

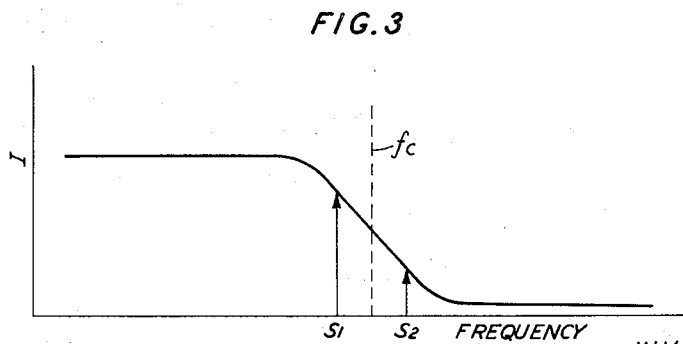
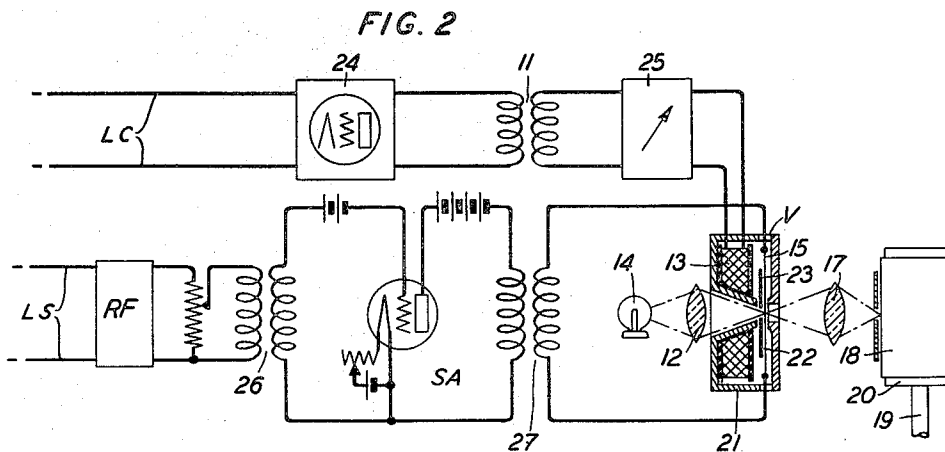
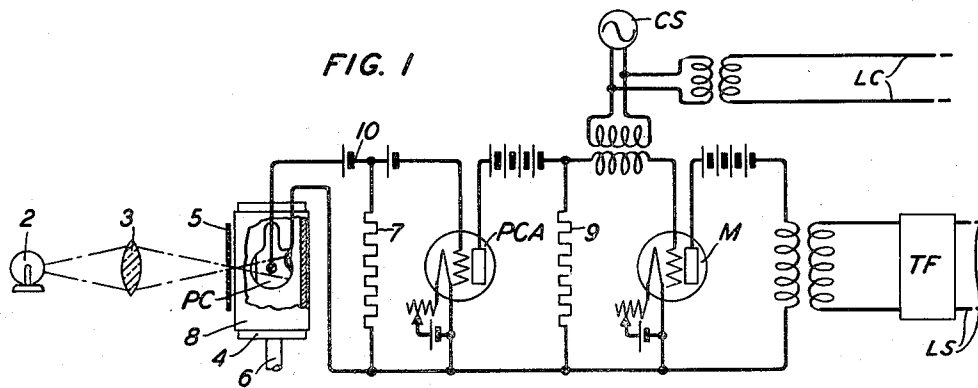
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ELECTROOPTICAL SYSTEM

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ELECTROOPTICAL SYSTEM

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This invention relates to electro-optical systems, and more particularly to systems for producing pictures or images of an object.

An object of the invention is the production of a modulated light beam from a modulated carrier current with a minimum of distortion.

In the accomplishment of this object a light valve is employed in which the light control is effected by the reaction of electrically produced fields. One of these fields is energized by modulated carrier waves and another by unmodulated carrier waves of the same frequency. The resulting light beam will represent the original modulating energy theoretically without distortion. In an example of practice chosen to illustrate the invention there is employed an electro-magnetic light valve of the kind disclosed in Patent No. 1,667,805, issued to H. E. Ives on May 1, 1928. This light valve has a field winding and an aperture controlling vibrating string located in a gap in the magnetic path of said field. According to this invention the field winding of such a light valve is energized by unmodulated carrier waves, while carrier waves modulated with the characteristics of a picture, an image of which is to be produced, is impressed upon the vibrating string. The resulting variations in light intensity are used to variably expose a light sensitive record blank suitably moved in synchronism with the picture at the transmitter for producing a similar picture at the receiver. This invention is particularly advantageous when the modulated carrier waves consist of one side band only or substantially only one side band of the kind disclosed in H. Nyquist Patent No. 1,748,186 issued February 25, 1930. It has been shown by another that the only detector capable of ideally recovering a signal from a single side band is one for which the output wave may be expressed as a pure product of the impressed single side band and a current of carrier frequency. The light valve used according to this invention is such a pure product detector, the output of which, however, is light energy. Therefore, when modulated carrier waves consisting of a single side band, are impressed upon the vibrating string of the light valve, the field winding of which is energized by unmodulated carrier waves, the resulting light is ideally representative of the modulating signals.

