

Sept. 15, 1942.

M. G. CROSBY

2,296,091

FREQUENCY MODULATION DETECTOR CIRCUITS

Filed June 25, 1941

2 Sheets-Sheet 1

Fig. 1.

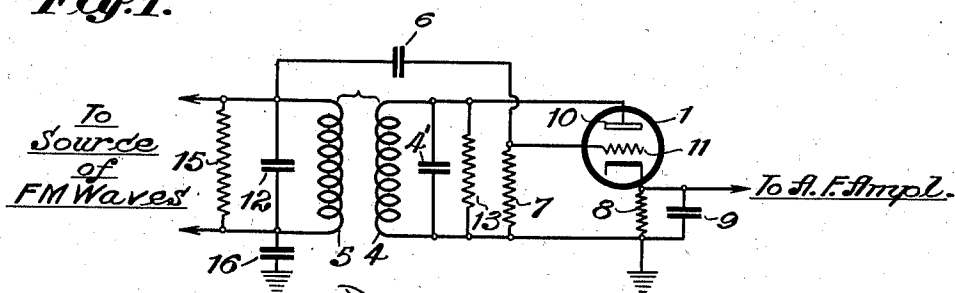


Fig. 1a.

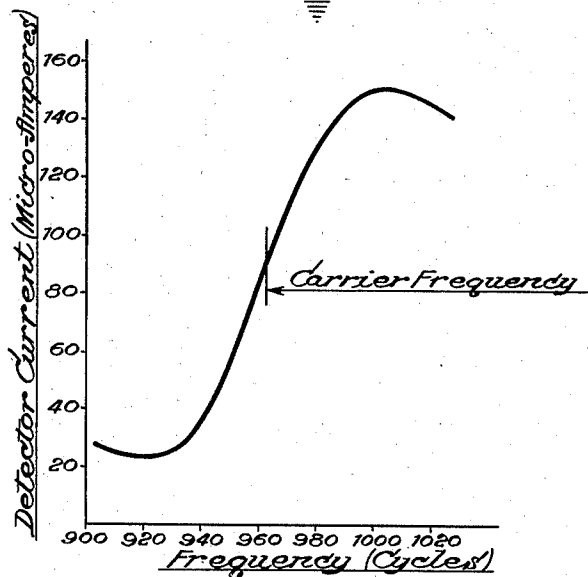
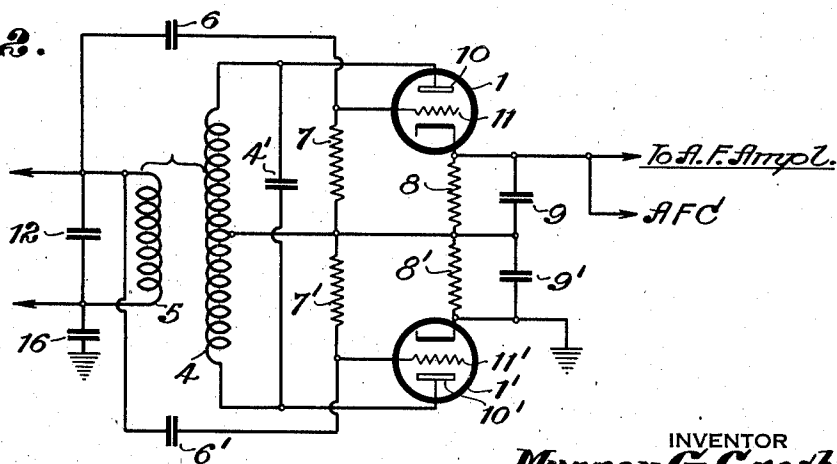


Fig. 2.



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Fig. 3.

