

Nov. 29, 1938.

F. GRAY

2,138,577

ELECTRO-OPTICAL TRANSMISSION

Filed April 6, 1934

3 Sheets-Sheet 1

FIG. 1

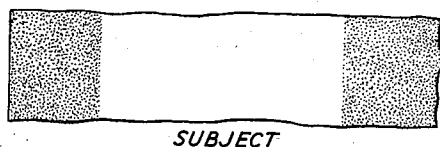


FIG. 7

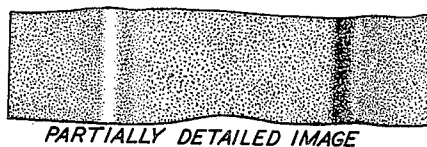


FIG. 2

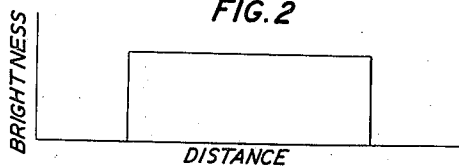


FIG. 3

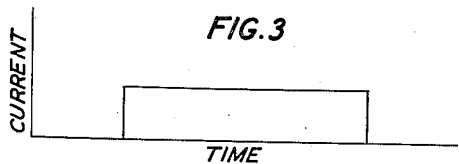


FIG. 9

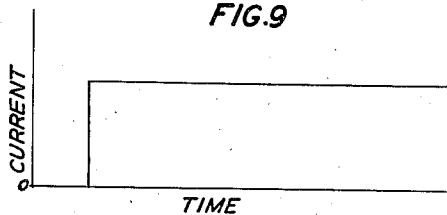


FIG. 4

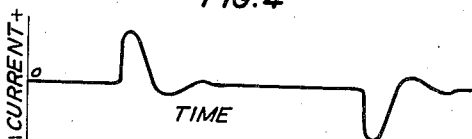


FIG. 10

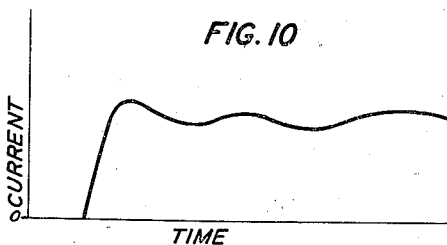


FIG. 5

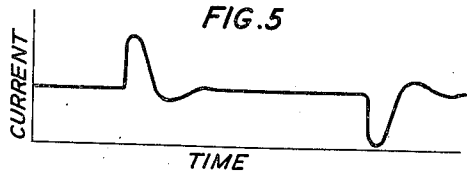


FIG. 6

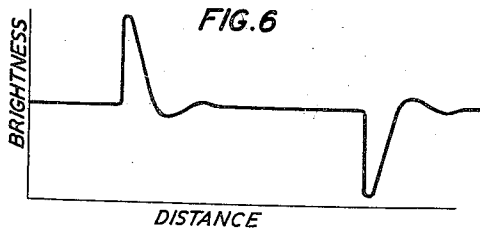
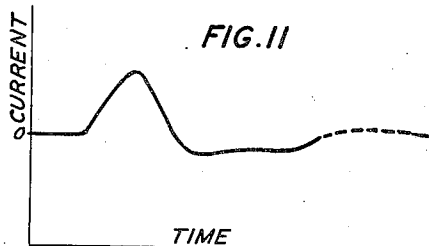


