Feb. 15, 1944. J. E. MAYNARD 2,341,937

RADIO RECEIVER

Filed June 29, 1942 2 Sheets-Sheet 1

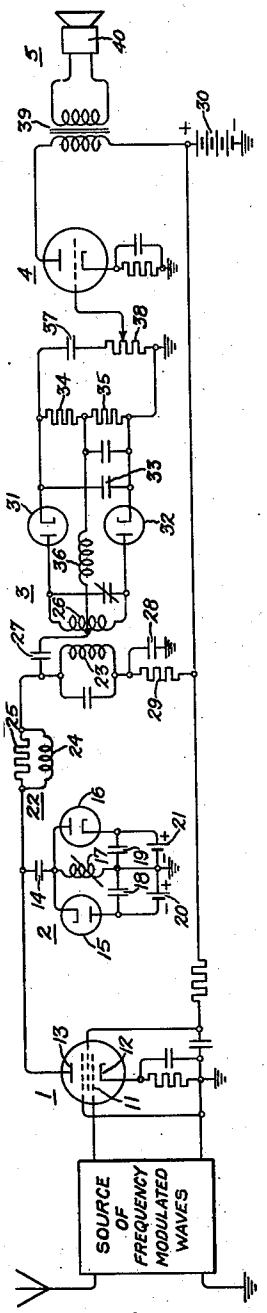

Fig. 1.

