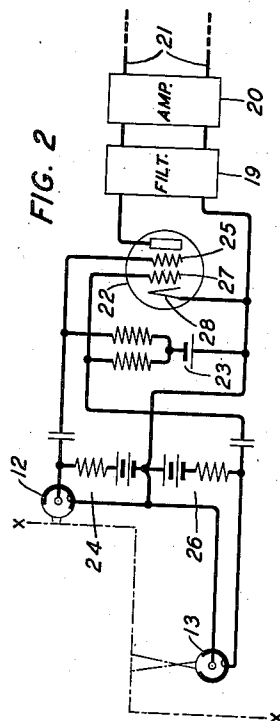
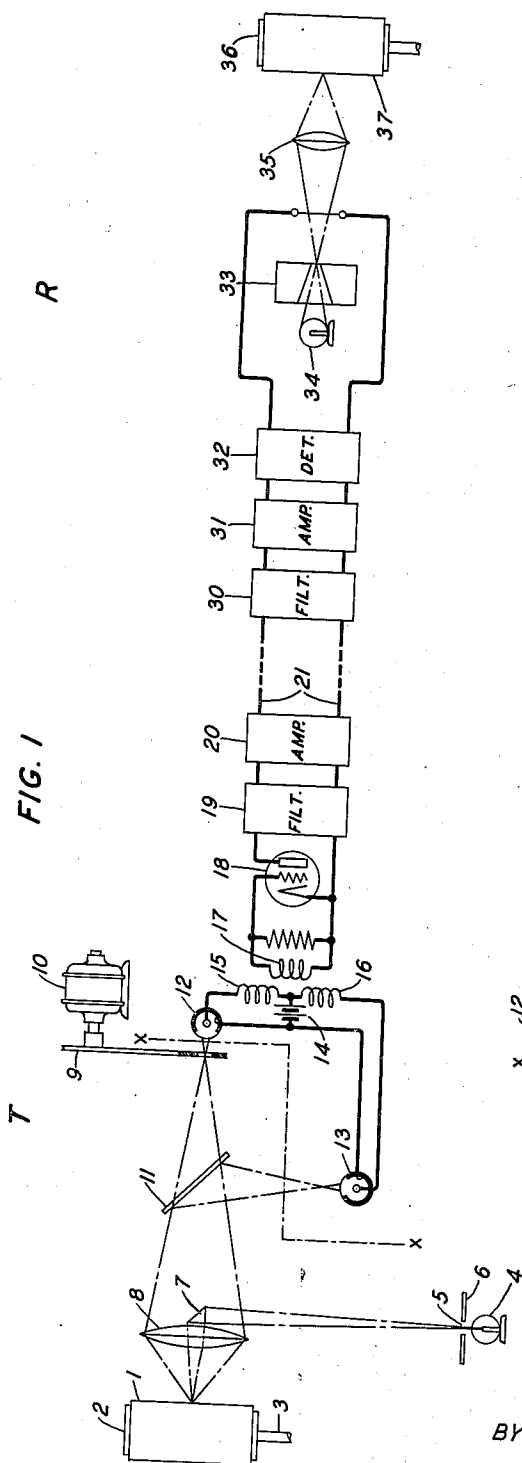


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M. W. BALDWIN, JR.
ELECTROOPTICAL APPARATUS

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INVENTOR
M. W. BALDWIN JR.
BY *J. H. Neville*

ATTORNEY

UNITED STATES PATENT OFFICE

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ELECTROOPTICAL APPARATUS

Millard W. Baldwin, Jr., Bloomfield, N. J., assignor to Bell Telephone Laboratories, Incorporated, a corporation of New York

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This invention relates to electro-optical apparatus and more particularly to a method of and means for producing a signal modulated carrier electric current.

5 In the operation of an electro-optical system, a field of view or representation and a beam of light are moved with respect to each other in such manner that light supplied by the beam and controlled by the tone values of successive elemental areas of the subject is applied to a light sensitive electric device which is thereby activated to cause the production of a signal current having a frequency band with extending from substantially zero to an upper limiting frequency of many thousand cycles for television and one or more thousand cycles per second for picture transmission. For high quality picture transmission, the upper limiting frequency of the picture band may be of the order of two thousand cycles per second.

