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R. C. MATHES

ELECTROOPTICAL TRANSMISSION

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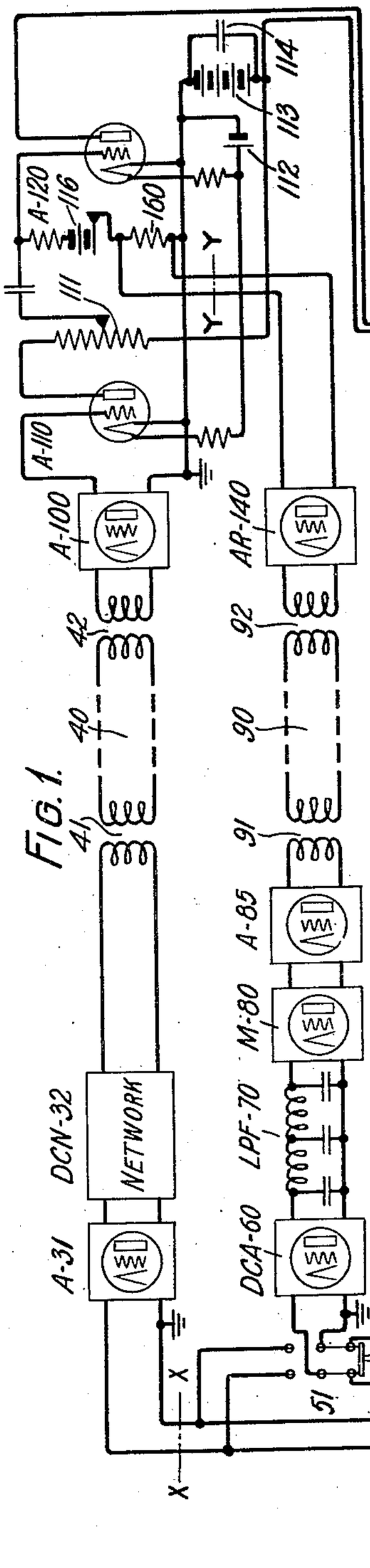
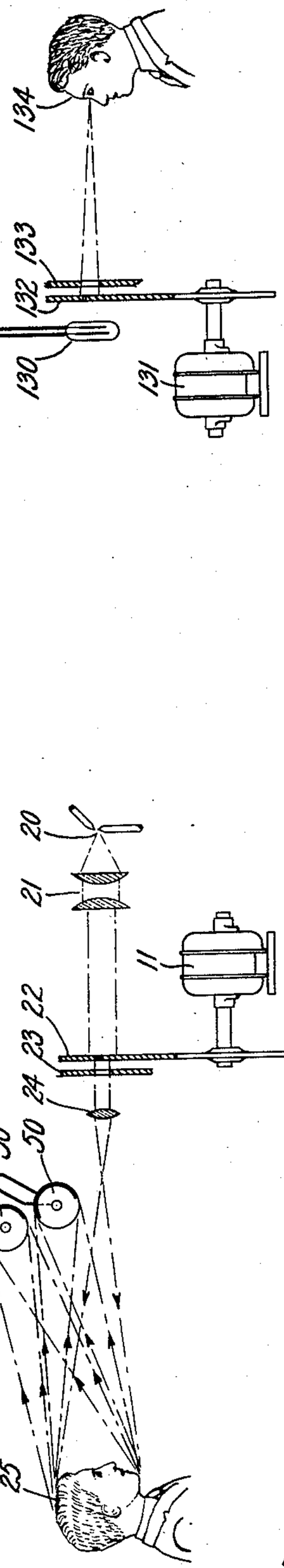


FIG. 1.



