

R. V. L. HARTLEY.
REDUCTION OF DISTORTION OF SIGNALING CURRENTS.
APPLICATION FILED SEPT. 8, 1917.

1,360,740.

Patented Nov. 30, 1920.
2 SHEETS—SHEET 1.

Fig. 1.

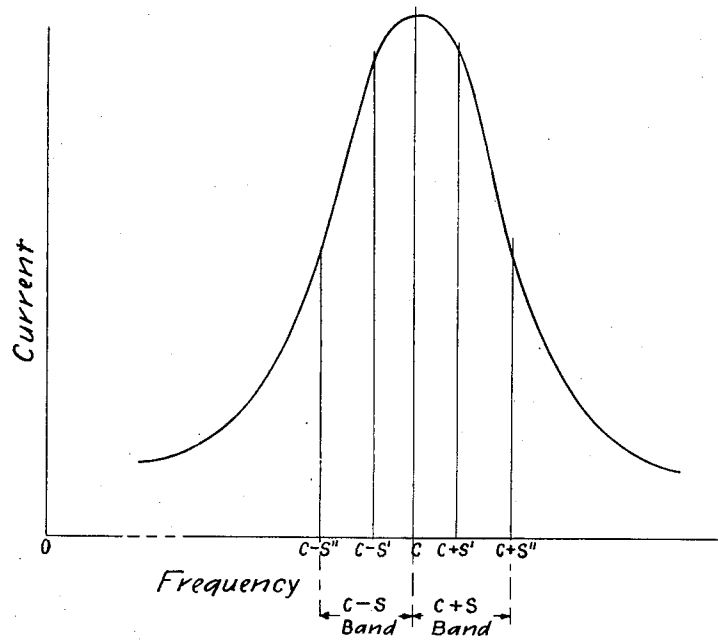
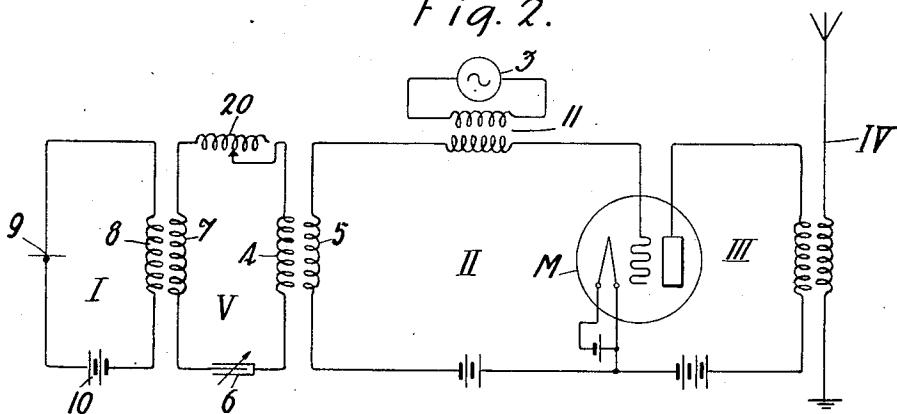


Fig. 2.



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2 SHEETS—SHEET 2.

Fig. 3.

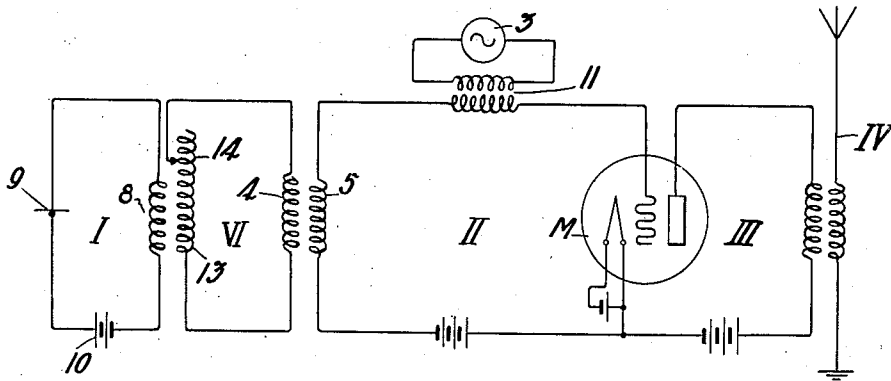


Fig. 4.