Efficient transmission of a signal current of the above-mentioned band width is impossible over either a telegraph or telephone line, for the reason that the former distorts the high frequency components and the latter distorts the low frequency components. Again satisfactory transmission over other types of communicating channels or media can only be effected by providing a signal band which occupies a position in the frequency spectrum corresponding to the transmission range of the channels or media.

In order to provide for the transmission of a signal current band of the type referred to above over the circuits of a telephone network or other communicating media, it has been the practice to produce a signal modulated carrier current, based on a carrier of such frequency that the resulting modulation products lie within the efficient frequency transmission range of the network or media.

According to one method of producing a picture or image modulated carrier current, heretofore proposed, a light beam, after being chopped or otherwise varied at a carrier frequency rate is used to scan the field of view or picture, the doubly modulated light is applied to a light sensitive electric device, which is thereby activated to cause the production of current components corresponding to the different fluctuations of the light, that is, a signal modulated carrier current including the upper and lower side-bands of the carrier and the picture or signal current per se.

In order to provide a signal modulated carrier current having an energy level suitable for trans-

mission to a remote station, the currents produced by the light sensitive device are supplied to an amplifier. Unless the light beam carrier variation is sufficiently removed from the upper limiting frequency of the signal band, the reproduced signal current will include current components which correspond in frequency with certain current components of the lower side-band of the modulated wave and hence there will be a frequency overlap. Since any means that can be used to suppress the former will also suppress a portion of the modulation products, serious distortion will be introduced and hence it will be impossible to produce a facsimile of the scene or picture scanned at the transmitter.

By varying the light beam at high frequency compared with the upper limiting frequency of the signal band, the modulation products can be made to occupy a position in the frequency spectrum such that the upper frequency component of the picture band and the lower frequency component of the lower side-band are spaced apart sufficiently to permit a filter to select the modulated wave without attenuating any of its components and to suppress the undesired signal current. In this case, the frequency of the carrier is so high that the resulting modulation products cannot be efficiently transmitted over telephone lines, and, as a result, a second stage of modulation must be used to effect a transfer of the modulation products to a point in the frequency spectrum such that they lie in the efficient frequency transmission range of the line.

In one system, which has been successfully used for transmission over telephone lines, the frequency of the carrier light variation was so chosen and the frequency band width of the signal current was so limited that only one stage of modulation was employed, and a filter was used to select the essential components of the lower side-band and to suppress the signal current. In this system, the signal current overlaps the selected side-band to some extent and, due to the curved characteristic of the filter cut-off, certain components of the selected side-band are somewhat attenuated, with the result that some distortion is introduced. By holding the band width of the signal current within selected frequency limits and properly choosing the carrier frequency, the system operated to produce a modulated wave including a lower side-band which lies within the range that can be efficiently transmitted over telephone circuits, and the amount of distortion introduced was well within permissible limits, with the result that a satis-

factory reproduction was produced at the receiving station.

Aside from the fact that successful operation of this system requires that the band width of the signal current be limited to the minimum frequency range which can be used to produce a satisfactory picture at the receiver, the system is deficient in that, even with a picture current of minimum band width, this current extends over a considerable part of the efficient transmitting range of the line and hence a material part of the range is not usefully employed. Again, since the only method of preventing overlap is to use a carrier variation having a frequency which is equal to at least twice the upper limiting frequency of the picture or image band, the latter serves to definitely fix the minimum value of the carrier variation that can be used in the system.

For satisfactory picture reproduction at the receiving station in the system described above, it is essential to transmit a picture current having a band width of at least 1200 cycles, over a medium the efficient transmission range of which extends from 200 cycles per second to not more than 3000 cycles per second. As a result, the portion of the range between 200 cycles per second and 1200 cycles per second cannot be used for transmission, and the minimum rate of carrier variation that can be used is 2400 cycles per second, because the amplifiers, used to amplify the currents supplied by the light sensitive device, are designed to repeat all current components supplied by this device which lie in the transmission range of the line, frequencies below 1200 cycles per second are suppressed by the filter used to suppress the picture current, the line distorts the frequencies above 3000 cycles per second to such an extent that they cannot be used for picture reproduction, and overlap can only be prevented by using carrier variations of 2400 cycles per second.

