May 27, 1941. M. G. CROSBY 2,243,417

FREQUENCY MODULATION RECEIVER

Filed June 1, 1939

2 Sheets-Sheet 1

Fig. 1

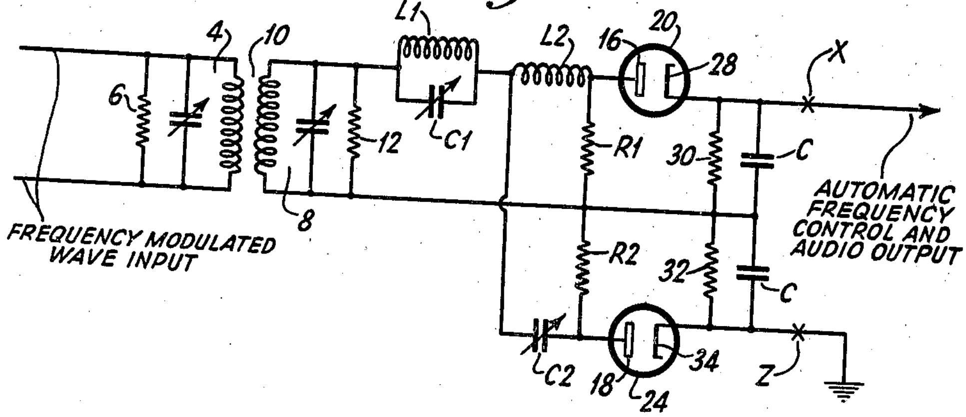
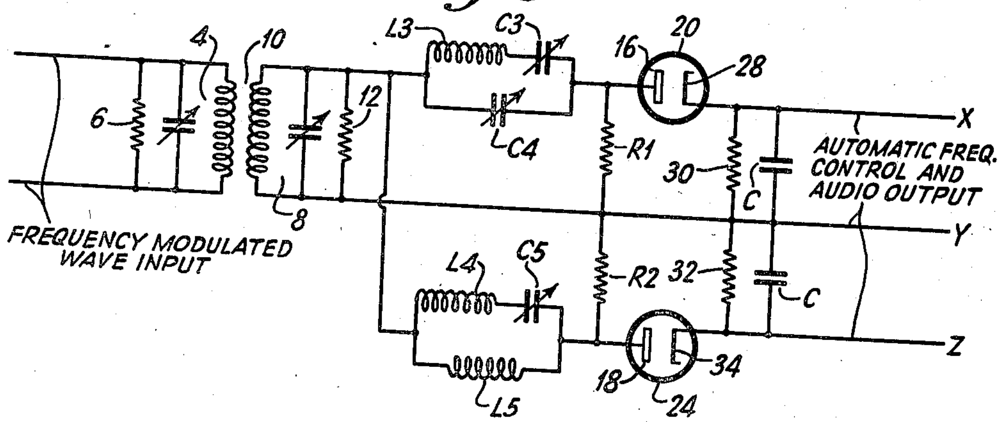


Fig. 2



INVENTOR.
MURRAY G. CROSBY

BY H. S. Grover

ATTORNEY.

