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H. E. IVES

2,274,687

ELECTRO-OPTICAL APPARATUS

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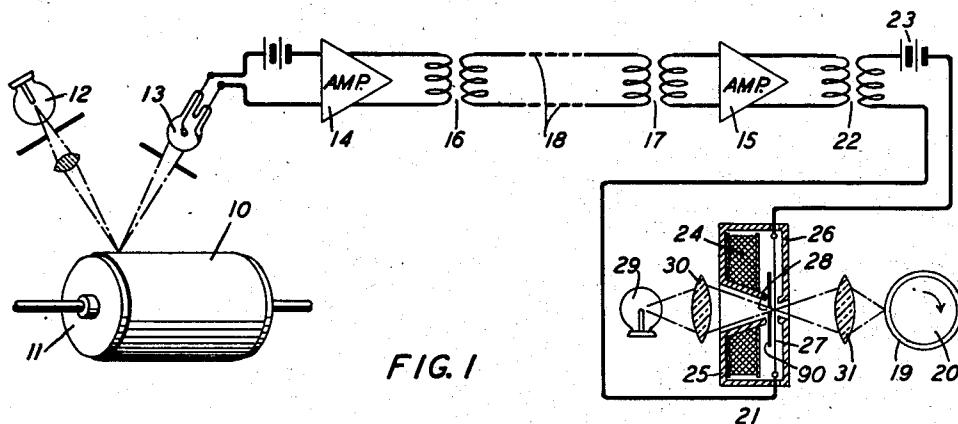


FIG. 1

FIG. 2

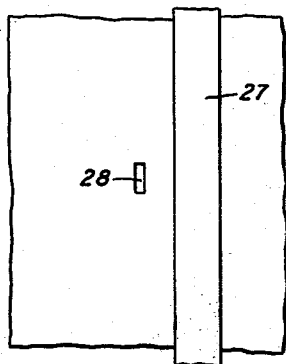


FIG. 3

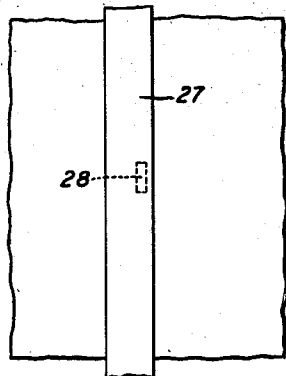


FIG. 4

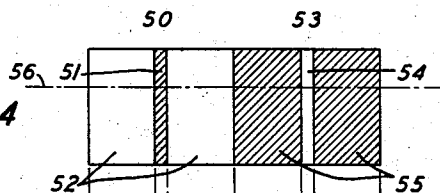


FIG. 5

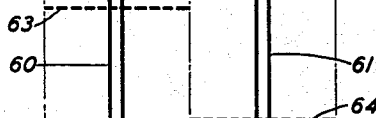


FIG. 6

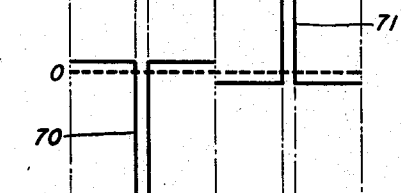
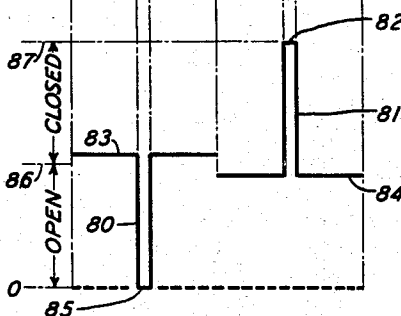


FIG. 7



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ELECTRO-OPTICAL APPARATUS

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10 Claims. (Cl. 178—6)

This invention relates to electro-optical apparatus and particularly to an arrangement which is specially adapted for use in the reproduction of two-tone pictures or messages, at a signal receiving station.

One object of the invention is to provide a novel system for transforming electrical variations into light variations.

Another object of the invention is to provide an improved system for producing images under control of current transmitted over an alternating current transmission line.

Another object is to increase the speed of reproduction of a picture.

Another object is to automatically correct for the distortion which normally results in a two-tone reproduction of a picture due to the suppression of low frequency components of the picture current.

