July 23, 1940. J. R. HEFELE 2,208,927

ELECTRO-OPTICAL IMAGE PRODUCTION

Filed Sept. 2, 1936 2 Sheets-Sheet 1

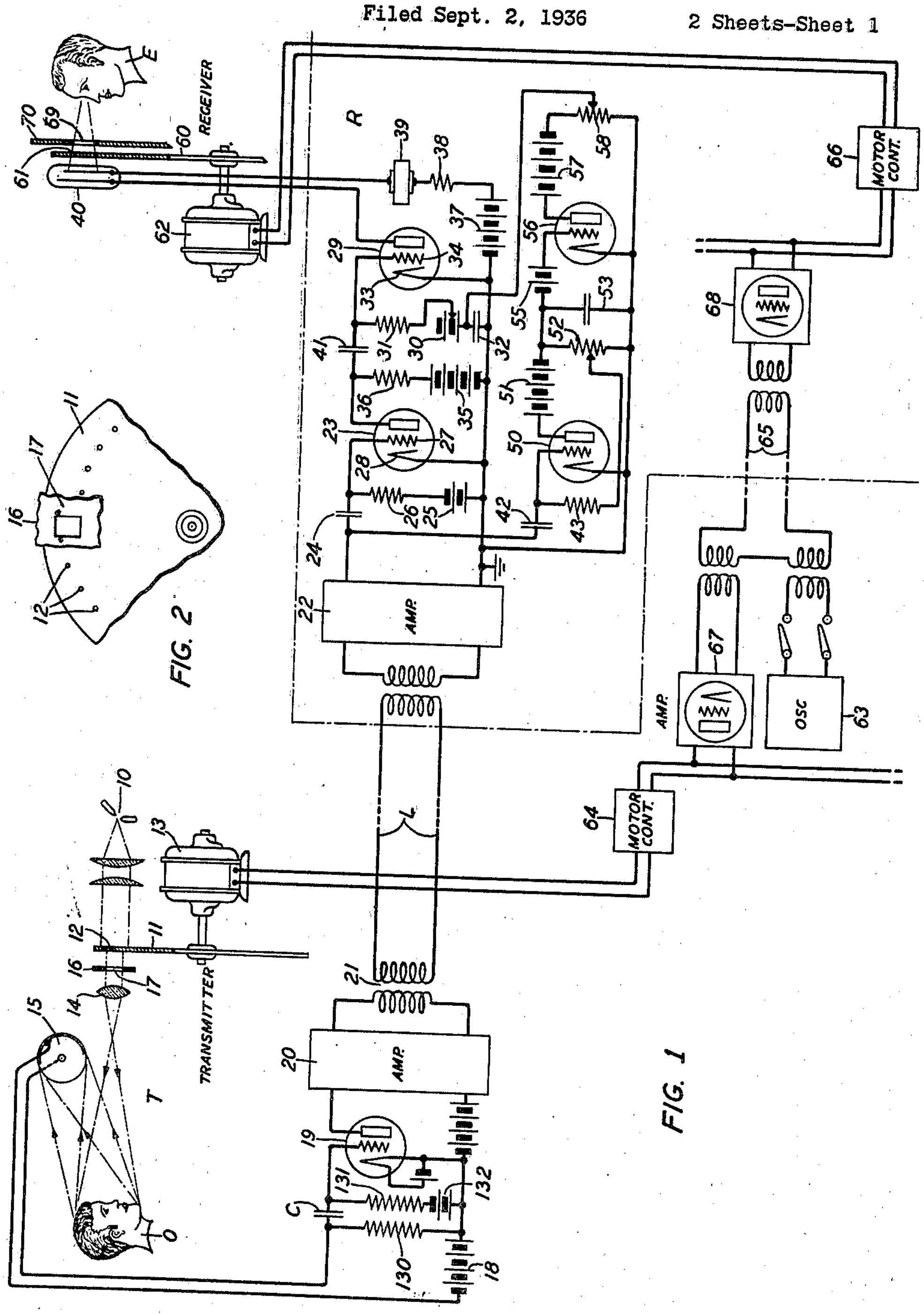

FIG. 1

FIG. 2

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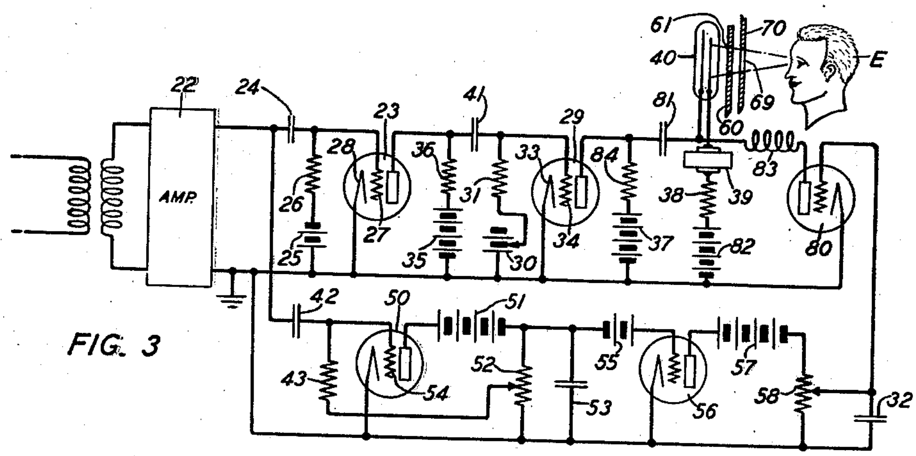

FIG. 3

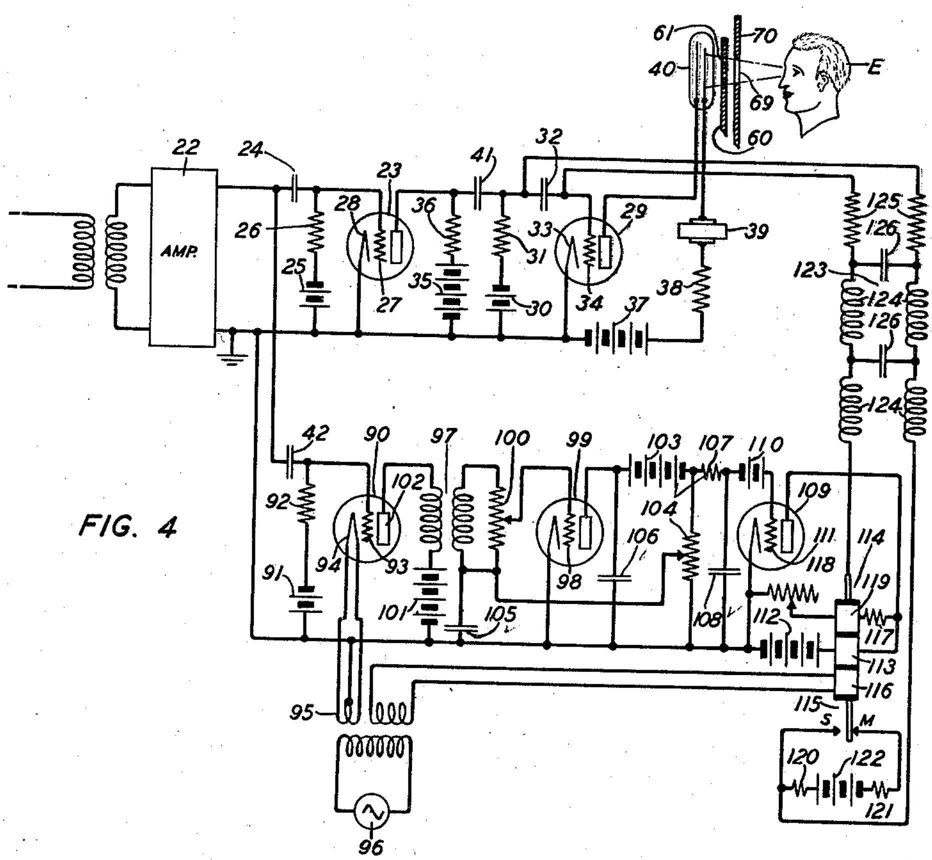

FIG. 4

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ELECTRO-OPTICAL IMAGE PRODUCTION

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3 Claims. (Cl. 178—7.3)

This invention relates to electro-optical image production and particularly to apparatus for and method of producing television images.