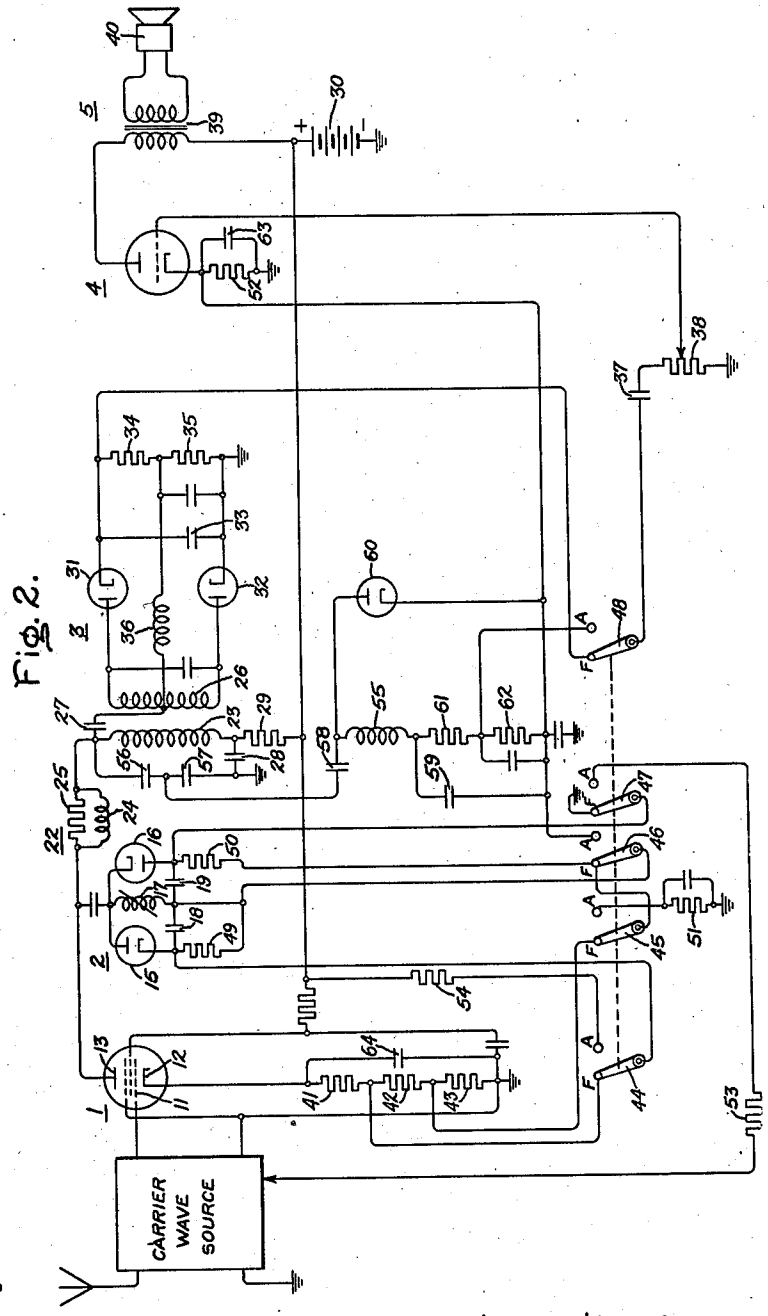

Fig. 2.

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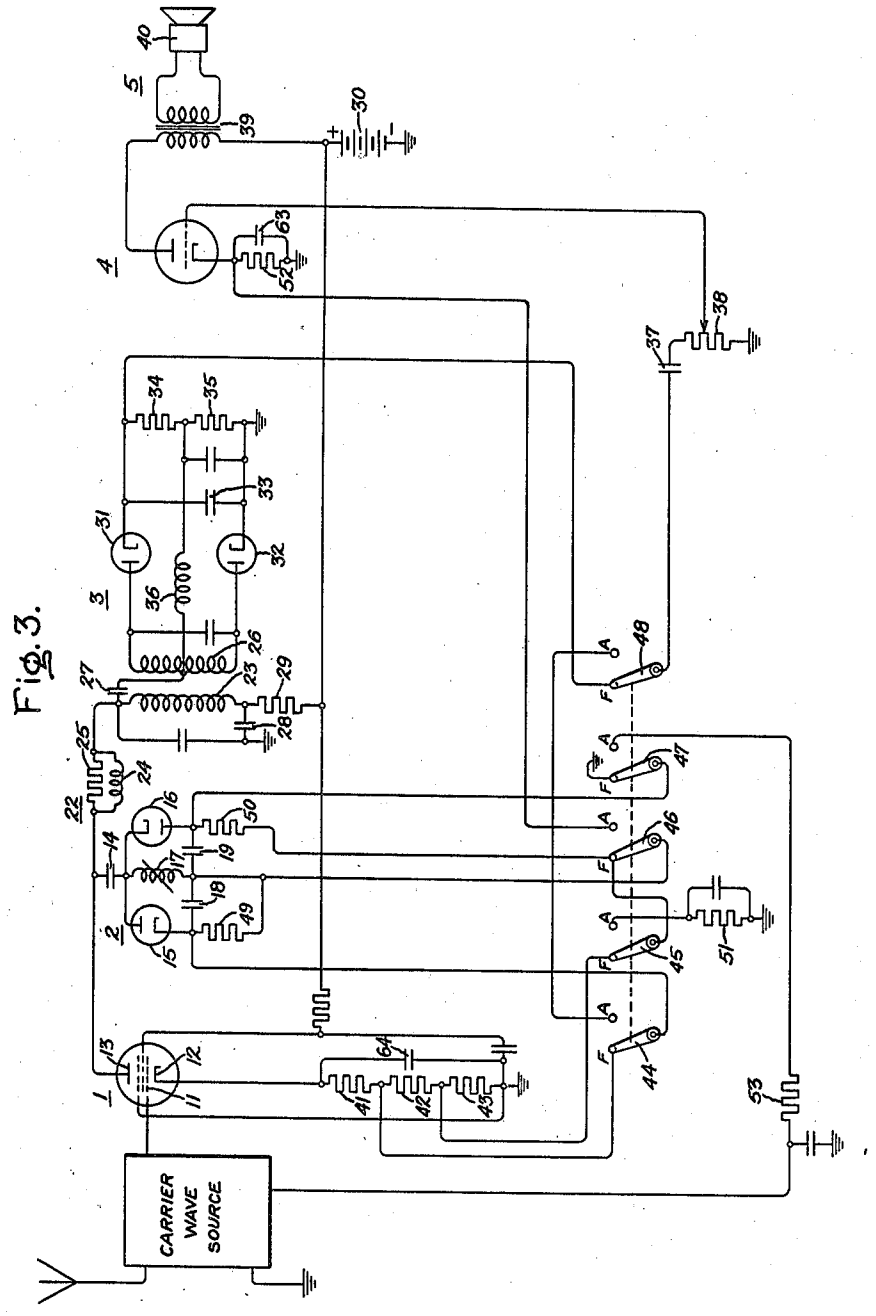

