Dec. 15, 1936. M. G. CROSBY 2,064,106

RECEIVER

Filed Dec. 27, 1933 2 Sheets-Sheet 1

Fig. 1

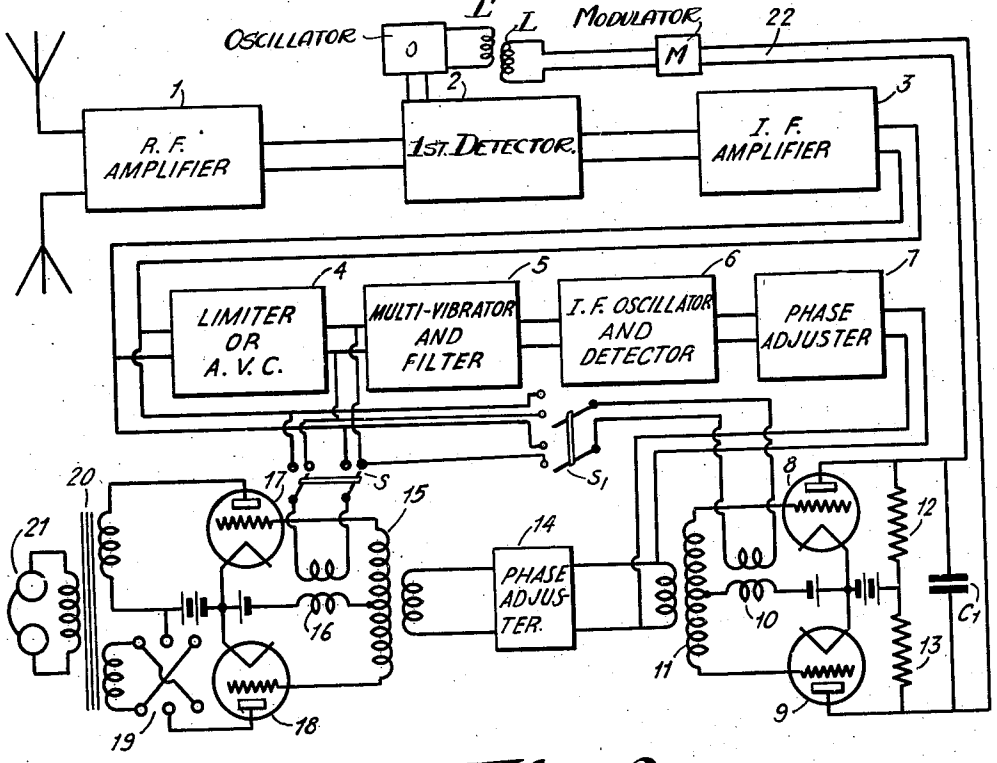
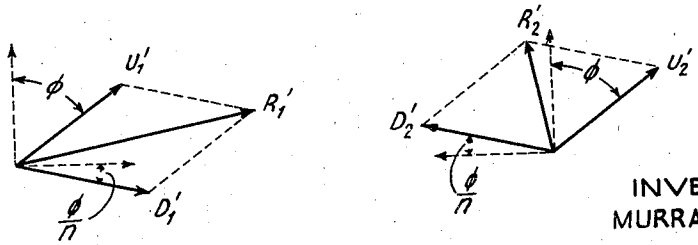


