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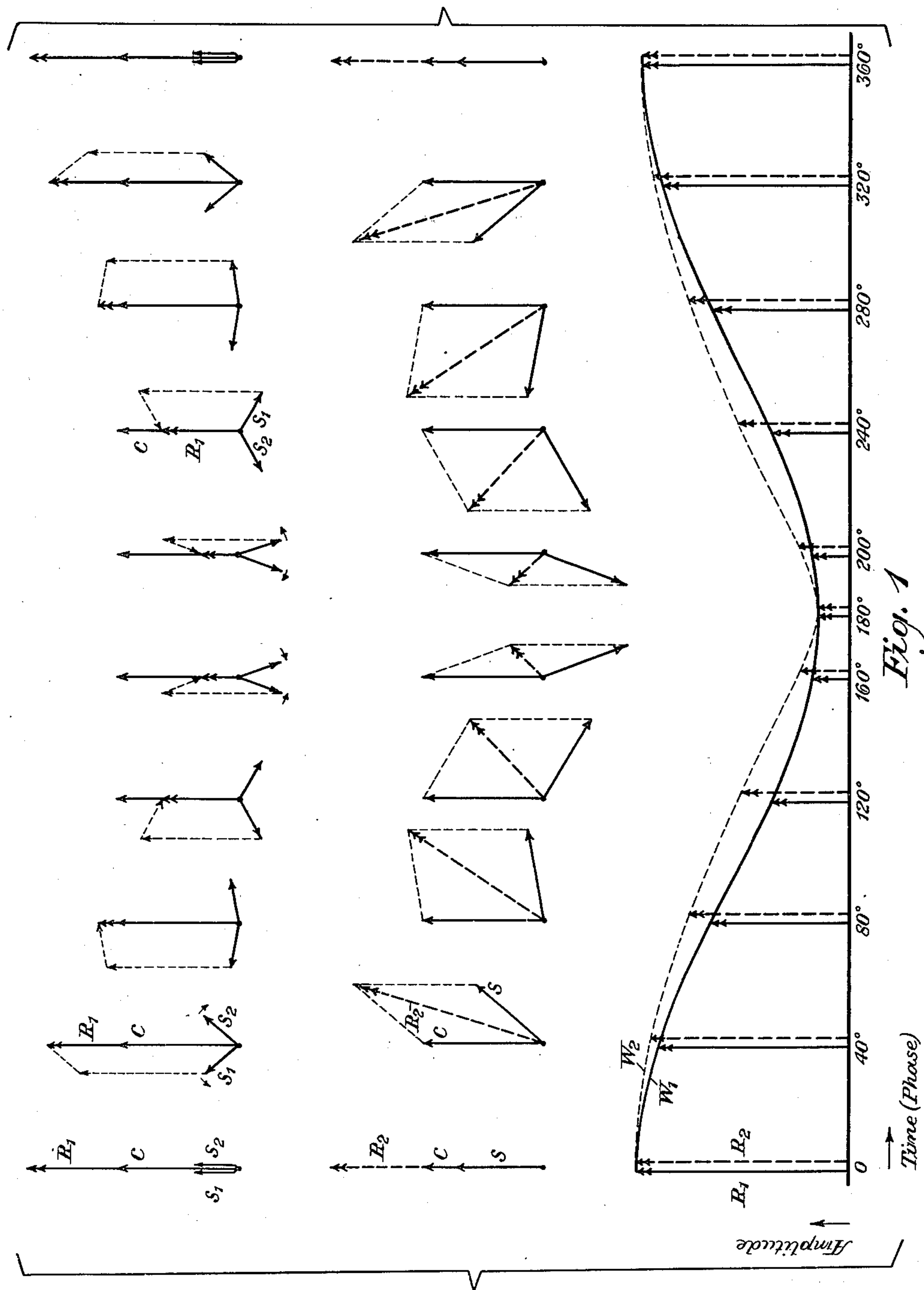
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SIGNALING WITH HIGH FREQUENCY WAVES