An object of this invention is to improve the quality of television images by increasing the accuracy with which the light tone values of the field of view are reproduced in the images thereof.

In the television system shown and described herein for the purpose of illustrating this invention, there is produced a unidirectional image current having amplitude variations corresponding to the tone values of successively scanned elemental areas of a field of view and having other amplitude variations produced as the result of periodically reducing the current to a value equal to or preferably less than that produced when scanning an area of black tone value. Such a reduction in amplitude may be introduced at the end of each scanning line of a field of view, as, for example, by periodically interrupting the scanning of the field of view, and, therefore, the light activation of the light sensitive element employed in scanning. The electrical transmitting apparatus upon which this unidirectional image current is impressed suppresses the direct component which is representative of the average tone value of the field being scanned and which varies in amplitude as the average tone value of the field changes. The amplitude of the steady component of the unidirectional image current, which component is representative of the average tone value over a given period, varies in accordance with the amplitude of the impulses set up as the result of periodically interrupting the scanning. In the alternating image current, the amplitude of the impulses produced as the result of periodically interrupting the scanning, measured between the peaks of the impulses and zero, varies in accordance with the amplitude of the suppressed direct component and, therefore, in accordance with the average tone value of the elemental areas scanned between successive interruptions of the scanning. These "black" or "correcting" impulses are utilized at the transmitter or receiver for controlling apparatus for correcting for the suppression of the direct component of the unidirectional image current.

In accordance with the invention, a television system is provided in which a source of image electromotive force, the direct component of which has been suppressed, is connected to the input of one of a plurality of amplifier stages of a television current transmission circuit and in parallel therewith to a circuit for correcting for the suppression of the direct current component, the output of the correcting circuit being connected to the television transmission circuit at a position subsequent to the first stage.

In a preferred embodiment, the television electromotive force is supplied to an amplifier stage of the corrector circuit through a small condenser. The output of the amplifier is connected to a self-biased detector which selects the peaks of the impulses representing black tone values. A mechanical relay controlled by the detected current controls the charging of a condenser in the input circuit of the final amplifier stage of the television circuit to control the average current in the output circuit of the amplifier.

Other arrangements for correcting for the suppression of the direct and low frequency components of the television image current, which components are representative of the average tone value of the field of view at the transmitting station may be used. Several of these arrangements are described in greater detail hereinafter.

While the correction for the suppression of the direct component is important in all television systems to improve the quality of the received image, it is especially necessary in color work. For example, assume a three-color system having red, green, and blue components such as is shown in Patent 2,037,166 issued April 14, 1936, to J. R. Hefele. If the elemental area of the object is red, the green and blue lamps at the receiver would still glow with average brightness unless means such as the circuits to be hereinafter described are provided to reduce the current flowing through the blue and green lamps to a negligible amount.

The invention will be more readily understood from the following description taken in connection with the accompanying drawings forming a part thereof in which:

Fig. 1 is a diagrammatic view of a television system, including apparatus for inserting a direct component into an image current which corresponds to that which has been suppressed at the transmitting station;

Fig. 2 is a detail showing of a portion of the scanning apparatus of Fig. 1; and

Figs. 3 and 4 are diagrammatic views of other arrangements for correcting for the suppression of the direct component of the image current generated at the television transmitting station.

