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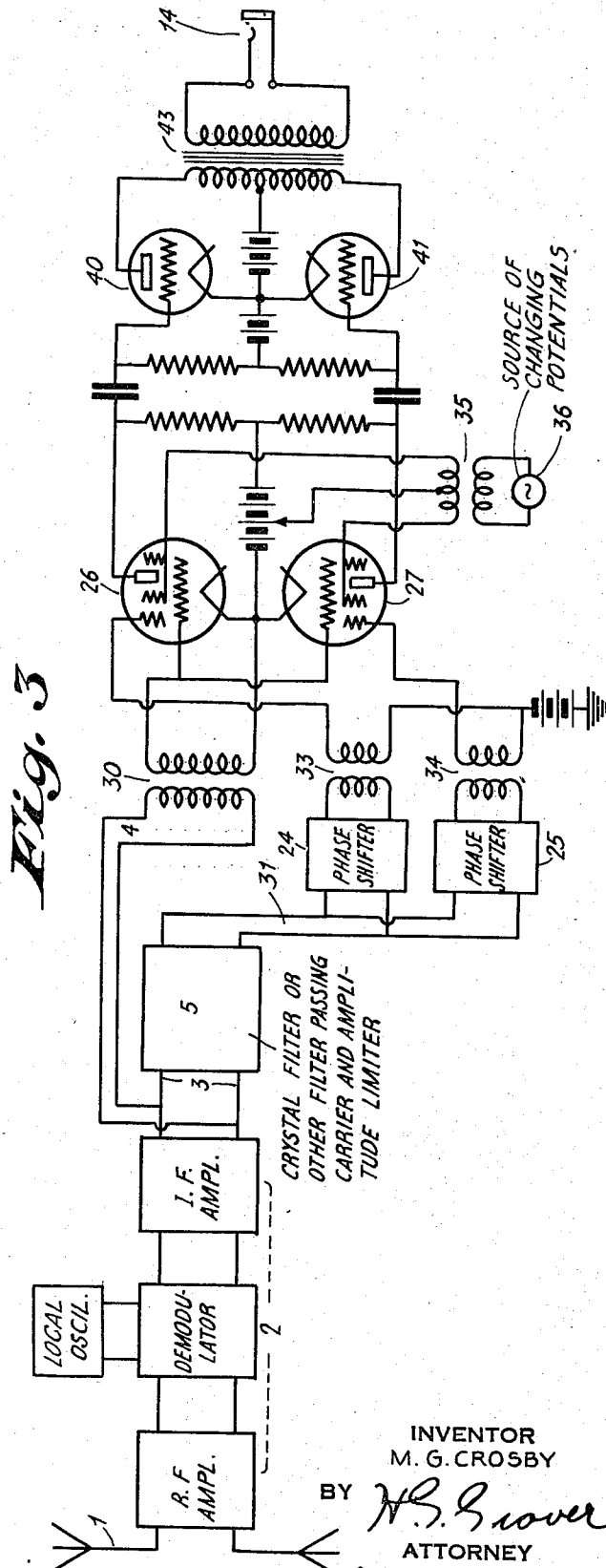
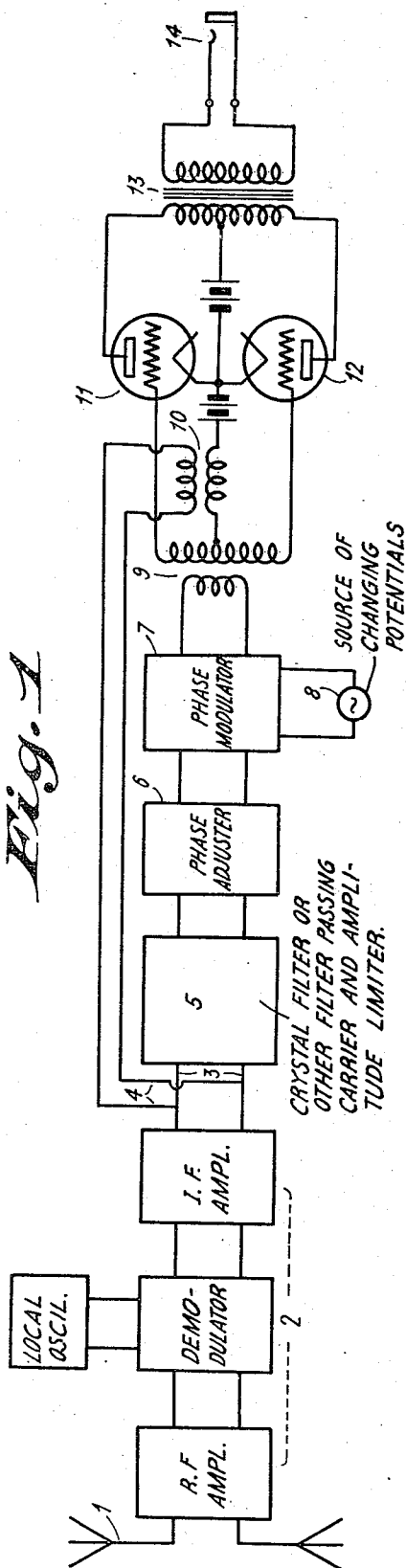
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PHASE AND AMPLITUDE MODULATION RECEIVER