It is known that a current produced as the result of scanning a picture has a direct component and alternating components extending over a range of frequencies and that, when such a picture current is directly transmitted over a commercial telephone transmission line, the direct component and some of the low frequency alternating components are suppressed and the higher frequency components only are transmitted. To avoid the distortion in the reproduced picture which would normally result due to the suppression of the direct and low frequency components, it has heretofore been the practice to transmit a carrier wave modulated by the picture current. This practice has the disadvantage that it requires the transmission of current of a wide frequency range as compared with the frequency range required for transmitting the picture current without modulating a carrier wave. Since a given transmission line is capable of transmitting current of a limited range of frequencies, and since an increase of speed of transmission involves the transmission of current of an increased frequency range, the practice of modulating a carrier wave by a picture current limits the speed of transmission of a picture.

This difficulty is obviated, in accordance with the present invention, by producing an image under control of only the higher frequency components of an image current which can be transmitted over a commercial transmission line and automatically correcting for the distortion which would normally result due to the suppression of the lower frequency components of the image current.

In the illustrative embodiment of the invention herein shown and described, a two-tone picture is moved with respect to a fixed light beam at a transmitting station in such a manner that the elemental areas of the picture are illuminated in succession. Light reflected from the successively illuminated elemental areas impinges upon a light sensitive device to control the production of a picture current having a direct component and alternating components extending over a range of frequencies. A transmission line which suppresses the direct and certain low frequency components of the picture current and transmits the higher frequency components thereof connects the transmitting station with a receiving station. A steady component, preferably corresponding to the average tone value of the original picture, is reinserted at the receiving station. This may be accomplished, for example, by impressing an alternating electromotive force which varies in accordance with the transmitted picture current upon the input circuit of a three electrode vacuum tube to control the production of a unidirectional current, having alternating components corresponding to the components of the transmitted picture current, in its output circuit. This unidirectional current actuates a device such as a light valve for controlling the exposure of a moving light sensitive surface for controlling the reproduction of the picture. Due to the suppression of the low frequency components of the picture current, there would ordinarily result fluctuations in tone value of the reproduced picture which are not present in the original and which may become apparent in the reproduced picture as a mottled background for example. In order to obviate distortion of this type, there is employed a light valve which emits no light when actuated and which emits a fixed amount of light when unactuated, or vice-versa, regardless of the amplitude of the actuating current. There may be employed, for example, a light valve similar to that disclosed in Patent 1,667,805, granted to me May 1, 1928, but having a very narrow light aperture so that the aperture is completely covered for a certain range of movement of the string of the light valve and completely uncovered for a different range of movement of the light valve string.

Referring to the drawing:

Fig. 1 shows schematically a picture transmission system embodying the present invention;

Figs. 2 and 3 are detailed views of the light valve employed in the system shown in Fig. 1

showing the relationship between the light valve aperture and the vibrating string for different operating conditions, respectively;

Figs. 4 to 7 are diagrams for facilitating the explanation of the operation of the picture transmission system.

Referring to Fig. 1, a positive black and white picture 10 which may be a typewritten message, for example, is mounted on the drum 11. The drum 11 is rotated and at the same time moved in an axial direction in a well known manner so that a beam of light from source 12 in effect traces a helical path on the picture surface to illuminate the elemental areas thereof in succession. Light reflected from the successively illuminated elemental areas of the picture is received by the photoelectric cell 13 to produce in the circuit of the photoelectric cell an image current having variations corresponding to the tone values of the successively illuminated elemental areas of the picture. This image current is impressed upon a transmission channel comprising vacuum tube amplifiers 14 and 15, transformers 16 and 17 and the line 18 which connects the transmitting and receiving stations.

At the receiving station a sheet of light sensitive photographic paper 19 is mounted on a drum 20 similar to drum 10 at the transmitting station and moved in synchronism therewith. The two drums may be maintained in synchronism by the use of any of the well known methods employed for this purpose. For example, independent constant frequency current sources may be employed for controlling the energization of the driving motors at the two stations as disclosed in Patent 1,808,923 granted to J. W. Horton June 9, 1931. The image current from amplifier 15 is impressed upon the string 27 of the light valve 21 either through transformer 22 and a suitable biasing battery 23 or if desired, the light valve may be connected directly in the anode circuit of the last stage of the vacuum tube amplifier 15.

The light valve 21 and the optical system employed therewith may be of the type disclosed in Patent 1,667,805 granted to me May 1, 1928, except that the light aperture of the valve is very narrow with respect to the width of the string 27 and with respect to its amplitude of movement so that the light valve transmits a fixed amount of light when the amplitude of the energizing current is less than a fixed amplitude and transmits no light when the amplitude of the energizing current is greater than this fixed amplitude. The light valve comprises a magnetizing winding 24 which is mounted on a hollow central core of the magnetic frame 25. A plate 26 is fastened to the frame 25 and provides an air chamber within which is located the string 27. The string is suspended in the valve so as to vibrate before the opening 28 in the screen 30 in a direction perpendicular to that of the trace of the picture receiving paper 19. As shown more clearly in Figs. 2 and 3, the string 27 of the light valve when energized by current having an amplitude less than a predetermined fixed value occupies a position so as to completely uncover the light aperture 28 as shown in Fig. 2. When the amplitude is greater than this predetermined fixed value the aperture is completely covered by the string 27 as shown in Fig. 3.