Referring now to Fig. 1, there is shown, by way of example, a television transmitter T and a television receiver R connected by a suitable line L. The transmitter comprises a source of light 10 of constant intensity associated with an optical system, including a disc 11 provided with a row of apertures 12 arranged in a spiral line and adapted to be rotated by a motor 13, and a lens system, shown by way of example as a lens 14. Rotation of the disc 11 causes light from the source 10 to pass through the successive apertures 12 to thereby produce a moving beam of light which is directed by means of the optical system 14 to illuminate successively the elemental areas of the field of view O. The disc 11 is rotated at a speed such that, for one complete revolution, elemental areas of parallel adjacent lines of the complete field of view O are successively illuminated within the period of persistence of vision. Light reflected from the successive elemental areas of the field of view O reaches a light sensitive electric device 15, which is thereby activated to produce an image current varying in accordance with the tone values of such elemental areas. In front of the disc 11 is a screen 16 of opaque material provided with an opening 17 which determines the size of the field O. The opening 17 is so dimensioned that light passes through the apertures 12, one at a time, to the field of view O.

For the purpose of the present invention, the scanning apparatus operates in such a manner that the scanning of the field of view is periodically interrupted for a brief interval one or more times during each complete scanning period. In a preferred arrangement for effecting this result, the lateral distance between the apertures 12 of the disc 11 is made greater than the width of the opening 17 in the screen 16, by an amount equal to the width of one or a few elemental areas, as shown in Fig. 2.

The light sensitive device 15, supplied with energizing current from the direct current source 18, will be activated, under control of the above described optical system, to produce a unidirectional image current. This unidirectional image current consists of a slowly varying direct component the amplitude of which corresponds to the average of the tone values or brightness of the field of view O, and alternating components of different frequencies, respectively, the amplitudes of which are determined by the successively scanned elemental areas of the field of view. The frequencies of these alternating components may extend from a frequency of one million cycles or more, to a low frequency which is approximately the frequency of scanning of the entire field of view, i. e., around twenty cycles per second. When no light is applied to the light sensitive device, due to the interruption of the scanning light beam, for example, the amplitude of the current supplied by the light sensitive device 15 will be reduced to a low value, substantially zero, for example.

While the major portion of the image current band may be satisfactorily transmitted over well-known communication circuits, for example, telephone lines or coaxial cables, it is well known that such transmission circuits include apparatus which suppresses or greatly attenuates the direct and very low frequency components of a television signal.

The electromotive force across a resistive element 130 in circuit with the light sensitive device 15 is applied to a circuit including a coupling condenser C and the input circuit of an amplifier thermionic tube 19 which includes a resistor 131 of relatively high resistance and a biasing battery 132. The coupling condenser C suppresses the direct current component of the unidirectional image current. The tube 19 is connected through additional stages of amplification 20 and transformer 21, to a line L. There is thus impressed upon the line L an alternating image current including the correction impulses which are of larger amplitude than other portions of the image current and of a polarity the same as that produced by scanning black elemental areas. In this respect, the present invention is similar to the invention in an application of W. A. Knoop filed Sept. 2, 1936, Serial No. 99,023. Different means are used in the present invention, however, to correct for the suppression of the direct current component. In the circuits of this invention, there is no possibility of oscillations being set up due to feedback through the correcting circuit.

At the receiving station the line L is connected through a transformer to a suitable amplifying device 22 which may comprise a plurality of stages, and the output circuit of the amplifier 22 is connected through the condenser 24 to the input electrodes of an electron discharge device 23. The customary biasing battery 25 and resistor 26 are used in the circuit between the grid 27 and the cathode 28 of the electron discharge device 23. The output circuit of the device 23 includes a source of plate potential 35 and an output resistor 36. The output of the tube 23 is connected to the input circuit of a second electron discharge device 29 by means of a circuit including a coupling condenser 41. The circuit between the cathode 33 and the grid 34 of the device 29 consists of a biasing battery 30, a resistor 31 and a condenser 32 connected in series, a portion of resistor 53 being shunted across this condenser. The output circuit of the tube 29 includes a source of plate potential 37, resistor 38, thyrite resistor 39 and neon lamp 40. The purpose of the thyrite resistor 39 and the ballast resistor 38 in connection with the operation of the neon lamp 40, is to produce a straight line relationship between the current flowing through the lamp and the thyrite element in series and the electromotive force across the lamp and thyrite. For a more complete description of the purpose and method of operation of these elements, reference may be made to the above-mentioned Knoop application.

