April 25, 1933. J. W. HORTON 1,905,714

SIGNALING SYSTEM

Filed April 10, 1931 2 Sheets-Sheet 1

FIG. 1

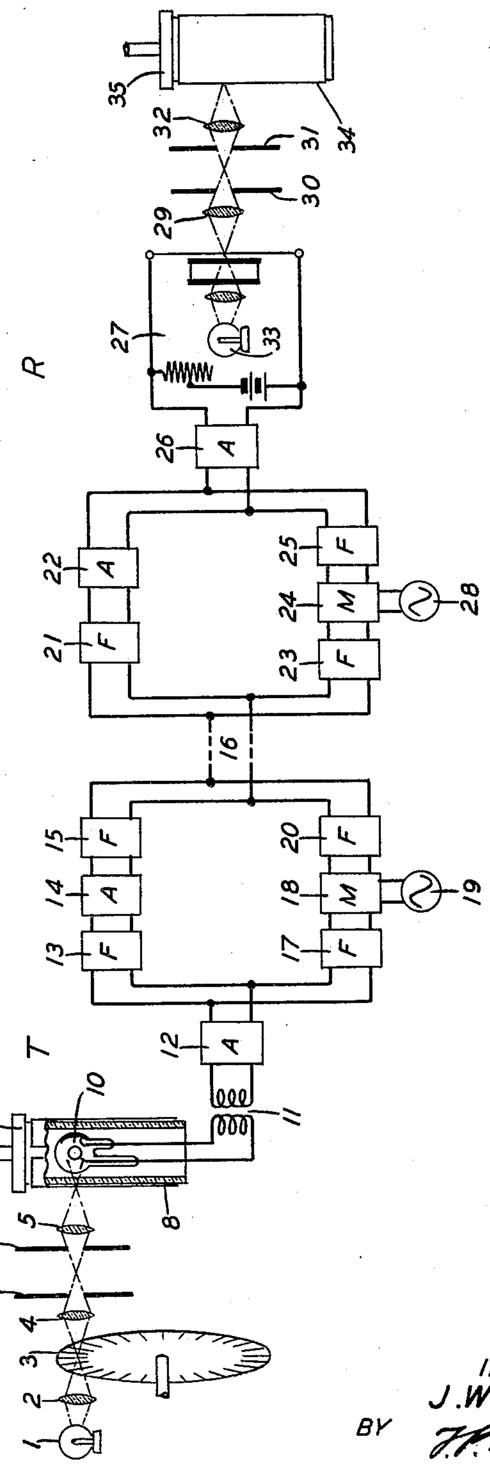

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FIG. 2

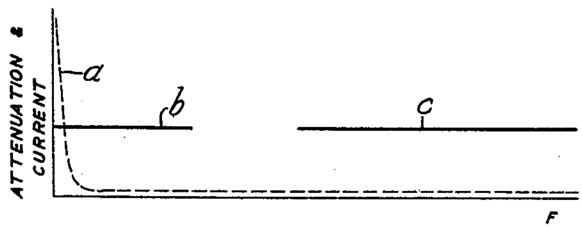


FIG. 3

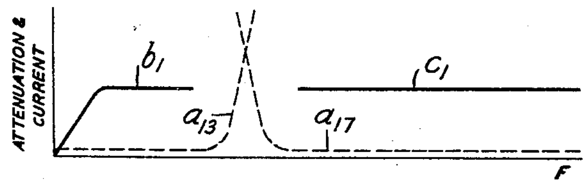


FIG. 4

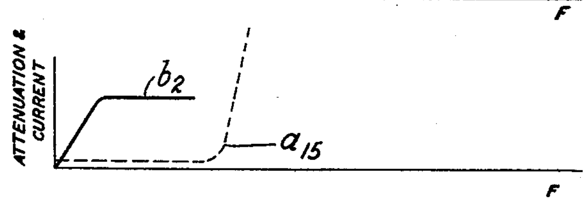


FIG. 5

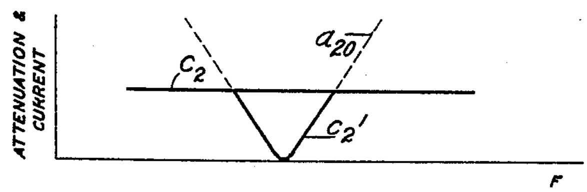


FIG. 6

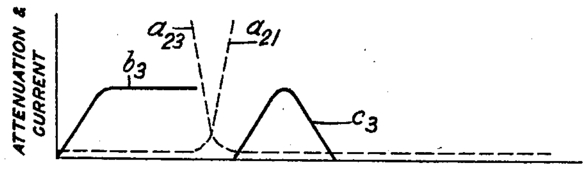


FIG. 7

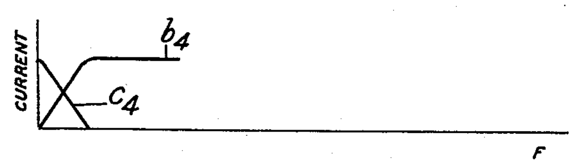
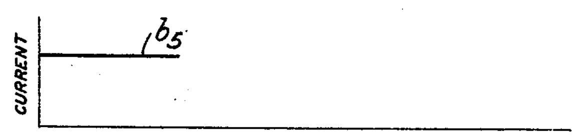


FIG. 8



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Patented Apr. 25, 1933

1,905,714

UNITED STATES PATENT OFFICE

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SIGNALING SYSTEM

Application filed April 10, 1931. Serial No. 529,048.

This invention relates to signaling systems and more particularly to means whereby a signal band, extending from zero frequency to a frequency of considerable value, may be effectively transmitted to and faithfully reproduced at a receiving station.

Systems of this general type have previously been disclosed. In one such system involving electro-optical operation, an image current band is separated into two parts by filters. One part, including the higher frequency current components, is amplified and supplied to the transmission circuit. The second part, comprising the low frequency current components, is used to modulate a carrier wave, and the modulated wave is supplied to the transmission circuit. At the receiving station, the modulated wave is detected to yield the low frequency current components, which are passed through attenuating and phase correcting networks to compensate the distortion introduced by the filters at the transmitting station and the compensated components are combined with the directly transmitted part to reproduce the signal band originated at the transmitting station.

In another prior system the image current band is used to modulate a carrier wave, a filter selects one of the resulting sidebands and this sideband is transmitted. At the receiving station, the incoming sideband is combined with oscillations to produce the image current wave originated at the transmitting station.

Both of the above described systems were devised for the purpose of producing a wave extending over a frequency band which lies within the transmission range of the transmitting circuit and which permits the image current band to be faithfully reproduced at the receiving station.

