July 20, 1948. E. H. LANGE 2,445,621

DEMODULATOR DEVICE FOR FREQUENCY AND AMPLITUDE MODULATIONS

Filed Nov. 5, 1945

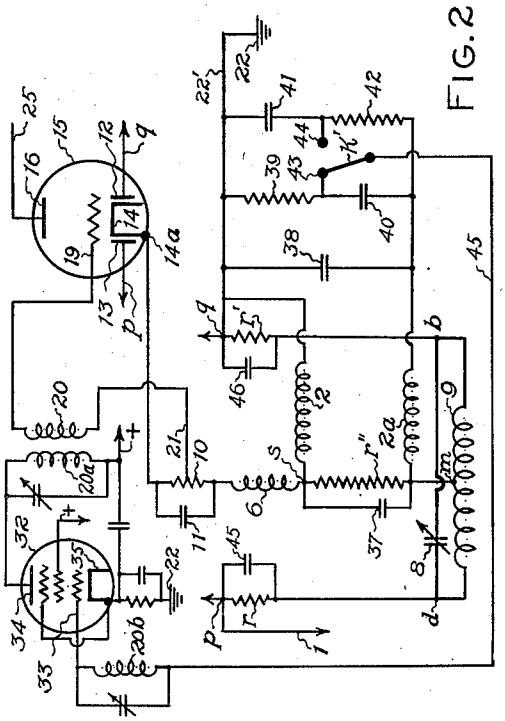


FIG. 2

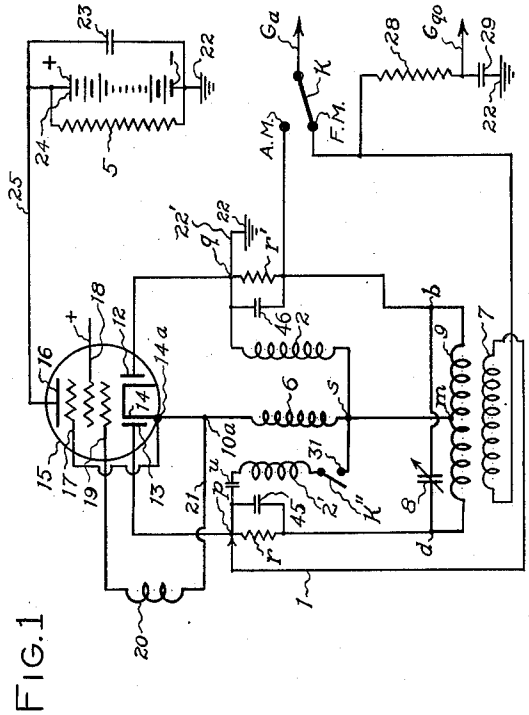


FIG. 1

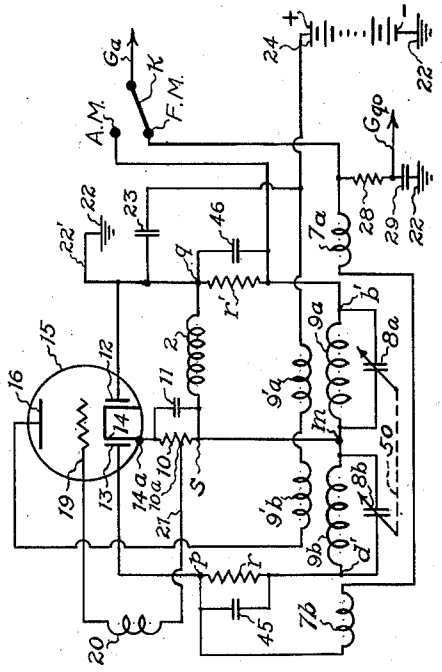


FIG. 3

Edward H. Lange.

INVENTOR

Patented July 20, 1948

2,445,621

UNITED STATES PATENT OFFICE

2,445,621

DEMODULATOR DEVICE FOR FREQUENCY AND AMPLITUDE MODULATION

Edward H. Lange, Baltimore, Md.

Application November 5, 1945, Serial No. 626,733

21 Claims. (Cl. 250—27)

1

This invention relates to demodulators for carrier waves having frequency-modulation or amplitude-modulation, or having both of these modulations, and more particularly to such demodulators in connection with receiving systems for these carrier waves.

The principal object of this invention is to provide such demodulator devices with economy and simplicity of component circuit parts and electronic equipment, and with improved facilities for tuning, for compensating amplitude-modulation, and for control of average signal amplitudes.

A first object of this invention is to provide unilaterally-grounded output voltages for the series-parallel circuit type frequency-demodulator described in U. S. Patent 2,369,055, of February 6, 1945, and more particularly to provide such operation with direct anode-cathode series connection of the series-parallel circuit as distinguished from a shunt supply of said circuit, and with a double-diode rectifier employing diode-anodes each capable of thermionic conductance with said cathode, and in the same tube with the common cathode.

A second object of this invention is to provide such unilaterally grounded output voltages upon a conductive connection to ground, and to provide sustained output voltages which persist as long as a frequency deviation exists between the carrier wave and the centre or balance-frequency of the demodulator, for use in controlling the frequency of waves impressed upon the demodulator, for example in a superheterodyne receiver, and when receiving either amplitude-modulation or frequency-modulation.

A third object is to provide simple separating means for separating or annulling the voltages of carrier frequency from the desired output voltages of modulation frequency.

