

April 21, 1942.

M. G. CROSBY

2,280,569

FREQUENCY MODULATION RECEIVER

Filed May 4, 1940

3 Sheets-Sheet 1

Fig. 1

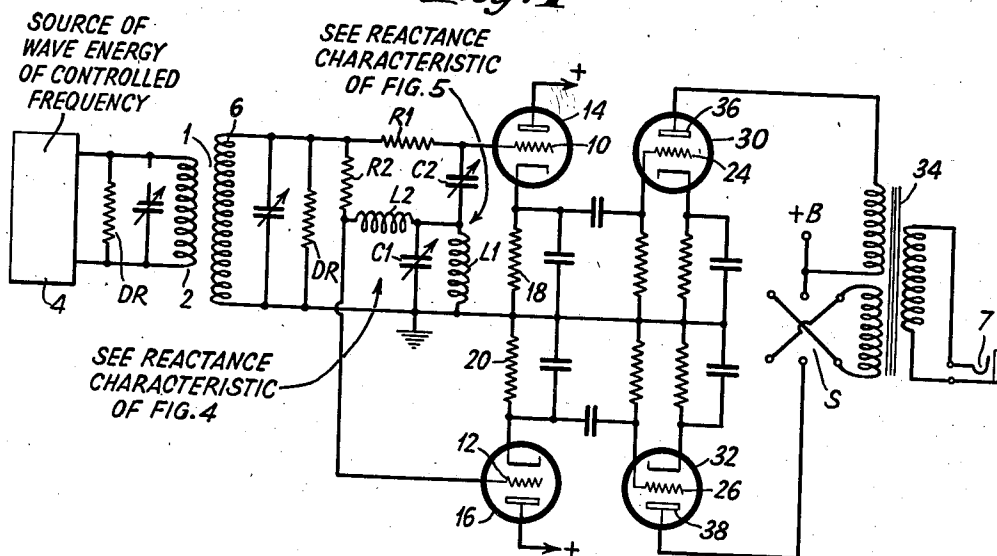
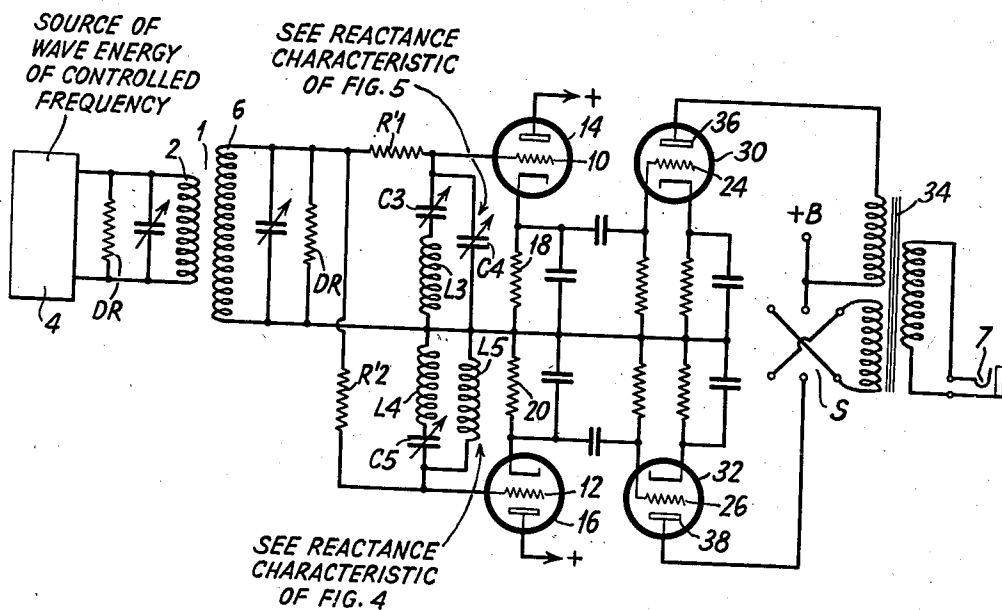


Fig. 2



INVENTOR
MURRAY G. CROSBY
BY *H. S. Swover*
ATTORNEY

April 21, 1942.