FIG. 11



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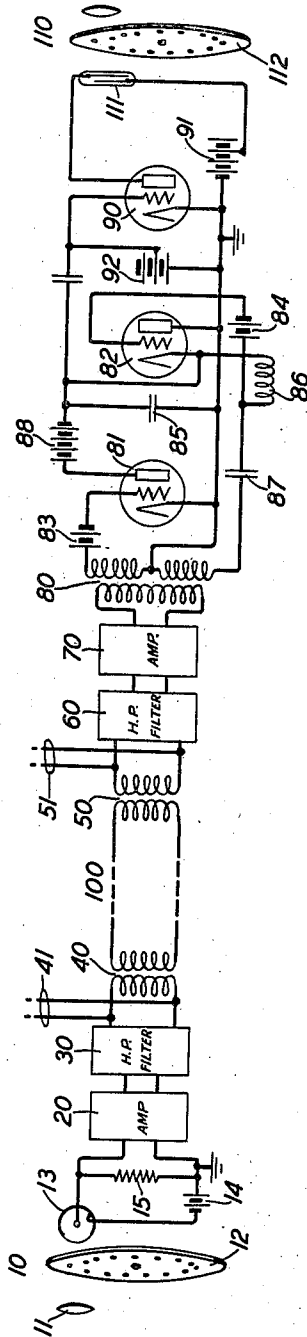
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FIG. 8



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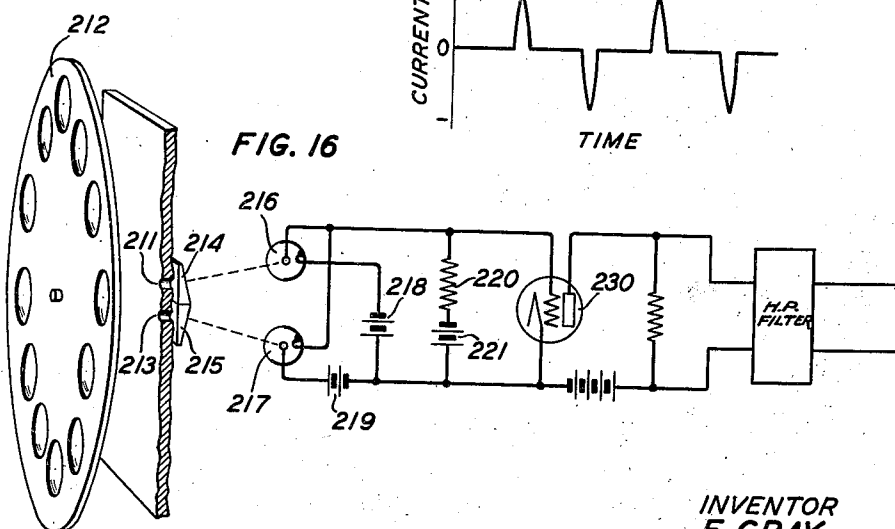
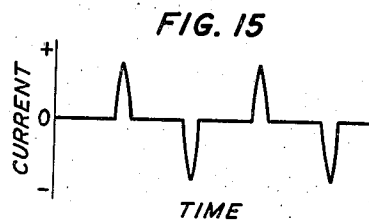
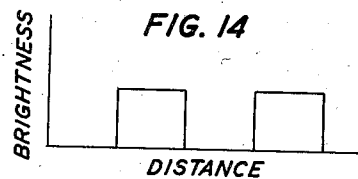
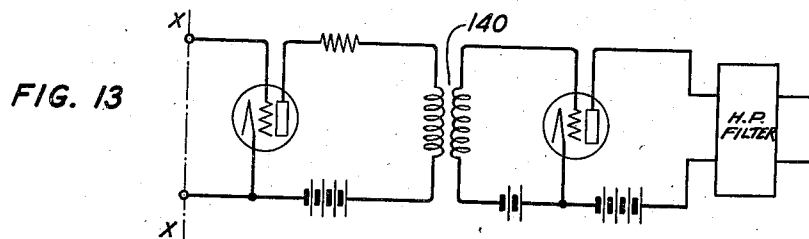
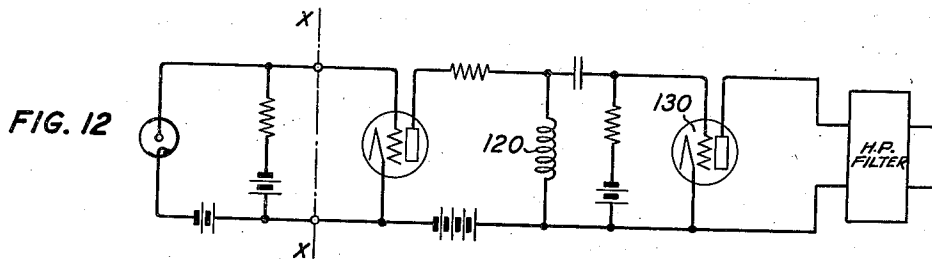
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ELECTRO-OPTICAL TRANSMISSION

