame 1, 2 and 3 positions of the filters. At the right of Fig. 6, is illustrated the colors which are successively passed by the filters in their various positions with respect to the various lines and frames.

In operation, the image to be transmitted is focused on photosensitive cathode 2 of tube 1 by the optical system 25 and the color filter 28 passes light of wave lengths corresponding to those present on the elemental areas of the image. Assuming that the top line of the image is being scanned with the filter in the frame 1 position, as shown in Fig. 6 of the drawings, it will be seen that a red filter intercepts all light from line 1 of the image. Only the red light present on the elemental areas of line 1 will have any effect on the photosensitive screen 2 and, therefore, when this line of the electron image emitted by screen 2 is deflected past the aperture in anode 3, the signals transmitted will be representative of the red portions in the first line of the picture, as indicated in Fig. 6. Assuming that interlaced scanning is used, the next line of the picture to be scanned and transmitted will be line 3 and, therefore, since the third line of the filter passes only blue light emitted from the elemental areas therein, line 3 will be scanned for the blue portions therein. Line 5 will be scanned for the green light emitted from the elemental areas therein, and line 7 will be scanned for the red light therein. Thus, the odd lines of the picture are scanned for blue, green and red colors in that sequence.

The next field to be scanned will include the even lines of the picture and, therefore, since line 2 of the filter passes only green light, line 4 passes only red light and line 6 passes only blue light, the elemental areas of these lines will be scanned for those colors respectively.

After the scanning period of frame 1 is completed, filter 26 must be elevated through a distance equivalent to the width of one scanning line. Referring to Fig. 6 of the drawings, filter 26 is illustrated in frame 2 position with a green filter in alignment with line 1 of the picture. Thus, as the odd lines of frame 2 are scanned, the picture signals transmitted from collector 4 will represent the green, red, blue, etc., colors in successive odd lines, respectively. As the even lines are scanned, signals will be transmitted representative of the blue, green and red portions of the respective lines, as illustrated in Fig. 4.

Between the scanning of frame 2 and frame 3, filter 26 is moved downwardly a distance corresponding to two lines to thereby change the alignment of the filter elements so that a blue filter is in alignment with line 1 of the picture. As the odd lines are scanned, beginning with line 1, signals will be transmitted representative, respectively, of blue, green and red colors of the respective odd lines. The next field-scanning will trace the even lines of the picture and they will be scanned for red, blue, and green colors on the successive even lines. At this point in the scanning sequence, each line of the picture has been scanned for each of the colors red, green and blue so that signals have been transmitted for every color in every point of the picture. As successive frames of the picture are scanned, the odd and even lines will be successively scanned for the primary colors therein in the color sequence outlined above.

It will be assumed that it is desired to divide the picture into 343 lines and scan 120 fields per second interlaced or 60 complete frames per second. As described hereinbefore, the filter 26 must be oscillated successively from its normal or frame 1 position through a distance equivalent to one line of the picture to a frame 2 position downwardly a distance equivalent to two lines of the picture to its frame 3 position. This is one complete cycle of filter oscillation. Therefore, the frequency of oscillation of the filter must be one-third of the frame frequency or 20 cycles per second in the specific example illustrated. Since it requires three frames to completely scan all points of the picture for each of the three primary colors, the coincidence rate is 20 cycles per second and the color repetition frequency is 40 cycles per second.

Filter 26 and filter 54 are driven at the rate of 20 cycles per second by means of the frequency converters 30 and 53, respectively. They reduce the 120 cycle field-scanning wave to a wave having a frequency of 20 cycles per second. This is accomplished by a pair of multivibrators such as illustrated in the publication referred to heretofore. Since the oscillation frequency of the filter must be 20 cycles per second, the first multivibrator, having a natural period slightly less than 20 cycles per second, is keyed by every sixth impulse of the 120 cycle wave and pulled into step generating a square top impulse such as 63 in Fig. 5.

Fig. 5 illustrates a typical television signal 60 consisting of picture signals separated by synchronizing and blanking impulses 61 which occur at the rate of 120 cycles per second. Thus, during the synchronizing period of the television signal, the multivibrator may be keyed to generate the impulse 63 having a period equal to $33\frac{1}{3}\%$ of the total pulse period or $\frac{1}{120}$ of a second. Thus, in the output of the frequency converter 30 there would appear impulse 63 which would be amplified in power amplifier 31 and fed through driving coil 28 of filter 26 and the filter would be driven into the intermediate position to scan frame 2 of the picture, as illustrated in Fig. 4 of the drawings. Since impulse 63 extends over the period of $\frac{1}{120}$ of a second, its trailing edge will coincide with a portion of the synchronizing period for frame 3 and at this time would key the second stage of the multivibrator to pull it into step for generating an impulse of opposite polarity with respect to impulse 63 and of the same duration and amplitude. This pulse would oscillate filter 26 through a distance equivalent to two lines into the position shown for frame 3 in Fig. 4.