The invention will now be described more in detail having reference to the accompanying drawing.

Fig. 1 is a circuit diagram of an electro-optical arrangement for producing unmodulated carrier

waves and carrier waves modulated in accordance with the tone level of a picture to be transmitted;

Fig. 2 is a circuit diagram of an electro-optical arrangement for receiving the modulated and unmodulated carrier waves to effect reproduction of the picture; and

Fig. 3 is a curve showing the relation between current amplitude and frequency of certain of the filters employed.

Referring now to Fig. 1 a three electrode vacuum tube modulator M receives from a photoelectric cell PC a picture current which has been amplified by the vacuum tube amplifier PCA and at the same time receives voice frequency carrier waves from a source CS. The frequency range of the picture current may be represented by zero to f_m frequencies and the frequency of the carrier current from the source CS, by f_c frequency. The resulting carrier wave modulated by the amplified picture current is impressed upon the transmission line LS through a filter TF. The frequency range of the modulated picture current which enters the filter TF extends from $f_c - f_m$ to $f_c + f_m$ the range of the upper side band being approximately f_c to $f_c + f_m$ and the range of the lower side band from $f_c - f_m$ to f_c . This filter TF is of the band pass type such as is illustrated in Nyquist Patent 1,748,186 by filters 13 and 60, shown in Figs. 1 and 5 respectively, and described in detail in the specification of that patent. Fundamentally its characteristics are such that for a modulated double side band carrier wave, such as described above, having a frequency range from $f_c + f_m$ to $f_c - f_m$ applied to the input of the filter substantially only the lower side band frequencies whose range is approximately from $f_c - f_m$ to f_c will be transmitted, the upper side band being cut off near the carrier frequency. The resulting modulated carrier wave of substantially only the lower side band is transmitted over the line LS to the receiver illustrated in Fig. 2.

The arrangement illustrated in Fig. 1 is employed to produce a modulating picture current in the following manner. The photoelectric cell PC is mounted inside of a transparent drum 4 which is rotated in the desired manner by shaft 6. A film 8 carrying a transparency of the picture to be transmitted, is wrapped around the drum 4. Light from an incandescent source 2 is focused by means of lens 3 upon the film 8 through a narrow opening in the screen 5. The amount of light transmitted to the photoelectric cell at any instant varies in accordance with the tone value

or density of the small area of film 8 then exposed. The rotation of the drum 4 on the axis 6 in a suitable manner effects a scanning operation in which the entire film is exposed by elemental portions at the focal point of the light beam. The amount of light received by the photoelectric cell PC determines the magnitude of the current which will flow from battery 10 through the cell PC and the non-inductive resistance 7. The current flowing through this resistance causes a potential drop which is impressed upon the input circuit of the three electrode vacuum tube amplifier PCA. The photoelectric cell currents are amplified by this tube in a well known manner. The output of this amplifier is impressed upon the modulator M by means of resistance 9 simultaneously with the carrier current from the source CS. The resulting modulated carrier wave is impressed upon the line LS as previously described and is transmitted over this line to the receiver.

Referring now to the receiver illustrated in Fig. 2 the carrier waves modulated by the picture current are received upon the line LS and impressed upon the input of the filter RF. This filter is of the same type as the filter TF shown in Fig. 1. Like filter TF it is designed to pass substantially only the lower side band frequencies. The output current from filter RF is impressed by means of transformer 26 upon the well known type of vacuum tube amplifier SA. The amplified current from amplifier SA is impressed by means of transformer 27 upon the string 15 of the light valve V. The string 15 is suspended in a magnetic field and is arranged to vibrate in a direction transverse to the plane of the paper. This light valve is of the kind described in detail in the H. E. Ives patent supra.