Light from source 29 is directed upon the light valve 21 by means of a lens 30 so as to intensely and uniformly illuminate the aperture 28 of the light valve. A lens 31 is arranged so as to cause

an image of the light valve aperture to be formed upon the sheet of photographic paper 19.

It is now well known that the current produced in the circuit of a photoelectric cell as the result of scanning a picture may be analyzed, in accordance with a well known mathematical principle discovered by Fourier, into a steady direct component and a number of sinusoidal components of different frequencies. The direct component is representative of the average tone value of the entire picture. If we consider the picture to be divided into several areas, the average tone value of one area may be different from the average tone value of another area, that is, one portion of the picture may be relatively dark in average tone value while another portion is relatively light. In a printed page, for example, a large number of letters may appear within a certain fixed area, resulting in a dark average tone value, while in another area of the same size a much smaller number of letters may appear, thus resulting in a light average tone value. The relatively low frequency alternating components of the image current represent these changes in average tone value which occur in going from one portion of the picture to another.

The operation of the system may be readily understood by considering the diagrams of Figs. 4 to 7. The area 50 represents a portion of the picture having a black line 51 on a white ground 52, and the area 53 represents a portion of the picture having a white line 54 on a black ground 55. When the areas 50 and 53 are scanned along the line 56 there is produced in the circuit of the photoelectric cell 13 a varying direct current which may be represented by the curves 60 and 61, respectively. Since the area 50 is of light tone value, the average value of the current represented by curve 60 is high as indicated by the dotted line 63. The average tone value of the area 53 being dark, the average value of the current represented by curve 61 is low as indicated by the dotted line 64. The areas 50 and 53 may represent extreme conditions which would probably not occur in practice, that is, the average tone value of different portions of a picture would probably not vary as much as indicated by the dotted lines 63 and 64. As stated heretofore, a commercial telephone transmission line including elements such as the transformers 16 and 17 will suppress the direct and certain low frequency alternating components. Moreover, the frequency range which can be transmitted substantially without distortion over such a signal transmission channel is known to be limited. Therefore, if a considerable band of the low frequency components of the image current is suppressed by a suitable filter at the transmitting station, the upper limit of the frequency range which can be transmitted is correspondingly increased, thus permitting an increase in the speed of scanning. Since the direct current component represented by the dotted lines 63 and 64 of the current represented by curves 60 and 61 is not transmitted, the received voltage wave impressed upon the amplifier 15 at the receiving station or upon the secondary winding of the transformer 22 may be represented by the curves 70 and 71, portions of which extend above and below the line of zero voltage represented by the dotted line 72. Due to the action of the battery 23 connected in series with the secondary winding of transformer 22 and the string 27 of the light valve 21, the current flowing through the string of the light valve varies between zero, corresponding to the

dark element 51 on the light ground 52, and a maximum amplitude corresponding to the light element 54 on the dark ground 55 as shown by the curves 80 and 81. It is apparent that if an ordinary type of light valve were to be employed to control the exposure of a negative film from which a positive picture is produced, such a picture would not correctly correspond to the original picture as represented in Fig. 4. The maximum amplitude 82 would be reproduced as white, the amplitude 83 would be reproduced as light gray, the amplitude 84 as dark gray, and the amplitude 85 as black. Thus, when transmitting printed matter consisting of black letters on a white ground, the letters in the reproduction would appear as black but the background would appear mottled. When employing an "all or none" type light valve, as described above, the light valve is adjusted to give a full exposure of the photographic paper for current values between zero and some value indicated at 86 which lies between the values 83 and 84. For the range of current values lying between 86 and 87 the light valve aperture is completely closed. Thus there will be produced a black and white picture which corresponds correctly to the original, that is, the light valve aperture will be closed when a current flowing through the string of the light valve has the amplitude 82 or the amplitude 83, thus reproducing white, and the aperture will be completely open when the energizing current for the light valve has the amplitude 84 or the amplitude 85, thus reproducing black. Thus a printed page consisting of black letters on a white ground, for example, would be correctly reproduced and the background would not appear mottled.

