March 16, 1948. P. C. GOLDMARK 2,437,690

COLOR TELEVISION

Filed Dec. 12, 1945

Fig. 1,

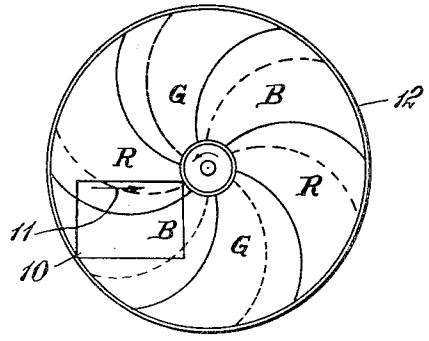


Fig. 2,

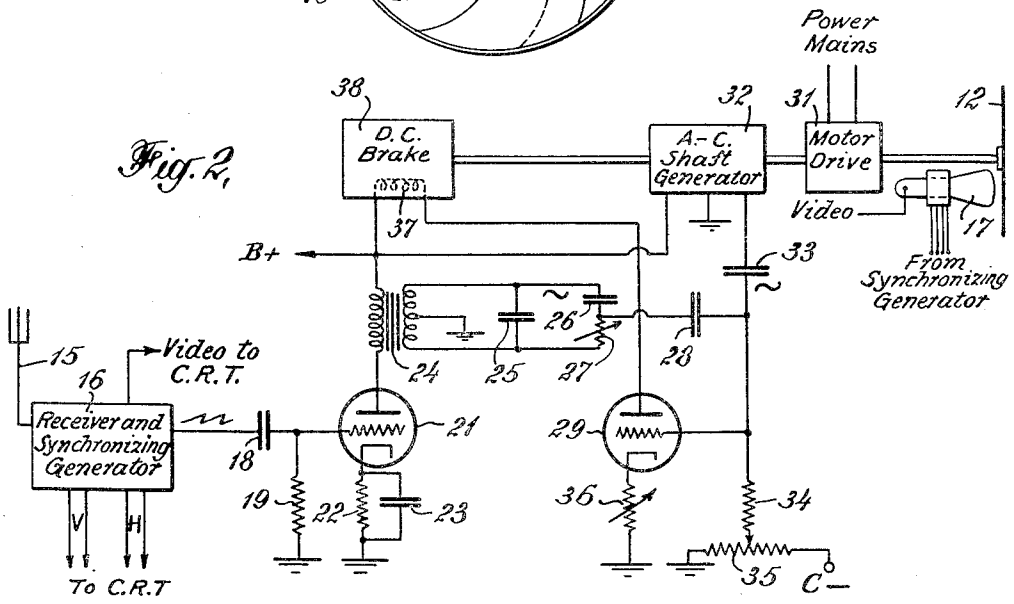


Fig. 3,

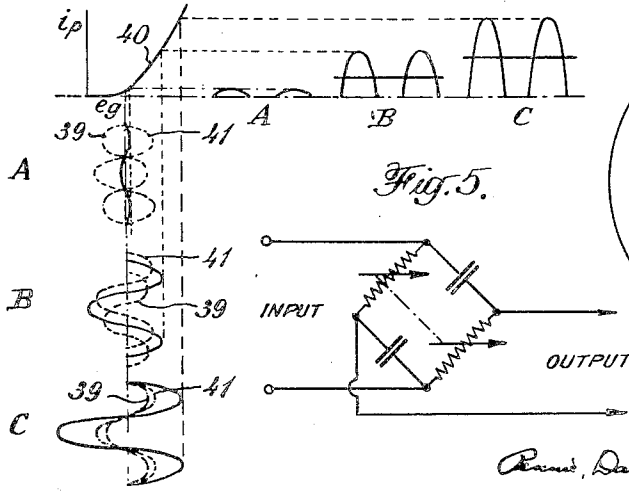
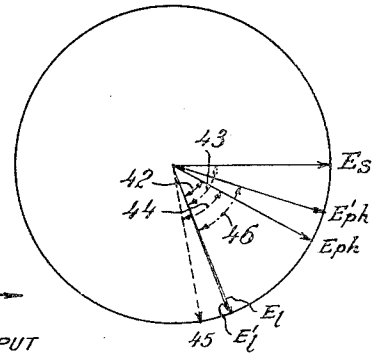


Fig. 5.

