April 20, 1943. S. HUNT 2,316,868

FREQUENCY MODULATION DETECTOR

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Fig. 1.

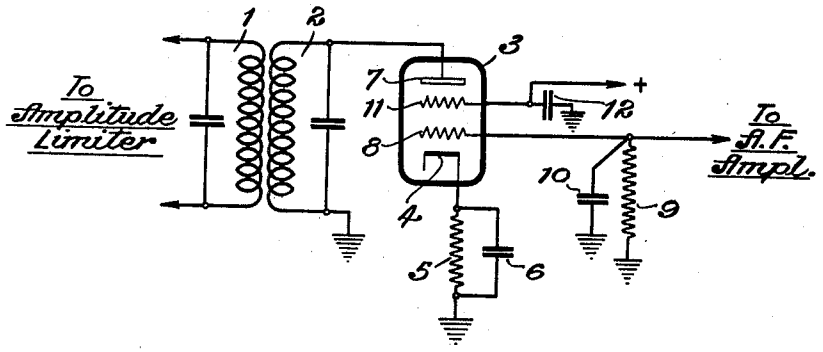
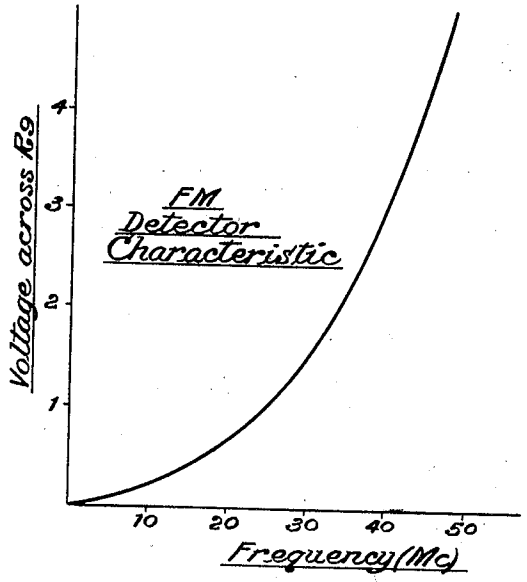


Fig. 2.



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FREQUENCY MODULATION DETECTOR

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5 Claims. (Cl. 250—27)

My present invention relates to detectors of angular velocity-modulated carrier waves, and more specifically to detectors of frequency modulated carrier waves.

One of the main objects of my invention is to provide a detector circuit for angular velocity-modulated carrier waves, the latter term generically denoting phase, or frequency, modulated carrier waves; and the detection circuit utilizing a tube provided with a cathode and at least three successive cold electrodes, the furthermost cold electrode being at a negative potential, and the transit time current to the electrode adjacent the cathode being utilized to indicate deviations in the center, or mean, frequency of the modulated waves to be detected.

Another object of the invention is to provide in a frequency modulated carrier wave detector, a tube provided with a cathode, a plate and at least two spaced control grids therebetween, a frequency modulated carrier wave input circuit being connected between the plate and the cathode, the plate being maintained at a negative potential, and the grid adjacent the plate being maintained at a positive potential while transit time current flow to the grid adjacent the cathode is utilized to indicate the mean frequency deviations of the applied modulated waves.

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 drawing in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a circuit diagram of a frequency modulation detector employing the invention,

Fig. 2 shows the frequency modulation detector characteristic.

Referring now to Fig. 1, it will be understood that the resonant primary circuit 1 is tuned to the center, or mean, frequency of the applied angular velocity-modulated carrier waves. In the present case frequency modulated carrier waves will be specifically considered. As is well known, the frequency modulation (FM) band is presently 42 to 50 megacycles (mc.). It is, also, well known that in each of the FM channels the carrier frequencies may be deviated 100 kilocycles (kc.) to each side of the center, or carrier, frequency. Hence, the overall deviation is 200 kilocycles (kc.) in the case of each FM channel. It is common practice to utilize a superheterodyne receiver in the FM reception band, and it is not believed necessary for the purpose of this application to show such circuits in detail since those skilled in the art are fully acquainted with the construction of superheterodyne receivers employed for FM reception.

