Aug. 19, 1930. F. W. REYNOLDS 1,773,119

ELECTROOPTICAL TRANSMISSION SYSTEM

Filed Feb. 18, 1927 2 Sheets-Sheet 1

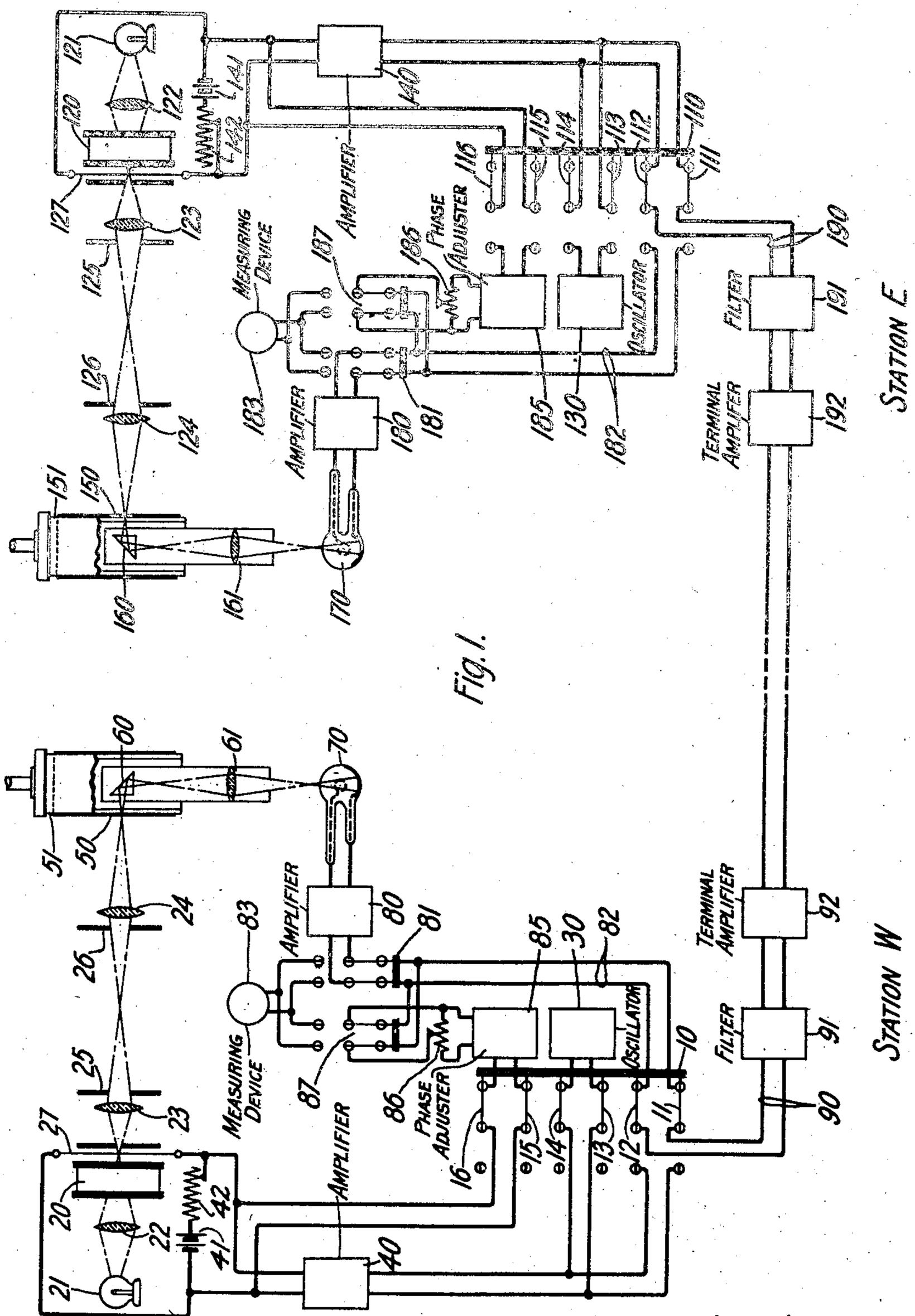

Fig. 1.