Fig. 3.

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UNITED STATES PATENT OFFICE

2,341,937

RADIO RECEIVER

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Application June 29, 1942, Serial No. 448,881

9 Claims. (Cl. 250—20)

My invention relates to carrier wave receivers and more particularly to such receivers adapted for reception of both frequency modulated and amplitude modulated signals in which a stage utilized as a limiter when receiving a frequency modulated signal is used as a source of voltage the variations of which may be utilized for automatic volume control purposes when an amplitude modulated signal is received. It has for one of its objects to provide a limiter circuit for such a receiver which is capable of acting on weak signals.

In radio receivers that are designed for the reception of either frequency or amplitude modulated carrier waves, it is desirable that the switching of the receiver circuit from one type of reception to the other be accompanied with a minimum of disturbance of the tuning of the preceding circuits of the receiver. Hence it is another object of my invention to provide a radio receiver in which all switching from one type of reception to the other is effected in the unidirectional potential connections without any disturbance of radio frequency or intermediate frequency tuning.

A further object of my invention is to provide a diode type of limiter for a radio receiver which sharply limits the intensities of frequency modulated carrier waves without loading the following circuits of the receiver and which may be easily adapted, by means of switching in the direct current circuits of the diode when the receiver is employed for the reception of amplitude modulated carrier waves, to provide a continuous potential for automatic volume control purposes.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which Fig. 1 represents a receiver for frequency modulated carrier waves embodying my invention; Fig. 2 represents a receiver for both frequency modulated and amplitude modulated carrier waves embodying my invention; and Fig. 3 represents a modification of the receiver of Fig. 2.

As shown in Fig. 1, high frequency carrier waves are supplied to the amplifier 1, either directly from a receiving antenna or through a channel such as a radio frequency amplifier. In the usual form of super-heterodyne receiving apparatus they are carrier waves having the intermediate frequency of the receiver and may be supplied from a preceding intermediate frequency amplifier.

The high frequency carrier waves are subjected to amplitude limitation in the limiter circuit 2. They are then demodulated in a detector and discriminator 3 and the demodulated signals, which are ordinarily audio frequency signals, are supplied to a low frequency signal amplifier 4. From the output of the amplifier 4 the signals may go to further stages of amplification or may be coupled directly, as shown, to a sound reproducer 5.

The amplifier 1 comprises an electron discharge device having a control electrode 11 coupled to a source of frequency modulated waves, a cathode 12, and an anode 13. The anode 13 is coupled by means of capacitor 14 to the limiter 2. The limiter consists of a pair of diodes 15 and 16 connected with polarity reversed with respect to each other so that one conducts during positive peaks and the other during negative peaks of intermediate frequency voltage. The inductance 17 provides a direct current return path for the diodes so that they function as rectifiers. A bypass capacitor 18 is connected between inductance 17 and the anode of diode 15, while a bypass capacitor 19 is connected between inductance 17 and the cathode of diode 16. The value of inductance 17 is so adjusted that, when combined with the stray capacities of the diode circuits, these circuits resonate at the frequency of the carrier wave. As a result, when the diodes are non-conducting, the limiter 2 presents a high impedance to the anode circuit of amplifier 1. The bias batteries 20 and 21 prevent the diodes from operating at small intermediate frequency voltages. The capacitor 14 serves to block the anode potential of amplifier 1 from the limiter diode. Since there is no direct current load circuit for these diodes other than their own internal impedance, when the intermediate frequency voltage rises above the bias voltages 20 and 21, these diodes present practically a short circuit to the intermediate frequency amplifier 1.