Fig. 4,



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COLOR TELEVISION

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Application December 12, 1945, Serial No. 634,464

9 Claims. (Cl. 178—5.2)

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This invention relates primarily to color television, particularly to color television apparatus employing a moving filter element. In its broader aspects, however, it can be used in other fields. While especially designed and adapted for use in color television receivers, it can also be applied to transmitters.

The color television system preferred at the present time is of the sequential type, in which video signals corresponding to different primary colors of an object field are successively generated, transmitted and reproduced. Commonly, successive field scansions correspond to different primary colors, and interlaced scansion is preferred. Such a system has been described in my application Serial No. 355,840, filed September 7, 1940, and has been found satisfactory in practice.

In apparatus at present employed, a moving filter element, such as a rotating disk, drum or other form, is utilized at the transmitter so that successive portions of the video signal correspond to successive color-separation values of the object field. At the receiver a similar filter element is employed, usually in cooperation with a cathode-ray receiver tube, to exhibit successive color-separation images in their respective colors. By analogy to the color photographic art, the term "color-separation image" refers to a monochrome image, usually black and white, representing a primary color. Such an image may be that of the complete object field to be reproduced, or only a portion thereof.

For proper operation it is necessary that the rotating filter element move in synchronism and correct phase with the transmitting or receiving scanning device employed. Referring to the receiver for convenience, it is necessary the filter element rotate in synchronism with the reproduction of successive color-separation images, so that successive images will be exhibited through successive filters of corresponding color. It is also necessary that the moving filter be phased with respect to the images so that, say, the red color-separation image will be displayed through the red filter, the green color-separation image through the green filter, etc. This may be termed "color phasing." An additional requirement is that the filter segments be properly phased with respect to the line-by-line reproduction of corresponding images, so that as successive lines are reproduced they will be exhibited through the proper color filter. If there is any afterglow or storage effect in the image reproduction, the filter segments must be sufficiently wide and properly

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phased so that proper color rendition is obtained. This may be termed "color field phasing" of the filter element.

In my Patents Nos. 2,329,194 and 2,323,905, I have disclosed various methods and apparatus for synchronizing and phasing a rotating color filter with respect to a scanning device. Patent No. 2,319,789 to Chambers discloses a similar system in which the color phasing is performed automatically.

In Patent No. 2,323,905 the color filter is driven by an asynchronous motor. A local control wave is generated by the rotation of the filter and its phase compared with that of an incoming synchronizing signal in a phase-comparing circuit. The output of the phase-comparing circuit is supplied to a brake to alter the speed of rotation of the filter so as to maintain it in proper synchronism. Other patents have disclosed different means for utilizing a difference in phase between a locally generated wave and an incoming synchronizing wave to effect synchronization. In these systems field phasing of the rotating filter has been accomplished by mechanically adjusting the position of the filter on its shaft, or by adjusting the position of the stator of the local generator, or by other mechanical means.

The initial mechanical adjustment may be somewhat troublesome unless provision is made to effect the adjustment while the receiver is in operation, in which case the necessary mechanical means add to the expense and complication of the receiver, and are likely to get out of adjustment due to vibration, etc. Furthermore, it will be appreciated that if the power line voltage where a receiver is installed differs from that used for the initial adjustment, or changes from time to time, the proper field phase relationship will be disturbed. This results from the fact that a greater or smaller difference in phase between the locally generated wave and the incoming synchronizing wave is then required to maintain proper synchronism. Thus, if the locally generated wave normally lags the incoming synchronizing wave, an increase in the power supply voltage to the asynchronous motor requires a smaller lag in order to maintain synchronism. A similar effect results from an increase in the frictional losses of the rotating parts. Therefore, it is highly advantageous to provide as simple means as possible for adjusting the field phasing of the filter, both for the initial factory adjustment of the receiver and for servicing the equipment at the point of installation.