Filed April 9, 1934

3 Sheets-Sheet 1



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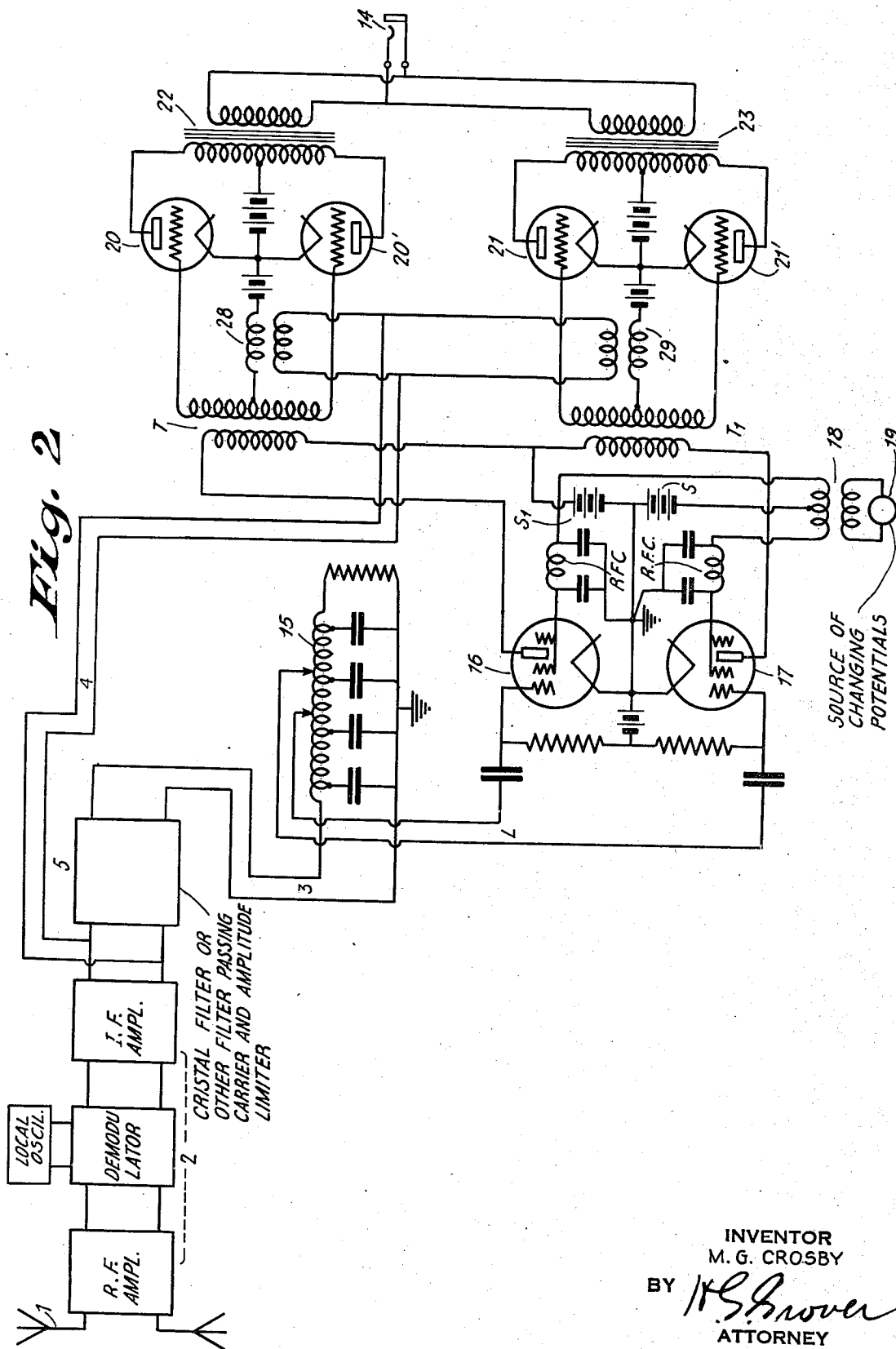
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PHASE AND AMPLITUDE MODULATION RECEIVER

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3 Sheets-Sheet 2



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PHASE AND AMPLITUDE MODULATION RECEIVER

