June 4, 1935.

J. W. HORTON

2,003,294

TELEVISION SYSTEM

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FIG. 1.

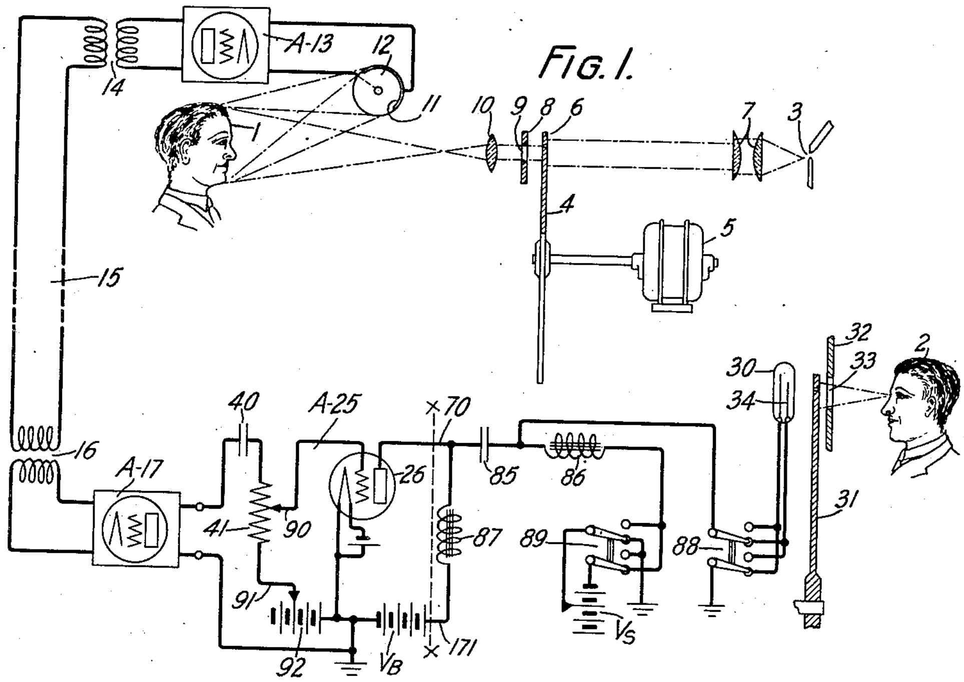

FIG. 9.

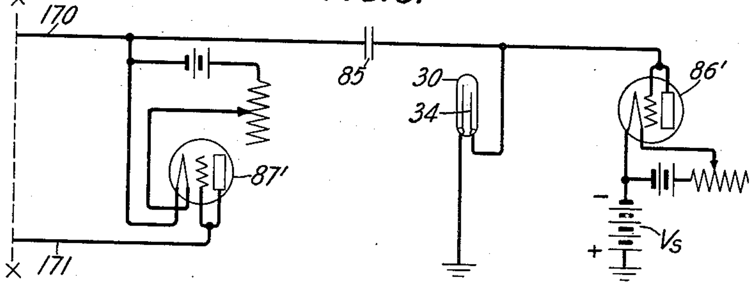

FIG. 10.

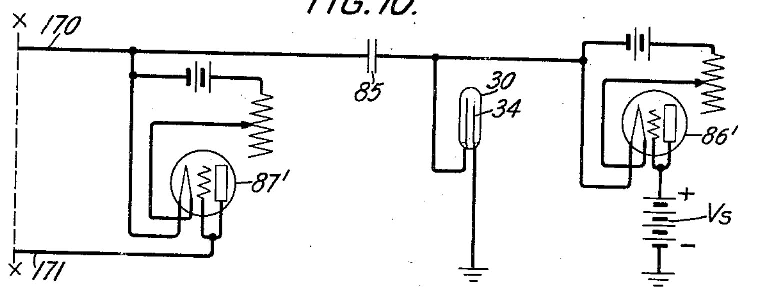

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FIG. 2b.

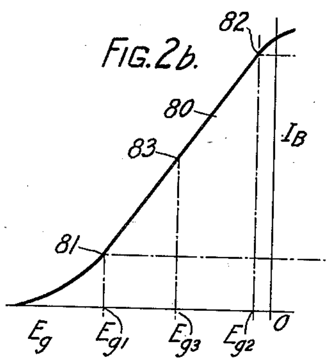

FIG. 3.

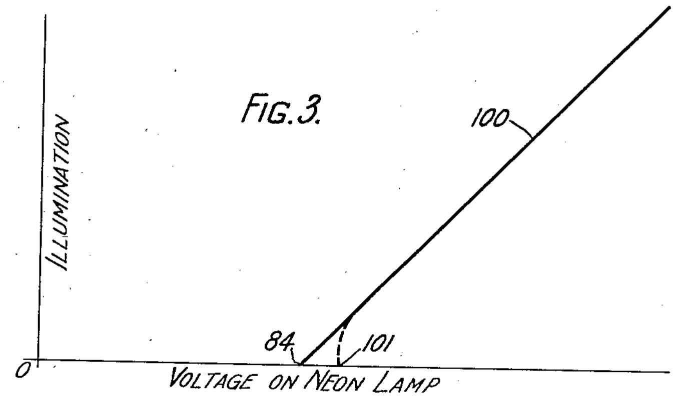

FIG. 2-a.

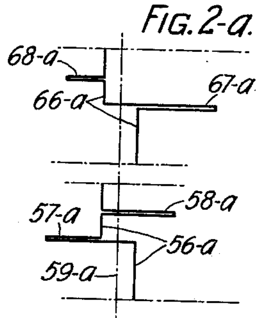

FIG. 2.

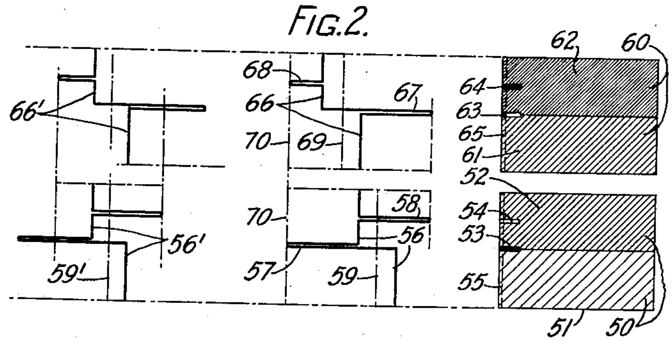

FIG. 6.

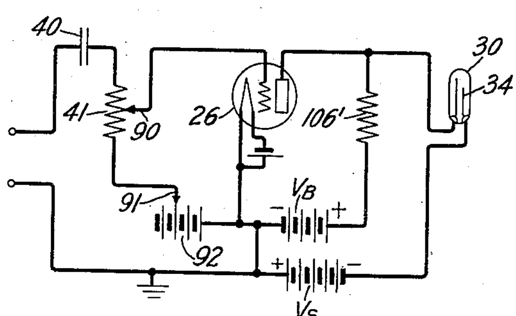

FIG. 7.

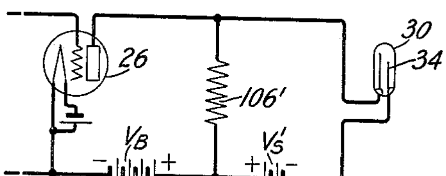

FIG. 8.

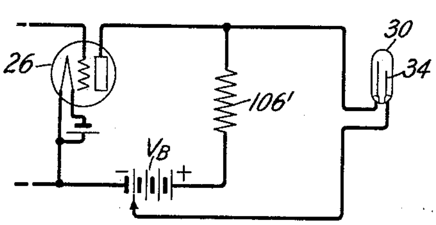

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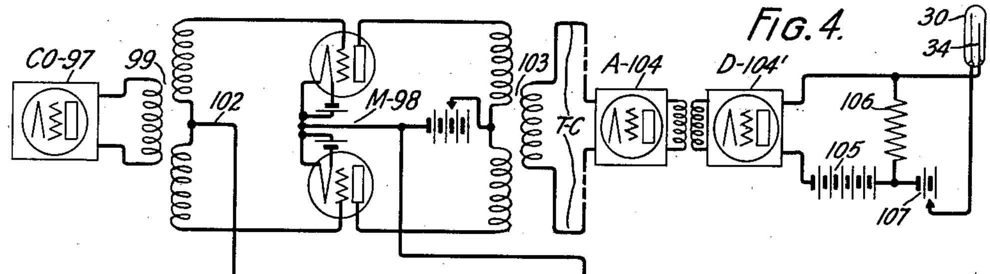
FIG. 4.