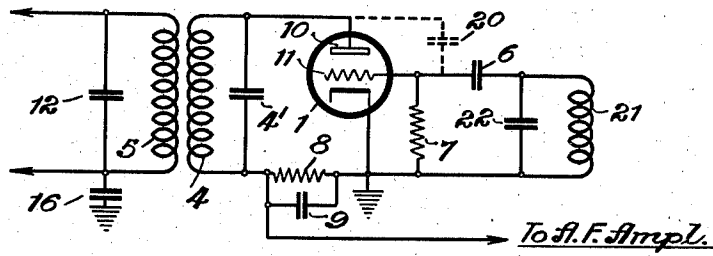
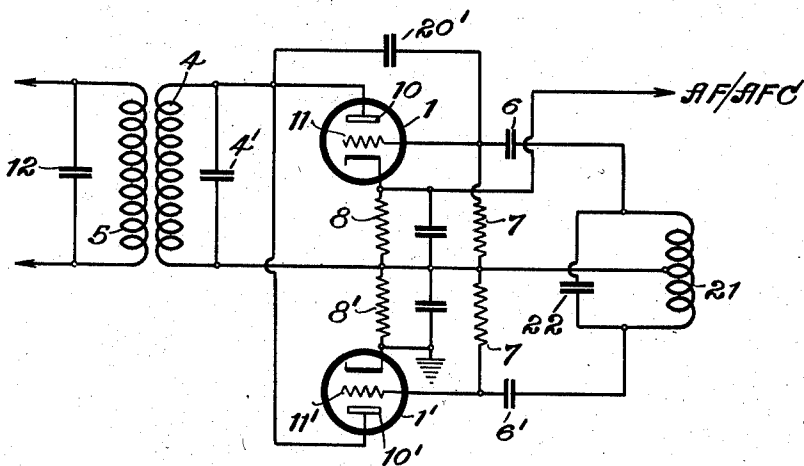


Fig. 4.



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FREQUENCY MODULATION DETECTOR
CIRCUITSMurray G. Crosby, Riverhead, N. Y., assignor to
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Delaware

Application June 25, 1941, Serial No. 399,586

14 Claims. (Cl. 250—27)

My present invention relates generally to detectors of angular velocity-modulated carrier waves, and more particularly to an improved frequency modulated carrier wave detector of the type wherein the applied modulated waves have a portion thereof retarded and the retarded and unretarded portions are then applied to separate points of the detection network.

In my application Serial No. 328,354, filed April 6, 1940, there have been disclosed detection systems for angular velocity-modulated carrier waves, it being understood that the latter term is generically used to cover frequency, or phase, modulated carrier waves. In the circuits of said application detection is accomplished by the application of retarded and unretarded modulated carrier waves to separate points in the detection network thereby to secure demodulation of the applied waves. Specifically, in my aforesaid application the retarded and unretarded frequency modulated carrier waves are applied to separate control grids of a multi-grid detector tube.

It may be stated that it is one of the main objects of my present invention to provide a frequency modulation detector wherein the retarded and unretarded modulated carrier waves are applied to an anode and a grid of a detection tube thereby permitting greater convenience in the design of FM (frequency modulation) receivers.

Another important object of the invention is to provide an FM detector circuit including a tube which includes at least a grid and an anode, and the collected FM waves being divided into a retarded portion and an unretarded portion, one of the portions being fed to the grid and the other portion being fed to the anode, and the detected modulation voltage appearing at the output terminals of the detector tube as the varying center frequency of the applied waves varies the relative phase relation between the retarded and unretarded wave portions.

Another object of the invention is to provide an FM detection system of the type wherein retarded and unretarded FM waves are applied to an anode and a grid respectively of a detector tube whereby it is possible to use a simpler tube for a detector, and, also, there being allowed the use of a diode connection in which there is no permanent anode voltage applied to the anode of the detector tube.

The novel features which I believe to be characteristic of my invention are set forth in 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 an embodiment of an FM detector circuit embodying the invention.

Fig. 1a illustrates the type of detection characteristic secured with the circuit of Fig. 1.

Fig. 2 shows a modification of the detection network of Fig. 1.

Fig. 3 shows an FM detector with a simple tuned circuit functioning as the retarding circuit.