Filed Feb. 10, 1934

2 Sheets-Sheet 1



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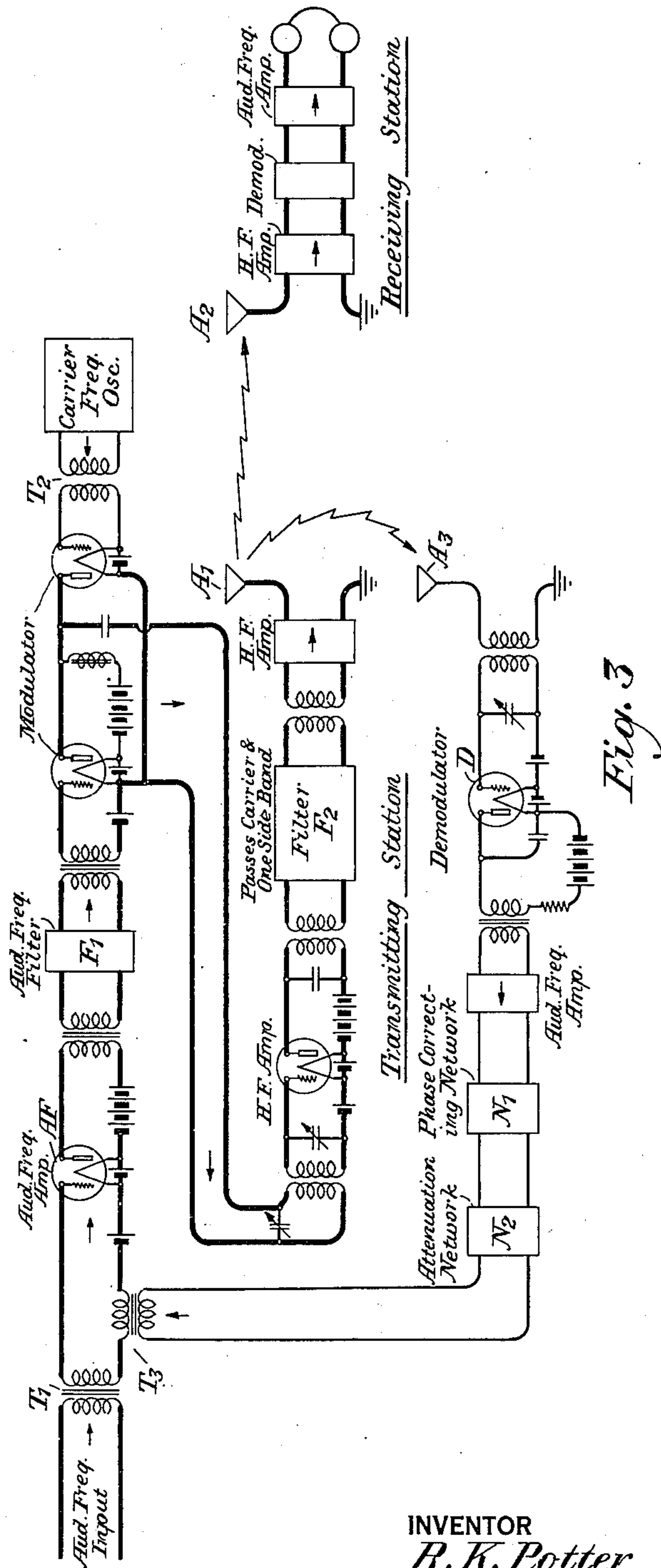
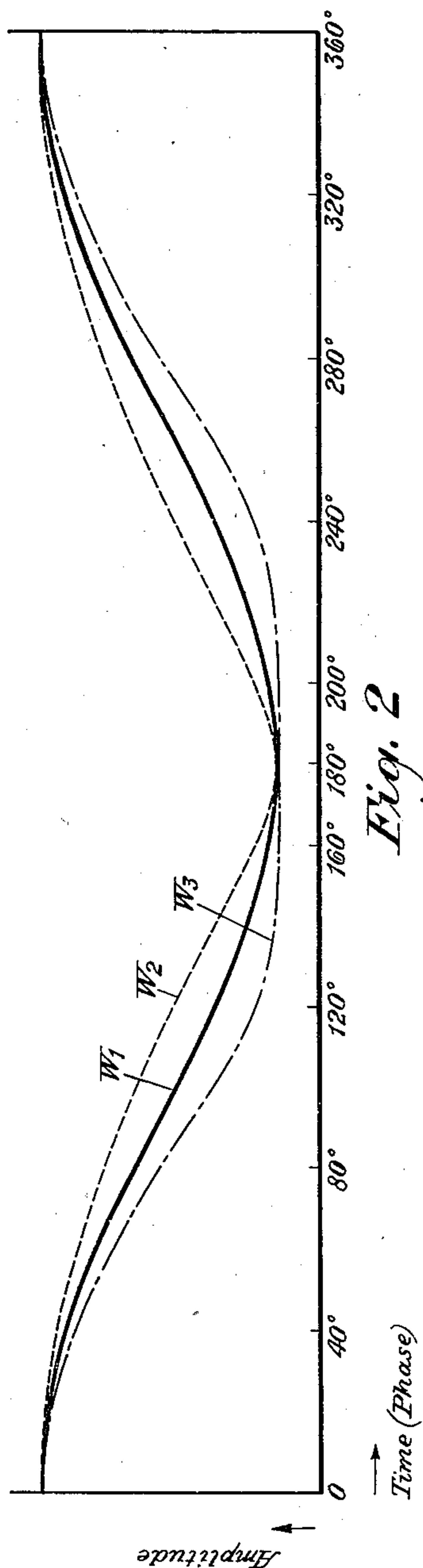
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SIGNALING WITH HIGH FREQUENCY WAVES