As will be evident from Fig. 5 of the drawings, there would be no pulse for the remaining interval between 120 cycle pulses and, therefore, at the end of pulse 64, filter 26 will be restored to its rest position, as shown in Fig. 5, for the frame 1 position. Thus, filter 26 is repeatedly oscillated to shift the color scanning for each frame under the influence of pulses 63 and 64. Each one added together form a combined signal wave such as is illustrated at 63 in Fig. 5.

The signal train transmitted from transmitter 21 contains signals representative of each color in the image, together with synchronizing and blanking pulses. At the receiver, the cathode ray beam of tube 38 is modulated in accordance with the received signals and deflected across the screen 45 in accordance with the outputs of line-scanning wave generator 51 and field-scanning wave generator 52.

The picture reproduced on fluorescent screen 45 is a black and white image representative of a succession of red, green and blue colors in the transmitted image, the sequence of colors depending upon that at the transmitter. Since the filter 54 is oscillated in synchronism with filter 25 at the transmitter, it will pass the red image on line 1 at the same time that filter 25 passes a red image on line 1. Filter 54 passes color images identical with those transmitted from filter 24 so that the optical images appearing on screen 45 are converted to color images when viewed through filter 54.

Since the color filters 25 and 54 are oscillated at a frequency of 20 cycles per second, the successive optical images reproduced on screen 45 overlap and because of the persistence of vision, the reproduced picture does not flicker.

An alternative form of color filter is illustrated in Fig. 4 of the drawings. Instead of providing finite linear filter elements as in the filter shown in Fig. 3, it is within the scope of this invention to provide linear filter elements which pass light within the entire visible spectrum. Thus, the element 70 in Fig. 4 may be positioned to pass the violet end of the spectrum along its upper edge and the filter characteristics may so vary that the light passed by the filter between its upper and lower edge will vary from the violet end of the spectrum to the red end of the spectrum. The element 71 may be arranged to have its red portion adjacent the red portion of the element 70 and its filtering characteristic will vary from red at the upper edge to violet at the lower edge. Element 72 may be arranged to pass the violet at its upper edge and red at its lower edge. Successive filter elements are arranged in the manner described above so that when the filter is vibrated it successively passes color lines varying from violet to red and red to violet. Thus, there is no finite color change as a result of the vibration of the filter.

From the above it will be apparent to those skilled in the art that this invention provides a color television system which requires only very simple synchronizing apparatus. The synchronizing problem has been simplified because of the fact that the filter inherently is of such nature that it may be synchronized from the field-scanning synchronizing pulses. The synchronizing period is not critical since it may occur at any instance within the synchronizing and blanking period of the television signal. Furthermore, this invention provides a color filter mechanism which is naturally economical to manufacture and which does not materially add to the bulk of a monochrome receiver. It should also be noted that the nature of the color filter reduces the color flicker which is produced in systems of the prior art since there is a color change on every line of the picture rather than for every frame. The color filter is also of such a nature that if the screen is viewed at an angle other than 90°, the color values are not completely destroyed but only shifted slightly in the spectrum.

It is not intended that this invention shall be limited to television systems, as it will be apparent to those skilled in the art that it is equally applicable to systems for reproducing optical images in natural colors. For instance, this invention may be applied to a field of motion picture photography. In accordance with this invention a series of negative films may be exposed to light emanating from a color image through the linear filters which comprise the vibratory filter 32. Thus, three successive negatives may be exposed through the color filter, the color filter having been vibrated through three successive positions. The three films would thus constitute a complete record of the color components of a single optical image.

The negative films could thus be developed and run through the projector to form successive images in black and white, each of which would be converted into colored images by the vibrating filter, such as 54. So long as the black and white images are projected at a rate within the persistence of vision, there could be no visible flicker and the successive images would be combined to produce a moving color picture.

This invention is not limited to the particular circuit elements illustrated in the drawings as it is obviously adapted for use in connection with the cathode ray type of transmitting tube instead of the dissector tube. It is not necessary to utilize the particular form of synchronizing apparatus since any suitable synchronizing means may be utilized for controlling the television system together with the transmitting and receiving color filters. It is not necessary that the color filter be operated by a moving coil magnetic motor as any form of motor for providing an oscillating motion is adapted for oscillating the color filters. Furthermore, it is not necessary that the color filter be oscillated in the particular sequence described hereinbefore as it is even conceivable that the filter may be oscillated in continuous motion rather than intermittent motion.