Fig. 4 shows a modification of the arrangement in Fig. 3.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, the FM detector tube is designated by the numeral 1, and is shown as a simple triode. The plate 10 thereof is connected to the grounded end of the cathode load resistor 8 through a path which includes the secondary coil 4 of the input transformer. The coil 4 is shunted by condenser 4' which resonates the coil to the mean, or center, frequency of the applied modulated carrier waves. The primary coil 5 is shunted by condenser 12 which resonates the coil to the same mean frequency. Each of the primary and secondary resonant circuits is shunted by a damping resistor. The damping resistors 13 and 15 act so as to provide a pass band characteristic of a desired wide band shape.

As those skilled in the art well know, the present FM band covers a range of 42–50 megacycles (mc.). The permissible frequency deviation of the mean, or carrier, frequency of each channel is 75 kilocycles (kc.) on each side of the mean frequency. Therefore, the over-all channel width is 150 kilocycles (kc.). Accordingly, each of circuits 12–5 and 4–4' is tuned to the mean frequency, that is any of the carrier frequencies in the 42–50 mc. band, if the receiver is of the tuned radio frequency type. However, where the receiver is of the superheterodyne type, which is most commonly used at the present time, then these resonant circuits are each tuned to the operating intermediate frequency (I. F.) of the system. In such case the usual converter network is used to reduce the collected FM waves to the waves whose mean frequency is equal to the operating I. F. value. Following the converter stage one or more I. F. amplifiers may be used, and it is common practice to transmit

the amplified I. F. waves through an amplitude modulation limiter.

The purpose of the limiter is to eliminate from the FM waves any amplitude modulation which may appear on the carrier, and which amplitude modulation effects are due to the cascaded resonant circuits, fading or noise impulses. Let it be assumed, therefore, that the primary circuit 12—15 is fed from the plate circuit of the limiter tube. It is, also, to be understood that the effect of damping resistors 15 and 13 is to impart to the entire network between the limiter and the detector tube 1 a pass band of substantially 150 kc. in width and with a substantially flat top. It is to be understood, of course, that the present invention is not limited to the aforementioned FM frequency range, nor to the noted pass band, but that these values are given merely by way of illustration. The control grid 11 of tube 1 is connected to the junction of a condenser 6 and resistor 7 arranged in series between the high potential side of primary circuit 12—5 and the grounded side of the secondary circuit 4—4'. The low potential side of circuit 12—5 is bypassed to ground by condenser 16.

Across the load resistor 8 there is developed modulation voltage which represents the modulating signal applied to the carrier at the transmitter; it being understood, of course, that the amplitude of the modulating signal voltage appears in the FM wave as a deviation of the mean frequency, whereas the modulation frequencies themselves determine the rate of the aforesaid deviation. The resistor 8 is shunted by an I. F. by-pass condenser 9, and the modulation voltage developed across resistor 8 may be applied to one or more audio frequency amplifiers, assuming that the modulation voltage is of audio frequency.

Where the mean frequency of the applied FM waves falls in the middle of the pass band of the network 12—4', at this midband frequency the transformer effects a permanent phase shift of 90 degrees, and also a phase shift that is proportional to the frequency of the applied FM waves. This retarded FM wave is fed to the anode 10 of the detector tube 1, while grid 11 has applied to it the unretarded FM voltage directly from the primary circuit 12—5 through the resistance-condenser coupling 6—7. It is not believed necessary for the purpose of this application to outline in detail the mathematical analysis for the general case of a retarded and unretarded voltage being fed to the plate and grid of the detector tube. It is believed sufficient to point out that in the absence of voltage on the grid of the detector tube the current in the plate or cathode circuit will be proportional to the voltage applied to the plate, or anode, 10. However, due to the controlling nature of the grid the anode current flowing is also proportional to the voltage applied to the grid. Hence, when voltages are present on both the grid and plate the resulting current is proportional to the product of these voltages. Consequently, with an unretarded voltage applied to the control grid 11 and the retard voltage applied to the plate 10 the resulting current will be proportional to the product of expressions defining the retarded and unretarded voltages.

The circuit of Fig. 1 was experimentally tested at a carrier frequency of 962 cycles to determine the nature of the detection characteristic. The tube 1 was of the 6J5 type; resistor 8 was

of 100,000 ohms; resistor 7 was 1 megohm; condenser 6 was 0.1 microfarad; condenser 9 was 1.0 microfarad. The curve in Fig. 1a shows the detection (S shape) characteristic secured.