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14 Claims. (Cl. 250—17)

This invention relates to methods of and means for signaling which involve the transmission of the signal by the modulation of a high-frequency carrier wave. More particularly the invention relates to carrier transmission in which the carrier and a single side-band are transmitted, the other side-band being suppressed at the transmitting end of the signaling system.

While the invention is generally applicable to signaling with high-frequency waves in the manner indicated hereinabove, whether the transmitting medium be the ether or a circuit formed by one or more metallic conductors or a combination of one or more radio links and wire links, it is particularly applicable to radio broadcast transmission and will be specifically described and discussed hereinafter with reference to such transmission.

It is well known in the art of radio transmission that it is desirable that the range of frequencies necessary to transmission from a given transmitting station be reduced to limits as narrow as due regard for the quality of the signal transmission will permit. Accordingly, in the case of radio broadcasting, in which it is usually necessary to transmit the carrier frequency along with the side frequencies produced by modulation of the carrier in accordance with the signal, it has been proposed that one of the sidebands be removed by suppression at the transmitting station. One objection to this proposal has been that the removal of one of the side-bands leads to substantial distortion, as will be discussed at greater length hereinafter.

The ultimate object of the present invention is to reduce the range of frequencies which it is necessary to transmit with unsuppressed carrier transmission in order to produce high quality, and thus to permit a more efficient channel spacing in such transmission as radio broadcasting; the proximate object of the invention is to eliminate for practical purposes, or, at the least, very greatly reduce the distortion normally resulting from the suppression of one side-band in unsuppressed carrier transmission.

In general, the above-stated proximate object is accomplished by producing at the transmitting station an auxiliary wave and modulating the carrier wave by the auxiliary wave, this auxiliary wave having a form such that there will be effected a substantial compensation for the distortion resulting from the suppression of the side-band. More specifically, the proximate object may be accomplished, after the suppression of one of the side-bands, by deriving at the trans-

mitting station from a portion of the transmitted energy a demodulated signal wave, which will be a distorted representation of the signal input wave, effecting adjustment of the amplitude and phase of this demodulated signal wave, and combining the demodulated signal wave with the signal input wave for modulation with the carrier wave, the adjustment of the demodulated signal wave being such as substantially to compensate for the distortion introduced as a result of the suppression of the one side-band.

