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METHOD AND MEANS FOR SIGNALING BY FREQUENCY FLUCTUATION

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2 Sheets-Sheet 1

Fig. 1.

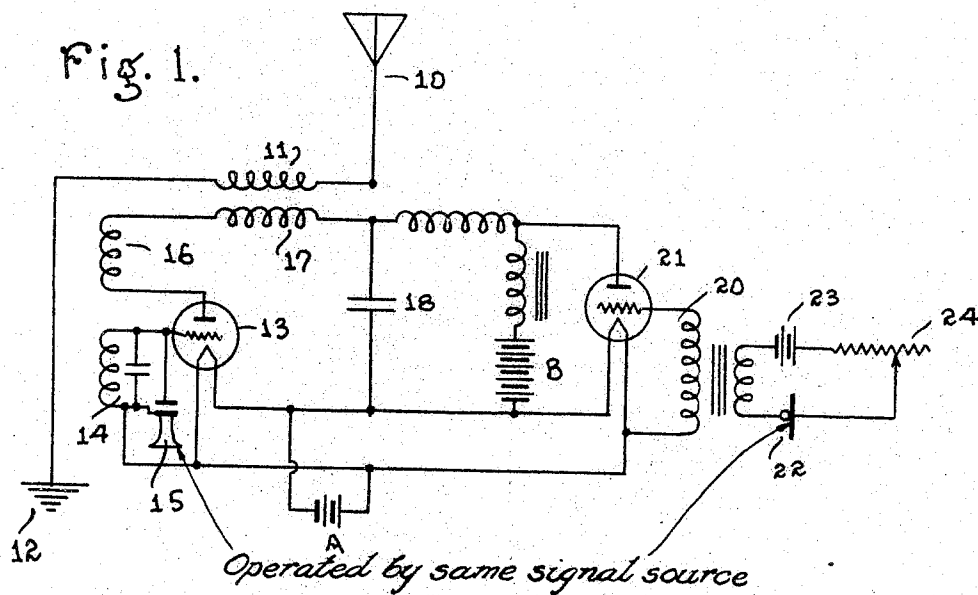
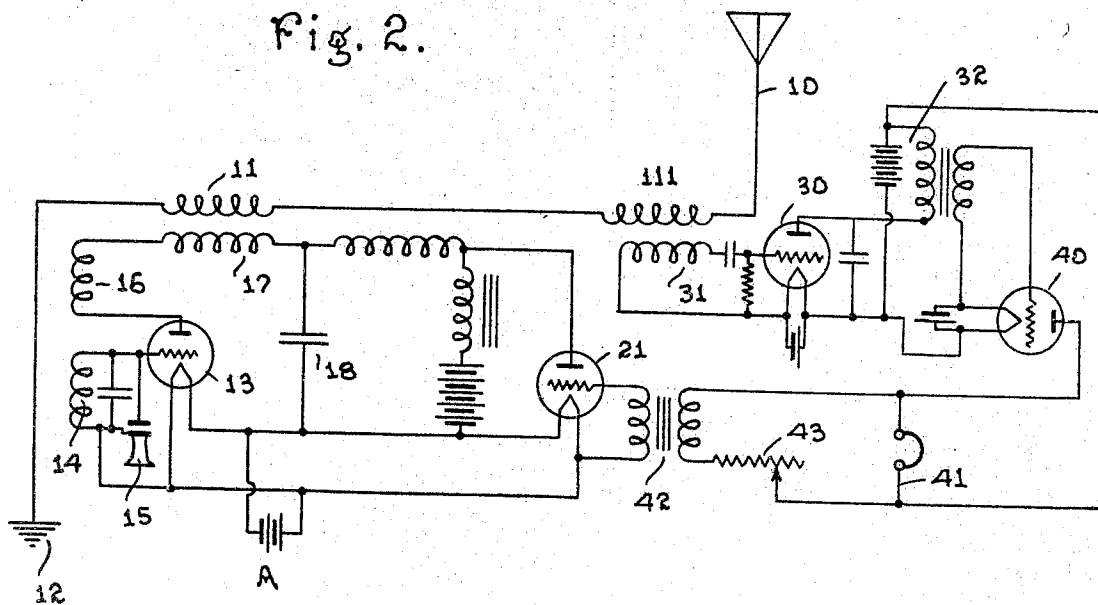


Fig. 2.