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3 Sheets-Sheet 3

Fig. 4

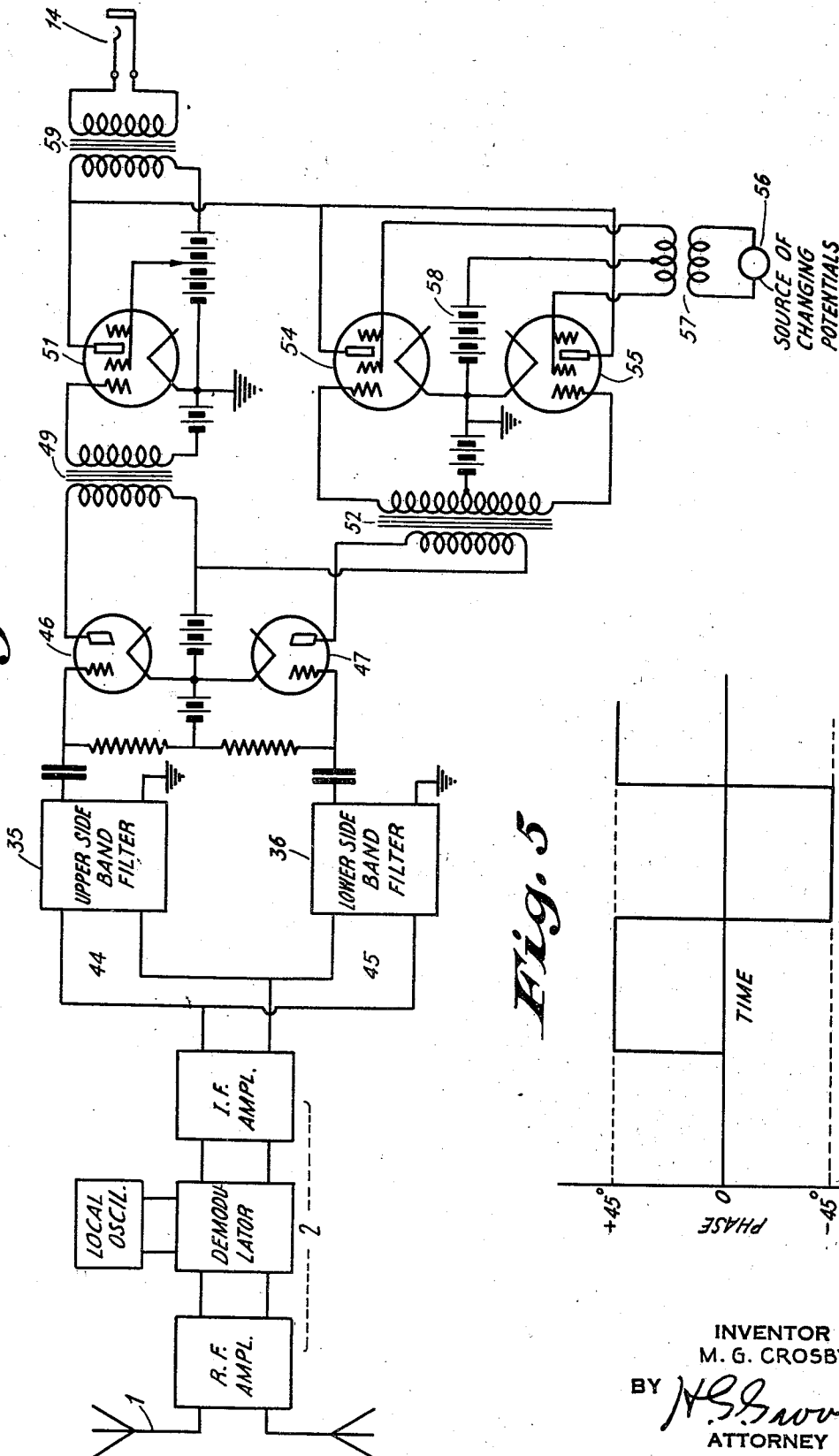
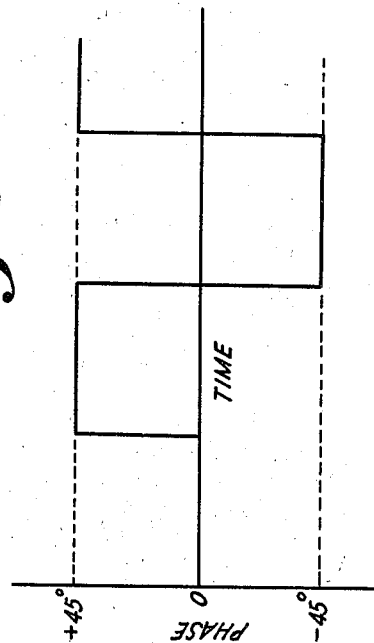


Fig. 5



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PHASE AND AMPLITUDE MODULATION
RECEIVERMurray G. Crosby, Riverhead, N. Y., assignor to
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Application April 9, 1934, Serial No. 719,643

18 Claims. (Cl. 250-20)

This invention relates to a new and improved receiver which is constantly receptive to either a phase or an amplitude modulation on the carrier wave or to both. The purpose of this receiver is to eliminate the defects present in receivers known heretofore resulting from fading of the wave or multi-path transmission of the wave which in turn causes distortion of the wave modulations from an amplitude modulation to a phase modulation, or from a phase modulation to an amplitude modulation. Briefly, my invention contemplates the use of a receiver which is adapted to demodulate amplitude modulated waves and is also adapted to demodulate phase modulated waves and a switching device or a modulating device for constantly changing the characteristics of the receiver at a super-audible rate so that the receiver is alternately responsive to either phase or amplitude modulation.

