

May 2, 1939.

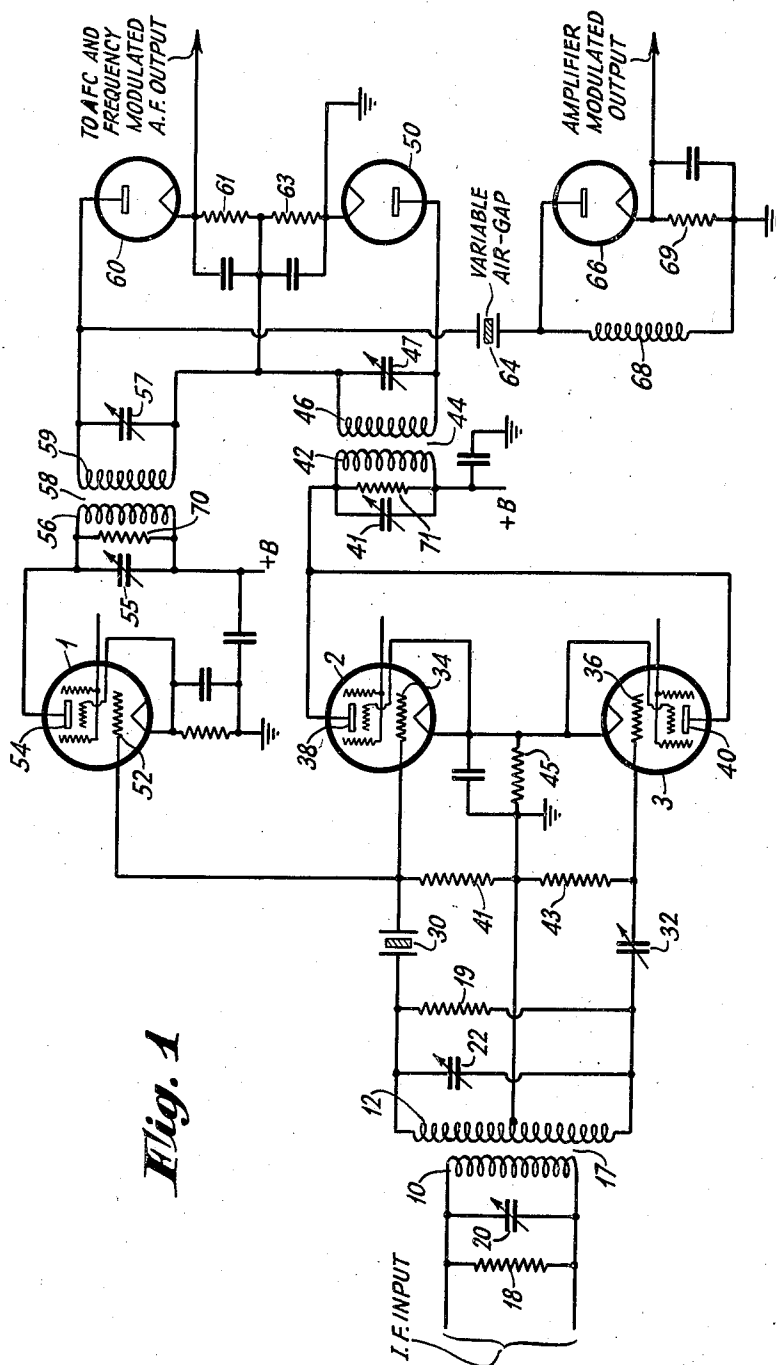
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2,156,374

BACK TO BACK PHASE MODULATION RECEIVER

Filed Sept. 22, 1937

3 Sheets-Sheet 1



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BACK TO BACK PHASE MODULATION RECEIVER