While the carrier was at 962 cycles, it is obvious that higher carrier frequencies may be used by merely tuning the input transformer to a higher frequency and by changing the values of the condensers in accordance with carrier frequency. The carrier is tuned to the middle of the linear portion of the detection characteristic so that as the frequency is modulated to either side of carrier frequency, the detected current is modulated up and down to give an output in accordance with frequency modulation.

The push-pull embodiment shown in Fig. 2 has the advantage of added linearity due to the push-pull action and balances out amplitude modulation. It is somewhat more suited to automatic frequency control (AFC) action. In the circuit of Fig. 2 detector tube 1 has its plate connected to one end of the coil 4 while the cathode thereof is connected to the mid-point of coil 4 through the load resistor 8, the latter being shunted by the I. F. by-pass condenser 9. The grid 11 is connected to the junction of condenser 6 and resistor 7, the lower end of resistor 7 being connected to the mid-point of coil 4. The opposite tube 1' has its plate 10' connected to the opposite end of coil 4 while the grid 11' is connected to the junction of condenser 5' and resistor 7'. The cathode of tube 1' is connected through the resistor 8' to the mid-point of coil 4, and the I. F. bypass condenser 9' shunts the load resistor 8'. The cathode end of resistor 8' is established at ground potential. The connections to the audio frequency amplifier and to the AFC line are made in common to the cathode end of load resistor 8.

In the arrangement of Fig. 2, insofar as the production of modulation voltage is concerned, the circuit operates in the manner of a push-pull circuit, and the modulation voltage across load resistors 8 and 8' in series is taken off from the cathode end of resistor 8. The AFC bias is taken off from the same point, because for AFC purposes it is required that the permanent voltage across the load resistors be zero for the condition when the applied FM waves have their mean frequency equal to the operating I. F. value of the input circuit of the detector. The balancing of one cathode voltage against the other produces the zero value for the in-tune condition so that there will be no AFC bias produced when the desired FM channel is properly tuned to. This balance of detector currents, also, balances out amplitude modulation detected by the detectors.

In Fig. 3 there is shown a circuit arrangement which is an adaptation of the simple tuned circuit type of retard circuit. The unretarded voltage is applied directly to the anode 10 of the detector tube 1, and through the inherent plate to grid capacity 20 (shown in dotted lines) to the tuned circuit 21—22. The latter is arranged between the grid 11 and the grounded cathode. The load resistor 8 is arranged in series between the low potential end of resonant circuit 4—4' and the grounded cathode, the resistor being shunted by the I. F. by-pass condenser 9. The audio frequency voltage connection is made to the anode end of resistor 8. The tuned circuit 22—21 is resonated to the mean frequency which is the operating I. F. value, and, hence, is resistive at that frequency

so that the high reactance of the inherent capacity 20 produces a permanent shift of substantially 90 degrees. As the mean frequency deviates, the phase of the voltage across the tuned circuit 22—21 varies in the same manner as the tuned transformer type of retard circuit. The detected output is taken from a resistive element in the anode circuit of the tube, or may be taken from the cathode circuit in the same manner as in Fig. 1.

The arrangement shown in Fig. 4 is the push-pull, or back-to-back, modification of the arrangement shown in Fig. 3. In this arrangement the plate 10' of tube 1' is connected to the plate 10, while the low potential end of coil 4 is connected to the junction of the respective load resistors 8 and 8' of tubes 1 and 1'. The cathode end of resistor 8' is grounded, while the modulation voltage and AFC bias are taken off from the cathode end of resistor 8. The tuned circuit 22—21 has its opposite sides connected to the grids 11 and 11' of the detector tubes through grid leak and condenser elements 6—7 and 6'—7', respectively. The mid-point of coil 21 is connected to the junction of resistors 8 and 8'. The inherent plate to grid capacity of tube 1 is augmented by an external condenser 20'. Without this external condenser the inherent plate to grid capacity of one tube would neutralize the other. Hence, the external capacity must be added to feed the FM voltage to the tuned circuit 22—21, and thereby form the phase-shifting retard circuit.