The anode 13 is likewise coupled by means of impedance 22 to the primary 23 of the discriminator transformer. This impedance 22, shown as comprising an inductance 24 and a resistance 25, serves both to allow the limiter to cut off sharply the peaks of voltage waves and to prevent the limiter from short-circuiting the discriminator transformer.

The discriminator circuit 3 is of well known

form. Its function is to demodulate the frequency modulated waves which are coupled thereto from the anode 13. The circuit comprises a transformer having, in addition to the primary winding 23, a secondary winding 26, both of these windings being tuned to a desired fixed intermediate frequency. The primary winding is connected between ground and the mid-point of the secondary winding 26 through a condenser 27. Unidirectional operating potential for the anode 13 is supplied through the resistor 29 from the positive terminal of a source of potential shown as a battery 30. The opposite terminals of the secondary winding 26 are connected to the respective anodes of the diodes 31 and 32, the cathodes of these diodes being connected together for alternating current through condenser 33 and for direct current through resistances 34 and 35. The cathode of the diode 32 is grounded and the mid-point between resistances 34 and 35 is connected to the mid-point on secondary winding 25 through a choke coil 36.

In the operation of the discriminator circuit, when the tuning control of the radio receiver is adjusted for accurate resonance with the received carrier waves, the intermediate frequency has a desired value to which the primary and secondary windings 23 and 26 are each tuned. The voltage across the secondary winding of the transformer, in accordance with well known theory, is displaced in phase with the voltage across the primary by 90°. With the connection shown, the voltage of the primary is connected in series with one-half the voltage on the secondary across the discharge device 31 and the condenser 33 and it is connected in series with the other half of the voltage on the secondary across discharge device 32. Because of the quadrature relation between the primary and secondary voltages, the voltage on one-half of the secondary leads the voltage on the primary by 90°, whereas that on the other half of the secondary lags behind the voltage on the primary by 90°. Thus, the voltage applied to the two diodes 31 and 32, when the intermediate frequency is at its desired value, is equal and accordingly equal values of unidirectional current flow through each of the diodes and hence through resistances 34 and 35. It will be observed that these resistances are poled oppositely, that is, the voltages across the two are opposite in polarity in the circuit between the cathode of discharge device 31 and ground, with the result that the cathode of discharge device 31 is at ground potential when the intermediate frequency is at the desired value.

The quadrature relation between the primary and secondary voltages of the discriminator transformer exist, however, only when the oscillations supplied thereto have the desired intermediate frequency. If this frequency changes in either direction the phase of the secondary voltage varies from its 90° relation with the primary voltage in one direction or the other, dependent on whether the frequency increases or decreases. For example, if the frequency increases, the phase shift may be in such a direction that the voltage on the upper half of the secondary winding approaches the aiding relation with the primary voltage, whereas that on the lower half of the secondary winding approaches the opposing relation with the primary voltage. Thus, the voltage applied to diode 31 increases and that applied to diode 32 decreases with the result that the unidirectional potential on resistance 34 increases, whereas that on resistance 35 decreases. On the other hand if the intermediate frequency decreases, an opposite shift in phase of the secondary voltage occurs, with the result that the larger alternating current voltage is supplied to diode 32 and the potential on the resistance 35 increases, whereas that on resistance 34 decreases and the cathode of device 31 is driven negative with respect to ground.

The output voltage of the discriminator is supplied to the control electrode of signal amplifier 4 by means of the coupling condenser 37 and the volume control resistor 38. The output of signal amplifier 4 may be increased through succeeding stages of amplification, if desired, or may be, as shown, coupled directly into an audio transformer 39, the secondary of the audio transformer being connected to reproducing means such as a loud speaker 40.