While this disadvantage is especially marked in the case of picture transmission over telephone lines, it will be apparent that, if the amplifiers used to repeat the currents supplied by the light sensitive devices in systems of similar type, such as, for example, the signal band resulting from scanning an object for transmission in a television system which band may extend from a few cycles per second to upwards of a hundred thousand cycles per second, the presence of such signal band will prevent the use of the lower portion of the range of the medium over which transmission is effected and will fix the minimum frequency of the carrier to be employed.

The present invention provides a simple arrangement whereby the above-noted disadvantages may be overcome.

An object of the invention is to utilize the signal variations to simultaneously control the production of a signal modulated carrier current and effect suppression of the signal current per se.

Another object is to extend the frequency range which may be utilized for the carrier light variations that are used to control the production of a picture or image modulated carrier wave to be transmitted over a given medium.

A further object is to permit the use of picture or image variations, having a frequency band width determined solely by the efficient transmission range of the medium over which the modulated wave is transmitted, to control the production of a picture or image modulated wave,

the current components of which are not distorted.

A feature of the invention relates to an apparatus for producing a signal modulated wave including means for effecting suppression of the signal current.

According to one embodiment for practicing the invention, which will be hereinafter described for illustrative purposes, a beam of light of constant intensity and supplied by a stationary source is applied to a picture carried by a drum or cylinder which is rotated and given a motion of translation, whereby successive elemental areas of the picture are illuminated, a lens placed close to the picture surface forms an image of the illuminated areas in the plane of a rotating chopping disc having openings and bars which are equal in size to the image. Between the lens and the disc, and in the path of the light beam produced by the lens, is a partially silvered glass plate which forms a second image of the scanned areas, the silvering being such that the reflected image is half as bright as the image transmitted through the plate. To photoelectric cells having similar characteristics are respectively positioned to receive picture modulated light which has been chopped by the disc and to receive the picture modulated light of the second image, and the electrical output circuits of these cells are connected differentially to the input circuit of an amplifier, whereby the picture currents produced by the respective photoelectric cells neutralize each other in this circuit and hence only the picture modulated carrier wave, comprising the two side-bands is repeated by the amplifier.

Fig. 1 is a diagrammatic representation of a picture transmission system involving the invention; and

Fig. 2 shows an arrangement which may be substituted for that to the right of the irregular section line X—X on Fig. 1.

Referring to Fig. 1, there is shown a picture or other representation 1, mounted on a transmitting cylinder 2, carried by a shaft 3. In accordance with well-known practice, the cylinder is given a motion of rotation and translation by suitable driving means (not shown), connected to the shaft 3. Such means may, for example, be of the type disclosed in Fig. 2 of U. S. Patent 1,606,227, November 9, 1926, to Horton et al.

The picture or representation is scanned by a beam of light supplied by a stationary optical system comprising a source from which light passes through an aperture 5 in a mask 6, to a light directing element 7 associated with a large-aperture lens 8, which serves to focus the light rays in the form of a small spot of great brilliance on the surface of the representation mounted on the cylinder. Due to the motion of the cylinder, the light spot serves to illuminate successively elemental areas of the picture in a spiral path, and light reflected from these areas is gathered by the lens 8 which should be adjacent to the picture surface, and the portion which is not covered by the light directing element 7, serves at each instant to form an image of the illuminated area in the plane of a disc 9, having openings and bars which are of the same size as the image. The disc is driven at a desired rate to interrupt the light beam at a carrier frequency rate by a motor 10.

Between the lens 8 and chopping disc 9 is mounted a partially silvered glass plate 11, or semi-transparent mirror, which forms a second image of the illuminated areas, at a point re-

moved from the chopping disc. The silvering of the plate 11 should be such that the reflected image is half as bright as the image transmitted through the plate to the disc 9.

Two light sensitive devices, for example, photoelectric cells 12 and 13, having identical operating characteristics, are respectively mounted adjacent to the apertured portion of the rotating disc 9 and in the path of the reflected image. As shown, cell 12 occupies a position adjacent to the disc 9, and cell 13 is in the path of the reflected image and they are included in circuit with an energizing source 14, having its negative terminal connected to the cathodes of the respective cells, and its positive terminal connected by circuits, each including the primary winding 15 or 16, respectively, of a transformer, to the anodes of the cells. A single secondary 17, associated with the primaries 15 and 16, is included in the input circuit of an amplifier or repeater 18, the output circuit of which includes a filter 19, through which selected signal components are transmitted to an amplifier 20. The latter supplies amplified signal currents selected by the filter to a transmission circuit 21, which may be a line extending to a remote station R.

