Aug. 5, 1941. G. C. SZIKLAI 2,251,382

FREQUENCY MODULATED WAVE RECEIVER

Filed June 4, 1940

Fig. 1

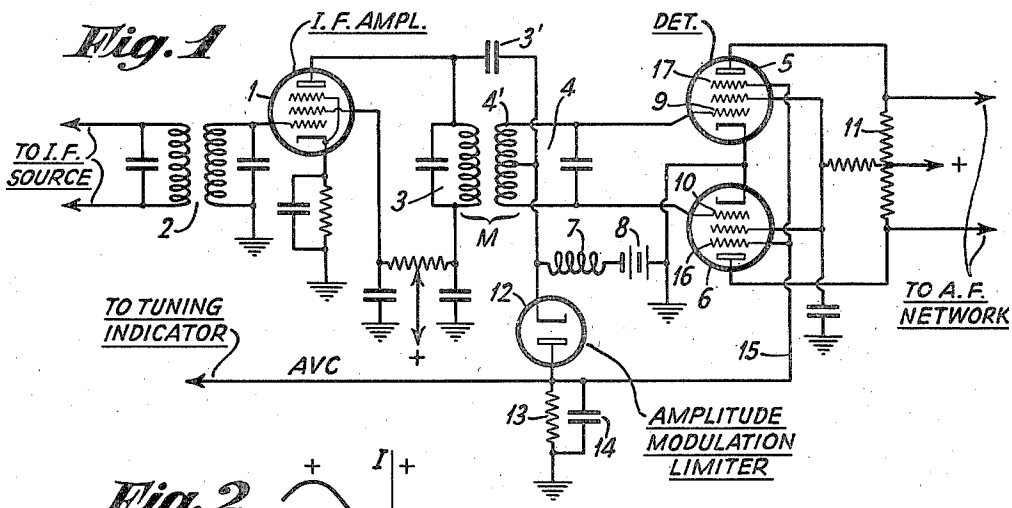


Fig. 2

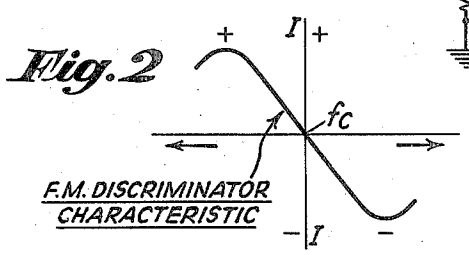


Fig. 3

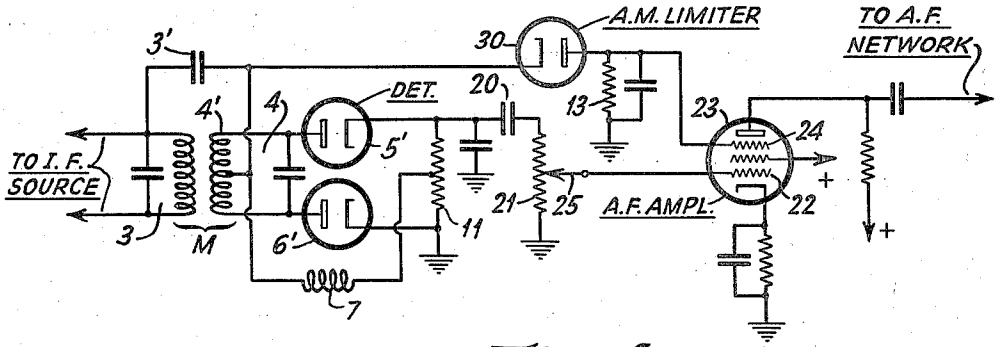
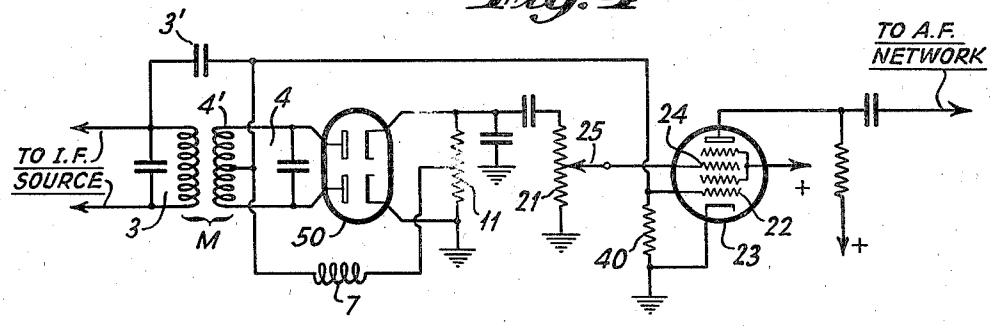