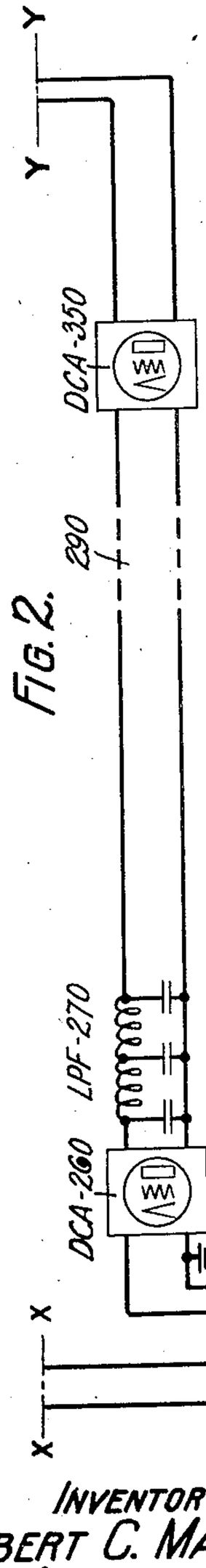


FIG. 2.

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UNITED STATES PATENT OFFICE.

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ELECTROOPTICAL TRANSMISSION.

Application filed May 31, 1927. Serial No. 195,252.

This invention relates to electro-optical transmission, and more particularly to television of moving objects or pictures.

In the usual type of television system the scanning of an object causes a photoelectric or other light sensitive cell to produce direct current fluctuations which vary from a very low to a very rapid rate. For the correct production of an image or picture of the object being scanned, it is necessary to produce at the receiving point effects corresponding to substantially all frequencies involved in the process of scanning the object, from direct current, or zero frequency, to very high frequencies.

The current variations generated in a photoelectric cell are very minute and in order to bring their intensity up to a usable value a vacuum tube amplifier having a large number of stages is required. It has been found, however, that such large amplification, at least from a practical point of view, necessitates the suppression of the low frequency components from zero up to frequencies of the order of 10 cycles per second, as disclosed in the copending application of Herbert E. Ives and Frank Gray, Serial No. 181,511, filed April 6, 1927. Furthermore, when transmission takes place over a commercial telephone channel arranged for the transmission of frequencies up to approximately 40,000 cycles per second, it is very difficult to arrange for the transmission of these very low frequencies, especially if intermediate or repetition amplification is required, even if they are not earlier suppressed to avoid terminal amplifier difficulties.

The effect of eliminating these lower frequencies may be illustrated by considering the results obtained in transmitting images of objects having different average tone values. Let the first be quite dark in average value and require fluctuations in the signal current of a certain absolute amount for its transmission. Such a picture would have a low direct current component. Let the second consist largely of medium grays and require about the same fluctuations in signal intensity for its delineation as the first. Such a picture will have a medium direct current component. Let the third be very light in average tone value with such differences in light and shade as would require the same fluctuations in signal intensity as the other two. Such a picture would have a high direct current component. The signals from all three types in passing through the amplifier are changed to alternating current fluctuations of about the same average value. For satisfactory image production effects corresponding to these direct current components must be obtained at the receiving station either by inserting corresponding components there from a local source or by transmitting them from the transmitting station. In either case the value of these direct current components at the receiving station should vary substantially in accordance with those at the transmitting station in order to maintain the correct tone value of the object whose image is being transmitted. If they are not so varied the best average result may be obtained by having the direct current component correspond to that most suitable for the gray picture, above referred to, in which case it would be most correctly produced and the dark and the light pictures would also be produced as pictures having a medium gray average tone value instead of their true average tone values. An arrangement for manually providing the direct current components at the receiver is disclosed in the Ives-Gray application, supra.

The present invention comprises an arrangement for automatically obtaining substantially correct average tone value of the picture produced at the receiving station. This result is brought about by inserting and automatically varying the value of the direct current component at the receiving station substantially in accordance with the variations of the direct current component generated in the process of scanning at the transmitting station. When an object is scanned in a television system, as already set forth, the resulting current variations are manifest as alternating and direct current components, the former primarily representing the details of the picture and the latter the average tone value of the picture.

In an arrangement selected for illustrating this invention two transmission channels are employed, one having a wide frequency range for transmitting the alternating current components and another having a narrow frequency range for transmitting the

direct current component. By such a division of the picture current a commercial telephone circuit may be used for transmitting the alternating current component and a commercial telegraph circuit may be used for transmitting the direct current component, though neither one of such commercial circuits may be capable of transmitting all of the picture current variations. Such an arrangement facilitates high quality television transmission over circuits of these types.

