

Feb. 17, 1942.

S. HUNT.

2,273,771

FREQUENCY MODULATED CARRIER DETECTOR

Filed April 10, 1941

2 Sheets-Sheet 1

Fig. 1.

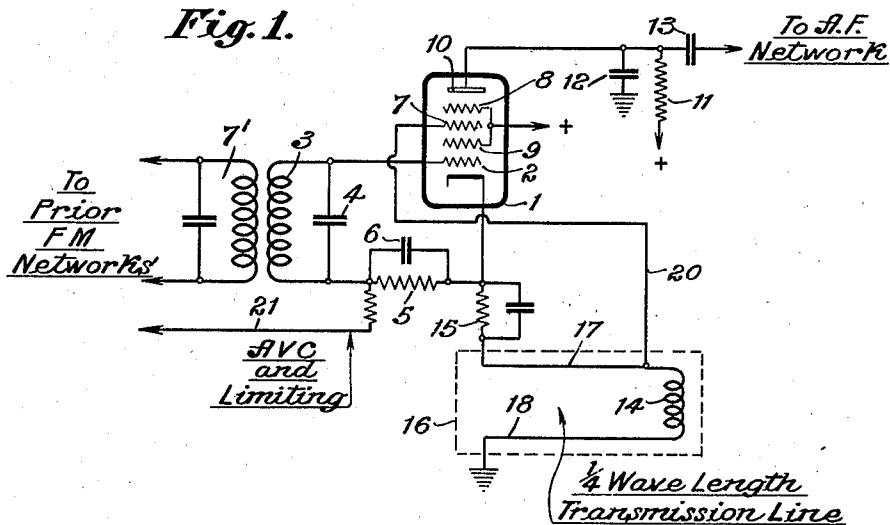


Fig. 2.

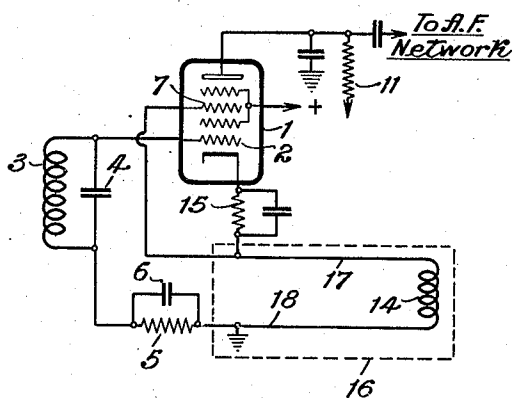
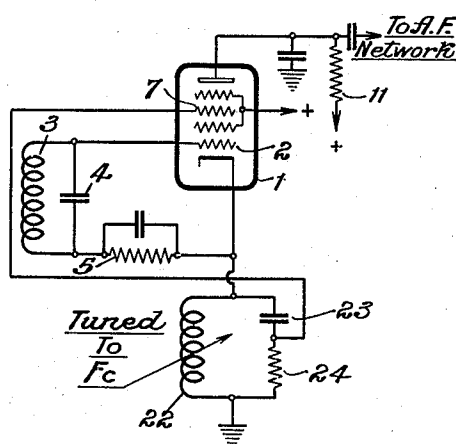


Fig. 3.



INVENTOR
BY *Seymour Hunt*
H.S. Snover
ATTORNEY

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S. HUNT

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Fig. 4.

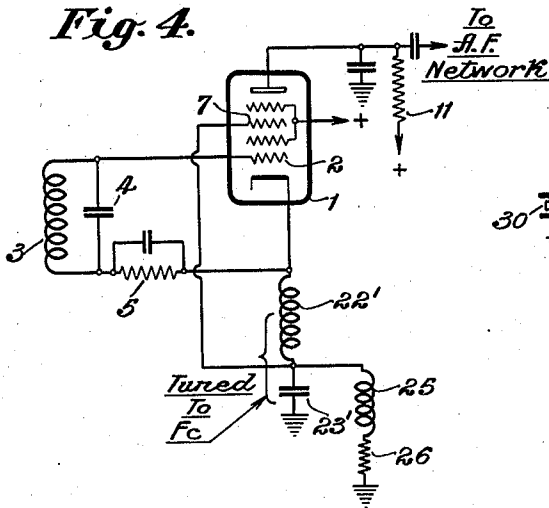


Fig. 5.