Signal currents after being amplified by the device 22 are also applied to the input circuit of an electron discharge device 50 by means of a circuit including a coupling condenser 42 of relatively low capacity so that it will present a high impedance to low frequencies but permit the relatively high frequency correcting impulses to pass. The output circuit of the device 50 comprises the source of plate potential 51 and the resistor 52, a portion of the resistor being connected in series with resistor 43 across the grid-cathode circuit of the device 50. The device 50 is a self-biased detector which selects the peaks of the impulses representing black tone values. The signals applied to the input circuit of the detector 50 are so phased by properly selecting the number of stages in the amplifiers 22 that an increase in amplitude of the correcting impulses produces an increase in current in the output circuit of the device. This tends to increase the negative bias on the grid and hence decrease the output current. Finally a state of equilibrium is attained between the "correcting" signals and the grid bias potential of the detector. Shunting the resistance 52 is the condenser 53 which is adapted to integrate or smooth the pulses through the resistance 52. The integrated pulse is then amplified by the direct current amplifier 56, the grid of which is biased by the battery 55 so that the electron discharge device 56 will amplify the smoothed voltage impressed across its input circuit without distortion. The output circuit of the tube 56 comprises a source of plate potential 57 and a resistor 58, a portion of which is connected across the condenser 32. The voltage to which condenser 32 becomes charged, due to the voltage drop across the portion of resistance 58 connected in shunt with condenser 32, thus controls the output current of the tube 29 in accordance with the value of the average of the tone values of the scanned elemental line at the transmitting station.

The amplified alternating image current and the direct current component, both of which are present in the output circuit of the tube 29, are applied to the glow lamp 40. With no picture signals (the correcting signals thus being of minimum amplitude) the biasing battery 30 is adjusted so that the dark signal level for the neon lamp is produced. If the voltage across the condenser 32 is lowered (because of the action of the corrector circuit in responding to pulses of greater amplitude), the brightness of the lamp 40 rises with the increase in amplitude of the "correcting" pulses. The increased impulse decreases the bias on the tube 29, thus increasing the output of this tube and decreasing the output of tube 56. This lowers the bias on tube 29 and increases the current through the neon lamp 40. If a pulse is generated which is of smaller amplitude than this last pulse, the bias on the tube 29 will be increased and the brightness of the lamp reduced.

Associated with the lamp 40 is a scanning disc 60 provided with a row of apertures 61 arranged in a spiral line and driven by a motor 62 in synchronism and in phase with the scanning disc 11 at the transmitting station. Any suitable system for maintaining the discs 11 and 60 in synchronism may be used. In one such system, which is herein described by way of example, alternating current of substantially constant frequency is produced by a vacuum tube oscillator 63 which is located at the transmitting station for controlling the operation of the motor speed control circuit 64 at that station. Current from this source is also transmitted over line 65 to the receiving station R for controlling the operation of motor speed control means 66 at that station. The motors 13 and 62 of both stations are thus maintained in synchronism. Suitable amplifiers 67 and 68 at the transmitting and receiving stations, respectively, are used to amplify the current generated by the oscillator 63. For a more complete description of the synchronizing system herein briefly described, reference may be made to U. S. Patent 1,999,376 of H. M. Stoller issued April 30, 1935.

An observer at E may view the image produced by the cooperation of the receiver scanning means 60 and the light source 40 through an opening 69 in an opaque screen 70. Glow lamp 40 may be of any desired type adapted to supply light which varies with variations in amplitude of the applied image current. A suitable lamp for this purpose is disclosed in U. S. Patent 1,918,309 of H. W. Weinhart, issued July 8, 1933. As therein described, the glow lamp may include a charge comprising a rare gas and a small percentage of active gas, as disclosed in U. S. Patent 1,871,266 of F. Gray, issued August 9, 1932.