Assuming that circuit 1 is in the output circuit of the usual amplitude limiter employed prior to the FM detector, it will be understood that the resonant circuit 2 is also tuned to the center frequency of the applied modulated waves. Of course, the amplitude limiter functions to eliminate amplitude modulation effects in the modulated wave. In that case the output of the detector will be an indication solely of the carrier frequency deviation. The network 1—2 will, of course, be constructed so as to pass with substantial uniformity the entire pass band which is 200 kilocycles wide.

The tube 3 may be a tube of the screen grid type, for example, and capable of efficient operation in the 42 to 50 mc. range. Of course, this invention is not limited to that range, since more efficient operation may be secured when operating in the ultra-high frequency band up to 100 mc. The cathode 4 of the tube 3 is connected to ground through a self-biasing resistor 5 which is shunted by a high frequency by-pass condenser 6. Hence, the plate or anode, electrode 7 of tube 3 will be at a negative direct current potential equal to the voltage drop across resistor 5. Plate 7 is connected to the high potential side of circuit 2 while the low potential side of the latter is at ground potential. The control grid 8, which is adjacent the cathode 4, is connected to ground through a load resistor 9 shunted by a high frequency by-pass condenser 10. The screen grid 11 is connected to a source of positive voltage, the screen grid being by-passed for high frequencies by condenser 12.

There is developed across resistor 9 the modulation voltage which was originally applied to the modulator tube at the FM transmitter. The modulation voltage is transmitted to one or more modulation voltage amplifiers, and the modulation may be, for example, at audio frequency. The detection of the FM carrier wave occurs because of the following reasons. The anode 7 has a negative potential with respect to the cathode. The negative voltage developed across resistor 5 may be augmented by an auxiliary negative bias source in the plate circuit, if desired. The grid 11 has a positive potential which could

be of the order of 100 volts, while the grid 8 is at a negative potential equal to the voltage across resistor 5. Electrons are drawn from the cathode region through the grid 8 by the positive potential of grid 11, and the electrons enter the space between grid 11 and anode 7 with a velocity v given by $mv^2=2eV_2$. In this expression V_2 is the positive voltage of grid 11 and m and e are respectively the mass and the electric charge of an electron.

In the space between the anode and grid 11 the velocity of the electrons is slowed down to zero and the electrons travel towards and through grid 11, coming in the vicinity of grid 8. If no frequency modulated waves are applied to the plate 7 no electrons can reach grid 8. It can be shown that an alternating voltage of high frequency on the plate 7 will accelerate some electrons so much that they are enabled to reach grid 8 in spite of its negative voltage. It may be shown mathematically that the transit time current to grid 8 is proportional to the following expression: $f^2E_a^2d^2/V_2$ where f is the frequency, E_a the anode voltage amplitude, d the distance between grid 11 and plate 7, and V_2 the potential of grid 11.

It will, therefore, be seen that when frequency modulated carrier waves are applied to the input circuit 2 of tube 3 transit time current will flow through the circuit including grid 8, and, hence, a voltage will develop across resistor 9 which is a function of the square of the applied frequency. In Fig. 2 there is shown qualitatively, and merely by way of illustration, a characteristic which relates the applied frequency (mc.) as abscissae to the voltage across resistance load 9 as ordinates. It will be seen that the characteristic is in the nature of a parabola. Since the center frequency of the applied FM waves is in the 42 to 50 mc. band, detection operation will take place along the upper more linear portion of the characteristic shown in Fig. 2. For example, let it be assumed that FM waves having a center frequency of a predetermined value are applied to the detection circuit.

