

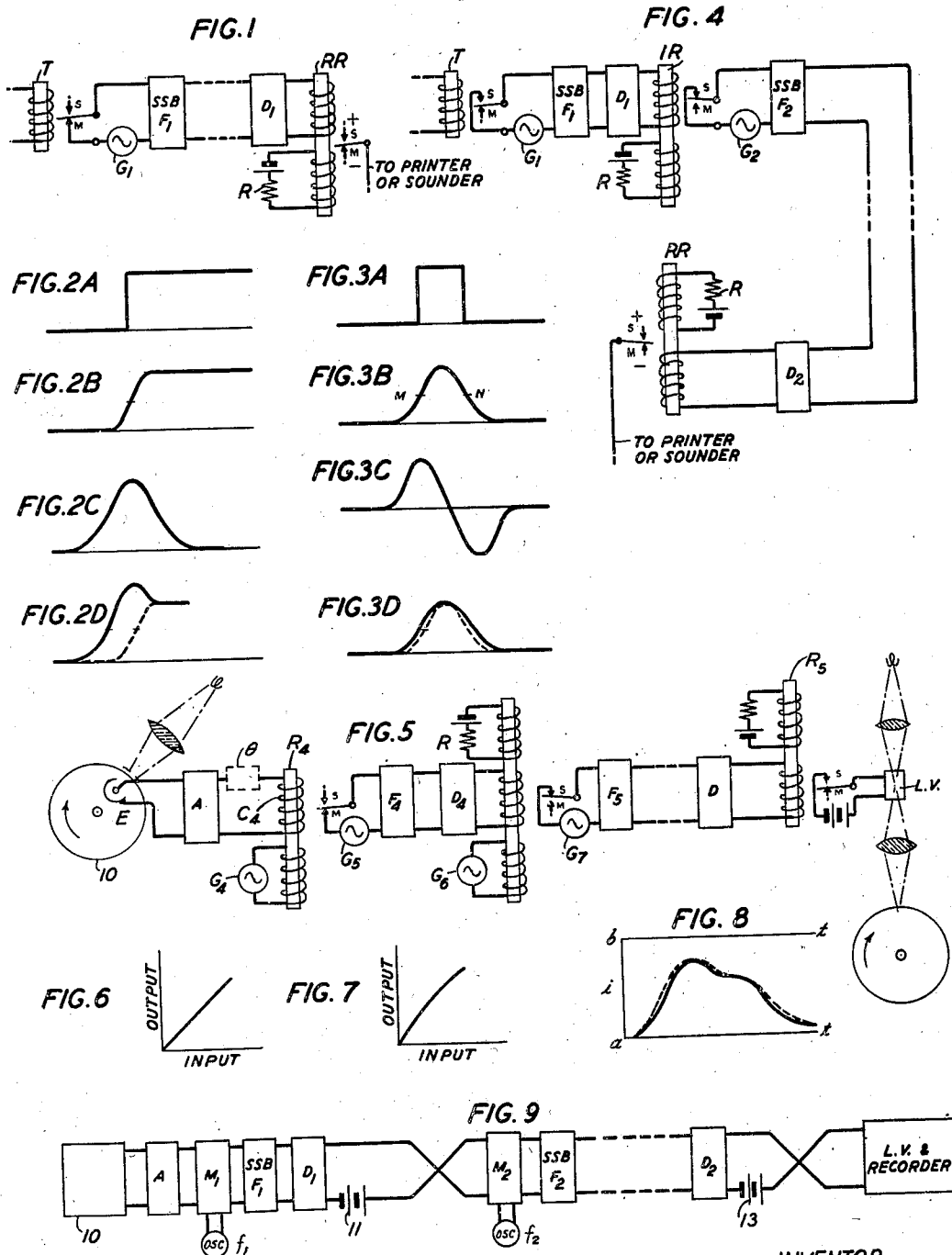
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SIGNALING SYSTEM

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SIGNALING SYSTEM

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This invention relates to telegraph signaling both for usual telegraphy and for some forms of picture transmission or television by a series of marking and spacing intervals. In such signaling the problem of distortion as represented by departure from correct ratio of marking and spacing intervals has received much consideration and substantial improvements have been made as exemplified in such patents as that to Herman 1,886,808, November 8, 1932. To some extent, however, the problem still remains, especially with some particular types of telegraph systems.