Fig. 2



Fig. 3



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Fig. 4

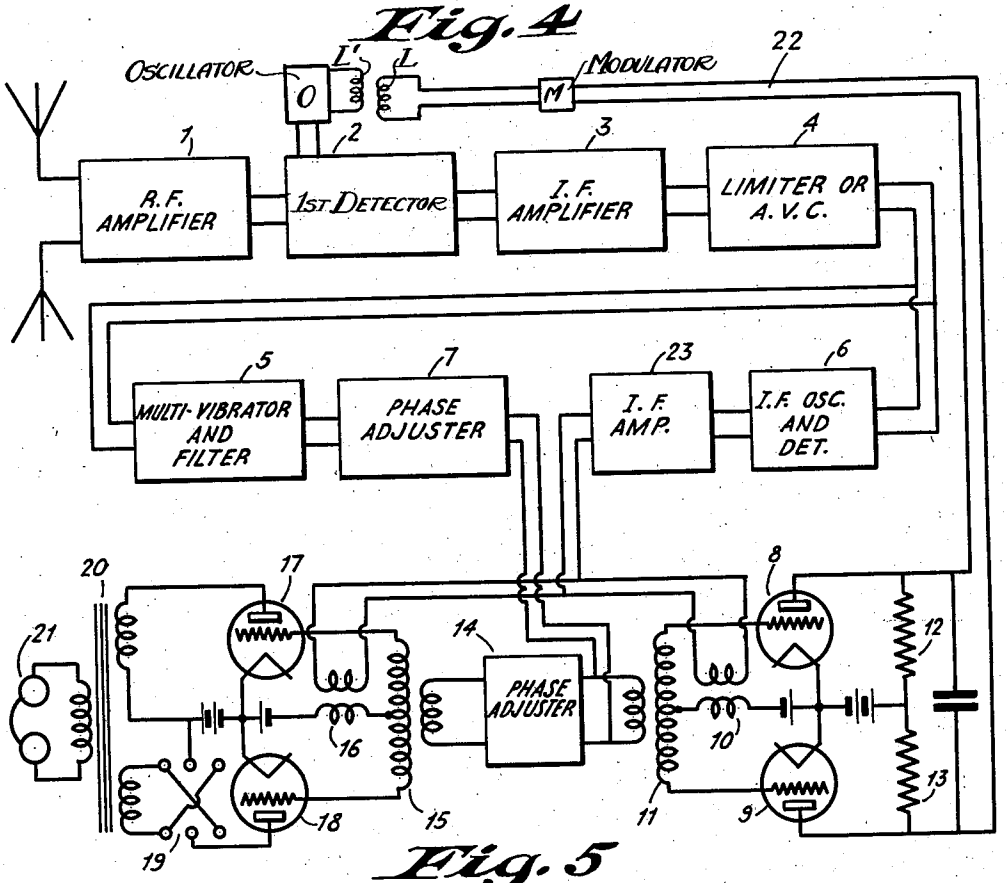


Fig. 5

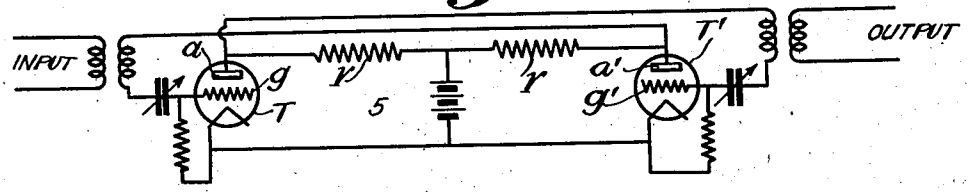
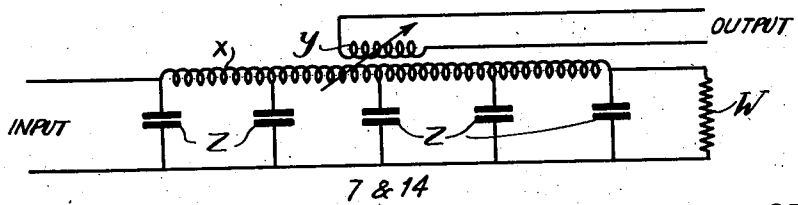


Fig. 6



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UNITED STATES PATENT OFFICE

2,064,106

RECEIVER

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Application December 27, 1933, Serial No. 704,122

22 Claims. (Cl. 250—20)

This invention discloses a receiver for receiving a phase modulated wave or a frequency modulated wave or an amplitude modulated wave. In this receiver frequency division of the signal modulated carrier is utilized to obtain a new carrier with a reduced degree of modulation, which new carrier is synchronized with the original modulated carrier wave. Thus, the phase modulation of the carrier may be converted to amplitude modulation for subsequent detection. Adjustments may also be made to make the receiver receptive to frequency modulation.