The following description of the invention is to be read with reference to the accompanying drawings, of which—

Figure 1, by means of vector diagrams and curves, illustrates the problem introduced by the suppression of one side-band in unsuppressed carrier transmission;

Fig. 2, by means of curves, indicates graphically the nature of the correction provided by the applicant; and

Fig. 3 shows diagrammatically, and in part schematically, a suitable arrangement of circuits for effecting the applicant's elimination or material reduction of the distortion introduced by the single side-band suppression.

With reference first to Fig. 1 of the drawings, it is to be understood that in the case of transmission with the carrier suppressed at the transmitting end of the system and reapplied for demodulation at the receiving end, the ratio of carrier amplitude to side-band amplitude is readily adjustable and may be made high so that any distortion introduced as a result of the suppression of one side-band at the transmitting end is negligible, whereas in the case of the transmission of the carrier with one side-band, with which the applicant is dealing, the carrier amplitude will exceed the side-band amplitude by a very much smaller amount if the same effective level of signal is to be maintained at the receiver, and the result of the suppression of the one side-band will be distortion which is quite considerable, as shown in this figure. The vector diagrams and curves are drawn to scale and represent a particular case of 75% modulation of a high-frequency wave by a single tone, it being understood that the single tone case does not differ in general principle from the case of modulation by a voice wave, for instance, but permits of a more graphic illustration.

The upper row of diagrams of Fig. 1 represents in terms of vectors a high-frequency wave modulated by the tone in the ordinary manner and comprising the carrier (C) and the two side-

bands (or side-frequencies) (S_1 and S_2) each represented by an unbroken, single-headed vector. The side-band vectors S_1 and S_2 are indicated as rotating in opposite directions with respect to the carrier vector C through 360° or one cycle of alternation, the successive diagrams showing the side-band vectors at intervals of 40° . In each diagram the resultant amplitude of the combination of the carrier and side-bands is indicated by the length of the resultant vector, shown with unbroken line and double head (R_1); since the two side-band vectors form equal angles with the carrier vector at any time, the direction of the resultant vector is always that of the carrier vector. Accordingly, in this case of carrier and two side-bands, the amplitude variation represented by the resultant vectors (R_1) gives a modulated wave envelope corresponding to the modulating wave (tone). This correspondence is graphically shown by the diagram appearing at the bottom of Fig. 1, in which the unbroken curve W_1 is determined by plotting the amplitudes represented by the vectors R_1 , the envelope amplitude varying with time in a simple sinusoidal fashion. Thus, in the case of carrier and double side-band transmission, the shape of the low-frequency signal wave resulting from proper demodulation at the receiving end corresponds to the shape of the low-frequency signal wave applied at the transmitting end.

If, however, after the modulation of the high-frequency wave, one of the side-bands is suppressed, the resultant amplitude variation (or wave envelope) no longer corresponds to the shape of the modulating wave. In the lower row of vector diagrams of Fig. 1, the unbroken, single-headed vectors C and S represent the carrier and the unsuppressed side-band (or side-frequency), respectively. It will be noted that in order to maintain the normal percentage amplitude modulation (75%) or the same signal level at a receiving point, the amplitude of the unsuppressed side-band S is made twice as great as the amplitude of the side-band S_1 or the side-band S_2 in the case of carrier and double side-band transmission discussed hereinabove. Since the side-band vector S is now rotating with respect to the carrier vector C without the directionally compensating effect of a side-band vector rotating in the opposite direction, the resultant vectors no longer coincide directionally with the carrier vector, except at the beginning and end of each half-cycle, and the resultant amplitudes represented at intervals of 40° by the lengths of the broken, double-headed vectors R_2 , are equal only at those points to the resultant amplitudes at the corresponding points in the case of the carrier and double side-band transmission. Accordingly, with the suppression of the one side-band, the amplitude variation represented by the vectors R_2 will give a modulated wave envelope which does not correspond to the modulating wave (tone). The distortion is graphically shown in the diagram at the bottom of Fig. 1, in which the broken curve W_2 is determined by plotting the amplitudes represented by the vectors R_2 . It will be noted that the envelope amplitude varies with time in a non-sinusoidal fashion, the degree of distortion being indicated by the displacement of curve W_2 with respect to curve W_1 . It will now readily be seen that, in the case of carrier and single side-band transmission, one side-band having been suppressed, the shape of the low-frequency signal wave resulting from demodulation at the