While there has been described what is at present considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In a television system for transmitting images in their natural colors, a photoemissive surface, means for forming an optical image on said photoemissive surface, means for scanning the electron emission from said surface, a color filter interposed between said surface and said image-forming means comprising identical groups of linear filter elements, each element in a group being adapted to pass light of a different primary color, whereby during any frame period the electron emission from each line of said surface is representative of one of the primary colors in the corresponding line of the optical image, means for converting said emission into trains of electrical signals each train being representative of a primary color in a line of the image, and means controlled by said scanning means for oscillating said filter through such an amplitude that said filter elements are displaced sufficiently to analyze each line of the image as to the colors in the groups of filter elements.

2. In a television system for transmitting images in their natural colors, a photosensitive device, means for forming an optical image on said photosensitive device, means for analyzing the image on said device and producing electrical signals, a color filter interposed between said device and said image-forming means comprising linear filter sections, each section being adapted to pass light of several different primary colors, whereby during any frame period said image is partially analyzed for the primary colors therein and electrical signals representative thereof are produced, and means controlled in synchronism with said analyzing means for oscillating said filter through such an amplitude that said filter sections are

displaced sufficiently to analyze each line of the image as to the colors passed by said filter sections.

3. A television transmission system comprising means for forming an optical image, a photosensitive member in the plane of said image, means for developing an electron beam and directing it toward said photosensitive member, means for developing synchronizing signals and deflecting said beam to scan said member, a screen interposed between said image-forming means and said photosensitive member including groups of linear primary color filter elements, each group consisting of adjacent elements of different color transmitting characteristics arranged in spectral order, and means controlled by said synchronizing signal developing means for oscillating said screen through an amplitude equivalent to the width of several linear elements whereby the color components of said image may be analyzed.

4. A television transmission system comprising means for forming an optical image, means for analyzing said optical image and converting it to a train of electrical signals, a screen interposed between said image-forming means and said analyzing means comprising groups of linear primary color filter elements, each of said groups constituting adjacent elements of different color transmitting characteristics arranged in spectral order, and means for oscillating said screen through an amplitude equivalent to the width of several linear elements whereby the color components of said image may be analyzed.

5. A television transmission system comprising means for forming an optical image, means for analyzing the optical image by interlaced scanning and converting it to a train of electrical signals, a color filter interposed between said image-forming means and said analyzing means including a screen comprising linear primary color filter elements, and means for oscillating said color filter in timed relation with each frame-scanning period through an amplitude equivalent to the width of at least one linear element whereby the color components of said image may be analyzed.

6. A television receiving system comprising a receiver for receiving successive television signal trains each of which is representative of a primary color in a line of an optical image, means including a cathode ray tube and its control circuits for converting said signal trains into sensible optical images in black and white, a color filter screen in optical relation with said cathode ray tube consisting of groups of linear filter elements, each of said groups including linear filter elements each of which is adapted to pass a different primary color whereby during any frame period any line of the black and white image is converted into a line representative of a primary color, and means controlled by said control circuit for oscillating said filter in synchronism with reception of said signal trains to maintain the filter in such positions relative to said cathode ray tube that it passes only the colors represented by said signal trains.

7. A television receiving system comprising a receiver for receiving television signals representative of color images, a cathode ray tube for converting said signals into sensible optical images in black and white, means for synchronizing said cathode ray tube with received signals, a screen in optical relation with said cathode ray tube consisting of groups of linear primary color filter elements, each group consisting of adjacent elements of different color-transmitting characteristics arranged in spectral order, and means controlled by said synchronizing means for oscillating said screen in its own plane in a direction perpendicular to the linear filter elements through an amplitude equivalent to several element widths whereby said black and white image is converted to an image in natural colors.

8. A color filter for analyzing the colors in an optical image comprising a screen including identical groups of linear color filter elements, each element in a group having the characteristic of passing light of a different primary color.

9. A television system for reproducing optical images in natural colors comprising transmitter means for converting optical images into a train of electrical signals, receiver means responsive to said transmitter means for reproducing said train of electrical signals in the form of black and white optical images, means for holding said transmitter means and said receiver means in synchronism with one another and color filters in optical relation with said transmitter means and said receiver means comprising screens each consisting of groups of filter elements, each of said groups including linear filter elements of several primary colors and means at the transmitter means and the receiver means controlled by said synchronizing means for oscillating said filters in a direction perpendicular to the linear filter elements through an amplitude equivalent to several element widths whereby said signals represent an optical image in natural colors and said black and white image reproduced at the receiver means may be converted into an optical image in natural colors.

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