In the prior art in general, the reception of signal modulated waves is accomplished by means of receivers which are receptive only to the type of modulation impressed on the wave at the transmitter. Consequently in these receivers of the prior art, if for any reason whatever the nature of the modulation on the wave is changed or distorted so that it deviates from that type of modulation accomplished by the transmitter the receiver will not translate the signal wave from the carrier wave. Since fading is capable of distorting a modulated wave from one type of modulation to another, that is from amplitude modulation to phase modulation or vice versa, such a condition of modulation conversion is one which is common and a receiver which will receive both the applied modulation and the modulation to which the applied modulation may be distorted or converted is valuable.

The receiver of the present invention eliminates the above described defect by providing demodulators operative to render amplitude modulations from carrier energy or to render phase modulations from carrier energy. One demodulator is therefore capable of demodulating the modulation intentionally applied at the transmitter and the other demodulator is capable of rendering the type of modulation to which the fading or other effects converts the applied modulation.

Thus by switching first one demodulator on and then the other, at a super-audible rate, the desired signal will be constantly rendered and delivered from the receiver.

In a modification one demodulator only is utilized and its operative characteristics is altered at an above audible rate so as to make the receiver

alternately receptive to the two types of modulation.

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 and the manner in which the same is carried out will be clear from the following detailed description thereof and therefrom when read in connection with the attached drawings throughout which insofar as possible like reference characters indicate like parts and in which Figures 2 to 4 inclusive illustrate various modifications of my novel receiver in which a pair of demodulators of different types are rendered operative at a super-audible rate;

Figure 1 illustrates a modification wherein a single demodulator is utilized and the demodulating characteristic of the same is altered at a super-audible rate;

While Figure 5 is a graphic representation of the manner in which the demodulators of Figures 2, 3 and 4 are alternately rendered operative and of the manner in which the characteristics of the demodulator of Figure 1 is changed.

Referring to the drawings, and in particular to Figure 1 thereof, a radiant energy absorption device 1 is connected as shown with a receiver 2 of the superheterodyne type. The receiver 2 may include radio frequency amplifiers, a source of local oscillation, a demodulator and an intermediate frequency amplifier. The receiver 2 converts the incoming signal modulated energy to an intermediate frequency and impresses the same on the lines 3 and 4. Part of the intermediate frequency energy from 2 is passed by way of lines 4 to the primary winding of a co-phased transformer 10. The secondary winding of the transformer 10 is connected as shown to apply the energy set up therein co-phasally to the control grids of demodulators 11 and 12. Another portion of the intermediate frequency energy from the output of 2 is passed by way of lines 3 to a unit 5 which may include a filter of the crystal or any other type and an amplitude limiter or an automatic volume control. The frequency limited and amplitude limited energy from the output of unit 5 is impressed on a unit 6 which may include a phase adjusting device. The energy from the output of the phase adjusting device is impressed on a phase modulator 7. The phase of the energy in 7 is modulated by oscillations from the source 8. The frequency of the oscillations from the source 8 should be above audibility. The energy from the output of the phase modulator 7 is applied to the primary wind-

ing of a transformer 9, the secondary winding of which feeds the energy anti-phasally to the control grids of demodulators 11 and 12. In this manner the energy applied co-phasally by transformer 10 is combined with energy applied anti-phasally by the transformer 9. The output electrodes of the demodulators 11 and 12 may be connected as shown to the primary winding of a transformer 13, the secondary winding of which may be connected with a jack 14 in which any indicating device may be inserted. The phase modulator 7 and source 8 may of course be replaced by any means for shifting the phase of the energy in 7 substantially 90 degrees at an above audible rate.

