

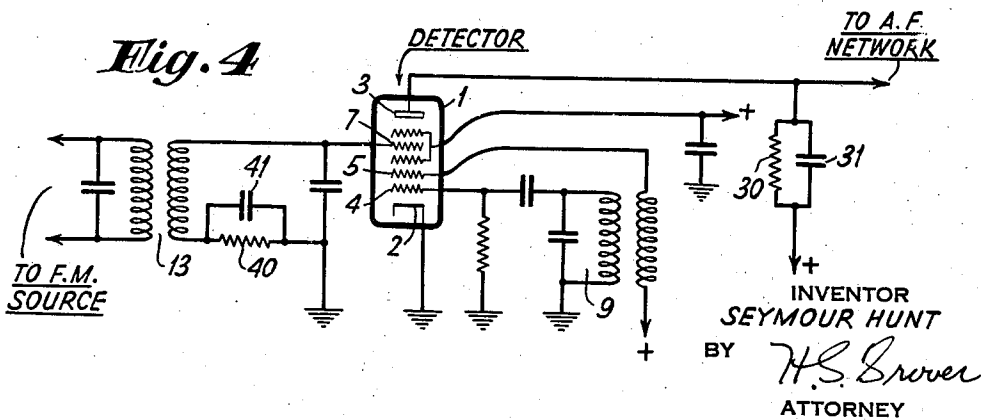
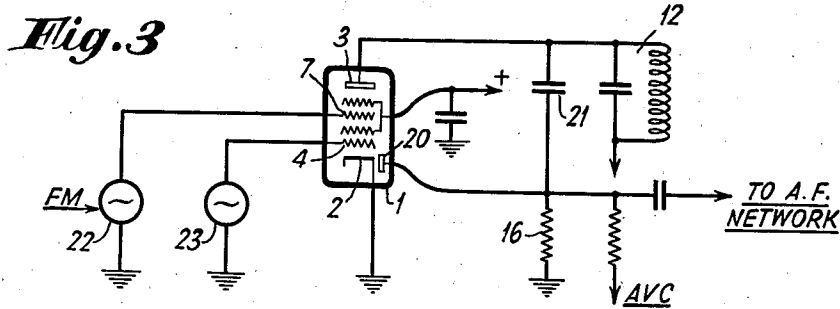
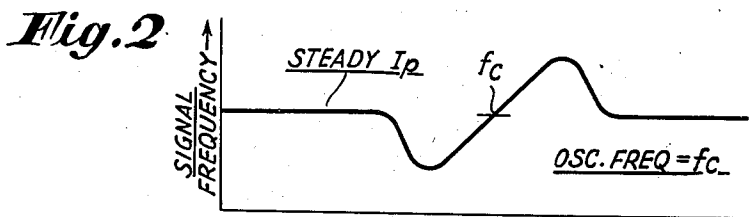
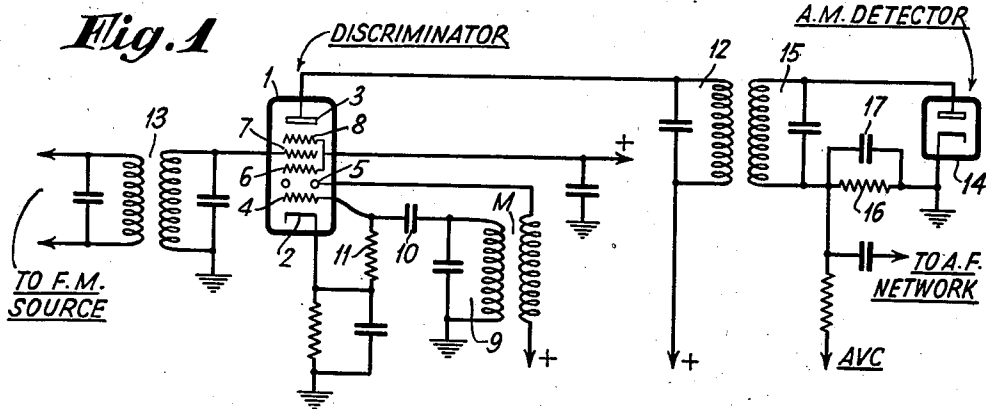
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FREQUENCY MODULATED WAVE DETECTOR

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FREQUENCY MODULATED WAVE DETECTOR

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3 Claims. (Cl. 250—27)

My present invention relates to frequency modulated carrier wave detectors, and more particularly to novel and improved types of networks adapted to derive modulation voltage from frequency, or phase, modulated carrier waves.