A fourth object is to provide filter means for demodulators of the unilaterally-grounded common cathode type, whereby the grid control means of a pre-amplifier coupled with such a demodulator is supplied with either amplitude-envelope responsive and opposing voltages for reducing undesired amplitude-modulation, or average-amplitude responsive voltages for regulating signal strength employed, or both, and through a conductive path between the ground and said grid control means of the pre-amplifier.

A fifth object of this invention is to provide the features stated in the second to fourth objects inclusive through simple structures, applicable also to other types of demodulator circuit than

2

designated in the first object, and also employing a common cathode type double-diode rectifier for supplying such unilaterally-grounded output voltages.

A sixth object is to provide resistance-capacitance filter means in the common cathode type demodulators of this invention, for transferring to the quadrature-phase controlling grid of an oscillator or reactance-modulator connected with an oscillator in a superheterodyne receiver, sustained voltages, determined by the amount and algebraic sign of the difference between the balance-frequency of the demodulator and the centre-frequency or unmodulated frequency of the carrier wave, independent of the presence of frequency-modulation upon the carrier wave, and for alignment of tuning in the receiver.

A seventh object of this invention is to provide simple impedance-balance means for annulling or substantially reducing minor impedance-asymmetry introduced by unilateral impedance connections of this invention.

These objects, and others, are hereinafter pointed out in reference to the accompanying drawings and appended claims.

In the drawings,

Fig. 1 illustrates the series-parallel type demodulator circuit heretofore disclosed by the present inventor in U. S. Patent No. 2,369,055, utilized in a novel organization with common cathode type double-diode rectifier, unilateral grounding impedance means, output-circuit high-frequency voltage removing means, filter means for transferring sustained voltages to the quadrature-phase or frequency-controlling grid of a thermionic generator system, and with means employable for compensating impedance-asymmetry.

Fig. 2 illustrates a pre-amplifier coupled with the input-impedance of one of the demodulators of this invention, and a transfer-filter means for transferring control voltages from a common conductive path between the diode-anodes and the cathode of the demodulators of this invention, and illustrated with particular reference to the demodulator of Fig. 1.

Fig. 3 illustrates application of the principles and structure of this invention to another type of demodulator circuit.

Referring to the figures, at 15 is a thermionic tube having the cathode 14, cathode-terminal 14a, the diode-anodes 12 and 13 each capable of thermionic conductance with the common cathode 14; also having a control-grid 19 connected through input-impedance 20 and conductor 21 to

terminal 10a, which terminal is either directly connected to terminal 14a, or connected to terminal 14a through a bias-resistance 10 having one terminal connected to terminal 14a. At 16 is a third anode capable of thermionic conductance with the common cathode 14, it being understood that thermionic conductance between the third anode 16 and cathode 14 is controllable by the control-grid 19 between cathode 14 and anode 16. At 17, Fig. 1, is shown a suppressor-grid directly connected to cathode terminal 14a, and at 18 is a screen-grid understood to be connected to a positive terminal upon the source 24 of unidirectional voltage, the source 24 having its negative terminal connected to ground 22. For simplicity of illustration the suppressor-grid 17 and screen-grid 18 are omitted from Figs. 2 and 3, tube 15, however it will be understood that these grids may be present and similarly connected in these figures, for controlling the transconductance and impedance properties in a manner well understood.

One of the diode-anodes, for example diode-anode 12 is connected directly to ground 22 through conductor 22' of negligible impedance. At *m* is a junction-terminal upon a phase-shifting network connected to the diode-anodes 12 and 13 and to the common cathode 14, and between junction-terminal *m* and common cathode 14 is a common conductive path for thermionic currents of both diode-anodes 12 and 13.

Referring to Fig. 1, the positive terminal of source 24 is directly connected through conductor 25 to the third anode 16 of tube 15. For purposes of illustration it will be understood that the source of unidirectional voltage 24 may be a battery or other well known means, and having a conductive path from the positive terminal to ground such as illustrated by resistance 5, for unidirectional components of current. At 9 is an inductance coil, and at 8 is a variable condenser connected across the terminals of coil 9, and for tuning coil 9 to resonance with the carrier frequency impressed upon input-impedance 20. At 6 is a high-frequency choke-coil connected between the cathode-terminal 14a and the junction-terminal *m* upon the inductance coil 9, the junction-terminal *m* being between the terminals *b* and *d* of the inductance coil 9, which terminals are connected to condenser 8. Choke-coil 6 is similarly connected in Fig. 2, except that series resistance may be included in the conductive path from junction-terminal *m* to cathode-terminal 14a as hereafter pointed out.

