

Feb. 11, 1930.

H. E. IVES

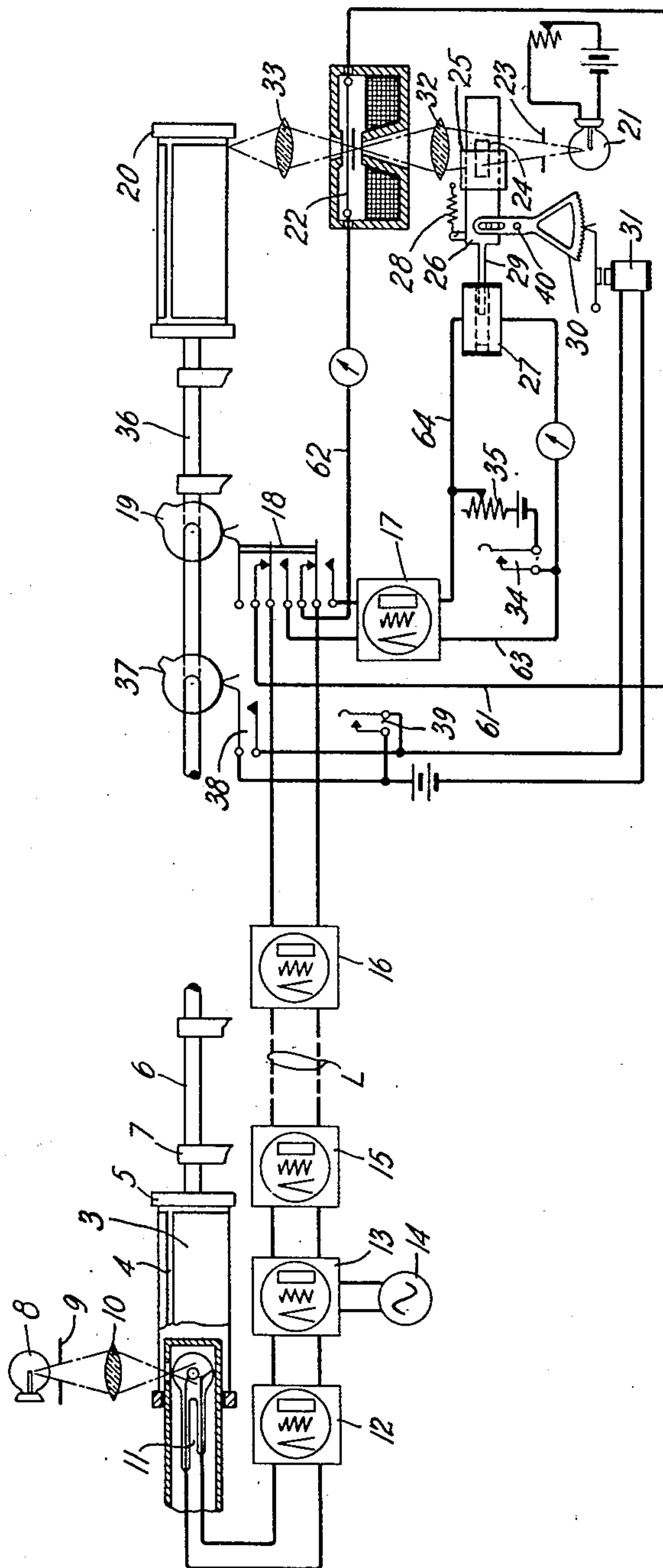
1,746,729

ELECTROOPTICAL SYSTEM

Filed Dec. 6, 1927

2 Sheets-Sheet 1

FIG. 1.



INVENTOR:
HERBERT E. IVES
By *C. C. Sprague*
ATTORNEY

UNITED STATES PATENT OFFICE

HERBERT E. IVES, OF MONTCLAIR, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

ELECTROOPTICAL SYSTEM

Application filed December 6, 1927. Serial No. 238,009.

This invention relates to electro-optical systems and devices and more particularly to methods and means for automatically optically compensating for changes in the condition of the line or other elements of the system used for propagating image currents. This patent application is a continuation in part of the patent to H. E. Ives, No. 1,743,856, issued Jan. 14, 1930.