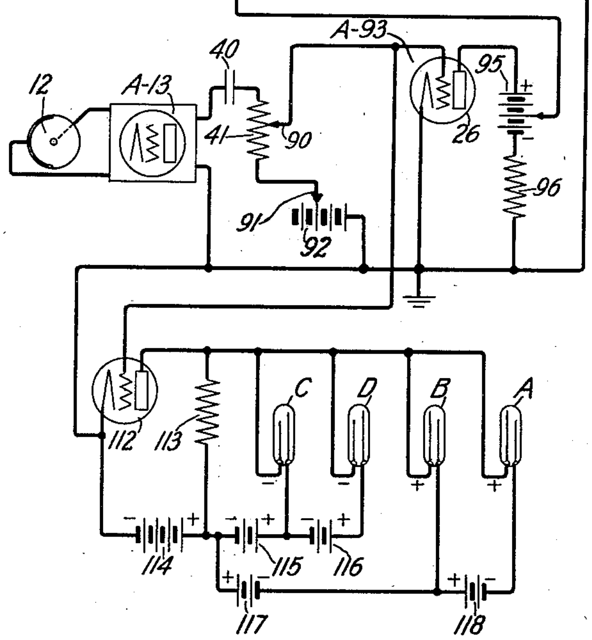


FIG. 4b.

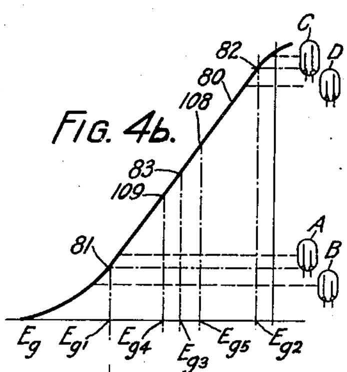


FIG. 4c.

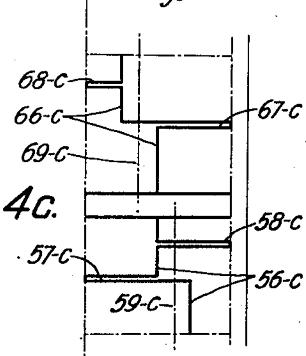
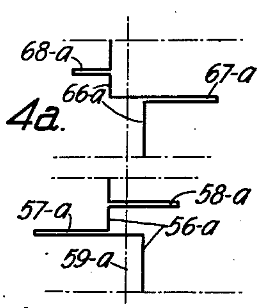


FIG. 4a.



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TELEVISION SYSTEM

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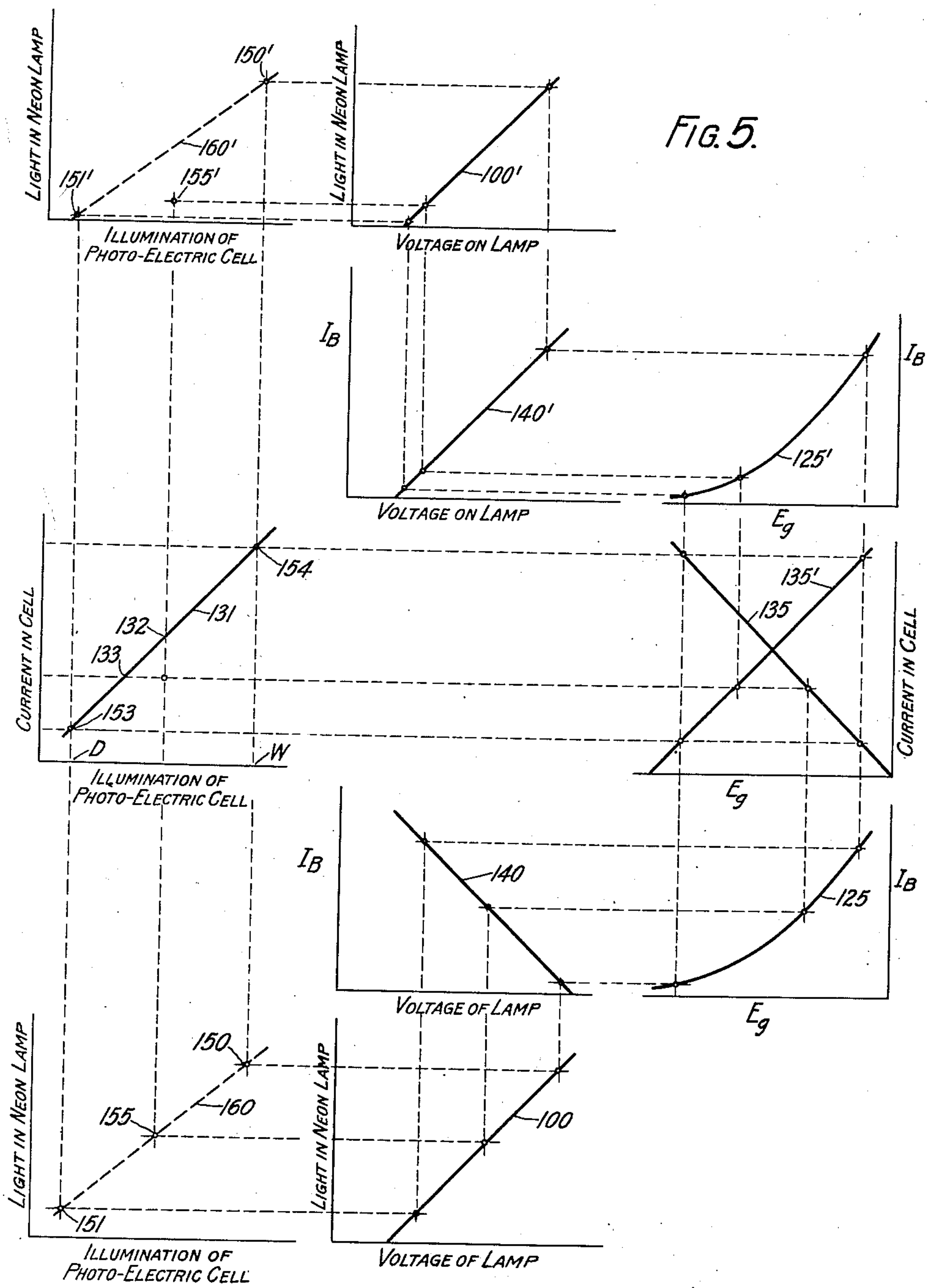

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Patented June 4, 1935 2,003,294

UNITED STATES PATENT OFFICE

2,003,294

TELEVISION SYSTEM

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Application November 2, 1927, Serial No. 230,418
Renewed June 22, 1931

19 Claims. (Cl. 178—6)

This invention relates to picture transmission and television systems, and especially to electrical wave amplifying systems the field of application of which includes picture transmission and television, the general object of the invention being reduction of distortion.

As a system for transmitting to a distance a pictorial representation of a subject, one embodiment of the invention herein chosen by way of example comprises, specifically stated, means at the transmitting end of the system for rapidly scanning the subject point by point and producing by a photo-electric cell an electric current varying in accordance with the light received from the successive elemental areas of the explored subject, and a transmission channel for amplifying and transmitting to the receiving end of the system the variations utilized at the receiver in the production of the image, the direct current component and very low frequency components being suppressed at the transmitter and compensation effected at the receiver. The receiving system includes a thermionic amplifier in the output circuit of which is a glow discharge lamp to emit light of intensity varying in accordance with the initial current. In accordance with the invention the receiving system may include means for establishing the region of operation on the characteristic curve of the amplifier and independent means for establishing the region of operation on the characteristic curve of the lamp. Thus by properly polarizing the lamp an attendant at the receiver can introduce a direct current component in the signal to replace that suppressed at the transmitter, to more nearly approach accurate reproduction of the tone values of the subject, and at the same time the attendant can adjust the amplifier entirely independently to give the character of amplification best suited for distortionless overall transmission in the system.

This amplification may be linear. On the other hand, it may be non-linear, as for example, to control the tone values of the image as described hereinafter for reducing apparent distortion, due for instance to difference between the photo-electric cell and the eye as regards the relative sensitiveness of each to light waves of different frequencies. Thus one aspect of the invention is a system in which different amplitudes of signal waves are amplified to different degrees, respectively, to counteract deleterious effects due to the characteristics of a portion of the system for translating waves of one kind into waves of another kind, as light waves to electric current waves.