In the operation of my limiter circuit, the pair of diodes 15 and 16 being connected in reverse polarity, the one conducts on positive peaks and the other on negative peaks of intermediate frequency voltage. The inductance 17 provides a direct current return path to these diodes so that they function as rectifiers. At the same time, this inductance is turned with the circuit and stray capacities of the limiter to a resonance condition so that the limiter circuit presents a high impedance to the anode circuit of amplifier 1 while the diodes are non-conducting, the bias batteries 20 and 21 preventing the diodes from operating at small intermediate frequency voltages. Since there is no direct current load circuit for these diodes, other than their own internal impedance, when the intermediate frequency voltage rises above the bias voltages, the diodes present practically a short circuit to the intermediate frequency amplifier 1. The impedance 22 performs the important function of both preventing the limiter from short-circuiting the discriminator transformer and allowing the limiter to chop peaks of intermediate frequency voltages abruptly. The limiter circuit being tuned broadly, it has a small fly-wheel effect, that is, a small circulating current; hence, the limiter responds sharply to small changes in voltage. Since the discriminator transformer, on the other hand, has a much greater inertia or fly-wheel effect, the limiter circuit and the discriminator transformer would have detrimental inter-acting effects for the presence of the greater fly-wheel effect of the discriminator transformer would be detrimental to limiting. At the same time, the loading represented by the limiter would reduce the ability of the discriminator to build up circulating current, with a resultant lowering of its quality and sharpness of tuning. These effects are greatly reduced by the insertion of the coupling impedance 22 having an impedance value as high as or higher than that of the primary of the discriminator transformer.

One of the advantages of this limiter is that it limits at very small voltages in the anode circuit of the final intermediate frequency amplifier 1. Such early limiting is an important factor in obtaining the advantages of frequency modulation insofar as the reduction of noise is concerned. Also, since the final intermediate frequency amplifier is of the pentode type, having a high plate impedance and operating in a constant current manner into a low impedance load, such as the discriminator transformer, it will be seen that the introduction of the impedance 22 causes very little reduction in gain and makes

but a small change in the voltage produced across the primary of the discriminator transformer. Also, since the amplifier 1 operates at normal unidirectional potential, its amplifying properties are not compromised by the action of a limiter circuit.

In the circuit shown in Fig. 2, representing a receiver for both frequency modulated and amplitude modulated carrier waves, the limiter 2 functions in the above-described manner. The biasing voltages for the diodes 15 and 16 respectively are obtained from the potential drops across resistors 42 and 43 in the cathode circuit of the preceding amplifier 1. By means of these resistors, the anodes of the two diodes are maintained negative with respect to the cathodes, preventing current flow into these diodes for a no signal condition in the receiver. For the reception of amplitude modulated signal waves the inter-connected switches 44, 45, 46, 47, and 48 are shifted from the contacts marked F to those marked A. With this shift the resistors 49 and 50 are inserted respectively in the circuits of diodes 15 and 16. These resistances have a large value so that when current flows in the diode, a sufficiently high impedance is presented to the anode of amplifier 1 that limiting does not occur. The circuit of diode 16 can now be traced through resistor 50, switch 45, resistor 51, resistor 52 in the cathode circuit of amplifier 4, switch 46 and inductance 17. It will also be seen that the anode of diode 16 is now connected through switch 47 and resistor 53 to the carrier wave source. The potential developed across resistor 50 may be used by means of this circuit to control the gain of the preceding stages of the receiver. The potential across resistor 52 serves to maintain the cathode of diode 16 positive with respect to the anode so that until the intensities of the signals across diode 16 are greater than a predetermined intensity, no current will flow through diode 16 to set up the potential across resistor 50 for automatic volume control purposes. Also, by the shifting of switch 44 to the contact A, the cathode of diode 15 is connected through resistor 54 to the source of potential 30, thus establishing a positive bias between the cathode and anode of diode 15 to prevent conduction of current by the diode.

It will be seen that the intermediate frequency amplifier now operates in a normal manner, all switching in the limiter circuit having been effected at unidirectional potential without disturbing the intermediate frequency tuning. It will be seen also that the automatic volume control circuit precedes the audio signal circuit, thus providing automatic volume control selectivity broader than signal selectivity.