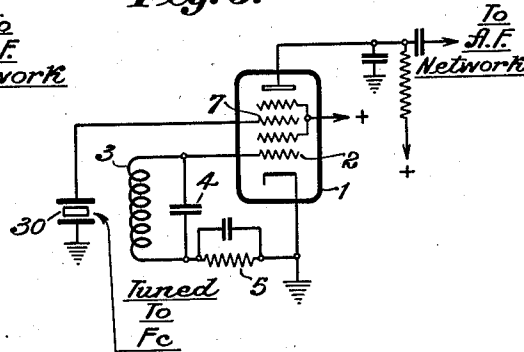


Fig. 6.

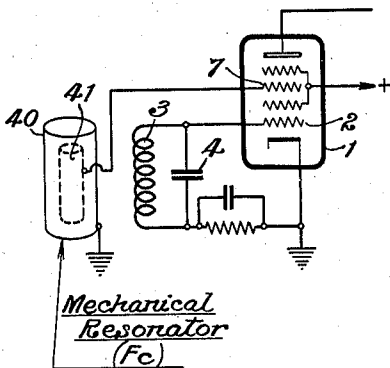
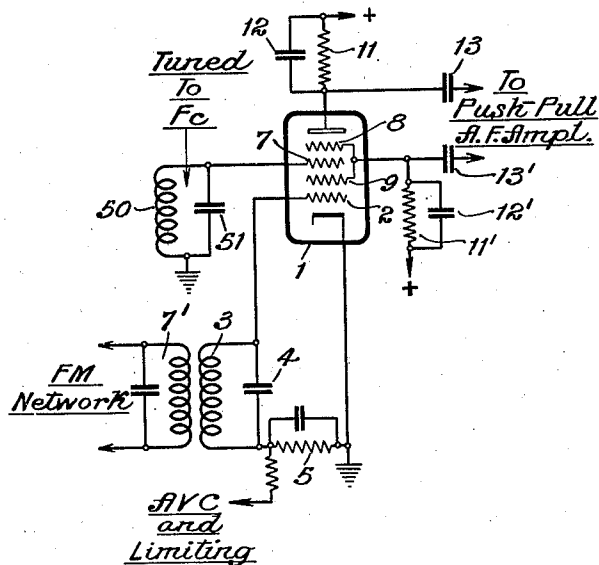


Fig. 7.



INVENTOR
Seymour Hunt
BY
H. S. Brown
ATTORNEY

UNITED STATES PATENT OFFICE

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FREQUENCY MODULATED CARRIER
DETECTORSeymour Hunt, Flushing, N. Y., assignor to Radio
Corporation of America, a corporation of Dela-
ware

Application April 10, 1941, Serial No. 387,829

9 Claims. (Cl. 250—27)

My present invention relates to detectors for frequency modulated carrier waves, and more especially to detectors of the multi-grid type capable of deriving modulation components from angular velocity-modulated carrier waves.

It has been shown in the past that if angular velocity-modulated carrier waves are applied in phase quadrature relation to spaced electrodes in a common electron stream to an output electrode, there will be produced in the output circuit modulation voltage corresponding to the modulation-representative deviations of the center frequency of the applied waves.

My present invention has for an object the provision of various arrangements for securing the aforesaid phase quadrature relation.

Another object of my invention is to provide in the cathode circuit of a multi-grid detector tube for frequency modulated carrier waves, a network acting to maintain modulated carrier voltage at one grid in phase quadrature with the carrier voltage at a second grid.