The light from source 14 is focused by means of lens 12 through the hollow core of the magnetic frame 21 upon the string 15 of the light valve V. Members 22 and 23 form the longitudinal aperture in the light valve; other members forming the horizontal aperture are not shown. If the string 15 is displaced with respect to this aperture in the light valve, light will pass through the lens 17 to expose the light sensitive record blank 18 mounted on drum 20 which is rotated by means of shaft 19. The lens 17 is arranged so as to cause an image of the light valve aperture to be formed upon the sensitive film 18 whose surface is such that it is exposed to full depth by a single exposure to light from source 14.

The carrier wave generator CS shown in Fig. 1 serves as a common source of carrier waves, some of which are modulated by picture current as described above and transmitted over line LS, and others of which are transmitted in their original unmodulated form over a separate line LC to the receiver illustrated in Fig. 2. Here the unmodulated carrier waves are impressed upon the input of the well known vacuum tube type amplifier 24. The output of this amplifier is impressed upon the input of the phase corrector 25 by means of transformer 11. This phase corrector is of the type shown in the Nyquist patent supra and is used in this invention to equalize the delays on the line and through the filters insuring that the phase of the unmodulated wave when impressed upon the field winding 13 of the light valve V will be the same as the phase of the modulated carrier wave impressed upon the string 15 of said light valve. The output of the phase corrector 25, which is an amplified unmodulated car-

rier wave of correct phase, is impressed upon the field winding 13 of the light valve V.

The modulated and unmodulated carrier waves transmitted over separate channels as described above are received simultaneously upon the string 15 and field winding 13 respectively of the light valve V and produce reacting electrical fields therein. The reaction of these electrical fields causes the string 15 located in a gap in the magnetic path of said fields to vibrate in a crosswise direction with respect to aperture forming members 22 and 23. The magnitude of vibration of the string 15 is a measure of the original modulating picture current and determines the effect of the resulting light beam which is focused by lens 17 upon the sensitive film 18.

By this arrangement of apparatus a carrier current modulated in accordance with the characteristics of the picture at the sending end is used to produce a modulated light beam with a minimum amount of distortion. It has been shown that the only type of detector which can recover the signal from a single side band without distortion is one in which the output wave may be expressed as a pure product of the impressed single side band and a current of carrier frequency. The balanced vacuum tube circuit shown in the Nyquist patent supra is a detector of this type and the light valve used according to this invention is also such a pure product detector the output of which, however, is light energy. In this case the expression of the entire output may be represented as a product of the expressions for the carrier wave and the modulated signal wave. For every component in the latter wave there is in the recovered signal a component having a frequency equal to the difference between its frequency and the frequency of the carrier and having an amplitude proportional to the product of its amplitude and the amplitude of the carrier. To use this device, however, the carrier must be applied to the detector independently of the signal and must be identical in frequency with the carrier used at the transmitting end. These requirements are met by applicant's arrangement of apparatus as previously described and illustrated in Figs. 1 and 2.

In an example illustrative of the invention for the transmission of pictures, the receiver illustrated in Fig. 2 is connected to the transmitter illustrated in Fig. 1 over lines LC and LS. Synchronism between revolving drums 4 and 20 is obtained by suitable arrangement such as that shown in M. B. Long Patent 1,706,032 issued March 19, 1929. These drums not only rotate in synchronism but have an axial movement relative to the shafts 6 and 19. The drum 4 rotates exposing elemental areas of the sensitive film to the light scanning beam and the resulting picture currents are amplified and then used to modulate a voice frequency carrier wave which is filtered and transmitted to the receiver illustrated in Fig. 2 where it is amplified and impressed upon the string 15 of the light valve V. Simultaneously with this action, unmodulated carrier waves of identical frequency are transmitted from the common source CS over line LC to the amplifier 24 and phase corrector 25 and finally impressed upon the field winding 13 of the said light valve V. Details of these operations have been previously described. The output of this light valve, which is light energy, controlled by the modulated and unmodulated waves as described above, is used to expose elemental portions of the sensitive film 18 for producing

a picture at the receiver which is a copy of the picture 8 at the sending end.