Fig. 4



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Patented Aug. 5, 1941

2,251,382

UNITED STATES PATENT OFFICE

2,251,382

FREQUENCY MODULATED WAVE RECEIVER

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Application June 4, 1940, Serial No. 338,724

8 Claims. (Cl. 250—20)

My invention relates to frequency modulated wave receivers, and more particularly to amplitude limiting devices adapted for use in such receivers.

As is well known, a frequency modulated wave (referred to as FM hereinafter) receiver utilizes an amplitude limiter prior to the discriminator. The general purpose of the limiter is to limit the amplitude variations in the FM wave energy applied to the discriminator. These variations are caused by noise pick-up as well as by signal strength variation. Since the FM signal must be converted back into variable audio currents in order to deliver to the ear the variations in loudness which have been incorporated in the original FM signal in the form of amount of frequency "swing," it follows that amplitude variation in the FM signal is highly undesirable. Prior limiters have usually been provided by a special tube located ahead of the frequency-responsive detector, or discriminator.

One of the main objects of my present invention is to provide amplitude limitation in an FM receiver at a point following the discriminator input.

Another important object of my invention is to derive from the FM signal a unidirectional voltage whose magnitude varies with any amplitude variation in the signal, and means being utilized to control the receiver, at a point following the discriminator input circuit, with said voltage so that the effect of the amplitude variation is compensated for.

Another object of the invention is to provide in association with the FM detector tubes, a device which is responsive solely to FM signal amplitude variation and is adapted to vary the mutual conductance of each detector tube in a manner such as to compensate for the amplitude variation.

Still another object of my invention is to regulate the gain of an audio amplifier, following the discriminator of an FM receiver, in such a manner that amplitude variation in the FM signal is substantially compensated for.

Yet other objects of this invention are to improve generally the simplicity of amplitude limiters in FM receivers, and more especially to provide improved limiters capable of economic manufacture and ready assembly in FM receivers.

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 orginization 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 diagram of an FM receiver network employing the invention,

Fig. 2 illustrates the FM discriminator characteristic,

Fig. 3 shows a modification of the invention.

Fig. 4 illustrates still another modification.

Referring now to the accompanying drawing, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 that portion of an FM receiver comprising the last intermediate frequency (I. F.) amplifier and the FM detector. The amplifier tube 1 is provided with an input transformer 2 whose primary and secondary windings are each tuned to the central frequency (f_c) of the I. F. band applied to the transformer 2. Where the receiver is a superheterodyne receiver operating to collect FM signals in the 40 to 50 megacycle (Mc.) band, as is now the practice, the I. F. value will be of the order of 2.1 Mc. Depending on the permissible frequency swing of the FM wave, and such swing may be chosen from a range of 20 to 200 kilocycles (kc.), the I. F. transformer 2 will pass a band of signal frequencies whose width is sufficient to accommodate the various components of the FM wave. Hence, the input circuit 2 can be a band pass network of the flat top type whose mid-band frequency (f_c) is the FM carrier frequency reduced to the I. F. value. The amplifier tube 1 is conventional, and is provided with an I. F.-tuned output circuit 3 arranged in the plate circuit of the tube. The succeeding tuned circuit 4 is resonated to the same I. F. value, and the circuits 3 and 4 are magnetically coupled, as at M, to provide a flat top, band-pass network similar to network 2.

The high potential side of circuit 3 is connected by condenser 3' to the mid-point of coil 4' of circuit 4. By virtue of the network 3—4 the I. F. voltage appearing across the tapped secondary 4' should vary in frequency only. In prior circuits an amplitude limiter was used at tube 1 so as to insure freedom from amplitude variation across coil 4'. According to my invention, however, amplitude variations are allowed to appear across the coils of the primary and secondary circuits 3 and 4. Compensation of such variation is secured in the detector tubes themselves.

