

Aug. 12, 1930.

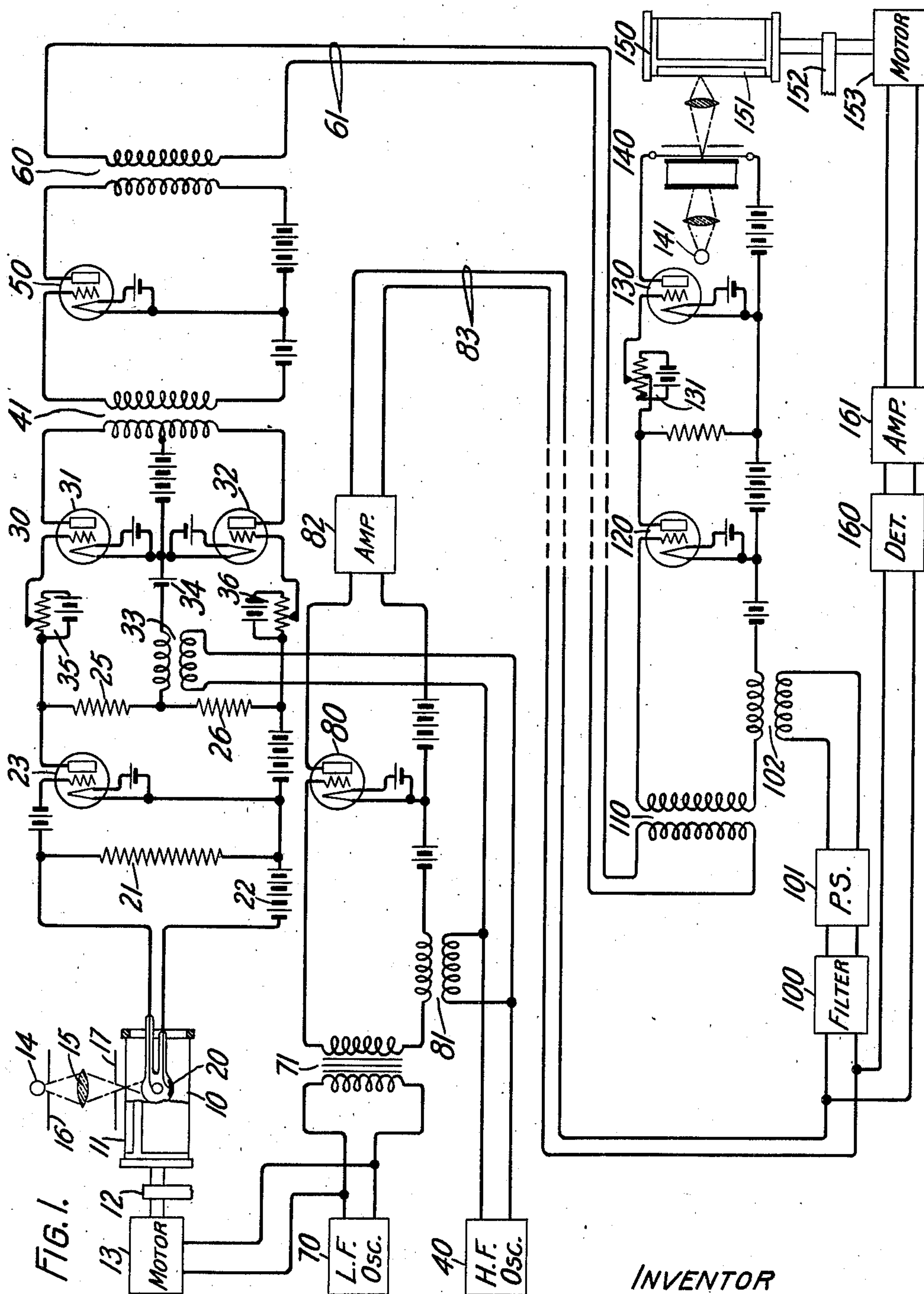
R. K. POTTER

1,772,519

ELECTROOPTICAL TRANSMISSION

Filed March 12, 1927

2 Sheets-Sheet 1



INVENTOR
RALPH K. POTTER

BY

g. f. for.