In the known phase modulation art the phase modulations on the wave are converted to an amplitude modulation by combining the phase modulated wave with a locally generated and synchronized carrier in time quadrature with the signal modulated wave or with energy filtered from the phase modulated wave carrier or by receiving the phase modulated wave on a frequency modulation receiver followed by an audio frequency correction circuit.

Of these three receivers the receiver of the present invention has characteristics in common with the first.

However the locally synchronized carrier wave type becomes more unstable as the frequency of the received wave is increased due to the difficulty of maintaining exact synchronism between the local carrier and the received wave with the desired space separation. The receiver of the present disclosure has the advantage over prior receivers that the modulation may be removed in various degrees, depending upon the number of frequency dividers used and the order of frequency division employed. As a result, the stability of the receiver with regard to synchronism between the local carrier and received wave, and the depth of the resulting amplitude modulation are adjustable to suit the frequency of the received wave and other conditions of reception or transmission.

The novel features of my invention have been pointed out with particularity in the claims at the end of the specification.

The nature of my invention, circuit arrangement for carrying out the same, and the mode of operation of said circuits will be clear from the following detailed description thereof and therefrom when read in connection with the attached drawings in which:

Figures 1 and 4 are wiring diagrams of the essential components of a receiver arranged in accordance with the present invention;

Figures 2 and 3 are vector diagrams illustrating the operation of same circuits to obtain the result desired; while

Figures 5 and 6 illustrate details of portions of the circuits of Figures 1 and 4.

Figure 1 shows a circuit diagram of a receiver including the essential features of my invention. In this figure certain of the elements which are well known to the art are represented by rectangles for simplicity. The signal picked up by the antenna is amplified by radio frequency amplifier 1 and passed to unit 2. Unit 2 contains the first detector and is coupled to the high frequency oscillator O of the superheterodyne receiver. The frequency of the high frequency oscillations generated by the local oscillator in 2 is partly dependent upon the voltage received from line 22. In this manner automatic frequency control is applied to the heterodyne receiver to maintain the same properly tuned. This automatic tuning of the local oscillator may be accomplished as disclosed in my U. S. Application Serial No. 616,803, filed June 13, 1932.

After being converted to intermediate frequency in unit 2 the signal is passed through intermediate frequency amplifier 3 to amplitude limiter or automatic volume control device 4 and may also be passed by way of switch S_1 in the upper position to the automatic frequency control detector input transformer 10 and by way of switch S in the left hand position to the audio detector input transformer 16. The amplitude of the signal is maintained constant in unit 4 and the signal of constant amplitude is fed to the multi-vibrator in unit 5. The multi-vibrator is adjusted to normally oscillate at a frequency $1/n$ times the intermediate frequency where n is the order of frequency division. Unit 5 also contains an output filter to remove all frequencies except the desired divided frequency. Unit 6 contains an intermediate frequency oscillator and detector which heterodynes the divided frequency back to the original intermediate frequency, i. e. to the frequency of the signal in unit 3. Unit 7 contains a phase adjuster consisting of an artificial line or any other means to vary the phase wave. The output of unit 7 is fed differentially by transformer 11 to the control grids of the automatic frequency control detectors 8 and 9 and, via phase shifter 14, to transformer 15 and thence in phase opposition to the control grids of the audio detectors 17 and 18. Tubes 8 and 9 are differential detectors with resistors 12 and 13 in their plate circuits. The differential potentials appearing at the terminals of 12 and 13 are used as described in detail in

my U. S. application Serial No. 616,803, filed June 13, 1932 to control the frequency of the oscillations produced in 2. Tubes 17 and 18, transformer 20, switch 19, and phones 21 comprise the audio detectors for converting the modulated wave to its signal wave.

The operation of this receiver has for its novelty the fact that frequency division is used to remove or decrease the degree or amount of frequency or phase modulation. Thus, the intermediate frequency which is phase modulated is arranged to hold a multi-vibrator in step to obtain a frequency division. The divided frequency is then heterodyned back to the intermediate frequency. In the frequency division the degree of phase modulation is divided by the order of frequency division, but when the divided frequency is brought back to the intermediate frequency by heterodyning there is no change in degree of phase modulation.