receiving end does not, without the introduction of some correction, correspond to or very closely approximate the shape of the low-frequency signal wave applied at the transmitting end. In other words the signal is seriously distorted.

It can now be seen that, in the case of carrier and single side-band transmission, if the distortion resulting from the suppression of the one side-band is to be eliminated or very greatly reduced, there must be applied to the modulator at the transmitting end, for modulation of the carrier wave, a wave of such shape that after the modulation and the suppression of the side-band there can be derived at the receiving end a low-frequency wave substantially corresponding to the envelope shape of the modulated wave in the carrier and double side-band case. With reference to Fig. 1, the wave W_2 must be altered in shape to correspond substantially to the wave W_1 .

In order to present this point graphically, there are shown in Fig. 2 the unbroken wave W_1 of the carrier and double side-band case and the broken wave W_2 of the carrier and single side-band case (these two waves being the same as the waves of like designation in Fig. 1) and in addition a wave W_3 (shown in mixed curve), which is the auxiliary or corrected wave which must be used at the transmitting end to modulate the carrier wave. It will be understood, of course, that the wave W_3 of Fig. 2 represents the requirement for perfect correction; in practice, this wave will closely approximate the form shown, with the object of substantial elimination or very great reduction of the distortion which would otherwise result from the side-band suppression. It can be seen from an examination of Fig. 2 that if the envelope shape of the wave from which the signal output is to be derived at the receiving end of the system is the result of a combination of a wave having the shape of curve W_2 and a wave substantially corresponding to curve W_3 , there can be produced at the receiving end a low-frequency wave having substantially the shape of the curve W_1 . It will be understood, however, that the wave represented by W_2 is formed only as a result of the suppression of the one side-band. Therefore, the problem must be solved by applying at the transmitting end for modulation with the carrier a wave substantially in the form of W_3 ; in other words, the final modulating energy acting on the carrier in the modulator at the transmitting station must be substantially represented by the curve W_3 . The product of the modulation will then represent a distortion which will be substantially eliminated or offset by the distortion subsequently introduced as a result of the side-band suppression. Viewed somewhat differently, the case is one in which there is introduced at the transmitting end an auxiliary distortion which will in the ultimate effect substantially compensate for the distortion introduced by the side-band suppression.

An arrangement of apparatus suitable for the practice of the invention is shown in the circuit diagram of Fig. 3. At the transmitting station the signal energy from the audio-frequency input is passed through the transformer T_1 , the audio-frequency amplifier AF and the audio-frequency filter F_1 to the vacuum tube circuits of the modulator, in which this low-frequency wave modulates the high frequency wave produced in the carrier frequency oscillator, associated with the modulator through the transformer T_2 . The

product of the modulation comprises the carrier and the double side-band components. The output of the modulator is then passed through a high-frequency amplifier and through a filter F_2 , which suppresses one of the two side-bands and passes the carrier and the other side-band. The carrier and single side-band energy is amplified in another high-frequency amplifier and is radiated from the transmitting antenna A_1 . Without correction in accordance with the invention, this energy, when picked up by the antenna A_2 at the receiving station and demodulated, would give the distortion indicated in Fig. 1, which distortion has been shown hereinabove to be the result of the suppression of the side-band, as in filter F_2 .