ATTORNEY

Aug. 12, 1930.

R. K. POTTER

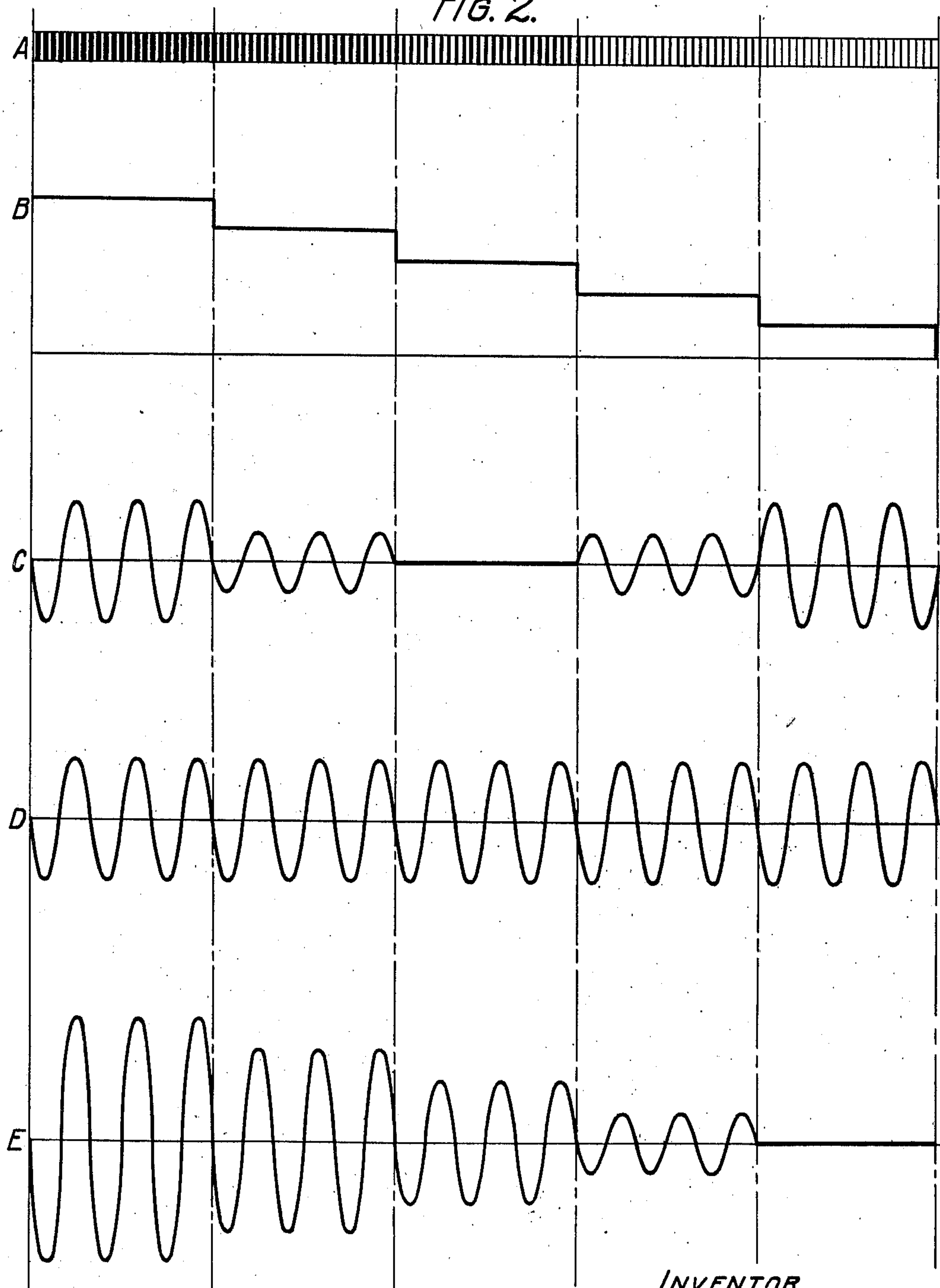
1,772,519

ELECTROOPTICAL TRANSMISSION

Filed March 12, 1927

2 Sheets-Sheet 2

FIG. 2.