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M. G. CROSBY

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Fig. 3

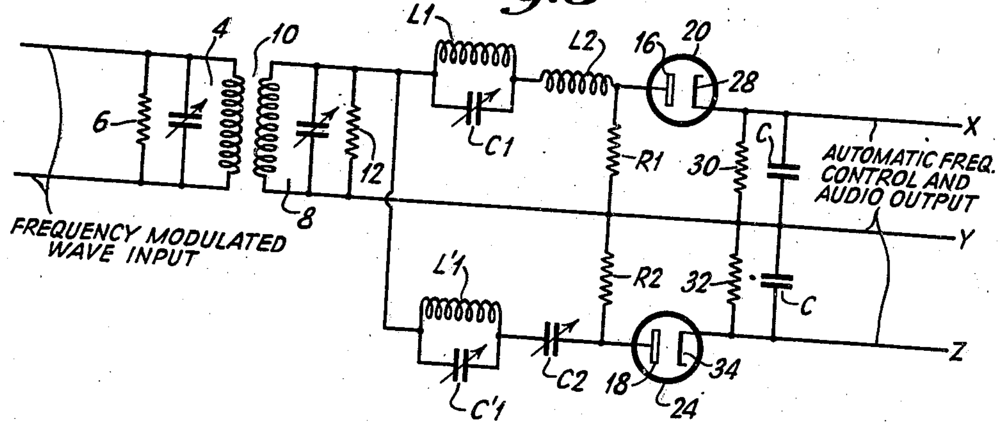


Fig. 4

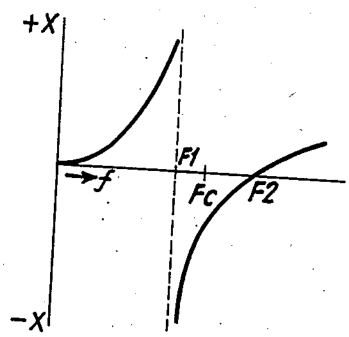
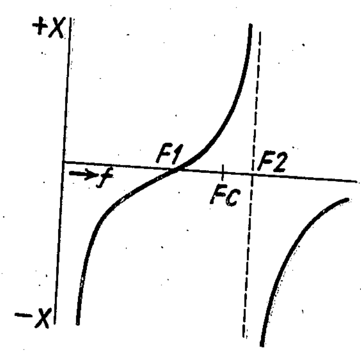


Fig. 5



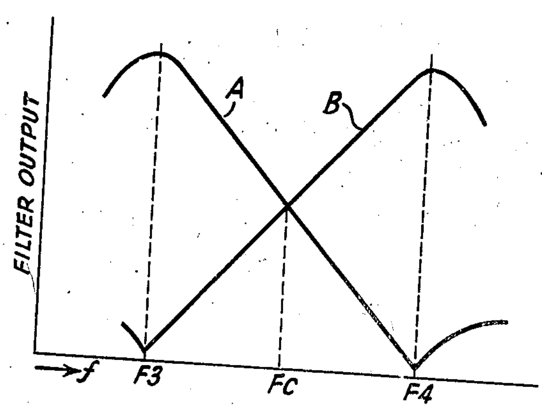


Fig. 6

INVENTOR.
MURRAY G. CROSBY

BY H. S. Grover

ATTORNEY.

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FREQUENCY MODULATION RECEIVER

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

Application June 1, 1939, Serial No. 276,771

4 Claims. (Cl. 250—20)

This application concerns new and improved circuits of simple nature to be used for converting frequency modulation on wave energy into amplitude modulation on wave energy so that the amplitude modulation can be detected in the ordinary manner and the signal received. The filters produced are of sloping characteristic and as the frequency of the modulated wave energy passed thereby changes, corresponding amplitude changes are produced in the output thereof which are detected. In my converter various multiple-tuned circuits are used to produce the desired linear sloping filter characteristics in a simple manner.

In describing my invention reference will be made to the attached drawings wherein:

Figures 1, 2 and 3 each illustrate a form of my compound filter circuit for converting frequency modulations on wave energy into corresponding amplitude modulation for detection; Figures 4 and 5 are reactance curves of the resonant and anti-resonant characteristics of the said filters; while Figure 6 illustrates by curves the outputs of the filters plotted against the input frequency of the waves passed by the filters.

In these multiple-tuned circuits, enough elements are included to produce a filter which is series-resonant at a frequency adjacent the carrier frequency and a filter which is anti-resonant at a frequency adjacent the carrier frequency. This causes the filters to have a peak output frequency, and a rejection frequency. These characteristics have been illustrated in Fig. 6 wherein F4 is a peak output frequency for one filter (curve B) and a rejection point for the other filter (curve A) and vice versa. The circuits are so arranged that the pass characteristics thereof oppose as indicated by curves A and B of Fig. 6. The carrier is tuned to the frequency Fc. A filter having this same type of characteristic is described in United States Patent #2,071,113, dated February 16, 1937.