Station R comprises a filter 30 for selecting the incoming picture modulated carrier current, which is amplified by device 31, detected by element 32 to yield the picture current, which is applied to the ribbon of a light valve 33 included in an optical system, comprising a steady light source 34, valve 33 and a lens 35 for focusing the varying light transmitted through the light valve in the form of a small spot upon a light sensitive recording material 36 carried by a drum 37. This drum is given a motion of rotation and translation by any suitable driving means and should be maintained in synchronism and in phase with the drum 2 at the transmitting station. A satisfactory means for this purpose is disclosed in the above-mentioned patent to Horton et al.

By virtue of the application of the doubly varied light beam to the photoelectric cell 12, this cell will be activated to control the production of a picture modulated carrier current which includes two side-bands of the carrier, and a picture current. Application of the picture modulated light beam to the cell 13 results in this cell being activated to control the production of a picture current. The intensity of the light directed toward the cell 12 is twice the intensity of that applied to cell 13. However, due to the intervention of the chopping disc, the light of double intensity applied to cell 12 is continuously changing from full amount to zero amount and back again, while the light of lower intensity is applied to the cell 13 continuously, consequently the picture currents resulting from the activation of these cells will be equal in amplitude.

From an inspection of the drawing, it will be apparent that the picture current, resulting from the activation of cell 12, flows in a clockwise direction and hence downwardly through winding 15, whereas that produced by cell 13 flows in a counterclockwise direction and hence upwardly through the winding 16. Consequently, these currents neutralize each other, or are balanced out, with respect to the secondary winding 17, and hence are not impressed upon the amplifier 18.

On the other hand, the picture modulated carrier current, comprising the two side-bands of the carrier, flows downwardly through the wind-

ing 15, is transferred to the secondary winding 17, and thence to the amplifier 18, which supplies this current in amplified form to the filter 19.

One side-band of the modulated wave and a small fraction of the other side-band are selected by the filter 19, which may be of the type disclosed in Nyquist Patent 1,748,186, issued February 25, 1930, and may have combined therewith, if desired, an equalizing network. The selected side-band is impressed upon the amplifier 20, which operates to raise its energy level to a value suitable for transmission over a telephone circuit 21 to a remote station or to control a modulator, in which it may be combined with a high frequency carrier current suitable for transmission over a radio link or other medium, for example, in the high frequency range provided by a coaxial conductor line.

In the single-stage modulation systems heretofore proposed, the portion of the transmission range of the medium between its lower limiting frequency and the upper limiting frequency of the picture band cannot be used for transmission of the picture modulated wave; the rate of carrier interruption must be at least twice the maximum frequency of the picture band if the lower side-band is transmitted, and equal to the upper limiting frequency of the picture band, if the upper side-band is transmitted, and in either case, this rate of interruption must be included in the transmission range of the medium.

On the other hand, by virtue of the suppression of the picture current, as herein disclosed, the complete transmission range of the line may be used, and the rate of carrier interruption may be at any point in the frequency spectrum, from a point corresponding to the lower limiting frequency of the medium plus the width of the picture band, to the upper limiting frequency of the medium provided the lower side-band is transmitted, or from a point removed from the lower limiting frequency of the medium by an amount considerably less than half the picture band width to a point corresponding to the upper limiting frequency of the medium, less the picture band width, in case the upper side-band is selected for transmission.

Referring back to the concrete case hereinbefore mentioned, in which the lower side-band of a carrier current modulated by a signal band of 1200 cycles per second is transmitted over telephone lines having a transmission range of 200 cycles per second to 3000 cycles per second, and applying the principles of the present invention, the light beam may be regularly interrupted at any frequency lying between 1400 and 3000 cycles per second. If the latter rate of interruption is used, the picture band width may be increased to 2800 cycles per second and by using a rate of interruption corresponding to the mid-frequency of the transmission range, i. e., 1600 cycles per second, a signal modulated wave comprising both side-bands may be transmitted. Under similar conditions, if a 1200 cycle picture current is used and the upper side-band is selected for transmission, the rate of interruption may be between 600 cycles per second and 1800 cycles per second, or a picture band width of 2000 cycles may be used to effect modulation. In this case, the rate of carrier interruption and the maximum band width that can be transmitted are somewhat less than when the lower side-band is transmitted, because the lower side-band produced by the light sensitive cell will include components

ranging up to 600 cycles per second, in the first case, and to 1000 cycles per second, in the second case, and hence this portion of the range cannot be used for transmission.