Terminal *d* is connected through diode-resistor *r* to terminal *p* of diode-resistor *r*, which terminal *p* is directly connected to diode-anode 13; likewise terminal *b* is connected through diode-resistor *r'* to terminal *q* of diode-resistor *r'*, which terminal *q* is directly connected to diode-anode 12. Diode-resistor *r* is shunted by condenser 45, and likewise diode-resistor *r'* is shunted by condenser 46. Terminals *d* and *b* are similarly connected in Fig. 2. At K is a switch-blade understood to be directly connected by connector G_a to the control-grid of an amplifier for amplifying the demodulated voltages of either amplitude-modulation or frequency-modulation, and the switch-terminal indicated by A. M. for amplitude-modulation is directly connected to the terminal of diode-resistor *r'* opposite the terminal *q* of said resistor, that is to terminal *b*. The switch-terminal indicated by F. M. for frequency-modulation is connected through coil 7 by way of conductor 1 to the terminal *p* of diode-resistor *r*. Coil 7 is understood to be inductively coupled with coil 9, and to be so connected in the circuit through conductor 1 that the resultant alternating voltage of carrier frequency in the circuit *q*—*r'*—*b*—9—*d*—*r*—*p*—1—7—F. M. is substantially zero, the magnitude of voltage induced in coil 7 by carrier frequency of coil 9 being understood to be equalized with the magnitude of alternating voltage in coil 9. Connected in series between the terminal F. M. and ground 22 is the filter-resistance 28 connected to the terminal F. M. and the filter-condenser 29 connected to ground 22. The junction between filter-resistance 28 and filter-condenser 29 is understood to be connected by the conductor G_{fc} to the frequency-controlling grid of a thermionic generator system of a superheterodyne receiver, for example to the quadrature-phase controlling grid of a thermionic oscillator, or reactance modulator connected with a generator, and for modifying the resultant carrier frequency impressed upon the input-impedance 20.

At 2 is a high-frequency choke-coil having one terminal connected to the ground 22, and the other terminal *s* connected to the junction-terminal *m*. At 2' is another high-frequency choke-coil having one terminal connected through condenser *u* to the ungrounded diode-anode, for example diode-anode 13, and the other terminal connected to the switch-blade K'' which is connectable to switch-terminal 31 connected to the terminal *s* of the choke-coil 2. Choke-coil 2 is similarly connected in Fig. 3; likewise it will be understood that the choke-coil 2' for compensating impedance-asymmetry is similarly connectable in Fig. 3 between the terminal *s* of choke-coil 2 and the ungrounded diode-anode 13.

Referring to Fig. 3, third anode 16 is connected through the primary coils 9'*b* and 9'*a* in series to the positive terminal of source 24, and by-pass condenser 23 is connected from ground conductor 22' to the positive terminal of source 24 as in Fig. 1. Coil 9*b* is inductively coupled with coil 9'*b*, and coil 9*a* is inductively coupled with coil 9'*a*, and coils 9*a* and 9*b* are connected in series at the junction-terminal *m*, the terminal *d'* of coil 9*b* opposite terminal *m* being connected through diode-resistor *r* to diode-anode 13, and the terminal *b'* of coil 9*a* opposite terminal *m* being connected through diode-resistor *r'* to diode-anode 12. Terminal *m* is connected to cathode-terminal 14a through the bias-resistance 10. It will be understood that bias-resistance 10 is for introducing a small voltage drop through flow therethrough of steady component of current from third anode 16 to cathode 14, for negatively biasing the control-grid 19 from cathode 14; that the employment of such negative biasing means is optional. Negative bias voltage so introduced biases the diode-anodes from the cathode 14, however when small amounts of such bias are employed in relation to the maximum voltages employed upon the diode-anodes from the network, such small amounts do not appreciably affect the operation of the demodulator. It will be understood that the condenser 11 shunted across the bias-resistance 10 has a small impedance in relation to resistance 10 for the low or modulation frequencies, and that such biasing means may also be employed in Fig. 1, similarly connected to cathode 14 and in series with coil 6, between terminal 10a and terminal 14a. Coil 9*b* is shunted by tuning condenser 8*b*, and likewise coil 9*a* is shunted by tuning condenser 8*a*; these tuning condensers may be mechanically connected

as indicated by connection **50**, indicating an electrically insulated mechanical connection between rotors of condensers **8***a*, **8***b*. Tunable circuits between terminals *m*—*b'* and between *m*—*d'* are understood to be spaced as to tuning, the carrier frequency being intermediate with reference to resonance frequencies set by condensers **8***a* and **8***b*, as hereafter further pointed out. At **7***a* is an inductance coil inductively coupled with coil **9***a*, and at **7***b* is another inductance coil inductively coupled with coil **9***b*. Coils **7***a* and **7***b* are connected in series, one terminal of coil **7***b* being connected to the ungrounded diode-anode **13** and one terminal of coil **7***a* being connected to the terminal F. M. of the selector switch having switch-blade K, as heretofore described. It will be understood that coils **7***a* and **7***b* are each so connected in the series circuit **22**—*r'*—*b'*—*m*—*d'*—*r*—**7***b*—**7***a*—F. M. that the carrier-frequency voltage in **9***b* is equalized by the carrier-frequency voltage in **7***b*, and likewise the voltage in **9***a* equalized by the voltage in **7***a*, leaving only the resultant of the rectified voltages across *r'* and *r* in said series circuit, the resultant voltage of carrier-frequency being substantially annulled.