In the circuit of Fig. 1, the frequency modulated energy, which is preferably an intermediate frequency, is fed to a tuned circuit 4 including the primary winding of a transformer 10 having a secondary winding in a tuned circuit 8. The tuned circuit 8 is coupled at one end to the cathodes of a pair of diode rectifiers 20 and 24 and at the other end by reactances L1C1L2 to the anode 16 of tube 20 and by L1C1C2 to the anode 18 of tube 24. The cathode 28 of tube 20 is connected to a resistance 30 which is connected by a resistance 32 to the cathode 34 of tube 24. Both resistances 30 and 32 are shunted by by-pass condensers C large enough to by-pass the radio-frequency waves and small enough to supply voltages of modulation frequency and voltages characteristic of slow changes in the mean frequency of the modulated wave.

Signal voltages and frequency control voltages may be taken from points X and Z.

The tuned circuit L1C1 combines with inductance L2 to form a multiple-tuned circuit having a reactance characteristic as shown in Figure 4. This reactance determines the current that flows through resistor R1. The drop across R1 is fed to the detector 20. The series-resonant frequency F2 will thus produce a point of maximum output and the anti-resonant frequency F1 will produce a minimum output. That is, when the frequency supplied to the filter is the same as the frequency to which the filter formed by L1C1 and L2 is resonant, the impedance thereof will be low and maximum voltage will be applied to the resistance R1. When the frequency supplied to the filter shifts to F1, the anti-resonant frequency, the impedance of the filter is maximum and the voltage supplied to R1 is minimum. The circuit forms a filter of sloping characteristic and the slope of the filter will be in the positive direction as shown by curve B of Fig. 6.

The parallel combination L1C1 also combines with C2 to form a multiple-tuned circuit, by means of which a reactance characteristic as shown in Fig. 5 is obtained. This filter is anti-resonant at the frequency F2 and series-resonant at the frequency F1. This reactance feeds R2 and detector 24. The voltage output of this filter is minimum at F2 and maximum at F1. The interchange of the resonant and anti-resonant frequencies illustrated in Fig. 5, as compared to Fig. 4, causes the resulting sloping filter to have a characteristic as shown by the curve A of Fig. 6. The frequencies F3 and F4 of Fig. 6 correspond to frequencies F1 and F2 of Figs. 4 and 5 and vice versa. Thus the required back-to-back sloping filters are formed so that undesired amplitude modulation may be balanced out.

The circuit of Fig. 2 shows an alternative arrangement of the multiple-tuned circuits. Circuit L3C3C4 has a reactance characteristic as shown by Fig. 5 and produces the sloping filter of curve A of Fig. 6. Circuit L4C5L5 has a reactance characteristic as shown by Fig. 4 and produces a filter of sloping characteristic as shown by curve B of Fig. 6.

The circuit of Fig. 3 shows how the elements of Fig. 1 may be rearranged so that the tuned circuit L1C1 is not common.

In this modification L1C1 and L2 are series-resonant at say the frequency F2 and anti-resonant at the frequency F1—see Fig. 4. An additional loop circuit C'1 L'1 with condenser C2 forms a circuit anti-resonant at the frequency F2 and series-resonant at the frequency F1—see Fig. 5. This circuit has the advantage that it is easier to tune up due to the absence of reaction between the multiple-tuned circuits. The circuit of Fig. 1 makes a slight sacrifice in this respect for the sake of simplicity.

In all of the modifications the tuned circuits **4** and **8** are shunted by sufficient resistance **6** and **12** respectively to widen the band-pass characteristics of the system the amount necessary to accommodate the width of the wave worked with.

In Fig. 1 the audio-frequency potentials and automatic frequency control potentials are taken from the points X and Z on the differentially connected resistances **30** and **32**. In Figs. 2 and 3 this is also true but in these figures provision for double-ended output is provided. The detector stage here may feed a differentially connected coupling or amplifying tube stage.

