April 2, 1946.

M. G. CROSBY

2,397,841

PHASE MODULATION DETECTOR

Filed April 3, 1943

2 Sheets-Sheet 1

Fig. 1.

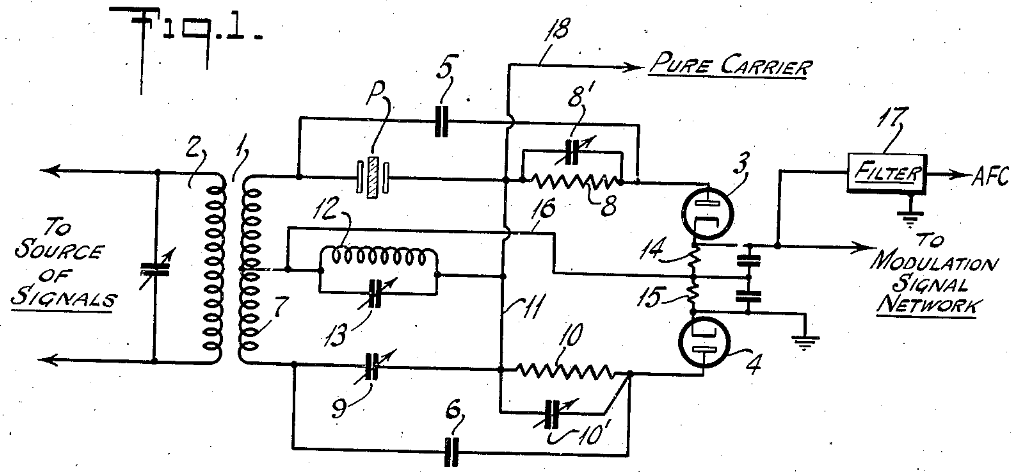

Fig. 2a.

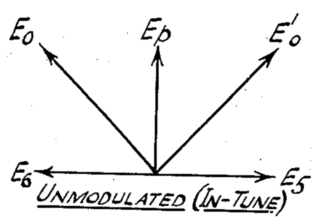

Fig. 2b.

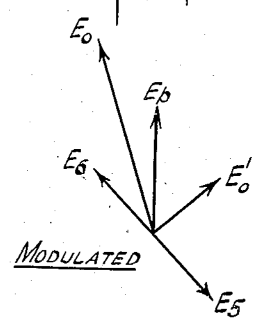

Fig. 2c.

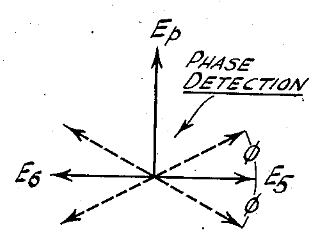

Fig. 2d.

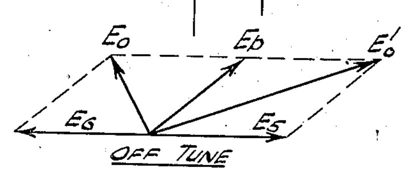

Fig. 3.

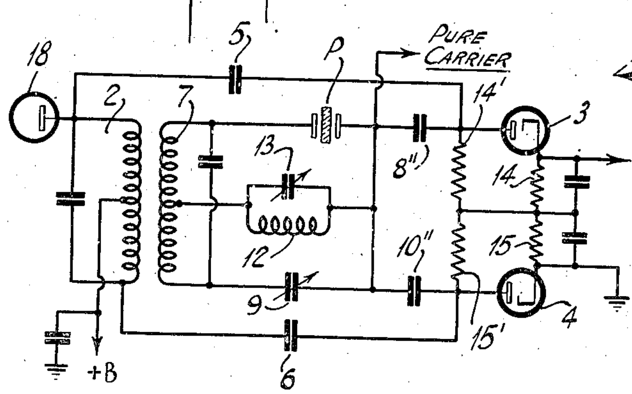

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Fig. 4.

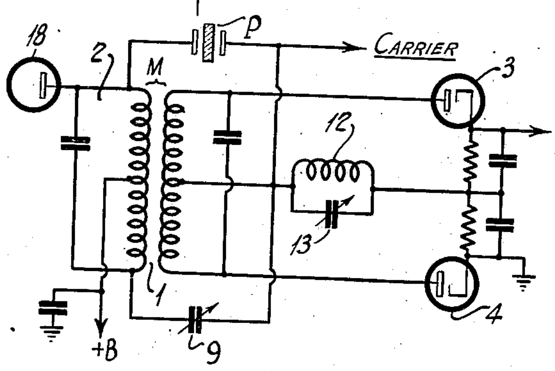


Fig. 4a.