This invention relates more specifically to so-called single side-band carrier frequency signaling systems and to methods and means for reducing certain distortion effects therein. In carrier frequency telegraph signaling it is common to intermittently impress the output of a carrier frequency source on a transmission line by means of a key or equivalent device, the duration of the trains of waves on the line corresponding more or less closely to the keying motion. The process associated with the closing and interrupting of the circuit, however, is not so simple as that of merely introducing on the line the carrier frequency alone but it gives rise to a band of higher frequencies adjacent to the carrier and a band of lower frequencies, the two constituting an upper and a lower side-band as modulation products. Since the signaling information in the one side-band is the same as that in the other side-band, it is possible to eliminate one of these and transmit the other only, thus reducing the width of the frequency band required for signaling. Also, the carrier itself may be eliminated to such extent as may be desired, and reintroduced at the receiving end for demodulation purposes, sometimes called homodyne reception.

My invention relates to a system in which a filter is used to eliminate one of the side-bands and to substantially reduce the carrier but no provision is made for the reintroduction of the carrier at the receiving end.

In an article published by me entitled "Certain topics in telegraph transmission theory," appearing in the Transactions of the American Institute of Electrical Engineers, vol. 47, April 1928, page 617, I have called attention to the fact that when a filter is used to pass one side-band only, the output wave of the filter may be considered as made up of two components which I there call the in-phase component and the quadrature component. Referring to the frequencies in the side-bands, the in-phase component may, for the

purposes of this disclosure, be defined as one whose zeros coincide with the zeros of the steady state carrier frequency. Its envelope is substantially identical with the total wave received in double side-band transmission and by properly designing the filters it is possible to make this component distortionless in the sense in which that term is used here. The quadrature component is one whose zeros are a quarter period out of phase with the zeros of the steady state carrier frequency. This component is present when the in-phase component is changing in amplitude and tends to have its maximum value when the in-phase component is changing most rapidly. When the steady state is reached it falls to zero. The quadrature component modifies the shape of the received wave and when single side-band is used will, in general, introduce some bias at the receiving end; this being in addition to such other biasing effects as may be present and which would presumably be compensated for. The purpose of my invention is to compensate for the type of bias due to this quadrature component.

The invention will be better understood by reference to the following specification and the accompanying drawing in which

Fig. 1 shows a telegraph circuit adapted for single side-band transmission, with certain bias compensating features;

Figs. 2A to 3C are explanatory of certain aspects of my invention;

Fig. 4 is a form of circuit in which more complete compensation is made for the quadrature component;

Fig. 5 shows the application of the principles of my invention to certain forms of telephotography or television;

Figs. 6 and 7 are curves explanatory of certain aspects of my invention; and

Figs. 8 and 9 relate to the application to certain other forms of telephotography.

Referring more particularly to Fig. 1, there is shown a sender T subject to signal waves of direct current corresponding to the signal elements to be transmitted. The sender T controls the output of a carrier frequency generator G_1 as a result of which there is impressed on the line a succession of marking and spacing intervals of the carrier frequency. A single side-band filter F_1 is introduced in the line passing the upper side-band or the lower side-band and in any case with its cut-off at or near the carrier frequency f_c . At the receiving end this signal is detected by the detector D_1 , the output of which operates

on a relay RR to control a sounder or a circuit going to printing or other equivalent apparatus.

Referring to Fig. 2A there is represented the envelope of a single reversal such as would be obtained from the circuit of Fig. 1 at the input of the single side-band filter F_1 . As one of the results of the effect of the filter the output thereof may be represented by two components. Of these Fig. 2B represents the envelope of the in-phase component of the wave received at D_1 and this will be assumed distortionless in the sense in which that term is used herein. Fig. 2C represents qualitatively the accompanying envelope of the quadrature component which, as pointed out above, has the property of being present only when a change is occurring, reducing to zero when the transmitted current has been held constant for some time. In the absence of homodyne reception the envelope of the received wave is obtained by combining the curves of Figs. 2B and 2C by root-mean-square addition. The result is shown in Fig. 2D. Since the addition of two components in quadrature to each other always gives a resultant which is greater than either, the presence of the quadrature component results in a bias indicated in Fig. 2D where the dotted line is a reproduction of a curve of Fig. 2B.

Inspection of Fig. 2D suggests the need of a correcting constant bias by the use of a constant biasing current on the receiving relay or the transmitting relay, or an auxiliary relay in tandem with either. The bias determined from Fig. 2D is not, however, the correct one for all cases, as will be apparent from a study of the following figures.