M. G. CROSBY

2,280,569

FREQUENCY MODULATION RECEIVER

Filed May 4, 1940

3 Sheets-Sheet 2

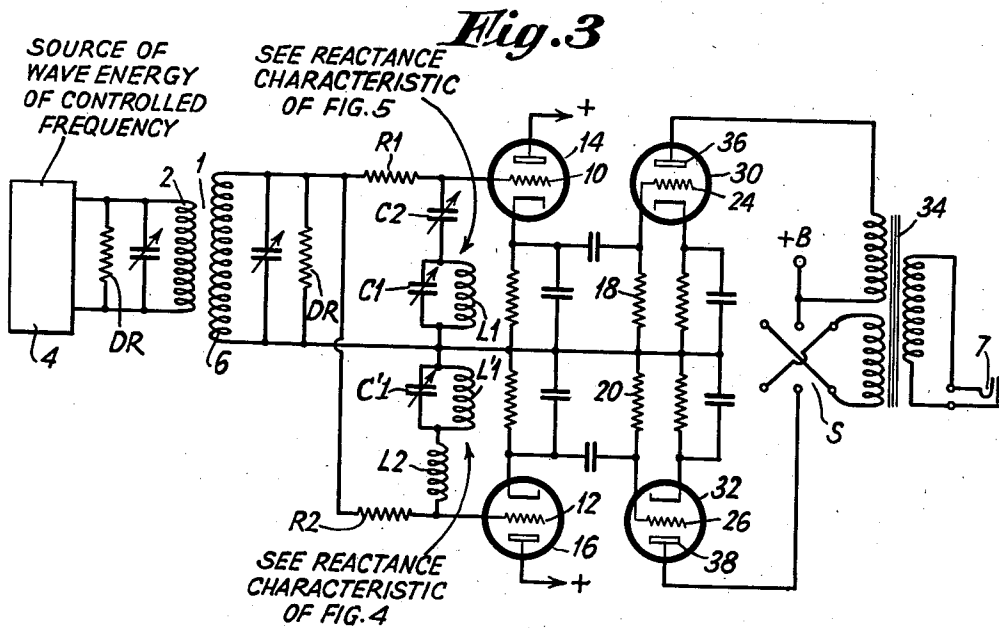


Fig. 4

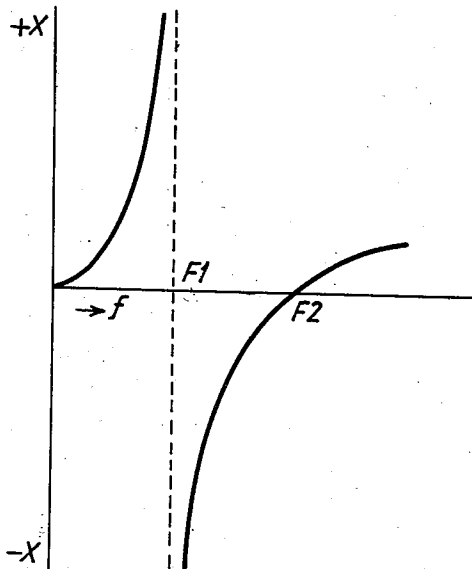
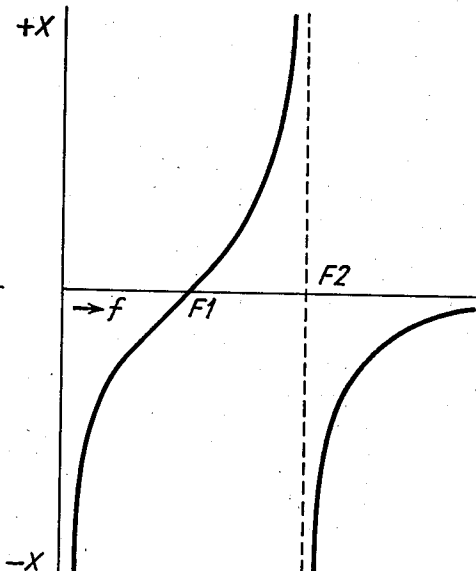


Fig. 5



INVENTOR
MURRAY G. CROSBY
BY *H. S. Grover*
ATTORNEY

April 21, 1942.