As illustrating other specific aspects of the invention there is also described hereinafter a television system in which the picture current generated by the photo-electric cell is reproduced in amplified form and the amplified wave is employed to modulate a carrier wave for wire or radio transmission of the signal variations to the receiving station, the production of the amplified picture current wave being accomplished by applying the picture current to A. C. amplifier which suppresses D. C. and very low frequencies and restoring the D. C. component of the signal wave before applying it to the modulator. The suppression of the D. C. and the very low frequenices in the amplifier avoids excessive disturbance of the grid biasing potential of the final stage of the amplifier due to great amplification by preceding stages of very small slow voltage changes in the batteries associated with the amplifier. Means is provided at the sending station for indicating when the magnitude of the D. C. component being restored to the signal is correct for reproducing the initial signal wave. Thus, one aspect of the invention relates to suppressing a D. C. component of a signal in initial stages of an amplifier and replacing it in proper magnitude relative to the A. C. components at the final stage or before transmission of the signal to a distance, and another aspect relates to indicating, at the sending station, when the D. C. component being restored to the signal wave before it is applied to the modulator or transmitted to the receiving station has the proper magnitude relative to the A. C. components of the signal.

Other objects and aspects of the invention will be apparent from the following description and claims.

Fig. 1 of the drawings is a schematic showing of a television system embodying a form of the invention; Fig. 2 is a diagram; Figs. 2*a* and 2*b* and 3 curves, for facilitating explanation of the operation of the system of Fig. 1; Fig. 4 is a schematic showing of a television system embodying another form of the invention; Figs. 4*a*, 4*b* and 4*c* are curves which, together with Fig. 2, are employed in explaining the operation of the system of Fig. 4; Fig. 5 is a set of graphs for facilitating explanation of operation of the system of Fig. 1 or modifications thereof; and Figs. 6 to 10 show amplifier and neon lamp operating circuits embodying forms of the invention, which may be used for example in place of the amplifier and neon lamp operating circuits of Fig. 1.

In the television system of Fig. 1, the subject 1 whose image is to be viewed at the receiving end of the system by the receiving operator 2 is shown as the face of a man and is located in front of scanning apparatus at the transmitting end of the system. That apparatus comprises an arc or constant intensity light source 3, and an optical system for causing a slender pencil of substantially parallel rays of intense light derived from the arc to sweep across the region in front of the scanning apparatus and scan the subject 1 in a series of successive parallel substantially horizontal lines. The optical system includes an opaque disc 4, which is rotated at a speed of about 18 revolutions per second by a motor 5 and has a number of small circular apertures 6 arranged in a spiral extending around the disc near its rim. Two plano-convex lenses 7 direct light from arc 3 upon disc 4 so that an intense beam of light passes through each aperture as the aperture moves across the illuminated area on the disc. An opaque screen 8 in front of the disc has a substantially rectangular opening 9 of such width as to transmit light from only one aperture at a time. A lens 10 bends the slender pencil of substantially parallel rays passing through the aperture and the opening 9 and forms an image of the moving aperture on the subject 1. As a result of this arrangement, the subject is completely scanned in a series of successive parallel lines by a small, rapidly moving intensely bright spot of light once for each revolution of the disc.

It is not necessary that the subject be at the exact position of the aperture images. The optical system is such that the slender beams of light sweeping across the region in front of the scanning apparatus just barely overlap each other even at a considerable distance from the apparatus. So, in this respect, within wide limits no confusion results as the subject moves toward or away from the apparatus.

As the spot of light passes over the subject, light is diffusely reflected from the subject, and a portion of the reflected light falls on one or more large photo-sensitive surfaces, such as the large photo-sensitive surface 11 of a large aperture photo-electric cell 12, and generates a picture current. The brightness of the image seen by the observer 2 at the receiving end of the system depends upon the distance of the subject 1 from the photo-sensitive surface.

The scanning system described above is disclosed in more detail in British Patent 288,238, complete accepted April 18, 1929. The large aperture photo-electric cell having the large photo-sensitive surface is disclosed in more detail in Patent No. 1,942,501, granted to G. R. Stilwell, January 9, 1934.

The picture current from the photo-electric device is amplified by an alternating current amplifier A—13, and the amplified current is transmitted through a transformer 14 to a line 15 or other transmission channel connecting the sending end of the system to the receiving end. At the receiving end of the system, the current from line 15 is transmitted through a transformer 16 and an amplifier A—17 to an amplifier A—25 including an electric space discharge amplifier tube 26 which feeds a neon glow discharge lamp 30.

In front of the lamp is a disc 31 similar to the disc 4 and rotated synchronously with it by any suitable means (not shown). In front of the disc is an opaque screen 32 having an opening 33 of such size that only one of the apertures of disc 31 at a time is in the field of view of the observer 2. The lamp 30 is preferably of the type disclosed more in detail in Patent No. 1,865,516, granted to Frank Gray, July 5, 1932, with a rectangular cathode 34 slightly larger than the field of view on the disc, the glow discharge covering the entire front surface of the cathode. The television field defined by the opening 33 and illuminated by light coming from lamp 30 through the moving apertures of disc 31, is viewed from in front of the disc without the aid of any optical system. The observer 2 sees at any instant a single aperture in the same relative position as the spot of light on the subject 1 at the transmitting end of the television system, and the brightness of the aperture corresponds to the amount of light reflected from that particular elemental area of the subject. On account of the persistency of vision the observer 2 consequently sees an apparent image of the subject on the front surface of the disc 31.

Complete views of the subject are transmitted at the rate of about 18 per second, so that the subject can be seen in motion. On account of the relatively slow movements of the usual subject, succeeding views in the series will remain about alike over a number of views. Consider, as a function of time, the varying light intensity that falls on the sensitive cell during a period of time covering the transmission of several views, or in other words, during a period approximately equal to several flicker periods. By applying a well-known mathematical principle, discovered by Fourier, to this varying light intensity, it may be approximately considered as a constant intensity plus the sum of a series of sinusoidal components.

The constant component is really the average light intensity of the views, or a luminous field upon which the views occur as variations from the average light intensity. The expression "light-ground" may be used to designate this uniform field of average brightness. The current generated by the photo-electric cells is likewise a unidirectional current, which is the sum of a constant current, corresponding to the luminous light-ground, and a series of sinusoidal currents, corresponding to the variations from the light-ground.

The constant component or direct current component representing the light-ground could not be transmitted through transformers and over telephone lines even if an amplifier could be designed for properly amplifying it to the requisite degree before putting it on the line 15. However, the signals as generated by the photo-electric cells are very minute, and when it is attempted to employ a direct current amplifier that will amplify them to the requisite degree, the amplifier is found to lack the requisite stability. The image at the receiver may be clear for a time and then gradually become indistinct due to loss of detail in either the high lights or the shadows, because large amplification of very small slow changes in the potentials of the batteries employed in the first stages of the amplifier introduces prohibitive bias in the final stages of the amplifier. Therefore, the amplifier A—13 (and also the amplifier constituted by amplifiers A—17 and A—25) used to produce the requisite amount of amplification of these feeble signals is a vacuum tube amplifier embodying resistance-condenser coupling circuits which prevent zero drift in the amplifier and give it the requisite stability. These coupling circuits are preferably such that the amplifiers have a substantially constant efficiency over a frequency range extending from a frequency below the frame frequency of 18 cycles per second to a frequency above the picture element frequency, say 20,000 cycles per second. Such a coupling circuit, comprising a capacity 40 and a resistance 41, is shown coupling amplifiers A—17 and A—25. The low frequency range suppressed ordinarily includes the range from zero to 10 cycles, which covers the range of the slow disturbing potential variations of the batteries associated with the amplifiers. The suppression of the low frequency and direct current components is preferably brought about by the coupling circuit condensers in the outputs of the first stages of the transmitting amplifier and the receiving amplifier, which are so designed that there is a gradual cut-off below 10 cycles. As there are many stages of amplification, it may be necessary to use such condensers in the output circuits of other stages of the amplifiers.