For the purpose of effecting the desired correction in accordance with the particular arrangement of Fig. 3, a portion of the high-frequency energy radiated from the antenna A_1 is picked up by the auxiliary receiving antenna A_3 at the transmitting station. In this auxiliary circuit a demodulator D , which is of the type preferably used at the receiving station, serves to demodulate the received portion of the signal energy, and the output of the demodulator is then passed through an audio-frequency amplifier. By means of a phase-correcting network N_1 and an attenuation network N_2 , elements which in themselves are well understood in the art, the demodulated signal is adjusted in phase and amplitude and is then impressed on the input or grid circuit of the audio-frequency amplifier AF in the main transmission circuit, through the transformer T_3 . It has been seen that the signal input is normally impressed on this grid circuit of tube AF through transformer T_1 ; it is now seen that with the circuit arrangement of Fig. 3, a combination of the normal input signal wave and the auxiliary demodulated signal wave, the latter having been subjected to suitable adjustment, can be impressed on the amplifier AF and passed through the audio-frequency filter F_1 for modulation of the carrier wave. The fundamental component from the auxiliary circuit should be adjusted in networks N_1 and N_2 so that it will be out of phase with the normal signal input and of amplitude approaching that of the signal input. With reference to Fig. 2, it will be understood that this adjustment should be such that the combination of the signal input and the adjusted auxiliary wave will produce a wave which takes substantially the form of the curve W_3 (in the single tone case presented). The modulation of the carrier by this wave (W_3) introduces the effect which substantially compensates for the distorting effect of the suppression of the side-band in filter F_2 , and the effective envelope shape of the carrier and single side-band energy radiated from the antenna A_1 , is changed to a degree such that the output of the receiver at the distant receiving station will substantially correspond to the original audio-frequency input at the transmitting station.

In practice the degree of correspondence depends upon the extent to which the input from transformer T_3 approaches that from transformer T_1 ; to retain normal modulation it is required only that the output of transformer T_1 be increased. The practical limit to the reduction of the distortion is determined by that distortion which arises from other unrelated sources.

It will therefore be understood by those skilled in the art that in the applicant's case of carrier and single side-band transmission with

distortion correction introduced through a feed-back circuit, there should be a step-up of amplitude in the audio-frequency input, in comparison with the normal carrier modulation case.

The correction introduced as described hereinabove will necessarily result in additional side-band components that are not present in the case of the carrier and double side-band transmission. In other words, in order to eliminate the distortion produced at the output of the receiver demodulator, it is necessary to transmit components which are out of phase with and will neutralize those produced in the demodulation process at the receiver. However, these additional side-band components will not limit the usefulness of the frequency band, and they need not extend beyond the band in such a way as to cause interference with adjacent channels. If, for example, the transmitted audio-frequency signal band has a range from 0 to 10,000 cycles, the regeneration can be limited to this range by means of the audio-frequency filter F_1 of Fig. 3, connected in the circuit between the first audio-frequency amplifier (AF) and the modulator, this filter performing the dual function of limiting the normal and the feed-back inputs to the modulator. Since, because of the presence of filter F_1 in the circuit, no distortion component above 10,000 cycles is put back into the modulator, none will be transmitted. At the output of the receiver demodulator the distortion products below 10,000 cycles which normally appear will be largely neutralized; distortion products above 10,000 cycles will be produced in the demodulation process, but these will normally be suppressed in the circuits of the receiver, or, if not, will be tolerable because of their low amplitude and the natural limitations of the ear.

It will be understood that, while the simple case of modulation of the carrier by a single tone, used for illustration, would permit of correcting the envelope shape of the modulated wave through the simple adjustment of the signal input, in the practical case of the transmission of the voice or music this would not be so, since modulation components result for which no compensation would be effected without some such arrangement as the applicant's for applying the adjusted demodulated low-frequency wave.

While the invention has been disclosed as embodied in a specific form, for the purpose of illustration, it is to be understood that with respect to such embodiment many changes and modifications may be made within the true scope of the invention as defined in the appended claims.