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3 Sheets-Sheet 2

Fig. 2A

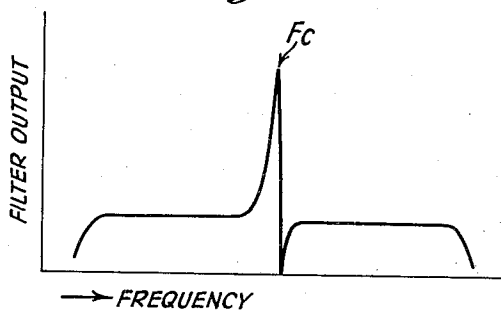


Fig. 2E

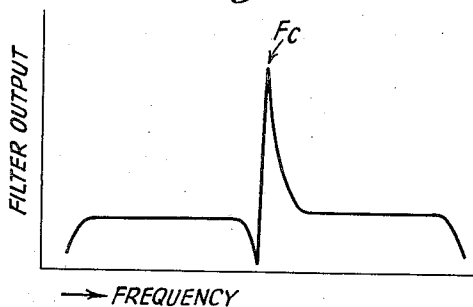


Fig. 2B

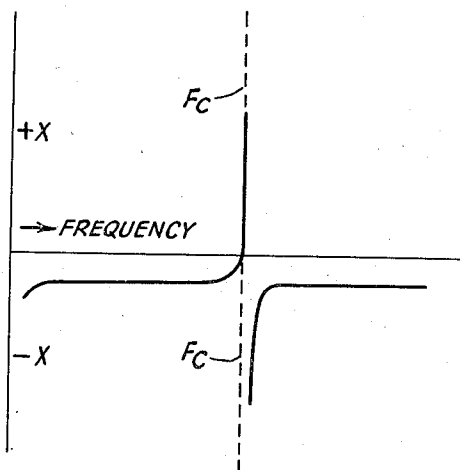


Fig. 2F

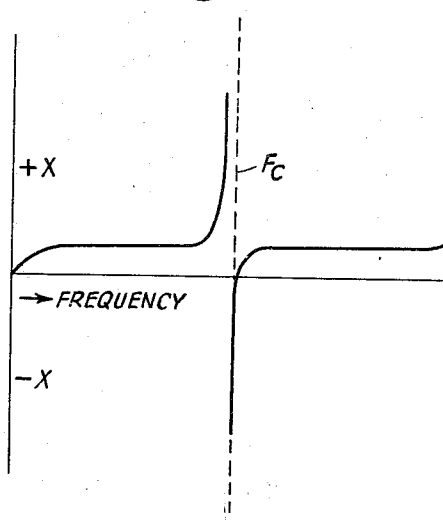


Fig. 2C



Fig. 2D

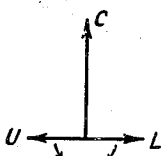


Fig. 2G

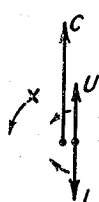
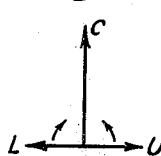


Fig. 2H



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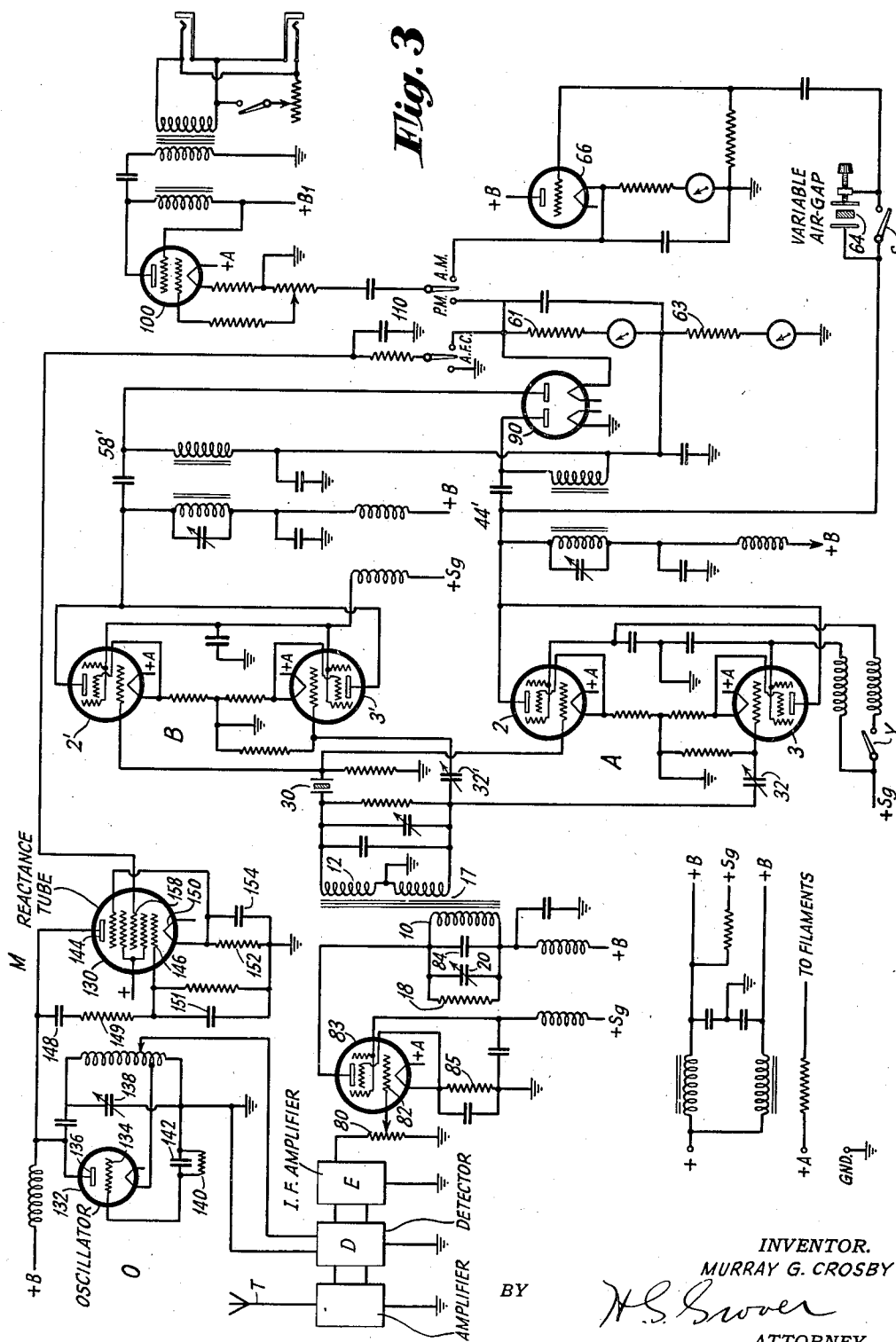
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BACK TO BACK PHASE MODULATION RECEIVER

Filed Sept. 22, 1937

3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

2,156,374

BACK TO BACK PHASE MODULATION
RECEIVERMurray G. Crosby, Riverhead, N. Y., assignor to
Radio Corporation of America, a corporation of
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Application September 22, 1937, Serial No. 165,056

19 Claims. (Cl. 250—20)

This application describes a phase modulation receiver employing crystal filters of the off-neutralized type in which a back-to-back or push pull type of detecting system is used with two filters which convert the phase modulation to two waves of characteristic amplitude modulation with a 180° phase relation between their modulation envelopes. This enables detection of the phase modulation, balancing out of unwanted amplitude modulation and also allows the automatic frequency control energy to be obtained from the same detecting system that is used to detect the phase modulation for utilization.