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ELECTRO-OPTICAL TRANSMISSION

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Application April 6, 1934, Serial No. 719,244

14 Claims. (Cl. 178—6)

This invention relates to electro-optical transmission and more particularly to the production of electro-optical images by means of a part of the total signal frequency band generated in scanning an object.

An object of this invention is the elimination of certain of the signal frequency components and the production of an image with the remaining frequency components.

Another object is a material reduction in the width of the frequency band necessary for transmission and for forming an image, thus permitting the transmission of greater detail or a larger image within a given transmission frequency band.

A further object is the suppression of a band of low frequency components of the signal so that when the signal is transmitted on a carrier current the upper and the lower sidebands will be well separated, thus permitting the separation of the two sidebands by means of filters and the transmission of only one sideband for the production of the image.

A feature of this invention is the production of images by only a part of the light tone effects which generate the electro-optical signal. While this may give the formed image an appearance somewhat different from that of the object, it however gives useful images which for some purposes are particularly advantageous. The elimination of a part of the signal frequency band or components is particularly adapted to the production of a silhouette image or the contour lines of the object.

With the elimination of a band of low frequencies in the transmission of images, this method is particularly applicable to black and white subjects containing no intermediate tone values. The changes in tone values may be transmitted by the transmission of the higher frequencies, and the intervening portion of the image automatically blocked in at the receiving station. The procedure of suppressing the lower frequency components, say up to or well above the line scanning frequency, has been found to result in a loss of coarser image details and to introduce certain spurious shadings. However multitone fields made up of only fine details may be reproduced surprisingly well. While such reproduction is not satisfactory for certain purposes, it may be utilized in the transmission of certain kinds of information. Two-tone fields of the type of line drawings, writings, etc., can be reproduced without including or correcting for the low frequency components of the signal.

However, two-tone subjects comprising broad bands or regions of illumination can be more accurately reproduced by blocking in one of the tones at the receiving station.

The band of low frequency components suppressed may extend up to a frequency well above the line scanning frequency.

The resulting empty frequency range may be utilized to transmit speech or other signals.

The elimination of such a band also permits, as indicated above, single sideband carrier transmission; for it separates the two sidebands so that one of them may be filtered out, a procedure that is otherwise very difficult in image transmission.

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

Fig. 1 shows a portion of a field of an object comprising a broad white strip on a dark background transverse to the direction of scanning;

Fig. 2 is a diagram showing the brightness contour along a scanning line across an object such as shown in Fig. 1;

Fig. 3 shows the signal current resulting from scanning a line across such an object;

Fig. 4 shows the signal current with a wide band of low frequencies suppressed;

Fig. 5 shows the signal current of Fig. 4 combined with a direct current;

Fig. 6 shows the produced brightness contour resulting from the signal current shown in Fig. 5;

Fig. 7 shows the produced image simply as a bright line defining one edge of the strip and a dark line defining the other edge, the central portion of the strip being undefined;

Fig. 8 shows the essential elements of both the transmitting and the receiving stations of an electro-optical system in accordance with this invention arranged for suppression of a band of low frequency components before transmission and for blocking in the image in black and white at the receiving station;

Fig. 9 shows an ideal signal for a abrupt change of tone value in the image field;

Fig. 10 shows the effect of a high frequency cut-off filter on the signal current of Fig. 9;

Fig. 11 shows the effect of a low frequency cut-off filter on the signal current of Fig. 9;

Fig. 12 diagrammatically shows a circuit arrangement for generating an image signal by the usual method of scanning, which upon passing through an inductance produces surges in the output circuit;

Fig. 13 shows a modified circuit arrangement

of Fig. 12, employing a transformer instead of an inductance;

Fig. 14 shows the brightness contour of an image along a scanning line;

- 5 Fig. 15 shows the surges corresponding to signal represented by the brightness contour of Fig. 14; and

- Fig. 16 diagrammatically shows the transmitting scanning apparatus modified to produce 10 similar signal pulses by scanning in such a manner as to give the space rate of change of brightness along the scanning line.