10 In a transmission system for producing images of pictures or other objects employing carrier current modulated according to the characteristics of the picture or other object, it is important to maintain faithful re-
15 sponsiveness of the image receiving apparatus irrespective of changes in the constants of the transmission line and the associated apparatus. In systems requiring the use of long transmission lines, the electrical proper-
20 ties of these systems inevitably vary in accordance with conditions which cannot be controlled directly, such as changes in atmospheric conditions, temperature conditions, and the like. Further variations may
25 be caused by changing conditions in the electrical apparatus associated with the transmission line. The effect of the existence of these varying conditions upon the production of images is a non-uniform intensity of like
30 tone values of the picture or other object in the received picture. This is especially pronounced in such systems where the picture or other object is scanned element by element and a comparatively long interval elapses be-
35 tween production of the first element and the production of the last element. Such abnormal variations cause streaks or areas in the produced picture which are unusually light or dark.

40 In accordance with the present invention an optical method and means are provided for automatically compensating for changes, particularly in the characteristics of the transmission line interconnecting the trans-
45 mitting and the receiving stations.

In one arrangement two optically aligned light valves of the variable aperture type acting in tandem to control the light from a single source are used in the receiving sta-
50 tion. One valve may be under the control of

the image current and the other utilized to compensate for line level and other changes. The arrangement is such that the action of one valve causes rays from the light source to act as a varying carrier light beam while
55 the other valve modulates the carrier light beam. In a preferred form the light valves are consolidated in one structure with a common steady magnetic field, the vibratory members being positioned at right angles in
60 that field so that the currents therethrough will cause a minimum reaction upon each other.

The two light valves or the two vibrating members of a valve of the unitary structure
65 type may be simultaneously controlled and inter-currently operated or they may be simultaneously controlled and simultaneously operated. In the first arrangement only one
70 of the vibratory members is in operation at any time, while in the second arrangement both members are continuously in operation.

The invention is shown as embodied in a picture transmission system similar to that disclosed in Horton et al. Patent No. 1,606,-
75 227, issued November 9, 1926. While this invention is shown as a part of a picture transmission system it obviously is applicable to other types of electro-optical transmission such as television systems and also other sig-
80 naling systems.

The term "light" as used herein includes not only the visible spectrum but also the radiation above and below the visible por-
85 tion. The term "optically aligned" as used herein applies to any elements in the light path irrespective of whether these elements are in a straight line or in a path of different directions provided the light path passes
90 through these elements, the change in direction of the light being effected by mirrors or prisms or the like.

Fig. 1 is a diagrammatic showing of a picture transmission system utilizing two light valves of the variable aperture type posi-
95 tioned in tandem for controlling the light intensity of the light rays impressed upon the receiving surface where a picture is produced.

Fig. 2 is a diagrammatic showing of a pic- 100

ture transmission system which is in general similar to that of Fig. 1 but with separate sources of image carrier current and of compensating carrier current and a light valve having a plurality of independently controlled ribbons.

Fig. 3 is an end view of the central portion of a light valve constructed in accordance with this invention with the front end plate removed, showing particularly the relation of the light valve ribbons and the light aperture through the valve.

Fig. 4 is a longitudinal section view of the central part of the valve.

Fig. 1 shows both the transmitting and the receiving stations of a picture transmission system. The picture 3 in the form of a transparent film is wrapped around the drum 5 which is rotated and advanced longitudinally by means of a threaded shaft 6 and the threaded bearing 7. The picture film does not completely surround the drum 5 and is so mounted that the portion of the drum 4 between the picture edges permits covering this area with a material having uniform transparency of the proper degree so as to uniformly excite the photoelectric cell 11 and thus cause a carrier current of the desired value to be transmitted. This portion of the drum revolution will be designated hereinafter as the "underlap" period. The light from the source 8 passes through the opening in the baffle plate 9 and is focussed by means of lens 10 upon an elemental area of the picture. The light rays pass through the transparent film to affect the photoelectric cell 11 thereby producing varying picture or image current. The varying current from the cell 11 is passed through an amplifier 12 and then impressed upon a modulator 13, whereby the current waves from the oscillation source 14 are correspondingly modified. The mechanically actuated switch 18 at the receiver is in the position shown in Fig. 1 when the picture currents are being received and is in its alternate position during the underlap period as will be described hereinafter.

