

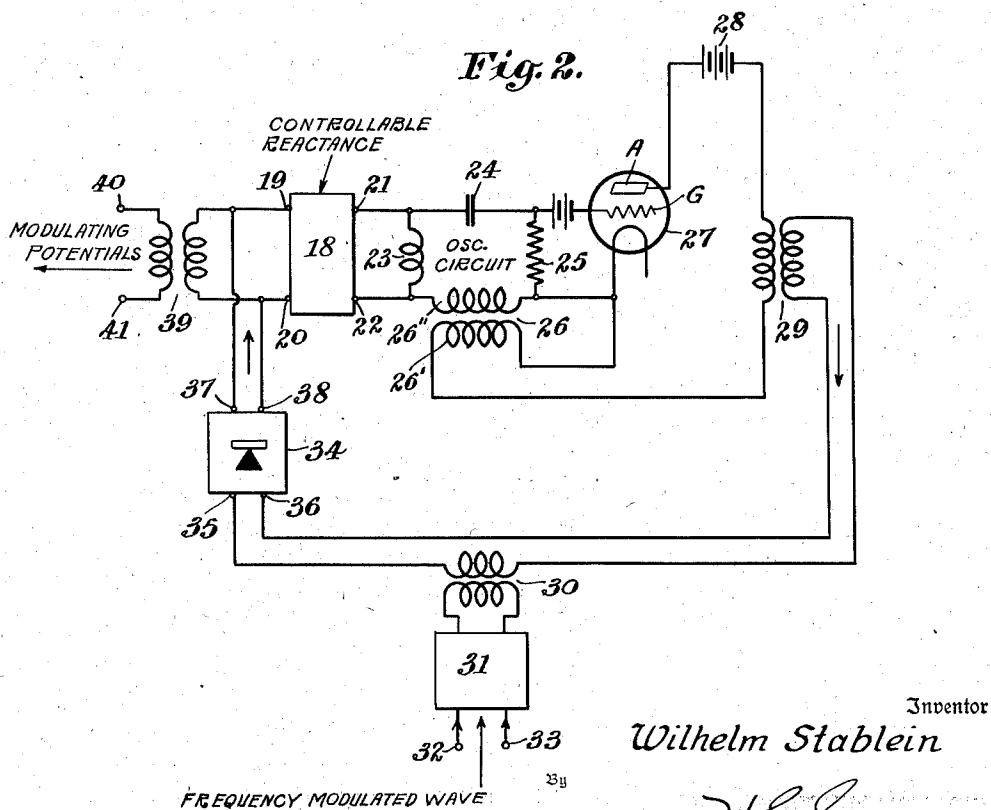
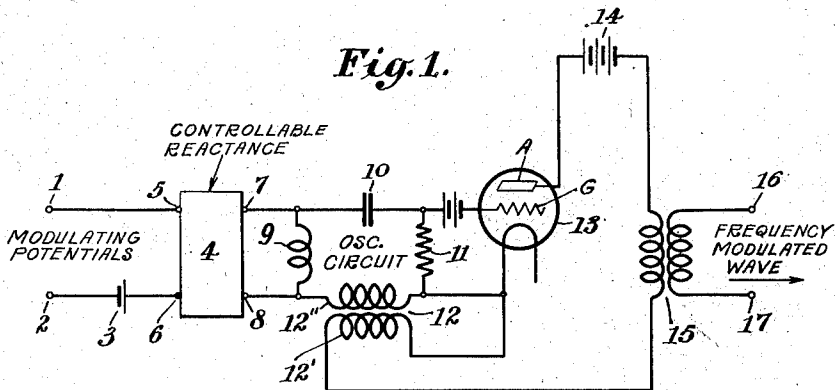
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FREQUENCY MODULATION

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FREQUENCY MODULATION

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The application concerns a method adapted to transmit intelligence or signals by means of frequency-modulated carrier waves. According to the invention, for modulation at the sending end and for demodulation at the receiving end, circuit organizations basically of like design and thus causative of like distortions in such an arrangement are used so that the distortions will mutually neutralize.