In the modification shown in Figure 2 two separate demodulating devices may be utilized. The transmitted energy may be received on an absorption member 1 and a superheterodyne receiver 2 and applied to the lines 3 and 4 in the same manner as in the arrangement of Figure 1. A portion of the energy is fed by way of line 3 to the filter and amplitude limiter in 5 and the frequency limited and amplitude limited energy from the output of 5 is impressed on a line or phase shifter device 15 comprising series inductive reactances and parallel capacitive reactances terminated by an impedance. Energy of the desired phase relation is taken from the line by means of leads L connected as shown to movable taps on the line 15. The energy diverted from the line 15 by the leads L is applied to the control grids of modulator tubes 16 and 17 as shown. The modulators 16 and 17 may be of the screen grid electrode type and may have their screen grids connected as shown by way of radio frequency by-pass networks RFC to the terminals of the secondary winding of a transformer 18, the primary winding of which is connected with a source of modulating potentials 19. A direct current charging potential for the screen grid electrodes is provided by means of a source S connected as shown. The anode of the modulator 16 is connected to the cathode thereof by way of the primary winding of a transformer T and a source S₁. The anode electrode of the modulator 17 is connected to the cathode by way of the primary winding of a transformer T₁ and source S₁. The secondary winding of the transformer T connects as shown the control grids of a pair of detector tubes 20 and 20' in pushpull relation. The secondary winding of the transformer T₁ connects the control grids of a second pair of detector tubes 21 and 21' in pushpull relation. Intermediate frequency energy from the superheterodyne receiver is fed by way of line 4 to the primary windings of transformers 28 and 29. The secondary winding of transformer 28 applies this energy co-phasally, that is, in phase to the control grids of tubes 20 and 20'. The secondary winding of transformer 29 applies energy co-phasally to the control grids of detectors 20 and 21'. The anode electrodes of tubes 20 and 20' are connected in pushpull relation by the primary winding of a transformer 22 while the anode electrodes of tubes 21 and 21' are connected in pushpull relation by the primary winding of a transformer 23. The energy from the outputs of both pairs of detectors are combined by connecting the secondary windings of transformers 22 and 23, together as shown. The combined energy may be applied to any indicating device from the jack 14.

In the modification of Figure 3 the demodulators of the arrangement of Figure 2 are replaced

by multi-grid detectors. The signal, after being converted to intermediate frequency wave energy, is fed by way of lines 4 to the primary winding of a transformer 30, the secondary winding of which is connected to the control grids of detectors 26 and 27 as shown to apply energy to said control grids in phase. A second portion of the intermediate frequency energy is fed by way of the filter circuits and amplitude limiters in 5 to a line 31, which is connected as shown to the inputs of a pair of phase shifters 24 and 25 whose respective outputs feed energy by way of transformers 33 and 34 to the suppressor grids of detectors 26 and 27 respectively. A modulating frequency generator 36 is connected as shown by way of transformer 35 to the screen electrodes of detectors 26 and 27 to modulate the potentials on said screen grid electrodes alternately at an above audible frequency rate. The anode electrodes of detectors 26 and 27 are connected as shown by way of resistances and capacities to the control grids of amplifiers 40 and 41. The anodes of amplifiers 40 and 41 are connected in pushpull relation by the primary winding of transformer 43, the secondary of which is connected to a jack 14. An indicator of any type may be inserted in jack 14. The phase shifters 24 and 25 may be of any nature. For example, they may take the form of the line 15 shown in Figure 2.

In the modification of Figure 4, energy from the intermediate frequency amplifier is fed by way of a line 44 to an upper side-band filter 35 and by way of a line 45 to a lower side-band filter 36. Energy from the output of the upper side-band filter 35 is supplied to the control grid of a demodulator 46 while energy from the lower output of the lower side-band 36 is supplied to the control grid of a demodulator 47. The signal components of the demodulated waves are supplied from the output of detector 46 by way of a transformer 49 to a coupling tube 51. Energy from the output of the detector 47 is supplied to the primary winding of a transformer 52, the secondary winding of which is connected in pushpull relation to the control grids of coupling tubes 54 and 55 as shown. The screen grid electrodes of coupling tubes 54 and 55 are connected in phase opposition as shown to the secondary winding of a transformer 57, the primary winding of which is connected to a source of modulating potentials 56. Modulating potentials from the source 56 are superimposed in phase opposition on the direct current potential applied to the screen grid electrodes of tubes 54 and 55 from source 58. These superimposed modulating potentials render the tubes 54 and 55 alternately operative to supply energy to their output circuit. The anode of tube 51 and the anodes of tubes 54 and 55 are connected as shown in parallel with the primary winding of a transformer 44, the secondary winding of which is connected with a jack 14 from which the signal components may be applied to any indicating device.