One of the main objects of my present invention is to provide a frequency modulated (FM) wave detector wherein there is varied the voltages of at least two control electrodes of an electron discharge tube at common frequencies corresponding to the mean, or center, frequency of an applied FM wave, and there being maintained substantially a phase quadrature relation between the voltages of the control electrodes whereby the output current of the detector tube is amplitude modulated (AM).

Another important object of my present invention is to derive the modulation from an FM wave by applying the latter to the control electrode of an electron discharge tube, simultaneously varying the voltage of a second control electrode of the tube at the mean frequency of the FM wave, and producing modulation voltage in the tube output circuit by virtue of the space charge coupling between said control electrodes which are arranged in the same electron stream of said tube.

Another object of the invention is to provide an FM detector tube which has an oscillator section producing voltage whose frequency is the mean frequency of received FM waves, a second control electrode being arranged in the space current path to the tube output electrode and being energized by the FM waves in such phase that the modulation voltage is developed in the output electrode circuit.

Still other objects of my invention are to improve generally the simplicity and reliability of FM detectors, and more especially to provide FM detectors capable of efficient operation and economical construction.

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 several circuit organizations whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a circuit constructed according to my invention,

Fig. 2 graphically shows the plate current variation of the discriminator tube,

Fig. 3 illustrates a modification,

Fig. 4 shows still another modification.

Referring now to the accompanying drawing, wherein like reference characters in the different figures designate similar circuit elements, let it be assumed that the tube 1 in Fig. 1 is of the 6A7 type, the latter being a pentagrid tube usually employed for signal frequency conversion to an intermediate frequency (I. F.). That type of tube generally comprises a cathode 2, a plate 3 and five successive grid electrodes 4 to 8. The grid 5 usually consists of a pair of spaced rods, as is well known by those skilled in the art. In such a tube the plate current depends on the combined effects of the voltages of grids 4 and 7. Now, I have found that the plate current (I_p) can be varied in amplitude, in the manner shown in Fig. 2, if there is applied to grid 7 a voltage of variable frequency, while grid 4 is maintained fixed at a voltage whose frequency is the center, or mean, frequency (f_c) of the frequency deviation at grid 7.

In other words, assume that there is applied to grid 7 a signal of variable frequency, such as an FM wave. Grid 4 may be varied at the center frequency of the wave by reactively coupling electrode 5 to the resonant tank circuit 9. The latter is tuned to f_c , and the coil thereof may be coupled, as at M, to the coil in the positive voltage lead to the anode, or oscillator plate, electrode 5. The grid leak condenser 10 and leak resistor 11 are associated with oscillator grid 4 as shown so as to establish grid 4 at a proper negative bias for oscillation production. Hence, it will be seen that grid 4 has applied to it an unmodulated oscillation voltage whose frequency is fixed at f_c . Grids 6 and 8 are positively biased, and act to shield signal grid 7 from the oscillation grid 4.

The plate 3 includes in its positive voltage lead the resonant circuit 12 which is tuned to f_c . The variable frequency signal applied to grid 7 may be derived from the band pass network 13 which is tuned to f_c . Of course, the signal voltage applied to network 13 comprises a wave whose instantaneous frequency varies above and below f_c in accordance with modulation signals applied to a carrier frequency (f_c) at the transmitter. As the signal frequency at grid 7 approaches the value f_c , that is the fixed frequency of oscillator grid 4, the plate current flow through circuit 12 will change from its steady value. When the signal frequency is equal to f_c , the plate current

returns to normal value. Fig. 2 illustrates, in a purely qualitative manner, that the plate current (I_p) change produces an S shaped curve with respect to the mean frequency f_c as the signal frequency is varied in equal amounts and in opposite senses with respect to f_c .

