Oct. 26, 1943. C. TRAVIS 2,332,540

METHOD AND APPARATUS FOR RECEIVING FREQUENCY MODULATED WAVES

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Fig. 1.

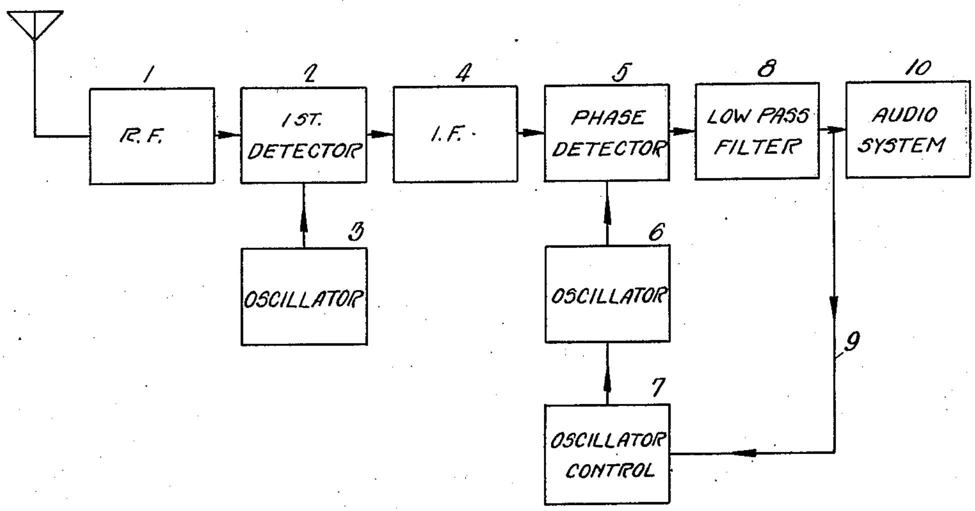

Fig. 2.