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2 Sheets-Sheet 2

Fig. 3.

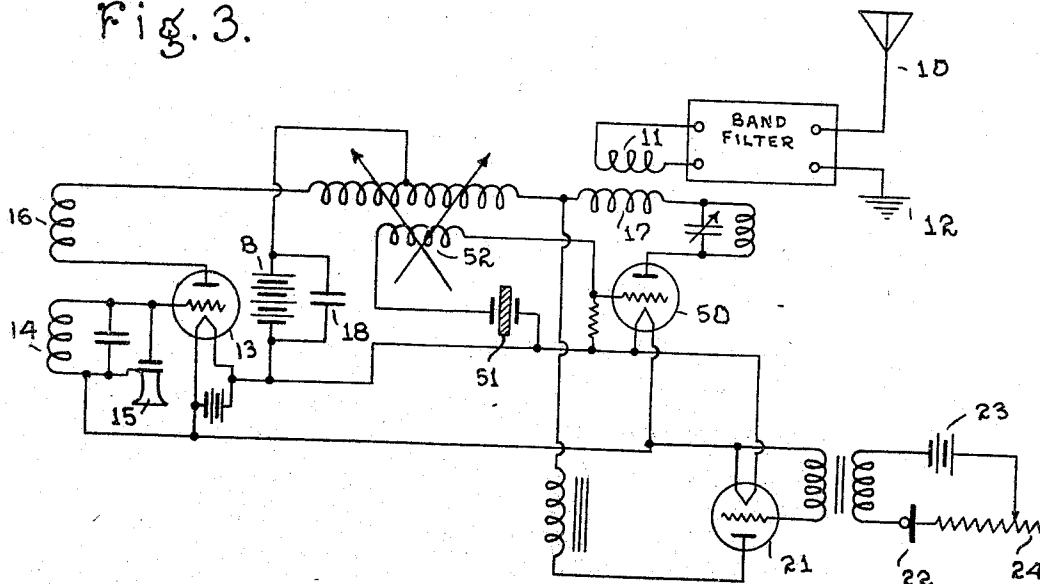
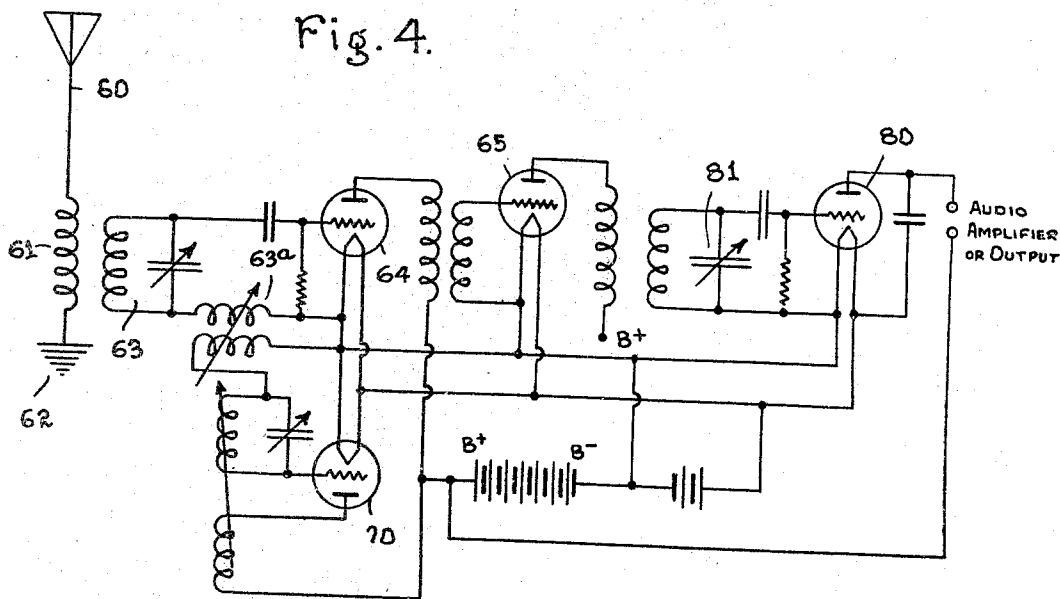