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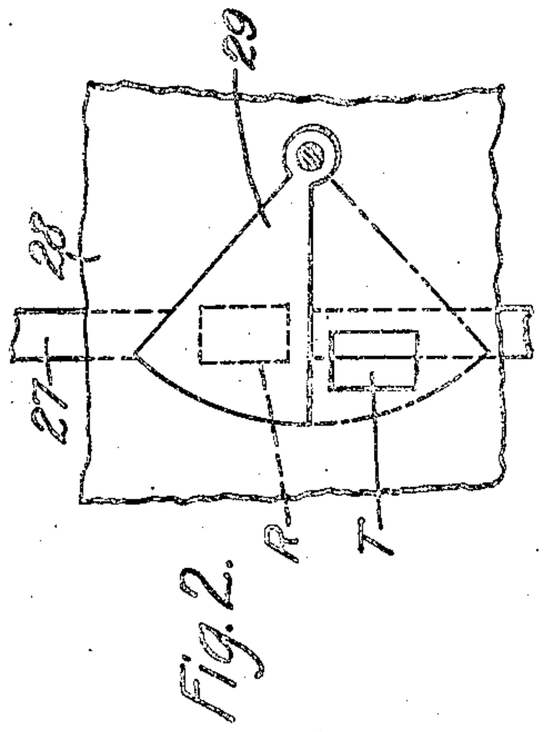

Fig. 2.

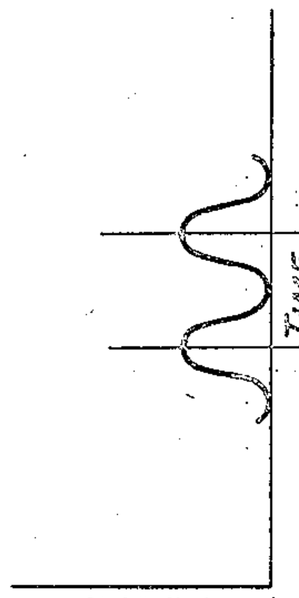

Fig. 3.

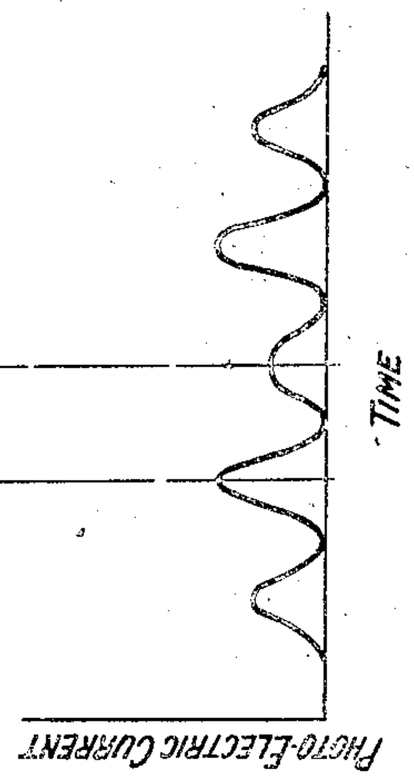

Fig. 4.