- Figs. 1 to 7 illustrate the various steps in the production of an image of a broad white strip 15 across a scanning field when the low frequency components of the signal current are suppressed.

- Fig. 1 shows a portion of a field of an object comprising a broad white strip on a dark background transverse to the direction of scanning.

- 20 Fig. 2 shows the brightness contour along a scanning line across the object shown in Fig. 1 and signal current resulting from scanning a line across such an object is shown in Fig. 3, the current having a finite value when the object is

- 25 white and zero when the object is black. The actual signal current, however, is made up of a wide frequency band. When a wide band of the lower frequency components, is suppressed, the resulting current is as shown in Fig. 4. This

- 30 figure shows particularly that upon a transition from black to white in the object, the signal is characterized by a surge in one direction followed by smaller oscillations, and a transition from white to black is characterized by a surge

- 35 in the opposite direction, also followed by smaller oscillations. The signal current is combined with a direct current at the receiving station and Fig. 5 shows the resulting signal. The reproduced brightness contour resulting from the above signal

- 40 current is shown in Fig. 6, the general appearance of the signal and of the brightness contour of these two curves being similar as indicated in the two figures. The image is produced

- 45 as shown in Fig. 7 simply as a bright line defining one edge of the strip and a dark line defining the other edge, the central portions of the strip being undefined in tone values. However, in the particular case of a black and white subject containing only two tone values, it is possible to

- 50 block in the white parts in the produced image and obtain faithful image production which will appear substantially as the object shown in Fig. 1. While the application of this blocking in principle herein specifically described is for two-

- 55 tone work, the invention in its broader aspects is not limited in its application to the simple case of black and white or other two-tone image production.

- The apparatus here shown and described for 60 scanning an object thereof is designed particularly to produce faithful images of objects of two tones by blocking in the tone values at the receiving station for one of the tones. Obviously, the blocking in may be omitted and the contour

- 65 lines alone relied upon to produce a useful image. When a wide band of low frequency components is suppressed, a change from black to white always gives a surge current in one direction and a change from white to black gives a surge in

- 70 the opposite direction. Consequently the complicated signal resulting from scanning a black and white subject may be made to reproduce the original, providing that the receiving apparatus is so arranged that a surge corresponding to a change

- 75 from black to white causes current to flow at a

constant value until a surge in the opposite direction stops the flow and providing that the apparatus is biased so that it is unaffected by the smaller oscillations following a change in tone value. The result is to block in the received signal 5 to reproduce substantially the original signal as it was before the low frequency components were removed. Such a transmission system is illustrated in Fig. 8.