- 5 Fig. 2 illustrates an arrangement in which the photo-electric cells 12 and 13 are resistance-capacity coupled to a four-electrode vacuum tube 22, including coplanar grids upon which are respectively impressed the picture and picture
10 modulated carrier currents resulting from the activation of cell 12 and the picture current produced by the activation of cell 13.

The coplanar grids are supplied with a negative polarizing potential by the source 23, and the positive terminal of the circuit 24, including cell 12, is connected to grid 25 while the negative terminal of the circuit 26, including cell 13, is connected to grid 27, and the opposite terminals of these circuits are connected to the cathode 28.
15 The flow of picture currents of equal amplitudes simultaneously through the equal resistances included in the respective cell circuits 24 and 26 will cause potentials, which at every instant are equal in value and opposite in sign, to be applied
20 to grids 25 and 27, with the result that the effect of these potentials upon the tube 22 is neutralized or balanced out. Picture modulated carrier current flowing through the circuit 24 causes corresponding potentials to be impressed upon the
25 grid 25 to control the operation of tube 22. This tube is thereby caused to supply an amplified picture modulated current, comprising the two sidebands, to filter 19, which operates to freely pass one of the side-bands and supply it to the power
30 amplifier 20, which, in turn, transmits the selected components in amplified form to the circuit 21. The operation of this apparatus is identical with that shown in Fig. 1.

While the invention has been described, for
35 purposes of illustration, as applied to picture transmission systems employing a picture current of comparatively narrow frequency band width is suitable for transmission over a telephone line, and, in order to bring out the advantages of the
40 invention, certain specific details have been given, it is apparent that its principles may be advantageously used to increase the operating efficiency of other similar systems, which may employ other types of media. Thus, when applied
45 to television transmission, which involves the use of an image band that may extend from a few cycles per second to one or several hundred thousand cycles per second, the invention may be used
50 to render the complete frequency spectrum of the medium available for the transmission of image modulated carrier waves, and to increase the frequency range of carrier variations which may be used.

Either of the transmitters herein disclosed in
55 detail may be utilized in combination with a receiver of the type disclosed in the above-mentioned Horton patent. Again, by suitable modification of the apparatus herein disclosed, which will be apparent to those skilled in the art, the
60 invention may be applied to a signal system in which the subject is scanned by a moving beam of light which is then varied at a carrier frequency rate before being applied to the light sensitive electric devices. In accordance with well
65 established picture transmission practice, the picture may be scanned by rotating the picture carrying drum at a uniform speed and moving an optical system longitudinally of the drum, as disclosed, for example, in Pfannenstiehl Patent
70 No. 2,120,989, patented June 21, 1938. The modi-

fied apparatus would include an optical system of the type herein disclosed. For television operation, the scanning arrangement disclosed, for example, in United States Patent 1,161,734, November 23, 1915, to Rosing may be modified in an obvious manner to permit utilization of the invention herein disclosed.

What is claimed is:

1. An electro-optical system comprising a plurality of light sensitive electric devices, means for applying light modulated in accordance with the tone values of a subject and at a carrier frequency rate to one of said devices to thereby control the production of a signal modulated carrier wave accompanied by a signal current, means
10 for activating another light sensitive device to control the production of a current corresponding to said signal current, and means for utilizing the last mentioned current to neutralize the signal current produced by the first mentioned device.

2. A method of operating an electro-optical system to control the production of a signal modulated carrier current which comprises utilizing a light beam, modulated in accordance with the tone values of a subject and at a carrier frequency rate, to control the production of a current wave including a signal modulated carrier current and a current, utilizing a portion of the signal modulated beam to control the production
25 of a signal current, and using the latter to neutralize the first mentioned signal current.

3. A method of operating an electro-optical system which comprises varying a light beam in accordance with the tone values of a record, utilizing a portion of said varying beam to control the production of a signal current, interrupting another portion of said varying beam at a carrier frequency rate, utilizing said doubly modified beam to control the production of an electric
30 wave including a signal modulated carrier current and a signal current, and using the first mentioned signal current to neutralize the signal current which accompanies the signal modulated carrier.