In certain signaling systems, the signal current produced comprises a band which extends continuously from zero to an upper limiting frequency, the various components having amplitudes which are insufficient for transmission to a distant station or for effecting modulation. As a matter of fact, for either purpose, the signal current must be increased many times, consequently such systems require the use of a direct current amplifier. Moreover, in order that the signal current may be raised to the energy level required to effect modulation, it has been found that multi-stage amplifiers must be used.

Although direct current amplifiers can be successfully operated, their use necessitates very special care in the design of the circuit and they must be constantly supervised in order to ensure stable operation. When a direct current amplifier including a number of cascade connected stages is used, the design and operating requirements are especially burdensome. For these reasons, the use of direct current amplifiers is undesirable.

An object of the present invention is to enable signal systems of the type described above to be successfully operated without requiring the use of direct current amplifiers.

Another object is to permit an alternating current device to be used to repeat signal current bands, having direct current components, and to reproduce an undistorted replica of the signal band.

One typical embodiment of the present invention may comprise an electro-optical transmitting terminal apparatus including an interrupter for chopping a light beam supplied to a photo-electric cell, which is thereby activated to produce a composite current consisting of two sections, a transformer coupled device for amplifying the composite current produced by the photo-electric cell, filters for selectively separating the two sections of the composite photo-electric current, one of which is amplified and supplied to the transmission circuit, while the other is combined with local oscillations to step it down to a frequency such that its mid-frequency is slightly above the upper limiting frequency of the first section, and a filter for selecting a mid-portion of the second section and having a cut-off characteristic adapted to distort the components included in the selected portion.