It is a primary object of the present invention

to provide an electrical means for adjusting the field phasing in a simple manner, while the apparatus is in operation, so as to avoid the expense and complication of mechanical adjustments and permit quick change. Thus an initial adjustment can be readily made at the factory for nominal operating conditions and readjustment made by a service man during the installation of the equipment. It also allows quick change of adjustment to take care of temporary abnormal conditions of operation of the set.

In accordance with the invention, an adjustable electrical phase-shifting circuit is inserted in the circuit of either the synchronizing or locally generated control signals before it is fed to the phase-comparing circuit. The output of the phase-comparing circuit is used to control the speed of rotation of the filter element in any desired manner. Then, if in operation the field phasing is incorrect, it can be readily adjusted by changing the amount of phase shift introduced by the phase-shifting circuit. The circuit can be made extremely simple and the adjustment may be a simple screw driver or knob adjustment as desired.

The invention will be more fully understood by reference to the specific embodiment illustrated in the drawings and the following description thereof. In the drawings:

Fig. 1 is a drawing illustrating proper and improper color field phasing;

Fig. 2 is a circuit diagram of an embodiment of the invention;

Fig. 3 is a diagram illustrating the input and output of the phase-comparing circuit under different conditions of operation;

Fig. 4 is a vector diagram illustrating the manner in which an improper field phase angle may be corrected; and

Fig. 5 is an example of an alternative phase-shifting circuit.

Referring now to Fig. 1, the rectangle 10 represents the reproducing area of a receiver tube such as a cathode-ray tube. Arrow 11 indicates the line being scanned at the instant illustrated. A scanning disk 12 with filters R, G, B rotates in front of the scanning area so as to exhibit successive images reproduced on the scanning area in successively different colors. The segments of filter disk 12 have the configuration described in my Patent No. 2,304,081, but any other type of disk may be employed as desired. The scanning is assumed to proceed from top to bottom, and the disk to rotate counter-clockwise. It will be understood that a filter drum or other form of filter may be employed instead of a disk.

In the position shown in full lines, it will be observed that the red filter is phased slightly in advance of line 11 being scanned, and line 11 will be understood to correspond to the red aspect of the image to be reproduced. As scanning proceeds towards the bottom, the red filter will maintain its position slightly in advance so that the lines will be exhibited in the proper color as they are scanned, over the entire image area 10. The width of segment R is sufficient to allow some afterglow of the scanning lines and still exhibit them through the red filter as long as they remain luminous. When the green color-separation image is beginning to be reproduced by scanning line 11, the green filter segment will be in proper position to exhibit the line therethrough. Thus proper phasing is attained.

While considerable latitude in phasing is available by the design of disk 12, the dotted position

shows the disk in an improper phase relationship. If scanning line 11 is again assumed to represent a red aspect of the image, it will be observed that the line is being exhibited through the blue filter, since the red filter is lagging slightly behind the scanning line. Hence a mixture of blue and red colors will be obtained from line 11, assuming that some afterglow is present. This situation may be corrected by rotating filter disk 12 on its axis through the necessary angle, but this is an inconvenient adjustment to make and requires stopping the apparatus and perhaps making several adjustments before the proper one is obtained.

Referring now to Fig. 2, means are shown whereby the necessary correction in the field phase angle may be obtained very simply. The color video and accompanying synchronizing signals are received through antenna 15 and supplied to the receiver and synchronizing generator 16. In 16, the video is amplified and detected and supplied to the control grid of cathode-ray receiving tube 17. The synchronizing signals will ordinarily include line and field synchronizing pulses and are used to control the generation of suitable horizontal and vertical sawtooth deflecting waves which are applied to the deflecting coils or plates of tube 17.