Assuming a specific case of an intermediate frequency of 100 kilocycles, the intermediate frequency energy maintained constant by unit 4 may be fed to the multi-vibrator in unit 5 which is normally adjusted to oscillate at a frequency of 10 kilocycles for the case of a division order of 10. In this case the multi-vibrator is held "in step" at $\frac{1}{10}$th the intermediate frequency. Thus, a frequency shift from 100 to 101 kilocycles changes the divided frequency from 10 to 10.1 kilocycles. Consequently, a frequency modulation having a deviation frequency of 1 kilocycle will have its deviation reduced to .1 kilocycle or 100 cycles.

In the same manner phase modulation may have its phase deviation or degree of phase modulation reduced. This is apparent from a consideration of the fact that phase modulation is equivalent to a frequency modulation with its modulation ratio fd/fm (fd=deviation frequency; fm=modulation frequency) equal to the phase deviation ϕ. If in the frequency division of frequency modulation fd is multiplied by $1/n$, the modulation ratio is also multiplied by $1/n$ so that the divided modulation ratio would be equal to $1/n$ (fd/fm). Since a phase modulated wave is equal to a frequency modulated wave with ϕ substituted for (fd/fm) the divided phase modulation deviation would be equal to $1/n$ (ϕ).

By this type of frequency division the depth of phase modulation is reduced to $1/n$ of its value. The divided frequency is then returned to the intermediate frequency by means of a heterodyne so that the wave with its phase modulation reduced can be combined in time quadrature with the undivided intermediate frequency wave to convert the phase modulation to amplitude modulation. The combination is made in the differential detector input transformers 15 and 16 in the same manner as the energies in the filtered carrier type of receiver are combined. See Crosby U. S. application 558,309, filed January 23, 1932 and U. S. application 616,803 filed June 13, 1932. Thus, in Figure 2, U_1 and U_2 represent the undivided intermediate frequency voltages fed to each of the differential detectors 17 and 18 by way of winding 16. D_1 and D_2 represent the divided (and heterodyned) intermediate frequency voltages fed by way of winding 15 to detectors 17 and 18. The resultants, for this assumed instant of zero modulation, are represented by vectors R_1 and R_2, which are equal in amplitude. As the phase shifts with modulation the amount ϕ, the voltages are as shown in Figure 3. The undivided voltages designated by vectors U_1' and U_2' have shifted the amount ϕ in phase and the divided voltages indicated by vectors D_1' and D_2', the amount ϕ/n, where n is the order of frequency division. The resultants have changed to R_1' and R_2' in a manner producing a differential modulation, that is, a positive amplitude modulation on one detector grid as for example 17 and a negative modulation on the grid of 18. The detector outputs are combined in the proper phase in transformer 20 by means of reversing switch 19.

The automatic frequency control detectors 8 and 9 function in the same manner as the audio detectors 17 and 18. The differential voltage produced by a shift of phase of the intermediate frequency appears across resistors 12 and 13 and is fed via line 22 and a modulator M to a reactance L in the output of the modulator M to the high frequency oscillator to vary the reactance of a frequency determining element there in the same manner as shown in the automatic frequency control circuits of my United States application No. 616,803, filed June 13, 1932. For example, the reactance L may be coupled to a reactance L' in the oscillator circuit. The reactance L' may determine in part the frequency of the oscillations produced in and by the oscillator O. In other words, the potential variations produced in 12 and 13 due to a shift in the intermediate frequency may be used to control the value of a reactance in a frequency determining circuit of the oscillator of 2 to correct for said shift. Condenser C_1 and resistors 12 and 13 form a time constant circuit to prevent the signal wave from appearing in line 22. This prevents the automatic frequency control from tending to remove the modulation.

If it is desired to receive frequency modulation condenser C_1 may be removed to allow the detected signal wave appearing across resistors 12 and 13 to change the value of the frequency determining element in said oscillator sufficient to modulate the high frequency oscillator. This modulation demodulates the signal in such a manner as to convert the frequency modulation to phase modulation suitable for detection in the audio detectors. This detection of the phase modulations resulting from said conversion is accomplished in the same manner normal phase modulated waves are demodulated as described above.