The invention is concerned with a method of carrier-frequency signal transmission in which the carrier waves are frequency modulated, in other words, in which the frequency of the carrier currents are varied at the rate of the intelligence or signals to be transmitted, say, in the form of voice signals.

The methods known in the art predicated upon frequency modulated carrier waves have the drawback that distortions are introduced which are fundamentally dissimilar because of the fact that basically different circuit organizations are used for the modulation at the sending end and in the circuit organizations used for demodulation at the receiving end. These distortions as a consequence are not neutralized resulting in distortions which are far greater than those inherent in transmission systems caused in amplitude modulation. It has been for this reason that frequency modulation, in spite of certain advantages over amplitude modulation, has so far failed of being used in practice to any appreciable extent.

Now, the object of this invention is a method of signal transmission predicated upon the use of frequency-modulated carrier waves in which the drawback inherent in methods known in the earlier art are avoided. According to the invention, the circuit organization used for modulation at the sending end and the circuit organizations used for demodulation at the receiving end are of basically similar construction so that the ensuing distortions are equal, arrangements being thus made so that the distortions will mutually cancel out and become neutralized.

Because of the similarity in the circuit organization, what is used according to the invention at the receiving end is really a modulation circuit scheme, the latter, however, being automatically so operated that the frequency produced thereby stays in agreement with the transmitter frequency which is picked up at the receiving point. In other words, the demodulator arrangement, in its essential nature, consists of an automatically controlled modulation organ-

ization analogous to the modulation circuit organization of the sending end.

The invention shall now be described in more detail by reference to the schematically shown exemplified embodiment in Figures 1 and 2 of the appended drawing. Figure 1 shows the modulation arrangements at the sending end and Figure 2 the demodulation circuit organization of the receiving end.

Referring to Fig. 1, 1 and 2 denote the input terminals for the modulating audio frequency. 3 is a direct-current source of biasing potential, 4 a controllable reactance device at the terminals 7 and 8 of which a reactance arises which is a function of the control or modulator potential impressed upon the terminals 5 and 6 of the said device. 13 is the transmitter tube for the modulated carrier frequency which is operated regeneratively by means of a transformer 12 having a winding 12' connected to the anode A and a winding 12'' connected to the grid G. The oscillation circuit of the said tube comprises an inductance 9 and a capacity 10. 11 denotes a series resistance, 14 is the source of plate potential of the transmitter tube, 15 its output transformer the secondary terminals 16 and 17 of which deliver the frequency-modulated carrier frequency potential.

Referring next to Figure 2, 18 denotes a reactance means (corresponding to device 4 of Figure 1) which comprises terminals 19 and 20 (corresponding to terminals 5 and 6 of Fig. 1) for the control potential, and terminals 21, 22 (corresponding to terminals 7 and 8 of Figure 1) for the reactance. 27 is a transmitter valve (corresponding to tube 13 of Figure 1) the oscillation circuit of which contains an inductance 23 (corresponding to inductance 9) and a capacity 24 (corresponding to capacity 10). 25 is a series resistance (corresponding to resistance 11), 26 the feed-back or tickler transformer (corresponding to transformer 12), 28 the plate potential source (corresponding to 14) and 29 the output transformer (corresponding to transformer 15) of transmitter valve 27. 31 denotes an amplifier upon which the signal potential is impressed by way of terminals 32, 33, while the amplified potential is put out across the transformer 30. 34 is a rectifier having input terminals 35, 36, and output terminals 37, 38. 39 denotes a transformer across the secondary terminals 40 and 41 of which the demodulated audio frequency is delivered.

The operation of an embodiment as shown in Figures 1 and 2 is as follows: The sending valve

13 regeneratively connected is so operated that by way of transformer 12 a certain portion of the alternating-current energy acting in the plate circuit is returned to the grid circuit. Disregarding a certain constant grid biasing potential, the grid potential is equal to the drop of potential across series resistance 11, the latter, in turn, being to a marked degree a function of the frequency since a series resonance circuit is connected in series. As known in the art, the transmitter tube becomes excited at the resonance frequency of the oscillation circuit. This frequency is essentially a function of the inductance 9 and the capacity 10; inside certain limits it may be varied by the regulable reactance 4, which, for instance, may be a variable inductance or variometer so that the aggregate active inductance comprises the parallel arrangement of the fixed inductance 9 and the variable inductance 4 of the arrangement.