In describing the operation of the receivers of the present invention, reference will first be made to Figure 1 of the drawings. The receiver of Figure 1 is arranged as shown for the reception of phase or amplitude modulated waves. This receiver is similar in many respects to the receiver disclosed in Crosby United States application No. 616,803, filed June 13, 1932. The carrier is filtered in 5 so that the modulation sidebands are removed and after limiting the ampli-

tude of the filtered carrier, the said carrier is combined with the unfiltered signal applied to the control electrodes of 11 and 12 in the proper phase relationship. For phase modulation reception the filter carrier is adjusted in 6 so as to be shifted 90 degrees with respect to the unfiltered energy applied by way of lines 4 to the primary winding of transformer 10 and thence in phase to the control grids of 11 and 12. This combination in phase quadrature of the limited and filtered and unfiltered signal energy produces amplitude components which vary in accordance with the variations in phase of the unfiltered energy. For amplitude modulation reception the carrier applied to the control grids of modulators 11 and 12 should be either in phase or 180 degrees out of phase with respect to the unfiltered signal energy reaching the control grids of the demodulators 11 and 12 from the line 4. Obviously if means is provided for shifting the phase of the filtered carrier energy reaching the control grids of the demodulators so that at one instant said carrier is shifted 90 degrees with respect to the unfiltered carrier, and the next instant said filtered carrier is shifted in phase or 180 degrees out of phase with respect to the unfiltered carrier, the receiver will be responsive to both phase and amplitude modulated waves. Consequently, if fading distortion is such that it distorts the modulation applied to the wave in the transmitter from amplitude to phase modulation or vice versa correction may be made in my novel receiver by varying the phase adjustment of the filtered carrier. In order to make manual adjustment of the filtered carrier phase unnecessary, the phase modulator of unit 7 is included in the line between the carrier filter 5 and the demodulators 11 and 12. This demodulator is capable of modulating the carrier over a range of 90 degrees in phase. The rate of modulation is determined by the tone generator 8 which may have a square wave form so that the phase of the carrier will be shifted from plus 45 to minus 45 degrees, as shown in Figure 5. At plus 45 degrees the receiver will then be adjusted for phase or amplitude modulation and at minus 45 degrees the receiver will be receptive to amplitude or phase modulation respectively. Hence, by means of the phase modulator the receiver may be switched so that it is alternately receptive to phase or amplitude modulation for equal intervals of time determined by the nature of the oscillations generated by 8. Such an arrangement eliminates the necessity of a receiver receptive to either type of modulation one-half the time and prevents fading distortion on either type of modulation from distorting the signal in the output of the receiver or from preventing the signal from reaching the output of the receiver. The rate of switching may be made super-audible so that the modulation due to the switching action is not objectionable.

The principles of reception described above in connection with Figure 1 are applicable to the modifications shown in Figure 2. In Figure 2, however, two sets of detectors are utilized. One set of detectors may be adjusted to receive phase modulation while the other set of detectors may be adjusted to receive amplitude modulation. More specifically the unfiltered carrier from line 4 may be applied to the control grids of detectors 20 and 20' in 90 degrees phase shifted relation with respect to the filtered carrier supplied to the control grids of detectors 20 and 20' from the modulator tubes 16 and 17, while the unfiltered

carrier may be applied to the control grids of tubes 21 and 21' in phase or 180 degrees out of phase with respect to the filtered carrier applied to the control grids of these tubes from the modulators 16 and 17. The tubes 16 and 17 are modulated on their screen grid electrodes in such a manner that energy is fed from modulators 16 and 17 so that first one set of these detectors gets carrier energy and then the other set of these detectors gets carrier energy. The output circuits of the two sets of detectors are connected to combine the energy so that whichever detector is switched on, that detector will supply signal to the jack 14 and any indicator connected therewith. Consequently the receiver is alternately receptive to either phase or amplitude modulation and said receiver will eliminate the effect of modulation distortion in the same manner in which said distortion is eliminated by a receiver as illustrated in Figure 1. The generator 19 may have a square wave form so that the interval during which each receiver is alternately inoperative is short while the interval during which each receiver is operative is comparatively long. Furthermore, the modulations produced by 19 may be audible or may be super-audible.

In the receiver of Figure 3, which is otherwise similar in many respects to the receiver of Figure 2, multi-grid detector tubes are used as shown. These detectors are rendered alternately operative and inoperative at the desired rate by modulating the screen grids differentially by modulating potentials applied from the modulating potential source by way of transformer 35 to said screen grid electrodes. Phase shifter 24 may be adjusted so that the demodulator 26 is receptive to phase modulated waves. Phase shifter 25 may be adjusted so that the demodulator 27 is receptive to amplitude modulated waves. When this adjustment has been made rendering first one detector operative and then the other detector operative by the modulating potentials causes the receiver to be receptive to both types of modulation. The signal components, both phase and amplitude, appearing in the outputs of these detectors are applied to the amplifiers 40 and 41 and from the amplifiers to an indicating device. Here, as in the prior modification, the tone generator may have a square wave form and may operate at a super-audible rate.