Figure 4 shows an alternative arrangement wherein detection takes place at the divided frequency. Thus, instead of heterodyning the divided frequency back to the intermediate frequency for combination with the undivided wave as in Figure 1, the undivided intermediate frequency is heterodyned down in a second heterodyne arrangement in 6 to the divided frequency. The arrangement of Figure 4 may be adapted very easily to a triple detection superheterodyne receiver wherein units 3 and 23 are the two band pass intermediate frequency amplifiers.

A receiver as described above may be used in a space diversity receiving system of the automatic phase controlled type as described in my United States application No. 727,931 filed May 28, 1934. The apparatus in units 5 and 6 of Figure 1 may be substituted for the crystal filter or intermediate frequency oscillator of said application.

In the previous description, a multivibrator is given as the means for obtaining frequency division of a wave to obtain corresponding energy

of reduced frequency. A multivibrator need not necessarily be used since any circuit capable of effecting a frequency division or reduction may be used. Thus, a vacuum tube oscillator of the tuned circuit type might also be used to an advantage. Likewise a mechanical frequency divider may be substituted.

A circuit for dividing or reducing the frequency of the wave modulated as to phase or frequency in accordance with signals has been shown in Figure 5 of the drawings. In this figure the leads marked "in" may be connected to the limiter or atuomatic volume control in unit 4 of Figures 1 and 4, while the leads marked "out" may be connected with the intermediate frequency oscillator and detector 6 of Figure 1 or with the phase adjuster 7 of Figure 4. The signal modulated intermediate frequency oscillations from 4 appear in the line marked "in" and are applied to an inductance between the control grid g of a tube T and the anode a' of tube T1. The oscillations of reduced frequency appear in a circuit connected between the anode a of tube T and the control grid g' of tube T1 and are transferred from said circuit to the line marked "out". The anodes a and a' are interconnected by resistances r and r' and a common source of potential. The electrodes of the tubes being interconnected as shown by variable condensers and resistances produce in the circuit marked "out" signal modulated oscillations of a frequency which may be made a sub-multiple of the frequency of the oscillations impressed on the circuit marked "in". The condensers connected with the control grids of the interconnected tubes charge and discharge alternately at a rate determined in part by the size of the condensers, in part by the value of the resistances, and in part by the frequency and amplitude of the waves fed to the line marked "in". The extent to which the frequency and degree of modulation of the impressed wave is reduced by the multi-vibrator is accordingly determined in part by the constants of the circuit which may be varied to obtain therefrom a harmonic frequency.

Any type of phase adjusting circuit known in the art may be used. For example, a circuit as illustrated in Figure 6 may be used. In this figure the incoming signal modulated carrier wave of intermediate or reduced frequency may be applied to the leads marked "input" from the intermediate frequency oscillator and detector 6 of Figure 1 or from the frequency reducer 5 of Figure 4. The phase adjuster may comprise series reactance X and parallel reactances Z and may be terminated by a resistance W equal to the surge impedance of the line so that traveling waves only appear in the line. Waves at the reduced frequency flow in X and by moving Y relative to X, waves of the desired phase relative to the phase of the applied waves may be induced in Y. The outgoing leads marked "output" may be connected with the primary winding of the input transformer connected with the frequency controlled detectors and with the phase adjuster 14 of Figures 1 and 4. The phase adjuster of unit 14 may be the same as the phase adjuster of unit 7, as described above.

Although the receivers have been described above as being primarily adapted to the reception of phase or frequency modulated waves I contemplate the reception of amplitude waves also on said receivers when desired. This may be accomplished by closing the switch S in its left hand position and switch S' in the lower position so that unlimited energy from the unit 3 is fed to the windings 16 and 10 for signal indicating purposes in detectors 17 and 18 and frequency control purposes in detectors 8 and 10. The action of the detectors 17 and 18 when amplitude modulated waves are received is substantially as indicated above. The potentials on the grids of tubes 17 and 18 is the vectoral sum of the potentials applied in phase opposition and in phase.

