



## UNITED STATES PATENT OFFICE

EMANUEL C. MANDERFELD, OF BOONTON, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

## ELECTROOPTICAL IMAGE PRODUCING SYSTEM

Application filed February 24, 1928. Serial No. 256,522.

This invention relates to electro-optical image producing systems and particularly to methods and means for maintaining apparatus employed at different stations of a television system in synchronism.

It has heretofore been proposed in connection with television systems to produce an image current by scanning a field of view, an image of which is to be produced, and periodically interrupting the scanning of the field of view for a brief interval during which a special synchronizing impulse of an amplitude greater than that of the image current is transmitted to the receiving station where it is utilized for maintaining the image producing apparatus in synchronism with the scanning apparatus. Such a system is disclosed in a copending application of E. R. Morton, Serial No. 242,998, filed December 28, 1927. One method of generating the synchronizing impulse is to periodically cause the scanning element to scan an auxiliary field outside of the field of view of which an image is to be produced. This auxiliary field may contain a source of light or a light reflecting element such that the light which actuates the light sensitive element employed for scanning is of greater intensity when the auxiliary area is being scanned than when the field of view of which an image is to be produced is being scanned.

In accordance with the present invention, the image current produced as the result of scanning the field of view of which an image is to be produced is utilized both for controlling the production of the image of the field of view and for maintaining the movable elements of the scanning and image producing apparatus in synchronism.

In a copending application of F. Gray, Serial No. 227,649 filed Oct. 21, 1927, there is disclosed a television system in which the field of view is defined by an opaque screen having an opening therein in the form of a rectangle. This field of view is scanned by means comprising a revolving disc of opaque material having a plurality of apertures therein arranged in the form of a spiral near the periphery thereof. As the disc revolves a beam of light from a fixed source passes

through the apertures and sweeps across the field of view in a succession of parallel lines. This light beam then impinges on the object of which an image is to be produced and the light reflected from the object is received by a photo-sensitive device for setting up an image current which is transmitted to the receiving station for controlling the production of the image.

In a preferred embodiment of the present invention, there is employed scanning apparatus similar to that disclosed in the copending application of F. Gray, supra. The dimension in the direction of the scanning lines, of the opening in the screen which defines the field of view is made less than the distance between centers of adjacent apertures in the scanning disc so that the light beam is periodically interrupted at the end of the scanning of each line before the scanning of the succeeding line is initiated. With such an arrangement the light actuating the photo-sensitive device is periodically reduced to a low value at a rate determined by the number of apertures in the scanning disc multiplied by the speed of rotation of the disc and a corresponding frequency component is introduced into the image current. Instead of interrupting the scanning between successive lines as just described, the width of the opening in the screen for defining the field of view may be made such that the last element of one line and the first element of the succeeding line are scanned simultaneously, thus periodically increasing the light which actuates the photo-sensitive device to a high value and, as in the preceding case, introducing a corresponding frequency component into the image current. This frequency component which is introduced into the image current by either of the arrangements just described is utilized to maintain the moving element of the image producing apparatus in synchronism with the moving element of the scanning apparatus by selecting a portion of the energy represented by this frequency component from the image current by means of a frequency discriminating device.

For this purpose there may be employed

at the receiving station a circuit arrangement similar to that disclosed in Patent 1,663,890 to H. M. Stoller, March 27, 1928. In this arrangement, the synchronizing frequency component which is selected from the received image current may be impressed on the input circuit of a three-electrode electron discharge device. A generator which is driven by the motor which drives the rotatable element of the image producing apparatus and which generator produces a current of the same frequency as the frequency of the synchronizing component of the received image current, supplies current to the output circuit of the electron discharge device. The amplitude of the output current of the electron discharge device varies in accordance with the phase difference between the locally generated current and the synchronizing component of the received image current and an electromotive force which varies in accordance with the variations of the output is impressed on a control winding of the driving motor at the receiving station to maintain the rotatable element of the image producing apparatus at that station in synchronism with the rotatable element of the scanning apparatus.

The invention may be readily understood by referring to the following detailed description and the accompanying drawing in which

Fig. 1 shows diagrammatically a television system embodying features of this invention;

Fig. 2A is a detailed showing of a portion of the scanning apparatus constructed in accordance with this invention; and

Fig. 2B shows a modification of the portion of the scanning apparatus shown in Fig. 2A.

Fig. 3A shows diagrammatically the wave form of the current produced as the result of scanning when employing apparatus such as shown in Fig. 2A.

Fig. 3B shows diagrammatically the wave form of the current produced as the result of scanning when employing apparatus such as shown in Fig. 2B.