Still another object of my invention is to improve frequency modulated carrier wave detectors of the type wherein wave voltages are applied in phase quadrature to spaced grids of a multi-grid tube, and the improvement residing in a tuned device employed in association with one of the grids for producing the phase quadrature relation.

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 a circuit embodying the invention.

Fig. 2 illustrates a modification of the cathode circuit of Fig. 1.

Figs. 3 and 4 show respectively different additional modifications.

Figs. 5 and 6 show two different embodiments.

Fig. 7 shows still another form of the invention.

Referring, now, to Fig. 1 of the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, the tube 1 may be a multi-grid tube of the 6A8 type. The grid 2 is the signal voltage input grid, and it is connected to the cathode

of tube 1 through a path comprising coil 3 and resistor 5. The coil 3 is shunted by condenser 4, and the two are tuned to the operating intermediate frequency (I. F.) of the system, assuming the latter is a superheterodyne receiver. The I. F. may have a value of 4.2 mc. (megacycles), where the FM (frequency modulated carrier wave) band covers 42 to 50 mc. As is well known, there are impressed upon circuit 7' frequency modulated carrier waves whose center frequency is of the 4.2 mc. value. The circuits prior to tuned circuit 7 may include a signal collecting circuit, a converter, one or more I. F. amplifiers and a limiter stage.

As is well known to those skilled in the art, the function of the limiter is to eliminate amplitude modulation effects in the carrier. The limiter tube may be a saturated amplifier, and the circuit 7' will be located in the plate circuit of the limiter tube. Hence there will be delivered to input circuit 3—4 frequency variable waves of constant amplitude. It is, of course, well known that in frequency modulation transmission the modulating signal amplitude appears as a frequency deviation of the carrier, or center, frequency, while the modulating frequencies themselves correspond to the rate of deviation of the center frequency. The function of tube 1 and its associated circuits is to derive from the frequency-variable wave the modulation voltage which corresponds to the original modulating signals.

The grid 7 of tube 1 is located between a pair of positively biased screen grids 8 and 9, while the output electrode, or plate, 10 is connected to the positive terminal of a source of direct current by a load resistor 11. The plate end of resistor 11 is by-passed to ground by condenser 12 which has a low impedance to I. F. currents. Modulation voltage developed across resistor 11 is transmitted to a succeeding audio frequency utilization network by condenser 13 which has a low impedance to modulation frequency voltage.

The cathode of tube 1 is connected to ground through a path including coil 14 and by-passed bias resistor 15. The dotted rectangle 16 encloses the leads 17 and 18, the latter being terminated by the series termination 14. The network within rectangle 16 is a one-quarter wave length transmission line, and functions as a phase shifting network. The grid 7 is connected by lead 20 to the junction of resistor 15 and coil 14. The resistor 5 develops thereacross a unidirectional voltage which may be utilized for automatic volume control (AVC), and the lead

21 is connected to the grid end of resistor 5 through a filter resistor; the voltage transmitted over lead 21 is to be understood as being applied to the grid circuits of amplifier tubes preceding the limiter stage. Condenser 6 acts as an I. F. by-pass condenser across resistor 5.

It has been shown in the past that when frequency modulated carrier waves of the same center frequency are applied to grids 2 and 7 in substantially phase quadrature, then there will be developed modulation voltage across load resistor 11. In other words, the circuit functions as a demodulator. Of course, where the bypassed resistor 5 is inserted in the grid circuit of tube 1 then there will be provided further limiting action in the grid circuit of the demodulator. In that case a special limiter stage prior to the input circuit of detector tube 1 may be dispensed with.