What is claimed is:

1. An electro-optical image producing system for the transmission of black and white pictures comprising means for scanning a field of view to produce an image current having components extending over a range of frequencies, means for suppressing certain low frequency components and transmitting the higher frequency components of said current, and light control means which emits the same amount of light when energized by current of different amplitudes for controlling the production of an image of said field of view and establishing a uniform background under control of said transmitted current.

2. An electro-optical image producing system for the transmission of black and white pictures comprising means for scanning a field of view to produce an image current having components extending over a range of frequencies, means for suppressing certain low frequency components and transmitting the higher frequency components of said current, and light control means capable of emitting either a fixed amount of light or no light only for controlling the production of an image of said field of view and establishing a uniform background under control of said transmitted current.

3. An electro-optical image producing system for the transmission of black and white pictures comprising means for scanning a field of view to produce an image current having components extending over a range of frequencies, means for suppressing certain low frequency components and transmitting the higher frequency components of said current, and light control means which emits the same amount of light when energized by current of different amplitudes ex-

tending over a range of values between a minimum and a maximum value and no light when the magnitude of the energizing current is outside of said minimum and maximum values for controlling the production of an image of said field of view and establishing a uniform background under control of said transmitted current.

4. An electro-optical image producing system for the transmission of black and white pictures comprising means for scanning a field of view to produce an image current having a direct component and alternating components extending over a range of frequencies, means for suppressing said direct component and certain low frequency alternating components and transmitting the higher frequency components of said current, means for producing a current having a direct component and alternating components corresponding to the components of said transmitted current, and light control means which emits the same amount of light when energized by current of different amplitudes for controlling the production of an image of said field of view and establishing a uniform background under control of said last mentioned current having direct and alternating components.

5. A system for reproducing two-tone pictures which comprises a transmitting station and a receiving station, means at said transmitting station for producing a beam of light, means for supporting a picture and moving it with respect to said light beam so as to illuminate elemental areas thereof in succession, light sensitive electric means for receiving light reflected from said picture to produce a picture current having a direct component and alternating components extending over a range of frequencies, means for suppressing said direct component and certain low frequency alternating components and transmitting the higher frequency components of said current to said receiving station, means for producing a light beam at the receiving station, means for supporting a picture surface and moving it with respect to said light beam, and means responsive to the transmitted current for controlling the exposure of said light sensitive surface to said light beam to reproduce the picture, said means being adapted to transmit either a fixed amount of light or no light only, to establish a uniform background.

6. A system for producing images of a field of view having only black and white tone values, comprising a transmitting station and a receiving station, means at said transmitting station for scanning the field of view to set up an image current having components extending over a range of frequencies, a transmission channel connecting said stations for transmitting the higher frequency components and suppressing the lower frequency components of said image current, and means for emitting a fixed amount of light or no light at said receiving station for producing an image of said field of view and a uniform background under control of said transmitted components.

7. In an image producing system a source of image current representative of an object having two light-tone values only and from which the low frequency components have been eliminated and which is per se in no manner indicative of the amplitudes of said eliminated components, means for receiving said image current and means for automatically producing an image of the scanned object in two tones under control of said received image current and independently

of any other current indicative of the amplitudes of said eliminated components.

8. In an image producing system, a source of image current representative of an object having two light-tone values only and from which the low frequency components have been eliminated and which is per se in no manner indicative of the amplitudes of said eliminated components, means for receiving said image current and means for automatically producing an image of the scanned object in two tones under control of said received image current and independently of any other current indicative of the amplitudes of said eliminated components, said means responding to current amplitudes within a predetermined range of amplitudes to produce one of said tone values and to current amplitudes within a different range to produce said other tone value.

9. In an image producing system, a source of image current representative of an object having two light-tone values only and from which the low frequency components have been eliminated and which is per se in no manner indicative of the amplitudes of said eliminated components, means for receiving said image current and means for automatically producing an image of the scanned object in two tones under control

of said received image current and independently of any other current indicative of the amplitudes of said eliminated components, said means including a movable element the movement of which is controlled by said received image current.

10. In an image producing system, a source of image current representative of an object having two light-tone values only and from which the low frequency components have been eliminated and which is per se in no manner indicative of the amplitudes of said eliminated components, means for receiving said image current and means for automatically producing an image of the scanned object in two tones under control of said received image current and independently of any other current indicative of the amplitudes of said eliminated components, said means including a movable element the position of which is controlled in accordance with the instantaneous amplitudes of said received current, one of said tone values being produced when said movable element occupies one of a plurality of positions within a predetermined range and the other of said tone values being produced when said movable element occupies one of a plurality of positions within a different range.

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