In that case detection will take place on the characteristic of Fig. 2 about the point corresponding to the particular center frequency. Since the center frequency deviates back and forth 100 kc. on each side of the center frequency, it will be seen that a variable voltage will be developed across resistor 9 whose amplitude corresponds to the extent and rate of deviation of the carrier of the applied FM waves. Of course, such a variable amplitude voltage correctly represents the modulation voltage, since in FM transmission the carrier is deviated to an extent depending upon the amplitude of the modulating voltage, and the modulating frequency per se determines the rate of the deviation of the carrier frequency.

It will, also, be appreciated that the FM waves may be directly applied to the detector input circuit without any preliminary translation of the FM carrier wave into a variable amplitude carrier wave of constant frequency, as is customary in presently known FM detectors. Furthermore, where the system is used in a superheterodyne receiver, the FM waves applied to the detector tube will have a center frequency of constant I. F. value regardless of the channel selected, and this I. F. value may be chosen sufficiently high so that detection will take place at the upper linear portion of the parabolic characteristic thereby minimizing distortion. Of course, where the FM waves are of the order of 100 mc., then it may be advantageous to apply the waves to the detection tube immediately after cascaded tunable ultra-high frequency amplication.

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

What I claim is:

1. In a detection circuit for angular velocity-modulated carrier waves, a tube provided with a cathode, an anode and at least two spaced control electrodes therebetween, a modulated wave input circuit connected between the anode and cathode for applying modulated waves thereto, means for establishing the anode at a negative direct current potential with respect to the cathode, means for establishing the control electrode adjacent the anode at a positive potential, means for establishing the control electrode adjacent the cathode at a negative potential, a load resistor in circuit between the cathode and the negative control electrode, and the potentials of said control electrodes and anode being so related that transit time current flows to said negative control electrode in response to the application of modulated waves to said anode.

2. In a detection circuit for angular velocity-modulated carrier waves, a tube provided with a cathode, an anode and at least two spaced control electrodes therebetween, a modulated wave input circuit connected between the anode and cathode for applying modulated waves thereto, means for establishing the anode at a negative direct current potential with respect to the cathode, means for establishing the control electrode adjacent the anode at a positive potential, means for establishing the control electrode adjacent the cathode at a negative potential, a load resistor in circuit between the cathode and the negative control electrode, and the potentials of said control electrodes and anode being so related that transit time current flows to said negative control electrode in response to the application of modulated waves to said anode, and the magnitude of said transit time current being a function of the square of the center frequency of the applied modulated waves.

3. In combination with an electron discharge tube of the type provided with an electron emission element and at least two cold electrodes arranged in the electron stream emitted from said element, a frequency variable wave input circuit connected to the cold electrode most distant from the said emission element, means for establishing said distant electrode at a negative potential relative to the emission element, a load element in circuit between the second cold electrode and said cathode, means establishing said second cold electrode at a negative potential, and means providing a positive potential field intermediate said distant electrode and said second cold electrode.

4. In a detection circuit for frequency modulated carrier waves, a tube provided with a cathode, an anode and at least two control grids therebetween, an input circuit connected between the anode and cathode for applying modulated waves thereto, means for establishing the anode at a negative direct current potential with respect to the cathode, means for establishing the

control grid adjacent the anode at a positive potential, means for establishing the control grid adjacent the cathode at a negative potential, a load element in circuit between the cathode and the negative control grid, and the potentials of said control grids and anode being so chosen that electron current flows through the negative control grid circuit in response to the application of modulated waves to said anode.

5. In combination with an electron discharge tube of the type provided with an electron emission element and at least two control electrodes arranged in the electron stream emitted from said element, a frequency variable wave input circuit connected to the electrode most distant from the said emission element, a resistor in circuit between the second electrode and said cathode, means establishing said second electrode at a negative potential, a positive screen grid providing a positive potential field intermediate said distant electrode and said second electrode means establishing said distant electrode at a potential substantially lower than said screen grid, and the potentials of said control electrodes and screen grid being so chosen that electron current flows through said resistor in accordance with the square of the center frequency of input frequency variable waves.

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