Those skilled in the art know that the one-quarter wave length transmission line in rectangle 16 produces a phase shift thereacross which is 90 degrees. Thus, the voltages on grid 2 and grid 7 differ 90 degrees in phase. The line impedance at the cathode end of lead 17—18 is very low and the radio frequency voltage drop at that point is very small. At the terminating end of the line the impedance is high and the radio frequency voltage drop is high. In other words, the network in rectangle 16 may be considered as an open end line, and the radio frequency choke coil 14 closes the line to direct current. Of course, the line can be of any convenient wave length such that gives a 90 degrees phase shift, as, for example, a one and a quarter wave length or two and a quarter wave length.

Since the impedance of the cathode end of line 17—18 is very low and the radio frequency voltage drop is low, the end of resistor 5 shown connected to the cathode in Fig. 1 may be returned to ground. This is shown in Fig. 2. In this case grid 2 has degeneratively applied to it radio frequency voltage developed across 14. However, there is but small degeneration applied to grid 2 compared to a large voltage developed for grid 7 by the resonant rise due to the transmission line in the cathode circuit of the tube.

Another method of producing a 90 degrees phase shift between the frequency modulated voltages applied to grids 2 and 7 is shown in Fig. 3. In this figure the cathode of tube 1 is connected to ground through a coil 22 which is shunted by condenser 23. Circuit 22—23 is tuned to the center frequency F_c of the applied FM waves. A small resistor 24 is placed in series with condenser 23 to provide quadrature voltage thereacross. Grid 7 is connected to the junction of condenser 23 and resistor 24 and takes off the quadrature voltage across the latter. In this way FM voltage developed across the cathode network of tube 1 is applied to grid 7 in phase quadrature with the FM voltage applied to grid 2 by input circuit 3—4.

In Fig. 4 there is shown still another modification. This arrangement differs from that shown in Fig. 3 in the arrangement of the cathode phase shifting network. Here coil 22' and condenser 23' are arranged in series between the cathode and ground. The series path 22'—23' is series tuned to F_c , the junction of the series elements being connected to grid 7. In shunt with condenser 23' is connected radio frequency choke coil 25 in series with resistor 26. The radio frequency current through condenser 23' is 90 degrees out of phase with the voltage across tuned

circuit 22'—23'. Thus, voltage applied to grid 7 is 90 degrees out of phase with voltage at grid 2.

The circuit modification in Fig. 5 differs from that shown previously in the other figures in that the grid 7 is connected to ground through a piezo-electric crystal element which is tuned to F_c . Thus, the numeral 30 designates the crystal which is tuned or cut to F_c , those skilled in the art being fully aware of the manner of mounting the crystal between appropriate electrodes or crystal holder elements. One of the crystal electrodes is connected to grid 7, while the opposite one is connected to ground. The electrical equivalent circuit of the crystal would appear as an inductance, capacity and resistance, all constants of the crystal, arranged in series between grid 7 and ground, whereas the capacity of the crystal holder would be arranged in shunt with the aforesaid series constants. These equivalent components may be made to appear as a tuned circuit.

In Fig. 6 is shown another modification wherein the piezo-electric resonator 30 of Fig. 5 is replaced by a mechanical resonant line. The latter comprises an outer metallic tube 40 having one end thereof grounded, whereas there is disposed concentrically within the tube 40 a second metallic tube 41 connected to grid 7. Of course, the grid 7 will be tapped to a proper point on the inner tube 41. The mechanical resonator 40—41 is adjusted to tune to F_c .