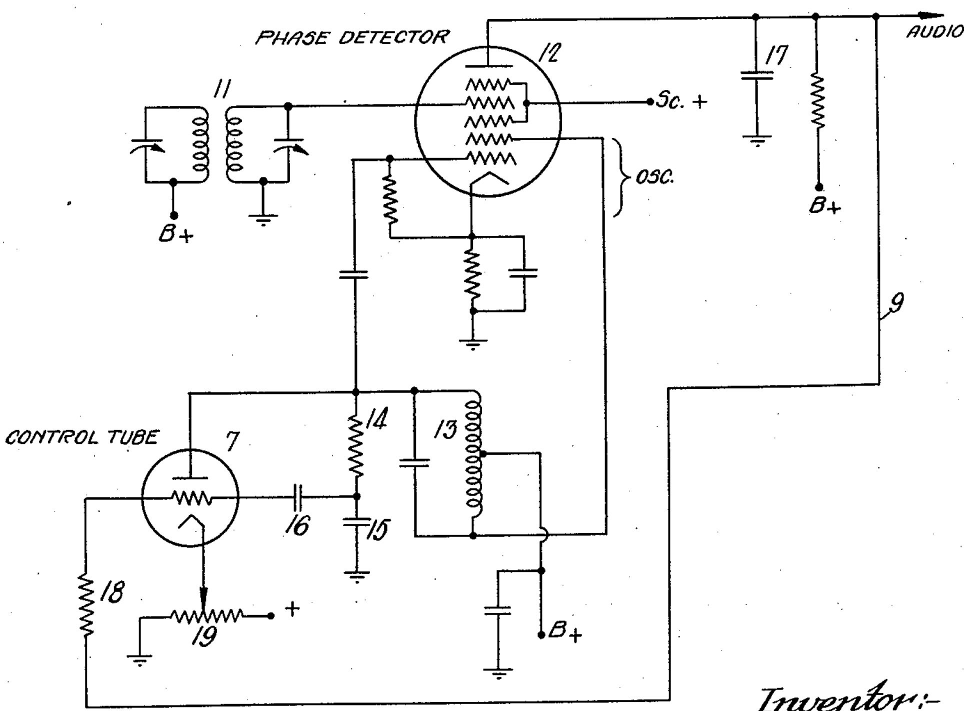

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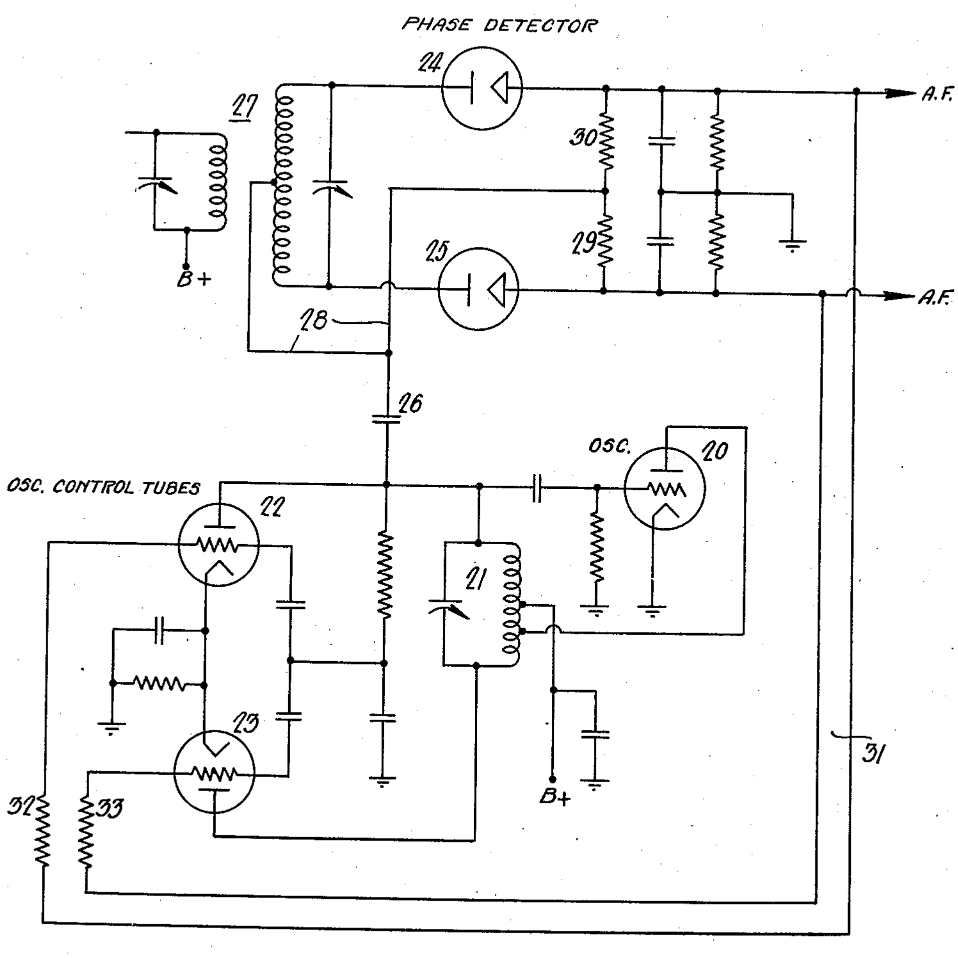
Fig. 3.



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METHOD AND APPARATUS FOR RECEIVING FREQUENCY MODULATED WAVES

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3 Claims. (Cl. 250—27)

This invention relates to a novel method for the reception of frequency-modulated waves and to apparatus adapted therefor.

In the conventional method of detecting a frequency-modulated signal, the signal is first converted into a hybrid wave having amplitude modulation superimposed on the frequency modulation, following which the amplitude modulation is detected by a rectifying device. According to the present invention, detection is not employed at all in the narrow sense involving a rectification process.

An object of the present invention is to eliminate, in a frequency-modulation receiver, the necessity of forming a hybrid wave having amplitude modulation corresponding to the frequency-modulation of the received wave.

Another object of the present invention is to provide a novel frequency-modulation receiver which responds effectively and efficiently to the frequency modulation of the received carrier wave, but substantially not at all to amplitude modulation, thereby eliminating any need for an amplitude limiting circuit.

A further object of the invention is to provide a circuit which can be manufactured more economically than can one using a current limiter for discrimination against amplitude variations resulting from noise signals and related disturbances.