In other words, there is produced across circuit 12 a voltage of variable amplitude, and the amplitude corresponds to the instantaneous frequency of the signal frequency at grid 7. This characteristic is adapted for detection of FM waves, since the modulation existing as a frequency variation of a constant amplitude carrier has been converted into modulation existing as an amplitude variation of a constant frequency carrier. Hence, it is merely necessary to apply the voltage across circuit 12 to a rectifier of any well known type. Thus, the diode 14 has its resonant input circuit 15 coupled to circuit 12, circuit 15 being tuned to f_c .

The load resistor 16, shunted by carrier bypass condenser 17, is arranged in the low potential side of the diode input circuit. The modulation voltage developed across resistor 16 is utilized in an audio network, assuming the modulation on the carrier to be of audio frequency. The direct current voltage across resistor 16 may be used for automatic volume control (AVC) of FM transmission tubes prior to tube 1 so as to compensate for fading of the carrier at the signal collector.

While the FM source feeding network 13 may be of any known type, it is generally the practice at the present time to use a superheterodyne type of receiver. Since the FM band covers a range of 42 to 50 megacycles (mc.), the collected FM signals are applied to a first detector with local oscillations which differ from the center frequency of the FM waves by a desired I. F. value generally chosen to 2.1 mc. The I. F. energy is amplified by one or more I. F. amplifiers to a relatively high level, and then the highly amplified I. F. energy is applied to a limiter stage which acts to eliminate any amplitude variation produced in the FM waves by noise or other causes. The limiter output, still at I. F., is applied to network 13 in Fig. 1. Therefore, the value of f_c will be the I. F. value of 2.1 mc. The AVC voltage will, of course, be applied to the I. F. amplifiers and prior tubes, if desired.

It is possible to provide the elements of rectifier 14 within the envelope of tube 1. As shown in Fig. 3 the cathode 2 has arranged adjacent to it an auxiliary anode 20. The latter has an electron stream flowing thereto which is independent of the stream to plate 3. Load resistor 16 is provided between anode 20 and cathode 2. The carrier coupling condenser 21 connects the high potential side of resonant circuit 12 to the anode 20. The FM source is schematically designated at 22, while the local oscillation source is schematically represented at 23 as being connected to grid 4; the oscillator anode 5 having been omitted.

While the arrangements in Figs. 1 and 3 function as discriminators, the circuit in Fig. 4 is arranged to provide the modulation voltage directly across the load impedance of the plate circuit. In other words, in the arrangements of Figs. 1 and 3 the tube 1 and associated circuits function to convert the FM wave into an AM wave, whereas in the circuit of Fig. 4 there occurs simultaneous demodulation of the AM wave. To accomplish this effect there is connected a resistor 30 in the positive voltage lead to plate 3,

and the resistor is shunted by the I. F. carrier by-pass condenser 31. The resistor-condenser network 40-41 in the grid circuit of tube 1 may provide amplitude variation limiting, if such limiting is necessary. As the carrier amplitude increases in level grid 7 becomes increasingly negative due to resistor 40 and will flatten off the output in the plate circuit.

While the following theoretical explanation of the physical phenomena underlying the operation of the invention is not believed essential, it is supplied to assist those skilled in the art better to comprehend the invention. If e is the voltage developed across the tuned signal input circuit by the oscillator voltage E , then the voltage e tends to make grid 7 (considering Fig. 1) either more or less positive, or negative, with respect to the cathode 2. This changes the g_m of tube 1. If the oscillator frequency is on the high side (above the value f_c) of the signal circuit frequency, then e is out of phase with E . Conversely, when the oscillator frequency is less than f_c the voltage e is in phase with E . Hence, there occurs a variation in g_m or gain, of tube 1 which depends on the relation between the voltage frequency at grid 7 and that at grid 4. It should be pointed out that the voltage e is developed by the "virtual cathode" (or space charge coupling) which exists between grids 7 and 4. This cloud of electrons, often termed a "virtual cathode," is caused by the negative bias of grid 7, and hence a negative voltage source may be provided to establish grid 7 at such a negative potential. The virtual cathode varies at the oscillator frequency, and develops the voltage e across the signal input circuit. When the frequency difference between the signal and oscillator grids is small, then the effect on the plate current becomes large. Hence, as the oscillator frequency is held fixed, and the signal frequency is varied with respect to the mean frequency f_c , the plate current traces the S curve shown in Fig. 2.