Such a variable reactance, for instance, may consist of an iron-cored choke-coil which is subject to a bias magnetizing force and the inductance value of which varies with the value of the bias magnetization. It could also consist of a reactance tube arrangement of the kind used in the recent art for the automatic sharp tuning of broadcast receiver sets which reactance also comprises an inductance or a capacity which is a function of a direct-current voltage. A more detailed description of reactance tubes satisfactory for use in frequency modulators may be found in Crosby's United States application #209,919, filed May 25, 1938. However, a great number of other circuit arrangements are conceivable though these shall not be enumerated here because it is solely the fundamental effect that is of interest.

The variable reactance 4, as will be noted, has its terminals 7 and 8 connected so that it is actively included in the oscillation circuit whereas its control terminals 5 and 6 are subjected to the control potential. The latter consists of audio-frequency potential impressed upon the input terminals 1 and 2 for modulation purposes, the said audio-frequency potential being raised by the biasing voltage 3 to a point so that even in the presence of the highest amplitudes of the alternating potential, no negative aggregate potential will result. On the contrary, the instantaneous values of the control potential will always stay in the positive region.

As a consequence, the oscillatory circuit has its tuning varied at the rate of the audio frequency so that the desired frequency modulation ensues. It will be noted in this connection that insofar as the value of the frequency existing at any given instant is concerned, it is not the audio frequency prevailing at such instant that is of importance, such as is true, for example, in either side-band of an amplitude-modulated carrier frequency, but that this factor is only governed by the amplitude of the control potential prevailing at such instant.

The frequency-modulated carrier frequency or wave by way of the output transformer 15 and its output terminals 16, 17 is delivered for further uses; for instance, it may be further amplified and put on a transmission line.

The receiver circuit arrangement shown in Figure 2 corresponds in its elementary parts 18 to 29 to elements denoted by 4 to 15 of the sending scheme Fig. 1. The frequency delivered by way of the transformer 29 corresponds to the control potential impressed upon the terminals 19 and 20 just as shown in connection with the send-

ing end. The sole difference resides in the external circuit organization; for while at the sending end the control potential is directly derived from the audio-frequency potential designed for modulation, it is obtained in a different way at the receiving end, that is, so that the frequency produced by the transmitter tube 27 is always identical with the frequency generated at the sending end by tube 13 and transmitted to the receiving place. At the receiver the said frequency modulated wave is put in at the terminals 32 and 33 and amplified in amplifier 31 and impressed upon the transformer 30. The latter is so connected that its potential will be added to that of transformer 29. In other words, what is operative across the alternating-current terminals 35 and 36 of the rectifier 34 is the summation potential of the two frequencies one of which is generated in tube 27 and the other supplied at 32, 33. The summation may be conceived to be a beat potential whenever the two frequencies are not alike. Hence, the potential may vary between zero and the double potential if the potentials supplied by transformer 29 and 30 are of like value. Rectifier 34 rectifies this potential and feeds it across the terminals 37 and 38 in the form of a control potential to the terminals 19 and 20.

Now, if conditions have been chosen in such a way that, in the presence of zero control potential the frequency generated in the transmitter valve 27 is definitely lower than the lowest frequency to be received, and that, in the presence of the highest beat potential the frequency produced in the tube 27 is reliably higher than the highest frequency to be received, it follows there is no real chance for beats being formed, in fact, the frequency of tube 27 will always be identical with the frequency of the received modulated wave, save for this circumstance that between the potentials of transformer 29 and transformer 30 a variable phase angle will arise if the frequency received varies in order that a control potential may arise which will lead to the correct frequency of the transmitter valve 27.

The control potential across terminals 19 and 20, which, because of equality of circuit organization bears the same relationship to the modulated carrier frequency as the control potential across terminals 5 and 6 in the transmitter arrangement shown in Figure 1, may be taken off across terminals 40 and 41 of transformer 39 according to the alternating potential contained therein. Because of the agreement of the frequencies and agreement of relation between control potential and frequency the same must be perfectly identical, without any distortion, with the original audio frequency supply to the transmitter.