The optical system for affecting the receiving film includes a source of light 21. The rays from this source pass through the opening in the baffle plate 23 and then through the variable opening 24 controlled by the shutters 25 and 26. The plane of the shutters 25 and 26 is normal to the path of the light rays but to show the opening 24 they are turned in the drawing at right angles to their normal position. The rays are then focussed by means of lens 32 upon the light valve aperture and by means of an appropriate arrangement of lenses represented symbolically by the lens 33 are focussed upon the receiving film mounted on the drum 20. Shutter 25 is fixed while shutter 26 is capable of sliding longitudinally to

vary the size of the opening 24. When the magnet 27 is completely deenergized shutter 26 is drawn towards the right by means of the retractile spring 28 to completely open the opening 24. The extension 29 is of soft iron and is adapted to be moved by means of a magnet 27 when the latter is energized. The position of the shutter 26 is locked, when not undergoing adjustment, by the mechanism controlled by the magnet 31, the armature of which engages in the teeth of the lever 30 when this magnet is deenergized to hold the shutter 26 in its last adjusted position. The lever 30 rotates about the point 40 when the plunger 29 is moved. Prior to the reception of picture signals key 34 is closed and current to the winding of the magnet 27, indicated by the meter in its circuit, is adjusted by means of the rheostat 35 to a value corresponding to the value of the current from the demodulator 17, which value is determined by the unmodulated carrier current when the line L is in standard condition. With this standard current flow to the winding of the magnet 27, the armature of the magnet 31 is temporarily released by means of the operation of key 39 from engagement with the locking member associated with shutter 26, said shutter assumes the position which is the result of the energization of magnet 27 and the retractile force of the spring 28. Key 39 is then restored, whereby the armature of magnet 31 is allowed to cause reengagement with the teeth of the lever 30 controlling the shutter 26. Key 34 may now be restored but shutter 26 is held in its adjusted position by means of the armature of the magnet 31. Thus by means of the tension of spring 28 a predetermined width of the opening 24 may be secured corresponding to a given standard condition of the line. With the opening 24 so adjusted the receiving apparatus is in readiness to reproduce the picture.

As described in the above mentioned patent of Horton et al. the sending and receiving drums are started in operation and rotated synchronously. The current from the carrier source 14 is then modulated in accordance with the intensity of the successive elemental areas of the picture 3 and is impressed upon the line L. As noted hereinbefore, during the picture transmission period of the sending and receiving drums, the switch 18 is in its normal position as shown. Accordingly, the circuit for the picture current includes normal contacts of the switch 18, conductors 61 and 62, and the light valve ribbon or string 22. Under the influence of the varying picture current the light valve opening is changed to allow the light from the source 21 to correspondingly affect the sensitized receiving surface which is mounted on the drum 20.

The shafts 36 upon which the drum 20 is

mounted carries two cams 19 and 37. The cam 19 is so positioned on the shaft 36 that it actuates the switch 18 at the beginning of the underlap period and the length of its camming surface is sufficient to maintain the switch 18 in its operated position during the complete underlap period. During the underlap period, unmodulated carrier current is transmitted over the line L. Since the switch 18 is now actuated the current being received, instead of passing through the normal contacts of the switch 18, passes through the alternate contacts thereof, through the demodulator 17, over the conductors 63 and 64 and through the winding of the magnet 27. Under control of this current the magnet 27 acts on the plunger 29 but the shutter 26 is held by means of the armature of the magnet 31 which engages teeth in the lower edge of the lever 30 controlling the locked position of the shutter 26. A short interval later the cam 37 operates the switch contacts 38 whereby the magnet 31 is energized to remove its armature from engagement with the teeth of the lever 30. The shutter 26 can therefore assume a position determined by the resultant of the attractive force of the magnet 27 and the retractile effect of the spring 28. Should the line L be in a standard condition the current through the magnet 27 is of the same value as that which flowed through the previously adjusted resistance 35. Accordingly, under these conditions the shutter 26 does not move when the magnet 31 is energized. However, should the transmission level be different from the standard causing greater or less attenuation of the received currents then the current flowing through the winding of magnet 27 will be in proportion to the transmission level of the line L and the size of the opening 24 in the shutter 26 will bear an inverse relation to the transmission level. When the underlap period is passed, the switch 18 is restored to normal and transfers the incoming current conductors from the windings of the magnet 27 to the light valve.

From the foregoing description it will be seen that means are provided for automatically testing the strength of the current operating the light valve once during every revolution of the receiving drum; namely during the underlap period, and for controlling, in accordance with current changes, the amount of light reaching the receiving film. The current changes may be due to changes in transmission characteristics of the line or to variations in terminal apparatus through which the current passes.

The two light controlling devices, the light valve having the ribbon 22 and device having the shutters 25 and 26 are optically aligned, that is they are so positioned that light from the source 21 passes through them

in tandem and to the receiving surface on the drum 20. Their position may be such that the light path is a straight line as shown, or such that the light path has a change in direction which may be effected by a minor or prism.