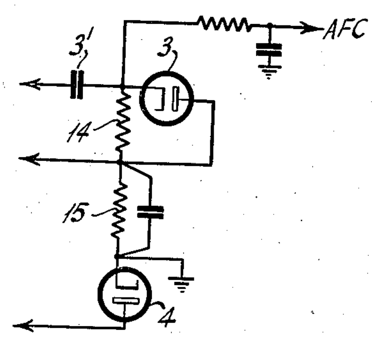


Fig. 5.

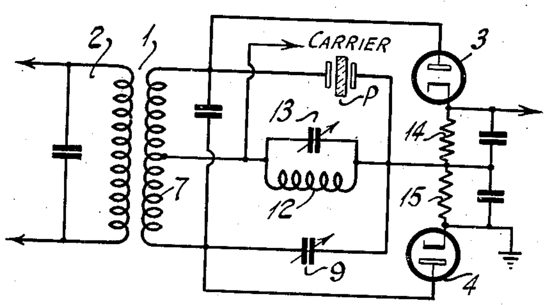


Fig. 5a.

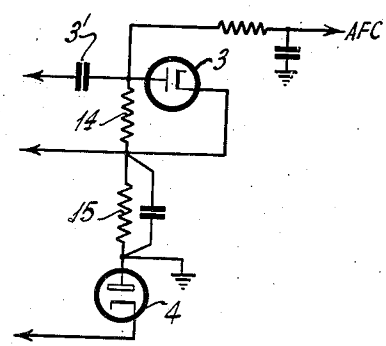
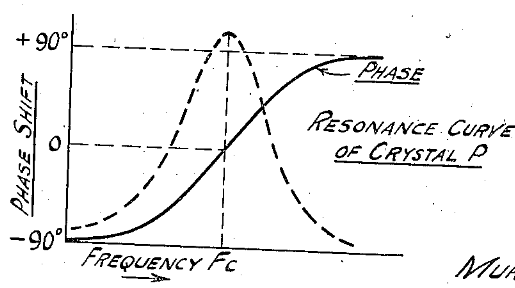


Fig. 1a.



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UNITED STATES PATENT OFFICE

2,397,841

PHASE MODULATION DETECTOR

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Application April 3, 1943, Serial No. 481,691

14 Claims. (Cl. 250—27)

My present invention relates to phase modulation detector circuits, and more particularly to improved forms of a phase modulation detector of the piezo-electric crystal type.

In the past I have disclosed various circuits for utilizing the inherent properties of a simple crystal filter to convert phase modulation of carrier energy into amplitude modulation for detection. For example, in "Communication by Phase Modulation," Proceedings of the I. R. E., for February 1939 (pages 126 to 136), I have shown a crystal filter phase modulation translating network, and have explained the operation thereof on the basis of over and under-neutralization of crystal holder capacitance.

It is one of the main objects of my present invention to provide improved and modified types of crystal filter phase modulation ("PM" hereinafter for brevity) detectors, in each type, or form, of circuit the basic functioning being considered as involving the application to each of a pair of opposed rectifiers the resultant of crystal-filtered carrier-energy and modulated carrier energy in normal phase quadrature relation at resonance.

Another important object of my present invention is to detect PM wave energy by a process which involves passing the PM energy through a piezo-electric crystal filter to secure substantially unmodulated carrier energy, applying the unfiltered PM wave energy to a pair of opposed rectifiers, shifting the relative phase between the filtered and unfiltered energy to quadrature relation for the resonance condition, and applying the filtered energy to the rectifiers thereby to cause each rectifier to rectify its respective vector resultant energy.

Another object of my invention is to provide a PM wave energy detection network for PM wave energy or AM (amplitude modulation) wave energy, the network being capable of providing automatic frequency control (AFC) voltage, substantially pure carrier energy for carrier exaltation, and modulation signal voltage.

Yet another object of my invention is to provide a device for controlling the selectivity of a crystal filter circuit feeding opposed rectifiers of PM carrier wave energy.