In the prior art of receivers of this general type, a single off-neutralized crystal filter has been used to convert the phase modulation into amplitude modulation for subsequent detection while the same crystal filter neutralized provides energy for detection to obtain automatic frequency controlling potentials. This type of receiver is described in Crosby Patent #2,085,008 dated June 29, 1937, application #138,116 filed April 21, 1937, and application #138,117 filed April 21, 1937. In my continued development on this type of receiver, I have found that an under-neutralized filter converts phase modulation to amplitude modulation with an envelope phase which is opposite to that obtained when phase modulation is converted by an over-neutralized filter. The converted energies are combined in a manner such that amplitude variations characteristic of the phase modulations on the wave produce an accumulative component characteristic of said phase modulations, unwanted amplitude variations on the received phase modulated wave oppose and cancel, while slow variations in the mean frequency of the wave produce potentials which are in turn used to synchronize the receiver with the received wave.

This fact has made possible the provision of receivers which balance out any undesired amplitude modulation which is likely to be detected in receivers known heretofore which do not have my balanced arrangement. It also simplifies the receiver since it allows the use of a single detecting system for automatic frequency control and for obtaining the output potentials. Moreover, by a simple addition to this receiver the same is adapted to the reception of amplitude modulation with or without the automatic frequency control feature.

In describing my invention reference will be made to the drawings wherein,

Figure 1 illustrates the principle elements of my novel means for converting phase modulations of

wave energy to amplitude modulations and detecting the same, while suppressing or substantially suppressing any undesired amplitude modulations on said phase modulated wave and for converting amplitude modulations on wave energy to characteristic phase modulations and re-converting the same to amplitude modulations for detection and for producing automatic frequency controlling potentials during the above operations;

Figures 2A to 2H inclusive, are resonant curves, reactance curves, and modulated energy component vectors which serve to illustrate my novel method of and means for demodulating modulated wave energy, while

Figure 3 illustrates a complete receiver arrangement utilizing the principal elements and methods described in connection with Figure 1.

The circuit of Figure 1 shows a specific embodiment of my invention in which neutralizing through coupling tubes, as described in my United States Patent #2,085,008 dated June 29, 1937, is utilized. To simplify the description of the basic principle of my method and means, it is assumed that by the use of heterodyning means phase or amplitude modulated wave energy has been reduced in frequency and is impressed at intermediate frequency on the primary winding 10 of a transformer 17 having a secondary winding 12. The primary winding 10 is shunted and properly damped by a resistor 18 and tuned by a variable condenser 20. The secondary winding 12 is likewise properly damped by a resistor 19 in shunt thereto and is tuned by a variable condenser 22. The secondary winding 12 has its terminals connected as shown to a piezoelectric crystal 30 and a variable capacity 32 which serves as means for neutralizing, under-neutralizing, or over-neutralizing the crystal 30. In this particular case the crystal is over-neutralized by 32. The winding 40 12, crystal 30, and capacity 32 connect the control grids 34 and 36 of electron discharge tubes 2 and 3, as shown, to feed wave energy thereto from 12. The energy passed by the crystal 30 is amplified by the electron discharge tube 2 while the neutralizing energy passed by 32 is amplified by the electron discharge tube 3. The anode 38 of tube 2 and the anode 40 of tube 3 are tied together as shown and connected to the tuned primary winding 42 of a transformer 44. The winding 42 is tuned by a condenser 41 and is damped by resistor 71. The secondary winding 46 of transformer 44, tuned by condenser 47, is connected as shown to the electrodes of a diode rectifier 50. The combination of the current passed by crystal 30 and

tube 2, and capacity 32 and tube 3, takes place in the primary winding of transformer 44. Resistors 41 and 43 furnish a direct current connection to ground for the grid direct current circuits of tubes 2 and 3 while resistor 45, which is properly by-passed, furnishes self-bias to these tubes.

Un-neutralized filtered wave energy to be converted is also taken from the terminal of crystal 30 and fed to the control electrode 52 of electron discharge tube 1. The anode 54 of tube 1 is connected to the primary winding 56 of a transformer 58, the secondary winding 59 of which is connected to the electrodes of a diode rectifier 60. Windings 56 and 59 are tuned by condensers 55 and 57 respectively. The primary is damped by resistor 70 and the secondary by the diode input impedance. Transformers 17, 44 and 58 are band pass transformers with their tunings and dampings adjusted so that the center of the band passed is substantially equal to the mean frequency of the phase modulation energy received at 10. The transformer 58 in the plate circuit of tube 1, feeds the unneutralized crystal energy to diode 60. By adjusting condenser 32 so that an over-neutralized crystal filter characteristic, as to the intermediate frequency phase modulated wave energy, is obtained in transformer 44, detector 50 will be detecting energy passed by said filter of over-neutralized characteristics, whereas detector 30 60 will be detecting energy passed directly by 30, that is, energy passed by a filter having an unneutralized characteristic.

The diode resistors 61 and 63, which are properly by-passed as shown, are connected in series so as to properly combine the detected outputs from the two transformers 44, 58. The resultant energy from these two resistors 61 and 63 is fed to an automatic frequency control tube (for simplicity, not shown here) which in turn may control the tuning of the high frequency oscillator used to convert the received energy to intermediate frequency. Similar control circuits have been disclosed in my prior United States applications #124,967 filed February 10, 1937, Patent #2,065,565 dated December 29, 1936, and Patent #2,085,008 dated June 29, 1937. Potentials from 61 and 63 are also fed to an audio frequency amplifier to produce the output characteristic of the phase modulations on the received wave.