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

Fig. 1 is a schematic representation of a television system illustrating this invention.

Fig. 2 shows an alternative arrangement for a part of Fig. 1.

The transmitting terminal equipment includes suitable apparatus for illuminating and scanning the object and for translating the light variations of the object into electric current variations, amplifying these currents and impressing them on transmission circuits for transmitting to the receiving apparatus which includes apparatus for amplifying, controlling and translating these currents into light varying in intensity and in position in a manner to product a picture of the object whose image is being transmitted.

As shown in Fig. 1 the scanning apparatus at the transmitting station includes a powerful light source 20 whose light is directed by means of lenses 21 upon the scanning area of a scanning disc 22. This disc contains a series of small apertures arranged in spiral form. The area which may be scanned by such a disc is determined by the pitch of the apertures and the radial width of the spiral and the distance of the object from the disc. The light upon passing through any one of the apertures in the scanning disc passes through the apertured screen 23, whose opening is so dimensioned that light coming through only one aperture in the disc 22 can at any instant pass, and a lens 24, to the object 25 whose image is transmitted. The scanning disc 22 is operated by the driving motor and synchronizing apparatus 11 in synchronism with the receiving apparatus. As the scanning disc rotates it causes a small beam of intense light, passing successively through each one of its apertures, to scan in a series of parallel paths the object whose image is transmitted, and reflected light from each elemental area of the object is successively impressed upon a photoelectric cell or other suitable light sensitive device 30, thereby setting up current variations in accordance with the light tone values of the elemental areas of the object. Further details of a suitable scanning and light translating arrangement of this type are shown in the copending application of Frank Gray, Serial No. 181,538, filed April 6, 1927. A suitable synchronizing system for driving both the transmitting and the receiving apparatus is disclosed in a copending application of H. M. Stoller and E. R. Morton, Serial No. 181,314, filed April 6, 1927.

The picture current of varying amplitude from the light sensitive device 30 is amplified with substantially no distortion for variations above 10 or 15 cycles per second by the multi-stage space discharge amplifying apparatus A—31. It is next passed through a delay circuit network 32, whose function will be described later, and then impressed through the repeating coil 41 on the transmission line 40. The transmitted current is an alternating current of varying amplitude representative of light variations above and below the average tone value of the object being scanned. The advantages of employing alternating signal current and further details of apparatus for its transmission are disclosed in the copending application of Herbert E. Ives and Frank Gray, Serial No. 181,511, filed April 6, 1927, supra.

The incoming alternating signaling current from the transmission line is impressed upon the input circuit of the receiving amplifying apparatus A—100 by repeating coil 42. The amplified alternating signaling current is then impressed upon the input circuit of the space discharge device A—110 which further amplified the signal and has a potentiometer 111 in its output circuit to provide means for varying the amplitude of the signaling current at this point. The alternating signaling current of the proper intensity is next impressed upon the grid circuit of space discharge device A—120 which in turn connects with receiving glow discharge lamp 130. Filament current for the amplifier tubes is supplied by the common battery 112 and space current is supplied from the common battery 113. The battery 113 is shunted by a condenser 114 which facilitates the passage of alternating signaling current and substantially eliminates the effects of voltage variations of the battery. A grid bias of the proper amount is applied to each stage and in connection with the last stage an adjustable fixed biasing is provided for by the movable contact connecting to the biasing battery 116.

The general operation of the scanning device at the receiving station is similar to that of the scanning device at the transmitting station. The essential elements comprise a synchronous driving motor element 131 which operates the scanning disc 132 in synchronism and in phase with the scanning disc 22 at the transmitting station. The field of view at the receiving station is bounded by a rectangular opening in the aperture plate 133 and the dimensions of the field are equal to the radial depth of the spiral of aper-

tures in the scanning disc 132 and the distance between any two adjacent apertures in the disc. The position for viewing a received picture is indicated by the observer 134 and is such that the line of sight upon passing through the field of view bounded by the opening in the plate 133 and through an aperture of the scanning disc, an elemental area of the receiving glow discharge lamp 130 is visible. Each revolution of the scanning disc successively passes each aperture across the field of view and causes a scanning of its entire area.