Fig. 3A represents a short transmitted mark and Fig. 3B represents the corresponding received distortionless in-phase component. This component is distortionless in the sense that if the receiving relay is appropriately adjusted, it will open and close at points corresponding to M and N of Fig. 3B and the marking interval will be the same as indicated in Fig. 3A. The corresponding quadrature component is shown in Fig. 3C and is the sum of two curves such as shown in Fig. 2C displaced from each other by the duration of the marking interval and being of opposite sign. The result is that there is mutual interference between them, the extent of the interference being in proportion to the shortness of the marking interval. It is evident that as a result of the combining of Figs. 3B and 3C by root-mean-square addition the bias on the resultant envelope will be less on a short mark than on a long mark. Further, it is evident that in general the bias caused by the quadrature component is a function of what has gone before, at least in large measure. Still further, it becomes evident that if a constant correcting bias is introduced it should not be made equal to that deduced from Fig. 2C but should be made equal to a representative or average value. Moreover, it becomes evident that for the best results the bias should be made variable and be made a function of the preceding signals.

Referring again to Fig. 1, the circuit there shown is one in which the average bias due to the quadrature component is compensated. As already stated, T is the transmitting relay which sends unbiased signals, F_1 is a single side-band filter, D a detector and RR a receiving relay. R is a resistance in a constant biasing circuit so chosen that the average quadrature bias is compensated.

The best value for the resistance R in any particular case can best be determined by trial, using any standard or well-known type of bias measuring circuit and adjusting the value of resistance R until minimum bias is obtained. One known type of bias measuring circuit is disclosed in a paper by Nyquist, Shanck and Cory, published in the Journal of the American Institute of Electrical Engineers, March, 1927, pages 231 to 240, particularly Fig. 7 and its accompanying description.

While compensation for the quadrature component indicated in Fig. 1 is useful, further refinement is obtained by compensating for variations in bias as well as for the average. A circuit for this purpose is shown in Fig. 4. The transmitting relay T sends out unbiased signals as before but the contacts are so arranged that the signals are turned over, i. e., marking intervals become spacing intervals and the reverse. The output of the single side-band filter F_1 is detected at D_1 and is in turn used to control a second oscillator G_2 preferably of the same frequency as G_1 . The output of the generator G_2 is passed through a second single sideband filter F_2 substantially the same in form as F_1 . It will be noted, however, that the intermediate relay IR is so connected as to give an additional turnover to the signal so that in the signals as received from relay RR marking intervals correspond to marking intervals as impressed on T. The quadrature component resulting from filter F_1 causes the signal at the input of the intermediate relay IR to be biased to marking but by virtue of the turnover for the contacts of relay IR this will appear as a spacing bias and this spacing bias will balance out the tendency toward marking bias due to filter F_2 . It will be desirable by means of a resistance R to adjust the bias of the relay IR to take out or compensate for the average bias. The residual variations are then impressed on the transmitted signals and will compensate for residual variations due to F_2 . An alternative arrangement is to introduce no bias in the relay at the receiving station but to introduce a bias in the sending relay T of such value as to make it cancel the average bias introduced at IR.

From the above it is seen that, speaking broadly, (1), the first single side-band filter is introduced to undo the bias introduced by the second; (2), relay IR is preferably biased so that the two filters will work on nearly similar signals (except for the turnover); (3), the remaining bias present at IR is taken out either in the receiving relay or in the sending relay.

Whereas in Fig. 4 the transmission line is shown as extending from filter F_2 to the receiving station, it is evident that the long length of transmission line may be placed at other portions of the circuit. Thus the line might come between D_1 and IR or between F_1 and D_1 , the over-all electrical effects being substantially the same.

In some systems for transmitting half-tone pictures a steady stream of reversals, using double side-band carrier frequency, are transmitted, a neutral tone corresponding to equal marking and spacing intervals. The output of the picture transmitting machine is used to vary the bias of these signals in accordance with the shade to be transmitted. At the receive end the bias is used to reproduce the shade, yielding a half-tone picture. The use of single side-band for such transmission and incorporating the principles of compensation for quadrature component is illus-

trated in the circuit of Fig. 5. In this figure the rotating drum 10 carries the picture to be transmitted. Light passing therethrough to a photoelectric cell E gives rise to a current in the photoelectric circuit, the magnitude of which varies in accordance with the shade at the successive points on the picture. A generator G_4 maintains the reed of the relay R_4 in continual vibration, alternately making and breaking contact for the circuit of generator G_5 of any desired carrier frequency. With the current in the photoelectric cell corresponding to an arbitrary neutral tone, the relay R_4 is adjusted so that the marking intervals are equal to the spacing intervals. As photoelectric current flowing through the coil C_4 varies in amplitude from the arbitrarily chosen neutral value, the marking to spacing ratio of relay R_4 is correspondingly altered. In order to operate the system on a single side-band the filter F_4 is introduced but with it there appears the quadrature component referred to above. Accordingly, there is introduced in the circuit the detector D_4 and relay which operates to turn over the signal and to then control a second generator G_7 preferably of the same frequency as G_5 , whereupon the signal is transmitted through the filter F_5 to the receiving station. At the receiving station a second reversal is made by the detector and relay R_5 . The wave that is finally received is, therefore, compensated for the quadrature component introduced incidental to the single side-band transmission and the light valve L. V. registers the picture on the revolving drum in the form of a half tone picture as previously stated.