In order to receive amplitude modulated wave energy and demodulate the same, I make use of an additional crystal in series with the un-neutralized crystal effect as disclosed in my United States Patent #2,085,008 dated June 29, 1937, application #138,116 filed April 21, 1937, and application #138,117 filed April 21, 1937. Thus, a variable airgap crystal holder and crystal 64 is connected to the high potential side of winding 59 of transformer 58 so as to be fed or excited by un-neutralized filtered energy passed by crystal 30. The crystal 64 feeds this energy to a diode detector 66. This branch circuit is, as stated above, used to demodulate amplitude modulations on the received wave and may be used for monitoring purposes when phase modulated waves are received and to render the signal when amplitude waves are received. Amplitude modulation fed into the intermediate frequency input terminals connected with 10 are converted to phase modulation by the crystal 30 and its following amplifier 1 and impressed on transformer 58. The variable airgap crystal and holder 64 is adjusted so as to synchronize its resonance with that of the crystal 30 and in this way the phase modulation present at transformer

58 is converted to amplitude modulation for detection in detector 66. The choke coil 68 furnishes a direct current circuit for the detector 64 and resistor 69 is the diode detector resistor. The drop of potential across 69 is fed to the audio amplifier circuit when the receiver is receiving amplitude modulation signals. The process of this detection of amplitude modulation signals will be clear from the following description of the operation of the complete receiver and has also been set forth completely in my United States Patent #2,085,008 dated June 29, 1937, application #138,116 filed April 21, 1937, and application #138,117 filed April 21, 1937.

In the operation of the receiver of Figure 1 two filter characteristics are produced to be fed to the two diode detectors 50 and 60. The energy fed from the crystal output terminal to amplifiers 1 and 2 is un-neutralized crystal energy and has a characteristic as shown in Figure 2A. This energy appears in transformer 58. The characteristic of the energy present in transformer 44 is as shown in Figure 2E, being derived from a filter of the over-neutralized type such as is obtained by over-neutralizing 30 by means of 32. This is obtained by adjusting condenser 32 so that its capacity is greater than that of the crystal holder which holds crystal 30. These two crystal filter characteristics as shown in Figures 2A and 2E have reactance characteristics as shown in Figures 2B and 2F respectively. In the case of Figure 2B a negative reactance is present on both sides of the carrier frequency, that is, the circuit would be capacitive on both sides of the carrier except for the very short interval near the carrier frequency. Since the reactance is capacitive in the frequency region in which the side bands are disposed and is resistive at the carrier frequency, the phase of the side bands will be shifted 90° with respect to the carrier. In Figure 2C the carrier and side bands of a phase modulated wave are shown. The carrier is marked C, the upper side band U and the lower side band L. The positive direction of rotation is taken as clockwise and the directions of rotation of the side bands with respect to the carrier are indicated by arrows attached to the side band vectors. Side bands of an order greater than 1 have been neglected due to their small amplitude and for simplicity of explanation. When the phase modulated wave of Figure 2C is passed to the crystal filter having the characteristic of Figure 2A and the reactance characteristic of Figure 2B the side bands are shifted 90° with respect to the carrier so that the side band relation shown in Figure 2D is effected. With the relation of 2D between the carrier and side bands, the wave is an amplitude modulated wave. There would also be an attenuation of the side bands which is not shown in Figure 2D. This conversion of the phase modulated wave to an amplitude modulated wave takes place in 17, 30 and 1 and the converted energy appears in 58.

The energy present in transformer 44, is passed by 30 and 32 comprising a filter having an over-neutralized characteristic and having an input-output characteristic as shown in Figure 2E and having a reactance characteristic as shown in Figure 2F. Thus, the reactance of this last filter is positive or inductive on both sides of the carrier frequency except for a short interval near the carrier frequency. Consequently the side bands are shifted 90° in phase by this filter also but in an opposite direction to the shift produced by filters having the characteristics shown in 75

Figures 2A and 2B. Hence, the phase modulated wave as shown in Figure 2G is converted to the amplitude modulated wave as shown in Figure 2H. From an examination of Figure 2D and Figure 2H it can be seen that the side bands are approaching cancellation of the carrier in Figure 2D and are approaching aiding the carrier in Figure 2H. Thus, the envelope of the amplitude modulations produced by the two filters having characteristics as shown above, are 180° apart and their detected output must be combined in a push pull or series combination to reproduce the converted modulations instead of a parallel combination. This combination is effected in the diode circuit of Figure 1 by reversing the connections of one of the diode resistors 16 and 17 as shown and connecting the same in series to produce the receiver output. Unwanted amplitude modulations on the wave received which is not converted to phase modulations by the action of 30 as described herein and in my United States Patent #2,085,008 dated June 29, 1937, have the same or substantially the same effect on the energies passed by both filters and consequently due to the phase displaced combination of energies cancel each other more or less completely. The unwanted amplitude modulations which are converted to characteristic phase modulations have no effect in the diode detectors 50 and 60. By an examination of the filter characteristics of Figures 2A and 2E it can be seen that when the carrier frequency drifts the relative amplitudes of the two filter outputs vary differentially. That is, as the frequency drifts lower the output of the filter of Figure 2E approaches the dip point whereas the output of the filter of Figure 2A reduces more gradually. This results in a differential action which produces differential detected energy which may be used for automatic frequency control purposes.