Fig. 4.



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METHOD AND MEANS FOR SIGNALING BY
FREQUENCY FLUCTUATIONWalter J. Albersheim, New York, N. Y., assignor
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This invention relates broadly to the electrical communications art, and deals more specifically with a new method and means for signaling, in which modulation of a carrier wave is accomplished by fluctuating the frequency of the same, instead of varying its amplitude.

Modulation by frequency fluctuation has been proposed heretofore but the systems and methods thus far evolved have not been found suitable for commercial application. One of the reasons that the known methods and systems for frequency fluctuation have not been used commercially resides in the fact that during the process of fluctuating the frequency of the carrier wave at an audio signal frequency, a certain small percentage of amplitude modulation was introduced. With the introduction of amplitude modulation, there of course followed the creation of sidebands over the range of the signal frequency spectrum on both sides of the carrier frequency, thus reintroducing the conditions which the frequency fluctuation was designed to eliminate. This amplitude variation (modulation) occurred for two reasons:

1. Since the fluctuations in frequency according to the frequency fluctuation system were obtained by varying the impedance of the oscillating circuit, there necessarily followed a change in amplitude of the carrier wave.

2. The fluctuated wave is generally amplified by a tuned system, and in the case of wireless communication, broadcast through a resonant antenna. Both the tuned system and the resonant antenna are discriminating to frequency changes, and respond to the frequency fluctuations by a secondary amplitude modulation. This modulation will be of the double signal frequency, when the amplifying and radiating means are in tune with the carrier frequency, and will be of the signal frequency itself when these means are out of resonance.

It is, therefore, an object of this invention to provide a system employing frequency fluctuation modulation in which a carrier wave of constant amplitude is transmitted.

And it is a further object of this invention to compensate for inherent changes in amplitude of the carrier when signaling by frequency fluctuation.

Briefly, I accomplish these objects by first detecting all impurities in the outgoing wave by means of an aperiodic detector coupled to the output line such as the antenna cable feeder, or open air wires line. It is important that the detector be aperiodic or broadly tuned for the

reason that a sharply tuned detector would in itself create the modulations it is designed to detect. If the output is a purely fluctuating one of constant amplitude, the output of the aperiodic or monitoring detector will be purely D. C. and inaudible. If, however, there is an admixture of modulation due to variations in the amplitude of the carrier, this will be detected and will be audible in the output of the detector. An operator, while listening in on the monitoring detector, may vary a compensating or neutralizing modulator, so that minimum or zero signal is heard in the monitoring detector. Alternatively, automatic control of the compensating modulator may be utilized, thus eliminating the necessity of an operator for this purpose.

Another defect which has rendered frequency fluctuation impractical heretofore resides in the fact, that the desired exactness of frequency of the carrier wave has not been attained. In a system based upon such extreme sharpness of signal, such as is required in this method, it is evident that any change in the carrier frequency will produce variations in the received signal strength, fading, and cross-talk to a much greater degree than in the modulating systems now used. Unfortunately, a system operating on the frequency fluctuating method does not lend itself well to pure crystal control for the reason that frequency fluctuations are most conveniently produced by varying the impedance of a free oscillating circuit. It is difficult, however, to hold a free oscillating circuit within the narrow frequency limits required.