INVENTOR
RALPH K. POTTER
BY *gerv*
ATTORNEY

UNITED STATES PATENT OFFICE

RALPH K. POTTER, OF NEW YORK, N. Y., ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

ELECTROOPTICAL TRANSMISSION

Application filed March 12, 1927. Serial No. 174,949.

This invention relates to electro-optical transmission, and more particularly to a method of and means for increasing the range of tone values represented by the permissible range of amplitude of the transmitted current in a picture transmission or television system.

In the usual picture transmission or television system one extreme of tone value of an object or picture the image of which is to be produced electrically, is represented by maximum amplitude of transmitted current, while the other extreme is represented by minimum amplitude. According to the present invention an intermediate tone value is represented by minimum amplitude of transmitted current which is preferably an alternating carrier current. Tone values lying to either side of this intermediate value are represented by currents of increasing amplitudes. A current representative of the tone values lying to one side of this intermediate value is displaced in phase by 180 degrees from the currents representative of the tone values lying to the other side of this intermediate value. Thus twice the signal level may be handled by a given repeater circuit where the system of this invention is used in place of the formerly used systems.

An arrangement embodying this invention, specifically stated, comprises a balanced vacuum tube modulator arrangement having a divided input circuit and a divided output circuit. Carrier waves are impressed upon the common portion of the divided input circuit, while amplified current from a photoelectric cell varying in accordance with the varying tone values of a picture, the image of which is to be produced, flows through the divided input circuit so that the potential produced thereby and impressed upon the grid of one tube increases, while that upon the other tube decreases. The grids are oppositely polarized so that for an intermediate value of amplified photoelectric current, minimum amplitude of carrier current is present in the output circuit of the modulator and transmitted to the receiving station. A portion of the carrier wave, unmodulated, is also transmitted to the receiving station over a

separate channel. At the receiving station the incoming modulated carrier wave and the unmodulated carrier wave are impressed upon the input of a detector, the phase of the unmodulated carrier wave being so adjusted that the output current of the demodulator contains a component of uni-directional current which varies in accordance with the variations in the amplitude of the amplified photoelectric current. This component of the detected current after amplification is impressed upon a light valve for controlling the exposure of a light sensitive record blank.

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

Figure 1 is a schematic representation of the arrangement of the transmitting and the receiving terminal apparatus of a picture transmission system selected for illustrating this invention.

Fig. 2 is a set of diagrams and curves illustrating light and current conditions at various points in the system.

The picture transmitting apparatus schematically shown in the upper half of Fig. 1 scans the object and controls the excitation of a light sensitive cell which translates the light effects of an object or picture being scanned into corresponding electric picture current. The picture scanning apparatus includes a transparent drum 10 on which is placed a transparent film 11 of the picture whose image is to be transmitted, which is given a motion of rotation and translation so that all elemental areas of the picture successively pass a given point. This drum is supported by the framework 12 mechanically actuated by means of the motor 13. A light source 14 and a suitable optical system consisting of the lens 15 and the apertured plates 16 and 17 focus a beam of light upon a small elemental area of the film 11. The beam of light upon passing through the film 11 impinges upon the light sensitive cell 20 and causes electric current variations through this cell which are substantially proportional to the intensity variations of the light excitation. The scanning apparatus above described may be similar to that shown in

Patent No. 1,695,048 granted to H. E. Ives December 11, 1928.