When the receiver of Figure 1 is adjusted to receive amplitude modulation, two filters having a characteristic as shown in Figure 2A are cascaded. The first one of these filters, say 30, converts the amplitude modulated wave such as might be portrayed by Figure 2D into a phase modulated wave such as might be portrayed by Figure 2C and the second of these two filters, say 64, converts this phase modulated wave back to a wave such as shown in Figure 2D. Thus, conversion is made from amplitude modulation to phase modulation and thence back to amplitude modulation with a resultant carrier exaltation. This carrier exaltation with its attendant advantages with regard to selective fading would be the advantage effected by this type of amplitude modulation reception.

In Figure 3 I have shown a complete circuit arranged in accordance with the present invention. Here, wave energy modulated in phase or amplitude is picked up on an aerial T and fed by way of amplifiers to a first detector D of a superheterodyne receiver having a source of local oscillations O which are beat with the incoming wave to produce characteristic wave energy of intermediate frequency. The output of detector D feeds the energy of reduced frequency to an intermediate frequency amplifier and filter E. The radio frequency amplifier and/or the intermediate frequency amplifier E may include limiters if desired when phase modulated wave energy is being received. The output of the intermediate frequency amplifier and filter E is connected with a resistor 80 of a potentiometer, the movable tap of which is connected to the control

grid 82 of an electron discharge tube 83 having its anode connected to the primary winding 10 of the transformer 17. The winding 10 is tuned, as described in connection with the Figure 1, by a condenser 20 and shunted by a resistance 18. Condenser 20 is supplemented by a fixed condenser 84. Self-bias for the tube 83 is obtained by a resistor 85, while by-passing condensers are used in the conventional manner.

The secondary winding of transformer 17 and the following circuits through tubes 2' and 3' to the double diode rectifier tube 90, which in this case replaces the two diode rectifiers 50 and 60 of Figure 1, are substantially similar to those in Figure 1, differing therefrom only in detail and circuit refinement, such as for example, the tuned impedance coupling 44' which replaces the transformer 44 of Figure 1. Phase modulated energy to be demodulated is fed from 30 to coupling tube 2 and neutralizing energy is fed through 32 to tube 3 and supplied to 44' and thence to one side of the double diode 90'. If condenser 32 is adjusted to over-neutralize the capacity of the holder of 30 the characteristics of the circuit will be as shown in Figures 2E and 2F and will convert the phase modulations to amplitude modulations as shown in Figures 2G and 2H. This circuit A may be under-neutralized instead of over-neutralized, in which case the upper circuit now to be described will be over-neutralized. In place of using a single tube 1 to derive and feed energy from 30 by an un-neutralized circuit to coupling 58' and thence to the other side of 90, in the sake of flexibility I use another circuit B similar in all respects to A except that where A is over-neutralized as suggested above, B is under-neutralized by 32' so that its characteristics are as shown in Figures 2A, 2B, 2C, and 2D.

The rectifier 90 replaces the diode rectifiers 50 and 60. The diode resistors 61 and 63 supply energy by a switching means PM to an output amplifier comprising a tube to an audio frequency output amplifier comprising a tube 100 resistively coupled in a conventional manner to 61 and 63 at its input and impedance coupled at its output to a transformer feeding energy to indicating devices by way of parallel jacks in a manner known in the art.

The rectified potentials appearing in resistors 61 and 63 also supply energy by way of a switch AFC to a time constant circuit 110 and from such circuit to the local oscillator O by way of a modulator M in the form of a reactance tube 130 to control the frequency of the oscillator O. Similar arrangements have been shown in my United States application #124,967 filed February 10, 1937, Patent #2,065,565 dated December 29, 1936, and Patent #2,085,008 dated June 29, 1937, and application #136,578 filed April 13, 1937. The oscillator O is of the grounded grid type and includes a tube 132 having its grid 134 and anode 135 coupled in a frequency stabilizing and determining regenerative circuit 138 as shown. The grid end of the circuit is grounded for radio frequency since the grid leak 140 is shunted by a bypass condenser 142. The reactance tube 130 has its anode 144 coupled to its grid 146 by phase shifting condenser 148 and resistance 149. Anode 144 is also coupled to the high potential end of 138 while the cathode 150 is grounded by a biasing resistance 152 shunted by a bypass condenser 154. The value of 149 is high as compared to the reactance of 151 for the frequency used so that the current through the circuit is largely

resistive and is in phase with the voltage. However, the voltage drop through 151 leads the current by substantially 90° and the phase quadrature relation between the radio frequency potentials on 144 and 146 necessary for the reactive effect is obtained. The tube reactance shunts the circuit 138 and consequently the reactance tube controls, to some extent, the frequency of oscillations of 132 and 138. This reactive effect, which may be considered inductive or capacitive, is in turn controlled by the potential supplied from time constant circuit 110 to the grid 153 of reactance tube 130. The potential supplied to 153 is a function of the mean frequency of the intermediate frequency energy supplied by 58' and 44' changing as the intermediate frequency drifts in either direction from this mean frequency. Such drift may be caused by change in frequency of the received wave or of the frequency of oscillator O or both and results in a correcting change in the reactance reflected by the reactance tube 130 into the circuit 138 or a part thereof. Since the plate 144 is connected to the plate 136 and the grid 146 is excited by voltage displaced in phase relative to that in the circuit 138, the plate current in 130 is likewise out of phase with the voltage of 138 and the control tube 130 looks like a reactance to the circuit 138.

A reactance tube somewhat similar to the one described above has also been shown in my United States application #209,919 filed May 25, 1938. The shifts of the mean intermediate frequency act through 58', 44', 90, 61 and 63 to produce potentials of a nature determined by the extent of said drift and these potentials act through the time control circuit 110 to produce characteristic reactance changes in tube 130 which appear in 138 to produce a correcting shift in the frequency of the oscillations produced by oscillator O and supplied to detector D.