Fig. 2 shows a picture transmission system utilizing one source of oscillations for the picture carrier current and another source of oscillations for the compensating current. The transmitting station is similar to that shown in Fig. 1 with the exception that there is added a second source of oscillations for providing the compensating current, and at the receiving station the optical system is a modification of that shown in Fig. 1 which instead of employing a light valve and an auxiliary shutter arrangement intermittently operated, has a light valve having a plurality of independently controlled ribbons. At the transmitting station the light incident upon the photoelectric cell 90 after passing through the transparency film generates photoelectric current which is impressed upon the picture current amplifier 91. The output of the amplifier 91 by means of the modulator 92 correspondingly changes the amplitude of the carrier wave generated by the oscillator 93. The modulated wave is then impressed upon the transmission line after passing through the terminal amplifier 94. At the same time a compensating carrier current of constant amplitude having a frequency preferably above that of the picture current is generated by the oscillator 95, amplified by the terminal amplifier 96, and impressed upon the line L simultaneously with the picture modulated carrier current.

At the receiving terminal as shown in the right of Fig. 2 the picture and compensating carrier currents are separated by their respective filters 97 and 100. The image current passing through the filter 97 is impressed upon the amplifier 98 and transmitted over the circuit 99 through the picture controlling light valve ribbon 111. The compensating carrier current after passing through the filter 100 is impressed upon the amplifier 101, demodulated by the balanced demodulator 102, and passed through the low pass filter 103 and transmitted by the circuit 104 through the compensating light valve ribbon 112. The carrier current generated by the oscillator 93 for transmitting the picture current may have a frequency of the order of about one thousand cycles per second, while the carrier current generated by the oscillator 95 for compensating for line variations may have a frequency of the order of about two thousand cycles per second. The latter frequency is preferably chosen higher than the highest required image current frequencies. The filters 97 and 100 respectively separate the image current and the compensating current. The light valve ribbon 111 through

which the image current passes, vibrates in synchronism with this current while the light valve ribbon 112 through which the compensating current passes carries a current of relatively low frequency varying substantially in accordance with the transmission line level changes. This ribbon controls the area of the light valve aperture and performs the same function as the shutter arrangement including the members 24, 25 and 26 shown in Fig. 1. Thus, it is obvious that the ribbon 112 assumes a position which is a function of the transmission line characteristics, and as a result changes in the characteristics are automatically optically compensated for at the receiving terminal. The details of this light valve are disclosed more fully in Figs. 3 and 4. The optical system in Fig. 2 is a preferred arrangement over that shown in Fig. 1. The light from the light source 121 passes through the lens 122 which focusses the light rays on the light valve ribbons. The light after passing through the light valve passes through lens 123, the apertured screen 124 and the lens 125 by means of which an image of the aperture in the screen 124 is focussed on the sensitive film on the drum of the receiving apparatus. The intensity of the light passing through the apertured screen 124 varies in accordance with the image current and this light is in turn focussed on an elemental area of the picture receiving film.

Fig. 3 which is an end view of the central portion of the light valve, with the front end plate removed, showing particularly the relation of the two light valve ribbons 111 and 112 and the light transmitting aperture 113 through the center of the valve and the pole piece 114. These two ribbons are preferably positioned at right angles to one another to reduce to a minimum any possible mutual reaction between the ribbons which might interfere with their proper response to their own control current. The ribbons are placed as close together as practicable and yet not in contact with each other or the pole pieces as is shown in Fig. 4, which, however, is drawn with exaggerated clearances for clearness. The winding 115 sets up a steady magnetic field between the pole piece 114 and the pole piece 116 in the front plate 117 of the light valve so that the light valve ribbons cut the magnetic field in the air gap between the pole pieces at right angles. With this arrangement it is obvious that each light valve ribbon will take up a position dependent upon the current flowing through it and yet the action of each light valve ribbon is substantially the same as that of a single ribbon in a light valve having only one ribbon. In the system here shown, one of the ribbons slowly changes the size of the light valve aperture while the other varies the opening with signal rapidity. The action of the ribbons may be biased either mechanically or electrically. It is obvious

that more than two light valve ribbons may be employed and as a result further independent control of the amount of light which is allowed to pass through the light valve obtained.

What is claimed is:

1. In an electro-optical system, a source of light and a plurality of light valves optically aligned with said source, each of said valves having a light transmitting opening of variable cross-section and electrically controlled means for varying the opening.

2. In an electro-optical system, a source of light and a plurality of light valves optically aligned with said source, each of said valves having a light transmitting opening of variable cross-section and electrically controlled means for varying the cross-sectional area of the opening.

3. In an electro-optical system, a source of light, a plurality of light valves optically aligned with said source, each of said valves having a light transmitting opening of variable cross-section, and means for causing said openings to vary at different rates.