It often happens that it is desirable to arrange an FM detector so that it will deliver a pair of audio voltages 180 degrees out of phase whereby a push-pull audio amplifier may be driven. In Fig. 7 there is shown such an arrangement. Here the tube 1 has its grid 7 connected to ground through the coil 50 of resonant circuit 50—51. The latter circuit is tuned to F_c , and develops across it FM voltage which is in phase quadrature with the voltage applied to grid 2. Screen grids 8 and 9 are connected to the positive terminal of a direct current source through a load resistor 11', the latter being shunted by an I. F. by-pass condenser 12'. A modulation voltage developed across plate load resistor 11 is transmitted through condenser 13 to the grid of one of a pair of push-pull connected amplifier tubes, while the voltage developed across resistor 11' is transmitted through condenser 13' to the opposite push-pull amplifier. As the FM voltage applied to grid 2 has its instantaneous frequency shifted above and below F_c more or less voltage is built up across circuit 50—51 by virtue of space charge coupling between grids 2 and 7. The mutual conductance of tube 1 changes as the voltage of grid 7 changes. When more plate current flows, less screen grid current flows and vice versa. This is, of course, the proper polarity sense for the audio voltages developed across resistors 11 and 11'. Of course, the phase quadrature voltage for grid 7 may be developed by using any of the cathode load networks shown in Figs. 1, 2 and 3 and 4 instead of relying upon space charge coupling of the detector tube.

The following explanation of the operation of Fig. 7 is equally applicable to Figs. 5 and 6. Electrons are first attracted by the positive screen 8. Some go through the open mesh of the screen and are attracted by the positive plate. Due to grid 7 being less positive than the screen 8 many electrons are slowed down in speed. A cloud, or pile, of electrons gather in front of grid 7. This is the virtual cathode. The plate draws electrons from the virtual cathode. The

virtual cathode waxes and wanes in relation to the voltage applied to grid 2. This motion of electrons causes a current to flow in grid 7 and tuned circuit $L_{50}-C_{51}$. At resonance $L_{50}-C_{51}$ looks like a resistor, and it has been found that the voltage across $L_{50}-C_{51}$ at resonance is 90 degrees out of phase with the voltage applied to grid 2. The actual plate current flowing is proportional to the voltage on grid 2 and the voltage on grid 7. As the carrier shifts $L_{50}-C_{51}$ is not a resistor any longer, but either a capacity or inductance depending upon whether the applied frequency is above or below the tuned frequency of $L_{50}-C_{51}$. Thus, the voltage across $L_{50}-C_{51}$ is either more or less than 90 degrees out from the applied grid 2 voltage. Thus, as the modulation causes the voltage of grid 2 to vary in frequency the plate current varies in step with the modulation, and provides the audio output.

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 an angular velocity modulated carrier wave detection network, a tube provided with at least a cathode, an output electrode and a pair of spaced control grids in the electron stream between the cathode and output electrode, a modulated carrier input circuit connected between one control grid and the cathode, an output load element across which is developed modulation voltage connected to the output electrode, a phase shifting network connected in the space current path of said tube between said cathode and a point of relatively fixed alternating potential, said shifting network developing modulated carrier voltage which is in phase quadrature with the voltage at said input circuit, and means for applying said quadrature voltage to the second control grid of said tube.

2. In an angular velocity modulated carrier wave detection network, a tube provided with at least a cathode, an output electrode and a pair of spaced control grids in the electron stream between the cathode and output electrode, a modulated carrier input circuit connected between one control grid and the cathode, an output load element across which is developed modulation voltage connected to the output electrode, a phase shifting network connected in the space current path of said tube between said cathode and a point of relatively fixed alternating potential, said shifting network developing modulated carrier voltage which is in phase quadrature with the voltage at said input circuit, and means for applying said quadrature voltage to the second control grid of said tube, said phase shifting network consisting of a quarter wave length transmission line.

3. In an angular velocity modulated carrier wave detection network, a tube provided with at least a cathode, an output electrode and a pair of spaced control grids in the electron stream between the cathode and output electrode, a modulated carrier input circuit connected between one control grid and the cathode, an output load element across which is developed modulation voltage connected to the output electrode, a phase shifting network connected in the space current

path of said tube between said cathode and a point of relatively fixed alternating potential, said shifting network developing modulated carrier voltage which is in phase quadrature with the voltage at said input circuit, and means for applying said quadrature voltage to the second control grid of said tube, said phase shifting network comprising a resonant circuit tuned to the center frequency of the carrier wave of said input circuit.