Referring to Fig. 2, at **32** is a thermionic tube of a pre-amplifier having an output-impedance **20***a* coupled with the input-impedance **20**, for example of demodulator of Fig. 1, and for transferring voltages of carrier frequency to input-impedance **20**. Tube **32** is understood to have a cathode **35** connected to ground **22**, for example through a bias-resistor, to have a control grid **33** connected to one terminal of the input coil **20***b* of the pre-amplifier, and to have an anode **34** connected with the positive terminal of a source of unidirectional voltage through output-impedance **20***a*, or otherwise energized from a unidirectional voltage source. Control-grid **33** is understood to control thermionic currents between anode **34** and cathode **35**; also it will be understood that other grid controls may be present such as a screen-grid and suppressor-grid between the anode **34** and control-grid **33**, for controlling currents between anode **34** and cathode **35**, and for controlling transconductance and impedance characteristics of tube **32**, in a manner well known, and with particular reference to transconductance of control-grid **33**. Connected in series in the conductive path between junction-terminal *m* and the terminal **14***a* of cathode **14**, is the control-resistor *r''*, connected between the junction-terminal *m* and the terminal *s* of the high-frequency choke-coil **2** one terminal of control-resistor *r''* being directly connected to junction-terminal *m*. Control-resistance *r''* is shunted by the control-condenser **37**. Connected between the junction-terminal *m* and the ground **22**, is the high-frequency choke-coil **2***a* in series with the high-frequency by-pass condenser **38**, one terminal of coil **2***a* being connected to junction-terminal *m* and one terminal of condenser **38** being connected to ground **22**. Shunted across the terminals of by-pass condenser **38** is the filter-resistance **39** in series with the filter-condenser **40**, one terminal of resistance **39** being connected to ground **22** and one terminal of condenser **40** being connected to the ungrounded terminal of condenser **38**. The common terminal **43** between condenser **40** and resistance **39** is connectable by switch-blade K' through conductor **45** to the terminal of the input coil **20***b* of the pre-amplifier, opposite the terminal of said coil connected to control-grid **33** of tube **32**. Likewise shunted across the terminals of by-pass condenser **38** is the filter-resistance **42** in series with the filter-condenser **41**, one terminal of condenser **41** being connected to ground **22**, and one terminal of resistance **42** being connected to the ungrounded terminal of condenser **38**. The common terminal **44** between resistance **42** and condenser **41** is connectable by switch-blade K' through conductor **45** to control-grid **33** of tube **32**, through input coil **20***b*.

It will be understood that the control-resistor *r''* shunted by condenser **37** illustrated with reference to Fig. 1 can be likewise connected in the structure of Fig. 3, in the common conductive path between cathode **14** and junction-terminal *m*, and between the junction-terminal *m* and the terminal *s* of choke-coil **2**.

Condensers **45**, **46**, and **37**, shunted respectively across the resistances *r*, *r'*, and *r''*, are understood to be for smoothing out the unidirectional voltages set up across these resistances by unidirectional currents respectively to diode-anode **13**, diode-anode **12**, and to both of these diode-anodes, and to provide a time-constant sufficiently large in relation to the half-cycle time of the carrier wave to smooth out the rectified pulses of carrier frequency.

Referring to Fig. 1, operation of the devices will be evident from the following further considerations. The path for the unidirectional current component from ground **22** through source **24**, and third anode **16** to cathode **14**, is completed through choke-coils **6** and **2** in series to ground **22**. When high-frequency voltage is impressed upon the input-impedance **20** currents of corresponding carrier frequency are set up in the external network between cathode-terminal **14***a* and ground **22**. The effective impedance of the external network is that of the series-parallel circuit composed of the choke-coil **6** in series with the parallel resonant circuit between the terminals *m*—*b*; substantially equal voltages of carrier frequency are present upon the parts *m*—*b* and *d*—*m* of inductance coil **9**, the parallel circuit between terminals *m*—*b* operating as a pure resistance when tuned to the carrier frequency. The high-frequency voltages impressed between cathode **14** and diode-anodes **12**, **13**, are thus composed of a vector sum of voltages for one diode-anode and a vector difference for the other diode-anode, as detailed in the U. S. patent previously referred to; in the **series circuit from ground 22** to conductor **1**, the resultant rectified voltage can thus be made zero for a specific carrier frequency, positive for frequency deviations therefrom of the carrier frequency, and negative for frequency deviations of opposite algebraic sign.

The choke-coil **2** is many times larger in inductance value than the inductance of the part *m*—*b* of coil **9**; choke-coil **2** is nevertheless substantially in shunt with terminals *m*—*b*, the reactance of condenser **46** for carrier frequency being substantially smaller than the reactance of coil **2**, and the equivalent inductance across the terminals *m*—*b* is thus slightly smaller than the inductance of the part *m*—*b* of coil **9**. The junction-terminal *m* is normally the mid-inductance point upon the coil **9**, however it will be understood that this position may be advantageously slightly modified when no impedance-compensation is employed for compensating impedance-asymmetry of the network, introduced for example by coil **2**. The reactance of coil **2** is also substantially higher than the equivalent resistance at resonance of the parallel resonant circuit *m*—*b* and *m*—*d*—*b*, and the total alternating current

of choke-coil 6 differs but little from the alternating current from terminal *b* to ground 22, the components in coil 2 and through *b*—22 being vectorially substantially in quadrature-phase. Without the employment of any additional compensating impedance for impedance-asymmetry, advantageous use may also be made of the inclusion in the circuit from ground 22 to conductor 1 of equalized unidirectional voltages at the centre or carrier frequency, equalized by the inclusion in said circuit of less than the full rectified voltage from the diode-resistor having an excess of rectified voltage at said frequency.

It will be noted that when a high degree of impedance symmetry is required, the network can be balanced as to high-frequency impedance by means of the choke-coil 2' connected from the terminal *s* of choke-coil 2 and through the stopping-condenser *u* to the ungrounded diode-anode. Condenser *u* is understood to have negligible impedance for the carrier frequency in relation to the impedance of choke-coil 2', and to insulate the diode-anodes against an alternative low-impedance path for the low or modulation frequencies.