4. An electro-optical system comprising a plurality of light sensitive electric devices, means for applying light, modulated at a carrier rate and in accordance with the tone values of a representation, to one of said devices which is thereby activated to control the production of a signal modulated carrier wave and a signal current, means for activating another light sensitive device by light varying in accordance with the tone values of said representation to control the production of a signal current, and means for utilizing the last mentioned current to neutralize the signal current which accompanies the modulated wave.

5. An electro-optical system comprising means for producing light varying at a carrier rate and in accordance with the tone values of a subject, light sensitive electric means activated by said light, light sensitive means activated in accordance with the tone values of said subject, an amplifier, and means for connecting said plurality of light sensitive devices differentially with respect to said amplifier.

6. An electro-optical apparatus comprising means for producing light varying at a carrier frequency rate and in accordance with the tone values of an object, means controlled by said varying light for producing an image modulated carrier wave accompanied by an image current, means for producing a second image current, an

amplifier, and means for connecting said two first mentioned means differentially with respect to said amplifier.

7. An electro-optical system comprising means for producing a beam of light and for scanning successive elemental areas of a field therewith, a light chopper, means for imaging the illuminated elemental areas on said light chopper, a light sensitive electric device activated by light controlled by said chopper, a second light sensitive electric device, means for imaging said illuminated elemental areas on said second light sensitive device, an amplifier, and means for connecting said plurality of light sensitive electric devices differentially with respect to said amplifier.

8. A picture transmission system comprising means for producing light which is controlled by a picture and then varied at a carrier frequency, a light sensitive electric device, means for directing picture controlled light to said light sensitive device, a second light sensitive device, means for directing picture controlled and carrier varied light to said second light sensitive device, an amplifier, and means for connecting said devices differentially with respect to said amplifier.

9. An electro-optical system comprising means for producing a beam of light for scanning a field of view, a plurality of light sensitive electric devices, means for concentrating the light reflected from said field of view into a beam, means for directing a portion of the rays constituting said beam of reflected light to one of said light sensitive devices, means for varying the remainder of the rays constituting said beam of reflected light at a carrier frequency rate, means for applying the doubly varied light rays to a second light sensitive device, a repeater, and means for connecting said light sensitive devices differentially with respect to said repeater.

10. An electro-optical system comprising a transmission circuit, means for modulating a light beam in accordance with the tone values of a field of view, means controlled thereby to cause the production of a varying signal current, means for varying said modulated beam at a carrier frequency rate, means controlled by the doubly modulated beam for causing the production of a carrier current modulated in accordance with said tone values accompanied by a varying signal current, and means for supplying said carrier modulated current and said signal currents to said transmission circuit, said last-mentioned means, comprising means supplied with said first-mentioned signal current, for suppressing the

signal current which accompanies said modulated carrier current.

11. An electro-optical system comprising means for producing a doubly modulated light beam, means supplied with said doubly modulated beam for controlling the production of a signal modulated carrier current and a varying signal current, and means for neutralizing said varying signal current comprising means, utilizing one of the modulations of said doubly modulated light beam, for controlling the production of a current which is applied in phase opposition to said varying signal current.

12. A method of operating an electro-optical system which comprises producing a doubly modulated light beam, utilizing said beam to control the production of a signal modulated carrier wave accompanied by a varying signal current, producing a second variable current, and utilizing said second variable current to neutralize said varying signal current.

13. An electro-optical system comprising means for controlling the production of a doubly modulated light beam and for utilizing said beam to produce a signal modulated carrier wave accompanied by a varying signal current, means for producing a current corresponding to said varying signal current, and means controlled by said last-mentioned current for neutralizing the signal current accompanying said modulated wave.

14. An electro-optical system comprising a plurality of light sensitive electric devices, means for activating one of said devices to control the production of a signal modulated wave accompanied by a signal current, means for activating said other device to control the production of a current corresponding to said signal current, and means controlled by said last-mentioned current for neutralizing the signal current accompanying said modulated wave.

15. The method of producing a signal modulated carrier current which comprises producing a beam of light of constant intensity, scanning a subject with said beam, utilizing a portion of the light reflected from said subject to control the production of a signal current, causing another portion of said reflected light to vary at a carrier rate, utilizing said second portion to control the production of a signal modulated carrier accompanied by a signal current, and using said first-mentioned signal current to neutralize the signal current accompanying said signal modulated carrier.

MILLARD W. BALDWIN, JR.