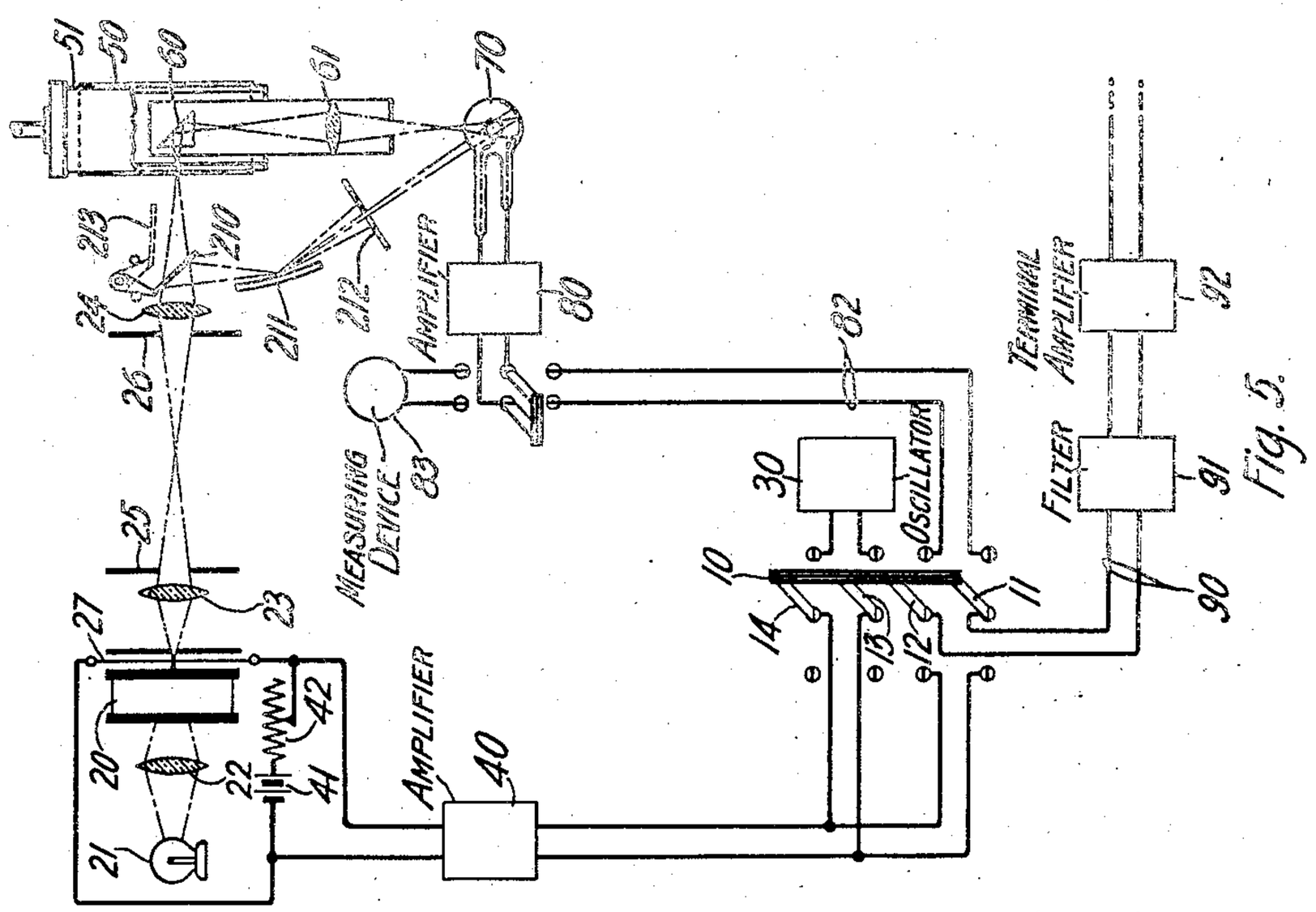

Fig. 5.

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Patented Aug. 19, 1930 1,773,119

UNITED STATES PATENT OFFICE

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ELECTROOPTICAL TRANSMISSION SYSTEM

Application filed February 18, 1927. Serial No. 169,322.

This invention relates to electro-optical transmission and more particularly to the electrical transmission of pictures.

An object of the invention is the simplification of the terminal equipment by the employment of certain elements for either the transmission or the reception of pictures. This invention is particularly applicable to the transmission of pictures in either direction over telephone circuits.

In an embodiment of the invention selected for illustration a string or ribbon electromechanical light valve such as disclosed in Patent No. 1,667,805, May 1, 1928, of Herbert E. Ives, is positioned between a source of light and a holder for the transmitting or receiving film, depending upon whether transmission or reception is taking place. For picture transmission the light valve ribbon is vibrated by alternating current from a vacuum tube oscillator or other suitable source at a substantially constant frequency thereby generating a pulsating light beam which is hereinafter called a "carrier" light beam. This carrier light beam is modulated by the picture at the transmitter and is subsequently directed onto a photoelectric cell which in turn produces pulsating photoelectric currents representative of the light effects of the picture. By means of a transformer, these currents set up alternating current which constitutes the modulated carrier current for the line. For reception at the same terminal station the oscillator is disconnected from the light valve and the incoming carrier picture currents are impressed upon this valve thereby causing it to pass to the film holder, which now holds the receiving film, a varying beam of light corresponding to the light intensities of the elemental areas of the picture which is being transmitted from the distant station. The scanning at the terminals may be carried on in accordance with standard practice well known in the art. A suitable scanning system is disclosed in Patent No. 1,706,032, March 19, 1929, of M. B. Long. The level of the line carrier currents may be raised at the transmitting terminal, to minimize the effect of disturbances entering by way of the line, by impressing some of the voltage of the oscillation generator upon the line in phase with the line currents, or the same result may be obtained optically by shunting some of the carrier light beam to the photoelectric cell.