Referring to the drawing there are shown two stations, A and B, which comprise transmitting and receiving stations, respectively, of a television system of the type similar to that disclosed and claimed in the copending application of F. Gray, supra. At the station A the field of view, an image of which is to be produced, is defined by the opening 11 in the opaque screen 12 and takes in the subject 10. This field of view is scanned by apparatus comprising an arc lamp 13 and an optical system for causing a slender pencil of substantially parallel rays of intense light to sweep across the field of view in a series of successive parallel lines. The optical system includes a scanning disc 14 driven by the mo-

tor 15, a number of small circular apertures 16 being arranged in a spiral extending around the disc near its periphery. The speed of this motor may be maintained substantially constant by any suitable means, for example, by an arrangement disclosed in Patent 1,663,891 to H. M. Stoller and E. R. Morton, March 27, 1928. The light from the arc 13 is directed by a lens system 17 so that an intense beam of light passes through each aperture as it moves through the illuminated area on the scanning disc. Lens 18 bends the slender pencil of parallel rays passing through the apertures 16 and the opening 11 to form an image of the moving aperture on the subject 10. As a result of this arrangement the subject is completely scanned once for each revolution of the disc in a series of successive parallel lines by a small, rapidly moving, intensely bright spot of light. As the spot of light passes over the subject light is diffusely reflected therefrom and a portion of the reflected light falls on the photo-sensitive surface of a large aperture photo-electric cell 19. The resulting image current generated by the photo-electric cell is amplified by an electron discharge amplifier 20 and is transmitted through a transformer 21 to a line 22 connecting the transmitting station A with the receiving station B.

At the receiving station B the image current from the line 22 is transmitted through a transformer 23 to an electron discharge amplifier 24, the output circuit of which is connected to a neon glow discharge lamp 25 which is arranged in front of a disc 26 similar in construction to the scanning disc 14 at the transmitting station A. In front of the disc there is located an opaque screen 27 having an opening 28 therein of such size that at one time only one of the apertures of the disc 26 is in the field of view of the observer 30. The lamp 25 is preferably of the type disclosed in detail in Patent No. 1,865,516, granted to F. Gray, July 5, 1932. The optical field defined by the opening 28 and illuminated by the light passing from the lamp 25 through the moving apertures of the disc 26 is viewed by the observer 30 without the aid of any optical system. The observer sees at any instant a single aperture in the same relative position as the spot of light on the subject 10 at the transmitting station A and the brightness of the aperture corresponds to the amount of light reflected from that particular elemental area of the subject. On account of the persistency of vision the observer consequently sees an apparent image of the subject on the front surface of the disc 26, complete views of the subject being transmitted at the rate of about 18 per second so that the subject can be seen in motion.

The width of the opening 11 in the screen 12 at the transmitting station is preferably

made slightly less than the distance between centers of adjacent apertures 16 in the scanning disc 14 as indicated in Fig. 2A. With such an arrangement the light beam passing through one aperture of the disc for scanning one line of the field of view passes beyond the opening 11 which defines the field of view before the scanning of a succeeding line by light passing through an adjacent aperture of the disc is initiated. The light from source 13 reaching the photo-electric cell 19 is thus periodically interrupted for an instant between the scanning of successive linear elements of the field of view and as a result there is introduced into the image current set up by the photo-electric cell a frequency component of predominant amplitude, the frequency of which is determined by the number of apertures in the scanning disc multiplied by its speed of rotation. The wave form of such an image current is shown in Fig. 3A. It has been found satisfactory to employ a disc having 70 apertures therein and a speed of rotation of 18 revolutions per second. The frequency of the predominant frequency component of the image current in this case is 1260 cycles per second.

In another embodiment shown in Fig. 2B, the width of the opening 11 in the screen 12 is made slightly greater than the distance between centers of adjacent apertures of the scanning disc so that the scanning of one linear element of the field of view is initiated before the scanning of the preceding linear element is complete. When this arrangement is employed the light reaching the photo-electric cell is periodically increased to a relatively high value and as a result a 1260 cycle component is introduced into the image current when a disc having 70 apertures is employed and is rotated at a speed of 18 cycles per second. The wave form of such an image current is shown in Fig. 3B. The opening 28 in the screen 27 at the receiving station should in this case also be such that only one aperture of the disc 26 appears at a time in the opening 28.