Referring now to Fig. 3, a curve is shown to illustrate the transmission characteristics of the filter designed for substantially single side band carrier wave transmission. The terms, "substantially single side band", as used in this application refer to a range of frequencies which includes the full range of frequencies of one side band together with a small portion of the frequencies of the other side band which are unavoidably transmitted. Unlike the wave resulting from the modulation of a carrier by a speech wave, the wave modulated by picture currents of the type employed in this invention and described previously in this specification has no free interval between the upper and lower side bands. In fact the two side bands overlap at the carrier frequency, the upper and lower side band components corresponding to the zero frequency component of the original signal having a frequency identical with that of the carrier. The presence of the zero frequency in the original picture signal is due to the light, which falls upon the photoelectric cell at the transmitting station, always having a positive value. This follows, of course, from the fact that variations of light intensity cover a range of positive values, negative values never being encountered. These facts are significant in single side band transmission of a carrier wave modulated with picture current, for to effect complete separation of the carrier and side bands it would be necessary that the discriminating network transmit with uniform efficiency up to the frequency differing from that of the carrier by an infinitesimal amount. Such a network is obviously unattainable physically. It is possible, however, to accomplish a result which is practically as good as a complete separation of the two side bands by the use of specially designed filters such as TF and RF shown in Figs. 1 and 2 respectively and described previously in this specification. This type of filter has an attenuation characteristic such that the sum of the amplitudes of the upper and lower side band components corresponding to any component in the original, is independent of the frequency of this component. The relation between current amplitude and frequency must obviously be expressed by a characteristic which is symmetrical with respect to the carrier frequency. This relation may be realized physically by a filter whose transmission characteristic is shown in Fig. 3.

It is apparent that although the upper side band has not been completely eliminated the main portion of it has been suppressed and the components present in the transmitted wave occupy a region only a little greater than that of an ideal single side band. If now the method of detection is such that the signal components recovered from the unsuppressed portion of the upper side band are in phase with the corresponding components from the lower side band, they will add together to give a signal identical with that which should have resulted from an ideal single side band. Detection of a substantially single side band modulated carrier wave as described above by pure product detection will effect reproduction with a minimum amount of distortion. Such a method is realized by application in the electro-optical system employing specially designed filters TF and RF and a pure product detector such as the light valve V illustrated in Figs. 1 and 2.

One embodiment of this invention has been described in detail but the scope of the invention is limited only by the appended claims.

What is claimed is:

1. In an electro-optical system, a source of modulated carrier waves, a source of unmodulated carrier waves, a light valve controlled directly by the reaction between electrically produced fields, means to produce one of said fields by said modulated carrier waves, and means to produce another of said fields by said unmodulated carrier waves.

2. In an electro-optical image producing system, a source of carrier waves modulated with the characteristics of an object an image of which is to be produced, a source of unmodulated carrier waves of the same frequency, image producing means controlled directly by the reaction between electrically produced fields, means to produce one of said fields by said modulated carrier waves, and means to produce another of said fields by said unmodulated carrier waves.

3. In an electro-optical image producing system, a source of substantially single side band carrier waves modulated with the characteristics of an object an image of which is to be produced, a source of unmodulated carrier waves of the same frequency, image producing means controlled by the reaction between electrically produced fields, means to produce one of said fields by said single side band modulated carrier waves, and means to produce another of said fields by said unmodulated carrier waves.

4. In an electro-optical image producing system, a source of carrier waves modulated with the characteristics of an object an image of which is to be produced, a source of unmodulated carrier waves of the same frequency, means for correcting the phase of the unmodulated carrier waves in accordance with the phase of the modulated carrier waves, image producing means controlled directly by the reaction between electrically produced fields, means to produce one of said fields by said modulated carrier waves, and means to produce another of said fields by said unmodulated phase corrected carrier waves.

5. In an electro-optical image producing system, a source of substantially single side band carrier waves modulated with the characteristics of an object an image of which is to be produced, a source of unmodulated carrier waves of the same frequency, means for correcting the phase of the unmodulated carrier waves in accordance with the phase of the modulated carrier waves, image producing means controlled by the reaction between electrically produced fields, means to produce one of said fields by said single side band modulated carrier waves, and means to produce another of said fields by said unmodulated phase corrected carrier waves.

6. In an electro-optical image producing system, a source of carrier waves modulated with the characteristics of an object an image of which is to be produced, a source of unmodulated carrier waves of the same frequency, image producing means comprising a stationary member and a movable member, means to impress unmodulated carrier waves from said unmodulated carrier wave source upon said stationary member, and means to impress modulated carrier waves from said modulated carrier wave source upon said movable member to effect a reaction between said stationary and movable member to produce the image.

7. In an electro-optical image producing sys-

tem, a source of carrier waves modulated with the characteristics of an object an image of which is to be produced, a source of unmodulated carrier waves of the same frequency, a variable aperture light valve having a field winding and an aperture control member, means to impress unmodulated carrier waves from said unmodulated carrier wave source upon said field winding, and means to impress modulated carrier waves from said modulated carrier wave source upon said control member.

8. In an electro-optical image producing system, a source of carrier waves modulated with the characteristics of an object an image of which is to be produced and consisting of substantially a single side band, a source of constant amplitude alternating current waves of the same frequency as said carrier waves, a variable aperture light valve having a field winding and an aperture control member, means to impress unmodulated carrier waves from said constant amplitude alternating current source upon said field winding, and means to impress modulated carrier waves from said modulated carrier wave source upon said control member.

