

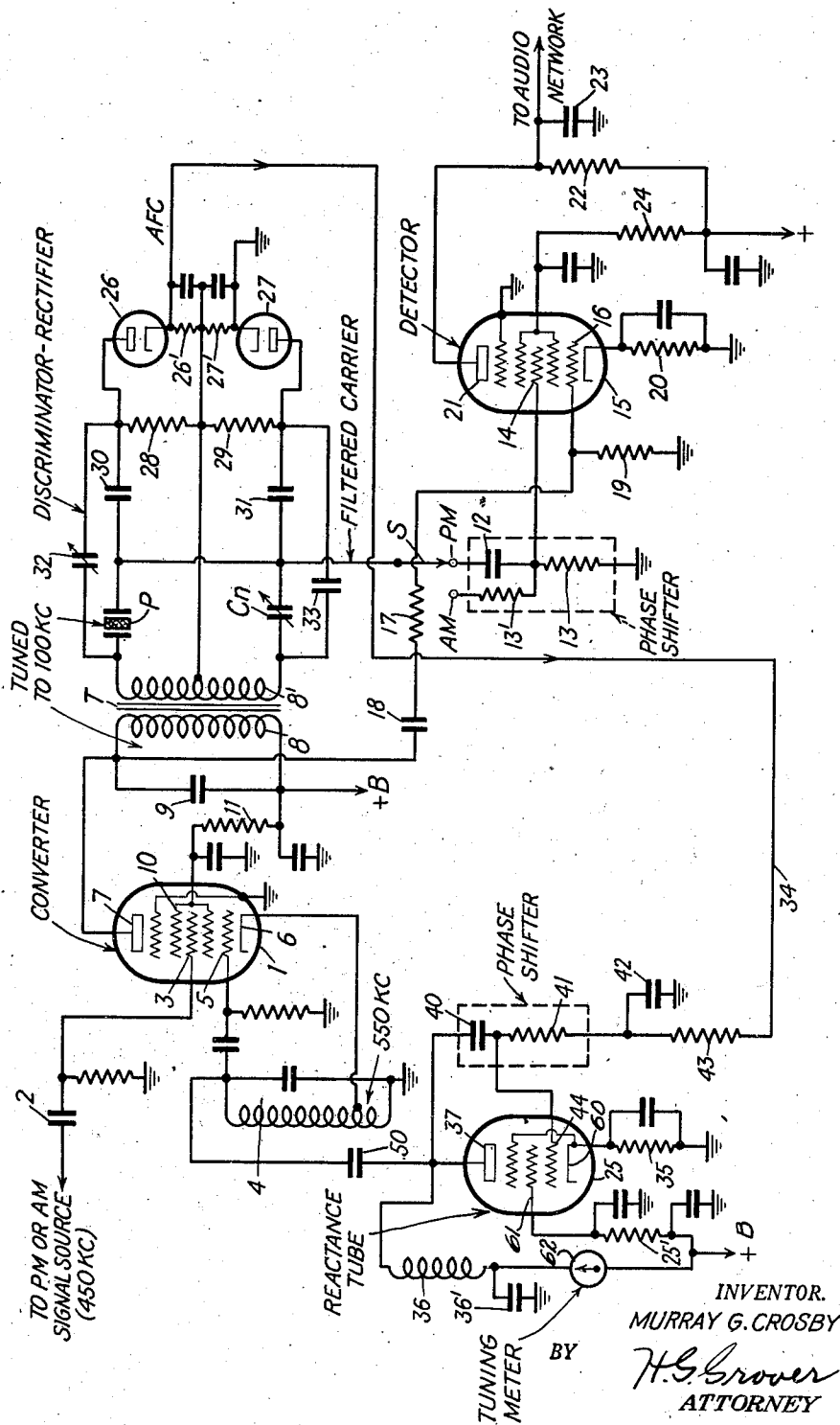
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M. G. CROSBY

2,416,795

PHASE OR AMPLITUDE MODULATION RECEIVER

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PHASE OR AMPLITUDE MODULATION
RECEIVERMurray G. Crosby, Riverhead, N. Y., assignor to
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Application June 7, 1943, Serial No. 489,924

6 Claims. (Cl. 250—20)

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My present invention relates to receivers of phase, or amplitude, modulated carrier waves, and more particularly to a system for receiving phase modulated, or amplitude modulated, waves with carrier exaltation.