At the receiving station B the primary winding of high impedance, loosely coupled transformer 31 is connected across the output circuit of amplifier 24 in parallel with the neon tube 25. The secondary winding of this transformer is connected to a frequency discriminating device which may comprise any suitable number and arrangement of reactive elements such as the shunt condenser 33 and the shunt inductance coil 34. The characteristics of this frequency discriminating device are such that only the predominant frequency component of the received image current (1260 cycles in example referred to above) is passed efficiently while the remaining frequency components of the image current are greatly attenuated thereby. The impedance looking into the primary winding

of transformer 31 is high compared with the impedance of lamp 25 so that only a small portion of the image current is diverted from the lamp 25. One of the output terminals of the frequency discriminating device is connected to the cathode 35 of the electron discharge device 38 through a grid biasing battery and the other output terminal is connected to the control electrode 36. The motor 40 which drives the disc 26 also drives the generator 41 which produces a current of a frequency the same as that of the predominant component of the received image current when the disc 26 of the image producing apparatus is in synchronism with the disc 14 of the scanning apparatus. The electromotive force produced by generator 41 is impressed on the primary winding of transformer 42, the secondary winding of which is connected to the cathode 35 and the anode 37 of the electron discharge device 38 through the resistance element 43. This resistance element is connected to the control electrode and cathode of the electron discharge device 44. The cathodes of electron discharge devices 38 and 44 are heated by any suitable means to make them electron emitting. The motor 40 has a series field winding 45, a shunt field winding 46 and a regulating field winding 47, all of these windings being cumulative. A source of electromotive force for motor 40 is connected to the terminals 48 and the regulating field winding 47 is connected in the anode circuit of the electron discharge device 44.

In order to explain the method by which the scanning and image producing discs are maintained in synchronism, assume that the disc 14 at the transmitting station is rotating at a constant speed and that the electromotive force derived from the image current and impressed on the control circuit of the electron discharge device 38 commences on the positive portion of its cycle when the electromotive force from generator 41 impressed on the anode circuit of electron discharge device 38 is at the peak value of the positive portion of its cycle. The frequency of the electromotive force impressed on the anode circuit is the same as that impressed on the control electrode and the current through the control winding 47 is inversely proportional to the anode current of the electron discharge device 38 due to the action of the electron discharge device 44 when connected as shown. This current through the control winding 47 is such that the disc 26 rotates at the same speed as the disc 14 at the transmitting station. In case the disc 26 should tend to increase its speed due to an increase in the electromotive force applied to the terminals 48, for example, this tendency will be opposed in the following manner:—The first effect of the tendency of the speed of motor 40 to increase will be to in-

crease the phase difference between the electromotive force produced by generator 41 and the electromotive force impressed on the control electrode 36. Consequently, the average value of the variable electromotive force impressed on the control electrode 36 during the positive portion of the cycle of the anode voltage will be more negative and therefore the anode current through the coupling resistance 43 will decrease. The electromotive force applied to the control electrode of electron discharge device 44 will therefore be less negative, and the current through the anode circuit of electron discharge device 44, and the regulating winding 47 will be increased. This increase of current through the winding 47 will check the tendency of the motor to increase in speed and the motor will be maintained at its constant speed but at a different phase relation between the electromotive forces applied to the control electrode and anode respectively of electron discharge device 38. The current through the winding 47 changes so rapidly in response to a transient change in speed of motor 40 so that this motor speed remains constant as long as the speed of the disc 14 at the transmitting station remains constant. Conversely if the motor 40 should tend to decrease in speed the anode current of electron discharge device 38 will increase causing a decrease in the current in the anode circuit of electron discharge device 44 and the regulating field 47, thereby weakening the motor field and checking the tendency of the motor to decrease in speed. In the same manner if the speed of the disc 14 at the transmitting station should increase, the phase difference between the electromotive forces impressed on the control electrode and anode, respectively, of the electron discharge device 38 will decrease, the anode current through resistance 43 will increase, the anode current through the control winding 47 will decrease, and the speed of motor 40 will increase. The converse of this is also true, of course, so that the speed of disc 26 at the receiving station is maintained accurately in synchronism with the disc 14 at the transmitting station.

As is well known, a motor in such a system will tend to hunt, that is, it will tend to increase and decrease in speed alternately above and below its equilibrium point. To prevent such oscillations from effecting the disc 26 a suitable damping arrangement is provided. This damping arrangement may comprise the closed cylindrical structures 49 and 50 having flexible pleated walls and filled with a damping fluid such as oil. One end of each cylinder is connected to the flywheel 51 while the opposite ends of the cylinders are connected to the shaft 52 which in turn is connected to the motor 40 and the generator 41. The flywheel 51 and the disc 26

are connected rigidly to the shaft 53. This damping arrangement is similar to that disclosed in Patent 1,778,756 granted to L. A. Elmer, Oct. 21, 1930. In starting the motor 40 the manually operated resistance 32 is adjusted until the speed approaches the operating value at which point the motor 40 will pull into step with the motor at the transmitting station and operate as described above. In order to "frame" the image an arrangement may be provided for manually rotating the stator of motor 40 as disclosed in Patent No. 1,763,909 granted to H. M. Stoller and E. R. Morton June 17, 1930.