To obtain an amplitude modulated carrier wave voltage for detection purposes, a third winding 55 is provided on the discriminator transformer. Capacitors 56 and 57 are present for tuning the discriminator primary circuit to the intermediate frequency while capacitor 58 is tuned with coil 55 to the intermediate frequency. Capacitor 57 couples the primary circuit to the circuit of winding 55. The amplitude modulated carrier waves in the resonant circuit of the coil 55 and capacitor 58 are impressed across the diode 60 for demodulation. The output current of the diode 60 establishes potential drops across resistors 61 and 62 which vary in accordance with the amplitude of the audio frequency currents flowing in diode 60, capacitor 59 providing a bypass across these resistors for radio frequency currents. By means of switch 48 the audio voltages across resistor 62 are supplied to the coupling capacitor 37 connected to the control electrode of signal amplifier 4. It will be seen from the above description that the switches 44–48 all operate in the direct current circuits of the diodes of the limiter 2 and the detector 60.

In the modification of the invention shown in Fig. 3, instead of being derived from a third winding of the discriminator transformer and a special detector, audio voltages are supplied to the signal amplifier 4 from the potential variations across resistor 49 in the circuit of diode 15. In this circuit intermediate frequency currents flow from the anode 13 of the amplifier 1 through the coupling condenser 14, a tuned circuit comprising the inductance 17 and the diode 15 and bypass condenser 18, through switch 46 in its right hand position, resistor 52 and bypass condenser 63 in the cathode circuit of signal amplifier 4 and the bypass condenser 64 in the cathode of the intermediate frequency amplifier 1. Unidirectional currents flowing in the diode 15 through the resistor 49 and inductance 17 to the anode of the diode provide audio frequency voltage variations across resistor 49 which are supplied by means of switches 44 and 48 in their right hand positions, and coupling condenser 37 to the control electrode of signal ampliger 4. In all other respects the circuit of this modification is the same as that of the receiver illustrated in Fig. 2.

Thus, it will be seen that my invention provides a receiver which, while allowing limiting on weak signals, permits the last intermediate frequency amplifier to operate under optimum conditions. This is provided by the use of the diode limiter and the decoupling impedance which permit sharp limiting without unduly loading the discriminator circuit. Moreover, by means of the switching arrangement shown, the limiter circuit is converted to an automatic volume control rectifier for amplitude modulated waves. Modification of the circuits to permit reception of amplitude modulated waves or frequency modulated waves is effected by a simple switching arrangement in the direct current circuits of the audio frequency stages of the receiver, thus avoiding any disturbance of the tuning of the radio frequency stages of the receiver.

While I have shown particular embodiments of my invention, it will of course be understood that I do not wish to be limited thereto since various modifications may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The combination, in a radio receiver, of a source of signal modulated carrier waves, a limiter, said limiter comprising a plurality of diodes arranged to transmit opposite peaks of said waves, a frequency discriminator, and impedance means connected between said limiter and said discriminator, said impedance means comprising an impedance connected serially between said limiter and said discriminator and having a magnitude sufficient to decouple said limiter from said discriminator to prevent the inertia of said discriminator from affecting the limiting action of said diodes.

2. The combination, in a receiver for both frequency modulated and amplitude modulated car-

rier waves, of means for detecting said waves, a signal channel through which said waves are supplied to said detecting means, a diode connected in shunt to said channel, means for biasing said diode during reception of frequency modulated waves to be non-conductive to waves of less than a predetermined intensity and conductive to waves of greater than said predetermined intensity whereby said diode limits said waves to said predetermined intensity, a resistance, and means to remove said bias and to connect said resistance in series with said diode during reception of amplitude modulated waves thereby to produce a unidirectional voltage on said resistance having an intensity varying with the intensity of the received carrier wave, and means responsive to said unidirectional voltage to control the transmission characteristics of said channel.