A more detailed description of the invention follows and is illustrated in the accompanying drawing.

Figure 1 is a general schematic arrangement of an embodiment of this invention showing the terminal apparatus of two interconnected stations.

Fig. 2 is a detail, showing the light valve ribbon with relation to the light valve apertures when no current is flowing.

Fig. 3 is a curve, showing the variation in the intensity of the illumination of the picture at the transmitter with time.

Fig. 4 is a curve, showing the photoelectric current resulting from light modulation by the varying picture density plotted against time.

Fig. 5 is a general schematic arrangement of the terminal apparatus of one station, showing a modification of certain parts of the apparatus of Fig. 1.

Similar reference characters refer to similar parts of the apparatus.

In Fig. 1, in which two interconnected stations are shown, the terminal at the left, designated station W, will be described as a transmitting station and the switch 10 at this station is accordingly thrown to the right; while the terminal at the right, designated station E, will be considered as a receiving station and the switch 10 of that station is also thrown to the right, thus connecting the terminal apparatus of the two stations for transmission and reception, respectively. At station W, light valve 20 is positioned in the path of light obtained from any suitable source 21. A suitable lens system 22, 23 and 24 and apertured members 25 and 26 cause a beam of light to pass through the light valve and be focused on a small elemental area of the picture 50 where the light is modulated by the varying transparency of the elemental areas of the picture. The picture 50 is shown as a film of varying transparency mounted on a transparent drum 51 which is given a

motion of rotation and of translation in accordance with standard practice in picture transmission systems, thereby causing the light beam to successively scan the elemental areas of the entire picture. It is preferable to mount the light valve and the picture holding drum so that the axis of the light valve ribbon and the drum are at right angles to each other. The light beam, after passing through the picture, is reflected 90° by a prism or mirror 60 and passed through a lens system 61 to the light sensitive cell 70. The light sersitive cell, upon being activated by the varying light, causes varying electric currents to be transmitted to the amplifier 80. The amplifier connects through the switch 81 to the circuit 82 which in turn connects through blades 11 and 12 of switch 10 to the outgoing circuit 90. The outgoing circuit 90 connects through the filter 91 and the terminal amplifier 92 with the transmission line leading to a receiving station. The light beam activating the light sensitive cell 70 is a pulsating or carrier light beam and the variation in the intensity of the beam is caused by the light valve 20. The ribbon 27 of the light valve 20 is energized by an oscillator 30 which generates a sinusoidal wave of the order of 1,000 to 2,000 or more cycles per second. The oscillator 30 transmits its current through blades 13 and 14 of switch 10 and a connecting circuit to the amplifier 40 where the oscillating current is amplified and the output current of the amplifier passed through the ribbon 27 of the light valve thereby causing the light valve ribbon to oscillate at a substantially constant frequency. The movement of the light valve ribbon thus causes the light beam to rapidly vary in intensity in accordance with the frequency of the output current of the oscillator. The biasing battery 41 and the high resistance 42 afford means for adjusting the relation of the light valve ribbon with respect to the light valve aperture.