Fig. 3 shows another circuit for correcting for the suppression of the direct component of the image current generated at the transmitting station, which is a modification of the system shown in Fig. 1. Instead of the amplified and filtered correcting impulses being applied to the input circuit of the power tube 29 as in Fig. 1, they are applied to the input circuit of a second power tube 80, the output circuit of which includes the neon lamp 40 and the thyrite resistor 39. An advantage of this arrangement is that the alternating current amplifying tube 29 is not affected by changes in direct current from the correcting circuit. Thus the amplifying action or gain of the tube 29 is independent of the correcting circuit.

In this circuit, the output of the tube 29 is impressed by means of a circuit including a coupling condenser 81 (which prevents any direct current from the output circuit of the device 80 from reaching the output circuit of the power tube 29) upon the image producing circuit which comprises the neon lamp 40, the thyrite resistor 39 and the ballast resistor 38 (which also serves as a load resistor in the output circuit of the tube 80). A direct current source 37 applies plate potential for the tube 29 and resistor 84 is included in series with the source of potential. The output circuit of the power tube 80 includes an inductor 83 (for preventing any alternating current from the power tube 29 from reaching the tube 80), the image producing neon lamp 40, thyrite resistor 39, ballast resistor 38, and source of plate potential 82. The output of the correcting circuit thus is used to vary the brightness of the neon lamp 40 directly instead of through the tube 29 which now serves as the output tube of the image signal circuit alone rather than as the output tube for both image signal circuit and correcting circuit as shown in Fig. 1. With the exception of this difference, the description and method of operation of this circuit are similar to those above described in connection with Fig. 1.

Still another circuit, which may be considered a preferred arrangement, for correcting for the suppression of the direct component of a television current at the transmitting station is shown in Fig. 4. In this arrangement, the amplifying means for the alternating component is similar to the corresponding part of the circuit shown in Fig. 1, power tube 29 serving as the output tube for the alternating component. By means of the condenser 32 inserted in the input circuit of the power tube 29, the tube 29 also serves as the output tube for the direct component.

The television electromotive force after being amplified by the device 22 and applied to the input circuit of the alternating component amplifying tube 23, is also applied through a suitable coupling condenser 42 of small capacity to the input circuit of an amplifying device 90 which serves to isolate the input of the correcting circuit from the normal image signal amplifier, i. e., from the input circuit of tube 23. The circuit between the grid 93 and the cathode 94 of the device 90 includes a biasing battery 91 and resistor 92. Heating current for the cathode of tube 90 is obtained by means of a suitable transformer 95, the primary of which is shown connected to an alternating current generator 96. The output of the tube 90 is coupled by means of a transformer

97 to the grid 98 of the self-biased detector tube 99 through a potentiometer resistor 100. A source of plate patential 101 is also connected in the circuit between the plate 102 and the cathode 94 of the isolating tube 90. In the output circuit of the self-biased detector 99 is a source of plate potential 103 and a load resistor 104, which is tapped at an intermediate point thereof to supply self-bias through the resistor 100 to the grid 98. A condenser 105 connected across the part of resistor 104 used to supply grid bias may be used to smooth the feedback impulses. Condenser 106 connected across the output circuit of the self-biased detector 99 serves to integrate and smooth the impulses produced in the output circuit of the device 99. The purpose and method of operation of the self-biased detector 99 are similar to those of the self-biased detector 50 of Fig. 1 and reference may be made to the description given above in connection with that figure.

The detected and smoothed signals are applied through a smoothing filter circuit, generally represented by a resistor 107 and a condenser 108, to the input circuit of a direct current amplifying device 109. A biasing battery 110 with its positive terminal connected to the grid 111 of the tube 109 is used in the event that the detected and integrated signals are too negative. This battery 110, and similarly the batteries 55 of Figs. 1 and 3, may be omitted in some cases, depending on the intensity of the signal and on the type of tube. The device 109 amplifies the smoothed voltage impressed across its input circuit without distortion.