However, pictures or views can not be reproduced with fidelity as regards tone value when the constant direct current representing the light-tone or light-ground of the picture or view is eliminated from the picture current transmitted over the system until a correction which effectively replaces this component is made. For example, imagine that the shaded squares 50 and 60 in Fig. 2 are two types of pictures or views, or represent two aspects of a subject, which are to be transmitted by the system. Substantially half of area 50 is constituted by a block 51, the tone of which is light gray; and substantially half of area 50 is constituted by a block 52, the tone of which is medium gray. A block 61 having the same medium gray tone constitutes substantially half of area 60; and substantially half of area 60 consists of a block 62 dark gray in tone. At the middle of the left hand edges of areas 50 and 60 are rectangles 53 and 63, which are black and white, respectively; and at the middle of the left hand edges of blocks 52 and 62 are rectangles 54 and 64, which are white and black, respectively. Each of these four rectangles is made of small area compared to one of the blocks such as 51, and narrow in the vertical direction, compared to a block such as 51. The relative dimensions, locations and tones of the various portions of areas 50 and 60 have been so chosen that, assuming the scanning spot to move in the vertical direction in Fig. 2, when the spot traces a path on area 50 indicated by dotted line 55 there is generated in the photoelectric cell a current wave 56 which is exactly like a current wave 66 correspondingly generated by a spot scanning along path 65 on area 60 as regards the alternating current components of the two waves, except for the narrow peaks 57, 58, 67 and 68 created in these waves due to rectangles 53, 54, 63 and 64 respectively; and these narrow peaks have but a negligible effect in determining the average value of current for each wave. These waves 56 and 66 are plotted between current and the position or distance of the scanning spot along path 55 and 65 as the case may be. Points on the curves correspond to horizontally aligned points on the paths 55 and 65, as indicated by the horizontal projection lines connecting the curves with the paths. The current values for these waves are plotted toward the right from line 70 as the reference line or line representing zero current value. The average value of current for wave 56 or the magnitude of the direct current component of the wave is indicated by line 59; and the average value of current for wave 66 or the magnitude of the direct current component of the wave is indicated by line 69. Since the area 50 is fairly light in general effect (has a bright light-ground), whereas the area 60 is fairly dark in general effect (has a dark light-ground), the magnitude of the direct current component of wave 56 or the distance between lines 70 and 59, is greater than the magnitude of the direct current component of wave 66 or the distance between lines 70 and 69.

The amplifier A—13 and also the transformer 14, line 15 and transformer 16 and the condenser 40 in amplifier A—25 do not pass direct current, and therefore only the alternating current components of the waves corresponding to areas 50 and 60 reach the grid of tube 26.

These received alternating signal components are shown in Fig. 2 as voltage waves 56′ and 66′, respectively, with the axis or line of zero voltage indicated at 59′. Waves 56′ and 66′ are drawn each to the same scale as the other, since waves 56 and 66 are drawn each to the same scale as the other.

Fig. 2*b* shows the grid voltage-plate current characteristic 80 of tube 26. The straight portion, or range over which it will for the present be considered as desirable to operate, is the portion between points 81 and 82. The point 83 corresponds to a voltage just half way between the voltages corresponding to points 81 and 82, respectively, and would be the normal operating point of the tube for an average value of light-ground. Vertically aligned with this normal operating point is line 59*a* in Fig. 2*a*. This line corresponds to the average value (that is, the zero value) of voltage for wave 56′ and for wave 66′. If these waves were received by tube 26 when the grid biasing voltage of that tube had the value of the point 83, then the varying voltages on the grid, in the case of the two waves, would be the two voltages indicated by curves 56*a* and 66*a* respectively, and the operating region would be that determined by the vertical projections from the Fig. 2*a*. If the output current I_B were passed through the lamp 30 the apparent images of areas 50 and 60 as seen by observer 2 would be reproduced exactly alike unless compensation were made for the failure of the D. C. components of the waves corresponding to areas 50 and 60 to reach the grid of tube 26. Areas 51 and 61 would have equal tone values, and areas 52 and 62 would have equal tone values. Furthermore, peak 57*a* falls below the lower limit 81 of the assigned operating range, and peak 67*a* falls above the upper limit 82 of the assigned operating range.

The operating point 81 corresponds to zero signal amplitude at the transmitting end of the system. Therefore, if the direct current component of the initial signal had been transmitted, E_{g1} would be the normal operating bias of the tube. Consequently, the operation about operating point 83 which results from the use of grid bias E_{g3} is equivalent to the introduction of a direct current voltage component of the absolute value $E_{g1}—E_{g3}$.

The distortions due, as explained above, to the absence of the direct current component from the picture current received by amplifier A—25 from amplifier A—17 and the effective reintroduction of a component of improper amplitude, may be avoided or compensated for by inserting a blocking condenser 85 in the circuit between tube 26 and lamp 30 in Fig. 1, so that the plate current source V_B of the tube will supply no D. C. to the lamp, and adjusting a variable voltage direct current source V_S to restore the D. C. component of the picture current. A choke coil 86 prevents source V_S from shunting A. C. from tube 26 around lamp 30. A choke coil 87 is employed in series with the source V_B as usual. The function of switches 88 and 89 will be indicated hereinafter. For the present, these switches may be regarded as occupying the positions shown. The source V_S not only supplies the D. C. component of the picture current, but also applies a biasing voltage to the neon lamp so that when no photoelectric current is generated, that is, when the elemental area being scanned is black, the incoming signal reduces the voltage across the neon lamp until it is substantially just sufficient to maintain a glow discharge in the lamp. This biasing voltage is the voltage corresponding to point 84 of the solid line curve 100 in Fig. 3 which is the operating characteristic curve of the neon lamp 30 plotted between voltages on the lamp as abscissae and the intensity of illumination of the lamp or the current through the lamp as ordinates. The voltage corresponding to point 101 is the striking voltage of the lamp.

The desired gain for tube 26 can be obtained by proper adjustment of a gain controlling device comprising the resistance 41 in the input circuit of the tube and a contact 90 connected to the grid of the tube and movable along the resistance 41. The negative grid potential of the tube can be adjusted by a contact 91 adjustable on a battery 92 which has its positive pole connected to the filament of the tube.

In operating the system of Fig. 1, the adjustment of contacts 91 and 90 is preferably such that the tube 26 operates over the range from point 81 to point 82 about the point 83 on its characteristic 80, increase in brightness of the elemental area scanned producing increase in the space current of tube 26 and decrease in brightness producing decrease in the space current of tube 26, and the voltage of source V_S is adjusted for the best apparent relative tone values in both the shadows and the high lights in the image produced. If fading or loss of proper relative tone values is greater in the shadows than in the high lights, this indicates that the voltage from source V_S is too low. If the lack of proper relative tone values is greater in the high lights than in the shadows, the voltage from source V_S should be decreased. However, as indicated above, the voltage from source V_S should never be less than that indicated by point 84 of the lamp characteristic 100. The observer 2 can thus choose the lightground of the produced image to suit his best judgment in consideration of his general ideas as to the nature of the object being viewed. The system of Fig. 1 comprises no means for indicating when the direct current component being restored to the picture current has the proper value; but a system comprising such indicating means will be described presently.

Considering a period of time covering the transmission of a series of views comprising a large number of views, or in other words, considering a time period covering a large number of flicker periods, as the subjects move about or change in the particular series of views that is being sent, the average brightness of the field will vary slowly with time, and the receiving operator can vary the value of the direct current component being reinserted in the picture current at will, to suit his best judgment, or to accord with the indications of the above mentioned indicating means in the case of a system provided with such means.

It will be noted that in the system of Fig. 1 the gain control by the potentiometer contact 90, the negative grid bias control by the contact 91, and the neon lamp bias control by the adjustable voltage source V_S for reinserting the desired value of direct current in the picture current, are three separate and distinct controls and enable any part of the amplifier characteristic to be chosen for operation regardless of what part of the neon tube characteristic is chosen for operation, and vice versa.

Fig. 4 represents a carrier current or radio television transmission system. The system may employ at the sending station and the receiving station, scanning apparatus and viewing apparatus, respectively, which may be, for example, like the scanning and viewing apparatus of Fig. 1 and which therefore are not shown in Fig. 4. The scanning apparatus may be associated with photoelectric cell 12 at the sending station as in Fig. 1 and the viewing apparatus may be associated with neon lamp 30 at the receiving station as in Fig. 1. The transmitting amplifier at the sending station may comprise amplifier A—13 and an additional stage of amplification A—93, including tube 26 with its plate current battery or other source of unidirectional voltage 95 in circuit with resistance 96. The resistance 96 may be of the order of magnitude of the output impedance of the tube. The grid voltage-plate current characteristic of tube 26 in the system of Fig. 4 may be the curve 80 of Fig. 4*b*, which is the same as the curve 80 of Fig. 2*b*. The straight portion, or range over which it will for the present be considered as desirable to operate, is the portion between points 81 and 82. The operating point 81 then corresponds to zero signal amplitude, or in other words to the amplitude of the initial signaling current at any instant when the elemental area illuminated on the subject is black or non-reflective.