For the system illustrated successive field scansions correspond to different primary colors. If desired, the field synchronizing signal can be used to control the synchronization of the filter disk. Or, distinctive pulses transmitted with each field of the same color may be used as the filter synchronizing signal to simplify color phasing. The latter signal will be substantially fixed in time with the field scansions, even though not of the same frequency.

A sawtooth wave derived from whatever synchronizing signal is chosen is supplied through coupling capacitor 18 and resistor 19 to the grid of a suitable tube, here shown as a triode 21. Cathode bias for the triode is provided by cathode resistance 22 shunted by the capacitor 23. The plate is energized by a suitable source designated B+.

In the plate circuit of tube 21 is the primary of transformer 24. The secondary has its midpoint grounded and is shunted by a capacitor 25 which is chosen so as to tune the transformer to the frequency of the sawtooth, thereby converting it into approximately a sine wave. Since the initial sawtooth voltage applied to the grid of tube 21 is fixed in time with respect to the incoming synchronizing signal, the derived sine wave will also be fixed in time with respect to the synchronizing signal.

The sine wave so derived is applied to a phase-shifting circuit composed of capacitor 26 and the adjustable resistor 27. This is a conventional phase-shifting circuit whose functioning will be well understood in the art. The output of the phase-shifting circuit is supplied through coupling condenser 28 to the grid of a suitable tube, here shown as a triode 29.

The color filter element, here shown as a disk 12, is driven by a nonsynchronous motor 31 energized from a suitable source designated "mains." On the shaft is an A.-C. generator 32 energized from the B+ source and designed to provide an output substantially sinusoidal control wave whose frequency varies directly with the speed of rotation of the disk 12 and is the same frequency as that of the incoming synchronizing signal when the filter is rotating at synchronous

speed. The output of the generator is supplied through coupling capacitor 33 to the grid of tube 29. Thus both the incoming synchronizing signal, after passing through the phase-shifting network, and the locally generated control signal from generator 32 are supplied to the grid of tube 29. If desired the two signals could be coupled to separate grids of a multigrid tube, thus allowing more gain or separate adjustment of the signal amplitudes.

Resistor 34 is a coupling resistance and is connected to the variable tap of potentiometer 35 so as to supply a suitable bias for the grid of tube 29. This bias may be varied to regulate the characteristics of tube 29. In the cathode circuit of tube 29 is a variable resistance 36 which provides any desired amount of degeneration, and is also a means of regulating the characteristics of the tube. The plate is connected through the actuating coil 37 of the D.-C. brake 38 to B+.

The operation of a circuit similar to that of Fig. 2, except for the phase-shifting, has been explained in Patent No. 2,323,905 so that only a summary is required here.

Referring to Fig. 3, curve 40 represents the grid voltage-plate current characteristic of tube 29. Wave 39 is assumed to be the output of the phase-shifting circuit 26—27 and wave 41 is assumed to be the output of the local generator 32. They are preferably of similar wave form and magnitude, although this is not necessary. In Fig. 3 they are shown of slightly different amplitudes for convenience of identification.

At A the two waves are shown 180° out of phase and only a slight plate current from tube 29 results. Thus only a slight braking action from brake 38 is obtained. Motor 31 will ordinarily be selected so that with this minimum brake current the disk 12 may be brought up to synchronous speed at the lowest mains voltage for which the receiver is designed to operate. For a greater mains voltage the disk 12 will tend to be driven over synchronous speed, thus causing wave 41 to lag wave 39 by less than 180°, as shown at B. This will result in a somewhat greater current through tube 29 and hence will increase the brake action. A still greater mains voltage will tend to drive the disk still faster and the waves 39 and 41 may eventually be in phase as shown at C. This results in maximum plate current through tube 29 and maximum braking action.

It will be apparent that a change in current to the brake can be obtained only by a change in the relative phase of the synchronizing wave 39 and locally generated wave 41. In the absence of the phase-shifting circuit 26—27, this would also cause a change in the phase of disk 12 with respect to the scanning of the face of cathode-ray tube 17.