Other objects of my invention are to improve generally the construction and operation of PM or AM detectors of the crystal filter type, and more especially to provide such detectors in a simple and economically-manufacturable form.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description, taken in connection with the drawings, in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 shows one embodiment of the invention,

Fig. 1*a* graphically shows the phase shifting characteristic of the crystal,

Figs. 2*a* and 2*b* show vector relations between the filtered and unfiltered signal energy for the unmodulated and modulated states respectively,

Fig. 2*c* vectorially explains the manner of phase detection from another viewpoint,

Fig. 2*d* shows the vector relations between the filtered and unfiltered signal energy for a condition of off-tune, or off-resonance,

Fig. 3 shows a modification of the circuit of Fig. 1,

Figs. 4 and 4*a* show two further modifications,

Figs. 5 and 5*a* illustrate two additional modifications.

Referring to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 one form of a detector circuit which embodies the features of the present invention. The detector network is provided with an input transformer 1 whose primary circuit 2 is resonated to the center, or mean, frequency of the applied modulated carrier wave energy. Since the present invention is not in any way concerned with the source of the signal energy, the circuits prior to the primary circuit 2 are not shown in the drawings. The signals applied to the input transformer 1 may be PM, or AM, signal waves. Those skilled in the art are fully aware of the various networks which could be employed prior to circuit 2. Particular reference is made to my aforementioned publication for a more specific disclosure of such prior networks, where the receiver is of the PM type.

It will be sufficient for the purposes of this application to assume that the detector circuit is employed in a PM receiver of the superheterodyne type, and that the carrier frequency of the transmitted PM wave energy will be some predetermined frequency in the high frequency band. For example, the band below 25 megacycles (mc.) is particularly desirable for the radiation of PM signals. In the superheterodyne form of reception, a local oscillation circuit is employed to reduce the mean frequency of the received PM carrier energy to an intermediate frequency (I. F.), and it is the PM signal energy at the I. F. mean value which is applied to the primary circuit 2. Hence, the circuit 2 is resonated to the I. F. mean value of the incoming PM wave energy. If desired, an amplitude modulation limiter stage may be employed prior to the circuit 2. The modulation signal output of the detector will then be truly representative of the phase deviations of the carrier, and not of the amplitude variations of the latter.

Considering, now, the detector circuit per se, it is first pointed out that the circuit comprises a pair of opposed rectifiers 3 and 4. These rectifiers are shown as of the diode type, since such rectifiers are simple in construction. However, the present invention is in no way limited to the particular types of tubes shown, nor, indeed, to the above-mentioned specific frequencies which have been specified. The anode of rectifier 3 is connected to one end of the secondary winding 7 of input transformer 1. The last-mentioned connection includes in series a piezo-electric crystal P and a resistor 8.

The crystal P is located between a pair of metallic electrodes in the usual fashion, and the crystal is tuned to the mean frequency of the applied signal energy. That is to say, the crystal P is tuned to the resonant frequency of the input circuit 2. The electrodes of the crystal may, if desired, be metal coats on the opposite faces. The resistor 8 may be shunted by an adjustable condenser 8', and the function of the latter will be explained at a later point. The anode of rectifier 4 is connected to the opposite end of the secondary winding 7 through a path comprising the capacity 9 arranged in series with resistor 10. Resistor 10 is shunted by variable condenser 10'. The right-hand terminal of condenser 9 is connected by lead 11 to the right-hand crystal electrode. Between the midpoint of winding 7 and the lead 11 there is connected a resonant circuit which comprises the coil 12 shunted by the adjustable condenser 13. Normally, the resonant circuit 12—13 is tuned to the mean frequency value of the applied PM signal energy. The output load resistors of the circuit are designated by numerals 14 and 15, and these resistors are connected in series between the cathodes of diodes 3 and 4. The cathode end of resistor 15 is established at ground potential, and each of resistors 14 and 15 is shunted by a carrier bypass condenser. The junction of resistors 14 and 15 is connected by lead 16 to the midpoint of the secondary winding 7.

A second path connects the anode of each rectifier to the respective end of winding 7. Thus, condenser 5 connects the anode of diode 3 to the upper end of winding 7, while the condenser 6 connects the anode of diode 4 to the lower end of winding 7. Modulation signal energy may be taken off from the cathode end of resistor 14. Furthermore, that same point of the output resistor may be tapped for AFC voltage in order to control the frequency of the local oscillator, as is well understood. Where AFC voltage is taken off from the cathode end of resistor 14, a modulation voltage filter, schematically represented by numeral 17, is inserted in the AFC output line. Substantially pure, or filtered, carrier energy is taken off from lead 18. The filtered carrier energy will have a frequency equal to the mean value of the applied PM signal energy. Such filtered carrier energy may be utilized for carrier exaltation detection in the manner disclosed in my U. S. Patent No. 2,063,588, granted December 8, 1936. In such case, the pure carrier energy is fed to a separate phase modulation, or AM, detector. It is not believed necessary to show the demodulator in such case, since those skilled in the art will readily understand that it can be a second PM detector whose input is taken from the input circuit 2 of Fig. 1. If desired, the filtering of the energy applied to crystal P may be such as to leave modulation from zero to about 200 cycles on the carrier.