As a modification of the operation of Fig. 5 the intervening relay R_5 may be omitted and the signal is then effectively turned over by the addition of direct current after detection.

If the system of Fig. 5 is operated without the filters, that is, if it is operated on the basis of the double side-bands, then the system from the transmitting relay R_4 to the receiving relay is equivalent to a transmitter whose input-output characteristic is shown in Fig. 6, this being for the case where the transmission system itself introduces no bias. In Fig. 6 the input represents numerically the shade of gray of the transmitted picture and the output that of the received picture. Fig. 7 shows the corresponding characteristic with a single side-band system having the quadrature component uncompensated. As an alternative to the circuit arrangement of Fig. 5, it is possible to introduce a non-linear transducer ahead of the transmitting relay, as shown by θ of Fig. 5. This transducer should have the inverse characteristic of that shown in Fig. 7 so that when this non-linear element is worked in tandem with the remainder of the transmission system, the resultant characteristic is linear, as in Fig. 6.

Still a further application of the principles of my invention to telephotography is illustrated by Figs. 8 and 9. Referring to Fig. 9 there is shown a means at 10 for producing a direct current of variable magnitude in accordance with the characteristics of a picture to be transmitted. This device may well be identically the same as that shown in Fig. 5 and a portion of the output curve of the device 10 is shown by the full curve of Fig. 8. Using the line at as the base line, the ordinate of the curve may be taken as proportional to the intensity or degree of whiteness of the successive points on the picture. In some systems of telephotography it has been common

to use this variable direct current to modulate a high frequency with two side-bands. This high frequency signal with its two side-bands is then transmitted to the receiving station where it is directly detected and used to control some mechanism such as a light valve for the purpose of reproduction of the picture. In my system, however, I propose to transmit one side-band only. To that end there is shown in Fig. 9 a modulator circuit M_1 supplied with an oscillator of a convenient frequency f_1 . The output of the modulator passes through the single side-band filter F_1 , one edge of which filter is at or near the frequency f_1 .

As pointed out above, if the output of this filter were now directly transmitted and detected at the receiving station there would be distortion due to the quadrature component. Quite aside from any other distortions which might be present in the transmission system the form of the wave received would depart from the full curve of Fig. 8 in a manner indicated by the dotted curve, the distortion corresponding or being analogous to the marking bias introduced because of the quadrature component, as described in connection with the case of telegraphy. In order to compensate for this distortion I follow the same procedure as described above, namely, the output of the filter F_1 is detected in the detector D_1 , which would give rise to a current represented by the dotted curve of Fig. 8. A turnover is now accomplished in a manner to give rise to a current the reverse of that which came from the amplifier A. This is conveniently accomplished by subtracting what would be the output from the detector D_1 from a direct constant current. This again is illustrated in Fig. 8 in which a current of magnitude ab is supplied by a battery 11 in such a direction that the resultant current flowing is given by the portion between the curve of Fig. 8 and the line bt taken as a base. By a reversal of terminals in the circuit we have the equivalent of showing the resultant current with bt as base line. This current is now applied to a second modulator M_2 into which there is also fed a carrier frequency f_2 which may be different from the carrier frequency f_1 but would preferably be of the same value. To emphasize the point that there has been a turnover of the detector component, the terminals from the detector D_1 are shown as crossed over. The output of the modulator M_2 is now impressed on the single side-band filter F_2 and the output of the filter is then transmitted to the receiving terminal for detection by the detector D_2 . It will be recognized that ordinarily the output of the detector D_2 will be of substantially the same form as the current wave impressed on the modulator M_2 and if this were used to control a light valve recording the picture, the picture itself would then be reversed, appearing light where the original picture was dark. It is necessary, therefore, to bring about a second turnover to compensate for the turnover at the detector D_1 . Here again this is readily accomplished by means of the battery 13 poled in the correct direction to bring about the turnover, and again to emphasize that such a turnover occurs, the terminals from the detector D_2 are crossed over.

From the description thus given of this system it is seen that the distortion introduced by the filter F_1 is compensated for by the distortion introduced by the filter F_2 and that this becomes possible as a result of the turnover after detec-

tion at D_1 , and further, that a second turnover at D_2 or some equivalent point is thus necessary to compensate for the first turnover.