It has been found desirable in the transmission of pictures to provide for establishing a definite ratio between the maximum and minimum picture currents transmitted, and to provide for the transmission of a definite minimum carrier current at all times even when no light reaches the light sensitive cell. The purpose of this is to avoid overloading the transmission circuit apparatus such as repeaters and also to avoid inducing cross-talk in neighboring circuits, and to insure that the picture currents transmitted will be at an energy sufficient to avoid serious interference from noise currents. This may be accomplished as shown in Fig. 1 by using a part of the output current of the oscillator and adding it to the amplified picture currents, provision being made for adjusting both the phase and the magnitude of the former current with respect to the latter or vice versa. One way of adding a part of the oscillator output to the picture current is by means of the phase adjuster 85 and associated potentiometer 86 which connects the output side of the amplifier 40 through the circuit comprising the blades 15 and 16 of the switch 10 and the switch 87 to the circuit 82. By means of this phase adjuster, which may comprise a suitable network of variable impedances arranged in accordance with principles well known to the art, and the associated potentiometer, the output current of the oscillator can be phased with the picture current and the necessary unmodulated carrier current of the proper amplitude impressed upon the transmission circuit. With such adjustment the shunted carrier and the variable picture currents add directly. The variations in light shades or tones of the picture are represented in this case by a current in the output circuit of the light sensitive cell 70, whose frequency is the frequency of the current impressed upon the light valve ribbon and whose amplitude at any instant is proportional to the light transmitted by the picture. If the light valve is adjusted so that when there is no current flowing through its ribbon, the ribbon uncovers one-half of the light valve aperture, then the illumination will have a sinusoidal form represented by a constant added to a sine function, and at the same frequency as the current impressed upon the light valve ribbon, but with a phase displacement between its sine form component and the carrier of approximately 180° or multiple thereof. The width of the light valve ribbon should be equal to that of the light valve aperture and its maximum amplitude of vibration should be within one-half its width. It is obvious that the amplified photoelectric current will add directly to the shunted output current of the oscillator if the phase of the latter current is adjusted relatively to the former. The phase adjuster 85 is adapted to bring about the necessary phase adjustment. This arrangement of the light valve in association with the light sensitive cell is such that the varying currents from the cell have the same frequency as the variations of the light transmitted by the light valve and also the same frequency as the current from the oscillator operating the light valve. This arrangement is important for if the light valve ribbon were differently adjusted with respect to the light valve aperture with no current flowing through the ribbon, a double frequency in the light sensitive cell, for example, might be set up which would make it more difficult to add the desired carrier to the picture current.

In adjusting the apparatus for transmitting a picture it may be advantageous to ascertain the amount of current transmitted by the brightest and by the darkest portions of

the picture and for determining this a measuring device 83 is arranged so that by throwing switch 81 to its upper closed position the output circuit of the amplifier 80 may be connected to this measuring device. Upon placing in the light beam various portions of the film 50, or any other object of varying transparency, its transparency at different spots may be measured and indicated by the measuring device 83 in such units as may be desired. For example, the measuring device may have a scale calibrated to read in per cent of the total light. In putting the apparatus in operation the operator having ascertained the transparency of the lightest and the darkest portions of the picture may use this in adjusting the apparatus for transmission.

The same measuring device 83 which may comprise a suitable arranged vacuum tube amplifier detector unit is also used for indicating when the phase difference of the photo-electric current and the shunted oscillator output current is zero. In making such a comparison, both the switches 81 and 87 are thrown into their upper closed position, thereby causing the output from both the light sensitive cell 70 and the phase adjuster 85 to be impressed simultaneously upon the measuring device 83. Also the ratio between the maximum and minimum picture currents, and the magnitude of the shunted oscillator output can be determined by the use of this measuring device 83 and proper manipulation of the switches 81 and 87 for connecting with the two circuits. The magnitude of the picture current can be adjusted in a number of ways well known to the art such as by varying the voltage impressed upon the light sensitive cell.

The description so far has related primarily to the apparatus arranged for transmitting. When arranged for reception a part of the same apparatus as is employed for transmission is used and its connection is shown in the terminal station E at the right of Fig. 1. The switch 110 is thrown to the right and the relation of the light valve ribbon 127 with respect to the light valve aperture arranged so that with no current flowing through the ribbon the light valve is closed. When the switch 110 is thrown to the right only blades 111 and 112 are in circuit thus connecting the circuit 190 with the amplifier 140 and the light valve ribbon 127, and the other four blades 113, 114, 115 and 116 disconnect the oscillator 130 of the phase adjuster 185 from the operating circuit. The proper relationship of the light valve ribbon to the light valve aperture may be established mechanically by adjusting the light valve jaws or electrically by means of the biasing battery 141 and the potentiometer 142. The incoming picture current is amplified by the terminal amplifier 192 and then passed through the filter 191 and the amplifier 140 to the light valve ribbon. The received picture current impressed on the light valve ribbon controls its light transmission in a manner to reproduce the light effects of the distant picture and cause a light beam to be impressed upon the photo-sensitive film 150 on the cylinder 151 which is moved in synchronism and in phase with the picture at the transmitting station in accordance with standard practice well known in the art. Light from a steady source 121 is focused by the lens 122 on the light valve ribbon 127, and under control of the light valve is passed through the lenses 123 and 124 and the apertures 125 and 126 to the photo-sensitive film 150.