In explaining the functioning of the circuit shown in Fig. 1, it is first pointed out that the condenser 9 is adjusted so as to neutralize the capacity between the metal electrodes of crystal P. Referring to Fig. 2a there is shown the vector relations existing between the retarded and unretarded voltages insofar as they affect the opposed rectifiers 3 and 4. The PM signal energy which passes through the crystal P is stripped of its modulation side bands, so that there is applied to the anode of each of rectifiers 3 and 4 virtually unmodulated carrier energy. The vector E_p represents this crystal-filtered carrier energy applied to the rectifiers. The path from the crystal to the rectifier 3 is through resistor 8, while the path from the crystal to the rectifier 4 is through lead 11 and resistor 10. It will, therefore, be seen that the filtered carrier energy at the output electrode of crystal P is applied in like polarity, or in parallel, to the anodes of the respective diode rectifiers 3 and 4. The passage of the filtered carrier energy through resistors 8 and 10 to the respective detector input electrodes is accomplished without phase shift since the coupling is totally resistive except for the effect produced by condensers 8' and 10'. The effect of condensers 8' and 10' is compensated for by detuning 12—13 as will be described later.

The unfiltered PM signal energy which passes to each of rectifiers 3 and 4 through condensers 5 and 6 respectively is shifted 90 degrees in phase by virtue of the capacity feed to the respective detector input electrodes. Furthermore, since these energies are taken from the opposite ends of the winding 7 they are applied to the opposed rectifiers 3 and 4 in polarity opposition. It will be noted that the midpoint of winding 7 is effectively at ground potential with respect to radio frequencies, because the lead 16 connects the midpoint to ground through resistor 15. The vectors E_6 and E_5 denote the voltages applied to rectifiers 4 and 3 respectively, and it will be seen that these vectors are in phase quadrature with the crystal-filtered carrier energy. This phase quadrature relation of the two voltages at each rectifier results from the fact that the unfiltered signal energy is applied to the rectifiers 3 and 4 by condensers 5 and 6 respectively which are sufficiently small to effect a 90 degree phase shift, and are, also, of substantially equal capacities so as to produce equal phase shifts both of the unfiltered carrier and of signal components. The condensers 5 and 6 are non-selective to phase or frequency variations of the unfiltered carrier, and, accordingly, permit all signal components to pass to the rectifiers 3 and 4. The crystal P, however, effects no phase shift at the carrier, but substantially removes the phase modulation of the signal, thereby restoring the carrier substantially to the phase and wave form which it had before modulation at the transmitter. The crystal P is, of course, selective for frequencies off resonance. This follows from the sharp selectivity characteristic of the crystal, as depicted ideally in Fig. 1a.

The vector representing the resultant signal energy at each rectifier is also indicated in Fig. 2a. Thus, the vector E_0' represents the resultant energy applied to rectifier 3. The vector E_0 represents the resultant energy applied to rectifier 4. Fig. 2a depicts the situation when the mean frequency value of the applied PM signal energy is instantaneously equal to the frequency of circuit 2 and the frequency of the crystal P. The rectified outputs of each rectifier will, therefore, be equal, and the effective voltage at the cathode end of resistor 14 will, therefore, be zero. In other words, for the "in tune" state no AFC bias is developed.

In explaining the operation of this circuit, there are two separate conditions which must be considered. One is the case of the demodulation of a phase modulated signal, and the second is the case of the detection of slow frequency variations to obtain AFC potentials. These two cases represent two different degrees of modulation that are acted upon by the crystal filter in different manners. For the case of the relatively rapid modulation represented by the phase modulations of the signal, the filter acts as a device which selects the carrier from the side bands, and provides the equivalent of a synchronized local carrier free of modulation. When an unmodulated carrier is received there are delivered to each of diode rectifiers 3 and 4 voltages, one a filtered carrier from crystal P without phase change, and the other an unfiltered carrier substantially 90 degrees different in phase from the filtered carrier. When the received carrier is phase-modulated the filtered carrier remains as before, but the unfiltered signal energy is supplied to the rectifiers 3 and 4 in phases differing from the 90 degree, or quadrature, relation to an extent determined by the degree of phase modulation. If the degree of phase modulation is small, a relatively small direct current voltage is built up across rectifier output resistors 14 and 15 due to the signal voltage increasing on one of the rectifiers and decreasing on the other. The greater the degree of phase modulation the greater the combined voltage of the unfiltered signal energy and the filtered carrier from crystal P on one of the diode rectifiers, and the less the sum of such voltages on the other rectifier. The polarity of the direct current voltage drop across the load resistors 14 and 15 of the opposed rectifiers depends on the direction of the phase change of the received signal energy.