The same remarks apply to the frequency control detectors 8 and 10 the voltages in 12 and 13 depend on the phase of the oscillations applied to the control grids and consequently on the frequency of the oscillator in first detector 2. If the frequency of the oscillator in 2 is too high one of the detectors draws more plate current than the other and a correcting potential appears across 12 and 13 and acts on the frequency determining element in 2 to correct the frequency. If the frequency of 2 is too low the reverse action takes place.

Of course in some cases the detectors 8 and 10 may serve also to render the signals or the detectors 17 and 18 may furnish the frequency controlling energy as well as rendering the signal.

Having thus described my invention and the operation thereof, what I claim is:

1. The method of demodulating a carrier wave varied as to phase or frequency in accordance with signal potentials which includes the steps of, diverting energy from said phase or frequency varied carrier wave, reducing the mean frequency of the diverted energy and simultaneously the degree of modulation of said energy, increasing the mean frequency of the energy of reduced frequency to the frequency of the carrier wave without increasing the degree of modulation thereof, and combining said last named energy with carrier wave energy to render the signal.

2. The method of demodulating high frequency oscillations which are modulated as to phase or frequency at signal frequency which includes the steps of, reducing the frequency of the oscillations and the degree of modulation thereof, beating down the frequency of the oscillations to the frequency of said reduced oscillations without altering the degree of modulation thereof, and recombining said oscillations of reduced frequency and oscillations the frequency of which has been beat down in phase quadrature to render the signal.

3. The method of demodulating a carrier wave varied as to phase or frequency in accordance with signal potentials which includes the steps of, reducing the frequency of said carrier, deriving energy from said phase or frequency varied carrier wave of reduced frequency, reducing the frequency of said derived energy and simultaneously the degree of modulation, increasing the frequency of said last named energy to the frequency to which said carrier wave is reduced without increasing the degree of modulation, and combining said energies to render the signal.

4. The method of demodulating high frequency oscillations which are modulated as to phase or frequency at signal frequency which includes the steps of, reducing the mean frequency of said oscillations, deriving energy from said oscillations of reduced frequency, reducing the mean frequency of the derived energy and the degree of modulation thereof, beating down the frequency of the first oscillations of reduced frequency to the frequency to which the derived energy is reduced without altering the degree of modulation thereof, and recombining both of said en-

ergies in phase quadrature to render the signal.

5. The method of demodulating a carrier wave varied as to phase in accordance with signal potentials which includes the steps of, diverting energy from said phase modulated carrier wave, limiting the amplitude and reducing the mean frequency of said diverted energy and simultaneously the degree of phase modulation thereof, increasing the mean frequency of said limited and reduced energy to the frequency of the carrier wave without increasing the degree of phase modulation, adjusting the phase of said last named energy, and combining said last named energy with original carrier wave energy to render the signal.

6. The method of receiving phase modulated oscillatory energy which includes the steps of, diverting energy from said oscillatory energy, limiting the amplitude of the diverted energy, reducing the frequency of oscillations in said diverted and limited energy and simultaneously reducing the degree of phase modulation, changing the frequency of the original phase modulated oscillations to a frequency equal to the frequency of the oscillations of reduced frequency, and combining said oscillations to produce indications.

7. The method of receiving phase modulated oscillatory energy which includes the steps of, diverting energy from said oscillatory energy, limiting the amplitude of the diverted energy, reducing the frequency of the oscillations in said diverted and limited energy and simultaneously reducing the degree of modulation, adjusting the mean phase of the oscillations in said last named energy, changing the frequency of the original phase modulated oscillations to a frequency equal to the frequency of the oscillations of reduced frequency, and combining said oscillations in phase quadrature to produce indications.

8. A device for demodulating oscillations modulated as to phase or frequency in accordance with signals comprising, in combination, signal wave receiving means having an output, a frequency dividing device having an input and an output, said device being connected at its input with the output of said receiving means, demodulating means having an input, and a coupling between the output of said receiving means and the input of said demodulating means and between the output of said frequency dividing device and the input of said demodulating means.