In the operation of the transmitting apparatus, the alternating current amplifier will repeat without distortion the higher frequency components of the first section, which is identical with the image current, but will distort certain of its components in the neighborhood of zero frequency. The amplifier will also repeat the second section which comprises two sidebands extending continuously over a frequency range which corresponds to twice the frequency of the first section and includes the rate at which the light beam is chopped, as its mid-frequency. The locally supplied oscillations combine with the second section to step it down to a point in the frequency spectrum such that its mid-frequency lies slightly above the upper limiting frequency of the first section, the co-operating filter selects the mid-portion of the second section, which includes frequency components corresponding to those of the first section distorted by the amplifier. The cut-off characteristic of this filter is such, that it distorts the several current components of the selected portion in the same manner as the alternating current amplifier distorts the original current components in the neighborhood of zero frequency. Since the selected portion extends over a very limited range which lies closely adjacent the upper limiting frequency of the first section, the total frequency range occupied by the currents supplied to the transmission circuit is only slightly greater than that of the image current band.

At the receiving station, the two portions of the incoming energy are separated by filters. The mid-portion is combined with local oscillations to step it down in frequency, so that its mid-frequency component is zero.

After selection by a filter, the components derived from the sidebands and the distorted approximately zero frequency components of the first section are combined in such manner that the output current of the amplifier is a faithful reproduction of the photo-electric current produced at the transmitting station.

A more detailed description of the invention follows and is illustrated in the attached drawings.

Fig. 1 diagrammatically illustrates a system embodying this invention, and

Figs. 2 to 8 illustrate curves which will be used to explain the operation of various units of Fig. 1.

Transmitting apparatus T includes a light source 1 of constant intensity, a suitable lens 2 for focusing light rays from the source 1 upon an apertured or slotted section of the disc 3, adjacent its periphery. This disc is rotated to cause the light beam to pulsate or be chopped at a carrier frequency rate. In other words, source 1, lens 2 and disc 3 cooperate to produce a carrier light beam.

Lenses 4 and 5 and apertured members 6 and 7 cause the carrier light beam to be focused on a small elemental area of the picture 8, which is shown as a film of varying transparency mounted on a transparent drum 9. In accordance with standard practice in picture transmission systems, the drum is given a motion of rotation and of translation to cause the light beam to successively scan the elemental areas of the entire picture. Preferably the picture is scanned as disclosed in Patent 1,706,032, March 19, 1929, of M. B. Long.

The light beam passes through the picture to a light sensitive cell 10 which is thereby activated to cause varying electric currents, i. e., a signal or picture current band, to flow through the primary winding of transformer 11. The current flowing through the primary of transformer 11 may be mathematically represented by a Fourier series which includes a term corresponding to zero frequency, a term of signal frequency, in addition to terms corresponding to signal sidebands about the chopping frequency and possibly higher order sidebands about harmonics of the chopping frequency. Except for the harmonics, which are of negligible amplitude, these currents consist of two major groups of components, one group extending continuously from zero frequency to an upper limiting frequency representing the picture currents, and the other, comprising a band having the frequency of the carrier beam as its mid-frequency and extending continuously in the frequency spectrum on both sides thereof to a point removed from the mid-frequency by an amount equal to the limiting frequency of the picture currents. In other words, the second group constitutes the second order signal sidebands about the chopping frequency. At any given instant the envelope of the current in this second group is proportional to the light transmitted by the picture.

In Fig. 2 the ordinates of the dotted curve represent attenuation, and those of the full line curves represent current while the abscissæ represent frequency. Curve *a* represents the attenuation-frequency characteristic of the transformer coupled amplifier 11—12. Curve *b* represents the currents of the first group or picture currents, and curve *c* represents currents of the second group or sidebands, both of which flow through the primary of the transformer 11. As shown by curve *a*, the transformer 11 presents substantially infinite attenuation to current components of zero frequency, a gradually decreasing attenuation for current components of increasing frequencies extending from adjacent zero frequency to an upper limiting value, and substantially zero attenuation for current components of the higher frequencies. Because of the attenuation of the transformer, current components of zero frequency will be entirely suppressed, those of a continuous narrow section in the vicinity of zero frequency will be distorted more or less as their frequency departs from zero, and the remainder of the current components will be induced without distortion in the secondary winding of the transformer 11.