For the case of the relatively slow variations in frequency of the incoming signal, the crystal filter acts as a retard circuit having an output phase which varies with the frequency of the input. For this case, the circuit acts like a very narrow-band frequency modulation discriminator. The solid curve in Fig. 1a shows the "frequency vs. phase shift" characteristic of crystal P. At F_c, the center frequency, the crystal provides zero phase shift.

The vector diagrams of Figs. 2a, 2b and 2c show the conditions for the case of phase modulation detection. The filtered carrier, which is represented by vector E_p, remains fixed in phase. The unfiltered modulated signals, represented by vectors E_5 and E_6, vary in phase to produce differentially modulated resultants E_0 and E_0' which are fed to the opposed detectors. The manner in which the modulated signal varies in phase with respect to the filtered carrier is shown in Fig. 2c. A condition of modulation in one direction is shown in Fig. 2b. The unmodulated condition is shown in Fig. 2a.

The vector diagrams of Figs. 2a and 2d show the conditions for the case of AFC detection. Fig. 2a shows the "in-tune" condition which is effected when the applied signal carrier frequency is in the middle of the crystal filter characteristic. The diagram of Fig. 2d shows the relations for an "off-tune" condition. It will be noted that the carrier (or crystal output) phase shifts for the off-tune condition. This phase shift is brought about by the phase characteristic of the crystal, which is similar to that of an ordinary resonance circuit, as shown in Fig. 1a. The magnitude and sense of phase shift of the filtered carrier energy are respectively dependent on the amount and direction of frequency departure of the modulated carrier energy at circuit 2 relative to the predetermined frequency F_c. The latter is, of course, the resonant frequency of crystal P. The signal energy passing through condensers 5 and 6 will not shift in phase in response to carrier frequency departures from F_c. This follows from the fact that condensers 5 and 6 are non-selective elements. Hence, and as shown in Fig. 2d, the resultant vector voltages E_0 and E_0' will vary in relative magnitude depending on the extent and sense of the aforesaid frequency departure. These relative variations in E_0 and E_0' are translated into corresponding direct current voltage variations across load resistors 14 and 15, and the differential of these direct current voltages is used as AFC bias after filtering at 17. It is seen that the carrier phase for the off-tune condition is no longer in its proper quadrature relationship with the unfiltered signal so that it might be thought that the detection of phase modulation would be impaired. However, this off-tune condition is never allowed to exist to any appreciable degree, since the AFC circuit functions to correct the tuning and maintain it in the in-tune condition represented by Fig. 2a.

Winding 7 has its midpoint grounded, as pointed out above, and parallel resonant circuit 12, 13 connects the grounded midpoint of coil 7 to the lead 11 which connects the output electrode of the crystal P to the rectifiers. The circuit 12, 13 is, accordingly, in effect connected between the output side of crystal P and ground. Circuit 12, 13 may be tuned to crystal frequency, or may be detuned relatively thereto, and acts as a coupling circuit of finite impedance between the output of crystal P and the rectifiers 3 and 4. The circuit 12, 13 increases the "Q" of the crystal beyond what it would be if the resistance of circuit 12, 13 were infinite. By detuning resonant circuit 12—13 the phase of the filtered carrier energy can be shifted to a predetermined extent. This phase shift can be compensated by each shunt capacity 8' and 10'. Each of resistors 8 and 10 is, therefore, shunted by a respective compensation condenser. In this way, the selectivity of the crystal P may be improved without affecting the zero phase shift state of the filtered carrier energy. In other words, detuning the circuit 12—13 not only will cause a phase shift of the filtered carrier, but will also act to increase the selectivity of the crystal filter. If desired, resistor 8 and condenser 8' may be interchanged with condenser 5, and resistor 10 and condenser 10' may be interchanged with condenser 6. This would in no way affect the relative normal phase quadrature relation between the retarded and unretarded PM signal energy as depicted in Fig. 2a.