Fig. 8 shows the essential elements of both the 10 transmitting and receiving stations of an electro-optical system in accordance with this invention arranged for suppressing a band of low frequency components before transmission and for blocking in black and white images at a receiving station. 15 The signal is generated by the usual method of scanning. In describing the performance of the system shown in Fig. 8, a black and white or two-tone subject is considered as the object scanned. The essential elements for generating the photo- 20 electric current at the transmitting station 10 may comprise optical means 11 for forming an image of the object upon the scanning disc 12, a light sensitive cell 13, a source of current 14, and a resistance 15 over which a potential variation 25 occurs in accordance with the light tone values of the object scanned. The photoelectric signal thus generated is amplified by the amplifier 20, passed through a high pass filter 30 and through a suitable coupling 40 to the transmission line 100. 30 The high pass filter 30 transmits the higher frequencies and suppresses the lower frequencies, the cut-off point being arranged as may be desired, which as already stated would usually be above the line scanning frequency. Circuit 41 35 indicates the point at which connections may be made for utilizing the transmission line for transmitting a signal within the suppressed frequency band. In the arrangement here shown the empty frequency range might be utilized to trans- 40 mit speech or other signals. Connection at the receiving station is made with the transmission line through a suitable coupling 50. The speech frequency signal may be taken off by the circuit 51 which would include suitable filtering ap- 45 paratus, not here shown, to pass only the speech frequencies. The electro-optical signals are transmitted by the high pass filter 60 to the amplifier 70 and to the transformer 80 and applied to the grids of the electron discharge tubes 81 50 and 82. Surges corresponding to a change from black to white cause the tube 82 to pass current and surges corresponding to the reverse change in tone value cause the tube 81 to pass current, the biasing batteries 83 and 84 preventing the 55 smaller oscillations following a surge from causing either tube to pass current. A blocking coil 86 prevents the short-circuiting of the grid of tube 82 with its filament, and the blocking condenser 87 prevents the high side of the network being short-circuited to ground. A condenser 85 is connected across the tubes 81 and 82 and to the grid of the receiving tube 90 whose output is connected through the battery 91 with a light 60 source 111, of the electro-optical receiver 110 comprising a scanning disc 112 similar to the scanning disc 12 at the transmitting station. These two scanning discs are, of course, operated in synchronism and in phase by any suitable driving means. Associated with the tube 90 is an 70 adjustable grid biasing battery 92.

The operation of this network is such that if the condenser 85 is negatively charged, temporarily preventing any flow of current through the receiving tube 90, then the arrival of a surge 75

corresponding to a transition from black to white discharging condenser 85 through tube 82 results in a flow of current through tube 90. This flow continues until a surge in the opposite direction again charges condenser 85 from the source of power 83 through the tube 81 and thus stops the flow of current through the tube 90. As a result of this process the tube 90 gives a blocked-in signal that substantially reproduces the original signal generated at the transmitter by the light sensitive cell 13 since this tube 90 controls the light source 114 associated with the scanning disc 112.

The tubes 81 and 82 may be gas-filled to break down sharply at a definite grid voltage. In the case of very slow transmission, biased electromagnetic relays may be used instead of the tubes.

The width of the low frequency band that can be suppressed in the type of system illustrated depends on its characteristics, and can best be determined by direct tests. An estimate of the band width may be made, however, from the following theoretical consideration:

If there were no losses in a television or telephotographic system, a sudden transition in tone value would give a sharp cornered signal as illustrated in Fig. 9. In any physical system, however, the attenuation of the high frequency components rounds off the sharp corners of the signal as illustrated in Fig. 10. As an approximation the system may be considered as if it had a sharp upper cut-off frequency f_2 .

In the proposed method of transmission, the signal passes in addition through a filter that cuts off all frequencies below a chosen value f_1 . The resulting transient is the same as if the ideal sharp cornered signal went through a band-pass filter with cut-off frequencies at f_1 and f_2 . This transient may be mathematically expressed as a function of time:

$$(1) \quad F(t) = \frac{2a}{\pi} \int_{2\pi f_1 t}^{2\pi f_2 t} \frac{\sin \lambda d\lambda}{\lambda}$$

Its character is determined by the two cut-off frequencies. In the case under consideration it is a surge in one direction followed by smaller oscillations as illustrated in Fig. 11, which is drawn for

$$\frac{f_1}{f_2} = \frac{1}{3}$$

It is the smaller oscillations that limit the application of the method under consideration. If the suppressed band of frequencies is too wide, the oscillations from successive surges may build up to an amplitude almost as large as the surges themselves. Under such conditions it is impossible to bias out the oscillations.

The ratio of the initial amplitude of a surge to the amplitude of the first swing in the opposite direction is a function of the ratio of the two cut-off frequencies. This amplitude ratio may be determined graphically by plotting the integral of Equation (1) in its two parts. The following are rough values of the amplitude ratios for various values of the frequency ratios.

f_1/f_2	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$
Amplitude ratio.....	1	.65	.3	.3	.18

These values indicate that the lower cut-off frequency can be located at one-fifth to one-third of the upper frequency limit. Physical circuits do not have such sharp cut-offs as assumed

in the theory. Their gradual cut-offs tend to decrease the amplitudes of the oscillations, and for this reason it may be possible to suppress as much as one-third of the total frequency range.