9. A device for demodulating oscillations modulated as to phase in accordance with signals comprising, in combination, signal wave receiving means having an output, an amplitude limiter having an input and an output, said limiter being connected at its input with the output of said receiving means, a frequency dividing device having input and output, said device being connected at its input with the output of said amplitude limiter, a phase adjuster having an input and an output, said adjuster being connected at its input with the output of said frequency dividing device, demodulating means having an input and a coupling between the output of said phase adjuster and the input of said demodulating means and between the output of said signal receiving means and the input of said demodulating means.

10. Means for demodulating phase modulated waves comprising, a heterodyne receiver including an intermediate frequency amplifier having an output, signal amplitude limiting means having an input and an output, and being connected at its input with the output of said intermediate frequency amplifier, signal frequency reducing means having an input and an output, said means being coupled at its input with the output of said amplitude limiting means, a demodulator having an input, phase adjusting means coupling the output of said signal reducing means to the input of said demodulator, and means coupling the output of said intermediate frequency amplifier to the input of said demodulator.

11. Means for demodulating phase modulated waves comprising, a heterodyne receiver including an intermediate frequency amplifier having an output, signal amplitude limiting means having an input and an output, and being connected at its input with the output of said intermediate frequency amplifier, signal frequency reducing means having an input and an output, said means being coupled at its input with the output of said amplitude limiting means, a demodulator having an input, phase adjusting means coupling the output of said signal frequency reducing means to the input of said demodulator, and means coupling the output of said intermediate frequency amplifier to the input of said demodulator, said phase adjusting means insuring that the wave energies reaching the input of said demodulator are in phase quadrature.

12. A signalling device comprising, a signal absorption circuit, a heterodyne receiver including a local oscillator and an intermediate frequency amplifier having an output, an amplitude limiting device having an input and an output and being connected at its input with the output of said intermediate frequency amplifier, a frequency reducing device having input and output, said device being connected at its input with the output of said amplitude limiter, detecting means connecting the output of said frequency reducing device and the output of said intermediate frequency amplifier to said local oscillator, a signal translating device and a coupling between said signal translating device and the output of said intermediate frequency amplifier and the output of said frequency reducing device.

13. A signalling device comprising, a signal absorption circuit, a heterodyne receiver including a local oscillator and an intermediate frequency amplifier having an output, an amplitude limiting device having an input and an output, said device being connected at its input with the output of said intermediate frequency amplifier, a frequency reducing device having an input and an output and being connected at its input with the output of said amplitude limiter, detecting means connecting the output of said frequency reducing device and the output of said intermediate frequency amplifier to said local oscillator, a signal translating device, a coupling including a heterodyning circuit between said signal translating device and the output of said intermediate frequency amplifier, and a coupling between said signal translating device and the output of said frequency reducing device.

14. A phase modulated wave receiver comprising, wave receiving and amplifying means, said amplifying means including a local oscillator having frequency determining means and an intermediate frequency amplifier, a pair of thermionic detectors each having a control grid and an output electrode, a circuit for applying signal energy from said intermediate frequency amplifier in phase opposition to the control grids of said detectors including amplitude limiting means, frequency reducing means and phase adjusting means in series, a circuit for applying

energy from said intermediate frequency amplifier in phase to the control grids of said detectors, indicating means connected with the output electrodes of said detectors, a rectifier comprising a pair of thermionic tubes each having an output electrode and a control grid, said control grids being connected to said first circuit in such a manner that the control grids are energized in phase opposition by energy from said circuit including said amplitude limiting frequency reducing and phase adjusting means, means for applying energy from said intermediate frequency amplifier in phase to the control grids of said tubes of said rectifier, and a circuit including time element control devices interposed between the output electrodes of the tubes in said rectifier and the local oscillator in said signal amplifying means.