In Fig. 3 I have shown a modification of the arrangement in Fig. 1, wherein the resistors 8 and 10 are replaced by respective condensers 8'' and 10''. The unfiltered PM signal energy in that case is derived from the primary circuit 2. Since at resonance the primary voltage bears a phase quadrature relation with respect to the secondary voltage, it will be seen that the rectifiers 3 and 4 will have proper phase relations between the filtered and unfiltered signal energy. The numeral 18 designates an amplifier tube, or an amplitude limiter tube, whose plate circuit includes the resonant primary circuit 2. The +B energizing connection to the plate of amplifier 18 is made to the midpoint of the coil of circuit 2. Therefore, the unfiltered signal energy transmitted through condensers 5 and 6 respectively will be in polarity opposition when applied to the anodes of rectifiers 3 and 4. The selectivity control circuit 12—13 is connected in the same manner as shown in Fig. 1. The anode of each rectifier is connected to the junction of load resistors 14 and 15 through respective return resistors 14' and 15'.

In the arrangement of Fig. 4 the filtered carrier energy is derived from the primary resonant circuit 2. The unfiltered signal energy is shifted 90 degrees by virtue of the magnetic coupling M existing between the windings of the input transformer 1. In this case, the crystal P is connected between the upper end of the primary winding of the input transformer and the midpoint of the secondary winding. The condenser 9, connected between the midpoint of the secondary winding and the lower end of the primary winding functions to neutralize the crystal interelectrode capacity. The pure carrier energy is taken from the right-hand electrode of the crystal. Otherwise, the circuit functions in the same manner as described in connection with Fig. 1. It is sufficient to point out in connection with this modification that the filtered PM signal energy is applied to the anodes of rectifiers 3 and 4 in like polarity by virtue of the connection of the crystal to the midpoint of the secondary winding. On the other hand, the unfiltered signal energy is first shifted 90 degrees in phase by the magnetic coupling M, and the phase shifted energies are applied in polarity opposition to the anodes of the opposed rectifiers. It may happen that the circuit shown in Fig. 4 will give rise to second harmonics in the pure carrier energy taken off from the crystal P. This is brought about by full-wave rectified voltage, rectified from the secondary of transformer 1 and appearing across 12, 13.

In that case, the rectifiers 3 and 4 are reversed in connections to eliminate the full-wave connection, and cause the rectifier to conduct simultaneously instead of alternately and thereby suppress the production of second harmonics. This is done by connecting the load resistors 14 and 15 in the manner shown in Fig. 4a. The anode of rectifier 3 is connected to the junction of resistors 14 and 15, while the cathode of diode 3 is connected to the upper end of resistor 14. In other words, the only change that need be made in the circuit of Fig. 4 is that indicated with respect to resistor 14 and its associated diode 3. The diode-resistor condenser is no longer across resistor 14, but takes the form of condenser 3' inserted from the cathode of diode 3 to the connection leading to the upper end of the secondary winding of the input transformer.

In the modification shown in Fig. 5 the unfiltered modulated carrier energy is derived by inductive coupling from the primary circuit 2, and is applied to the rectifiers 3 and 4 from the transformer secondary circuit. Since the anode connections are made to the opposite ends of the secondary 7, whose midpoint is effectively connected to ground for radio frequencies, it will be seen that the unfiltered signal energy is applied to the opposed rectifiers in polarity opposition. The filtered carrier energy, however, is applied to the diodes in like phase. The filtered carrier energy is taken off from the left-hand terminal of 13—12. The filtered and unfiltered signal energ'es are both derived from the secondary circuit of the input transformer. However, the required 90 degrees phase shift is secured in this modification by deliberately detuning the resonant circuit 13—12. The detuning is so adjusted as to secure the 90 degrees phase retardation. Incidentally, the crystal selectivity is increased upon detuning of the resonant circuit. In other words, with a circuit of the form shown in Fig. 5 the network 12—13 not only functions as a phase shifter element, but also acts as a control element over the selectivity of the crystal filter.

In Fig. 5a there is shown the modification which is required in Fig. 5 such as to suppress the presence of second harmonics in the filtered carrier energy. In this case the anode of diode 4 is connected to the grounded end of load resistor 15, while the cathode will be connected to the lower end of secondary winding 7. The anode of diode 3 will be connected to the upper end of resistor 14, and its cathode will be connected to the junction of resistors 14 and 15. It will be noted that in both Figs. 4a and 5a the rectifiers are arranged to conduct simultaneously rather than alternately when fed by the push-pull secondary of transformer 1.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. A method of detecting modulated carrier energy which comprises removing substantially all the modulation from a portion of the energy, dividing the unmodulated energy into two portions of like polarity relation, dividing the original modulated energy into two additional portions of opposite polarity relation, displacing the relative phases between said two unmodulated portions and said two modulated portions to the extent of substantially 90 degrees at resonance, separately combining in pairs an unmodulated portion and modulated portion in phase displaced relation, separately rectifying the resultant of each of the combined pairs, and combining the rectification products of the separate rectification steps in opposition.