4. In a signaling system, variable light producing means at the receiving station comprising a source of light, a plurality of light valves optically aligned with said source, each of said valves having a light transmitting opening of variable cross-section and means for varying the openings, and means at a transmitting station for simultaneously controlling the openings in each of said valves.

5. In an electro-optical system, a source of light and a plurality of light valves optically aligned with said source, each of said valves having a light transmitting opening variable in one direction and electrically controlled means for varying the opening, said valves being oriented so that the direction of variation of the opening in one is different from that in the other.

6. In an electro-optical system, a source of light and a pair of light valves optically aligned with said source, each of said valves having a light transmitting opening formed in part by vibrating elements, and means for mounting said valves so that the directions of vibration of said elements are at right angles to each other.

7. A light valve comprising a mounting, an aperture therethrough, a plurality of movable members for controlling the cross-section of said aperture, and means for connecting said movable members into an electric system independently of each other.

8. A light valve comprising a mounting, an aperture therethrough, a plurality of movable members for controlling the cross-section of said aperture, means for connecting said movable members into an electric system independently of each other, and means for setting up a magnetic field to react on all of said movable members.

9. A light valve comprising a mounting, an aperture therethrough, a plurality of members movable in different directions for controlling the cross-section of said aperture, and means for connecting said members into an electric system independently of each other.

10. A light valve comprising a mounting, an aperture therethrough, a pair of vibratable current carrying elements at right angles to each other for varying the cross-section of said aperture, and means for setting up a magnetic field at right angles acting upon both of said vibratable members.

11. In an electric-optical system, a source of light, a plurality of light valve shutters optically aligned with said source, each of said light valve shutters varying the cross-section of a beam of light from said source, and electrical means for simultaneously controlling and for inter-currently operating said light valve shutters.

12. In an electro-optical system, a source of light and a plurality of means serially positioned in the path of a beam of light from said source to independently control the cross-sectional area of said beam at each position by each of said means.

13. In an electro-optical system, a source of light, a light valve having an aperture whose area is controlled by two electromagnetically actuated ribbons, means for vibrating one of said ribbons for generating a carrier light beam and means for vibrating the other of said ribbons for modulating the said carrier light beam in accordance with a signal current.

14. In an electro-optical transmission system, a signaling line, a receiving surface, a source of light therefor, two light valves responsive to impulses over said line to control the intensity of light upon the receiving surface, each of said valves having a light transmitting opening of variable cross-section, one of said valves being responsive only to changes in transmission levels of the signaling line and the other being responsive only to signaling current, both of said valves acting in tandem relation upon the light from said source to said surface.

15. The combination in an electro-optical system of a transmission line, a receiving surface and a source of light therefor, a light valve having a plurality of independently operated aperture controlling members acting to vary the cross-section of a beam of light from said source, one of said members actuated by image current received over said line to correspondingly control the intensity of the light from said source, and another of said members responsive to changes in the characteristics of the line to correspondingly control the intensity of the light from said source.

16. The combination in an electro-optical transmission system of a line, a receiving sur-

face, and a source of light therefor, a light valve having a plurality of independently controlled ribbons and one of said ribbons varying the intensity of the light reaching the said surface in accordance with the current received over said line, and another of said ribbons varying the intensity of the light reaching the said surface inversely as the current transmitting capacity of said line.

17. In an electro-optical system, a sending station, a receiving station, a transmission line for interconnecting said stations, means for sending image currents over said line, means for sending test current over said line, a light valve compensating device at the receiving station and means responsive to the sending of said test current only to cause the area of the opening of the aperture in said light valve compensating device to vary with said test current to maintain uniform contrast relation between the image and the object.

18. In an electro-optical system, a sending station, a receiving station, a transmission line for interconnecting said stations, a receiving surface and a source of light therefor at said receiving station, means for transmitting a carrier current modulated according to the tone characteristics of a picture or other object from said sending station to said receiving station, means for sending unmodulated carrier current to test said line, a light valve having an aperture of variable cross-section at said receiving station for varying the intensity of the light rays from said source in accordance with the modulated currents and a second light valve having an aperture of variable cross-section at the said receiving station for varying the intensity of the light of said source in accordance with said test.

19. The method of maintaining uniform reception in a system for producing images of pictures or other objects of the type employing a light beam to produce the image, which comprises varying the cross-section of the light beam directed to a receiving surface in accordance with changes in the transmission level of a line and independently of the image current being received and their control of the light beam.

In witness whereof, I hereunto subscribe my name this 3rd day of December, A. D. 1927.

HERBERT E. IVES.