In the conductive circuit through path 22—*r'*—*m*—*d*—*r*—1—7—F. M., when the carrier frequency voltage is annulled by coil 7, only the resultant of the rectified voltages upon resistances *r* and *r'* remains. The impedance of condenser 29 is negligible for the desired modulation frequencies, so that a substantial short-circuit exists across condenser 29 for these frequencies, and only the sustained voltage is applied to conductor G_{qo} determined by the difference between the balance-frequency of the demodulator and either the carrier frequency when receiving amplitude-modulation or the centre-frequency of the carrier when receiving frequency-modulation; this system for frequency regulation in frequency-modulation receivers is disclosed in U. S. Patent No. 2,395,413, February 26, 1946, of the present inventor. For receiving amplitude-modulation the switch-blade K connects with the terminal A. M.

In Fig. 3, the junction-terminal *m* is normally the mid-inductance point upon the two series-connected coils 9*a* and 9*b*, of equal inductance. In this type demodulator frequency-spacing is normally accomplished by spacing the capacitance of the condensers 8*b* and 8*a*, so that the capacitance is slightly different; coil 9*b* can then be tuned to a frequency below the carrier frequency while coil 9*a* is tuned to a frequency above the carrier frequency. It will be noted that in the present invention, the choke-coil 2 can be employed for double duty, not only for by-passing the unidirectional component of third anode-cathode current around the diode-resistor *r'* but also for spacing the resonance frequencies of the resonance circuits 9*b*—8*b* and 9*a*—8*a*, since this is an inherently asymmetrical type circuit. Thus alternatively, the condensers 8*b* and 8*a* may have equal capacitance and the inductances be made unsymmetrical by means of the effective shunt connection of coil 2 around 9*a*, or the compensating impedance 2'—*u* may be used between terminals *s* and *p*, and the spaced capacitances in condensers 8*a* and 8*b* then used; also asymmetry of the inductive couplings regulates the spacing of resonance frequencies, in a manner well understood.

Referring to Fig. 2, the control-impedance *r''*—37 is employed with a novel ground-connected transfer-filter means for taking off the voltages of modulation frequency and eliminating voltages of carrier frequency between the control-impedance and the ground. The voltage of carrier frequency across choke-coil 2 is substantially in shunt with the choke-coil 2*a*, the by-pass condenser 38 serving as an effective short-circuit for currents of carrier frequency. Employment of resistance 39 with ground connection, serves to provide negative bias-voltage impulse upon the conductor 45 to control grid 33 when the alternating current amplitudes, e. g., through choke-coil 6 are increasing, positive bias-voltage impulse when these amplitudes are decreasing, and no bias-voltage impulse when these amplitudes are constant; dynamic stabilization of amplitudes is thus accomplished for employment during reception of frequency-modulated carrier waves. The principles of such dynamic stabilization are originally disclosed in U. S. Patent No. 2,395,413, February 26, 1946. For relatively slow variations of alternating current amplitudes through choke-coil 6 of substantially longer duration than the period corresponding to the lowest modulation frequency which is intended for reception, voltages sufficient for amplitude stabilization are not transferred from terminal 43 to control grid 33. Tube 32 is understood to be of a well known variety capable of large changes in transconductance with negative bias-voltages upon a control grid. Alternating current amplitude variations of the slower variety above referred to, are controlled by the resistance 42 in series with condenser 41. Condenser 41 has negligible impedance for modulation frequencies in relation to resistance 42; thus in the parallel path between terminal *s* and terminal *m* the voltage of modulation frequency upon resistance 42 is equal to the voltage of modulation frequency upon control-impedance *r''*—37, and in the series path 22—22'—2—*r''*—2*a*—42—44—K'—45—33 the voltage of modulation frequency is cancelled, leaving only the voltage from control-impedance *r''*—37 of unidirectional sustained variety, determined by the carrier frequency amplitude independent of amplitude-modulation. It will be noted that the terminal of choke-coil 2*a* connected to resistance *r''* is at negative potential relative to terminal *s* which is connected to ground, and that increasing average carrier amplitude provides an increasing negative potential at terminal 44 relative to ground 22.

For purposes of illustration, switch-blade K' is shown as selectively connectable to terminal 43 for reception of frequency-modulation or to terminal 44 for controlling average amplitude of carrier employed during reception of amplitude-modulation, however it will be evident that connection to terminal 44 can be employed continuously, and connection to terminal 43 selectively only for frequency-modulation reception, for example by permanently connect-terminal 44 to other grid control means than 33 in a pre-amplifier having more than one thermionic tube and including tube 32. It will also be evident that with reference to the switch-blade K, and when the control-impedance *r''*—37 with transfer-filter of Fig. 2 is employed, the terminal indicated by A. M. can alternatively be connected to terminal 43 instead of to the ungrounded terminal of resistor *r'*.

Referring to Fig. 1, there is provided a simple demodulator structure requiring but a single thermionic tube, with direct cathode-anode series connection of a complete phase-shifting network,

as distinguished from a shunt-supply of alternating currents to a phase-shifting network, combinations of shunt and series supply, or other network couplings; said structure providing unilaterally-grounded output voltages, and providing sustained voltages to ground for a frequency-controlling grid of a thermionic generator in a superheterodyne receiver, whenever a sustained difference occurs between balance-frequency of the demodulator and centre-frequency of the carrier wave. When the filter means of Fig. 2 is employed with Fig. 1, the simple one-tube demodulator structure provides dynamic stabilization of amplitude-envelope and regulation of average carrier amplitude employed, with the pre-amplifier. It will be evident that the demodulator of Fig. 1 provides economies of circuit elements with reference to Fig. 3.