2. In a detector of modulated signalling energy, a signal input transformer having a primary resonant circuit tuned to the mean frequency of applied modulated signal energy, a secondary circuit including a piezo-electric crystal element tuned to the said mean frequency, a first rectifier, means connecting the rectifier electrodes in circuit with

said crystal element thereby to have the crystal output energy applied thereto, a second rectifier in circuit with the crystal element having said output energy applied thereto in like polarity, a common output circuit connecting said rectifiers in polarity opposition, separate connections from respectively separated points of the input transformer to the respective rectifiers for applying thereto unfiltered modulated signal energy, said separated points being of opposite polarity, and means for producing a normal phase quadrature displacement between the crystal output energy and the unfiltered energy.

3. In a detector of phase modulated signalling energy, a signal input transformer having a primary resonant circuit tuned to the mean frequency of applied signal energy, a secondary circuit including a piezo-electric crystal element tuned to the said mean frequency, a first rectifier, means connecting the rectifier electrodes in circuit with said crystal element thereby to have the crystal output energy applied thereto, a second rectifier in circuit with the crystal element having said output energy applied thereto in like polarity, a common output circuit connecting said rectifiers in polarity opposition, separate connections from respectively separated points of the input transformer to the respective rectifiers for applying thereto unfiltered phase modulated energy, said separated points being of opposite polarity, and a resonant circuit, normally tuned to said mean frequency, in circuit with the crystal element, said resonant circuit including means for adjusting its frequency whereby the phase relation between the crystal output energy and the unfiltered energy may be varied.

4. In a detector of phase modulated signalling energy, a signal input transformer having a primary resonant circuit tuned to the mean frequency of applied signal energy, a secondary circuit including a piezo-electric crystal element tuned to the said mean frequency, a first rectifier, means connecting the rectifier electrodes in circuit with said crystal element thereby to have the crystal output energy applied thereto, a second rectifier in circuit with the crystal element having said output energy applied thereto in like polarity, a common output circuit connecting said rectifiers in polarity opposition, separate connections from respectively separated points of the input transformer to the respective rectifiers for applying thereto unfiltered phase modulated energy, said separated points being of opposite polarity, said separate connections each including a condenser, and said separated points being on the primary resonant circuit to provide a normal phase quadrature displacement between said crystal output energy and the unfiltered energy.

5. In a detector of amplitude modulated signalling energy, a primary resonant circuit tuned to the mean frequency of applied signal energy, a secondary circuit including a piezo-electric crystal element tuned to the said mean frequency, a first rectifier, means connecting the rectifier electrodes in circuit with said crystal element thereby to have filtered output energy applied thereto, a second rectifier in circuit with the crystal element having said filtered energy applied thereto in like polarity, a common output circuit connecting said rectifiers in polarity opposition, separate connections from respectively separated points of the input transformer to the respective rectifiers for applying thereto unfiltered modulated energy, and means for producing a normal phase quadrature displacement between the filtered energy and the unfiltered energy at resonance.

6. In a detector of phase modulated or amplitude modulated signalling energy, a signal input transformer having a primary resonant circuit tuned to the mean frequency of applied signal energy, a secondary circuit including a piezoelectric crystal element tuned to the said mean frequency, a first diode rectifier, means connecting the diode electrodes in circuit with said crystal element thereby to have the crystal output energy applied thereto, a second diode rectifier in circuit with the crystal element having said output energy applied thereto, a common output circuit connecting said rectifiers, separate connections from respectively separated points of the input transformer to the respective rectifiers for applying thereto unfiltered phase modulated energy, said separate connections each including a condenser, and said separated points being on the primary resonant circuit to provide a normal phase quadrature displacement between said crystal output energy and the unfiltered energy.

7. A method of detecting phase modulated or amplitude modulated carrier energy which comprises removing substantially all the modulation from a portion of the energy by crystal filtering, dividing the filtered energy into two portions, separately dividing the original modulated energy into two additional portions, providing a phase shift between the filtered and unfiltered original energies such that the relative phases between said two filtered portions and said two unfiltered portions is substantially 90 degrees, combining the phase displaced portions in pairs, separately rectifying the combined pairs, and employing the differential resultant of the separate rectifications.