The amplitude of undesirable oscillations may be decreased to some extent by causing the change in tone value to generate current surges as a signal before it is passed through a high-pass filter. This may be done either by taking the time derivative of a signal generated by the usual method of scanning, or by scanning in such a manner as to take the spacial derivative of brightness.

Figs. 12 to 16, inclusive, illustrate the last mentioned methods in which a current surge is generated from a change in tone value. Fig. 12 diagrammatically shows a circuit arrangement in which an image signal generated by the usual method of scanning passes through the inductance 120. A connection across this inductance gives the time derivative, or rate of change, of the current with respect to time. As a result, the brightness contour of an object such as shown in Fig. 14 gives a signal made up of current surges illustrated in Fig. 15. A change from black to white gives a surge of current in one direction and a change of tone in the reverse sense gives a surge in the opposite direction. These surges are impressed upon an amplifier 130 which connects with the transmission line. Since the total flow of charge in one of these pulses is small, it will not generate such large oscillations on going through a high-pass filter as would otherwise be generated by the original signal. Fig. 13 illustrates another method of securing the time derivative of the signal by simply passing the usual signal through a loose inductive coupling 140. Such a time derivative may also be obtained by passing part of the signal through a retard network and recombining it with the other part of the signal.

Instead of taking the time derivative of the usual signal, similar pulses or surges may be obtained by scanning in such a manner as to give the space rate of change of the brightness. This may be done by utilizing two scanning apertures, one following the other at a very short distance, and allowing the light to fall on two photoelectric cells with battery poles in opposite directions as shown in Fig. 16. The combined current from the two cells is proportional to the difference in brightness at the two scanning apertures, that is, to the space rate of change of the brightness. In this particular arrangement a rotating lens scanning disc 212 sweeps successively displaced images across two closely positioned stationary scanning apertures 211 and 213 in a vertical direction. Prisms 214 and 215 respectively are placed behind the apertures to spread the light beams apart and direct them to the light sensitive cells 216 and 217 respectively. Batteries 218 and 219 oppositely poled connect respectively to the two light sensitive cells. The output sides of these cells are connected in common across the resistance 220 in the usual manner and a biasing battery 221 is connected in the circuit to apply the proper grid bias to the tube 230 amplifying the signal current which in turn connects with the transmission line. This line has a high-pass filter such as shown in Fig. 8. The circuit arrangements shown in Figs. 12 and 13 are similarly connected to the transmission line.

This invention permits, through the cutting out of the lower frequency components, the viewing of the contour or outline of the object being

scanned with the details more or less undefined within the boundary line, or the blocking in of a uniform tone within these boundary lines, as would be clear from what has been said above.

- 5 In the production of unblocked-in images one edge of an area of uniform tone value is reproduced as a black line and the other edge as a white line. However, both edges may be produced in the same tone value by employing a simple
10 receiving circuit associated with the receiving transformer and comprising an amplifier supplying current to any ordinary form of rectifier which rectifies both half waves, the resulting rectified wave being impressed upon the glow
15 lamp. The rectifier may, for example, be of the ordinary push-pull vacuum tube type. Or the surges from this secondary of the receiving transformer may be amplified and impressed upon a glow lamp of the type shown in Fig. 8 but having
20 both plate electrodes of wire mesh. This lamp will glow the same amount for equal amplitudes of impressed current regardless of the direction of the current. A diffusing element such as a plate of frosted glass may be inserted between
25 the lamp and the scanning disc.

What is claimed is:

1. The method of television which comprises scanning successive elemental areas of an object line by line, the light distribution along the whole
30 scanning path comprising sine wave components of frequency lower than the line scanning frequency, and generating a signal current representative of the light tone values along said scanning path, suppressing a band of the lower frequency
35 components of the signal current extending from zero frequency to a frequency in the vicinity of the line scanning frequency or higher, and forming a two-tone electro-optical image with the remaining signal components.