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. In a demodulation network for angular-velocity modulated carrier waves, at least one electron discharge tube, said tube being provided with at least a cathode, an output electrode and at least one intermediate cold electrode, means applying said modulated carrier waves to one of said intermediate electrode and output electrode, means for retarding the phase of a portion of the said modulated carrier waves, means for applying the retarded waves to the other of said two electrodes, said output and intermediate electrodes both being at substantially cathode potential in the absence of applied carrier waves, and a load element in the space current path of said tube for developing modulation voltage representative of deviations of the center frequency of said modulated carrier waves.

2. In a demodulation network for angular-velocity modulated carrier waves, at least one electron discharge tube, said tube being provided with at least a cathode, an output electrode and at least one intermediate cold electrode, means applying said modulated carrier waves to one of said intermediate electrode and output electrode, means for retarding the phase of a portion of the said modulated carrier waves, means for applying the retarded waves to the other of said two electrodes, said output and intermediate electrodes both being at substantially cathode potential in the absence of applied carrier waves, and a load element in the space current path of said tube for developing modulation voltage representative of deviations of the center frequency of said

modulated carrier waves, said retarding means comprising a pair of cascaded tuned circuits, each resonant to said center frequency.

3. In a demodulation network for angular-velocity modulated carrier waves, at least one electron discharge tube, said tube being provided with at least a cathode, an output electrode and at least one intermediate cold electrode, means applying said modulated carrier waves to one of said intermediate electrode and output electrode, means for retarding the phase of a portion of the said modulated carrier waves, means for applying the retarded waves to the other of said two electrodes, said output and intermediate electrodes both being at substantially cathode potential in the absence of applied carrier waves, and a load element in the space current path of said tube for developing modulation voltage representative of deviations of the center frequency of said modulated carrier waves, said retarding means comprising a pair of cascaded tuned circuits, each of said tuned circuits being substantially resonant to said center frequency, said output electrode being connected to the second of said tuned circuits and said intermediate electrode being connected to the first of said tuned circuits.

4. In a demodulation network for angular-velocity modulated carrier waves, at least one electron discharge tube, said tube being provided with at least a cathode, an output electrode and at least one intermediate cold electrode, means applying said modulated carrier waves to one of said intermediate electrode and output electrode, means for retarding the phase of a portion of the said modulated carrier waves, means applying the retarded waves to the other of said two electrodes, said output and intermediate electrodes both being at substantially cathode potential in the absence of applied carrier waves, and a load element in the space current path of said tube for developing modulation voltage representative of deviations of the center frequency of said modulated carrier waves, said phase retarding means being connected to said intermediate electrode, and the unretarded modulated carrier waves being applied to said output electrode.

5. In a frequency modulated carrier wave detection network, a detector tube of the triode type, a tuned network resonant to the mean frequency of applied modulated carrier waves connected between the plate and cathode of said tube, a second tuned network resonant to said mean frequency, said second tuned network being connected between the grid of said tube and the cathode, means for maintaining said plate, grid and cathode at a substantially common potential in the absence of applied carrier waves, and a resistive load element arranged in the space current path of said tube for developing modulation voltage thereacross.

6. In a frequency modulated carrier wave detection network, a detector tube of the triode type, a tuned network resonant to the mean frequency of applied modulated carrier waves connected between the plate and cathode of said tube, a second tuned network resonant to said mean frequency, said second tuned network being connected between the grid of said tube and the cathode, and a resistive load element arranged in the space current path of said tube for developing modulation voltage thereacross and the plate and cathode of said tube being at substantially the same direct current potential in the absence of applied modulated carrier waves.

7. In a frequency modulated carrier wave detection network, a detector tube of the triode type, a tuned network resonant to the mean frequency of applied modulated carrier waves connected between the plate and cathode of said tube, a second tuned network resonant to said mean frequency, said second tuned network being connected between the grid of said tube and the cathode, and a resistive load element arranged in the space current path of said tube for developing modulation voltage thereacross, a second tube of the triode type having its plate connected to the plate of the first tube, means connecting the grid of the second tube to said second tuned network, a second resistive load element arranged in a space current path of the second tube, said two resistive elements being in series relation and means connected to the plate, grid and cathode of each triode to maintain them at a common potential in the absence of applied waves.