It is to be noted as previously set forth that the same apparatus units so far as may be required are employed for reception as are used for transmission and the principal adjustment necessary to put the terminal equipment into proper relationship for transmission or for reception are the circuit changes governed by the switches 10 and 110 at the terminals and the proper adjustments of the light valve ribbon with respect to the light valve aperture when no current is flowing. The interchangeability or dual use of the apparatus units for either transmission or reception simplifies the terminal equipment and its operation.

The relation of the light valve ribbon to the light valve aperture when no current is flowing is such that for transmission the light valve is half open and for reception the light valve is substantially closed as is shown at T and R, respectively, in Fig. 2. The primary reason for the half open position when no current is flowing when transmitting, as already explained, is to produce a varying illumination which when impressed on a light sensitive cell causes the latter to set up a varying photo-electric current of the same frequency as the current actuating the light valve. The closed position of the light valve when no current is flowing when receiving is due to the fact that the photo-electric current approaches zero when a dark portion of the picture is being transmitted and a maximum when the lightest portion of the picture is being transmitted. The adjustment of the relationship between the light valve ribbon and the light valve aperture as described in connection with Fig. 1 is based upon passing the proper biasing current through the light valve ribbon to cause it to take up the proper position for transmission or for reception and this requires adjusting the biasing current when the light valve is changed from transmitting to receiving or vice versa. In Fig. 2 is shown a mechanical means for making this change. Two light valve apertures T and R are used and permanently positioned in the apertured

member 28 in proper relationship to the light valve ribbon. Only one of these apertures is open at a time and this may be mechanically effected by any suitable arrangement such as the opaque shutter 29 capable of being positioned in front of either aperture as shown in the drawing. However, even when the mechanical arrangement shown in Fig. 2 is used the electrical biasing control would probably be advantageous for fine adjustments.

The illumination of the picture or film when plotted against time may be represented by a curve as indicated in Fig. 3. The illumination output of a light valve, properly adjusted, is approximately a linear function of the current input to the light valve ribbon so that the distortion from this source is negligible. This pulsating illumination has been described herein as producing a carrier light beam and as already explained it is impressed by means of a suitable optical system upon elemental areas of the picture whose image is being transmitted. One reason for employing a pulsating carrier light beam is to make possible the use of an alternating current amplifier and thus use a photo-electric current under conditions which permit of its being amplified with ordinary voice frequency alternating current vaccum tube amplifiers. The employment of such apparatus permits its use on existing telephone or other transmission circuits.

The pulsating carrier light beam in passing through the picture at the transmitter is modulated in accordance with the light density of the elemental areas of the picture and the current variations resulting from the modulated light beam being impressed upon the photo-sensitive cell at the transmitting station may be represented by a curve having a substantially uniform fundamental frequency but of varying amplitude as shown in Fig. 4. The fundamental frequency of the photo-electric current as heretofore explained is the same as that of the illumination.

The unmodulated carrier current which is impressed upon the transmission circuit at all times, irrespective of the photo-electric current, may be obtained as described in Fig. 1 by shunting a part of the oscillator output current to the outgoing circuit. An alternative optical arrangement is shown in Fig. 5. In the latter arrangement in place of the electrical shunt comprising the electrical phase adjusting apparatus, as shown in Fig. 1, a part of the carrier light beam is diverted by means of a partially transparent mirror 210 positioned in the path of the light beam in such relation that it diverts a small percentage of the total light to the light sensitive cell 70. In the path of the light diverted to the light sensitive cell, is a plane or preferably a concave mirror 211 and an adjustable aperture 212 arranged for directing and controlling the diverted light. By such an optical arrangement the major portion of the carrier light beam passes through the mirror 210 to the picture and a minor portion of the light is diverted to the light sensitive cell. When the apparatus is used for receiving the semi-transparent mirror 210 is moved out of the path of the light beam into the position indicated at 213. The current produced in the light sensitive cell by the two parts of the light beam will be in synchronism and in phase and consequently add directly to each other. The magnitude of the carrier current produced by the deflected part of the light beam may be adjusted by means of the aperture 212.

The terminal apparatus shown in Fig. 5 with the exception of the omission of the electrical shunt and the substitution of the optical shunt, above described for impressing carrier current on the outgoing circuit, is the same as Fig. 1, and with the exception of these differences, the same description applies to both figures.

What is claimed is:

1. In an electro-optical transmission system, means for producing a light beam, an oscillating current generator, a light valve actuated by current from said generator for varying the strength of said beam at a periodicity equal to that of said oscillating current, and means including a light sensitive element activated by said varying light beam for producing varying current of the same frequency as the current produced by said oscillator.