What is claimed is:

1. In high-frequency transmission involving the modulation of a carrier wave by a signal wave and the suppression of one of the side-bands resulting from such modulation, the method which consists in producing an auxiliary wave and modulating the carrier wave by said auxiliary wave, said auxiliary wave having a form such as to effect a substantial compensation for the modulated wave envelope distortion resulting from the suppression of the side-band.

2. In high-frequency transmission involving the normal modulation of a carrier wave by an audio-frequency signal wave and the suppression of one of the side-bands resulting from such modulation, the method which consists in producing an auxiliary audio-frequency wave and modulating the carrier wave by said auxiliary wave, said auxiliary wave having a form such as to effect a substantial compensation for the modulated wave

envelope distortion resulting from the suppression of the side-band.

3. In high-frequency transmission involving the modulation of a carrier wave by a low-frequency signal wave and the suppression of one of the side-bands resulting from such modulation, the carrier and the other side-band remaining for transmission, the method which consists in producing an auxiliary low-frequency wave and modulating the carrier wave by said auxiliary wave, said auxiliary wave having a form such as to effect a substantial compensation for the modulated wave envelope distortion resulting from the suppression of the one side-band.

4. The method of carrier wave signaling which consists in producing a high-frequency wave, modulating said wave in accordance with the signal, suppressing one of the side-bands resulting from the modulation, producing an auxiliary low-frequency wave, and combining said auxiliary wave with the signal for the modulation of said high-frequency wave, said auxiliary wave being of such form that the effect of the modulation of the high-frequency wave by the combination low-frequency wave will substantially compensate for the envelope distorting effect of the suppression of the one side-band.

5. In high-frequency transmission involving the modulation of a high-frequency carrier wave by a low-frequency signal input wave, the suppression of one of the side-bands resulting from such modulation and the transmission of the carrier and the single remaining side-band, the method which consists in deriving from the transmitted wave a demodulated low-frequency wave, effecting an adjustment of said demodulated low-frequency wave, and applying the signal input wave and the adjusted demodulated low-frequency wave in combination for the modulation of the carrier wave, said adjustment being such as substantially to compensate for the wave envelope distortion introduced by the suppression of the one side-band.

6. The method of high-frequency transmission which consists in modulating a carrier wave with the signal input wave to produce a composite wave of carrier and two side-bands, suppressing one side-band, transmitting the resultant energy composed of the carrier and one side-band, deriving from a portion of the transmitted energy a demodulated low-frequency wave which is a distorted representation of the signal input wave, effecting adjustment of the phase and amplitude of said demodulated low-frequency wave, and applying the signal input wave and said demodulated low-frequency wave in combination for modulation with the carrier wave, said adjustment of the demodulated low-frequency wave being such as substantially to compensate for the modulated wave envelope distortion resulting from the suppression of the one side-band.

7. The method of signaling over a transmission system by means of high-frequency waves which consists in producing at the transmitting end of the system a high-frequency carrier wave, modulating the carrier wave with the signal input wave to produce a composite wave of carrier and two side-bands, suppressing one side-band, transmitting the resultant energy composed of the carrier and the remaining side-band, deriving at the transmitting end of the system from a portion of the transmitted energy a demodulated audio-frequency wave which is a distorted representation of the signal input wave, effecting adjustment of the phase and amplitude of said de-

modulated audio-frequency wave, applying the signal input wave and the adjusted demodulated audio-frequency wave in combination for modulation with the carrier wave at the transmitting end of the system, transmitting the resultant modulated wave, after the suppression of one side-band, to the receiving end of the system, and demodulating the received wave to produce the final signal output wave, the adjustment of the demodulated audio-frequency wave at the transmitting end being such that the signal output wave produced at the receiving end will represent without substantial distortion the signal input wave applied to the system at the transmitting end.