9. In an electro-optical system, a source of energizing current of modulated carrier waves, a source of energizing current of unmodulated carrier waves, a pure product light valve detector having separate current receiving members, means for transmitting simultaneously and on separate channels said energizing currents, means for receiving one of said energizing currents on one member of said detector, and means for simultaneously receiving the other energizing current on the other receiving member of said detector.

10. In a system for the transmission of pictures by electricity, a source of carrier waves of constant amplitude, a source of carrier waves whose amplitude varies in accordance with the density of the picture to be transmitted, an electromagnetic light valve having a field winding and a conductor, means to impress the carrier waves of constant amplitude on the field winding of the light valve, and means to impress the waves of varying amplitude on the conductor of said light valve.

11. In a system for the transmission of pictures by electricity, a source of unmodulated carrier waves, a source of modulated carrier waves, an electro-magnetic light valve, having a movable string and a field winding, means to impress unmodulated carrier waves upon the field winding of the light valve, and means to impress modulated carrier waves upon the movable string of said light valve.

12. In an electro-optical image producing system, means for producing an unmodulated carrier current, means for producing a carrier current modulated in accordance with the characteristics of an object an image of which is to be produced, means for transmitting separately and simultaneously said unmodulated carrier current and substantially only one side band of said modulated carrier current, a pure product light valve detector having separate current receiving members, means for impressing said modulated carrier current on one member of said detector, and means for impressing the unmodulated carrier current on another member of said detector to produce an image by the mutual reaction of magnetic fields produced in said detector by said unmodulated and said single side band modulated carrier waves.

13. The method of image production which comprises producing a carrier wave modulated in accordance with the characteristics of an object an image of which is to be produced, producing an unmodulated carrier wave of the same frequency, and producing an image by light directly controlled by the mutual reaction of two magnetic fields, one of which fields is produced by said unmodulated carrier current and the other by said modulated carrier current.

14. The method of image production which comprises producing a carrier wave modulated in accordance with the characteristics of an object an image of which is to be produced, producing an unmodulated carrier wave of the same frequency, transmitting substantially only a single side band of the modulated wave, and producing an image by the mutual reaction of two magnetic fields, one of which fields is produced by said unmodulated carrier current and the other by said single side band of the modulated carrier current.

15. Apparatus for image production which comprises means for producing a carrier wave modulated in accordance with the characteristics of an object an image of which is to be produced, means for producing an unmodulated carrier wave of the same frequency, a pure product light valve detector, and means for reacting said modulated and unmodulated carrier waves in said detector to produce an output wave of light energy which may be expressed as a pure product of the two waves, said output light wave being ideally representative of the modulating signals.

16. The method of image production which comprises producing a carrier wave modulated in accordance with the characteristics of an object an image of which is to be produced, producing an unmodulated carrier wave of the same frequency, reacting said modulated and unmodulated carrier waves to produce two opposing magnetic fields the output of which may be expressed as a pure product of the two waves, and utilizing said reacting fields to control the image forming light.

17. In an electro-optical image producing system, a source of carrier waves modulated with the characteristics of an object an image of which is to be produced, a source of unmodulated carrier waves of the same frequency, image-producing means comprising a stationary member and a movable member, means to impress unmodulated carrier waves from said unmodulated carrier wave source upon one of said members, and means to impress modulated carrier waves from said modulated carrier wave source upon the other of said members to effect a reaction between said stationary and movable members to produce the image.

18. In an electro-optical system, a source of modulated carrier waves, a source of unmodulated carrier waves, a light valve comprising a stationary member and a movable member controlled by the reaction between electrically produced fields, means to impress modulated carrier waves upon one of said members to produce one of said fields, and means to impress unmodulated carrier waves upon the other of said members to produce another of said fields.

19. In an electro-optical system, a source of modulated carrier waves, a source of unmodulated carrier waves, a light valve comprising a stationary member and a movable member controlled by the reaction between electrically produced fields, means to impress unmodulated car-

rier waves upon said stationary member to produce one of said fields, and means to impress modulated carrier waves upon said movable member to produce another of said fields.

5 20. In an electro-optical image producing system, a source of carrier waves modulated with the characteristics of an object an image of which is to be produced, a source of unmodulated carrier waves of the same frequency, image

producing means controlled directly by the reaction between electrically produced fields, means to produce one of said fields in one member of said image producing means by said modulated carrier waves, and means to produce another of said fields in another member of said image producing means by said unmodulated carrier waves. 80

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