15. A phase modulated receiver comprising, signal receiving and amplifying means, said amplifying means including a local oscillator having frequency determining means and an intermediate frequency amplifier, a pair of thermionic detectors each having a control grid and an anode, a circuit for applying signal energy from said intermediate frequency amplifier in phase opposition to the control grids of said detectors including amplitude limiting means, frequency and modulation degree reducing means, phase adjusting means and a frequency increasing means in series, a circuit for applying energy from said intermediate frequency amplifier in phase to the control grids of said detectors, indicating means connected with the anode electrodes of said detectors, a second detector comprising a pair of thermionic devices each having control grid and anode and a circuit coupling the control grids of said devices to said first circuit in such a manner that the control grids are energized in phase opposition by energy from said circuit including said amplitude limiting, frequency and modulaton degree reducing, phase adjusting and frequency increasing means in series, means for applying energy from said intermediate frequency amplifier in phase to the control grids of said thermionic devices, and a circuit including time element control devices interposed between the anodes of said thermionic device and the local oscillator in said signal amplifying means.

16. A phase modulated receiver comprising, signal receiving and amplifying means, said amplifying means including a local oscillator having variable tuning means and an intermediate frequency amplifier having an output, a pair of thermionic detectors each having control grid and anode, a first circuit for applying signal energy from the output of said intermediate frequency amplifier in phase opposition to the control grids of said detectors, said circuit including amplitude limiting means, frequency dividing means and phase adjusting means in series, a second circuit for applying energy from the output of said intermediate frequency amplifier in phase to the control grids of said detectors said second circuit including frequency reducing means, indicating means connected with the anodes of said detectors, a second detector comprising a pair of thermionic devices each having a control grid and an anode, the control grids of said tubes being coupled to said first circuit to be energized in phase opposition by energy from said first circuit including said amplitude limiting frequency dividing and phase adjusting means, a coupling between the control grids of said devices and said second circuit including said frequency reducing means for applying energy from said second circuit and said intermediate frequency amplifier in phase to the control grids of said last named devices, and a circuit including time element control devices interposed between the anode electrodes of the devices in said last named detector and the local oscillator in said signal amplifying means.

17. The method of reducing the degree or amount of phase or frequency modulation on a carrier wave modulated in phase or frequency at signal frequency, which includes the steps of setting up oscillatory energy characteristic of said modulated carrier wave, and dividing the mean frequency of said oscillatory energy.

18. Signal demodulating means comprising a heterodyne receiver including an intermediate frequency amplifier having an output, a pair of thermionic detectors each having input electrodes, circuits and switching means connecting the input electrodes of said detectors in parallel with the output of said intermediate frequency amplifier directly in one position of the switch and by way of an amplitude limiter in another position of said switch, and a circuit connected between said amplitude limiter and the input electrodes of said detectors for applying energy from said limiter in phase opposition to the input electrodes of said detectors in either position of said first named switch.

19. The method of demodulating a carrier wave varied as to phase in accordance with signal potentials which includes the steps of, diverting energy from said phase modulated carrier wave, limiting the amplitude and reducing the mean frequency of said diverted energy and simultaneously the degree of phase modulation thereon, increasing the mean frequency of said limited and reduced energy to the frequency of the carrier wave without increasing the degree of phase modulation, and combining said last named energy of increased frequency with original carrier wave energy to render the signal.

20. The method of demodulating high frequency oscillatory energy modulated in phase at signal frequency which includes the steps of reducing the frequency of a portion of said oscillatory energy and the degree of phase modulation therein, reducing the frequency of another portion of the oscillatory energy to a frequency equal to the frequency to which said first portion is reduced, said last named portion being reduced in frequency without altering the degree of phase modulation thereof and combining said oscillatory energies of reduced frequency to render the signal.

21. In a system for demodulating oscillatory energy modulated in phase or frequency in accordance with signals, in combination, phase or frequency modulated oscillatory energy receiving means having an output, a frequency reducing device having an input and an output said device being connected at its input with the output of said receiving means, demodulating means having an input, a coupling between the output of said receiving means and the input of said demodulating means, frequency changing means in said coupling and a coupling between the output of said frequency reducing device and the input of said demodulating means.

22. In a system for demodulating oscillatory energy modulated in phase or frequency in accordance with signals, in combination, phase or frequency modulated oscillatory energy receiving

means having an output, a frequency reducing device having an input and an output, said device being connected at its input with the output of said receiving means, demodulating means having an input, a coupling between the output of said receiving means and the input of said demodulating means, a coupling between the output of said frequency reducing device and the input of said demodulating means and frequency increasing means in said last coupling.

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