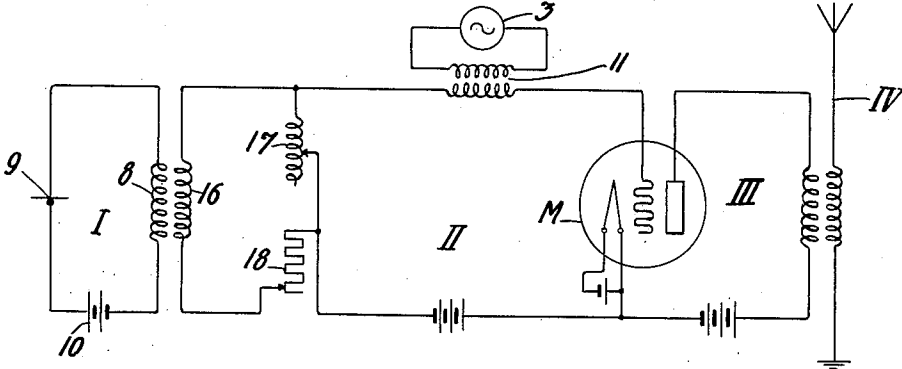
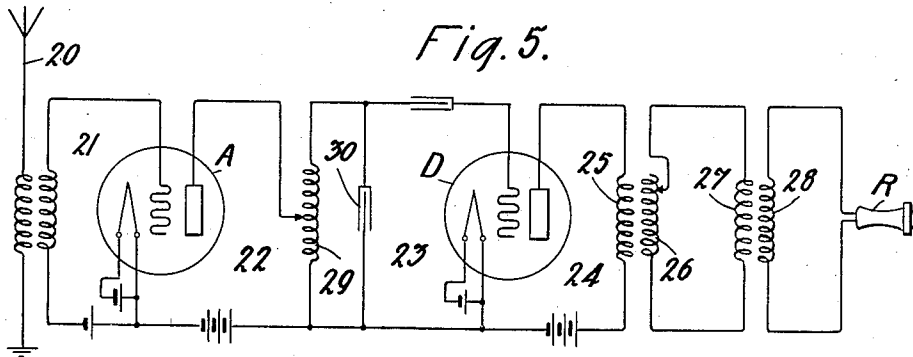


Fig. 5.



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UNITED STATES PATENT OFFICE.

RALPH V. L. HARTLEY, OF BROOKLYN, NEW YORK, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

REDUCTION OF DISTORTION OF SIGNALING-CURRENTS.

1,360,740.

Specification of Letters Patent.

Patented Nov. 30, 1920.

Application filed September 8, 1917. Serial No. 190,388.

To all whom it may concern:

Be it known that I, RALPH V. L. HARTLEY, a citizen of the United States, residing at Brooklyn, in the county of Kings and State of New York, have invented certain new and useful Improvements in Reduction of Distortion of Signaling-Currents, of which the following is a full, clear, concise, and exact description.

This invention relates to a method of and apparatus for reducing the distortion of a modulated current in wire or wireless telephone systems or other transmission systems employing modulated currents. In the preferred form it contemplates a distortion of the modulating or low frequency current in such a way as to partly or wholly counteract the distorting effect of the circuit.

The invention is well adapted for radio-telephone systems in which is provided a carrier alternating or oscillating current which is subjected to the influence of the voice currents. The carrier wave thus modulated is amplified to the desired amount and then radiated by an antenna tuned to the carrier wave frequency or neighboring frequency. Thus side band frequencies which differ most from the frequency to which the antenna is tuned are noticeably suppressed, thereby distorting the modulated wave and impairing the reproduction at the receiving station.

One remedy for this defect is to increase the damping of the antenna, thus making its impedance more nearly uniform over the band of frequencies being transmitted. This, however, involves dissipation of power in the added resistance so that it is desirable to prevent such distortion without adding to the damping. This is accomplished, according to one form of the invention, by providing means between the transmitter and the modulator for increasing the amplitude of the voice currents of higher frequency relative to those of lower frequency in the same ratio that the impedance of the antenna circuit increases for frequencies differing from the carrier frequency by the amount of voice currents. The amplitudes of the side band currents in the antenna are thus brought into the same proportion to each other as those of the original voice currents, and the effect of distortion by the antenna is overcome.