In my U. S. Patent No. 2,063,588, granted December 8, 1936, I have shown a receiving system for receiving either phase modulated ("PM" hereinafter for brevity) carrier wave energy or amplitude modulated ("AM" hereinafter for brevity) carrier waves which is characterized by its employment of a multi-grid detector tube capable of detecting either the PM or AM wave energies, with substantially unmodulated carrier energy being applied to one control grid of the detector tube and the modulated carrier wave energy being impressed upon a second control grid in predetermined phase relation. In that system a separate network is employed to provide automatic frequency control ("AFC" hereinafter for brevity) in order to maintain the receiver properly tuned to the desired carrier frequency.

In my copending application Serial No. 476,052, filed February 16, 1943, I have disclosed a novel detection network for PM, or AM, wave energy. The detection network utilizes a piezo-electric crystal element to provide substantially unmodulated carrier energy. AFC voltage is, also, provided by the network in response to a relatively slow shift in mean frequency of applied signal waves from a predetermined reference frequency.

It is one of the main objects of my present invention to supply the multi-grid detector circuit of my aforesaid patent with PM or AM waves, and to employ the crystal filter network of my said copending application for the supply of substantially unmodulated carrier energy to said detector whereby the latter functions as a PM detector or as a carrier-exaltation AM detector.

Another important object of my invention is to provide a compact circuit which is capable of receiving either PM or AM signal waves with a minimum of tubes.

Another object of this invention is to provide a receiving circuit employing a converter to reduce the mean frequency of either applied PM or AM carrier waves, a multi-grid detector tube having the waves applied to a grid thereof, a crystal filter network providing filtered carrier energy for a second grid of the detector tube, and there being derived AFC voltage from the crystal filter network for controlling the effect of a reactance tube on the oscillator section of the converter.

Still other objects of my invention are to im-

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prove the efficiency and reliability of PM-AM receivers, and more especially to provide a highly compact adapter for PM reception or for exalted-carrier AM reception.

Still other features of my invention will best be understood by reference to the following description, taken in connection with the drawing, in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

Referring now to the accompanying drawing, there is shown a pentagrid converter tube 1 which may be of the 6SA7 type. Its circuits are very well known. It acts to reduce the mean or center frequency of applied PM, or AM, carrier wave energy in conventional conversion manner. The coupling condenser 2 will be understood as functioning to couple the signal grid 3 to any desired signal source. The specific nature of the signal receiver circuits prior to condenser 2 is immaterial to this invention. The collected PM, or AM, carrier waves may be in the megacycle (mc.) or in the kilocycle (kc.) ranges. Prior to condenser 2 the collected waves will be heterodyned, either one or more times, until the mean frequency of signal energy at signal input grid 3 is equal, for example, to 450 kc. This is the conventional intermediate frequency (I. F.) value of the usual superheterodyne receiver.

Whether the wave energy at grid 3 is PM or AM the treatment thereof, according to my invention, is the same. Generally speaking, it is desired to reduce the mean frequency of the signal energy to a lower value. Thereafter, it is desired to derive from the reduced frequency energy substantially unmodulated carrier energy, modulation voltage and AFC voltage. These functions are accomplished in the following manner:

The local oscillator tank circuit 4 is resonated to 550 kc. Grid 5, the oscillation grid, is coupled to the high potential side of the tank circuit 4. The cathode 6 is connected to a tap on the tank circuit coil whose lower end is grounded. The plate 7 is connected to a positive potential point +B through the winding 8 of an iron core transformer T. Shunt condenser 9 tunes winding 8 to a beat frequency which may be lower or higher than that applied at condenser 2, but which will be assumed to be a lower frequency of 100 kc. The screen grids 10 are connected to the positive potential +B through a properly bypassed, voltage reducing resistor 11. There will be developed across tuned primary circuit 9—8 signal energy whose mean frequency is that of

the resonant frequency of the circuit. The pass band of transformer T should be sufficiently wide to pass all the side band components in the case of AM carrier energy and the maximum phase deviations in the case of PM carrier waves.