The output current of the photoelectric cell 20 varying in accordance with the impressed illumination produces a varying potential drop across the resistance 21 which is in circuit with the photoelectric cell and the source of current 22. This varying potential controls the space discharge amplifier 23 and the output current of this amplifier flows through the resistances 25 and 26 thereby setting up a varying potential drop across these resistances which is similar to that across the resistance 21. The potential variations across these resistances are impressed upon the "push-pull" space discharge modulating device 30, the varying voltage across the resistance 25 being impressed upon the grid circuit of the thermionic tube 31, and the varying voltage across the resistance 26 being impressed upon the grid circuit of the thermionic tube 32. A carrier current potential of suitable frequency is impressed through the coupling coil 33 equally upon the input circuits of these thermionic tubes. A negative grid biasing battery 34 is associated with each of the tubes 31 and 32. The push-pull relationship of the thermionic tubes 31 and 32 with the light sensitive cell is such that when light representative of the mean value or tone of the picture is impressed upon the light sensitive cell and causes a certain potential drop across the resistances 25 and 26, the amplitude of the resultant alternating current output from the modulating thermionic tubes 31 and 32 in the coupling coil 41 is, for this condition, reduced to zero and no current is transmitted through the coil. This zero condition is brought about by adjusting the biasing potentiometers 35 and 36, connecting with the grids of the thermionic tubes 31 and 32 respectively. Increasing the current from the light sensitive cell above that representative of the mean light value results in increasing the amplitude of the carrier current output of a given phase at the coupling coil 41 while decreasing the current below such mean value also results in increasing the amplitude of the carrier current output but with a phase displacement of substantially 180 degrees. The action of these tubes on the carrier current is illustrated and more fully described in connection with Fig. 2.

The picture current when it passes through a mean value as pointed out above varies the amplitude and causes a phase displacement of substantially 180 degrees of a high frequency carrier current which is generated by the oscillator 40. The phase reversal at medium light tone values results in a transmission current of one phase having a maximum amplitude variation over one-half of the light range of the picture and a transmission current of another phase displaced by substantially 180 degrees also having a

maximum amplitude variation over the second half of the light range of the picture. These currents are amplified by the amplifier 50 and impressed through the coupling coil 60 upon the transmission line 61.

In a picture or television transmission system it is necessary to operate the transmitting and receiving scanning systems in synchronism, and means are here shown employing a separate circuit or channel for interconnecting the scanning apparatus between stations. The transmitting synchronizing apparatus includes a low frequency oscillator 70 which controls the driving motor 13 of the transmitting scanning device and modulates a carrier current which is transmitted to the receiving station. A part of the output of the low frequency oscillator 70 is impressed through the coupling coil 71 upon the modulator 80 which is supplied through the coupling coil 81 with high frequency carrier current from the high frequency oscillator 40. The modulated synchronizing current is amplified by the amplifier 82 and then impressed upon the synchronizing transmission line 83.

The picture receiving apparatus schematically shown in the lower half of Fig. 1 comprises apparatus for receiving the picture current and translating it into light, and of apparatus for receiving the synchronizing current which causes the picture synthesizing apparatus at the receiving station to be given a motion of translation and rotation in synchronism and in phase with the scanning apparatus at the transmitting station.

The synchronizing transmission circuit 83, however, not only transmits a synchronizing modulated carrier current, but it also transmits the high frequency control picture carrier current, which is preferably not transmitted by the picture current transmission circuit 61 but is transmitted over this other channel and restored in proper phase relationship, frequency, and amplitude at the receiving station. This high frequency control picture carrier current may be generated at the receiving station and thus avoid the necessity of its direct transmission. A filter 100 passes the high frequency picture control carrier current which upon passing through the phase shifter 101 is impressed through the coupling coil 102 upon the circuits of the picture receiving apparatus. The picture transmission line 61 connects through the coupling coils 110 with the receiving circuit. The phase shifter 101 permits accurate adjustment of phase of the received constant frequency, constant amplitude picture control carrier current so that it can be properly combined with the incoming picture current. The potential variations of these two currents are superimposed and impressed upon the input circuit of the detector tube 120.

The detected picture currents in the output circuit of detector 120, having amplitude variations corresponding to the tone values of the picture, are amplified by the amplifier 130 and then impressed upon the light valve 140. The biasing potential on the amplifying tube 130 may be adjusted by means of the potentiometer 131.