The output circuit of the tube 109 comprises a source of plate potential 112 and winding 113 of an electromagnetic relay 114. The space current of the tube 109 passes through the winding 113 of the relay 114 in such a direction as to tend to bias the relay tongue 115 to the left or spacing contact S. The relay tongue is vibrating continuously because it is driven by 60-cycle alternating current from the transformer 95 through the winding 116 of the relay 114. When no space current flows through the tube 109, the tongue 115 of the relay 113 is biased to the right or marking contact M by the biasing current through the winding 119, the regulating resistance 117 and the variable resistor 118. When the average space current through the tube 109 equals the biasing current through the winding 119, the direct current voltage across the condenser 32 is half the voltage of the battery 122 which is connected between the spacing contact S and the marking contact M of the relay 114 through resistors 120 and 121. This potential is applied across condenser 32 through filter cirsuit 123 comprising inductors 124, resistors 125, and condensers 126.

The operation of the circuit shown in Fig. 4 is as follows: Assume an increase in amplitude of the signal applied to the input circuit of tube 90, representing a correcting impulse of large amplitude at the transmitter, the impulse being so poled that the grid is swung positive. The output of the tube 90 is thus increased, thus decreasing the output of tube 99, reducing the negative bias on tube 109 and thus increasing the output of this tube. As the average space current from the amplifying device 109 increases, the direct component correcting voltage across the condenser 32 decreases and vice versa. As the relay 114 serves as an amplifier it may be replaced by any other equivalent amplifier. It has the advantage in this case that the signals are amplified without their phase being reversed but this condition is also true if an even number of stages of electron discharge amplifiers are used.

As a modification the condenser 32 may be placed in the input circuit of another power tube in a manner similar to the circuit of Fig. 3. As a further modification, the self-biasing detector 99 may be replaced by a gas-filled tube. In this latter case the circuit elements are not changed but the constants may be. Various other modifications may be made in the invention as disclosed, the scope of which is indicated by the appended claims.

What is claimed is:

1. In a television system a source of television image electromotive force, the direct component of which has been suppressed and having recurring impulses of predominant amplitude and a predetermined polarity, the amplitude of which impulses is a measure of the suppressed direct component, means under control of said source of television electromotive force for producing a unidirectional electromotive force corresponding to said suppressed component, an electric discharge device comprising an anode, a cathode and a control electrode, means for impressing said unidirectional electromotive force between said control electrode and said cathode, a series circuit comprising a source of anode current for said electric discharge device, a light producing device and an inductive element, the amplitude of said anode current flowing through said light producing device being controlled in accordance with the amplitude of said unidirectional electromotive force impressed upon said control electrode-cathode circuit, and means for impressing said television image electromotive force upon the circuit including said light producing device for further controlling the current through said light producing device in accordance with the variations of said television image electromotive force.

2. In a television system in accordance with claim 1 in which an amplifier having a plurality of stages of amplification is provided for amplifying the television image electromotive force, in which the output of said amplifier is connected to the circuit including said light producing device, and in which the means for producing a unidirectional electromotive force corresponding to the suppressed component is connected to the input of the first of said stages through a condenser of small capacitance, such that it will have a high impedance to frequencies lower than the fundamental frequency of the predominant amplitude impulses of the television image electromotive force but a low impedance to said fundamental frequency.

3. In a television system, a source of television image electromotive force, the direct component of which has been suppressed and having recurring impulses of predominant amplitude and of a predetermined polarity, the amplitude of which impulses is a measure of the suppressed direct component, a current path, means comprising a first electric discharge device under control of said source of television image electromotive force, means for connecting the output circuit of said first electric discharge device across said current path to produce across said path variations of electromotive force corresponding to the variations of said source of television image electromotive force, a second electric discharge device, means for controlling the

input circuit of said second electric discharge device in accordance with the amplitude of the recurring impulses of said television image electromotive force, and means for connecting the output circuit of said second electric discharge device across said current path to produce across said path an electromotive force corresponding to the suppressed direct component of said television image electromotive force, the means for connecting the output circuit of the first electric discharge device across said current path comprising a capacitive element, and the means for connecting the output circuit of said second electric discharge device across said current path comprising an inductive element.

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