As already pointed out the amplifying apparatus employed in the main transmission system above described is not designed to pass frequencies below the order of 10 or 15 cycles per second, and the arrangement provided in accordance with this invention includes means for correcting for this limitation. The effect of the low frequency components which are not transmitted by the main transmitting channel are impressed upon the receiving apparatus by means of a second transmission channel which is controlled, either by the main or an auxiliary photoelectric cell at the transmitting station. This correcting current made up of direct current varying in amplitude is obtained from the auxiliary photoelectric or other light sensitive cell 50 when the switch 51 is in the position shown in the drawing or from the photoelectric cell 30 when the switch is in its alternative closed position. This current after being amplified by a direct current amplifier DCA—60 having as much amplification as can be reasonably maintained, is passed through a low pass filter LPF—70 having a cut-off at about 10 or 15 cycles per second so that the current coming out of it represents the average value of the variations over a period of time at least equal to the flicker time, the flicker time being substantially the same as that of the persistence of vision. It probably will be desirable to average the current over a somewhat longer period of time as in the case when the cut-off of the low pass filter LPF—70 is, say, 10 cycles per second. However, the current passed by the filter LPF—70 is transmitted to the modulator M—80, next to the amplifier A—85 and then impressed through the repeating coil 91 on the transmission line 90 for transmission to the receiving station. The current from line 90 is then impressed through the repeating coil 92 upon the amplifier rectifier AR—140 at the receiving station. The amplified resultant correcting current is now a direct current of suitable strength, and is impressed across the resistance 160 in the grid circuit of the last tube of the receiving amplifier A—120. The varying direct current passing through the resistance 160 from the second channel varies the biasing or the operating point on the characteristic curve of the last amplifying tube and thereby effects the insertion of the correcting direct current component, as the passing of a suitable correcting current through this resistance produces the desired result by changing the effective negative grid potential of this tube. The correcting current transmitted by the low pass filter LPF—70 is of low frequency and consequently causes a low frequency variation in the carrier current amplitude and hence the transmission channel required for this auxiliary current need not have a wide frequency range. This permits the use of a transmission channel, such as an ordinary voice frequency telegraph channel, for transmitting this current. By this arrangement of automatically biasing the last tube in the receiving amplifier, substantially the same effect is produced as would occur if the low frequencies were directly transmitted over the main transmission channel.

A refinement for the most correct production of pictures may be made by introducing a delay circuit network at some point in the main transmission system so that the low frequency correcting currents will be substantially in phase with the high frequency impulses. Such a compensating delay circuit network DCN—32 in the main transmission circuit has been referred to, but a description of its action has been deferred until all of the apparatus shown in Fig. 1 has been described since this delay circuit is designed to operate in cooperation with the low pass filter LPF—70 in the low frequency transmission circuit. The latter, which is a primary element in the low frequency circuit transmitting the direct current components, causes transmission lag in this circuit. The delay circuit network in the main transmission circuit is designed to introduce a corresponding lag in the high frequency transmission circuit so that there is substantially no time displacement between the alternating current components and the corresponding shifts in the value of the direct current component transmitted by the two circuits upon reaching the receiving station due to the action of the delay circuits under consideration. The delay circuit network DCN—32 would in general comprise a filter network of the low pass type. An acoustical arrangement suitable for this is shown in the copending application of R. C. Mathes, Serial No. 155,155, filed December 16, 1926. This compensating delay circuit network might be located at the receiving station. It may even be omitted as it will be a rare occurrence for the character of an object or scene to change so largely and so suddenly as to produce a serious disturbing effect. Such a disturbing effect furthermore would appear simply as an incorrect average tone value lasting only for the time of the delay

introduced in the correcting circuit while the details of the picture would come through correctly.

The light sensitive cell 50 need not have the highest speed of action, in fact a sluggish cell having a high sensitivity is preferable and may be used in the arrangement shown in Fig. 1. However, if it is possible to employ a cell so sensitive that the current with a small amount of amplification is large enough for transmission it may be transmitted over a direct current telegraph circuit and amplified at the receiving station.