Referring now to Fig. 4, vector E_s represents the phase of the synchronizing signal in synchronizing generator 16. Vector E_{ph} represents the phase of the output of the phase-shifting circuit 26—27 for a given setting, and is shown as lagging E_s by an arbitrary amount which takes into account all shifts in phase between the synchronizing generator and the output of the phase-shifting circuit. Vector E_{ph} corresponds to wave 39 in Fig. 3. Vector E_l represents the phase of the local control signal from generator 32 (wave 41 in Fig. 3) and lags E_{ph} by an angle 42 which is necessary to cause the filter disk to rotate synchronously. It is assumed that the position of disk 12 on its shaft, of generator 32 on its shaft, and the adjustment of the phase shifting network 26—27 is such that disk 12 is in proper phase relationship with the vertical scanning.

Therefore, since the phase of the vertical scanning is fixed in time with respect to E_s, and the phase of disk 12 is fixed in time with respect to E_l, angle 43 should remain approximately constant for correct field phasing.

Now assume that due to a decrease in the voltage of the power mains, or to some other change in the system, the disk tends to rotate slower, so that less brake current is required to maintain synchronization. To produce less brake current, the lag angle of E_l to E_{ph} must increase, and this is shown by the angle 44 between original vector E_{ph} and new vector 45. However, the angle between E_s and vector 45 is greater than angle 43, so that if E_l is allowed to lag to the position of vector 45 the field phasing will be altered. Hence, resistance 27 in the phase-shifting circuit may be adjusted to decrease the lag angle of E_{ph} with E_s, as indicated by vector E_{ph}'. The shift in phase is so chosen as to bring vector 45 back to the position of vector E_l as indicated by vector E_l'. (The slight difference in phase shown is to enable identification.) Phase angle 46 between E_l' and E_{ph}' is equal to angle 44, so that the brake current remains at the decreased value sufficient to maintain synchronization. Yet the angle between E_l' and E_s remains at its previous value indicated by angle 43 so that the field phasing of the disk with the vertical scanning is unchanged.

If the power line voltage should increase, thus decreasing the lag of E_l to E_s, resistor 27 can be varied to return E_l to its proper lag angle. It will thus be apparent that any change in power line voltage or other conditions which would affect the field phasing can be readily corrected by adjustment of the phase-shifting circuit 26—27.

Phase-shifting circuit 26—27 is extremely simple and provides considerable variation in phase angle. A switch can be used in the primary or secondary to extend the range of phase shift if required. It has the disadvantage that not all the voltage of the secondary of transformer 24 is available at the output of the phase-shifting network, and the output voltage varies somewhat with change of adjustment. If these disadvantages are undesirable in any application, other types of phase-shifting networks may be employed, as will be apparent to those skilled in the art. For example, the type shown in Fig. 5 may be employed and has the advantage that the output voltage is equal to the input and 180° electrical phase shifting is possible. This circuit is, of course, somewhat more complicated than the one shown in Fig. 2 but is still comparatively simple.

The phase-comparing circuit including tube 29 is supplied with sinusoidal synchronizing and local control waves to control the operation of the brake. This is not essential and other wave shapes may be employed as desired. Preferably the wave shapes of the two signals are similar, but even this may be departed from if desired. Furthermore, the sinusoidal synchronizing signal is shown as derived from a sawtooth scanning wave, which in turn is derived from the synchronizing signal in generator 16. Any other method of obtaining the synchronizing wave 39 from the incoming synchronizing signal may be used as desired.

As mentioned before, Fig. 2 may be considered as showing the use of the field synchronizing signal for synchronizing the rotation of the filter

disk. In such case means may be provided for interrupting the brake current momentarily for color phasing, as described in Patent No. 2,323,-905. The circuit of Fig. 2 may also be considered as employing distinctive color synchronizing pulses transmitted at the frequency of a given color. For example, in a three-color system with a 120-cycle per second field scansion, the color synchronizing pulses would be transmitted at 40 cycles per second. They may be used to generate a sawtooth for the input to tube 21 or may be converted into a sine wave, or other wave form, in any other desired manner. It will be understood that such color synchronizing pulses will be substantially synchronized with the field scansions even though they do not recur at the same frequency.