While I have described and indicated several systems for carrying out my invention, it will be apparent to one skilled in the art that the invention disclosed herein is not limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention.

What is claimed is:

1. A frequency-discriminator for providing unilaterally-grounded output voltages responsive in magnitude and polarity to modulation of frequency of a high-frequency carrier wave, having a thermionic tube with a cathode, a first and a second diode-anode with said cathode, a third anode, and grid control means for controlling thermionic currents between said third anode and cathode, an input-impedance connected between said grid control means and said cathode, a unidirectional voltage source with positive terminal connected to said third anode and negative terminal connected to ground, a phase-shifting network connected between said cathode and said diode-anodes including a common conductive connection between said cathode and each of said diode-anodes, and a junction-terminal of said conductive connection upon said network; a conductive ground connection of negligible impedance to one of said diode-anodes, a high-frequency choke-coil connected between said ground and said junction-terminal, and a high-frequency voltage neutralizing device including a conductive neutralizing-impedance coupled with said network for transferring opposing high-frequency voltages therefrom, and a conductive connection through said neutralizing-impedance to the ungrounded diode-anode.

2. In combination with the structure of claim 1, a pre-amplifier having a thermionic tube with grid control means and an output circuit coupled with said input-impedance, an amplitude-modulation responsive control-impedance connected in series with said common conductive connection, having one terminal thereof connected to said junction-terminal and the other terminal thereof connected to the ungrounded terminal of said choke-coil, and a transfer-filter connected to said control-impedance including a resistance-capacitance series connection with one terminal of the resistance thereof connected to said ground, and another terminal of said resistance thereof connected to said grid control means of said pre-amplifier, for transferring amplitude-modulation opposing pulses to said pre-amplifier grid control means to reduce undesired amplitude-modulation, when the rate of change of said carrier amplitudes exceeds a predetermined minimum value.

3. In combination with the structure of claim 1, a pre-amplifier having a thermionic tube with grid control means and an output circuit coupled with said input-impedance, an amplitude-modulation responsive control-impedance connected in series with said common conductive connection, having one terminal thereof connected to the ungrounded terminal of said choke-coil and the other terminal thereof connected to said junction-terminal, and a transfer-filter connected to said control-impedance including a second high-frequency choke-coil connected in series with a high-frequency by-pass condenser between said junction-terminal and said ground, one terminal of said second choke-coil being connected to said junction-terminal, and one terminal of said by-pass condenser being connected to said ground, and impedance means shunted across said by-pass condenser connected with the grid control means of said pre-amplifier.

4. A frequency-discriminator for providing unilaterally-grounded sustained output voltages responsive in magnitude and polarity to deviation of frequency of a high-frequency carrier wave, having a thermionic tube with a cathode, a first and a second diode-anode with said cathode, a third anode, and grid control means between said cathode and third anode, resonance-circuit means responsive to said high-frequency carrier wave, means for energizing said resonance-circuit means including a source of unidirectional voltage with positive terminal connected to said third anode and negative terminal connected to ground, conductive circuit connections from each of said diode-anodes to said cathode through a junction-terminal upon said resonance-circuit means; a connection from said grid control means to said cathode, a conductive connection of negligible impedance from one of said diode-anodes to said ground, and a high-frequency choke-coil connected between said ground and said cathode-connected junction-terminal upon said resonance-circuit means common to said conductive circuit connections.

5. In combination with the structure of claim 4, a neutralizing-impedance for neutralizing high-frequency voltages superposed upon said output voltages, a conductive connection to the ungrounded diode-anode serially including said neutralizing-impedance, and a coupling means for coupling said neutralizing-impedance with said resonance-circuit means.

6. A demodulator for demodulating frequency-modulation from a high-frequency carrier wave, having a thermionic tube with a cathode, a first and a second diode-anode with said cathode, a third anode, and grid control means for controlling thermionic currents between said third anode and cathode, a three-branch impedance network having a common junction, and having a first conductive impedance branch including a first inductance coil connected between said junction and one of said diode-anodes, a second conductive impedance branch including a second inductance coil connected between said junction and the other of said diode-anodes, and a third conductive impedance branch connected between said junction and said cathode; energizing means for said network including a source of unidirectional voltage with positive terminal connected to said third anode and negative terminal connected to ground, a conductive connection of negligible impedance from one of said diode-anodes to said ground, a high-frequency choke-coil connected from said ground to said common junction, and

a high-frequency voltage balancing means for balancing out the high-frequency voltage in an output circuit for demodulated voltages, including a conductive connection from the ungrounded diode-anode through a bucking-coil inductively coupled with said first and second inductance coils.