4. In an angular velocity modulated carrier wave detection network, a tube provided with at least a cathode, an output electrode and a pair of spaced control grids in the electron stream between the cathode and output electrode, a modulated carrier input circuit connected between one control grid and the cathode, an output load element across which is developed modulation voltage connected to the output electrode, a phase shifting network connected in the space current path of said tube between said cathode and a point of relatively fixed alternating potential, said shifting network developing modulated carrier voltage which is in phase quadrature with the voltage at said input circuit, and means for applying said quadrature voltage to the second control grid of said tube, said phase shifting network consisting of a coil and condenser series resonant to the center frequency of the waves of said input circuit, and said second control grid being connected to the junction of said coil and condenser.

5. In an angular velocity modulated carrier wave detection network, a tube provided with at least a cathode, an output electrode and a pair of electrodes arranged to control the electron stream between the cathode and output electrode, a modulated carrier input circuit connected between one control electrode and the cathode, an output load element across which is developed modulation voltage connected to the output electrode, a reactive phase shifting network connected between the cathode and a point of relatively fixed alternating potential and developing modulated carrier voltage which is in phase quadrature with the voltage at said input circuit, and means for connecting a point of said shifting network to the second control electrode of said tube.

6. In an angular velocity modulated carrier wave detection network, a tube provided with at least a cathode, a plate and at least two control grids in the electron stream between the cathode and plate, a modulated carrier input circuit connected between one control grid and the cathode, an output resistor element across which is developed modulation voltage connected to the plate, a phase shifting network connected in the space current path of said tube between said cathode and ground, said shifting network consisting of a transmission line of a length such as to develop modulated carrier voltage which is in substantial phase quadrature with the voltage at said input circuit, and means for applying said quadrature voltage to the second control grid of said tube.

7. In an angular velocity modulated carrier wave detection network, a tube provided with at least a cathode, an output electrode and at least a pair of spaced control grids in the electron stream between the cathode and output electrode, a modulated carrier input circuit connected between one control grid and the cathode, an output load element across which is developed modulation voltage connected to the output

electrode, a phase shifting network connected in the space current path of said tube between said cathode and a point of relatively fixed alternating potential, said shifting network including an open ended transmission line of a wave length chosen to develop modulated carrier voltage which is in substantial phase quadrature with the voltage at said input circuit, and means for applying said quadrature voltage to the second control grid of said tube.

8. In an angular velocity modulated carrier wave detection network, a tube provided with at least a cathode, an output electrode and a pair of spaced control grids in the electron stream between the cathode and output electrode, a modulated carrier input circuit connected between one control grid and the cathode, an output load element across which is developed modulation voltage connected to the output electrode, a phase shifting network connected in the space current path of said tube between said cathode and a point of relatively fixed alternating potential, said shifting network developing modulated carrier voltage which is in substantial phase quadrature with the voltage at said input circuit, and means for applying said quadrature voltage to the second control grid of said tube, said phase shifting net-

work comprising a coil and condenser arranged as a parallel resonant circuit tuned to the center frequency of the carrier wave of said input circuit, a resistor in series with the condenser, said applying means including a connection between the second grid and the junction of the resistor and condenser.

9. In an angular velocity modulated carrier wave detection network, a tube provided with at least a cathode, an output electrode and a pair of spaced control grids in the electron stream between the cathode and output electrode, a modulated carrier input circuit connected between one control grid and the cathode, an output load element across which is developed modulation voltage connected to the output electrode, a phase shifting network connected in the space current path of said tube between said cathode and a point of relatively fixed alternating potential, said shifting network developing modulated carrier voltage which is in phase quadrature with the voltage at said input circuit, means in circuit with said one grid for limiting the response of the network to carrier amplitude variation, and means for applying said quadrature voltage to the second control grid of said tube.

SEYMOUR HUNT.