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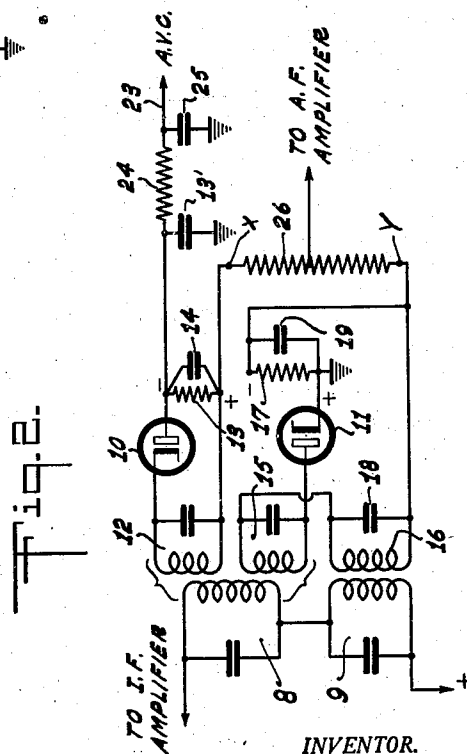
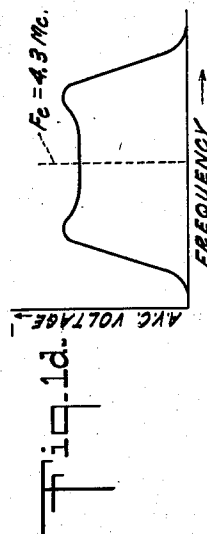
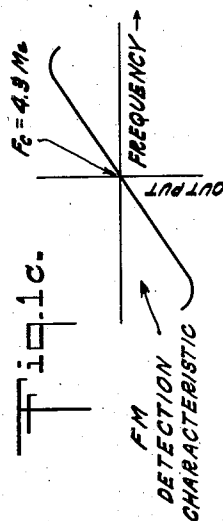
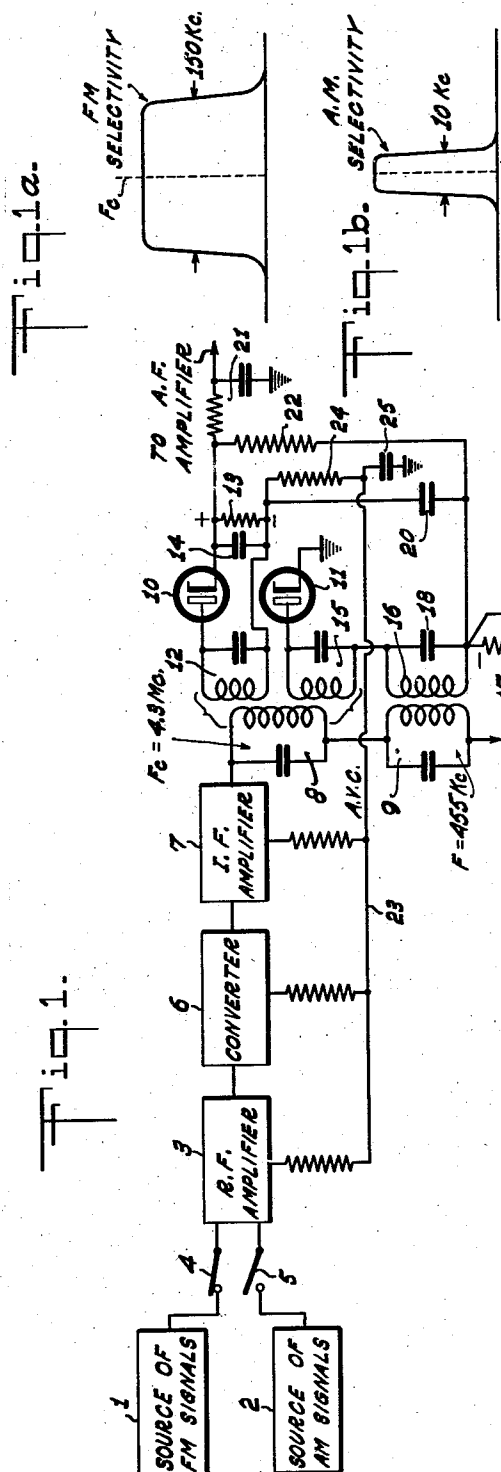
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2,429,762