Instead of inserting the phase-shifting circuit in the path of the incoming synchronizing signal, it may be inserted in the path of the local control signal between generator 32 and tube 29. The functioning of such a modification will be clear to those in the art.

The preceding paragraphs have mentioned a number of variations in the specific embodiment described. The phase-shifting circuit may also be employed at the transmitter, as mentioned hereinbefore, to maintain the transmitter color filter in proper synchronism and phase with respect to the scanning at the transmitter tube. Many other variations will occur to those in the art within the scope of the invention as defined in the claims.

I claim:

1. In a color television system of the sequential type having a synchronizing signal in fixed time relationship with the video signal, apparatus comprising a scanning device substantially in synchronism with said synchronizing signal, a movable color filter element cooperating with said scanning device, a nonsynchronous motor coupled to drive said color filter element, a generator coupled to said color filter element and adapted to produce a control signal, control means responsive to a change in phase of two signals supplied thereto to change the speed of movement of said color filter element, an adjustable phase-shifting circuit, and means for supplying one of said synchronizing and control signals to said control means and the other through said adjustable phase-shifting circuit to said control means, whereby the color filter element may be synchronized with said scanning device and the relative phase therebetween electrically adjusted.

2. In a color television system of the sequential type having a synchronizing signal in fixed time relationship with the video signal, apparatus comprising a scanning device in synchronism with said synchronizing signal, a rotatable color filter element cooperating with said scanning device, a nonsynchronous motor coupled to drive said color filter element, a generator coupled to said color filter element and adapted to generate a control signal whose frequency varies with the speed of rotation thereof, control means responsive to a change in phase of two signals supplied thereto to change the speed of rotation of said color filter element, a variable electrical phase-shifting circuit, and means for supplying one of said synchronizing and control signals to said control means and the other through said variable electrical phase-shifting circuit to the control means, whereby the color filter element may be synchronized with said scanning device and the relative phase therebetween varied.

3. In a color television system utilizing a sequential color video signal with a synchronizing signal in fixed time relationship therewith, apparatus comprising means for reproducing successive color-separation images from said color video signal, a movable color filter element for presenting successive color-separation images in their respective colors, a nonsynchronous motor coupled to drive said color filter element, a local generator coupled to said movable color filter element and adapted to produce a local control signal, control means responsive to a change in phase of two signals supplied thereto to change the speed of movement of said color filter element, an adjustable phase-shifting circuit, and means for supplying one of said synchronizing and local control signals to said control means and the other through said adjustable phase-shifting circuit to said control means, whereby the color filter element may be synchronized with the reproduction of successive color-separation images and the relative phase therebetween electrically adjusted.

4. In a color television system utilizing a sequential color video signal with a synchronizing signal in fixed time relationship therewith, apparatus comprising means for reproducing successive color-separation images from said color video signal substantially in synchronism with said synchronizing signal, a rotatable color filter element for presenting successive color-separation images in their respective colors, a nonsynchronous motor coupled to drive said color filter element, a local generator coupled to said rotatable color filter element and adapted to produce a local control signal whose frequency varies with the speed of rotation thereof, control means responsive to a change in phase of two signals supplied thereto to change the speed of rotation of said color filter element, a variable electrical phase-shifting circuit, and means for supplying one of said synchronizing and control signals to said control means and the other through said adjustable phase-shifting circuit to said control means, whereby the color filter element may be synchronized with the reproduction of successive color-separation images and the relative phase therebetween electrically adjusted.