This circuit scheme may be further improved and refined by measuring also the direct-current component of the control potential and by using the same for the purpose that undesired alterations between the sending and the receiving circuit organizations are equalized. Inasmuch as there is certainty that the sending and the receiving frequencies will be kept alike by positively acting means, it follows that, if all data of the sending and receiving circuit organizations were strictly in agreement, also the direct-current biasing potential across terminals 19 and 20 should be identical with that across terminals 5 and 6. If this condition does not prevail, the inference is that this would be only due to a change in the data, particularly those of the

two oscillatory circuits where the fixed inductances 9 and 23, respectively, or the capacities 19 and 24, respectively, may have experienced relative alterations as a result of fluctuations of the temperature or other agencies. Such shift manifests itself in a change in the adjusted direct-current voltage of the rectifier 34 the mean value of which without this variation should be in agreement with the value prescribed for the transmitter and adjusted by the source of potential supply 3. The departure which has been ascertained could, for instance, be used for the purpose of causing the oscillation circuit of the receiver circuit organization to come with its fundamental tuning to be in agreement with the oscillation circuit of the transmitter, which is accomplishable by the aid of a rotary condenser or by similar ways and means. This correction is accomplishable manually or else by an automatic check-up device. However, it is to be noted that the circuit organization is operable also without such accessory device as long as the ensuing discrepancies are not of such a high value that the control range above indicated is exceeded. Distortions in such case will be produced inasmuch as the sending and the receiving ends are no longer of identical adjustment so that their distortions as a general rule will be different. However, these are avoided by the re-adjustment as before described.

The exemplified embodiment as hereinbefore described in which the transmitter circuit scheme shown in Figure 1 and the receiver arrangement Figure 2 cannot be discussed separately, but only in their relationship to each other, constitutes only one of the many possible instances embodying the basic idea and method, namely, to use in the sending and the receiving equipments, to the end of insuring frequency modulation, equal or at least similar circuit organizations for frequency modulation, and to cause the frequency locally produced in the receiver to be automatically regulated and adjusted so as to be in constant agreement with the frequency to be received, the regulatory or control quantity containing the modulating audio frequency.

For example, the transmitter may be of the multistage kind. The amplifier 31 for the frequency to be received may preferably be provided with gain or volume control means whenever there is a likelihood of marked fluctuations being occasioned in the conditions of transmission, as is true mostly of radio transmission. It will be also understood that a different transmitting circuit organization may be used in which, for instance, the oscillatory circuits may be included in the plate circuit. However, these are details that are unimportant and immaterial so far as the essence of the invention are concerned.

In fixing the data and dimensions for the transmitter circuit organization and the receiver circuit organization there is no absolute need to insure equality of the construction elements which, in the case of the receiving circuit might, in certain circumstances, mean unnecessarily elaborate means, in fact, it will be evident that powers far smaller will suffice for the receiver. However, care must be taken so that the characteristic inter-relationship between control quantity and ensuing frequency for both must be equal or nearly so, indeed, it will be only if this pre-requisite demand is satisfied that the distortions of the sending end will be equalized and neutralized by those of the receiving end.

The circuit organization used at the receiving end for the purpose of producing the control potential and its rectification must involve a time-constant so that the control potential will be able to follow frequency variations with adequate rapidity. This end is attainable by choosing suitable dimensions for the inductances, capacities, and ohmic resistances by ways and means well known in the art.

What I claim is:

1. A frequency modulation system comprising an oscillator including a reactive circuit which determines in part the frequency of operation of the oscillator, means for controlling the reactance of said reactive circuit in accordance with signals to control the frequency of operation of said oscillator, transmitting means coupled to said oscillator, a receiver comprising an oscillator including a reactive circuit electrically similar to said first reactive circuit, means for combining transmitted wave energy and oscillations produced by said last oscillator, and means for detecting the combined wave energy and controlling the reactance of the reactive circuit of said last oscillator in accordance with the output of the detecting means.