7. A frequency-demodulator for providing unilaterally-grounded sustained output voltages responsive in magnitude and polarity to deviation of frequency of a high-frequency carrier wave, having a thermionic tube with a cathode, a first and a second diode-anode with said cathode, a third anode, and a control grid for controlling currents between said third anode and cathode, a source of unidirectional voltage with positive terminal connected to said third anode and negative terminal connected to ground, a series-parallel circuit including an inductance coil with terminals shunted by a condenser tuned to said carrier frequency, with a first choke-coil having one terminal connected to said cathode and the other terminal connected to the mid-inductance point upon said inductance coil, a diode-resistor shunted by capacitance connected between one of said diode-anodes and a terminal of said inductance coil, a second diode-resistor shunted by a second capacitance connected between the other diode-anode and the other terminal of said inductance coil, a conductive connection of negligible impedance from one of said diode-anodes to said ground, a second choke-coil connected between said ground and the terminal of said first choke-coil connected to said mid-inductance point, and a high-frequency voltage balancing means for balancing out high-frequency voltages in the conductive output circuit for demodulated voltages from said ground through said ungrounded diode-anode, including a second inductance coil inductively coupled with the first said inductance coil and having one terminal connected to the ungrounded diode-anode.

8. In combination with the structure of claim 7, selector means for selecting demodulated voltages, including a switch-terminal connected to the ungrounded terminal of the diode-resistor having a grounded terminal, and a switch-terminal connected to the other terminal of said second inductance coil, respectively for reception of amplitude-demodulated voltages or for frequency-demodulated voltages.

9. In combination with the structure of claim 7, the circuit connection to said ground from the other terminal of said second inductance coil serially including a filter-resistance and a filter-condenser, said filter-condenser having a terminal thereof connected to said ground, for transferring the sustained voltages across said filter-condenser from said demodulator, independent of frequency-modulation upon said carrier wave, and dependent as to magnitude and polarity upon the deviation of the centre-frequency of said carrier wave from the tuned frequency of said inductance coil shunted by said condenser.

10. In combination with the structure of claim 6, a second high-frequency choke-coil connected in series with a condenser from said ungrounded diode-anode to said common junction, for compensating impedance-asymmetry introduced by the first said choke-coil.

11. In combination with the structure of claim 1, a second high-frequency choke-coil connected in series with a condenser from said ungrounded diode-anode to said junction-terminal, for compensating impedance-asymmetry introduced by the first said choke-coil.

12. In a frequency-discriminator for providing sustained unilaterally-grounded output voltages responsive in magnitude and polarity to frequency deviations of a high-frequency carrier wave, having a thermionic tube with a cathode, a first and a second diode-anode with said cathode, a third anode, and a control grid for controlling currents from said third anode, a carrier frequency responsive network having a common conductive connection to said cathode from a junction-terminal thereon conductively connected to each of said diode-anodes, a conductive connection of negligible impedance to ground from one of said diode-anodes, and a high-frequency choke-coil connected between said ground and said junction-terminal, the filter-device for transferring voltages of modulation frequency from said network, including a control-resistance shunted by a control-capacitance and connected in series with said common conductive connection between said junction-terminal and the ungrounded terminal of said choke-coil, a second high-frequency choke-coil connected to said junction-terminal and in series with a high-frequency by-pass condenser connected to said ground, and circuit connections from the terminals of said by-pass condenser for transferring amplitude-modulation responsive voltages.

13. In combination with the structure of claim 12, a pre-amplifier for said frequency-discriminator, having a thermionic tube with grid control means and an anode coupled with said control grid of said discriminator, a filter-resistance connected to said ground and in series through a filter-condenser to the ungrounded terminal of said by-pass condenser, and a connection from said grid control means of said pre-amplifier to said ground including a circuit through said filter-resistance.

14. In combination with the structure of claim 12, a pre-amplifier for said frequency-discriminator having a thermionic tube with grid control means and an anode coupled with said control grid of said discriminator, a filter-condenser connected to said ground and in series through a filter-resistance to the ungrounded terminal of said by-pass condenser, and a connection from said grid control means of said pre-amplifier to said ground including a circuit through said filter-resistance.

15. In a frequency discriminator having a thermionic tube with cathode, anode, grid control means between said cathode and anode for controlling anode-cathode currents, and a first and second diode-anode with said cathode, a bilateral phase controlling network with a conductive connection to said cathode, a unidirectional voltage source with positive terminal connected to said anode, a first voltage-rectifying means including a conductive circuit from one of said diode-anodes to said cathode through said network and through a first diode-resistor, and a second voltage-rectifying means including a conductive circuit from the other of said diode-anodes to said cathode through said network and through a second diode-resistor, the means for unilaterally energizing said network with steady anode-cathode currents, including a choke-coil means conductively connected between a diode-anode connected terminal of one of said diode-resistors and said conductive connection to said cathode, for eliminating voltage upon said one

diode-resistor from said steady anode-cathode currents, and a conductive connection between the negative terminal of said source and said terminal of said diode-resistor.

16. A frequency discriminator having a thermionic tube with a cathode, an anode, and grid control means between said cathode and anode for controlling anode-cathode currents, a phase-controlling network connected between said cathode and anode for controlling phase of voltages upon said network in response to changes of frequency impressed upon said grid control means, having an inductance coil means connected in series with a parallel resonator-circuit having one branch including a resonator-inductance coil, said network having secondary coil means inductively coupled with said resonator-inductance coil for transferring voltages therefrom, a voltage-rectifying means includuing a diode means serially connected with a diode-resistor means, a second voltage-rectifying means including a second diode means serially connected with a second diode-resistor means, and circuit connections between said voltage-rectifying means and said phase-controlling network, including a circuit through said secondary coil means.