The receiver shown in Figure 4 may be somewhat similar in some respects to the receiver disclosed in Crosby United States application No. 616,803, filed June 13, 1932. Here the upper side-band of the intermediate frequency wave is filtered out and applied to a detector 46 as shown, while the lower side-band is filtered out and applied to the control grid electrode of a detector 47 as shown. If energy from the outputs of these detectors is combined in phase the receiver is receptive to amplitude modulation. If energy in the output of the detectors 46 and 47 is combined in phase opposition the receiver responds to a phase modulated wave. Consequently, if the modulating means 55, 57, 58 connected with the screen grids of coupling tubes 54 and 55 as shown is operative to switch from an in-phase to an out-of-phase combination of the detector output energy, the receiver will be responsive to both types of modulation. The modulating means and the single detector 51 and the push-pull detectors 54 and 55 as connected will couple the output of 46 and 47 alternately in an in-phase and an out-of-phase relation. If the out-

puts of the coupling tubes 51 and 54 are combined, an in-phase combination results, so that the receiver is responsive to amplitude modulated waves. If the energy from the outputs of tubes 51 and 55 are combined, an out-of-phase combination results and the receiver is responsive to phase modulated waves. Hence by differentially modulating tubes 54 and 55 so that first one tube is inoperative and then the other, the desired switching effects are obtained and the receiver is responsive to phase modulated waves or amplitude modulated waves. Here, as in the prior modifications, the source of modulating potential 56 may produce waves having a form as illustrated in Figure 5. Moreover, the frequency of these waves may be above or below audibility.

Automatic frequency control may be applied to each of the receivers described above. Such frequency control means may be as illustrated in Crosby United States application No. 616,803, filed June 13, 1932. The frequency control means per se forms no part of the present invention and need not be described here.

The principle involved in these receivers may, of course, be applied to diversity reception systems. In the receiver of Figure 2 the signal energy may be switched instead of the carrier energy. This may be accomplished by placing the modulator tubes 16 and 17 in the lines 4 which feed the signal energy to the detectors instead of as shown in the lines feeding the carrier energy to the detectors.

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

1. In a system for receiving and demodulating oscillations modulated in phase and in amplitude, a signal absorbing means, signal amplifying means coupled thereto, signal demodulating means coupled by circuits to said signal amplifying means, and means connected with one of said circuits for rendering said demodulating means receptive to different types of signal modulations.

2. In a system for receiving and demodulating oscillations modulated in phase and in amplitude, signal absorbing and amplifying means, a plurality of signal demodulating means responsive to signal modulations of different character each coupled by a plurality of circuits of different character to said signal amplifying means, and means in one of said circuits for alternately changing the character of the energy flowing therein to said demodulating means.

3. In a system for receiving and demodulating oscillations modulated in phase and in amplitude, signal absorbing and amplifying means, signal demodulating means coupled by two separate circuits to said signal amplifying means, and means in one of said circuits for modulating the phase of the energy reaching said demodulating means over one of said circuits.

4. In a system for receiving waves modulated in amplitude or in phase or both, signal modulated wave absorbing means, a device for reducing the frequency of said wave connecting with said absorbing means, demodulating means comprising a pair of thermionic tubes, a circuit for applying energy from said wave reducing means co-phasally to the like electrodes in said tubes, a circuit for applying energy from said wave reducing means in phase opposition to like electrodes in said tubes and a device in one of said circuits for varying the character of the energy therein.

5. In a system for receiving waves modulated

in amplitude or in phase or both, modulated wave absorbing means, a device for reducing the frequency of said wave connecting with said absorbing means, demodulating means comprising a pair of thermionic tubes, a circuit for applying energy from said wave reducing means co-phasally to the like electrodes in said tubes, a circuit for applying energy from said wave reducing means in phase opposition to like electrodes in said tubes, a filter in one of said circuits, and a device in one of said circuits for varying the character of the energy flowing therein at a sub-audible rate.

6. In a system for receiving waves modulated in amplitude or in phase or both, modulated wave absorbing means, demodulating means comprising a pair of thermionic tubes, a circuit for applying energy from said absorbing means co-phasally to the like electrodes in said tubes, a circuit for applying energy from said wave absorbing means in phase opposition to like electrodes in said tubes and a device in one of said circuits for modulating the energy therein at an above audible rate.

7. In a system for receiving and demodulating oscillations modulated in phase or in amplitude, signal absorbing means, signal amplifying means, a filter circuit connected with said amplifying means, differential detectors each comprising a control grid, a circuit for applying energy from said amplifier in phase to said control grids, a circuit for applying energy from said amplifier in phase opposition to said control grids, said last named circuit including a filter for removing the signal modulations from the energy, and means in said last named circuit for modulating the phase of the filtered energy reaching the control grids of said detectors in phase opposition.

8. In a system for receiving and demodulating oscillations modulated in phase or in amplitude, signal absorbing means, signal amplifying means, a filter circuit connected with said amplifying means, differential detectors each having control grids, a circuit for applying energy from said amplifier in phase to like control grids of said tubes, a circuit for applying energy from said amplifier in phase opposition to like control grids of said tubes, said last named circuit including a filter for removing the signal modulations from the energy, and means in said last named circuit for varying the phase of the filtered energy reaching the control grids of said detectors in phase opposition through 90 degrees.