The amplifier A—13 suppresses the direct current and very low frequency components of the picture current, as explained above in connection with Fig. 1. By varying the negative grid potential of tube 26 by means of contact 91 adjustable on battery 92 which has its positive pole connected to the filament of the tube, an operator at the sending station can cause the tube to restore the direct current component to the picture current, as will be described hereinafter.

An oscillator CO—97 applies a carrier wave to the grids of a balanced or push pull modulator M—98, in opposite senses at any instant, through an input transformer 99. The resistance 96 and an adjustable portion of battery 95 of the output circuit of tube 26 are included in the common grid lead 102 of the modulator and apply to each of the modulator grids a voltage corresponding to the A. C. and D. C. components of the picture current, preferably with the addition of a steady D. C. voltage of such sign and value that when the tube 26 operates over the portion of its characteristic extending from point 81 to point 82, the modulator operates on the straight sloping portion only of the characteristic represented by a graph (not shown) having as abscissae the voltage applied to the modulator from the output circuit of tube 26 and as ordinates the peak values of the modulated carrier current wave in the secondary winding of the output transformer 103 of the modulator. The latter graph, though lying in the first quadrant of the coordinate system, has the same general form as the curve **80**, its extreme lower portion being curved, and this additional voltage of proper sign and value causes the operating point at the upper end of this curved portion (or, if desired, a higher point of the straight sloping portion of the graph) to correspond to the operating point **81** of curve **80**.

The modulator suppresses the wave which the output circuit of tube **26** supplies to it, and transmits the modulated carrier wave to a receiving alternating current amplifier A—**104** at the receiving end of the system through a carrier current or radio transmission channel represented by channel T—C. The amplifier output circuit is transformer coupled to the input circuit of an electric space discharge tube detector D—**104'**.

The output circuit of detector D—**104'** includes, in addition to a source of unidirectional plate current **105**, a resistance **106** in parallel with the neon lamp **30** and a second source of unidirectional voltage **107**. The source **107** may be termed the polarizing battery or source for the lamp. The resistance **106** may be of the order of magnitude of the output impedance of the detector tube. The characteristic of this tube may be the characteristic **80**, and with these elements in the output circuit, a desired choice of grid bias for this tube does not prevent the application of voltage to the lamp from being controlled so that the lamp will be dark when the initial signal amplitude is zero and so that the brilliancy will vary linearly with the amplitude of the incoming signal. As indicated above, the operating characteristic of the lamp is the solid line graph **100** of Fig. 3. When the elemental area being scanned is black, the neon lamp preferably is operating at (or just above) point **84** of characteristic **100**. The requisite lamp biasing voltage, or the abscissa of point **84**, is ordinarily greater than the voltage drop in resistance **106** due to the minimum peak value of the modulated voltage wave appearing across resistance **106**. That is, although the carrier wave impressed on the modulator is not completely modulated therein, the abscissa of point **84** is ordinarily greater than the minimum value of the envelope of the wave appearing across resistance **106**. Therefore, a voltage from source **107** is added to this minimum voltage, the sum of these two voltages giving a voltage equal to the abscissa of point **84**.

Reverting to the restoration of the D. C. component of the picture current by adjustment of contact **91**, it will again be considered that waves **56** and **66** of Fig. 2 are initial picture current waves which are to be reproduced at the receiving end of the system. As indicated above, in the case of the system of Fig. 4 the D. C. is restored before the signal wave is applied to the modulator. Only the alternating components of the signal waves **56** and **66** are received by amplifier A—**93**, and these alternating components may be regarded as represented by the voltage waves **56'** and **66'** of Fig. 2, corresponding respectively to waves **56** and **66**. The point **83** in Fig. 4*b* corresponds to a voltage just half way between the voltages corresponding to points **81** and **82** and would be the normal operating point of the tube for an average value of lightground. Vertically aligned with this normal operating point is the line **59*a*** in Fig. 4*a*. As in Fig. 2*a*, this line corresponds to the average value (that is, the zero value) of voltage for wave **56'** and for wave **66'**. If these waves were received by tube **26** when the grid biasing voltage of that tube had a value equal to the abscissa of point **83**, then the varying voltages on the grid, in the case of the two waves, would be the two voltages indicated by curves **56*a*** and **66*a***, respectively, of Fig. 4*a*, (which are the same as curves **56*a*** and **66*a*** of Fig. 2*a*), and the operating region would be that determined by the vertical projections from Fig. 4*a*. The output current I_B applied to the modulator would be substantially alike for input waves **56*a*** and **66*a***. The operating point **81** corresponds to zero amplitude of the initial signal current. Therefore, if the direct current component of the initial signal had been transmitted to the grid of tube **26**, Eg_1 would be the normal operating bias of the tube. Consequently, the operation about point **83** is equivalent to the introduction of a unidirectional voltage component of the absolute value $Eg_1—Eg_3$.

The distortions due to the absence of the direct current component from the picture current received by tube **26** and the effective introduction of a component of improper amplitude may be avoided or compensated for by varying the point about which operation takes place on the characteristic curve **80**. To reproduce area **50** the grid bias should be altered as shown by Fig. 4*c* so that the average value of voltage is moved to the operating point **108**. Under these conditions peaks **57*c*** and **58*c*** fall properly upon the limits **81** and **82**, respectively, of the operating region of the characteristic. This alteration of the grid bias, to the value Eg_5, has effected the reintroduction of the proper direct current voltage component of the signal which is the absolute value $Eg_1—Eg_5$.

Similarly, to reproduce the area **60**, the grid bias should be altered as shown by Fig. 4*c*, so that the average value of the voltage is moved to the operating point **109**. Under these conditions peaks **68*c*** and **67*c*** again fall upon the limits **81** and **82**, respectively, of the operating region of the characteristic. This alteration of the grid bias, to value Eg_4, has effected the reintroduction of the proper D. C. component of the signal which is the absolute value $Eg_1—Eg_4$.

In other words, if the D. C. component had not been eliminated from the signal, the normal tube bias would have been Eg_1, which locates signal values corresponding to zero illumination at the lower limit **81** of the operating region of the characteristic of the tube. The reintroduction of the proper direct current components has therefore effectively shifted the operating bias with respect to alternating current components to the point Eg_5 for the reproduction of area **50** and Eg_4 for the reproduction of area **60**. The criterion of the proper adjustment is that peaks **57*c*** and **68*c*** fall on operating point **81** and peaks **58*c*** and **67*c*** fall on operating point **82**. When alternating current wave **56'** is delivered from amplifier A—**13** to tube **26**, the biasing voltage for the grid of tube **26** should be such that the variations of grid voltage which are caused by the wave occur about point **108** on characteristic **80** and the gain preceding the tube **26** should be such that these variations coincide with the range between points **81** and **82**. In other words, the wave **56'** and the grid bias combined should appear on the grid as the wave **56*c*** shown in Fig. 4*c*, the average voltage value of wave **56*c***, or the zero alternating voltage line being indicated by line

69c which is vertically aligned with point 108 of characteristic 80 of Fig. 4b as indicated by vertical projection lines extending from each figure toward the other.

Similarly, when alternating current wave 66′ is delivered from amplifier A—13 to tube 26, the biasing voltage for the grid of tube 26 should be such that the variations of grid voltage which are caused by the wave occur about point 109 on characteristic 80 and the gain preceding the tube 26 should be such that these variations coincide with the range between points 81 and 82. In other words, the wave 66′ and the grid bias combined should appear on the grid as the wave 66c shown in Fig. 4c, the average voltage value of wave 66c, or the zero alternating voltage line being indicated by line 69c which is vertically aligned with point 109 of characteristic 80 of Fig. 4b as indicated by vertical projection lines extending from Fig. 4b toward Fig. 4c.

The desired gain adjustment preceding tube 26 can be obtained by proper adjustment of the contact 90. To accomplish the desired variations, mentioned above, of the operating point on characteristic 80, an attendant or operator at the sending station varies the negative grid potential of the tube 26 by means of contact 91. As the subjects move about or change in the particular series of views that is being sent, the average brightness of the field will vary slowly with time, and this attendant or operator at the transmitting station can vary the grid bias of the tube 26 at will, to accord with the indications of the above mentioned means to be described presently, for indicating the proper adjustment.