8. In a detector of modulated signalling energy, a signal input transformer having a primary resonant circuit tuned to the mean frequency of applied signal energy, a secondary circuit including a piezo-electric crystal element tuned to the said mean frequency, means for neutralizing the crystal inter-electrode capacitance, a first rectifier, means connecting the rectifier electrodes in circuit with said crystal element thereby to have the filtered crystal output energy applied thereto, a second rectifier in circuit with the crystal element having said filtered output energy applied thereto in like polarity, a common resistive output circuit connecting said rectifiers, said rectifiers being arranged to suppress second harmonics of the filtered energy, separate connections from respectively separated points of the input transformer to the respective rectifiers for applying thereto unfiltered modulated energy, said separated points being of opposite polarity, and said separated points being located on the transformer to provide a normal phase quadrature displacement between said crystal output energy and the unfiltered energy.

9. In combination in a signal transmission network having a pair of input terminals and a pair of output terminals, a first path coupling one input terminal to its corresponding output terminal, said path including a piezo-electric crystal element of a predetermined frequency, a second path in shunt with the first path and having a non-selective characteristic with respect to signals, and a resonant circuit, tuned substantially to said frequency, in circuit with said two paths, said resonant circuit including means for adjusting the frequency thereof thereby to control the selectivity of said crystal element path.

10. In combination in a frequency-sensitive system, a pair of rectifiers connected in opposition and provided with a common load circuit, a selective input circuit adapted to have applied thereto alternating currents of a predetermined frequency, and the improvement which comprises a highly selective path tuned to said frequency, said path having an input connection to said input circuit and at least two parallel output connections to respective ones of said rectifiers, a first non-selective path connected from a point of said input circuit to one rectifier, a second non-selective path connected from a different point of said input circuit to the second rectifier, and said two points on said input circuit being so chosen as to be of opposite polarity with respect to alternating currents.

11. In combination in a frequency-sensitive system, a pair of rectifiers connected in opposition and provided with a common load circuit, a selective input circuit adapted to have applied thereto alternating currents of a predetermined frequency, and the improvement which comprises a highly selective path tuned to said frequency, said path having an input connection to said input circuit and at least two parallel output connections to respective ones of said rectifiers, a first non-selective path connected from a point of said input circuit to one rectifier, a second non-selective path connected from a different point of said input circuit to the second rectifier, and said two points on said input circuit being so chosen as to be of opposite polarity with respect to alternating currents, and means common to said input circuit and said rectifiers adapted to control the phase relation between currents flowing through said selective path with respect to currents flowing through each of the non-selective paths.

12. In combination in a frequency-sensitive system, a pair of rectifiers connected in opposition and provided with a common load circuit, a selective input circuit adapted to have applied thereto alternating currents of a predetermined frequency, and the improvement which comprises a highly selective path tuned to said frequency, said path having an input connection to said input circuit and at least two parallel output connections to respective ones of said rectifiers, a first non-selective path connected from a point of said input circuit to one rectifier, a second non-selective path connected from a different point of said input circuit to the second rectifier, and said two points on said input, said selective path including a piezo-electric crystal element resonant to said predetermined frequency, and each of the non-selective paths consisting of a condenser.

13. In a frequency-sensitive system, a piezo-electric crystal circuit adapted to filter substantially all the modulation from modulated carrier current, means adapted to divide the filtered carrier current into two currents of like polarity, means adapted to derive from said modulated carrier current two modulated carrier currents of opposite polarity, means adapted to separately combine in pairs each of the two filtered currents and a corresponding modulated current in substantially phase quadrature relation at resonance, at least two rectifiers connected in opposition and having a common output load circuit, and means adapted to apply to each respective one of said rectifiers the resultant of each of said combined pairs of currents.

14. In combination in a frequency-sensitive system, a pair of diode rectifiers connected in opposition and provided with a common resistive load circuit, a selective input circuit adapted to have applied thereto modulated carrier currents of a predetermined frequency, and the improvement which comprises a highly selective path consisting of a piezo-electric crystal tuned to said frequency, said path having an input connection to one side of said input circuit and at least two parallel resistor output connections to respective ones of said rectifiers, a first non-selective condenser path connected from said one side of said input circuit to one rectifier, a second non-selective condenser path connected from the opposite side of said input circuit to the second rectifier and a parallel resonant circuit tuned to said predetermined frequency connected between a potential point on said circuit intermediate said opposite sides and said resistor connections.

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