5. In a color television system for receiving a sequential color video signal with a synchronizing signal associated therewith, apparatus comprising means for reproducing successive color-separation images from said color video signal substantially in synchronism with said synchronizing signal, a rotatable color filter element for presenting successive color-separation images in their respective colors, a nonsynchronous motor coupled to drive said color filter element, a local generator coupled to said rotatable color filter element and adapted to produce a local control signal whose frequency varies with the speed of rotation thereof, means for converting said synchronizing signal into a wave form substantially similar to that of said local control signal, control means responsive to a change in phase of two signals supplied thereto to change the speed of rotation of said color filter element, a variable electrical phase-shifting circuit, and means for supplying one of said converted synchronizing and local control signals to said control means and the other through said adjustable phase-shifting circuit to said control means, whereby the color filter element may be synchronized

with the reproduction of successive color-separation images and the relative phase therebetween electrically adjusted.

6. In a color television system for receiving a sequential color video signal with a synchronizing signal associated therewith, apparatus comprising receiver circuits and associated cathode-ray tube for reproducing successive color-separation images from said color video signal substantially in synchronism with said synchronizing signal, a rotatable color filter element associated with said cathode-ray tube for presenting successive color-separation images in their respective colors, a non-synchronous motor coupled to drive said color filter element, a local generator coupled to said color filter element and adapted to generate a local control signal of the frequency of said synchronizing signal when the filter element rotates at synchronous speed, means for converting said synchronizing signal into a wave form substantially similar to that of said local control signal, control means for producing an output which changes in response to a change in phase difference of two signals applied thereto, a variable electrical phase-shifting circuit, means for supplying one of said converted synchronizing and local control signals to said control means and the other through said variable phase-shifting circuit to said control means, and means for controlling the speed of rotation of the color filter element in accordance with the output of the control means, whereby the color filter element may be synchronized with the reproduction of successive color-separation images and the relative phase therebetween electrically adjusted.

7. In a color television system for receiving a sequential color video signal with a synchronizing signal associated therewith, apparatus comprising receiver circuits and associated cathode-ray tube for reproducing successive color-separation images from said color video signal substantially in synchronism with said synchronizing signal, a rotatable color filter element associated with said cathode-ray tube for presenting successive color-separation images in their respective colors, a nonsynchronous motor coupled to said color filter element and tending to drive the element over synchronous speed, a local generator coupled to said color filter element and adapted to generate a local control signal of the frequency of said synchronizing signal when the filter element rotates at synchronous speed, means for converting said synchronizing signal into a wave form substantially similar to that of said local control signal, control means for producing an output which changes in response to a change in phase difference of two signals applied thereto, a variable electrical phase-shifting circuit, means for supplying one of said converted synchronizing and local control signals to said control means and the other through said variable phase-shifting circuit to said control means, a brake mechanism adapted to brake the rotation of the color filter element, and means for controlling the operation of the brake mechanism in accordance with the output of the control means, whereby the color filter element may be synchronized with the reproduction of successive color-separation images and the relative phase therebetween electrically adjusted.

8. Apparatus for synchronizing a movable element with a synchronizing signal and adjusting the phase therebetween which comprises a non-synchronous motor coupled to drive said movable element, a local generator coupled to said movable element and adapted to produce a local control signal, an adjustable phase-shifting circuit supplied with one of said synchronizing and local control signals, control means responsive to a change in phase of two signals supplied thereto to change the speed of movement of said movable element, and means for supplying said one signal from the adjustable phase-shifting circuit and the other of said synchronizing and local control signals to said control means, whereby the movable element may be synchronized with said synchronizing signal and the relative phase therebetween adjusted.

9. Apparatus for synchronizing a rotatable element with a synchronizing signal and adjusting the phase therebetween which comprises a non-synchronous motor coupled to drive said rotatable element, a local generator coupled to said rotatable element and adapted to produce a local control signal whose frequency varies with the speed of rotation of the element, a variable electrical phase-shifting circuit supplied with one of said synchronizing and local control signals, control means for producing an output which changes in value in response to a change in the relative phase of two signals supplied thereto, means for supplying said one signal from the variable electrical phase-shifting circuit and the other of said synchronizing and local control signals to said control means, and means for controlling the speed of rotation of the rotatable element in accordance with the output of said control means.

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