In Figure 3 the variable airgap of crystal 63 is shown with switching means S to shunt the same out of the circuit. With Y open tube 2 becomes ineffective to pass filtered energy from 30 to 44 and we have a circuit responsive to amplitude modulated waves from 12 through 32 and 3 to 44, 64 with S closed and to detector 66. The output of diode 66 is connected by a switch AM to the amplifier, including tube 100. When phase modulation is to be received PM and Y are closed and AM is opened. When amplitude modulation is to be received by conversion to phase modulation in 30 and back to amplitude modulation in 64, AM and Y are closed and PM and S are opened. When conventional amplitude modulation reception is to be used PM and Y are opened and AM and S are closed.

In operation for phase modulation reception, wave energy is received in the heterodyne receiver, reduced in frequency, amplified in 83 and impressed on 12. Wave energy from 12 is fed to crystal 30 and neutralizing condenser 32. Tubes 2 and 3 operate as described in connection with Figure 1, being excited by unneutralized energy from 30 and over-neutralizing energy from 32 respectively, to produce converted energy having an envelope of one phase in the coupling 44. Tubes 2' and 3' energized in like manner through the under-neutralized circuit, produce converted energy having an envelope of opposite phase in coupling 58. These two converted energies of opposed envelopes are impressed on the diode rectifier 90 to produce in 61 and 63 potential variations characteristic of the phase modulations on the waves when phase modulation is received.

These potentials are impressed on 100 and appear in the transformer output.

Slow variations in frequency of the intermediate frequency energy also set up potentials on 61 and 63 which are permitted to act through time constant circuit 110 on the frequency control modulator M and local oscillator 100 to correct the frequency in the manner described above.

When amplitude modulated waves are to be received the energy passed by 30 in series with 21, the coupling 44' and crystal 64 produce amplitude modulation components in 66 which are impressed in 100 and appear in the output transformer.

The first coupling tube 83 feeds a push pull transformer which in turn feeds energy to the crystal. Two sets of coupling tubes 2 and 3, and 2' and 3', marked A and B respectively, enable a flexible neutralizing system of the coupling tube type as has been described in my United States Patent #2,085,008 dated June 29, 1937. The tube 2' at the top of the diagram is fed crystal energy and the next tube 3' is fed neutralizing energy through the small tuning condenser 32'. These two tubes have their outputs combined in the impedance coupling 58' which feeds one of the plates of the dual diode 90. The lower two coupling tubes 2 and 3 marked A, perform the same function and feed the other diode plate of the dual diode 90. Since the neutralization is effected through coupling tubes a flexibility with respect to neutralization is effected such that the upper pair of tubes might pass over-neutralized energy and the lower pair under-neutralized or this function might be interchanged.

A variable airgap crystal 64 feeds energy to a second detector 66 which is used for amplitude modulation detection by means of a switch AM. The input of the audio amplifier 100 is switched to the phase modulation connection marked PM or to the amplitude modulation connection marked AM. The differential output obtained from the diode resistors 61 and 63 in series is thus used to produce the output potentials and is passed through the switch marked AFC and through the time constant circuit to the frequency control tube of the heterodyne detector.

Although I have shown converting circuits which include under- and over-neutralized filters of the crystal type, it will be understood that I contemplate the use of filters of any type to which can be imparted the general characteristics described and illustrated in Figures 2A to 2H inclusive.

I claim:

1. In a system for demodulating wave energy modulated in phase at signal frequency comprising a carrier and sideband frequencies, a filter circuit having a characteristic which is reactive in the same sense with respect to a band of sideband frequencies lying on both sides of the frequency to which the filter is resonant, a filter circuit the characteristic of which is reactive in the same sense but opposite to the sense of the aforesaid filter with respect to a band of sideband frequencies lying on both sides of the frequency to which the filter is resonant, means for applying phase modulated wave energy of a mean frequency substantially equal to said resonant frequency to said filter circuits, and means for detecting and combining the outputs of said filter circuits.

2. In a system for demodulating wave energy modulated in phase at signal frequency comprising a carrier and sideband frequencies, a filter

circuit having a characteristic which is reactive in the same sense substantially from the resonant frequency of the filter to the lowest sideband frequency and from the resonant frequency of the circuit to the highest sideband frequency, a filter circuit the characteristic of which is reactive in the same sense but opposite to the sense of the aforesaid filter substantially from the resonant frequency of the filter to the highest sideband frequency and from the resonant frequency of the circuit to the lowest sideband frequency, means for applying modulated wave energy of a mean frequency substantially equal to said resonant frequency to said filter circuits, and means for detecting the outputs of said filter circuits.

3. In a system for demodulating wave energy modulated in phase at signal frequency comprising a carrier and sidebands, a filter circuit having a uniform amplitude characteristic between the lowest sideband frequency and a lower sideband frequency adjacent the carrier, a rising characteristic from said sideband frequency adjacent to the carrier frequency, a falling characteristic from the carrier to an upper sideband frequency adjacent said carrier, a rising characteristic from said last adjacent upper sideband frequency to a still higher sideband frequency and a uniform amplitude characteristic from said higher sideband frequency to the highest sideband frequency, a second filter circuit having a uniform amplitude characteristic between the lowest sideband frequency and a lower sideband frequency adjacent the carrier, a falling characteristic from said last lower sideband frequency adjacent the carrier frequency to a frequency still nearer to the carrier frequency, a rising characteristic from said last named frequency to the carrier frequency, a falling characteristic to an upper sideband frequency adjacent said carrier, a falling characteristic from said last adjacent upper sideband frequency to a still higher upper sideband frequency and a uniform characteristic from said last upper sideband frequency to the highest sideband frequency, means for impressing modulated wave energy on said filters, and means for deriving wave energy from said filters and demodulating the same.