Light from a source 141 is passed through the light valve and by means of a suitable lens system is focussed upon the receiving film 151 which is carried on the drum 150 of the receiving scanning apparatus. This drum is held in a suitable supporting frame 152 and given a motion of translation and rotation in synchronism and in phase with that of the corresponding apparatus at the transmitting station by means of the motor 153. This motor is maintained in synchronism with the motor at the transmitting station by the current sent over the synchronizing transmission line 83. The low frequency synchronizing current is detected by the detector 160, amplified by the amplifier 161, and then transmitted to the motor 153.

A plurality of picture current channels may be operated in conjunction with one control channel and one source of carrier current. This arrangement has the advantage of reducing the amount of terminal apparatus and transmission line facilities per picture system.

The foregoing description discloses the essential apparatus elements for translating the light from elemental areas of an object into corresponding electric current, its transmission by means of a carrier current to the receiving station, the reconversion there of the electric energy into light energy, and the production of a picture similar to the original. The processes of translating the light energy into electric current, causing such current to vary the amplitude and shift the phase of a carrier current for transmission, and its transmission, reconversion and detection so that the current in the receiving station as finally impressed upon the light valve causes the production of a picture of the object whose image is transmitted is illustrated in Fig. 2. The illustrations are divided into five sections corresponding to various light values, the first section that of the darkest shade of the picture, the last section that of the brightest shade of the picture, the middle section that of the medium shade of the picture, and the second and fourth sections that half-way between the extreme shades and the medium shade. A represents five different values of light intensity of the picture, starting with the darkest or black and varying by five successive steps to the lightest or white section. B represents the potential drop across the resistance 25 and 26 connected in series corresponding to the picture current set up by the light sensitive cell. C represents the cor-

responding amplitude variations and phase shift of the carrier current after leaving the modulating tubes 31 and 32 and as impressed upon the transmission line. The amplitude of the carrier wave after it has been modulated is greatest for the darkest portion of the picture and as the lighter portion is approached becomes less until the medium light intensity is reached when the amplitude is zero as shown by the middle section of this curve. As the light intensity passes through its medium value the phase of the carrier current is displaced substantially 180° and the amplitude then increases as the light values decrease until a maximum amplitude is reached for the lightest shade substantially equal to that for the darkest shade of the picture. D represents a carrier current of uniform frequency and amplitude. This carrier represented by D and modulated carrier current represented by C are superimposed and impressed upon the receiving apparatus. The carrier current impressed upon the receiving circuit has the same frequency as that of the received picture current and the two currents are combined at the receiving station in such phase relationship that for the picture current on one side of the medium value they are substantially in phase and on the other side of the medium value there is a displacement between them of substantially 180 degrees. E represents the amplitude variation and the elimination of phase reversals resulting from combining the carrier current and the picture current at the receiving station. The amplitude of the resultant current has an envelope similar to curve B. This current is detected in detector 120. After amplification in amplifier 130 the detected current is impressed upon the light valve which transmits light having values similar to those which generated the current represented by B, and thus makes possible the production of a picture similar to the one whose image is transmitted.

This method of transmitting the picture current not only results in a doubling of the amplitude of the transmitted picture signaling current without increasing the load on the transmission line, but it also reduces the effect of foreign interference such as line noises, level changes, and the like. In the system here disclosed foreign interference can be introduced through both the signaling circuit and the control circuit. Such interfering currents, due to the fact that the picture currents and the control currents are controllable in phase, permits the phase relations of these two currents to be fixed to produce the maximum amplitude of the picture signaling current. The interfering components introduced by the picture transmission and the control circuits are always varying in phase with each other and tend to partly neutralize each other, and the relative

phases of the two interfering waves received over these circuits will vary from zero to 180 degrees with the result that the two components will be separated by an average phase displacement of 90 degrees. The resultant interference does not equal the sum of the two components causing the interference but equals the square root of the sum of the squares, and consequently the interference is only increased in the ratio of 1.4 while the picture current is double. The relative magnitude of the interference is, therefore, only .7 of its original value. It follows that disturbing line interference has a less effect upon the received picture signal employed in this invention than in the usual arrangement where the entire picture variation is produced with a current having half the effective amplitude.