8. In a frequency modulated carrier wave detection network, a detector tube of the triode type, a tuned network resonant to the mean frequency of applied modulated carrier waves connected between the plate and cathode of said tube, a second tuned network resonant to said mean frequency, said second tuned network being connected between the grid of said tube and the cathode, means for maintaining said plate, grid and cathode at a substantially common potential in the absence of applied carrier waves, and a resistive load element arranged in the space current path of said tube for developing modulated voltage thereacross and a capacitative element coupling said first and second tuned networks.

9. In combination with an electron discharge tube including at least a cathode, a control grid and an anode, a resistive load element in the space current path of said tube and connected between the anode and cathode, means for applying to one of said grid and anode angular velocity-modulated carrier wave voltage, means for deriving from said last named means angular velocity-modulated carrier wave voltage of the same mean frequency but shifted in phase, and means for applying the phase-shifted voltage to the other of said electrodes and additional means for maintaining the anode and grid at the cathode potential in the absence of applied carrier wave voltage.

10. In combination with an electron discharge tube consisting of solely a cathode, a control grid and an anode, a resistive load element in the space current path of said tube and connected between the anode and cathode, means for applying to said grid angular velocity-modulated carrier wave voltage, means for producing angular velocity-modulated carrier wave voltage of the same mean frequency but shifted in phase as the modulated carrier voltage on the grid, and means for applying the phase-shifted voltage to the anode and additional means for maintaining the anode and grid at the cathode potential in the absence of applied carrier wave voltage.

11. In a demodulation network for angular-velocity modulated carrier waves, at least one electron discharge tube, said tube being provided with at least a cathode, an output electrode and at least one intermediate cold electrode, means ap-

plying said modulated carrier waves to said output electrode, means for retarding the phase of the said modulated carrier waves, means for applying the retarded waves to the intermediate electrode, means for maintaining each of said output and intermediate electrodes at the cathode potential in the absence of applied carrier waves, and a load element in the space current path of said tube for developing modulation voltage representative of deviations of the mean frequency of said modulated carrier waves.

12. In a frequency modulated carrier wave detection network, a detector tube of the triode type, a tuned network resonant to the frequency of applied waves connected between the plate and cathode of said tube, a second tuned network resonant to said frequency, said second tuned network being connected between the grid of said tube and the cathode, said plate and grid being at cathode potential in the absence of applied waves, and a resistive load element arranged in space current path of said tube for developing modulation voltage thereacross.

13. In combination with an electron discharge tube including at least a cathode, a control grid and an anode, a resistive load element in the space current path of said tube and connected between the anode and cathode, a first means for applying to one of said grid and anode angular velocity-modulated carrier wave voltage, a second means for deriving from said first means angular velocity-modulated carrier wave voltage of the same mean frequency but shifted in phase, and a third means for applying the phase shifted voltage to the other of said two electrodes, a second tube including a cathode, a control grid and anode, means connecting one of the grid and anode of the second tube to said first means, means connecting the other of the grid and anode of the second tube to said third means, connections between the cathode and each of the anode and grid of each tube for maintaining said electrodes at a common potential in the absence of applied carrier voltage, and said load element being included in the space current path of the second tube.

14. In a frequency modulated carrier wave detection network, a detector tube of the triode type, a tuned network, resonant to the center frequency of applied waves, connected between the plate and cathode of said tube, a second tuned network resonant to said center frequency, said second tuned network being connected between the grid of said tube and the cathode, a resistive load element arranged in the space current path of said tube for developing modulation voltage, a second tube of the triode type having its plate connected to the plate of the first tube, means connecting the grid of the second tube to said second tuned network, a second resistive load element arranged in the space current path of the second tube, said two resistive elements being in series relation, the plate and grid of each tube being at the cathode potential thereof in the absence of applied waves, and means for deriving the modulation voltage from across said resistive elements in series.

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