During reception of frequency modulated waves as the frequency of the wave varies in accordance with signals about the carrier frequency Fc (Fig. 6), the amplitude of the voltages supplied to the resistances R1 R2 vary differentially in accordance with the said frequency variations. These voltage variations are impressed on the diode rectifiers **20** and **24** and rectified therein to produce signal potentials in the output resistances **30** and **32**. Slow shifts in the mean frequency F1 due to any cause whatever produce corresponding changes in the detected voltages and these changes may be used for frequency control purposes.

Unwanted amplitude changes on the waves impressed on **4** cause similar opposed changes in the detected voltages which oppose and cancel.

What is claimed is:

1. In a radio system in which a transmitter radiates energy which is frequency modulated in accordance with signals, a reactance on which said modulated wave energy is impressed, a pair of rectifier tubes of the diode type each having an anode and a cathode, impedances connecting the cathodes of said rectifier tubes in a differential output circuit, a connection between a first point on said reactance and the cathodes of said tubes, two loop circuits each comprising parallel inductance and capacity, a connection between one terminal of each loop circuit and a common second point on said reactance, said second point being at a substantially different alternating current potential than the first point, means connecting the other terminal of one of said loop circuits to the anode of one tube, means connecting the other terminal of the other loop circuit to the anode of the other tube, a reactance connected to one of said loop circuits to tune the same to series resonance at a frequency above the highest frequency of the modulated wave impressed on said first reactance, and a reactance connected with said other loop circuit to tune the same to series resonance below the lowest frequency of the modulated wave impressed on said first reactance.

2. In a frequency modulated wave demodulating system, a resonant input circuit upon which is impressed frequency modulated carrier wave energy, two reactive paths connected with said resonant input circuit, one of said paths being tuned to a frequency above the highest frequency of said frequency modulated wave, the second path being tuned to a frequency below the lowest frequency of said frequency modulated wave, a pair of rectifiers each having input and output electrodes, an output circuit connecting the output electrodes of said rectifiers in push-pull relation, means connecting the input electrode of one of said rectifiers to the output end of said one path, means connecting the input electrode of the second of said rectifiers to the output end of the second path, both paths having a common input point on said resonant input circuit, and means connecting a second point of said input circuit, which is at a lower alternating current potential than said common point, to an intermediate point on said output circuit.

3. In a frequency modulated wave demodulating system, a resonant input circuit upon which is impressed frequency modulated carrier wave energy, two reactive paths connected with said resonant input circuit, one of said paths being tuned to a frequency above the highest frequency of said frequency modulated wave, the second path being tuned to a frequency below the lowest frequency of said frequency modulated wave, a pair of rectifiers each having input and output electrodes, an output circuit connecting the output electrodes of said rectifiers in push-pull relation, means connecting the input electrode of one of said rectifiers to the output end of said one path, means connecting the input electrode of the second of said rectifiers to the output end of the second path, both paths having a common input point on said resonant input circuit, and means connecting a second point of said input circuit, which is at a lower alternating current potential than said common point, to an intermediate point of said output circuit and said reactive paths having a common portion arranged in series between said common input point and each of said input electrodes.

4. In a frequency modulated wave demodulating system, a resonant input circuit upon which is impressed frequency modulated carrier wave energy, two reactive paths connected with said resonant input circuit, one of said paths being tuned to a frequency above the highest frequency of said frequency modulated wave, the second path being tuned to a frequency below the lowest frequency of said frequency modulated wave, a pair of rectifiers each having input and output electrodes, an output circuit connecting the output electrodes of said rectifiers in push-pull relation, means connecting the input electrode of one of said rectifiers to the output end of said one path, means connecting the input electrode of the second of said rectifiers to the output end of the second path, both paths having a common input point on said resonant input circuit, and means connecting a second point of said input circuit, which is at a lower alternating current potential than said common point, to an intermediate point on said output circuit, each of said paths comprising a loop circuit including inductance and capacity.

MURRAY G. CROSBY.