4. In a system for converting phase modulated wave energy comprising a carrier and sidebands to characteristic amplitude modulated wave energy, a band pass filter tuned to resonant at substantially the carrier frequency having a substantially uniform amplitude characteristic for all frequencies except the carrier which is exalted and a narrow band of frequencies on each side of said carrier, said filter substantially attenuating a narrow band of side band frequencies on one side of said carrier, a second band pass filter tuned to resonate at substantially the carrier frequency having a substantially uniform amplitude characteristic for all frequencies except the carrier which is exalted and a narrow band of frequencies on each side of said carrier, said second filter substantially attenuating a narrow band of sideband frequencies on the other side of said carrier, and means for impressing phase modulated wave energy on said filters and deriving converted energy from said filters.

5. In a system for converting phase modulations on wave energy to characteristic amplitude modulations and detecting the same, a filter circuit which is capacitive on both sides of the frequency to which it is resonant as to a frequency spectrum of the order of a modulation frequency

band, a second filter circuit which is inductive on both sides of the frequency to which the filter circuit is resonant as to a frequency spectrum of the order of a modulation frequency band, means for impressing phase modulated wave energy on both of said filters, means for deriving converted wave energy from the output of said filters and detecting the same, and means for combining the detected energies.

6. In a system for converting phase modulations on wave energy to characteristic amplitude modulations and detecting the same, an over-neutralized filter circuit comprising a crystal in a crystal holder, said circuit being capacitive on both sides of the frequency to which it is resonant as to a frequency spectrum of the order of a modulation frequency band, an unneutralized filter circuit comprising a crystal in a crystal holder, said last circuit being inductive on both sides of the frequency to which the filter circuit is resonant as to a frequency spectrum of the order of a modulation frequency band, means for impressing wave energy on both of said filter circuits, means for deriving wave energy from said filter circuits, and means for detecting the wave energy derived from said filter circuits.

7. In a wave filtering system, two output circuits, a tuned reactance, a piezo electric crystal in a holder, a plurality of coupling tubes each having input and output electrodes, means connecting the input electrodes of one coupling tube to an electrode of said crystal and the output electrodes of said one coupling tube to one of said output circuits and an electrode of said crystal to said tuned reactance, said means and elements connected, thereby forming an unneutralized filter circuit for transferring energy from said reactance to one of said output circuits, and means for connecting the input electrodes of another of said coupling tubes to said crystal electrode and the input electrodes of a third coupling tube to said reactance and the output electrodes of said third coupling tube to said reactance and the output electrodes of said crystal to the other output circuit and an electrode of said crystal to said tuned reactance, said last means and elements connected thereby forming an over-neutralized filter for transferring over-neutralized energy to said output circuit.

8. In a wave energy filtering system, a crystal in a crystal holder, output circuits, a circuit responsive to wave energy to be filtered connected to said crystal, a pair of coupling tubes coupling said crystal and last circuit to one of said output circuits, one of said coupling tubes passing filtered energy and the other passing energy to over-neutralize said crystal holder, a second pair of coupling tubes coupling said wave energy responsive circuit and crystal to the other output circuit one of said last coupling tubes passing filtered energy and the other passing energy to under-neutralize said crystal holder.

9. In a phase modulation receiver the combination of a detecting circuit, a crystal in a holder, means connecting said crystal and holder in an under-neutralized filter circuit resonant substantially at the mean frequency of the phase modulated wave energy to be received, means connecting said crystal and holder in an over-neutralized filter circuit substantially resonant at the mean frequency of the wave energy to be received, means for impressing phase modulated wave energy on said filter circuits, and means for impressing resulting energy from said filter circuit on said detecting circuit.

10. In a system for converting phase modulations on wave energy to characteristic amplitude modulations and detecting the same, a filter circuit which is capacitive on both sides of the frequency to which it is resonant as to a frequency spectrum of the order of a modulation frequency

tions on wave energy into characteristic amplitude modulations and for simultaneously substantially completely suppressing any undesired amplitude modulations on said wave energy, a reactance tuned to the mean frequency of said modulated wave energy, a piezo electric crystal in a holder, one terminal of which is connected to said reactance, a rectifying system having input and output electrodes, an electron discharge tube having input electrodes connected to the other crystal holder terminal and having output electrodes coupled by circuits adapted to pass a band of frequencies to the input electrodes of said rectifying system, a pair of electron discharge tubes, one of said pair of tubes having input electrodes coupled to the said other holder terminal of said crystal and the other having input electrodes coupled to said reactance, both tubes having output electrodes coupled by circuits adapted to pass a band of frequencies to the input electrodes on said rectifying system, and a utilization circuit coupled to the output electrodes of said rectifying system.

11. In a system for demodulating phase modulated wave energy and simultaneously substantially suppressing undesired amplitude modulations, a reactance on which wave energy to be demodulated is impressed, a rectifier system having input and output electrodes, a piezo electric crystal in a holder, coupling circuits including said crystal and holder unneutralized coupling said reactance to the input electrodes of said rectifier system, coupling circuits including said crystals and holder over-neutralized coupling said reactance to the input electrodes of said rectifier system, and a utilization circuit coupled to the output electrodes of said rectifier system.

12. In a system for converting wave modulations on wave energy to characteristic amplitude modulations and simultaneously substantially suppressing undesired amplitude modulations on said wave energy while demodulating the same, a reactance on which phase modulated wave energy is impressed, a rectifier system having input and output electrodes, a piezo electric crystal in a holder, an electron discharge tube coupling circuit including said crystal and holder unneutralized coupling said reactance to the input electrodes of said rectifier system, an electron discharge coupling circuit including said crystal and holder over-neutralized coupling said reactance to the input electrodes of said rectifier system, and a utilization circuit coupled to the output electrodes of said rectifier system.