The signal wave energy appearing across secondary winding 8' is passed through a crystal filter to provide the substantially unmodulated carrier energy. The filter consists of piezo-electric crystal P whose inter-electrode capacitance is neutralized by shunt condenser C_n. The crystal P is tuned to 100 kc. Since my aforesaid application Serial No. 476,052 has described the functioning of the crystal filter network and its associated opposed rectifiers in detail, only a general description is given herein. The filtered carrier output of crystal P is transmitted through condenser 12, of a phase shifter 12-13-13', to the grid 14 of multi-grid detector tube 15. The latter is shown as a pentagrid tube of the 6SA7 type. The resistor 13 of phase shifter 12-13-13' is connected to ground from grid 14. The grid 16 of tube 15 has applied to it the PM or AM signal energy as the case may be. The grid 16 is connected to the high potential end of primary winding 8 through a series path consisting of attenuating resistor 17 and direct current blocking condenser 18. The resistor 19 acts as a direct current return path for grid 16 so that it can be biased by the voltage drop across a suitably bypassed cathode bias resistor 20.

The plate 21 of the detector tube 15 is connected to a point of suitable positive direct current potential through the output load resistor 22, the latter being bypassed to ground for high frequency currents by condenser 23. The screen grids of tube 15 are similarly connected to the source of positive voltage through a voltage reducing resistor 24 which is properly bypassed for high frequency currents. It is noted that in connection with tube 15 it may be of the metal envelope type. In that case the suppressor grid thereof may be connected to the metal shell of the tube. This may, also, be true in the case of converter tube 1.

As explained in my aforesaid U. S. Patent No. 2,063,588, the multi-grid detector tube of the type shown in this case functions to demodulate either PM signal waves or AM signal waves. Since my patent describes the electrical phase relations and functioning of the detector tube in detail it is not believed necessary to repeat such explanation in this description. It is believed sufficient to refer to the detailed and mathematical analysis of my said patent, and to make it clear that such mathematical analysis is to be considered as part of the disclosure of this application. The phase shifter 12-13-13' may be adjusted to properly phase the substantially unmodulated carrier energy applied to grid 14 so that the modulation voltage across resistor 22 will correspond to the modulation of the originally-modulated signal energy for either AM or PM detection. The phase shifter switch S has two contacts or positions indicated as "AM" and "PM." The "AM" contact is provided at the upper end of resistor 13'. Grid 14 of detector tube 15 is connected to the junction of resistors 13 and 13'. Hence, when switch S is adjusted to contact "AM" the output electrode of crystal P is connected to grid 14 through a path consisting of S, contact "AM" and resistor 13'. The filtered carrier energy undergoes no phase shift in this case due to the aperiodic nature of resistor 13'. The switch S is adjusted to contact "PM" in the drawing, and the "PM" contact is

provided at the input side of condenser 12. The grid 14 is connected to the output electrode of condenser 12, or at the junction of condenser 12 and 13. In the position of switch S the filtered output of crystal P is connected to grid 14 through a path consisting of S, contact "PM" and condenser 12. In other words, if there is transmitted to the grid 16 unfiltered AM signal energy, then there will be simultaneously applied to grid 14 energy of the mean frequency of the AM signal energy which has its phase properly adjusted by switching S to contact "AM." However, the energy at grid 14 will be unmodulated due to the filtering action of crystal P, and its phase will be such relative to the phase of the AM signal energy of grid 16 that the tube will function to provide across output resistor 22 the desired modulation components. The proper phase relation between the modulated carrier energy and the filtered carrier energy is zero or 180 degrees for AM detection. In other words when switch S is adjusted to contact AM the filtered output of crystal P will be applied to grid 14 through resistor 13'. Hence, the unmodulated carrier energy transmitted to grid 14 will have its phase substantially the same as the phase of the carrier of the unfiltered AM signal energy transmitted through condenser 18 and resistor 17 to grid 16. With this in-phase relation between the energies applied to grids 14 and 16 of tube 15, the latter will function to provide across output resistor 22 the desired modulation signal components.