M. G. CROSBY

2,280,569

FREQUENCY MODULATION RECEIVER

Filed May 4, 1940

3 Sheets-Sheet 3

Fig. 7

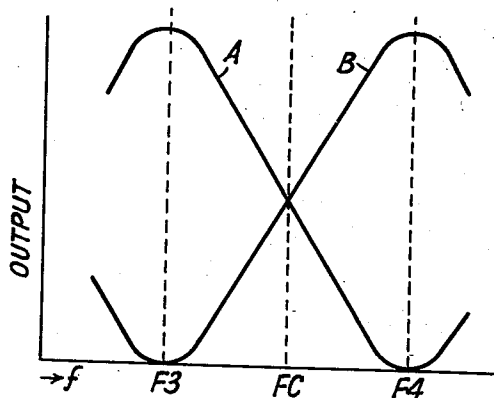


Fig. 6

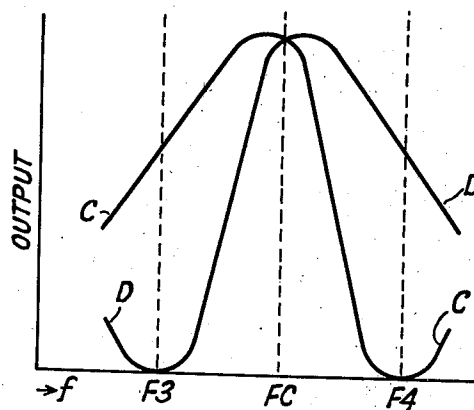


Fig. 8

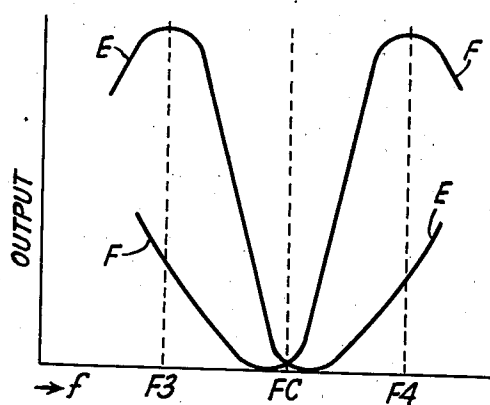
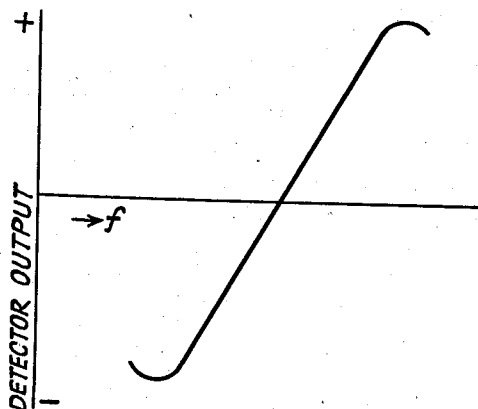


Fig. 9



INVENTOR
MURRAY G. CROSBY
BY *H. S. Snover*
ATTORNEY

UNITED STATES PATENT OFFICE

2,280,569

FREQUENCY MODULATION RECEIVER

Murray G. Crosby, Riverhead, N. Y., assignor to
Radio Corporation of America, a corporation
of Delaware

Application May 4, 1940, Serial No. 333,257

9 Claims. (Cl. 250—20)

This application concerns new and improved circuits and means for converting frequency modulation or other variations in the frequency of wave energy to amplitude modulation with a minimum of circuit elements. In the several modifications of my invention, multiple-tuned circuits are employed which have one point of high impedance and one point of low impedance which makes possible a sloping filter which slopes linearly between the high and low impedance points.

In describing my invention in detail, reference will be made to the attached drawings wherein,

Figs. 1, 2 and 3 each show the essential features of three modifications of my circuits and means for converting frequency changes in wave energy into corresponding amplitude changes and demodulating the same. In each modification, multiple-tuned circuits are used to produce the two opposed sloping filter characteristics necessary to accomplish the conversion. Figs. 4 and 5 are curves illustrating the reactive characteristics of the multiple-tuned circuits and Figs. 6, 7, 8 and 9 are curves illustrating the characteristics of the filters formed by the tuned circuits.

The circuit of Fig. 1 shows a specific embodiment of the invention in which one of the tuned circuits is common to the multiple-tuned circuits of both of the sloping filters which are provided. Transformer 1 has a primary winding 2 coupled to a source of wave energy 4 the frequency of which changes in accordance with signals. The secondary winding 6 of transformer 1 is tuned to the mean frequency of the wave energy supplied from winding 2 which is similarly tuned. Both windings are shunted by damping resistances DR and the secondary winding 6 feeds the circuits for both sloping filters one of which consists of resistor R1, condenser C2, and tuned circuit C1, L1. The other filter circuit consists of R2, L2, and tuned circuit L1, C1. The outputs of the two sloping filters are taken as the impedance drop across the multiple-tuned circuits and are fed to the control grids 10 and 12 of infinite impedance diodes 14 and 16. The detected outputs are taken from the cathode resistors 18 and 20 connected between the cathodes of the detectors and fed therefrom to the grids 24 and 26 of amplifiers 30 and 32. Transformer 34 connected with the anodes 36 and 38 of tubes 30 and 32 combines the detected outputs for frequency modulation reception when switch S is connected in the push-pull position or for amplitude modulation reception when switch S is connected in

the parallel or push-push position. The output is made available for utilization at jack 7.