Any one of the various known means may be employed for effecting this compensation

in the low frequency circuit. For example, a resonance transformer may be used having its maximum efficiency for a frequency somewhat above the voice range. Other examples are given below.

For a more complete understanding of the invention reference may be had to the accompanying drawings in which:

Figure 1 is a diagram showing the resonance curve for a transmitting antenna.

Fig. 2 is a diagrammatic view of an embodiment of my invention in which a tuned circuit is employed to effect the compensation in the low frequency circuit.

Figs. 3 and 4 are diagrammatic views of systems embodying the invention, in which other means are employed for effecting the compensation in the low frequency circuit.

Fig. 5 is a diagrammatic view of an embodiment of my invention, in which compensation is effected at the receiving station.

Like reference characters refer to like parts throughout the different views.

Fig. 1 shows the relation between the strength of current induced in the transmitting antenna and the frequency of the current, C denoting the carrier wave frequency, to which frequency the antenna is tuned. The current in the antenna is a maximum at the frequency C and falls off rapidly with either an increase or a decrease in frequency. If S denotes the frequency of the current employed to modulate the carrier wave at a transmitting station, the modulated high frequency current is made up of three components, viz: C , $C-S$ and $C+S$. In case the modulating current is produced by speech, the frequency S varies over a considerable range, so that the components $C-S$ and $C+S$ of the modulated current form bands upon either side of the carrier frequency C . The current in the antenna due to these side band frequencies is indicated in Fig. 1, where S' and S'' denote a relatively low and a relatively high speech frequency, respectively. $C+S'$ and $C-S'$ are the components of the modulated current due to the speech frequency S' , and $C+S''$ and $C-S''$ are the components due to the speech frequency S'' . Assuming that S'' is the highest speech frequency present in the modulating current and that the lowest speech frequency is very near zero, the side bands $C-S$ and $C+S$ will be as indicated in Fig. 1. It is evident that the components

$C+S''$ and $C-S''$ are attenuated by the antenna to a greater extent than the components $C+S'$ and $C-S'$. As stated above, the resonance curve may be flattened by increasing the damping of the antenna or other tuned circuit, which will make the attenuation more nearly the same for all frequencies. This is objectionable, however, as it decreases the efficiency. It would be possible also to employ a wave filter which would attenuate both the frequencies $C-S'$ and $C+S'$ more than the frequencies $C-S''$ and $C+S''$, but such a filter would be relatively complicated and not so efficient as the means hereinafter described. A filter suitable for this purpose is described and claimed in the patent to Campbell, No. 1,227,113 granted May 22, 1917.

Referring to Figs. 2, 3 and 4, each of these figures shows a radio-telephone transmitting system having an antenna circuit IV, with which is inductively associated the modulator M having the input circuit II and the output circuit III. The high frequency generator 3 is inductively connected to the circuit II through the transformer 11. The transmitter circuit I contains the telephone transmitter 9, the battery 10 and the primary 8 of a transformer.

Fig. 2 shows the tuned circuit V containing the variable condenser 6 and the variable inductance 20. This circuit is inductively connected to circuits I and II by transformers 7, 8 and 4, 5 respectively. The circuit V is tuned to a frequency in the range of the upper voice frequencies or somewhat above this range, the purpose being to transmit the voice currents of higher frequency with greater facility than those of lower frequency, thus imparting relatively great amplitudes to the higher frequencies.

Fig. 3 illustrates a second method of compensating for the antenna distortion. In place of the circuit V of Fig. 1 a linking circuit VI is employed. The resonance transformer 8, 13 connects this circuit to the circuit I. The coil 13 is connected into circuit through an adjustable contact 14. By properly adjusting the amount of the coil 13 which is not in inductive relation with the primary coil 8, with respect to the remaining portion, the transformer may be made to have its maximum efficiency at a frequency somewhat above the voice range.