Assume, now, that there is transmitted to the grid 16 PM signal energy. In this case, the substantially unmodulated carrier energy applied to grid 14 will be adjusted to be 90 degrees out of phase with the PM carrier energy applied to grid 16 by switching S to the contact "PM." In this "PM" position of switch S the condenser 12 feeds the unmodulated carrier energy output of crystal P to grid 14. Condenser 12, in order to impart the aforesaid 90° phase shift to the unmodulated carrier energy, is chosen sufficiently small for this function. The filtered carrier voltage at grid 14 normally, therefore, has a phase quadrature relation to the unfiltered PM signal energy at grid 16. This normal phase quadrature relation is departed from the instantaneous phase deviations of the PM signal wave. Detector tube 15 translates the departures from the normal phase quadrature relation of the voltages of grids 14 and 16 into modulation output voltage in the manner described in my aforesaid Patent No. 2,063,588. The action of the detector tube will therefore be to demodulate the PM signal energy, and to provide demodulation components thereof across output resistor 22. In the case of both the AM and PM signal energy detection there will additionally be provided carrier exaltation. Carrier-exaltation is secured by virtue of the fact that condenser 18 and resistor 17 are so chosen as to attenuate the unfiltered AM signal waves, including their sideband components, but so as not substantially to affect the phase of the carrier. Hence, selective fading effects are reduced or overcome due to the decrease in amplitude of sideband components relative to the strength of the carrier at the respective grids 14 and 16. The filtered carrier at grid 14 has been exalted or augmented relative to the attenuated sideband components at grid 16. This action is, also, true for PM signal waves, the path 18-17 attenuating the sideband components of the unfiltered PM signal wave relative to the filtered PM carrier energy applied through condenser 12 to grid

14. Such carrier exaltation detection is of especial value in connection with AM and PM reception in the frequency range below 30 megacycles, because in that range the effect of selective fading on the transmitted signal energy is to produce an apparent reduction in percentage modulation.

AFC voltage for reactance tube 25 is provided by the action of the opposed rectifiers 26 and 27. While these rectifiers are symbolically represented as separate diodes, it is preferred that the diodes be housed within a tube of the double diode type, such as a 6H6 type tube. The load resistors of the rectifiers 26 and 27 are represented by numerals 26' and 27' respectively. The cathode of rectifier 27 is grounded, and each of the load resistors is bypassed for high frequency currents. The junction of the load resistors is connected to the junction of a pair of direct current return resistors 28 and 29. The junction point of these latter return resistors is connected to the midpoint of secondary winding 8'.