From the foregoing description it will be seen that the input of the amplifier A—93 has a gain control device which determines the maximum amplitude of the alternating voltage applied to the grid; that the input also contains means for adjusting the grid bias to determine the operating point on the characteristic curve 80 of the amplifier; and that these two means together enable a region of the curve to be chosen for operation and enable the sweep or extent of variation to be determined. The amplitude of the A. C. can be controlled by the gain adjusting device to bring it within the desired range. It is desired to operate the amplifier over a linear portion of its characteristic 80 not only as regards the A. C. component of the signal but also to be able to vary the region operated over by the A. C. component on the characteristic curve to take care of different amounts of D. C. component which it is desired to introduce into the signal. It is further desired to control the application of voltage to the modulator so that the modulator will operate over the straight portion of its signal input-peak voltage output characteristic as described above.

Starting out with a given amplitude of signal as indicated at 66′ or 56′ some point on the characteristic 80 of tube 26 is chosen as the lowest suitable operating point from the standpoint of desired quality. The signal 66′ is given a certain amount of D. C. bias which is shown by the line 69c in Fig. 4c. The negative grid potential is thus chosen in accordance with the criterion given above. If a different D. C. component is desired, a different negative bias is chosen for the amplifier. For example, in the case of wave 56, having a large D. C. component representing a bright light-ground, such a tube bias is used as will cause operation further up on the characteristic curve 80. It is thus desired that the total range operated over not only by the individual signal variation but between the extremes of the D. C. component shall lie within the limits of a fairly linear portion of the characteristic curve 80. The amplifier grid bias is thus determined entirely from the standpoint of the amplifier characteristic 80 without reference to the modulator.

The proper adjustment of the grid bias of the modulator, to cause the modulator to operate over the desired portion of its signal input-peak voltage output characteristic is obtained by including the proper proportion of source 95 in the modulator grid circuit, as indicated above.

When the circuit is adjusted in this manner and a signal is received representing blacks and grays, such a grid bias is used for amplifier A—93 that the lower portions of the chosen ranges of characteristics 80 and 100 are used, which changes the apparent illumination of the lamp from dark to dim. If the picture corresponds to white and gray, such a grid bias for the amplifier A—93 is used that the upper ends of the operating ranges of characterstcs 80 and 100 are utilized and the neon lamp is illuminated all the time to a brilliant and less brilliant degree. In this manner the D. C. component which was eliminated in the first stages of the amplifier at the transmitter is reinserted, in effect, in the final stage. If desired, the restoration of the D. C. component can be accomplished by variation of the plate voltage supplied to the modulator by its space current source, instead of by adjusting the tap 91 in the grid circuit of amplifier A—93.

The indicating means mentioned above comprises an amplifier tube 112 which has its grid and filament connected directly to the grid and filament respectively of tube 26 and has in its output circuit a resistance 113 and four neon glow discharge lamps A, B, C and D with polarizing batteries 115, 116, 117 and 118. The grid voltage-plate current characteristic of tube 112 may be the characteristic 80 of Fig. 4b. Lamps A and B have their anodes connected to the plate of tube 112, whereas lamps C and D have their cathodes connected to the plate of the tube. Due to persistency of vision, lamps A and D appear lighted when the adjustment of contacts 90 and 91 is correct, that is when the variations of the grid voltage impressed on tube 112 coincide with the part of curve 80 extending from point 81 to point 82. If the range of the space current variations in tube 112 extends substantially above point 82, lamp C appears lighted. If their range extends substantially below point 81, lamp B appears lighted. The circuit constants for accomplishing these results may be, for example, as follows. The striking voltage of each of the four neon lamps may be 210 volts. Resistance 113 may be 2000 ohms. The space current of tube 112 corresponding to points 81 and 82 may be 5 milliamperes and 40 milliamperes, respectively, which will mean that the IR drops in resistance 113 corresponding to these points are 10 volts and 80 volts, respectively. The voltages of batteries 115, 116, 117 and 118, may be 125 volts, 10 volts, 215 volts and 10 volts, respectively.

In Fig. 4b, the intersection of the dotted lines extending from the lamps A, B, C and D, respectively, with the curve 80 indicate in a qualitative way the points on the curve corresponding to the space currents of tube 112 which cause the IR drops in resistance 113 to be such as, together with the voltages from the lamp polarizing batteries 115 to 118 will cause the voltages across the respective lamps to equal the striking voltage of the lamps, that is, the voltage at which the lamps begin to glow when their voltage is gradually increased from a value insufficient to cause the lamps to light. The lamp A has as its voltage the drop in resistance 113 and the voltage of the two batteries 117 and 118 in series, these batteries being so poled that their effect upon the lamp is diminished by the IR drop in resistance 113. The lamp B has a smaller voltage since its voltage is the voltage of battery 117 diminished by the IR drop in resistance 113. Lamp C has as its voltage the IR drop in resistance 113 series aided by the voltage of battery 115. The lamp D has as its voltage the IR drop in resistance 113 series aided by the voltages of the two batteries 115 and 116. Due to this arrangement lamps A and B are illuminated at the values of space current indicated and continue to glow for all lower values. Lamps C and D become illuminated at the values of space current shown and continue to glow for all higher values.

In the operation of this circuit, the attendant or operator at the transmitting station would need to know that the picture being transmitted, or the field being scanned at that station, has some portions which vary substantially all the way between the extremes of white and black. He manipulates the gain and bias of the amplifier tube until the lamps A and D are illuminated, and the lamps B and C are dark. This assures that the full operating range of the amplifier characteristic for tubes 26 and 112 is being covered but not exceeded in either direction. If lamp B, for example, is illuminated, the amplifier bias is too large and a point too far down on the amplifier characteristic is being used. If lamps B and C, for instance, are illuminated, it may be necessary to vary both the grid bias and the gain adjusting potentiometer to bring the maximum variations within the required range.

Since it is of assistance, in making the lightground of the received image closely approach that of the original if the field scanned at the transmitting end of the system has some portion which is black, as for example, the portion 53 in area 50, or the portion 64 in area 60, and some portion which is white, as for example, the portion 54 in area 50, or the portion 63 in area 60, such portions if not naturally present may be introduced in the subject being scanned or its background.

In the systems of Figs. 1 and 4 as described above, a linear relation obtains between signal and light intensities, that is between the current in the photo-electric cell 12 and the light in the neon lamp 30. This linear relation is not always desirable. To illustrate, it has been found that a curved portion of an input-output transmission characteristic of an element of the electro-optical system may be utilized in reducing departure from correct tone values which another part of the system causes to appear in a received image. Such departure may be due to the photo-electric cell, for example. A particularly important example arises because of the fact that the color sensitivity of the photo-electric cell may be different from that of the human eye or in other words the cell may be of a type which in translating colors to shades of black and white or tones of gray, assigns to them tone values which differ from those the eye would assign to them. Due to this difference, monochromatic tone values assigned to the various portions of a given object by such a cell differ considerably from those which are most satisfactory for visual observation. The effect is particularly marked in the case of faces. Since the photo-electric cell has high relative sensitivity in the green portion of the spectrum it renders an olive complexion, which would ordinarily be classed as dark, as extremely light. On the other hand a person with a fairly light complexion may, due to components at the red end of the spectrum to which the cell is not sensitive, be reproduced as though having a very dark complexion. To correct for this color sensitivity of the photo-electric cell would, of course, require the use of wave filters having variable attenuation over the spectrum so that the photo-electric cell would assign tone values more in accordance with the fancy of human beings. This, however, is difficult if for no other reason than the consequent decrease in total sensitivity. It is possible, however, by making the relation between signal intensity and light intensity such that it may be represented by a characteristic which is concave downward, to move tone values assigned to faces by the photo-electric cell nearer the high end of the light scale and so secure more satisfactory portraits. Such a characteristic may be obtained with the system of Fig. 1, for example, in a manner which will be explained with reference to the graphs of Fig. 5. With the aid of these graphs it will be shown how, when a face scanned is of a ruddy complexion which tends to produce an image of undesirably dark tone in comparison with other objects in the picture, the system can be made to assign to the face a relative tone value more nearly approaching the correct one by properly utilizing the curved portion of, for example, an amplifier characteristic, such as the lower curved portion of the grid voltage-plate current characteristic of amplifier A—25 of Fig. 1.