17. A frequency demodulator having a thermionic tube with a cathode, an anode, a grid control means for controlling anode-cathode currents, a first diode-anode with said cathode and a second diode-anode with said cathode, a voltage-combining network for combining frequency responsive voltages, including a three-branch conductive impedance circuit having a common junction between a terminal of each of said conductive impedance branches, one of said branches including inductance-coil means connected from one of said diode-anodes to said junction, another of said branches including a second inductance-coil means connected from the other of said diode-anodes to said junction, and a third branch having a conductive impedance connected from said cathode to said junction, energizing-circuit means for energizing said network with carrier frequencies, said energizing-circuit means having mutual impedance with said network and including a source of unidirectional supply-voltage with positive terminal connected to said anode; a first diode-resistor for rectified voltage connected in one of said diode-anode connected branches, a second diode-resistor for rectified voltage connected in the other of said diode-anode connected branches, and conductive output-circuit connections for conductively transferring frequency demodulated voltages from said diode-resistors and opposing transfer of carrier frequency voltages from said network, including a circuit through inductance means coupled with said network.

18. The combination with a diode voltage-rectifier having a cathode means, a diode-anode means with said cathode means, and the conductive circuit connections between said means serially including a diode-resistor for rectified voltages shunted by a condenser for smoothing said rectified voltages, and a conductive impedance means for impressing alternating voltages upon said diode-anode means, of a thermionic amplifier means including a second anode means with said cathode means, and grid control means between said second anode means and said cathode means, a source of unidirectional supply-voltage with positive terminal connected to said second anode means, and means for unilaterally energizing said amplifier means with unidirectional current from said source, including a junction-terminal consisting of the negative terminal of said source and the diode-anode connected terminal of said diode-resistor, and choke-coil means connected to said junction-terminal of said diode-resistor, by-passing said unidirectional current of said second anode means to said cathode means around said diode-resistor.

19. A frequency-demodulator having a thermionic tube with a cathode, an anode grid control means for controlling currents between said anode and cathode, and a diode means including a diode-anode with said cathode, a voltage phase-control circuit including a parallel resonator-circuit connected in series with a choke-impedance means, a circuit connection from said anode to said cathode for energizing said phase-control circuit with carrier frequencies, serially including said resonator-circuit, said choke-impedance means, and a diode-resistor means for rectified voltages; a capacitor means shunted across said diode-resistor means, and a conductive connection from said diode-anode to said diode-resistor means for providing rectified voltages responsive to frequency upon said diode-resistor means.

20. A frequency demodulator for separating output-voltages of modulation frequency from carrier frequency-modulated input-voltages, having a thermionic tube with a cathode, an anode, and grid control means between said cathode and anode for controlling anode-cathode currents, circuit connections between said anode and cathode including a source of unidirectional anode-supply voltage with positive terminal connected to said anode, and a path capable of serially carrying a cathode-anode alternating current with said frequency-modulated carrier frequency, having an end-terminal thereof connected to said cathode, said path serially including two inductance means mutually independent of each other, and a junction-terminal between said inductance means; impedance means including capacitance shunted across one of said inductance means for resonating said shunted inductance means with frequencies of said cathode-anode current and with energy transferred through the other of said inductance means, voltage-rectifying means including diode means serially connected with diode-impedance means having resistor means for said output-voltages, said voltage-rectifying means being connected across both of said serially connected inductance means for rectifying combined voltages therefrom, a common-terminal upon said resistor means in common with a negative terminal of said source of anode-supply voltage, a control-impedance means connected from said junction-terminal to a junction between said diode-impedance means and said diode means, said control-impedance means being capable of passing currents of either polarity with equal impedance thereto, a second control-impedance means connected from said junction-terminal to said common-terminal, said second control-impedance means being capable of passing currents of either polarity with equal impedance thereto, and a circuit through one of said inductance means and through said diode-impedance means for transferring frequency-demodulated voltages from said diode-impedance means, having a neutralizing-impedance means coupled with said one of said inductance means and with said diode-impedance means for cancelling alternating voltages of carrier frequency in said circuit.

21. A frequency discriminator for separating

output-voltages of modulation frequency from carrier frequency-modulated input-voltages, having a thermionic tube with a cathode, an anode, and grid control means between said anode and cathode for controlling anode-cathode currents, connections for carrying currents between said anode and cathode including a source of unidirectional anode-supply voltage with positive terminal connected to said anode, and including a path capable of serially carrying a cathode-anode alternating current with said frequency-modulated carrier frequency, having an end-terminal thereof connected to said cathode, said path serially including two inductance means mutually independent of each other, and a junction-terminal between said inductance means; impedance means including capacitance shunted across one of said inductance means for resonating said shunted inductance means with frequencies of said alternating current and by means of energy supplied through the other of said inductance means, voltage-rectifying means including diode means serially connected with diode-impedance means having resistor means for said output-voltages, said voltage-rectifying means being connected across both of said serially

connected inductance means for rectifying combined voltages therefrom, a common-terminal upon said resistor means in common with a negative-voltage terminal of said source of anode-supply voltage, and a control-impedance means connected from said junction-terminal to a junction between said diode means and said diode-impedance means, said control-impedance means being capable of passing currents of either polarity with equal impedance thereto.

EDWARD H. LANGE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,259,891	Hunt	Oct. 21, 1941
2,296,092	Crosby	Sept. 15, 1942
2,382,015	Lange	Aug. 14, 1945

FOREIGN PATENTS

Number	Country	Date
49,629	France	May 16, 1939