Fig. 4 illustrates a third method of effecting the compensation in the low frequency circuit. The transmitting circuit I is connected to the modulator by the transformer 8, 16, and adjustable impedance 18 having large resistance and small inductance or which may be non-inductive is connected in series with the transformer secondary 16. An adjustable inductance coil 17 is bridged across the input circuit and is in series with the coil 18 with respect to the secondary 16.

The purpose in having the resistance of coil 18 relatively large is to assist in making the current in the circuit 16, 17, 18 constant for all frequencies.

The operation of the systems shown in Figs. 2, 3 and 4 is as follows: The voice currents in circuit I, Fig. 2, induce currents in the tuned circuit V which has a natural frequency in the range of the upper frequencies of the voice currents or above that range, so that the amplitudes of the higher frequencies are increased relative to those of lower frequency. The energy of the current in circuit V is impressed upon the input or grid circuit II of the modulator M. The current from generator 3 induces a current of high frequency in the circuit II. The output current of the tube M is modulated in the well-known manner, and the alternating current component of the modulated current induces a modulated oscillatory current in the antenna circuit. This current consists of a component of carrier frequency and components of frequencies differing from the carrier frequency by the voice current frequency. The currents whose frequencies differ most widely from the carrier frequency are noticeably suppressed by the antenna, due to the frequencies being appreciably different from that to which the antenna is tuned. But the amount of suppression having been compensated for by the action of the tuned circuit V, the resultant current is undistorted.

The operation of the system of Fig. 3 is similar to that of Fig. 2, except that the compensation is effected by the transformer 8, 13, which is designed or adjusted to have maximum efficiency for a frequency somewhat above the voice range, so that the higher frequencies are thereby given relatively great amplitudes.

The system shown in Fig. 4 operates differently from that of Fig. 2 only to the extent that the compensation in the low frequency circuit is effected by the selective action of the impedance of circuit 16, 17, 18. The coil 17 offers negligible impedance to the lower voice frequencies but marked impedance to the higher frequencies. The coil 18 offers substantially the same impedance to currents of all frequencies. The drop in potential across the coil 17 therefore increases with the frequency, so that the effect is the same as that produced by the tuned circuit V of Fig. 2 and the transformer circuit VI of Fig. 3.

It is understood, of course, that an amplifier may be inserted between the circuits III and IV to amplify the modulated current to any extent desired.

This invention is not limited to the arrangement in which the low frequency current is distorted at the transmitting station to compensate for unequal attenuation in

the transmitting antenna. The compensating distortion may be produced at any other point in the system wherever the attenuation is a steadily increasing or decreasing function of the frequency. It is obvious that the distortion to be corrected may be produced by a transmission line as well as an antenna or by a local circuit at a terminal or intermediate station and that my invention is applicable to any of these conditions. Fig. 5 illustrates an application of the invention to a radio receiving station, use being made of a distorting transformer such as that shown in Fig. 3. Any other known means, such as either of those already described in connection with Figs. 2 and 4, may be used instead of that shown.

Referring to Fig. 5, an antenna 20 is connected through a transformer to the input circuit 21 of a vacuum tube amplifier A, the output circuit 22 of which is connected to the input circuit 23 of the vacuum tube detector D by means of variable impedance 29. The output circuit 24 of the detector D is connected through transformer 25, 26 to a circuit 26, 27, the function of the transformer 25, 26 being the same as that of transformer 8, 13 of Fig. 3. The telephone receiver R is inductively associated with circuit 26, 27 by means of transformer 27, 28. A condenser 30 is shunted across the inductance 29 and the circuit 29, 30 is tuned to the carrier wave frequency. The high frequency modulated current which is induced in the antenna 20 is amplified by the amplifier A, after which the detector D with its associated circuits functions in the usual manner to produce currents of speech frequency from the high frequency modulated current. The transformer 25, 26 is designed or adjusted to be more efficient for the speech currents of higher frequency than for those of low frequency, whereby compensation may be made for the distorting effect of the high frequency circuits of the system.

It is within the scope of my invention to produce either partial or complete compensation of the distortion produced by the tuned circuit, as circumstances may require.