The invention relates broadly to the use of image current generated in the process of scanning a field of view for the purpose of maintaining two cyclically movable elements of the image producing system in synchronism and the invention is therefore not limited to the specific arrangement herein shown and described for the purpose of illustration. For example, a harmonic of the frequency determined by the number of apertures in the scanning disc multiplied by its speed of rotation may be employed in place of the frequency so determined. Moreover, the selected frequency component of the image current may be employed to energize a synchronous motor for driving the disc 26 of the image producing apparatus. Instead of employing the mechanical damping device comprising the flywheel 51 and the cylindrical structures 49 and 50, electrical damping means, such as an induction motor coupled to slip rings tapped into the armature winding of motor 40, may be employed.

What is claimed is:

1. In an electro-optical image producing system, means including a cyclically moving element for scanning a field of view to produce an image current, means responsive to said image current and including a second cyclically moving scanning or distributing element for producing an image of said field of view, frequency discriminating means for selecting a component of said image current, and means responsive to said selected image current component for maintaining said cyclically moving scanning elements in synchronism.

2. An electro-optical image producing system comprising means including a cyclically moving element for scanning a field of view to produce an image current, means including a second cyclically moving scanning or distributing element for producing an image in accordance with the variations of said current, means for deriving from said image current a component the frequency of which varies in accordance with the speed variations of the first mentioned cyclically moving element, and means responsive to said component of the image current for

maintaining said cyclically moving elements in synchronism.

3. In an electro-optical image producing system, means including a cyclically moving element for scanning a field of view to produce an image current having a component the frequency of which varies in accordance with the speed variations of said cyclically moving element, means responsive to said image current and including a second cyclically moving element for producing an image of said field of view, means for generating a current the frequency of which is controlled in accordance with the speed variations of said second cyclically moving element, and means controlled jointly by said component of the image current and by the current generated by said last mentioned means for maintaining said cyclically moving elements in synchronism.

4. In an electro-optical image producing system, means including a cyclically moving element for scanning in succession fixed areas of a field of view, thereby producing an image current, means for periodically varying the area of the portion of the field of view being scanned, thereby introducing a corresponding frequency component into said image current, means responsive to said image current and including a second cyclically moving scanning or distributing element for producing an image of said field of view, means for deriving a portion of the energy of said frequency component from said image current, and means for utilizing the derived energy of said frequency component for maintaining said cyclically moving elements in synchronism.

5. In an electro-optical image producing system, means including a cyclically moving element for scanning in succession fixed areas of a field of view, thereby producing an image current, means for periodically varying the area of the portion of the field of view being scanned, thereby introducing a corresponding frequency component into said image current, means responsive to said image current and including a cyclically moving element for producing an image of said field of view, means for deriving a portion of the energy of said frequency component from said image current, means for generating a current the frequency of which is controlled in accordance with the speed variations of the second mentioned cyclically moving element and means the energization of which is controlled in accordance with the phase relation between said frequency component derived from said image current and said generated current for maintaining said cyclically moving elements in synchronism.

6. An electro-optical image producing system, comprising a transmitting station and a receiving station, a transmission medium con-

necting said stations, means at said transmitting station for defining a field of view, means including a rotatable element and a light sensitive element for scanning said field of view in parallel lines successively such that the scanning of one line is completed before the scanning of the succeeding line is initiated, thereby producing an image current having a component of predominant amplitude whose frequency varies in accordance with the speed variations of said rotatable element, means for impressing said image current on said transmission medium, means including a rotatable element and a source of light responsive to said image current for producing an image of said field of view, a frequency discriminating device for deriving said current component of predominant amplitude from said image current, means for impressing said derived current component on the input circuit of a three-electrode electron discharge device, means for generating and impressing on the output circuit of said electron discharge device an electromotive force whose frequency is controlled in accordance with the speed variations of the rotatable element of the image producing means, said frequency being the same as the frequency of the component derived from the image current when the two rotatable elements are running at the same speed, means for deriving an electromotive force proportional to the anode current of said electron discharge device, and means for impressing said electromotive force on the control winding of a motor for driving the rotatable element of the image producing means, thereby maintaining said rotatable element in synchronism with the rotatable element of said scanning means.