9. In a system for receiving and demodulating oscillations modulated in phase or in amplitude, signal absorbing means, signal amplifying means, a pair of differential detectors each comprising a control grid, an additional detector tube, circuits connecting the outputs of all of said detectors together, a circuit for applying energy from said amplifier to the control grids of said pair of detectors, a circuit for applying energy from said amplifier to the control grid of said single detector, said circuits each including a filter and means for rendering the differential detectors alternately operative at a super-audible rate.

10. In a system for receiving waves modulated in amplitude or in phase or both, modulated wave absorbing means, a device for reducing the frequency of said wave connecting with said absorbing means, wave demodulating means comprising a pair of thermionic tubes each having a plurality of control electrodes, a circuit for applying energy from said wave reducing means co-phasally

to like control electrodes in said tubes, other circuits for applying energy from said wave reducing means to like control electrodes in said tubes said other circuits having a portion in common, a filter in said common portion of said other circuits, and a modulating circuit connected in phase opposition with like control electrodes in said tubes.

11. In a system for receiving and demodulating oscillations modulated in phase or in amplitude, signal absorbing means, signal amplifying means, a filter circuit connected with said amplifying means, two sets of differential detectors each detector of each set having a control grid, a circuit for applying energy from said amplifier in like phase to the control grids in each set of detectors, a circuit for applying energy from said filter in phase opposition to the control grids in each set of detectors, means in said last named circuit for shifting the phase of the filtered energy reaching the control grids of one of said sets of detectors substantially ninety degrees relative to the energy reaching the control grids of said detectors from said amplifier, means for alternately increasing and decreasing the energy reaching said sets of detectors over said last named circuit, and an output circuit connected to the output of all of said detectors.

12. In a system for receiving and demodulating waves modulated in phase or in amplitude, signal wave absorbing means, signal wave frequency reducing means connected with said signal wave absorbing means, a filter circuit connected with said reducing means, differential detectors each comprising a control grid, a circuit for applying energy from said reducing means in phase to said control grids, a circuit for applying energy from said reducing means in phase opposition to said control grids, said last named circuit including said filter for removing the signal modulations from the wave energy, and modulating means in said last named circuit for shifting the phase of the filtered energy reaching the control grids of said detectors in phase opposition through substantially 90 degrees.

13. The method of eliminating the effect of fading on a signal modulated wave, which fading tends to change the character of the signal modulation on said wave which is being received on a receiver having a demodulator which includes the step of, and supplying energy from said wave to said demodulator over two paths changing the demodulation characteristic of said demodulator by shifting the phase of the energy supplied over one of said paths at a super-audible rate.

14. The method of eliminating the distortion caused in the demodulation of a signal wave, due to the tendency of said modulation to change from one type of modulation to another during transmission of the wave, which is to be received

on a receiver including a pair of differential detectors which includes the steps of, impressing energy characteristic of said wave in phase on the control grids of said pair of differential detectors over one path and in out-of-phase relation on said control grids over another path, and modulating the phase of one of said energies reaching said control grids over one of said paths through 90 degrees at an above audible rate.

15. The method of eliminating the effect of distortion on phase modulation at signal frequency on a wave which tends to change the said modulation of said wave to amplitude modulation when said wave is received on a receiver including a pair of differential detectors which includes the steps of, amplifying said wave, filtering out energy of said wave to remove therefrom the modulation thereon, applying said filtered energy in phase opposition to the control grids of said detectors, applying other energy characteristic of the modulation on said wave in phase to the control grids of said detectors, and modulating one of said energies at a super-audible rate.

16. Means for eliminating the effect of fading on a signal modulated wave which tends to change the type of modulation on said wave comprising signal absorbing means, signal demodulating means, a plurality of circuits connecting said absorbing means to said demodulating means, and phase modulating means in one of said circuits for changing the characteristic of said demodulator at a super-audible rate.

17. In means for eliminating the distortion caused in the demodulation of a carrier wave due to the tendency of said modulation to change from one type of modulation to another during transmission of the wave, a demodulating device, means for impressing signal modulated energy from said carrier wave on said device, means for impressing unmodulated energy characteristic of said carrier wave on said device and means for shifting the phase of one of said energies before the same is impressed on said device through 90 degrees at an above audible rate.

18. The method of eliminating the effect of distortion on an amplitude modulated wave which tends to change the same to phase modulation when said wave is received on a receiver including a pair of differential detectors which includes the steps of, amplifying said wave, filtering out energy of said wave to remove therefrom the signal modulations thereon, applying said filtered energy in phase opposition to the control grids of said detectors, applying additional energy characteristic of the modulations on said wave in phase to the control grids of said detectors, and modulating one of said energies reaching said control grids at a super-audible rate.

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