- 40 2. The method of electro-optical transmission which comprises scanning successive elemental areas of an object line by line, the light distribution along the whole scanning path comprising sine wave components of frequency lower than
45 the line scanning frequency, and generating a signal current representative of the light tone values along said scanning path, suppressing a band of low frequency components of the signal current, said band including components extending
50 up to the region of the line scanning frequency, transmitting a wide band of the remaining signal components, and forming a two-tone electro-optical image with the transmitted signal components.

- 55 3. The method of electro-optical transmission which comprises scanning successive elemental areas of an object line by line, the light distribution along the whole scanning path comprising sine wave components of frequency lower than
60 the line scanning frequency, and generating a signal current representative of the light tone values along said scanning path, suppressing a band of the lower frequency components of the signal current, the cut-off frequency being located
65 well above the line scanning frequency and all components below said frequency being suppressed, and forming a two-tone electro-optical image with the current from which said band has been eliminated.

- 70 4. The method of producing electro-optical images which comprises scanning successive elemental areas of an object line by line, the light distribution along the whole scanning path comprising sine wave components of frequency lower
75 than the line scanning frequency, and generat-

ing a signal current representative of the light tone values along said scanning path, transmitting only a band of the higher frequency components of the signal current extending from the vicinity of the line scanning frequency or higher,
5 utilizing the transmitted current to establish the contour of the object imaged, and automatically blocking in a substantially uniform tone in the produced image within desired contour lines or boundaries.

- 10 5. A method of producing in black and white electro-optical images which comprises scanning successive elemental areas of an object line by line, the light distribution along the whole scanning path comprising sine wave components of
15 frequency lower than the line scanning frequency, and generating a signal current representative of the light tone values along said scanning path, transmitting only a band of the higher frequency components of the signal current extending from
20 well above the line scanning frequency, utilizing the transmitted current to establish the contour lines of the object imaged, and automatically blocking in a desired portion of the produced image within the said contour lines or boundaries
25 to give said portion a substantially uniform dark tone.

- 30 6. An electro-optical image transmission system comprising means for scanning successive line series of elemental areas of an object wherein the light distribution along the whole scanning path comprises sine wave components of frequency lower than the line scanning frequency,
35 means for generating a signal current by said scanning, an electrical filter having a low frequency cut-off located well above the line scanning frequency of said scanning mechanism and suppressing substantially all components below said frequency, means for impressing said signal
40 current upon said filter, means for transmitting the signal frequency components passed by said filter, a source of light, means for utilizing the transmitted signal components to control said light source to produce light of two different
45 values, and scanning means for producing a two-tone electro-optical image from said transmitted signal.

- 50 7. In an electro-optical system, means for scanning an object in successive line series of elemental areas, the light distribution along the whole scanning path comprising sine wave components of frequency lower than the line scanning frequency,
55 means for generating a signal current from said scanning, means for taking the time derivative of the said signal current, means for suppressing a band of the lower frequency components of the signal current extending from zero frequency to a frequency in the vicinity of the line scanning frequency or higher, a source of light at an electro-optical receiving station,
60 means controlled by the unsurpassed portion of said signal current for controlling and limiting the amounts of light generated by said light source to two different intensities, and means for scanning the said light source in successive line series of elemental areas in synchronism and in phase with the process of scanning the said object.

- 65 8. In an electro-optical system, means for scanning an object in successive line series of elemental areas, the light distribution along the whole scanning path comprising sine wave components of frequency lower than the line scanning frequency, and generating photoelectric signal currents by said scanning, means for taking
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the spacial derivative of brightness of each successive increment of scanning of the object along the scanning path, means for suppressing a band of the lower frequency components of the signal current extending from zero frequency to a frequency in the vicinity of the line scanning frequency or higher, a source of light at an electro-optical receiving station, means controlled by the unsuppressed components of said signal current for controlling and limiting the amount of light generated by said light source to two different intensities, and means for scanning the said light source in successive line series of elemental areas in synchronism and in phase with the process of scanning the said object.