2. In a frequency modulation system, means for, generating oscillations of a frequency which varies in accordance with a control potential to be translated, similar means for generating oscillations of like frequency, means for combining said oscillations and rectifying the combined energy to obtain a second control potential, means for controlling said similar generator by said second control potential in a manner to cause said generating means to operate in synchronism, and, means for utilizing said second control potential.

3. In a frequency modulation system, an oscillation generator, a variable reactance coupled thereto for varying the frequency of operation of said oscillation generator, means for controlling said reactance in accordance with signals, a second oscillation generator similar to said first generator, a second variable reactance coupled to said second oscillation generator, means for combining oscillations from said generators and deriving from the combined energies a control potential characteristic of the phase of the oscillations produced by said second oscillator relative to the phase of the oscillations generated by said first oscillator, means for controlling said second reactance in accordance with said last control potential to synchronize the said generators, and means for utilizing said last control potentials.

4. A frequency modulation system comprising, an oscillation generator including a tuned circuit which determines in part the frequency of operation of the oscillation generator, means for controlling the tune of said circuit in accordance with signals to correspondingly control the frequency of operation of said oscillation generator, means for transmitting the generated oscillations of controllable frequency, a receiver comprising an oscillation generator including a circuit similar to said first circuit and tuned to operate at substantially the same frequency as said first circuit, means for combining transmitted oscillations and oscillations produced by said oscillation generator at said receiver, and means for detecting the combined oscillations and controlling the tune of the said circuit of the oscillation generator in said receiver in accordance with the output of the detecting means.

5. In a wavelength modulation system, an oscillation generator comprising an electron discharge tube having electrodes regeneratively coupled in an oscillatory circuit tuned to operate at a desired frequency, said circuit including a controllable reactance, means for controlling said controllable reactance in accordance with signals to thereby control the length of the oscillations generated, means for transmitting the generated oscillations, and means for demodulating the transmitted oscillations comprising a second electron discharge tube having electrodes regeneratively coupled in an oscillation generating circuit arranged to operate at said selected frequency, said last named circuits including a tunable reactance, means for combining the oscillations produced in said last named oscillation generator with transmitted oscillations, rectifying means connected with said last named means, and means for controlling said tunable reactance in said last named oscillation generating circuit in accordance with the output of said rectifying means.

6. In a timing modulation system wherein generated oscillations modulated in timing in accordance with signals are utilized, a circuit for generating oscillations of a frequency substantially equal to the mean frequency of said first mentioned oscillations, a circuit for combining said oscillations and rectifying the combined oscillations to obtain potentials characteristic of the variations in frequency of said first mentioned oscillations, a control circuit coupled with said oscillation generating circuit and with said combining circuit to control the operation of said generating circuit in accordance with the said potentials, and signal utilizing means coupled with said combining circuit.

7. In a timing modulation system wherein car-

rier wave energy modulated as to timing in accordance with signals is used to translate said signals, an electron discharge tube having electrodes regeneratively coupled in a circuit for generating oscillations of a frequency substantially equal to the frequency of the carrier wave energy, a combining circuit and a rectifier coupled to said generating circuit and excited by said modulated carrier wave energy for combining and rectifying the combined energies to obtain a potential characteristic of the timing modulation and other variations in the energies, a control circuit coupling said rectifier to said generating circuit to cause said generating circuit to operate substantially in synchronism with the timing modulated carrier wave energy, and a signal frequency circuit coupled to said rectifier for deriving the signals therefrom.

8. A frequency modulation system including an oscillator having a reactive circuit which determines in part the frequency of operation of the oscillator, a control circuit for controlling the reactance of said reactive circuit in accordance with signals to control the frequency of operation of said oscillator, a wave energy transmitting circuit coupled to said oscillator, a receiver comprising an oscillator including a reactive circuit electrically similar to said first mentioned reactive circuit, a combining circuit for combining transmitted wave energy and oscillations produced by said last named oscillator, a rectifier in a circuit for detecting the combined wave energy, and a control circuit coupling said rectifier to the reactance of the reactive circuit of the said last named oscillator to control the reactance thereof in accordance with the output of said rectifier.

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