2. In an electro-optical transmission system, a transmission circuit, an analyzing light beam, a light interrupter in the path of said light beam, means for controlling the said light beam to produce a modulated carrier current in said circuit, and a source of supplementary unmodulated carrier current for establishing a minimum transmission level in said circuit.

3. In an electro-optical transmission system, a transmission circuit, an analyzing light beam, a light interrupter in the path of said light beam, a picture whose image is to be transmitted, means for controlling the said light beam to produce a modulated carrier current in said circuit varying according to the lights and shades of the said picture, and means for establishing a definite ratio between the maximum and minimum current representing the darkest and lightest areas of said picture.

4. In an electro-optical transmission system, a light valve for producing a carrier light beam, an oscillating current generator for actuating said light valve, a light sensitive element for producing photo-electric current of the same frequency as the current produced by the said oscillator, and means for adding

to the output of the said light sensitive cell current from the said oscillator of the same phase and frequency as that produced by the said light sensitive cell.

5. In an electro-optical transmission system, a transmission circuit, a light beam, a light interrupter rapidly and regularly interupting said beam thereby producing a carrier light beam, a carrier current generator actuating said interrupter, a light controlling means modulating the said carrier light beam, a light sensitive element excited by said modulated carrier light beam thereby producing modulated photo-electric current which is impressed upon the said transmission circuit, and a phase adjuster shunt for applying carrier current pulsations produced by the said carrier current generator to the said transmission circuit in phase with said photo-electric current.

6. In an electro-optical system for the transmission of pictures, a source of light, a picture whose image is transmitted, a light valve positioned between said light source and said picture, a current generator actuating said light valve at a substantially uniform frequency thereby causing said light valve to pass a pulsating light beam which is modulated by elemental areas of said picture, a light sensitive cell excited by the modulated pulsating light beam thereby producing a modulated pulsating photo-electric current, an alternating current amplifier energized by the modulated pulsating current from said light sensitive cell, and a phase adjuster circuit shunting a part of the input pulsating current transmitted to said light valve to the output circuit of the said light sensitive cell thereby impressing on the output circuit unmodulated carrier current which is applied to the outgoing transmission line even when the picture current from the photo-electric cell is zero, and means for adjusting the amplitude of this additional carrier to control the level difference corresponding to the maximum contrast in the said picture.

7. In an electro-optical transmission system, terminal equipment comprising a source of light, an electro-mechanical light valve for controlling a beam of light from said source, transmitting means including an oscillator for actuating said light valve for producing carrier current modulated in accordance with the tone values of the elemental areas of a picture to be transmitted, receiving means including a circuit for impressing received picture current upon said light valve, and switching means for converting said equipment from the transmitting to the receiving condition by disconnecting said oscillator from said light valve and connecting the circuit of the receiving means thereto.

8. In an electro-optical transmission system, an optical arrangement adapted for use for either transmission or for reception, a light valve having two apertures so related with the light valve ribbon that when no current is flowing through the said ribbon one aperture is substantially half open and the other aperture substantially closed, one of said apertures being adapted for transmitting a carrier light beam for producing carrier current for transmission and the second of said apertures being adapted for controlling the intensity of a source of light in accordance with received current for reception.

9. The combination with optical means for producing and focusing a beam of light, of light controlling means for controlling a characteristic of said light, means for causing signals received from a distant point to control said light controlling means, means for holding a light-sensitive element in such a position that said beam is focused thereupon for obtaining a visible indication of the signals from said distant point, a light-sensitive current-controlling element, and means for transmitting signals to a distant point comprising said light-sensitive current-controlling element controlled by light from said beam.

10. In an electro-optical transmission system, a transmission circuit, a signal controlled light beam, means for interrupting said beam to produce modulated carrier current in said circuit, and means for producing an additional component of unmodulated carrier current in said circuit for establishing a minimum transmission level therein.

11. In an electro-optical transmission system, a transmission circuit, a signal controlled light beam, means for interrupting said beam to produce modulated carrier current in said circuit, and means for producing an additional component of unmodulated carrier current in said circuit in phase with said modulated carrier current.

In testimony whereof, I have signed my name to this specification this 17th day of February, 1927.

FREDERICK W. REYNOLDS.