9. In an electro-optical system, a television receiving station producing images by utilizing a television current produced by scanning an object along parallel elemental paths in succession, the light distribution along the whole scanning path comprising sine wave components of frequency lower than the line scanning frequency, and subsequently eliminating from the resulting signal current a wide band of the lower frequency components extending up to the line scanning frequency or higher, comprising means responsive to those portions of the current produced when the scanning reaches areas of one tone value for causing the flow of current in the output circuit of said receiver to reach a minimum, and means responsive to those portions of the current produced when the scanning reaches areas of another tone value for causing the flow of current in the output circuit of said receiver to reach a maximum.

10. In an electro-optical system, a television receiving station producing images by utilizing a television current produced by scanning an object along parallel elemental paths in succession, the light distribution along the whole scanning path comprising sine wave components of frequency lower than the line scanning frequency, and subsequently eliminating from the resulting signal current a wide band of the lower frequency components extending up to the line scanning frequency or higher, comprising means responsive to those portions of the current produced when the scanning reaches areas of one tone value for causing the flow of current in the output circuit of said receiver to reach a minimum, and means responsive to those portions of the current produced when the scanning reaches areas of another tone value for causing the flow of current in the output circuit of said receiver to reach a maximum and remain at this level until said first responsive means causes the flow of current in the output circuit of the receiver to reach a minimum value.

11. In an electro-optical system, a television receiving station producing images by utilizing a television current produced by scanning an object along parallel elemental paths in scanning succession, the light distribution along the whole scanning path comprising sine wave components of frequency lower than the line scanning frequency, and subsequently eliminating from the resulting current a band of the lower frequency components extending up to the line scanning frequency or higher comprising a vacuum tube amplifier in the circuit of said receiver, a condenser arranged to control the grid bias of said vacuum tube amplifier, means responsive to those

portions of the current produced when the scanning reaches areas of one tone value of said object for substantially instantaneously charging said condenser with a biasing potential sufficient to substantially instantaneously block the flow of current through the output of said amplifier, means responsive to those portions of the current produced when the scanning reaches areas of another tone value of said object for substantially instantaneously discharging said condenser to remove the said biasing potential thereon and thus cause said amplifier to transmit a maximum output current, a variable light source connected to the output circuit of said amplifier, and scanning means associated with said light source for causing light therefrom to scan an image field.

12. An electro-optical scanning system for generating photoelectric signal currents by said scanning proportional to the space rate of change of brightness of successive elemental areas of the object being scanned comprising simultaneously projecting two adjacent scanning beams into two respective light sensitive cells, a source of oppositely poled current for each of said cells, a circuit from each of said combined cells and said sources of current connecting them in multiple to a common resistance over which is produced potential variations substantially proportional to the said space rate of change of brightness of successive elemental areas.

13. An electro-optical system comprising means for scanning successive line series of elemental areas of an object, the light distribution along the whole scanning path comprising sine wave components of frequency lower than the line scanning frequency, having means for simultaneously scanning two closely positioned elemental areas along said line series of elemental areas of said object, means for separately directing the respective light modulated scanning beams from each of said areas in separate paths, a light sensitive cell positioned in each of said paths and each respectively controlled by one of said modulated beams, parallel electric circuits connecting each of said cells to a common resistance circuit, a source of current connected in each of said circuits and oppositely poled therein with respect to each other, means for suppressing a band of the lower frequency components of the signaling current produced in said common resistance circuit as a result of scanning, said band extending from zero frequency to a frequency in the vicinity of the line scanning frequency or higher, and means for utilizing the unsuppressed components for producing a two-tone image.

14. In an electro-optical system, means for differentially generating photoelectric signal currents, comprising means for simultaneously scanning substantially adjacently following elemental areas of a field of view, the light distribution along the whole scanning path comprising sine wave components of frequency lower than the line scanning frequency, optical means for directing the two respective modulated light beams resulting from said scanning in mutually exclusive paths, light sensitive elements in each of said paths each excited by one of said beams, and an electric circuit oppositely connecting said elements in parallel to a common output circuit.

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