Other objects and features of the invention will become apparent hereinafter. For an understanding of the manner in which the objects of the invention are achieved reference may be had to the accompanying drawings, in which

Fig. 1 is a simple block diagram illustrating the method and apparatus of the present invention;

Fig. 2 is a schematic diagram illustrating one embodiment of the invention; and

Fig. 3 is a schematic diagram illustrating a further embodiment of the invention employing a balanced control tube circuit and a balanced phase detector circuit.

Referring to Fig. 1, there is shown, in diagrammatic form, a radio receiver of the superheterodyne type embodying the present invention. This receiver may comprise, by way of example, a radio frequency amplifier stage 1, first detector 2, local oscillator 3, and intermediate frequency amplifier 4, all the foregoing being conventional elements of a standard superheterodyne receiver of frequency-modulated waves. The invention is, however, also adapted for use in the conventional tuned radio frequency type of receiver.

The present invention resides particularly in the novel combination of a modulator or phase detector 5, a local oscillator 6, and an oscillator frequency control device 7. The local oscillator 6 is adjusted to oscillate at the mean frequency of the frequency-modulated signal derived from I. F. amplifier 4, and, when the said signal is not being frequency-modulated, to oscillate at like frequency with, but in phase quadrature to, the signal derived from the I. F. amplifier. This desired frequency and phase relation is secured by means of the phase detector 5 and the oscillator frequency control device 7. As indicated in the drawing, signals from both the I. F. amplifier 4 and the oscillator 6 are applied to the phase detector 5. The phase detector provides in its output a control signal whose magnitude is proportional to the cosine of the phase angle between the two input signals. In order to discriminate against unwanted signals generated in the phase detector a suitable filter network 8, e. g., a low pass filter, may be provided as shown. The control signal, when applied by way of the connection 9 to the frequency control device 7, acts to oppose any tendency for the phase angle between the I. F. and oscillator signals to depart from quadrature. The sensitivity of the control device 7 is preferably adjusted, however, in such a manner that as the I. F. signal is swung during modulation from one extreme end of the band to the other end thereof, the phase angle between the signals may depart from quadrature by not substantially more than 90 degrees, and preferably, during normal operation, by considerably less than 90 degrees, say by not more than ± 30 degrees as a maximum.

Since the control voltage derived from the phase detector 5 is that which is required to deviate the oscillator frequency by substantially the same amount as the frequency deviation of the signal, it follows that this control voltage varies substantially as the instantaneous frequency of the modulated signal and hence may be simultaneously employed as the audio output of the system. This output may be amplified in a conventional audio amplifier and output system 10.

A specific embodiment of the invention is illustrated schematically in Fig. 2. In this figure, the I. F. transformer 11 represents the output of the I. F. amplifier 4 of Fig. 1. The No. 1 and No. 2 grids of the vacuum tube 12, together with the tuned circuit 13, correspond to the local oscillator 6 of Fig. 1. The phase detector, comprising the vacuum tube 12, provides an output signal which is proportional to the casine of the phase angle between the frequency-modulated I. F. signal applied to the No. 4 grid and the locally generated signal present on the No. 1 grid. In the embodiment of Fig. 2, the functions of phase detector and local oscillator are combined in a single tube for convenience, but it should be understood that a separate oscillator system may be employed if desired.

Quadrature voltage for the excitation of the frequency control tube 7 may be derived from the tuned circuit 13 by way of the circuit 14—15—16 in a manner well understood in the art. The invention is not limited to the use of any particular frequency control circuit, and reference may be had to applicant's Patent No. 2,240,428, issued April 29, 1941, in which a number of balanced control circuits of particularly desirable characteristics are described.

A radio frequency by-pass condenser 17 may be connected to the anode of the phase detector 12 so that only the desired control signal is transmitted by way of the path 9 and the R. F. filter resistor 18 to the control grid of the frequency control tube 7. The voltage divider 19, which through the control tube controls the no-signal frequency of the oscillator, should preferably be adjusted until the synchronized oscillator is in substantially exact phase quadrature to the signal applied to the phase detector from the I. F. transformer 11 when the latter signal is not deviated.