The small capacity 31 in Fig. 4 gives the plate load a time constant such that solely audio voltage will appear across 30. Proper design of the Q of the coils of the circuit will produce a desirable frequency spacing between the peaks of the curve in Fig. 2. Furthermore, since the oscillator section of the tube operates at a fixed frequency, it is readily crystal-controlled. In the arrangement of Fig. 3 it is possible to supply grids 7 and 4 with FM waves from a common input circuit, the grids being operated in phase quadrature. It can be shown that in such a case there will be provided across circuit 12 amplitude modulated waves of constant frequency. Any desired type of phase shifting network would be used in such case between the two grids.

While I have shown tube 1 as of the 6A7 type, it is to be clearly understood that there may be used a 6A8 type of tube in place thereof. In general, there may be used a tube which has a pair of spaced control grids in a common electron stream, the essential requirement being that the voltage applied to one grid is variable in frequency relative to the other, and that both voltages have a mean frequency and be so related as to cause the output current to vary in amplitude in accordance with the instantaneous frequency of the variable frequency voltage. In each of Figs. 1, 3 and 4 the signal and oscillator grids may be interchanged without effect on the plate current characteristic.

It will be noted that the voltages applied to

grids 4 and 7 must be in phase quadrature relation. The space charge coupling is a convenient manner of producing a quadrature phase difference between the voltages of grids 4 and 7. It can be analytically shown that for a resistive load in the circuit of grid 7 (and a tuned circuit at resonance may be regarded as a resistance) the induced voltage on grid 7 is 90 degrees out of phase with the voltage applied to grid 4. At the center frequency of the FM waves the quadrature relation exists between the voltages of grids 4 and 7.

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 combination with an electron discharge tube having at least a cathode, an output electrode and a pair of control electrodes arranged in the electron stream between the cathode and output electrode, means applying a variable frequency signal of constant amplitude to one control electrode, means applying a substantially constant frequency signal of the center frequency value of said variable frequency signal and of substantially constant amplitude to the second control electrode, said applying means comprising an anode electrode located in said tube, a resonant circuit tuned to said constant frequency reactively coupling said anode and second cold electrode, and rectifier means connected to the output electrode for deriving from the electron

stream modulation voltage proportional to the instantaneous frequency of said variable frequency signal.

2. In combination with an electron discharge tube having a cathode, a plate and at least three cold electrodes arranged in the electron stream between the cathode and plate, a source of substantially constant amplitude-frequency variable waves coupled to one of said cold electrodes, a resonant network regeneratively coupling the cathode and the other two cold electrodes to provide an oscillator section adapted to produce fixed frequency oscillations of the mean frequency of said source, and an output circuit coupled to said plate to develop a voltage whose amplitude varies in accordance with the frequency variations of said source waves.

3. In combination with an electron discharge tube having a cathode, a plate and at least three cold electrodes arranged in the electron stream between the cathode and plate, a source of substantially constant amplitude-frequency variable waves coupled to one of said cold electrodes, a resonant network regeneratively coupling the cathode and the other two cold electrodes to provide an oscillator section adapted to produce fixed frequency oscillations of the mean frequency of said source, and an output circuit coupled to said plate to develop a voltage whose amplitude varies in accordance with the frequency variations of said source waves, said output circuit comprising a resistor in circuit with the plate for developing said variable amplitude voltage, and an amplitude variation limiter network coupled between said wave source and said one cold electrode.

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