The picture current, with some components distorted, and the sidebands, as they are induced in the secondary winding of transformer 11, are indicated by full line curves b_1 and c_1, respectively, of Fig. 3. The induced picture current and sidebands are amplified by the device 12, the output circuit of which includes a filter 13 having a frequency-attenuation characteristic represented by the dotted curve a_{13}, and a filter 17, having a frequency-attenuation characteristic represented by the dotted curve a_{17}.

Amplified picture currents, represented by full line curve b_1, are selected by the filter 13, amplified by the amplifier 14, again selected by the filter 15 and supplied to the transmission circuit 16. Filter 15 has a frequency-attenuation characteristic represented by dotted curve a_{15} in Fig. 4, and hence it operates to supply picture currents, indicated by full line curve b_2 of Fig. 4, to the transmission line 16.

The sidebands are selected by the filter 17 and impressed upon the modulator 18, in which they are combined with oscillations supplied by the oscillator 19. The frequency of these oscillations is such that the sidebands are stepped down to a position in the frequency spectrum indicated by the full line curve c_2 of Fig. 5. The current band represented by the curve c_2 is supplied to the filter 20, which is designed to select the current components thereof on both sides of its mid-frequency, i. e., those which correspond to the components attenuated by the transformer 11, and to have a cut-off characteristic c'_2 which attenuates the respective components on opposite sides of the mid-frequency to the same extent as the transformer 11 attenuated similar components of the picture band.

From Fig. 6 it will be seen that the lowest frequency component of the selected portion c_3 of the stepped-down sidebands, occupies a position in the frequency spectrum immediately adjacent to the highest frequency component of the picture current band b_3. The selected portion of the sidebands c_3 is supplied to the line 16 along with the picture band b_3.

The receiving station R comprises two branches, one including a filter 21, and a second branch including a filter 23. Connected in series with the filter 21 is an amplifier 22, and in series with the filter 23 is a modulator 24, and filter 25. The output circuits of the amplifier 22 and filter 25 are connected together to constitute the input circuit of an amplifier 26 adapted to supply the picture current band to the light valve 27.

Picture currents, represented by the curve b_4 are selected by the filter 21, amplified by the device 22 and supplied to the amplifier 26. The sideband portion represented by the curve c_3 is selected by the filter 23 and supplied to the modulator 24 in which it is combined with oscillations supplied by the oscillator 28. The frequency of these oscillations is such that, when they are combined with the sideband portion, the latter is stepped down in frequency to a position in the frequency spectrum such that the mid-frequency component is at zero frequency as indicated by curve c_4. The stepped-down portion is selected by the filter 25 and is supplied to the amplifier 26. The current components of the stepped-down portion, represented by the curve c_4 in Fig. 7, are combined in the amplifier 26 with the picture current b_4 supplied by the amplifier 22 to produce a picture current band represented by the full line curve b_5 in Fig. 8, which is identical with curve b in Fig. 2. The combined amplified picture currents supplied by the amplifier 26 are impressed upon the light valve 27.

The light valve herein shown is designed and operated in a manner disclosed in Patent 1,667,805, May 1, 1928, of H. E. Ives. The amplified picture currents supplied by the amplifier 26 are applied to the ribbon of the light valve 27 to control the amount of light transmitted from a steady light source 33 through the optical system represented by the lens 29, apertured member 30 and 31, and lens 32, which latter serves to focus the light in the form of a beam on the unit areas of a photosensitive film 34 mounted on a drum 35. In accordance with standard practice the drum 35 is moved in synchronism and in phase with drum 9 at the transmitting station.

Any well known type of distortionless amplifier and any suitable design of modulator may be used, but those including space discharge devices are preferred. The filters may be of the type disclosed in U. S. Patent 1,227,114, May 22, 1917, to Campbell.

The present invention therefore provides a system in which alternating current amplifiers of standard design are used to amplify currents corresponding to elemental areas of a picture, without requiring the transmission of currents which occupy a materially greater frequency range than the picture band per se, and in which an undistorted picture current band is produced at the receiving station.

If desired, the modulated wave section may be selected, its components distorted in the manner described above and these components may be combined with the corresponding distorted components of the signal current band at the transmitting station, whereby an amplified undistorted signal band is supplied to the transmission circuit. In this case, the transmission circuit 16 will be directly connected to the light valve 27 at the receiving station.

While the invention is disclosed as applied to a picture transmission system, it is not limited to such use, since its principles may be utilized wherever desired to effect the result obtainable by the means or in accordance with the method defined in certain of the appended claims.