7. The method of producing an image electro-optically, which comprises scanning a field of view to produce an image current having a component the frequency of which varies in accordance with the speed variations of the scanning apparatus, utilizing said image current for controlling the production of an image of said field of view, generating a current the frequency of which is controlled in accordance with the speed variations of the image producing apparatus, and utilizing said component of the image current and said generated current for maintaining said scanning and said image producing in synchronism.

8. An electro-optical system comprising a source of image current having only variations produced as the result of scanning a field of view an image of which is to be produced, a rotatable scanning element, driving means for said element, and means, the energization of which is controlled in accordance with a characteristic of current from said source of image current, for controlling the speed of said driving means.

9. An electro-optical system, comprising a

scanning device, a motor for driving said device, a source of image current having only variations produced as the result of scanning a field of view an image of which is to be produced and a winding which is energized in accordance with a characteristic of said image current for controlling the speed of the motor in accordance with said energization.

10. Electro-optical means for producing an image of a field of view comprising a scanning device, a motor for driving said device, a source of image current having only variations produced as the result of scanning a field of view an image of which is to be produced, a lamp, means for energizing said lamp by current from said source, and an electro-magnetic element which is variably energized under the control of current from said source of image current for controlling the speed of said motor in accordance with said energization.

11. Electro-optical means for producing an image of a field of view comprising a rotatable image synthesizing element, a motor for driving said element, means comprising an inductive element for controlling the speed of said motor in accordance with the energization of said inductive element, a source of image current having only variations produced as the result of scanning a field of view, means for utilizing current from said source of image current for controlling the light tone values of an image of said field of view, a source of current for energizing said inductive element and means under the control of image current from said source for controlling the supply of energy from said source to said inductive element and thereby the movement of said motor.

12. In a television system, a rotatable scanning element, a motor having a rigid shaft for driving said element, a field winding for said motor, means for energizing said field winding for controlling the speed of said motor, and a relatively flexible element for coupling said scanning element to the rigid shaft of said motor for reducing or suppressing oscillations in the movement of said scanning element due to changes in speed of said motor.

13. In a television system, a rotatable scanning element, a motor for driving said element, means comprising a field winding for said motor, means for energizing said field winding for controlling the speed of said motor, and a hydraulic damping element for coupling said scanning element to said motor for reducing or suppressing oscillations in the movement of said scanning element due to changes in speed of said motor.

14. In a television system, a cyclically movable scanning element, a motor for driving said element, a speed control winding for said motor, two sources of cyclically varying electro-motive force normally of the same

frequency, means for controlling the energization of said speed control winding in accordance with the phase relation of the electro-motive forces of said sources, and a flexible element for coupling said cyclically movable scanning element to said motor for reducing or suppressing irregularities in the movement of said scanning element caused by changes in speed of said motor such as due to hunting.

15. An electro-optical image producing system comprising a rotatable element for scanning elemental areas of a field of view in succession, a source of varying electro-motive force having a component, the frequency of which is controlled in accordance with the speed of said rotatable scanning element, a rotatable element for synthesizing the elemental areas of an image of said field of view, a motor having a rigid shaft for driving said element, a source of varying electromotive force having a component, the frequency of which is controlled in accordance with the speed of said synthesizing element, means, the energization of which is controlled in accordance with the phase relation of the electromotive forces of said sources, for controlling the speed of said motor, and a relatively flexible member for coupling said rotatable synthesizing element to the rigid shaft of said driving motor therefor for reducing oscillations in the movement of said synthesizing element and thereby instability of the image which would normally occur due to changes in speed of the motor such as are due to the hunting tendency of the motor.

16. The method of image production which comprises setting up image current having only variations produced as a result of repeatedly scanning a field of view in a series of parallel lines, simultaneously scanning a second field of view, deriving energy having no component of a frequency lower than the line scanning frequency from said image current and utilizing said energy to completely control the maintenance of a desired time relation between said scanings.

17. The method of image production which comprises setting up image current as a result of repeatedly scanning a field of view in a series of parallel lines, simultaneously scanning a second field of view, deriving from said current energy the principal component of which is of the line scanning frequency and utilizing said energy to completely control the maintenance of a desired time relation between said scanings.

18. In an electro-optical system, means for producing an image current comprising means for repeatedly scanning a field of view in a series of parallel lines, means for simultaneously scanning a second field of view comprising a continuously rotatable element, means under control of said image current for generating a current the principal com-

ponent of which is of line scanning frequency and means for controlling the speed of said rotatable element by said last mentioned current.

5 In witness whereof, I hereunto subscribe my name this 20th day of February, 1928.

EMANUEL C. MANDERFELD.

10

15

20

25

30

35

40

45

50

55

60

65