In Fig. 5 this portion of the characteristic is shown as curve 125, the neon lamp characteristic 100 of Fig. 3 is reproduced for convenience, and a graph 131 is the characteristic of the photo-electric cell 12 with white light intensities incident on the cell as abscissae and the resulting photoelectric currents as ordinates. The light intensity corresponding to D is the intensity of the light received from a dark gray or practically black portion of the subject being scanned. The light intensity corresponding to W is the intensity of the light received from a white or high light portion of the subject. Due to the relative insensitiveness as referred to above of the photo-electric cell to red light, a red light, of the intensity which in the absence of such relative insensitiveness would affect the cell like a white (grey) light of an intensity equal to the abscissa of point 132, generates in the cell a current equal only to the ordinate of a point such as 133. To reduce consequent brightness distortion (reproduction of red in the subject as an undesirably dark tone of gray) in the received image, the system may be arranged for operating

(1) on the curved lower porton 125 of the characteristic of amplifier A—25,

(2) with increase in brightness of the elemental area scanned producing decreasing grid potential (increasingly negative Eg) in amplifier A—25, as shown by graph 135 in Fig. 5, and therefore producing decrease of tube plate current and

(3) with the decrease of tube plate current producing increase of neon lamp voltage, as shown by graph 140 in Fig. 5.

Condition (3) prevents condition (2) from resulting in a negative instead of a positive picture or image.

Condition (1) is preferably obtained by adjusting contact 91.

Condition (2)—that is, the proper phasing of the circuit so that negative-picture voltage, instead of positive-picture voltage, is received by the grid of tube 26—is preferably obtained either by reversing the connections to one of the windings of a transformer such as 14 or 16 or by increasing or decreasing the number of stages of vacuum tubes in amplifier A—13 or A—17 by one stage or by an odd number of stages.

Condition (3) is preferably obtained by (a) increasing the biasing voltage which source V_s delivers to the neon lamp to a magnitude at least equal to the arithmetical sum of the lowest illuminating voltage and the voltage which the maximum plate current of the amplifier produces across the lamp, and (b) reversing the polarity of the biasing source V_s and of the neon lamp, with respect to the amplifier output circuit, by operating switches 89 and 88 to their upper positions.

Two points 150 and 151 in Fig. 5, which are obtained by projection from graphs 100 and 131 as indicated, are the points which, if a curve were drawn between illumination of the photo-electric cell and light in the neon lamp, would correspond to points 153 and 154 respectively, of graph 131; and it will now be apparent from Fig. 5 that operation under the conditions just specified can cause the photo-electric cell current of the value given by the ordinate of point 133 to produce light in the neon lamp of the intensity represented by the ordinate of point 155, and that the point 155 lies in a straight line 160 connecting points 150 and 151. Thus this intensity is that which, if the graph 125 were a straight line, would be produced by the photo-electric cell current of the value given by the ordinate of point 132. In other words, the television system reproduces the brightness of a given red elemental area of the subject as a gray elemental area tone of a brightness occupying the same position in the scale of brightness formed by black, grays and white. Of course, it is realized that the system then reproduces medium grays, for example, in exaggerated brightness in the scale mentioned, since the relation between signal intensity is evidently represented by a characteristic (not shown) which is concave downward as mentioned above. However, the photo-electric cell gives a current of magnitude corresponding to a light intensity D from a very dark portion of the subject, as from a very dark portion of a man's coat, and a current corresponding to white incident light of intensity W, as from a white linen collar, and the current due to a face of ruddy complexion has a given average magnitude that does not bear the same relation to these two extremes that the brightness impression received through the effects of light from the ruddy face directly on the human eye would bear to the brightness impressions received through the direct effects of light from the very dark portion and the white portion, respectively, on the eye; and it has been found that operating the system under the conditions described above reduces the apparent distortion in the received image where the ratio of the red light to white light sensitivity of the photo-electric cell bears a less than unity ratio to the ratio of red light to white light brightness in the scale of brightness formed by black, grays and white.

Graphs 135', 125', 140', 100' and 160' in Fig. 5 correspond to graphs 135, 125, 140, 100 and 160, respectively, in the same figure, except that the former graphs represent conditions which would be obtained in the system if, when using the curved portion of the characteristic of amplifier A—25, the system were so arranged that increase of brightness in the elemental area scanned made the amplifier grid potential greater (less negative), as indicated by graph 135', and consequently increased the space current. The former graphs indicate that under such a condition of operation the curvature of the characteristic 125' would exaggerate the effect at the neon lamp of the relative insensitivity of the photo-electric cell to red light, since point 155' corresponding to point 155 is such that the ratio of the vertical distances between point 155' and points 151' and 150' is even less than the ratio of the vertical distances between point 133 and points 153 and 154.

Fig. 6 shows an amplifier and lamp circuit which may be used, instead of the amplifier A—25 and the associated lamp circuit in Fig. 1 for example, to obtain the operating conditions indicated by graphs 131, 135, 125, 140, 100 and 160 of Fig. 5.

In Fig. 6, the amplifier tube 26 has a resistance 106' connected between the plate and the B battery V_B, which together with a battery V_s polarizes the neon lamp 30 so that an increase in space current through the tube opposes on the lamp 30 the polarizing voltage (from V_s and V_B). As described above in connection with tube 26 in Figs. 1 and 4, so in Fig. 6 the input potentiometer and the negative bias of the tube 26 can be controlled to select a proper operating region on the tube characteristic. The circuit of Fig. 6 should be phased properly, as described above in connection with Fig. 5, so as to make a decrease in space current of tube 26 correspond to an increase in brightness of elemental area scanned and to an increase in the light in the neon lamp. Thus, increased illumination at the transmitter may produce an increased line current, which through the medium of a proper number of amplifier stages or proper connection of terminal circuits to the receiver corresponds to a decrease in space current in the tube 26. This means that the IR drop through resistance 106' is decreased and that the total effective voltage applied to the neon lamp 30 is increased, this total voltage being the algebraic sum of the IR drop through 106' and the voltages of batteries V_B and V_s. This sum should never be less than the minimum illuminating voltage for the lamp.

The circuit of Fig. 6 may be varied as shown in Figs. 7 and 8. The circuit of Fig. 7 can well be used in cases in which the voltage of battery V_s' can be small in comparison to the voltage of V_B and yet at least equal the maximum IR drop in 106' plus the minimum illuminating voltage for lamp 30. Similarly the circuit of Fig. 8 is well adapted to cases in which the maximum IR drop in 106' plus the minimum illuminating voltage for the lamp 30 is not too great to be obtained from a portion of the battery V_B included in series with resistance 106' and the lamp.

As to the operation of the circuits of any of Figs. 1 and 6 to 8, it is desirable to reproduce in black, white and gray tones the effect of the different color tones or values which may be present in the subject. When certain photo-electric cells are used and the circuit has a given adjustment, although a person having a sallow complexion yielding an appreciable amount of green reflected light may not appear unduly light when viewed through the television system, when a person with a ruddy complexion is placed before the transmitter the received image will be too dark on account of the red in the complexion. In the former case it may be desired to operate the amplifier on a practically straight line portion of the characteristic. In the latter case, however, it is desired to make intensity changes of given amount in the light incident on the photo-electric cell produce changes in brightness effect in the received image which are larger when the changes are near the dark end of the effective range than when they are near the light end of the range; so in this case the polarity of the neon lamp should be reversed as described above in connection with Figs. 1 and 6 to 8, the curved portion of the amplifier characteristic should be chosen for operation and the right degree of neon lamp bias should be used to give the proper tone to the picture. These three adjustments have been found useful in order to give the proper light relation between dark elements, such as clothing, white elements such as linen collar or background, and flesh tints which are intermediate.

With the amplifier and lamp circuit of Fig. 1, oscillatory conditions or other conditions undesirable for operation may develop in the system unless the circuit constants are carefully adjusted. These conditions are believed to be due to the energy storage properties of condensers and inductances and the dynamic characteristics of the neon lamp. Their occurrence can be prevented by substituting for the choke coils 86 and 87 current limiting electric discharge devices 86′ and 87′ as shown in Fig. 9 which corresponds to the part of Fig. 1 to the right of line X—X through conductors 170 and 171 when switches 88 and 89 are in their lower positions, and as shown in Fig. 10 which corresponds to that part of Fig. 1 when those switches are in their upper positions. Preferably each of the devices 86′ and 87′ is a two-electrode electron discharge device operating always with the saturation value of its space current, with the discharge path between its anode and thermionic cathode connected in circuit in the same manner as the choke coil which it replaces, to similarly suppress alternating current to the desired degree. Where the requisite stability of operation of the system does not require the use of both current limiting tubes, it may be preferable to employ tube 86′ and choke coil 87.