Each of detector tubes 5 and 6 is provided with at least a cathode, an output electrode, a signal grid, a gain control grid and a positive screen grid between the latter two grids. Thus, the cathodes of both tubes are at ground potential, and there is provided a path comprising choke coil 7 and negative bias source 8 between the mid-point of coil 4' and the grounded cathodes of tubes 5—6. Signal grids 9 and 10 are connected to opposite sides of the tuned circuit 4. A common output load resistor is connected between the plates of tubes 5 and 6. The mid-point of resistor 11 is tapped by the positive voltage connection for the plates and screens of the tubes. There is developed across resistor 11 a pulsating unidirectional voltage corresponding to the original modulation applied to the FM carrier. The detector tubes 5 and 6, and the discriminator network 3—4, function substantially in the following manner to convert the FM signal.

The variation in frequency is translated into a variation of voltage by the property of the changing of phase relationship between the voltages across the primary and secondary circuits 3 and 4. The magnetic flux in the primary winding, and the current producing it, are in phase. This primary flux linking with the secondary winding 4' induces a voltage in the secondary winding. The induced secondary voltage causes the secondary current to circulate through the coil and condenser of circuit 4. If an applied frequency is above the center frequency (f_c), then the secondary circuit 4 will be predominantly inductive and the current flowing in the secondary will lag. This lagging secondary current builds up a flux that induces a voltage back into the primary winding, and causes the voltage across the primary to lag behind the current. The reverse action happens when the frequency swings to the low side of resonance; that is, the voltage across the primary leads the current. Since the primary current and secondary voltage always bear a relation of 90°, the effect of swinging the applied frequency through resonance is to change the phase angle between the primary and secondary voltages.

Because the secondary winding 4' has a center tap, the secondary voltage is divided into two equal parts that are 180 degrees out of phase with each other as far as the detector grids 9 and 10 are concerned. When the applied frequency is equal to f_c, then the sum of the primary voltage and one half the secondary voltage is equal in magnitude to the sum of the primary voltage and the other half of the secondary voltage. These two equal voltages are applied to the two separate signal grids 9 and 10, and are independently detected by the biased detectors. The mid-tapped load resistor 11, therefore, has developed across each half thereof a uni-directional voltage which corresponds to the alternating voltage applied to its associated input grid. When the alternating signal voltage applied to grids 9 and 10 are equal in magnitude, then the voltages across the two halves of resistor 11 are equal. Since the two halves of resistor 11 are arranged in push-pull relation it follows that for equal signal voltages applied to grids 9 and 10 there will be no output derived from resistor 11.

As the applied frequency swings above and below resonance, the vector sums of the primary and each half of the secondary voltage are no longer equal. Hence, one detector grid will have a higher potential than the other during such frequency swinging. Since the detector tubes are no longer rectifying equal signal voltages, a difference in uni-directional voltage across the entire resistor 11 will result. Since the frequency is swinging through the resonant point f_c, at the audio frequency, the rectified voltage across resistor 11 will be the audio signal. The difference between the two signal voltages that are applied to grids 9 and 10 will be proportional to the amount of frequency departure from f_c. Hence, the discriminator changes variations in frequency and rate of variation into respectively volume and frequency of the audio signal.

In Fig. 2 there is presented in a graphical manner the FM discriminator characteristic. Those skilled in the art are fully aware of the characteristic shown, and will readily realize that the curve shows the manner in which rectified current is developed across resistor 11 as the applied frequency swings back and forth with respect to the center frequency f_c. The spacing between the peaks of the curve represents the maximum permissible frequency swing of the FM wave. The bias source 8 supplies a negative bias to the grids 9 and 10 in order to move the carrier centers to the cut-off point and thereby provide detection.