What is claimed is:

1. In single side-band telegraph signaling, the method for compensating for quadrature distortion associated with the single side-band and resulting in bias of marking to spacing which consists in passing a signal controlled wave through a filter for isolating a single side-band thereof, transmitting the said side-band, detecting and receiving it at the receiving end and applying thereat a balancing marking to spacing biasing effect equal to the average biasing effect due to the quadrature component.

2. In single side-band carrier frequency signaling in which the signal has been passed through a filter to pass one side-band, the method of reducing distortion due to the filter which consists in detecting the message, producing reversed signals thereof, controlling a second carrier frequency by said reversed signals, filtering the resulting signal-controlled wave, passing it through a second filter passing one side-band, and transmitting the resulting side-band.

3. In single side-band telegraph signaling, the method of compensating for quadrature distortion associated with the single side-band and resulting in bias of marking to spacing which consists in filtering a signal-controlled band for isolating a single side-band thereof, detecting the message, producing reversed signals thereof, controlling a second carrier wave by said reversed signals, filtering the resulting signal-controlled wave in a similar filter and transmitting the resulting side-band.

4. In a single side-band carrier frequency signal transmission system, a transmission line, means at the transmitting end to modify a carrier wave by message, a filter for passing one side-band only of the resulting message-modified wave whereby marking to signal bias due to the quadrature component of the filtered wave is produced, means for transmitting the resulting side-band over said line, means at the receiving end to detect the received side-band and a biasing means to balance out the average marking to spacing bias due to the filter distortion.

5. In a single side-band carrier frequency signal transmission line tending to produce transmission bias in the signals, means at the transmitting end to modify a carrier frequency wave by a message, a filter for passing one side-band only of the modified wave whereby marking to signal bias due to the quadrature component of the filtered wave is produced, means for transmitting said side-band over said line, means at the receiving end to detect the received side-band and a marking to spacing biasing means to balance out the average bias due to the filter distortion, and supplemental means to compensate for said transmission bias.

6. In single side-band carrier frequency telegraph signaling characterized by quadrature distortion associated with the single side-band and resulting in bias of marking to spacing, means for producing a carrier frequency modulated with a message to form an upper and a lower side-band, a filter for passing one side-band only, a detector, a relay operated thereby and so biased as to produce reversed signals, means subject to said relay for producing a modulated

carrier frequency, a second filter for passing one side-band thereof only, and means at the receiving end for detecting the said last-named side-band.

7. The combination of claim 6 characterized by the fact that the second modulated carrier frequency is of the same frequency as the first carrier frequency.

8. The combination of claim 6 characterized by the fact that the first-named detector has means to balance out the average bias effect of the quadrature component.

9. The combination of claim 6 characterized by the fact that the first-named detector has means to balance out the average bias effect of the quadrature component arising from the first filter, and means at the receiving detector to balance out the average bias effect of the quadrature component arising from the second filter.

10. In a picture transmission system, means for deriving a marking-spacing current characteristic of the picture to be transmitted, means for modulating said current against a carrier frequency, a filter for transmitting one side-band only, a detecting and receiving device at the receiving station and means thereat to compensate for the quadrature component distortion arising from the filter, said last-named means consisting of a bias equal and opposite to the marking-spacing bias introduced by the said quadrature component distortion.

11. In a picture transmission system, means for deriving a marking-spacing current characteristic of the picture to be transmitted, means for modulating said current against a carrier frequency, a filter for transmitting one side-band only, means to compensate for the quadrature component distortion arising from the filter, said means comprising a detector and a relay for turning over the marking-spacing signal, a second carrier frequency controlled by the detected message, a second filter for transmitting one side-band only, and means for impressing the resultant side-band on the transmission circuit.

12. The combination of claim 11 characterized by the fact that at the receiving station there is a second detecting circuit controlling a light valve and a biasing means associated with each detector adjusted to balance out the average biasing effect of the quadrature component at its point in the transmission circuit.

13. In a picture transmission system means for deriving a variable current characteristic of the picture to be transmitted, means for causing said current to control a carrier frequency, a filter for transmitting one side-band only, means to compensate for the quadrature component distortion arising from the filter, said means comprising a detector and a circuit for turning over the detected current, means for causing the turned over message to control a second carrier frequency, a second filter for transmitting one side-band thereof, and means for impressing the resultant side-band on the transmission circuit.

14. The combination of claim 13 characterized by the presence of a receiving circuit comprising a detector for the received side-band and circuit arrangements for turning over the detected current.

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