As explained in my aforesaid application Serial No. 476,052 the filtered carrier energy is applied in like polarity or parallel to the anodes of the respective rectifiers 26 and 27. Condensers 30 and 31 function as isolation condensers and apply the filtered carrier energy from the output electrode of crystal P to the respective anodes of the diode rectifiers. The modulated, or unfiltered, signal energy existing at the opposite ends of center-tapped winding 3' is applied to the rectifiers 26 and 27 in opposite polarity push-pull by virtue of the similar shunt coupling condensers 32 and 33 respectively. As explained fully in my aforesaid pending application, each rectifier 26 and 27 has applied to it filtered and unfiltered signal energy in phase quadrature relation. This phase quadrature relation of the two voltages at each rectifier 26 and 27 results from the fact that the unfiltered signal energy is applied to the rectifiers by condensers 32 and 33 which are sufficiently small to effect a 90° phase shift, and are also of substantially equal capacities so as to produce equal phase shifts both of the unfiltered carrier and its signal components. Condensers 32 and 33 are non-selective to phase or frequency variations of the unfiltered carrier energy, and accordingly permit all signal components to pass to both rectifiers 26 and 27. Crystal P, however, effects no substantial phase shift of the filtered carrier wave at modulation frequencies, but by its inertia effect substantially removes the modulation of the carrier thereby restoring the latter substantially to the phase and wave form which it had before modulation at the transmitter. The crystal P due to its sharp selectivity is of course, selective against frequencies off resonance, but will nevertheless pass a band of frequencies varying over a narrow range. The rectifiers function to rectify the respective resultant vector voltages of each pair of quadrature-related energies. When the applied signal energy at transformer T has a mean frequency equal to the predetermined frequency of the primary tuned circuit 9—8, then the respective resultant vector voltages applied to rectifiers 26 and 27 are equal in amplitude. This follows from the fact that each of the respective resultant vector voltages is the vector sum of the filtered carrier voltage from crystal P without phase change and of an unfiltered carrier voltage substantially 90° different in phase from the filtered carrier. Accordingly, the differential direct current voltage output of the rectifiers is substantially zero, since the voltages across resistors 26' and 27' are equal and of opposite

polarity. However, upon a relatively slow departure of the said mean frequency from the predetermined resonant reference frequency there will be a direct current voltage or AFC bias developed at the cathode end of resistor 26'. This follows from the fact that crystal P can respond to frequency changes over a limited range, and, in particular, to slow frequency changes such as may, for example, result from oscillator drift. As to such frequencies within the narrow band of frequencies passed by it, the crystal P acts as series-connected inductance and capacity. When the received signal energy frequency is exactly that of the crystal frequency, the crystal effects no phase change in the filtered carrier energy and the normal phase quadrature relation exists between the latter and the unfiltered energy passing through respective condensers 32 and 33. When, however, the frequency of the signal energy applied at transformer T tends slowly to change toward one side of the narrow passband of crystal P, the filtered output energy of the crystal changes in phase in a direction toward the phase of the current in one of condensers 32 and 33, and away from the phase of the current in the other of such condensers. In this way there is produced increased energy on one of the rectifiers 26 and 27 and decreased energy on the other. Should the signal energy frequency change in the opposite direction, the phase of the filtered output of the crystal changes in the opposite direction thereby reversing the relative magnitude of energies applied to rectifiers 26 and 27. Hence, there appear direct current voltages across each of resistors 26' and 27' whose relative magnitudes vary as the applied signal frequency slowly shifts relative to the reference frequency of crystal P. These voltages are differently combined to provide a resultant direct current voltage (AFC bias). The magnitude and polarity of the resultant direct current voltage will be functions respectively of the extent and direction of the aforesaid slow frequency shift. Reference is made to my aforesaid pending application for a further description of the electrical reactions existing in the crystal discriminator-rectifier network.

The direct current voltage output of the opposed rectifiers is utilized as AFC bias, and is applied over lead 34 to the reactance tube 25. The reactance tube 25 and its associated circuits are of the well known form. Generally, the tube may be of any known type, but is shown as of the pentode type by way of illustration. The cathode 60 of tube 25 is connected to ground through a suitably bypassed biasing resistor 35. The plate 37 may be connected to any source of positive potential +B through a radio frequency choke coil 36 whose lower end is bypassed for high frequency currents by condenser 36'. The screen grid 61 of tube 25 may, also, be connected to the source of positive potential +B through a properly bypassed, voltage-reducing resistor 25'. The plate 37 of the reactance tube 25 is connected back to ground through a path which comprises a phase shifter. The phase shifter is shown as a dash line rectangle, and consists of condenser 40 and resistor 41. The lower end of resistor 41 is connected back to ground for high frequency currents through the condenser 42. The AFC lead 34 is connected through filter resistor 43 to the lower end of phase shifter resistor 41. In this way, the control grid 44 is variably biased so as to control the gain of tube 25. The plate 37 is connected by the direct current blocking condenser

50 to the high potential side of the oscillator tank circuit 4. A tuning meter 62 is shown arranged in series with choke 36. The meter 62 has a fixed deflection for the "in-tune" condition of the oscillator. For "off-tune" conditions the meter 62 will be deflected from its mean correct tuning indication. The reactance tube plate current flows through the meter 62. Hence, the latter is capable of indicating correct tuning of the oscillator circuit.