13. In a system for demodulating phase modulated wave energy and simultaneously substantially suppressing undesired amplitude modulations on said wave energy and for maintaining the tune of said system substantially constant during such operations, a receiving system of the heterodyne type including a first detector, a tunable oscillator coupled thereto and an intermediate frequency amplifier coupled to the detector, a reactance coupled to the intermediate frequency amplifier, a rectifier system having input and output electrodes, a piezo electric crystal in a holder, a coupling circuit including said crystal and holder unneutralized coupling said reactance to the input electrodes of said rectifier system, a coupling circuit including said crystal and holder over-neutralized coupling said reactance to the input electrodes of said rectifier system, a utilization circuit coupled to the output electrodes of said rectifier system, and a frequency control

circuit coupling the output electrodes of said rectifier system to said local oscillator.

14. In a system for demodulating wave energy modulated in phase or in amplitude in accordance with signals, a reactance tuned to the mean frequency of said wave energy, a piezo electric crystal in a holder, a rectifier system having input electrodes and having output electrodes, an output circuit, a plurality of coupling tubes having input and output electrodes, means including said crystal and a second reactance for over-neutralizing the crystal holder capacity connecting the input electrodes of a pair of said tubes to said first reactance and the output electrodes of said pair of tubes to the input electrodes of said rectifier system, means including a third reactance for under-neutralizing the crystal holder capacity connecting the input electrodes of another pair of said coupling tubes to said first reactance and the output electrodes of said other pair of coupling tubes to the input electrodes of said rectifying system, a crystal in a holder having one terminal connected to the output electrodes of one of said coupling tubes, and switching means for coupling the output electrodes of said rectifier system to said output circuit when phase modulated wave energies are to be received and for coupling the other terminal of said second crystal holder through a second rectifier system to said output circuit when amplitude modulated wave energy is to be received.

15. In a system for converting phase modulated wave energy to characteristic amplitude modulated wave energies with envelopes of opposed phase and demodulating and combining the same to substantially eliminate or cancel undesired amplitude modulations on said wave energy, a reactance excited by said wave energy, a rectifier system having symmetrical input electrodes and a common output circuit, a piezo electric crystal in a holder, a pair of electron discharge coupling tubes having input and output electrodes, means connecting the output electrodes of said pair of tubes together and to one of the input electrodes of said rectifier system, circuits including said crystal and a variable capacity for over-neutralizing the capacity of said crystal holder coupling the input electrodes of said pair of tubes to said reactance, a second pair of coupling tubes having input and output electrodes, a circuit connecting the output electrodes of said second pair of tubes together and to the other of input electrode of said rectifier system, and circuits including said crystal and a variable condenser for under-neutralizing the capacity of said crystal holder coupling the input electrodes of said second pair of tubes to said reactance.

16. In a system for converting phase modulated wave energy to characteristic amplitude modulated wave energies with envelopes of opposed phase and demodulating and combining the same to substantially eliminate or cancel undesired amplitude modulations on said wave energy, a reactance excited by said wave energy, a rectifier system having symmetrical input electrodes and a common output circuit, a piezo electric crystal in a holder, an electron discharge coupling tube having input and output electrodes, means connecting the output electrode of said tube to one of the input electrodes of said rectifier system, a circuit including said crystal and holder coupling the input electrode of said tube to said reactance, a pair of coupling tubes having input and output electrodes, a circuit connecting the output electrodes of said second pair of tubes to-

gether and to the other input electrode of said rectifier system, and circuits including said crystal and a variable reactance for over-neutralizing the capacity of said crystal holder coupling the input electrodes of said second pair of tubes to said reactance.

17. In a system for demodulating wave energy modulated in phase at signal frequency comprising a carrier and sideband frequencies, a circuit having a characteristic which is reactive in the same sense with respect to a band of sideband frequencies lying on both sides of the frequency to which the circuit is tuned, a circuit having a characteristic which is reactive in the same sense but opposite to the sense of the aforesaid circuit with respect to a band of sideband frequencies lying on both sides of the frequency to which the circuit is tuned, means for applying phase modulated wave energy of a mean frequency substantially equal to the frequency to which said circuits are tuned to said circuits, and detecting means coupled with said circuits.

18. In a system for demodulating wave energy modulated in phase at signal frequency comprising a carrier and sideband frequencies, a circuit having a characteristic which is reactive in the same sense substantially from the resonant frequency of the circuit to the lowest sideband

frequency and from the resonant frequency of the circuit to the highest sideband frequency, a circuit the characteristic of which is reactive in the same sense but opposite to the sense of the aforesaid circuit substantially from the resonant frequency of the circuit to the highest sideband frequency and from the resonant frequency of the circuit to the lowest sideband frequency, means for applying modulated wave energy of a mean frequency substantially equal to said resonant frequency to said circuits, and means for detecting the outputs of said circuits.

19. In a system for converting phase modulations on wave energy to corresponding amplitude modulations, a filter circuit which is capacitive on both sides of the frequency to which it is resonant as to a frequency spectrum of the order of a modulation frequency band, a second filter circuit which is inductive on both sides of the frequency to which the filter circuit is resonant as to a frequency spectrum of the order of a modulation frequency band, an impedance on which phase modulated wave energy may be impressed, pairs of output terminals, and means connecting said impedance and each of said filters in a circuit including pairs of said output terminals.

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