20 What is claimed is:

1. The method of producing an image of a picture or object by means of scanning devices at the transmitting and receiving points, which method comprises translating variations in light into variations in electric potential, modulating the amplitude of a carrier current in accordance with said variations in potential so that minimum carrier current represents an intermediate light value at the transmitter, and shifting the phase of said current whenever the light passes through said intermediate value.

2. The method of producing an image of a picture or object by means of scanning devices at the transmitting and receiving points, which method comprises translating variations in light into variations in electric potential, modulating the amplitude of a carrier current in accordance with said variations in potential so that minimum carrier current represents an intermediate light value at the transmitter, and shifting the phase of said current 180 degrees whenever the light passes through said intermediate value.

3. The method of producing an image of a picture or object by means of scanning devices at the transmitting and receiving points, which method comprises translating the variations in light into variations in electric potential, modifying a current in accordance with said potentials for transmission to the receiving point, minimum energy transmission corresponding to an intermediate light condition at the transmitter.

4. The method of producing an image of a picture or object by means of scanning devices at the transmitting and receiving points, which method comprises translating variations in light into variations in electric potential, transmitting current which varies in accordance with said potentials so that minimum current represents an intermediate light condition at the transmitter.

5. The method of producing an image of

a picture or object by means of scanning devices at the transmitting and receiving points, which method comprises translating variations in light into variations in electric potential, modulating the amplitude of a carrier current in accordance with said variations in potential so that minimum carrier current represents an intermediate light value at the transmitter, shifting the phase of said current 180 degrees whenever the light passes through said intermediate value, transmitting the modulated carrier current to the receiving point, combining at the receiving point with the modulated current a carrier wave of substantially the same frequency and having a uniform amplitude at least as great as that of the received modulated current in such a way that the carrier wave is in phase with the modulated carrier current when representing tone values lying to one side of said intermediate light value and displaced in phase by substantially 180 degrees for tone values lying to the other side of said intermediate light value.

6. The method of producing an image of a picture or object by means of scanning devices at the transmitting and receiving points, which method comprises translating variations in light into variations in electric potential, modulating the amplitude of the carrier current in accordance with said variations in potential so that minimum carrier current represents an intermediate light value at the transmitter, shifting the phase of said current 180 degrees whenever the light passes through said intermediate value, transmitting the modulated carrier current to the receiving point, combining at the receiving point with the modulated current a carrier wave of substantially the same frequency and having a uniform amplitude at least as great as the greatest amplitude of the received modulated current and substantially in phase with the modulated current representing light tone values darker than said intermediate light value and displaced in phase by substantially 180 degrees for modulated currents representing light tone values lighter than the said intermediate light value.

7. The method of transmitting and reproducing pictures electrically which comprises generating a sustained alternating carrier current, modulating said carrier current by picture currents and synchronizing currents, transmitting said picture modulated current over one channel, transmitting said synchronizing modulated carrier current over another channel to a receiving station, separating at the receiving station the synchronizing modulated current into the carrier component and the synchronizing component, using the synchronizing component to control the movement of the receiving apparatus, and combining the separated carrier

and the picture modulated carrier to control the reproduction of the picture.

5 8. In combination, a photoelectric cell adapted to be excited by the light effects of elemental areas of a picture or object whose
10 image is to be produced, a source of sustained alternating current, means for modulating said current in accordance with the current of said cell, and means for balancing said
15 modulating device to give minimum output when photoelectric currents of mean value are applied thereto.

20 9. The combination with two electron discharge devices each having an anode, a cathode and an impedance control element, of
25 means for maintaining said cathodes at the same potential, an input circuit for each of said devices, means for biasing said impedance control elements in opposite directions
30 with respect to the potential of said cathodes, means for impressing a wave upon said input circuit so as to similarly affect the potentials of said impedance control elements, means
35 for setting up potentials which vary in accordance with the light tone values of elemental areas of an object or picture, an image of which is to be produced, and means for
40 impressing said potentials upon said input circuits in such a manner that when the potential of one control element is increased that of the other is decreased.

In testimony whereof, I have signed my name to this specification this 8th day of March, 1927.

RALPH K. POTTER.

35

40

45

50

55

60