In explaining the functioning of the reactance tube, it is first pointed out that its plate to cathode impedance is effectively connected in shunt across the tank circuit 4. The alternating voltage existing at plate 37 is applied across the phase shifter 40-41. If the capacitive reactance of condenser 40 is chosen sufficiently small compared to the resistance of resistor 41, the alternating voltage developed across resistor 41 and applied to grid 44 will be substantially in phase quadrature with the alternating plate voltage. Under these conditions the plate to cathode impedance of tube 25 will function as if it was capacitive, and it will appear effectively across tank circuit 4. The magnitude of this simulated capacitive reactance will then be a function of the gain of tube 25.

Obviously, the direction and extent of variation of the capacitive impedance of tube 25 will depend upon the variation in AFC bias transmitted over lead 34. This, of course, is the well known AFC action which is familiar to those skilled in the art. In this case the AFC circuit functions to maintain the mean frequency of the signal energy applied to circuit 9-8 substantially equal to the predetermined reference frequency which is the resonant frequency of the crystal P. Hence, the filtered carrier energy fed to grid 14 of detector tube 15 will be synchronized in frequency for proper detection.

While I have indicated and described a system 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 organization shown and described, but that many modifications may be made without departing from the scope of my invention.

What I claim is:

1. In a system of the type including a converter network provided with a signal input circuit and a local oscillator circuit, means for applying to said signal input circuit either phase modulated, or amplitude modulated, carrier wave energy, an output circuit connected to said converter for developing thereacross signal energy whose mean frequency is the difference between the signal carrier frequency and the frequency of said oscillator circuit, and means coupled to said output circuit for deriving therefrom substantially unmodulated carrier energy, the improvement which consists of an electron discharge tube provided with at least a pair of spaced input electrodes, means connecting one of the said input electrodes to said output circuit thereby to apply to the input electrode modulated signal energy, a phase shifter connecting the second input electrode to said deriving means thereby to apply to the second input electrode said substantially unmodulated carrier energy, said phase shifter comprising a resistor and a condenser having individual input terminals, a common output connection from the output terminals of the resistor and condenser to said second input electrode, means for selectively connecting said deriving means to either of said input terminals for appli-

cation to the respective resistor and condenser of the unmodulated carrier energy derived from the amplitude modulated and phase modulated waves respectively, and an output circuit connected to said tube for developing modulation voltage components.

2. In a system of the type including a converter and a local oscillator circuit, means for applying to said converter phase modulated carrier wave energy, and an output circuit connected to said converter for developing thereacross phase modulated energy whose mean frequency is the difference between the applied carrier frequency and the frequency of said oscillator circuit, the improvement comprising piezo-electric crystal filter means coupled to said output circuit for deriving therefrom substantially unmodulated carrier energy, an electron discharge tube provided with at least a pair of spaced input electrodes, means including a condenser in series with a resistor for connecting one of the said input electrodes to said output circuit thereby to apply to the input electrode said developed phase modulated energy, a phase shifter consisting of a resistor and a condenser provided with a common output terminal, means connecting the latter to said second input electrode, said resistor and condenser having respective input terminals, a switch for selectively connecting either of said input terminals to the output of said filter, and an output circuit connected to said tube for developing modulation voltage components.