Such an arrangement wherein the low frequency picture components are produced in a light sensitive cell which is so sensitive that the current is large enough for amplification in a direct current amplifier comprising a few stages to the point of being strong enough for transmission over a direct current telegraph circuit to the receiving station is shown in Fig. 2. A light sensitive cell, such as a selenium cell or a thalo-sulphide cell, which has a greater sensitivity than the photoelectric cell, but is sluggish in its action may be used in this arrangement. In Fig. 2 the auxiliary light sensitive cell 250 is connected with the direct current amplifier DCA—260 which in turn connects with a low pass filter LPF—270. This amplifier and filter are the same as the corresponding ones shown in Fig. 1, DCA—60 and LPF—70, respectively. The outgoing terminals of the filter LPF—270 connect with the direct current transmission circuit 290 which in turn connects with the incoming terminals of the direct current amplifier DCA—350 at the receiving station. The output circuit of this amplifier connects across the terminals of the resistance 160, the same as the amplifier-rectifier AR—140 shown in Fig. 1. The low frequency transmission circuit and terminal apparatus as described and shown in Fig. 2, may be used as a substitute for the corresponding low frequency circuit and terminal apparatus shown in Fig. 1. In substituting one circuit for the other the points of connection are indicated by X—X and Y—Y. In Fig. 1 the low frequency components modulate a low frequency carrier current and are transmitted as alternating current over a voice frequency telegraph circuit, while in Fig. 2 the low frequency components are transmitted as varying direct current over a direct current telegraph circuit. The arrangement shown in Fig. 2 requires a light sensitive cell sufficiently sensitive to produce picture currents of a strength which enables them to be amplified in a direct current amplifier with so few a number of stages that its stability may be maintained when producing outgoing picture currents of the required strength for direct transmission to the receiving station, while in the arrangement shown in Fig. 1 the pulsating picture currents passing through the low pass filter may be much weaker when used to modulate a carrier current which is subsequently amplified and transmitted. The type of low frequency transmission which will be used in any given case will depend upon the distance of transmission and the facilities available.

The general operation of the system is as follows: Photoelectric or picture current is produced in the light sensitive cells 30 and 50 by light impressed upon these cells in the process of scanning. The component frequencies of the picture current above 10 to 15 cycles per second are amplified by the amplifier A—31 and impressed as alternating current upon the transmission line 40. The picture current is also amplified by the direct current amplifier DCA—60 but only the low frequencies are passed by filter LPF—70 which has an upper cut-off frequency of the order of 10 to 15 cycles. The picture current resulting from scanning is thus divided for transmission at a frequency equal to or somewhat below the flicker frequency. In general the higher frequency components represent the details of the picture and the lower frequency components the average tone value of the picture. Each of these components has been amplified and is ready for transmission over suitable channels which may be provided by two circuits as shown in the accompanying drawing, or over a single circuit using carrier currents such as a radio channel. When the two components are impressed upon the receiving apparatus, they are so combined as to produce a resultant picture current corresponding to that produced by the scanning operation. The two components act jointly on the input circuit of the amplifier tube A—120, the component comprising the frequencies above 10 to 15 cycles being impressed directly upon the grid of this tube and the component comprising frequencies below 10 to 15 cycles varying the grid bias of this tube in such a manner that the output current from this tube varies substantially the same as the output current from the light sensitive cell at the transmitting station. When an object is viewed it presents a mean degree of illumination productive of a mean direct current value in the photoelectric cell upon which is superposed a varying current produced by the point by point variations in the reflective power of the object or the density of a film depending upon which is used for transmission. This mean direct current or direct current component will not have a constant value but will change from time to time during transmission as the general aspect of the field of view changes, rising with a greater proportion of bright areas in the field and falling

with an increasing preponderance of dark areas. The auxiliary transmission circuit which transmits the frequencies up to 10 or 15 cycles per second provides for properly producing this means direct current or direct current component at the receiving station and for automatically varying its value in accordance with the average tone changes in the picture, while the main transmission circuit which transmits all frequencies above those of 10 to 15 cycles per second produces the details of the picture superposed upon the correct average tone values produced by the direct current component.