Australian Patent 11,664/28, complete accepted June 22, 1928, discloses in more detail the means suppressing the D. C. component of picture current at the transmitting end of a picture transmission system, and also discloses means for inserting a D. C. component in the signal at the receiving end of the system.

Patent No. 1,728,122, issued September 10, 1929, discloses a television system generally similar to the system of Fig. 1 described above. The system of that application includes means, but not independent means, for establishing the region of operation on the characteristic curve of the receiving amplifier for the neon lamp and the region of operation on the characteristic curve of the lamp. In that system these regions are not determined entirely independently. That system transmits only A. C. components of the picture current to the receiving station, and an indicator generally similar to that disclosed herein is employed in connection with the receiving amplifier for the neon lamp, to indicate when the D. C. component being restored to the signal at the receiving station has the proper magnitude.

For further details of the design and operation of television systems of the type disclosed herein, reference may be had to the following papers which were presented at the summer convention of the American Institute of Electrical Engineers, Detroit, Michigan, June 20–24, 1927, and which appear in pages 551 to 652 of the October, 1927 issue of

The Bell System Technical Journal—published by the American Telephone and Telegraph Co., New York:

Television—Herbert E. Ives;

The Production and Utilization of Television Signals—Frank Gray, J. W. Horton and R. C. Mathes;

Synchronization of Television—H. M. Stoller and E. R. Morton;

Wire Transmission System for Television—D. K. Gannett and E. I. Green; and

Radio Transmission System for Television—Edward L. Nelson.

What is claimed is:

1. In combination, a glow discharge lamp, means for applying varying voltage to said lamp, a circuit across said lamp, a source of unidirectional voltage in said circuit, and means in said circuit, substantially free from inductance, for passing direct current and supressing current variations.

2. In a signaling system, a receiving circuit comprising an electric space discharge device having an output circuit, a source of unidirectional voltage for said output circuit, a glow discharge lamp and a source of biasing potential therefor connected to said output circuit, and a current limiting space discharge device receiving its saturation current from said second source and preventing current variations in said second source.

3. In combination, an electric space discharge device having an input circuit and an output circuit, a source of unidirectional voltage for said output circuit, means for supplying adjustable steady voltage to said input circuit, a glow discharge lamp and a source of adjustable biasing potential therefor connected to said output circuit, means preventing transmission of direct current from said first source to said lamp, and a current limiting space discharge device receiving its saturation current from said second source and preventing current variations in said second source.

4. An amplifier for amplifying a signal having a direct current component, said amplifier comprising means for eliminating that component and amplifying another of the components of the signal, and means included in said amplifier for combining with the amplified other component direct current for restoring the original proportion between the direct component and the other component.

5. In combination, a source of variations characteristic of visual aspects of a subject, said variations having a direct component and alternating components, a multi-stage amplifier for amplifying certain of said alternating components, means in the initial stage of said amplifier for eliminating said direct component, and means included in said amplifier for restoring said direct component at the proper amplitude at the final stage.

6. In combination, means for producing a wave characteristic of visual aspects of a subject, said wave having a direct component and alternating components, means for suppressing said direct component and amplifying certain of said alternating components, means for restoring said direct component, and means for transmitting the resulting wave to a distance.

7. In combination, means for producing a wave characteristic of visual aspects of a subject, said wave having a direct component and an alternating component, means for suppressing said direct component and amplifying said alternating component, means for restoring said direct component, means for transmitting the resultant wave to a distance, and means at said restoring means for indicating when the direct current restored has the proper magnitude to reestablish the original proportion between the direct component and the other component.

8. In combination, a carrier wave source, means supplying a wave having a variable direct current component and an alternating component, means suppressing the variable direct current component and amplifying the alternating component of said second wave, means for restoring said direct component to produce a resultant wave simulating said second wave, means modulating said carrier wave by said resultant wave to produce a modulated wave, and means transmitting said modulated wave to a distance.

9. The method of transmitting visual aspects of objects to a distance, which comprises generating a fluctuating unidirectional current wave representing the visual aspect of the object to be viewed at a distance, deriving alternating current from said unidirectional current wave, amplifying said alternating current and combining with it a unidirectional current of proper magnitude to cause the resultant wave to simulate said first wave, modulating a carrier wave in accordance with said resultant wave to produce a modulated wave, and transmitting said modulated wave to a distance.

10. A system for transmitting visual aspects of objects to a distance, comprising means for generating a fluctuating unidirectional current wave representing the visual aspect of the object to be viewed at a distance, means for deriving alternating current from said wave, amplifying said alternating current and combining it with direct current to produce a resultant wave, means at said combining means for indicating the value of the combining direct current relative to the value of the direct current component of the first mentioned current wave, means for modulating a carrier wave with said resultant wave to produce a modulated wave, a glow discharge lamp remote from said indicating means, and means for applying said modulated wave to said lamp.

11. The combination of a signal system for transmitting through the medium of electrical variations and reproducing at a receiving point light variations corresponding to light variations at a transmitting point, said system having an inherent tendency to give a distorted relation between reproduced light variations and initial light variations, a space discharge amplifier having a space current-input voltage characteristic exhibiting different degrees of distortion between space current variations and input voltage variations for different values of operating constants, and means for controlling said amplifier to amplify and repeat the electrical variations in the right relation to counteract the distortion of said system.

12. The method of operating a system for reproducing visual aspects of objects at a distance through the medium of electrical variations, which comprises so controlling the electrical transmission efficiency of the system as to reduce apparent distortion in the received image due to the discrimination of the system between colors with regard to the efficiency of the system in translating one kind of waves into another, one of said kinds being electrical waves and another being light waves.

13. A system for transmitting visual aspects of objects to a distance, comprising means for converting light waves differing in frequency into electrical waves, the sensitiveness of said means to different frequencies being different, electrical means for converting said electrical waves into other electrical waves of corresponding frequency, and means for transmitting said waves with a transmission efficiency substantially higher for the electrical waves of a given intensity than for the electrical waves of a different intensity, to compensate in large part at least for the deleterious effects of said difference.

14. Signal transmitting apparatus comprising means for generating signal waves of varying amplitude, a space discharge amplifying device upon which said waves are impressed, means for adjusting the gain of said device, monitoring means for indicating when said gain adjusting device is so adjusted that the impressed waves fall in part at least without a desired region of the space current-grid voltage characteristic of said device, and means for impressing the amplified waves upon a transmitting medium for transmission to a receiving station.

15. Signal transmitting apparatus comprising means for generating signal waves of varying amplitude, a space discharge amplifying device upon which said waves are impressed, means for adjusting the gain of said device, monitoring means including a lamp for visually indicating when said gain adjusting device is so adjusted that the impressed waves fall in part at least without a desired region of the operating characteristic of said amplifying device, and means for impressing the amplified waves upon a transmitting medium for transmission to a receiving station.

16. In a signaling system, an electric lamp having a light producing characteristic substantially proportional to impressed voltage over a range of voltages the lowest of which is of a value substantially above zero, and means to impress upon said lamp voltages within said range, the voltages within said range being alone representative of the transmitted signals, said means comprising a source of voltage, a path for current from said source, and means connecting said lamp to said path and applying to said lamp a voltage opposite to that across said path.

17. A source of unidirectional voltage, two circuits supplied in parallel with voltage from said source, a glow discharge lamp in one of said circuits, and means including a source of unidirectional voltage in said one circuit for maintaining the voltage across said lamp opposite in sign to the voltage across said other circuit.

18. A signaling system comprising a space discharge device having cathode, anode and a control element, an output circuit for said discharge device comprising a source of potential and a

current limiting device in series with each other, a circuit in shunt to at least a portion of said output circuit including said current limiting device, wave translating means in said last mentioned circuit, means for impressing a steady direct biasing potential across said cathode and control element corresponding approximately to the mid-portion of the voltage input-current output characteristic of said discharge device, and means for impressing variable signaling potentials across said cathode and control device of such value that they cause the device to operate only on the straight line portion of its characteristic.

19. A signaling system comprising an amplifier of the three-element type, an output circuit therefor comprising a source of space current and a current limiting device in series, a circuit in shunt to at least a portion of said output circuit comprising said current limiting device, and a source of potential and a second current limiting device in series relationship in said second circuit.

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