The amplitude limiting action is secured by applying the I. F. energy to a rectifier, such as a diode 12. The cathode of the latter may be connected to the grid end of coil 7, while the anode of the diode is connected to ground through resistor 13. The latter is by-passed for alternating current by condenser 14. There is developed across resistor 13 a direct current voltage whose magnitude will be directly proportional to any amplitude variation existing in the FM wave. The diode resistor 13 is connected by the direct current voltage connection 15 to the control grids 16 and 17 of detector tubes 6 and 5 respectively. In the absence of amplitude variation in the FM wave, grids 16 and 17 will assume ground potential, and will not affect the gain of each detector tube. However, upon a variation in amplitude of the FM wave, which affects the slope of each detector tube thereby causing a spurious output, there will instantaneously develop across resistor 13 a direct current voltage which is applied to grids 16 and 17 in a negative sense. The mutual conductance of each tube 5 and 6 will thereby be decreased to an extent sufficient to compensate for the effect of the amplitude variation.

As long as the carrier does not depart from f_c of the discriminator, amplitude variations have no effect on the output which is zero anyway. However, at other frequencies the resulting voltage across resistor 11 increases or drops with amplitude changes. The slope of the discriminator changes. The object of the compensator circuit is to change the slope of any amplifier in the receiver with the same magnitude but opposite direction as the discriminator curve changes.

The direct current voltage across resistor 13 may be utilized to vary the gain of one or more amplifiers of the receiving system. For example, the gain of each of the radio frequency, and intermediate frequency, amplifiers may be varied so as to maintain substantially uniform carrier amplitude at the input circuit of the detector stage. Furthermore, the usual type of visual tuning indicator tube may be operated by the voltage developed across resistor 13. Those skilled in the art are fully aware of such indicators, and a 6E5 type tube may be used for this purpose.

In Fig. 3 there is shown a modification wherein the detector tubes 5 and 6 are replaced by diodes

5' and 6'. The anodes of the two diodes are connected to opposite sides of the input circuit 4, while the cathodes of the diodes are connected to opposite ends of the output resistor 11. The mid-point of resistor 11 is connected to the mid-point of coil 4' through the choke 7. One end of the resistor 11 is at ground potential, and there is connected in shunt across resistor 11 an audio voltage potentiometer comprising a condenser 20 arranged in series with a resistor 21. The audio voltage across resistor 21 is fed to the signal grid 22 of the audio amplifier tube 23. Between the screen grid of tube 23 and the plate there is located an auxiliary grid 24 whose bias is regulated by a diode rectifier 30 which functions to rectify the applied I. F. energy.

Adjustable amounts of audio voltage may be applied to grid 22 by using a slidable tap 25 which is adjustable along potentiometer resistor 21. The audio voltage output of tube 23 may be transmitted to one or more further audio stages. It is not believed necessary to describe the specific manner in which the detector shown in Fig. 3 operates, since those skilled in the art are fully aware of the manner in which diodes 5' and 6' rectify the alternating voltages applied to their plates. Each half of resistor 11 develops a uni-directional voltage from the I. F. energy applied to its associated diode. For the center frequency the voltages across both halves of resistor 11 are equal, while for frequencies off resonance there is produced audio voltage.

The limiting action in this form of the invention is secured by connecting the cathode of diode 30 to the mid-point of coil 4', while the anode of the diode is connected to ground through the load resistor 13. The grid 24 is connected to the cathode end of resistor 13. Hence, signal energy impressed on input circuit 4 will cause direct current voltage to be developed across resistor 13 if the FM signal energy has any amplitude modulation. The direct current voltage is applied to the audio amplified grid 24, and the tube 23 is caused to change its gain at the same rate as the amplitude modulation changes the output of the diode detectors. Where tube 23 is of the 6L7 type, the compensator has no threshold sensitivity like a conventional limiter since the slope of such a tube changes at all grid voltages.

Fig. 4 shows a further modification, and differs from the arrangement of Fig. 3 in that the audio signal is applied to outer grid 24 of tube 23, while the inner grid 22 acts as a diode anode and provides its own bias by rectification of the FM signals when varying in carrier amplitude. The resistor 40 is the load resistor of the rectifying diode. The variable bias across resistor 40 varies the G_m of tube 23 in a sense to compensate for the amplitude variation. The numeral 50 denotes a double diode tube which functions in the same manner as the independent diodes in Fig. 3. By the circuit arrangement of Fig. 4 it is possible to eliminate the diode 30, and yet get the same effect as in Fig. 3.