Thus, for example, if we want to limit the frequency fluctuations for maximum signal to 500 cycles, the gradual changes in carrier frequency should not exceed the order of magnitude of 25 cycles. For a radio frequency carrier of about 1,000,000 cycles this means a percentage of permissible variation which is too small to maintain, since the changes due to variations in plate and filament voltages as well as variations in outside temperature will be of the same order of magnitude.

It is therefore a further object of this invention to provide a system in which the percentage of fluctuations in frequency due to extraneous causes such as voltage variations et cetera is not greater than the permissible percentage frequency fluctuation which is of the order of magnitude .05%.

I accomplish this result by modulating an intermediate carrier frequency of the order of

magnitude of 50,000 cycles by an audio signal. The permissible frequency fluctuation of 25 cycles is now only .05% of the 50,000 cycles and may be maintained without much difficulty at this low figure. The fluctuating intermediate frequency is now combined with a wave having a frequency of the order of magnitude of 950,000 cycles and then passed thru a band pass filter having cut off frequencies of 990,000 to 1,010,000 cycles. We thus obtain a fluctuating 1,000,000 cycle wave.

The third defect which has inhibited the commercial application of frequency fluctuation as a means of modulation is the lack of a receiving set, sufficiently selective faithfully to respond to the small fluctuations in frequency, which comprise the modulated signal. In the usual receiving system the fluctuating high frequency wave is transformed into a signal of varying amplitude by the frequency characteristics of a resonant circuit, i. e., by its tuning sharpness. If the entire fluctuation of a million cycle signal, as in the example given above, amounts to plus or minus 500 cycles, the total fluctuation is contained in a 1000 cycle band, which is 0.10% of the carrier frequency. For efficient reception the acceptor circuit should respond to this minute frequency change by a variation in signal amplitude of more than 25%. Consequently, the variation in impedance of the acceptor circuit must be more than 25%, during the reception of a frequency fluctuating in a band of 1000 cycles. To accomplish this necessary variation in impedance, the ratio of impedance to resistance must be at least 400 to one. Such a high ratio can only be obtained in practice, by using regeneration to a degree critically close to self oscillation. Since a regeneration receiver on the verge of "spilling over" into self oscillation is highly unstable as to frequency and impedance, this method does not afford the necessary constant sensitivity for proper reception. Therefore, by the use of a regenerative receiver of this type we reintroduce on the receiving side the phenomenon of fading.

It is therefore an object of this invention to devise a receiver, which is sufficiently selective to receive the signals modulated by the frequency fluctuation method.

Briefly, I receive with sufficient selectivity as follows:

I provide in the receiver a local oscillator which heterodynes with the incoming signals to produce an intermediate frequency of the order of magnitude of 50,000 cycles.

This intermediate frequency say of 50,000 cycles has a range of fluctuation within a 1000 cycle band in accordance with the fluctuations impressed on the original carrier. Fluctuation of 1000 cycles in 50,000 cycles is 2% as distinguished from 0.10% of the original carrier. Sufficient tuning sharpness can be obtained in the intermediate stage by an impedance-to-resistance ratio of less than 50 to 1; which may be easily attained without regeneration. I then detect the intermediate signal in a manner well understood in connection with superheterodyne receivers.

My invention will be more fully understood from the following description taken in connection with the accompanying drawings in which:

Fig. 1 shows a transmitting system embodying my invention.

Fig. 2 shows a modification.

Fig. 3 shows another modification of my invention in which the frequency fluctuations are first

impressed upon an intermediate frequency, which is in turn heterodyned with a higher frequency.

Fig. 4 shows a receiver embodying my invention.

Referring in detail to Fig. 1, 10 indicates an antenna having the coil 11 connected therein and grounded at 12. 13 is an oscillation generator having an input circuit 14, in which is connected a fluctuating impedance 15. The impedance 15 may be in the nature of a microphone, in that it varies the impedance of circuit 14 at an audio rate in accordance with the signal to be impressed upon the carrier generated by the valve 13. The device 15 is preferably a microphonic condenser, but I may also use a piezo-electric crystal designed to be activated by speech frequencies in such a way as to vary the impedance of 14, to produce the necessary frequency fluctuations.