Figs. 4 and 5 show the reactance versus frequency characteristics of the multiple-tuned circuits consisting of C2, L1, C1, and L2, L1, C1. The reactance curves for the respective multiple-tuned circuits are indicated on the figures. R1 is chosen large enough so that the current through its circuit is determined predominantly by the value of R1 and to a lesser extent by the impedance of the multiple-tuned circuit which it feeds. Consequently, when the frequency reaches the resonant point F1 of the reactance characteristic of multiple circuit C2, C1, L1, illustrated in Fig. 5, the sloping filter output will be as shown in Fig. 6 at the point F3 on curve D. When the frequency is at the high impedance point F2 of the reactance curve of Fig. 5, the voltage drop across the multiple-tuned circuit C2, C1, L1 will be as shown at frequency Fc of curve D, Fig. 6.

In the case of multiple circuit L2, L1, C1, the reactance curve of which is shown in Fig. 4, the anti-resonant point F1 of the reactance characteristic of Fig. 4 corresponds to the maximum output point Fc of curve C in Fig. 6. The resonant point F2 of the reactance curve of Fig. 4 corresponds to the minimum point F4 of curve C.

Fig. 3 shows another arrangement of elements of the type used in Fig. 1 in which the tuned circuit L1, C1 is not common to both multiple circuits. In this modification a second tuned circuit C'1, L'1 is connected in series with inductance L2, circuits C2, C1, L1 and C'1, L'1, L2 are tuned substantially to anti-resonance at the mean frequency of the wave energy. Such a circuit is desirable in the case where the maximum point of one sloping filter does not coincide with the maximum point of the other sloping filter as is the case with the filters the characteristics of which are shown in Fig. 7. In the tuning illustrated by the curves of Fig. 6 the maximum points of the two sloping filters coincide. It might be contended that such circuits would distort when used for reception of frequency modulation since the characteristic of the sloping filter is not linear over its complete range. However, since the desired resultant characteristic is that which exists between the frequency variation of the wave and the resultant detected current, a tuning as shown in Fig. 6 may be used. The differential detector current produced by a tuning as shown in Fig. 6 effects an overall detector characteristic such as shown in Fig. 9 so that the conversion of fre-

quency modulation to amplitude modulation is linear and undistorted. This linear resultant characteristic is present due to the fact that the detected output is equal to the difference between the detected outputs produced by curves C and D of Fig. 6 separately. It can be seen from the curves that the difference is equal to zero at the carrier frequency and increases as the carrier frequency is departed from in a manner similar to that illustrated by the tuning curves of Fig. 6.

The tuning characteristics illustrated in Fig. 8 in which the minimum points of the sloping filters coincide, also produces an overall characteristic which is linear as shown in Fig. 9 and will, therefore, convert frequency modulation into amplitude modulation without distortion.

The circuit of Fig. 2 is an alternative form of multiple-tuned circuit which may replace those used in Fig. 1 or in Fig. 3. This circuit operates in a manner exactly similar to the operation of Fig. 3. The only difference between the two circuits lies in the fact that Fig. 3 uses a different arrangement of the three elements of the multiple-tuned circuits to produce the same type of reactance-frequency characteristics and, therefore, the same type of filter characteristics. Further description of the "equivalences" of the multiple-tuned circuits of Figs. 2 and 3 is contained in the book: "Transmission Networks and Wave Filters," by T. E. Shea (D. Van Nostrand Co.) pages 129, 132, 139 and 140.

Any of these circuits may be used for the discriminator circuit in an automatic frequency control system as well as for demodulating frequency modulated wave energy. That is, the circuits can be operated to respond to fast or slow frequency variations. Also, the detected output from resistances 18 and 20 or from the transformer 34 may be used for both the frequency modulation output and automatic frequency control for the receiver.

What is claimed is:

1. In a system for demodulating wave energy modulated in frequency at signal frequency, a first circuit comprising parallel connected reactances tuned to the mean frequency of said wave energy, a pair of electron discharge devices each having input and output electrodes, a second tuned circuit comprising parallel connected reactances resonant to said mean frequency, the second circuit having one terminal connected to an input electrode of each of said tubes, a condenser coupling the other terminal of said second tuned circuit to the other input electrode of one of said tubes and to said first parallel circuit, and an inductance coupling said other terminal of said second tuned circuit to an input electrode of the other of said tubes and to said first parallel circuit.