What is claimed is:

1. The method which comprises producing two currents having the same signal modulations but occupying different frequency ranges, selecting a portion of one of said currents and stepping the selected portion into the frequency range of the other of said currents, and combining the selected portion with the said other current to selectively modify the amplitude of certain frequency components of said other current.

2. Signaling apparatus comprising means for producing a current modulated in accordance with a signal, means for producing a second current modulated with the same signal but having frequency components outside the range of the components of said first signal current, means for selecting components of one of said currents and stepping the related components into a desired portion of the frequency range of the other of said currents, means for combining said selected portion with said other current to selectively change the amplitudes of certain frequency components of said other current.

3. Signaling apparatus comprising means for producing a direct current modulated in accordance with a signal, means for producing an alternating current modulated with the same signal but comprising a frequency component outside the range of the components of the modulated direct current, means for selecting components of the modulated alternating current and stepping them into a desired portion of the frequency range of the modulated direct current, means for combining said selected components with certain components of the modulated direct current, whereby the amplitude of said certain components are selectively changed in value.

4. An electro-optical transmitter comprising means for producing a composite wave including image currents varying in accordance with the tone values of elemental areas of a field of view and extending over a frequency band from zero to an upper limiting value and a carrier wave modulated by said image current band, a transformer coupled device for amplifying said band and modulated wave, and means for supplying said band and the mid-portion of said modulated wave to a transmission circuit.

5. An electro-optical transmitter as described in the preceding claim characterized by this that the last therein mentioned means includes a filter for selecting the mid-portion of the modulated wave supplied to the transmission circuit.

6. An electro-optical transmitter as described in claim 4 characterized by this that the last mentioned means includes a filter having a cut-off characteristic such that it distorts the current components of the selected portion of the modulated wave.

7. An electro-optical transmitter as described in claim 4 characterized by this that the last therein mentioned means includes a filter which selects the current components of the modulated wave and distorts said components to the same extent as the corresponding components of the image current band are distorted by the transformer coupled amplifier.

8. An electro-optical transmitter comprising means for producing two currents having the same signal modulations but respectively occupying different frequency ranges, means for selecting the mid-portion of one of said currents, means for translating said mid-portion to a position in the frequency spectrum having its lowest frequency component slightly spaced from the upper limiting frequency of the other current, and means for supplying said other current and said mid-portion to a transmission circuit.

9. An electro-optical system comprising the transmitter defined in the preceding claim in combination with a receiver including means for translating the incoming mid-portion of the modulated wave to a point in the frequency spectrum such that one of its current components is at zero frequency.

10. An electro-optical system comprising the transmitter defined in claim 8 in combination with a receiver including means for translating the current components of the mid-portion of the modulated wave to a point in the frequency spectrum such that one of its current components is at zero frequency, and means for combining the translated current components with the incoming other current.

11. An electro-optical system comprising means for producing a composite wave including an image current varying in amplitude in accordance with the tone values of elemental areas of a field of view and extending over a frequency band for zero to an upper limiting frequency and a carrier current modulated by said image current band, a transformer coupled device for amplifying said band and said modulated wave, a filter for selecting the mid-portion of said modulated current, means for transmitting said band and said mid-portion of the modulated current, and means for receiving the transmitted currents including means for translating the mid-portion of the modulated current to a

position in the frequency spectrum such that one of its components is at zero frequency.

12. An electro-optical system as described in the preceding claim in which the receiver includes means for combining the frequency translated wave portion with the image current band.

13. An electro-optical transmitter, a light sensitive device, means for applying to said light sensitive device a light beam chopped at a definite frequency and controlled by elemental areas of the scanned field for producing a composite wave including an image current band extending from zero to an upper limiting frequency and a carrier wave modulated by said image current band, an alternating current amplifier for amplifying said band and said modulated wave, means for selecting and supplying the amplified band to a transmission circuit, means for selecting said modulated wave, translating the frequency thereof so that its carrier component is slightly above the upper limiting frequency of said band, and means for selecting the mid-portion of said frequency translated wave and supplying said selected portion to the transmission circuit.

In witness whereof, I hereunto subscribe my name this 6th day of April, 1931.

JOSEPH W. HORTON.