The output circuit of the generator 13 is provided with a tickler coil 16 in a manner well understood, and the coil 17 couples the output of 13 to the antenna. Obviously, a cable line, telephone line, or wired radio line may be substituted for the antenna, without departing from the spirit of this invention.

The usual batteries are provided as shown. 18 is a bi-pass condenser to permit the radio frequency currents to flow in the output circuit of 13.

The system thus far disclosed is a more or less conventional arrangement for modulation by the frequency fluctuation method. The valve 13 generates the carrier frequency and as the speech to be transmitted is impressed upon the microphone 15, the frequency of the carrier is fluctuated in accordance therewith.

As explained above, when the fluctuating frequencies are impressed upon the antenna, there will result certain variations in amplitude in the carrier wave. This means that the undesired amplitude modulation will be introduced.

To overcome the presence of this amplitude modulation, I provide a compensating amplitude modulating device indicated generally at 20. This device is seen to comprise a modulating valve 21, to the input circuit of which is coupled a microphone 22 provided with a battery 23 and variable resistance 24. The microphone 22 is associated with the microphone 15 in such a way that the signals to be transmitted are impressed upon both simultaneously. The valve 21 thus produces amplitude modulations corresponding to the amplitude modulations resulting from the frequency fluctuations. The modulations from 21 are impressed upon the antenna in opposite phase relation to the amplitude modulations from 13. The proper phase relation may be determined for example by reversing the coupling between the microphone 22 and the input circuit of the valve 21. Also the resistance 24 may be varied until the compensating modulations are of sufficient magnitude to neutralize the undesired amplitude modulations. Thus, it will be seen that whatever amplitude modulation results from the frequency fluctuation is neutralized by introducing signal impulses, which vary equally in amplitude, but which are in opposite phase.

In Fig. 2 I have shown a modified form of the invention in which the frequency fluctuating apparatus is the same as that shown in Fig. 1. Also, the valve for generating compensating amplitude modulation is the same as that in Fig. 1, with the exception that instead of the microphone 22 I provide the following apparatus:

To the antenna 10 I loosely couple at 111 an

aperiodic detector 30 having an input circuit 31 and an output circuit 32. The aperiodic detector 30 detects the amplitude modulation inherently produced during the operation of the frequency fluctuating system. An audio amplifier 40 is coupled to the detector 30 at 32 for the purpose of amplifying the output thereof, and a pair of phones 41 are connected in the output of the amplifier. Also the output of 40 is coupled at 42 to the input of the compensating valve 21. A rheostat 43 is provided as shown to vary the output of 40.

The operation of this system is as follows:

As already explained amplitude modulations 15 in the antenna are detected at 30 and amplified at 40. These amplified signals which are of an audio frequency are impressed upon the valve 21 in equal value and opposite phase to the amplitude modulations produced thru 13 and thus 20 neutralize them. A monitor listens at 41 and varies the rheostat 43 until a proper balance of the spurious modulation against the compensating modulations is obtained. Silence in the phones 41 indicates such balance for the reason 25 that, in the absence of amplitude modulation, there are present in the antenna a pure frequency fluctuations only, and these will affect the aperiodic detector equally.

In the modification of Fig. 3 I have shown a 30 system identical with that of Fig. 1 with the exception that the fluctuating frequencies are heterodyned with a higher frequency. The apparatus for producing the frequency fluctuations as well as the compensating amplitude modulation at 21 needs no further explanation here. 35 The similar parts have been given same reference characters as those in Figs. 1 and 2. I shall now describe in detail the heterodyning apparatus and its operation.