3. In a system of the type including a converter and a local oscillator circuit, means for applying to said converter phase modulated carrier wave energy, and an output circuit connected to said converter for developing thereacross phase modulated energy whose mean frequency is the difference between the applied carrier frequency and the frequency of said oscillator circuit, the improvement which consists of a piezo-electric crystal filter coupled to said output circuit for deriving therefrom substantially unmodulated carrier energy, an electron discharge tube provided with at least a pair of spaced input electrodes, means for connecting one of the said input electrodes to said output circuit thereby to apply to the input electrode said developed phase modulated energy, a phase shifter comprising a resistor and a condenser having a common output connection at the junction thereof to said second input electrode, means for selectively connecting the output of said filter to either input terminal of the resistor and condenser, and an output circuit connected to said tube for developing modulation voltage components, and means coupled to the output of the crystal filter responsive to a departure of the mean frequency of the modulated energy in said output circuit from a predetermined reference frequency for automatically controlling the frequency of said local oscillator circuit.

4. In combination with a converter network provided with a signal input circuit, means for applying to said signal input circuit either phase modulated or amplitude modulated carrier wave energy, and an output circuit connected to said converter for developing thereacross signal energy whose means frequency is lower than signal carrier frequency, piezo-electric crystal filter means coupled to said output circuit for deriving therefrom substantially unmodulated carrier energy, a detector tube provided with at least a pair of spaced input grids, means for connecting one of the said input grids to said output circuit there-

by to apply to the input grid modulated signal energy, a phase shifter consisting of a resistive element and a capacitive element, said elements having a common output terminal and independent input terminals, said second input grid being 5 connected to the common output terminal, means selectively connecting either of the input terminals to the output of said filter means whereby the phase of substantially unmodulated carrier energy may be adjusted relative to the phase of 10 the modulated signal energy applied to the first input grid whereby the detector is selectively conditioned for detecting said phase modulated or amplitude modulated carrier wave energy, and an output circuit connected to said tube for develop- 15 ing modulation voltage components.

5. In combination with a signal input circuit, means for applying to said signal input circuit either phase modulated or amplitude modulated carrier wave energy, and an output circuit, piezo- 20 electric crystal filter means coupled to said output circuit for deriving therefrom substantially unmodulated carrier energy, an electron discharge tube provided with at least a pair of spaced input electrodes, sideband attenuation means for connect- 25 ing one of the said input electrodes to said output circuit thereby to apply to the input electrode modulated carrier energy with substantially attenuated sidebands, a selective phase shifter connecting the second input electrode to said deriv- 30 ing means thereby to apply to the second input electrode said substantially unmodulated carrier energy, said phase shifter comprising a resistive impedance and a reactive impedance, said impedances having a common output terminal connect- 35 ed to said second input electrode, said impedances having separate input terminals, means for selectively connecting either of said input terminals to said deriving means, and a modulation output circuit connected to said tube for developing modulation voltage components.

6. A system of the type including a converter network provided with a signal input circuit and a local oscillator circuit, means for applying to said signal input circuit either phase modulated 40

or amplitude modulated carrier wave energy, and an output circuit connected to said converter for developing thereacross signal energy whose mean frequency is the difference between the signal carrier frequency and the frequency of said oscillator circuit, the improvement comprising a piezo-electric crystal filter means coupled to said output circuit for deriving therefrom substantially unmodulated carrier wave energy, an electron 10 discharge tube provided with at least a pair of spaced input electrodes, sideband attenuation means for connecting one of the said input electrodes to said output circuit thereby to apply to the input electrode modulated signal energy with attenuated sidebands, a phase shifter connecting 15 the second input electrode to said deriving means thereby to apply to the second input electrode said substantially unmodulated carrier energy, said phase shifter comprising a condenser for imparting a quadrature phase shift to unmodulated carrier energy for receiving phase modulated carrier waves, a resistor having a common output connection to the output terminal of said condenser, 20 said resistor and condenser having separate input terminals, means for selectively disconnecting the said deriving means from the condenser input terminal and connecting it to the resistor input terminal thereby eliminating the condenser and replacing it by said resistor for the reception of 25 amplitude modulated carrier wave energy, and an output circuit connected to said last tube for developing modulation voltage components.

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