While in the arrangement shown the circuit networks are divided as between the transmitting and the receiving stations, all of the circuit networks might be placed at the transmitting station for obtaining highly amplified picture currents containing all components for use in operating suitable transmitting apparatus. An advantage of such an arrangement is the production of powerful direct current picture current for transmission or use in any manner desired.

What is claimed is:

1. A television system comprising means for setting up picture currents corresponding to repeated point-by-point scannings of an object whose image is to be produced, means for transmitting the low frequency current components of the electric current which represent the average tone value of the object over one electrical transmission channel, and means for transmitting the remaining higher frequency components which represent the details of the picture over a second transmission channel.

2. A system for producing an image of an object at a distant point comprising means for setting up picture currents involving a wide range of frequencies, two independent transmission channels, means for transmitting a band of frequencies within said range over one of said channels and another band within said range over the other of said channels, and means for utilizing received currents within both of said bands in the production of the image.

3. A system in accordance with claim 2 in which said means for utilizing received currents includes means at the receiving station upon which effects produced by said currents are simultaneously impressed.

4. A system in accordance with claim 3 in which said means upon which received currents are simultaneously impressed is an impedance element in the input circuit of an electron discharge repeater.

5. A system in accordance with claim 2 including means for repeatedly scanning the object point by point, means for causing the band of frequencies transmitted over one channel to include frequencies corresponding to periods shorter than a single scanning period, and means for causing said band of frequencies transmitted over the other channel to include frequencies corresponding to periods longer than a single scanning period.

6. A system in accordance with claim 2 in which one of said bands comprises frequencies of the order of 10 cycles per second upward and the other band comprises frequencies of the order of 10 cycles per second downward.

7. A system in accordance with claim 6 in which one of said channels is a commercial telephone line.

8. A system in accordance with claim 6 in which one of said channels is a commercial telephone channel and the other is a commercial telephone channel.

9. A system in accordance with claim 2 including a delay circuit in at least one of said channels.

10. A system in accordance with claim 2 including a delay circuit in both of said channels.

11. A system in accordance with claim 5 including a source of carrier current, and means for modulating said carrier current with said lower frequency band.

12. In a television system, scanning means for producing picture current in one frequency range, other scanning means for producing picture current in a different frequency range, and means for combining the effects of the two currents to produce an image of an object or picture being scanned.

13. In a television system, a light sensitive device rapidly responsive to light variations but of low sensitivity, a second light sensitive device slowly responsive but having high sensitivity, means to excite both devices in accordance with point-by-point scanning of an object or picture whose image is to be produced, and means jointly controlled by both said devices to produce an image of the object or picture.

14. A television system comprising scanning means including a photoelectric cell, means for transmitting the current corresponding to the alternating current component of the direct fluctuating current generated by the photoelectric cell of the scanning means, means for transmitting the direct current component of the direct fluctuating current generated by the photoelectric cell, and means at a receiving station for combining the said alternating current component and the said direct current component to produce a received picture current having characteristics corresponding to the picture current generated by the photoelectric cell at the transmitting station.

15. A television system comprising a light-sensitive cell, means associated therewith at a transmitting station for suppressing the direct current component and for

transmitting the fluctuating current component from said cell, a second light-sensitive cell, means associated with said second cell at the transmitting station for suppressing the fluctuating current component and transmitting the direct current component from said second cell, and means to utilize effects of both transmitted current components in the production of an image.

16. A television system comprising a light-sensitive cell, a space discharge amplifier of high amplifying power, amplifying and transmitting substantially all frequencies above those of the order of 10 cycles per second from the said light-sensitive cell, a second light-sensitive cell, and a space discharge amplifier therefor of high amplifying power, amplifying and transmitting substantially all frequencies below those of the order of 10 cycles per second from the second said light-sensitive cell.

17. A television system comprising means to produce picture currents involving alternating current components and a direct current component, means for transmitting to a receiving station the alternating current component over one transmission channel and the direct current component over a second channel, means including an amplifying tube having a grid for amplifying the received alternating current component, and means for automatically varying the negative grid bias of said amplifying tube in accordance with variations in the received direct current component.

In witness whereof, I hereunto subscribe my name this 26th day of May A. D., 1927.

ROBERT C. MATHES.