As pointed out above, in order satisfactorily 40 to employ frequency modulation, the frequency of the carrier should not fluctuate more than the order of magnitude of 25 cycles, due to extraneous sources. Consequently, with a carrier of 1,000,000 cycles a variation of 25 cycles in 45 1,000,000 cycles is too small a percentage to maintain in actual practice. I have, therefore, proposed to modulate an intermediate frequency of say 50,000 cycles by fluctuating the same between 50 a band of 1,000 cycles. In accordance with this method a variation of 25 cycles in 50,000 may be readily controlled. I associate an oscillation generator 50 which is preferably provided with 55 a crystal control 51 designed to maintain the oscillator constant. The oscillator is preferably tuned to a frequency of 950,000 cycles which heterodynes with the intermediate frequency. The output of valve 13 is impressed upon the input circuit of 50 at 52, the tube 50 acting as a 60 mixing tube for the two frequencies. A band pass filter having a cut off of approximately 990,000 to 1,010,000 is connected in the antenna and the pure fluctuating 1,000,000 cycle wave is transmitted.

In Fig. 4 I have shown a receiver operating in 65 accordance with my invention. An antenna 60 is connected with an inductance 61 which is in turn connected to ground at 62. Inductance 61 is loosely coupled to the circuit 63 of the mixing valve 64. An oscillator 70 is tuned to produce a frequency which when beat with the incoming wave will produce an intermediate frequency of the order of magnitude of 50,000 cycles in the 70 output circuit of the mixing tube 64. The tube 64 is coupled to an amplifier 65, which is in turn

coupled to a detector 80. Obviously, any desired number of stages of amplification may be employed. In the case where this receiver is used for reception from a source transmitting on a fixed carrier, the oscillator 70 should preferably 5 be crystal controlled.

The stage of intermediate amplification shown diagrammatically at 65 may be either tuned or untuned. In the event that it is tuned, such tuning element is preferably coupled to the variable 10 condenser 81 for uni-control. The output of the second detector 80 may be fed to any suitable amplifier in a manner well known in the art.

By virtue of the tuned stage which exists either in the intermediate frequency amplifier or 15 in the second detector, the frequency fluctuations are transformed into amplitude variations which enable the detector to reproduce the transmitted signal. Such tuned stage is tuned to a point slightly off resonance, and such a tuned circuit 20 will respond to different frequencies in accordance with the well known characteristics of a tuned circuit I may convert the frequency fluctuations into amplitude variations.

Having thus described my invention, I claim: 25

1. The method of signaling which comprises generating a carrier wave of a substantially constant frequency, fluctuating said frequency at an audible rate, said fluctuations in frequency producing incidentally a relatively small percentage of amplitude modulation of said wave 30 corresponding to the said fluctuations, producing at said rate electrical oscillations corresponding to said amplitude modulation of said wave, combining said fluctuated frequency and said oscillations in proper phase relationship whereby to 35 balance out said incidental amplitude modulation, and transmitting the resultant of said combined frequency and oscillations.

2. In combination, an oscillation generator, a 40 source of signaling waves, means for fluctuating the frequency of oscillations of said oscillation generator in accordance with waves from said source, said means also inadvertently causing undesired amplitude modulation of said oscillations, 45 and means for simultaneously modulating said frequency fluctuated oscillations in amplitude in such a way as to reduce the undesired amplitude component of said frequency fluctuated oscillations.

3. In the art of signaling by means of a fluctuated carrier frequency in which amplitude variations are imposed upon the carrier, the method of neutralizing said amplitude variations which comprises, producing amplitude modulations 55 corresponding to said first mentioned variations, and bucking both said amplitude variations against each other.

4. In combination, an oscillation generator, a 60 source of signaling waves, means to fluctuate the frequency of oscillations produced by said oscillator with waves from said source, said means also producing an unwanted component of said oscillations which varies in amplitude, a detector responsive to the frequency fluctuated oscillations 65 and operating to produce a copy of the unwanted amplitude component of the frequency fluctuated oscillations, and means to apply the amplitude component produced by said detector to said frequency fluctuated oscillations in such a way as 70 to reduce the amplitude modulation component of said frequency fluctuated oscillations.