It is also within the scope of the invention to effect the necessary compensation by means at one place only in the system, or at more than one place, as, for example, when the compensation is effected in part at the transmitter and in part at the receiver.

Likewise it is within the invention to compensate for the distortion of the wave either when the distortion is incidental or when it is intentional, as when produced for the purpose of rendering a signal unintelligible to all receiving stations not equipped with means for compensating for the distortion. While several circuit arrangements are

described as illustrative of the application of the principles of this invention, it is understood that other arrangements may be employed for accomplishing the same or similar purposes without departing from the spirit and and scope of the invention.

What is claimed is:

1. The method of compensating for the distortion of a high frequency wave modulated in accordance with a low frequency wave which comprises distorting the low frequency wave.

2. The method of compensating for the distorting of a wave of varying form which comprises variably distorting a wave which is a component of said first mentioned wave but which has a characteristic differing therefrom.

3. The method of compensating for the distorting of a modulated wave which comprises variably distorting a wave which is a component of said modulated wave but which differs therefrom in frequency.

4. The method of compensating for the distortion of a high frequency current modulated in accordance with low frequency waves of different frequencies which comprises varying the form of the low frequency wave of one frequency relatively to that of a different frequency.

5. The method of compensating for the distortion of a high frequency current modulated in accordance with low frequency waves of different frequencies which comprises varying the amplitude of the low frequency wave of one frequency relatively to that of a different frequency.

6. The method of reducing distortion by a tuned transmitting circuit of a telephone system which consists in distorting the voice currents before their energy is impressed upon the circuit.

7. In a telephone system including a tuned transmitting circuit and a modulator, the method of counteracting distortion produced by the tuned circuit, which comprises distorting the voice currents impressed upon the modulator.

8. In the method of carrier wave transmission in which distortion of a modulating-frequency component of the modulated carrier wave takes place, the step of partly or wholly compensating for such distortion.

9. The method of modulating a carrier wave in accordance with a signal which comprises modulating said wave more effectively with a portion of said signal than with another portion.

10. The method of modulating a carrier wave in accordance with a signal which comprises modulating said wave more effectively with signaling currents of some frequencies than with others.

11. The combination with means for producing a wave having a constant character-

istic and a variable characteristic, of means for distorting the wave, and means for partly or wholly compensating for such distortion before such distortion takes place.

5 12. In an alternating current transmission system for transmitting currents of different frequencies having a circuit in which distortion of the current takes place, means
10 at one of the terminal stations for producing a variable current distortion of such form as to partly or wholly compensate for the distortion of the distorting circuit.

13. In an alternating current transmission system having a circuit in which distortion
15 of the current takes place, a transmitting station, and means at the transmitting station for producing a current distortion of such form as to partly or wholly compensate for the distortion of the distorting circuit.

20 14. A wireless telephone system comprising an antenna, a modulator associated therewith, a source of high frequency current for said modulator, a source of voice
25 voice currents and said modulator for distorting the voice currents to partially or wholly counteract the distortion produced by the antenna.

15. A wireless telephone transmitting system comprising a tuned antenna, a source of
30 high frequency oscillations associated with said antenna, means including a telephone transmitter for producing voice currents, means for distorting the voice currents by
35 increasing the amplitudes of the components

of higher frequencies relatively to those of lower frequency, and means for modulating the high frequency oscillations in accordance with the distorted voice currents, whereby the effect of the distortion of the
40 modulated current by the antenna is partly or wholly eliminated.

16. An electric system comprising a source of electric current to be modulated, means
45 for modulating said current in accordance with waves of different characteristics, a circuit upon which the modulated current is impressed and which distorts the current, and means associated with the modulating
50 means for affecting said waves of different characteristics differently to partly or wholly compensate for the distortion.

17. The combination with means for producing a wave having a constant characteristic and a variable characteristic, of means
55 for variably distorting the wave, and means for partly or wholly compensating for such distortion.

18. In a system of modulated current transmission in which distortion of the
60 transmitted wave takes place, a source of high-frequency current, a source of current of modulating frequency, and means for modifying the current of modulating frequency to compensate for said distortion.

65 In witness whereof, I hereunto subscribe my name this 28th day of August, A. D. 1917.

RALPH V. L. HARTLEY.