2. The method of converting frequency variations in wave energy into corresponding amplitude variations which includes the steps of, passing said wave energy over a first path which passes waves of carrier wave frequency with maximum intensity and attenuates upper side band energy as a function of the frequency spacing from said carrier frequency while attenuating to a higher degree the lower side band energy as a function of the frequency spacing from said carrier frequency, passing said wave energy over a second path which passes waves of carrier wave frequency with maximum intensity and attenuates lower side band energy as a function of the frequency spacing from said carrier frequency

while attenuating to a higher degree the upper side band energy as a function of the frequency spacing from said carrier frequency, and combining waves from the outputs of said paths to obtain a resultant of varying amplitude.

3. The method of converting frequency variations in wave energy into corresponding amplitude variations which includes the steps of, passing said wave energy over a first path which passes waves of carrier wave frequency with maximum intensity and attenuates upper side band energy as an inverse function of the frequency spacing from said carrier frequency while attenuating to a higher degree the lower side band energy as an inverse function of the frequency spacing from said carrier frequency, passing said wave energy over a second path which passes waves of carrier wave frequency with maximum intensity and attenuates lower side band energy as a function of the frequency spacing from said carrier frequency while attenuating to a higher degree the upper side band energy as a function of the frequency spacing from said carrier frequency, and combining waves from the outputs of said paths to obtain a resultant of varying amplitude.

4. The method of converting frequency variations in wave energy into corresponding amplitude variations which includes the steps of, passing said wave energy over a first path which passes waves of carrier wave frequency with maximum intensity and attenuates wave energy of lesser frequency as a function of their frequency spacing from said carrier frequency, passing said wave energy over a second path which passes waves of carrier wave frequency with maximum intensity and attenuates wave energy of higher frequency as a function of their frequency spacing from said carrier frequency, and combining waves from the outputs of said paths to obtain a resultant of varying amplitude.

5. The method of detecting wave energy of variable frequency and constant amplitude which includes the steps of passing said wave energy over a first path which passes over the operating range of frequencies waves of mid-band frequency with maximum intensity and attenuates upper side band energy as a function of the frequency spacing from said mid-band frequency while attenuating to a higher degree the lower side band energy as a function of the frequency spacing from said mid-band frequency, passing said wave energy over a second path which passes over said operating range waves of mid-band frequency with maximum intensity and attenuates lower side band energy as a function of the frequency spacing from said mid-band frequency while attenuating to a higher degree the upper side band energy as a function of the frequency spacing from said mid-band frequency, and deriving from said paths a resultant wave of constant mid-band frequency and of varying amplitude.

6. In a system for demodulating wave energy modulated in frequency at signal frequency, a resonant circuit tuned to the mean frequency of said wave energy, at least two electron discharge tubes each having a pair of input electrodes, two parallel tuned circuits each having one terminal thereof connected to a first input electrode of each of said tubes, a capacitive reactance coupling the second terminal of one of said parallel tuned circuits to the second input electrode of one of said tubes and to the said resonant circuit, and an inductive reactance coupling the

second terminal of the second of said parallel tuned circuits to the second input electrode of the second of said tubes and to the said resonant circuit.

7. The method of converting frequency variations in wave energy into corresponding amplitude variations which includes the steps of transmitting said wave energy so as to pass waves of a selected frequency greater than the mean frequency of said wave energy with maximum intensity and attenuate waves of lesser frequency as a function of their frequency spacing from said selected frequency, simultaneously transmitting said wave energy so as to pass waves of a second selected frequency less than the mean frequency of said wave energy with maximum intensity and attenuate waves of higher frequency as a function of their frequency spacing from said second selected frequency, and combining the passed waves to obtain a resultant of varying amplitude.

8. The method of detecting frequency modulated carrier waves which includes passing waves of carrier frequency with maximum intensity, attenuating waves of lesser frequency as a function of their frequency spacing from said carrier frequency, simultaneously passing said waves with maximum intensity while attenuating waves

of higher frequency as a function of their frequency spacing from the carrier frequency, and combining the total passed wave energy to produce a resultant wave of varying amplitude and constant frequency.

9. In combination with a tuned circuit resonated to a desired carrier frequency, means impressing upon said circuit a band of signal frequencies whose mid-band frequency is equal to said carrier frequency, a pair of electron discharge tubes, each tube having a cathode and at least one cold electrode, means connecting the cathodes of both tubes to a common alternating potential point of said tuned circuit, a resistive impedance connecting the cold electrode of one tube to a second point of said tuned circuit, a second resistive impedance connecting the second tube cold electrode to said second point, at least one resonant circuit connected in shunt with said tuned circuit, said shunt circuit being resonated to said mid-band carrier frequency, a first connection between said shunt circuit and the junction of one resistive impedance and its respective cold electrode, and a second connection between said shunt circuit and the junction of the second resistive impedance and its respective cold electrode.

MURRAY G. CROSBY.