3. The combination, in a radio receiver for either frequency modulated or amplitude modulated carrier waves, of an amplifier for such waves, detecting means for such waves connected to the output of said amplifier, a unilateral conducting device connected across the output of said amplifier, means to bias said unilateral conducting device during reception of frequency modulated waves to limit said waves to a desired value, means to remove said bias and to connect a resistance in series with said unilateral conducting device during reception of amplitude modulated waves thereby to produce a unidirectional voltage on said resistance, and means to vary the amplification of said amplifier in accordance with said unidirectional voltage.

4. The combination in a radio receiver for either frequency modulated or amplitude modulated carrier waves, of an amplifier for such waves, detecting means for such waves connected to the output of said amplifier, a unilateral conducting device connected across the output of said amplifier, means to bias said unilateral conducting device during reception of frequency modulated waves to limit said waves to a desired value, means to remove said bias and to connect a resistance in series with said unilateral conducting device during reception of amplitude modulated waves thereby to produce a unidirectional voltage on said resistance, means to vary the amplification of said amplifier in accordance with said unidirectional voltage, and means connected between said unilateral device and said detecting means to prevent said unilateral device from short-circuiting said detecting means during reception of said frequency modulated waves.

5. The combination, in a radio receiver, of a source of signal modulated carrier waves, a limiter, said limiter comprising a plurality of diodes arranged to transmit opposite peaks of said waves, and a tuned circuit connected to the output of said limiter through an impedance comprising a resistance and a reactance connected in parallel, said impedance having a magnitude of the order of the impedance of said tuned circuit to prevent the inertia of said tuned circuit from affecting the limiting action of said diodes.

6. The combination, in a receiver for both frequency modulated and amplitude modulated carrier waves, of means for detecting said waves, a signal channel through which said waves are supplied to said detecting means, a diode connected in shunt to said channel, means for biasing said diode during reception of frequency modulated waves to be non-conductive to waves of less than a predetermined intensity and conductive to waves of greater than said predetermined intensity whereby said diode limits said waves to said predetermined intensity, a resistance, and means to remove said bias and to connect said resistance in series with said diode during reception of amplitude modulated waves thereby to prevent said diode from limiting the amplitude of said amplitude modulated waves.

7. The combination, in a radio receiver for both frequency modulated and amplitude modulated carrier waves, of an amplifier for such waves, detecting means for such waves connected to the output of said amplifier, a unilateral conducting device connected across the output of said amplifier, means to bias said unilateral conducting device during reception of frequency modulated waves to limit said waves to a desired value, means to remove said bias and to connect a resistance in series with said unilateral conducting device during reception of amplitude modulated waves thereby to prevent said device from limiting the amplitude of said amplitude modulated waves.

8. The combination in a radio receiver for both frequency modulated and amplitude modulated carrier waves, of an amplifier for such waves, a unilateral conducting device connected across the output of said amplifier, means to bias said device during periods when said receiver is receiving frequency modulated waves to limit said waves to a desired value, a tuned circuit connected to the output of said amplifier through an impedance, said impedance being of sufficient magnitude to prevent the inertia of said tuned circuit from affecting the limiting action of said device, and means to remove said bias and to connect a resistance in series with said device during periods when said receiver is receiving amplitude modulated waves to prevent said device from limiting the amplitude of said amplitude modulated waves.

9. The combination, in a receiver for carrier waves modulated in frequency in accord with audio frequency signal currents, of a converter and a channel through which said carried wave is transmitted to said converter, said converter being adapted to reproduce said audio frequency signal currents from said frequency modulated carrier waves, means connected across said channel having high impedance to carrier waves of low intensity and low impedance to carrier waves of high intensity thereby to limit carrier waves supplied to said converter to values not exceeding a predetermined level, and an impedance in series with said channel between said last means and said converter of a value sufficiently high to prevent the low impedance of said means from affecting the operation of said converter during reception of carrier waves of high intensity.

JOHN E. MAYNARD.