If desired, diode elements may be employed in the phase detector as shown in Fig. 3. In this embodiment a separate oscillator 20, 21, a pair of balanced control tubes 22, 23, and a pair of balanced phase detector diodes 24, 25 are employed. The locally generated signal is applied to the phase detector from the upper end of the oscillator tank circuit 21 by way of the coupling condenser 26, while the received signal is applied to the phase detector by way of the tuned secondary of the I. F. transformer 27. The connection 28 between the center tap of the I. F. transformer secondary and the junction of resistors 29 and 30 provides a D. C. space-current return path for the two diodes.

The balanced control voltages derived from the diodes may be applied to the control tubes 22, 23 by way of the path 31 and the R. F. filter resistors 32, 33. This balanced control voltage varies in accordance with the instantaneous frequency of the received wave and may accordingly be employed as the audio output of the system. Since this output is balanced to ground it may be applied directly to a push-pull audio amplifier stage (not shown). The quadrature voltage for the control tubes is derived from the tank circuit as before and in this instance is applied to the grids of the control tubes in like phase.

In each of the circuits described it should be noted that synchronization of the local oscillator with the incoming signal is not obtained by the so-called injection method, but rather by an indirect method involving the use of frequency control systems. In the circuits shown the local oscillator may be said to be "loosely synchronized" with the signal. Thus while the phase difference between the signals is preferably held to within 90 degrees of the normal quadrature relation, the instantaneous frequencies of the signals may differ momentarily by many kilocycles without destroying this desired phase relation.

The embodiments of both Figs. 2 and 3 respond effectively and efficiently to frequency modulation, but substantially not at all to amplitude modulation. In neither the balanced nor the unbalanced circuits are amplitude limiters required, and as a result the preliminary gain of the R. F. and I. F. amplifier may be substantially reduced. The present circuit accordingly results in the elimination of one or more amplitude limiting stages and possibly one or more stages of amplification.

The manner in which the present system discriminates against amplitude variations (and hence against noise) may be explained as follows. The control voltage E_c derived from low pass filter 8 of Fig. 1 is proportional to the signal voltage (e_s) applied to the phase detector times the cosine of the phase angle (ϕ) between the signal and oscillator voltages, i. e., $E_c = ke_s \cos \phi$, where k is a constant. Now if the signal amplitude e_s should suddenly increase, E_c would increase, but this would result in a decrease in ϕ (because of the control action of the frequency control circuits) which would compensate for the increase in e_s, thus maintaining E_c constant. Thus for any amplitude change in e_s a compensating change in ϕ occurs, such that $e_s \cos \phi$ is substantially constant for a particular value of deviation.

While the invention has been described and illustrated with respect to certain specific embodiments it should be understood that this has been for the purpose of disclosure and should not be taken as a limitation of the invention to these particular circuits.

I claim:

1. In a radio receiver adapted to receive frequency-modulated carrier signals, a source of signals varying in frequency in accordance with the frequency variations of the transmitted signals, a vacuum tube having at least a cathode, an output anode, an input grid, an oscillator grid and an oscillator anode, an oscillator tank circuit adjusted to resonate at substantially the mean frequency of the signals from said source, said tank circuit being connected to oscillator elements of said vacuum tube, a frequency control tube connected to said tank circuit to enable the resonant frequency of said circuit to be varied on either side of said mean frequency, means connected to said tank circuit for deriving therefrom a quadrature voltage and for applying said voltage to a control element of said frequency control tube, means for supplying signals from said source to the input grid of said vacuum tube, an output circuit for said vacuum tube for deriving therefrom a voltage which is proportional to a function of the phase angle between the signal on said input grid and the signal on one of said oscillator elements, connections for applying said last-named voltage to a control element of said frequency control tube thereby to vary the frequency of the oscillator circuit in accordance therewith, and means for additionally utilizing said last-named voltage as the audio output signal of the system.

2. A frequency modulation receiver as claimed in claim 1, characterized in that said frequency control tube is constructed and arranged normally to maintain the phase relation of the signal applied to the said input grid and the oscillator signal within 30° of phase quadrature.

3. A frequency modulation receiver as claimed in claim 1, characterized in the provision of means for adjusting the no-signal frequency of the oscillator circuit until the oscillator signal is in substantially exact phase quadrature to the input signal.

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