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 a method of receiving frequency modulated carrier waves, collecting such waves subject to amplitude modulation effects, converting said collected waves into waves of constant carrier frequency and variable amplitude, detecting the converted waves by push-pull rectification thereby deriving modulation voltage from the waves, utilizing the modulation voltage, deriving a uni-directional voltage from the collected waves in response to said amplitude modulation, and controlling said push-pull rectification with said uni-directional voltage.

2. In a method of receiving frequency modulated carrier waves, collecting such waves subject to amplitude modulation effects, converting said collected waves into waves of constant carrier frequency and variable amplitude, detecting the converted waves by push-pull rectification thereby deriving modulation voltage from the waves, utilizing the modulation voltage, deriving a uni-directional voltage from the collected waves in response to said amplitude modulation, and controlling said modulation derivation with said uni-directional voltage in a sense to compensate for said amplitude modulation effects.

3. In a frequency modulated wave receiver of the type comprising a detector having an input circuit upon which are impressed frequency modulated waves, said detector consisting of a pair of rectifiers connected in a push-pull circuit constructed and arranged to convert the waves into modulation voltage, and means for utilizing the modulation voltage; the improvement which comprises means coupled to said input circuit for producing a uni-directional voltage in response to amplitude variations in the impressed waves, and means responsive to said uni-directional voltage for controlling the said rectifiers in a sense to compensate for said variations.

4. In a frequency modulated wave receiver of the type comprising a detector having an input circuit upon which are impressed frequency modulated waves, said detector consisting of a pair of rectifiers connected in a push-pull circuit constructed and arranged to convert the waves into modulation voltage, and means for utilizing the modulation voltage; the improvement which comprises rectifier means coupled to said input circuit for producing a uni-directional voltage in response to amplitude variations in the impressed waves, and means responsive to said uni-directional voltage for controlling the mutual conductance of each of said rectifiers in a sense to compensate for said variations.

5. In a method of receiving frequency modulated waves, detecting by push-pull rectification the waves to produce a uni-directional voltage which varies in magnitude in a manner corresponding to the frequency variation of said waves, amplifying the voltage, rectifying said waves to produce a second uni-directional voltage whose magnitude varies solely with amplitude variation of said waves, and utilizing the second voltage to control the said push-pull rectification of said waves in such a manner as to compensate for said amplitude variation.

6. In combination with a source of carrier waves of constant amplitude and variable frequency subject to amplitude modulation effects, means for detecting said waves to derive modulation voltages representative of said variation in frequency and said amplitude modulation, a tube having at least a cathode, an output electrode and at least two auxiliary cold electrodes, means impressing said modulation voltages on one of the auxiliary electrodes, means applying said carrier waves upon the second auxiliary elec-

trode, and a resistive impedance connected between said second auxiliary electrode and cathode to develop from said carrier wave amplitude modulation sufficient bias voltage to compensate for modulation voltage corresponding to the amplitude modulation of the carrier wave.

7. In combination with a source of carrier waves of constant amplitude and variable frequency subject to amplitude modulation effects, means for detecting said waves to derive modulation voltages representative of said variation in frequency and said amplitude modulation, a tube having at least a cathode, an output electrode and at least two auxiliary cold electrodes, means impressing said modulation voltages on one of the auxiliary electrodes, means applying said carrier waves upon the second auxiliary electrode, and a resistive impedance connected between said second auxiliary electrode and cathode to develop from said carrier wave amplitude modulation sufficient bias voltage to compensate for modulation voltage corresponding to the amplitude modulation of the carrier wave said auxiliary electrodes being a pair of grids disposed in the electron stream between said cathode and output electrode.

8. In combination with a source of carrier waves of constant amplitude and variable frequency subject to amplitude modulation effects, means for detecting said waves to derive modulation voltages representative of said variation in frequency and said amplitude modulation, a tube having at least a cathode, an output electrode and at least two auxiliary cold electrodes, means impressing said modulation voltages on one of the auxiliary electrodes, means applying said carrier waves upon the second auxiliary electrode, and a resistive impedance connected between said second auxiliary electrode and cathode to develop from said carrier wave amplitude modulation sufficient bias voltage to compensate for modulation voltage corresponding to the amplitude modulation of the carrier wave, the first of said auxiliary electrodes being a grid located adjacent the said output electrode, the second auxiliary electrode being a grid located between the cathode and said first grid.

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