8. In a transmitting circuit forming a part of a high-frequency transmission system, means for producing a high-frequency carrier wave, means for modulating said carrier wave by a low-frequency wave, means for suppressing one of the side-bands resulting from the action of said modulating means, means for producing an auxiliary low-frequency wave of such form as substantially to compensate for the envelope distortion resulting from the action of said suppressing means, and means for applying said auxiliary wave to said modulating means for the modulation of said carrier wave.

9. In a signaling system, means for producing a high-frequency carrier wave, means for modulating said carrier wave by an audio-frequency wave, said modulating means including a low-frequency input circuit, means at the transmitting end of the system for suppressing one of the side-bands resulting from the modulation, means at the transmitting end of the system for producing an auxiliary audio-frequency wave of such form as substantially to compensate for the envelope distortion resulting from the suppression of the one side-band, and means for impressing said auxiliary wave on the low-frequency input circuit of said modulating means.

10. In a high-frequency transmission system, a modulator at the transmitting end of the system, means for applying a carrier wave to said modulator, a circuit for applying a low-frequency wave to said modulator for the modulation of said carrier wave, means for suppressing one of the side-bands produced by the modulation, means for transmitting the wave composed of the carrier and the remaining side-band, means at the transmitting station for deriving from a portion of the transmitted energy an auxiliary low-frequency wave, means for effecting adjustment of said auxiliary wave, and means for combining the signal input wave and the adjusted auxiliary wave in the low-frequency application circuit of said modulator, the adjustment of said auxiliary wave being such that the combined low-frequency energy applied to the modulator will result in substantial compensation for the envelope distortion introduced by the suppression of the one side-band.

11. In a system for the transmission of signals by the modulation of a carrier wave in accordance with the signal wave, a modulator at the transmitting end of the system, means for impressing a high-frequency carrier wave on said modulator, a circuit adapted to apply low-frequency energy to said modulator to modulate the carrier wave, means for suppressing one of the side-bands produced by the action of said modulator, means for transmitting the energy composed of the carrier and the remaining side-band, means at the transmitting end of the sys-

tem for deriving from a portion of the transmitted energy an auxiliary low-frequency wave, means for effecting adjustment of the phase and amplitude of said auxiliary wave, and means for
5 applying the adjusted auxiliary wave in combination with the signal wave to the low-frequency input circuit of the modulator, said adjustment of the auxiliary wave being such as to produce substantial compensation for the wave
10 distortion resulting from the suppression of the one side-band.

12. In a system for the transmission of signals by the modulation of a carrier wave in accordance with the signal wave, a modulator at
15 the transmitting end of the system, means for impressing a high-frequency carrier wave on said modulator, a circuit adapted to apply low-frequency energy to said modulator to modulate the carrier wave, means for suppressing one of
20 the side-bands produced by the action of said modulator, means for transmitting the energy composed of the carrier and the remaining side-band, means at the transmitting end of the system for deriving from a portion of the transmitted energy an auxiliary low-frequency wave,
25 means for effecting adjustment of the phase and amplitude of said auxiliary wave, means for applying the adjusted auxiliary wave in combination with the signal wave to the low-frequency
30 input circuit of the modulator, said adjustment

of the auxiliary wave being such as to produce substantial compensation for the wave distortion resulting from the suppression of the one side-band, and means at the receiving end of the system for demodulating the received wave
5 to produce the output signal wave.

13. In carrier wave signal transmission involving the suppression of one side-band, the method of preventing the distortion normally introduced by the side-band suppression which
10 consists in employing at the transmitting end a carrier wave and a modulating wave and pre-distorting the modulating wave to a shape such as to compensate for the envelope distortion introduced by the suppression of the one side-
15 band.

14. In a carrier wave signaling system, a modulator, means associated therewith for impressing thereon a high-frequency wave, a modulating wave source, a circuit connecting said
20 source and said modulator, means for suppressing one of the side-bands produced by the action of said modulator, and means associated with said connecting circuit for distorting the modulating wave to a shape which will substantially
25 compensate for the distortion of the modulated wave envelope introduced by the suppression of the side-band.

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