5. In a signaling system the combination of means to generate a carrier wave of constant frequency, means to fluctuate said constant fre- 75

quency in accordance with a message, an output circuit coupled to said first mentioned means, whereby the fluctuated frequency is impressed thereon with comparatively small amplitude variations of the carrier, with means to neutralize said amplitude variations, said means comprising a modulating device responsive to said message, whereby electrical oscillations having amplitude variations in accordance therewith are produced, and means to impress said last mentioned oscillations upon said output circuit in proper magnitude and phase relation whereby the same neutralizes said first mentioned amplitude variations.

6. In a signaling system the combination of means to generate a carrier wave of constant frequency means to fluctuate said constant frequency, in accordance with a message, means to heterodyne said fluctuated frequency, an output circuit coupled to said last mentioned means, whereby the fluctuated frequency is impressed thereon with comparatively small amplitude variations of the carrier, with means to neutralize said amplitude variations, said means comprising a modulating device responsive to said message, whereby electrical oscillations having amplitude variations in accordance therewith are produced, and means to impress said last mentioned oscillations upon said output circuit in proper magnitude and phase relation whereby the same neutralizes said first mentioned amplitude variations.

7. In combination, an oscillation generator, a signaling source, means for fluctuating the frequency of the oscillations generated by said generator in accordance with waves from said source, said means also introducing unwanted amplitude modulation in said oscillations, and independent means responsive to waves from said signaling source to modulate in amplitude the frequency fluctuated oscillations in phase opposition with respect to the unwanted amplitude modulation introduced into said frequency fluctuated oscillations during the process of frequency fluctuating said oscillations.

8. In combination, an oscillation generator, a source of signaling waves, modulation means responsive to waves from said source introducing desired and undesired changes in the character of the oscillations from said oscillation generator at signal frequency, demodulating means responsive to the waves of changed character for introducing changes in the character of the oscillations from said oscillation generator which compensates the undesired changes introduced by said modulating means.

9. In combination, an oscillation generator, an output circuit coupled thereto, means for fluctuating the frequency of oscillations generated by said generator, a detector coupled to

said output circuit for detecting amplitude changes in the waves in said output circuit, and means responsive to the output of said detector for modulating oscillations from said oscillation generator in such a way as to reduce the amplitude modulation in the frequency fluctuated oscillations in said output circuit.

10. In combination, an oscillation generator, a source of signaling waves, means for modulating the frequency of the oscillations from said generator in accordance with waves from said signaling source, said means also inadvertently causing undesired amplitude modulation of said oscillations from said generator, means for simultaneously deriving a component from said frequency and amplitude modulated oscillations, and means for modulating said frequency and amplitude modulated oscillations in amplitude in accordance with said component and in a sense which opposes said amplitude modulation inadvertently accomplished, to thereby reduce the undesired amplitude modulation of said oscillations inadvertently caused.

11. In a signaling system, a thermionic tube having input and output electrodes connected in coupled circuits, to produce sustained oscillations, a signal responsive device connected with the input electrodes of said tube to apply modulating potentials thereto, a load circuit coupled to the output electrodes of said tube, a demodulating circuit coupled to said load circuit, amplitude regulating means coupled to the output circuit of said demodulating means, and a circuit coupling said amplitude regulating means to the output electrodes of said first named tube.

12. In a signaling system, a thermionic tube having input and output electrodes, a frequency determining circuit including an inductance connected between said input electrodes, a feed back circuit including an inductance connected between said output electrodes and coupled to said first named inductance, means for varying the character of said circuit connected between said input electrodes at signal frequency, a load circuit coupled to the output electrodes of said tube, said load circuit including an inductance, a second thermionic tube having input and output electrodes, an inductance connected between the input electrodes of said second thermionic tube, said last named inductance being coupled to said inductance in said load circuit, said thermionic tube acting as a demodulator of energy impressed on said inductance between its input electrodes, an output circuit coupled between the output electrodes of said last named thermionic tube and phase regulating and amplitude regulating means coupling said output circuit of said last named thermionic tube to the output electrodes of said first named thermionic tube.

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