COMBINED FREQUENCY MODULATION AND AMPLITUDE MODULATION DETECTOR CIRCUITS

Filed Feb. 5, 1944

2 Sheets-Sheet 1



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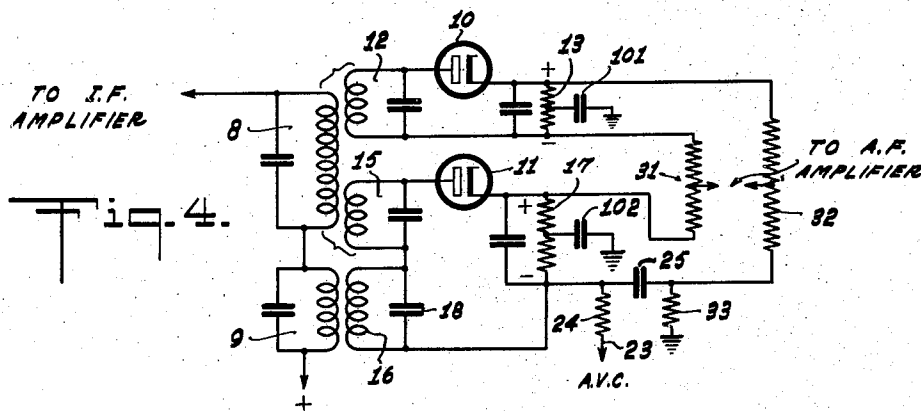
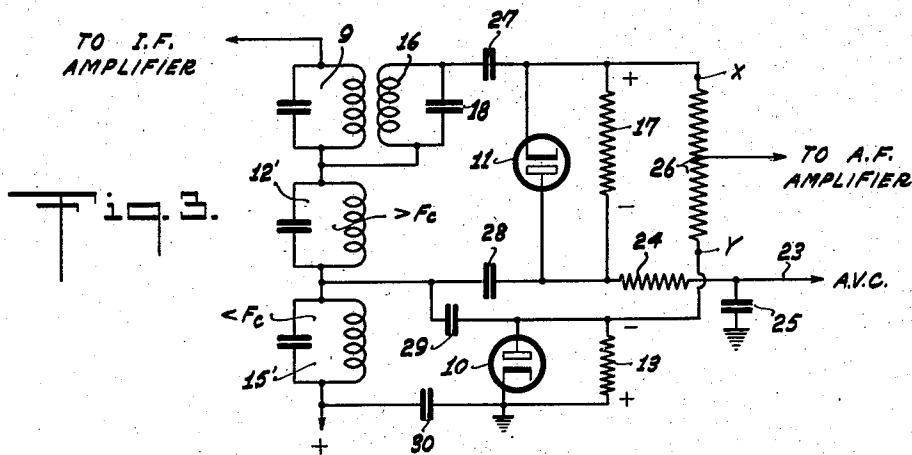
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UNITED STATES PATENT OFFICE

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COMBINED FREQUENCY MODULATION AND
AMPLITUDE MODULATION DETECTOR
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Radio Corporation of America, a corporation of
Delaware

Application February 5, 1944, Serial No. 521,193

10 Claims. (Cl. 250—27)

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My present invention relates to receivers of frequency modulated (FM) or amplitude modulated (AM) carrier waves, and more particularly to novel and improved receivers of FM or AM carrier waves utilizing switchless demodulator or detector circuits.

In his U. S. Patent No. 2,296,092, granted September 15, 1942, M. G. Crosby has disclosed a differential detector circuit adapted to receive FM and/or AM carrier waves. In his detector circuit Crosby provides automatic volume control (AVC) voltage at the detector output in response to either FM or AM reception. The AVC voltage is derived from the separate rectified voltages of the balanced rectifiers added in aiding phase, while the modulation signal corresponding to the frequency modulation of a carrier wave is derived from the rectified voltages added in phase opposition.

While Crosby showed a common signal input network for feeding the FM or AM signals to the detector, it is often desirable to provide separate and independent FM and AM signal channels to the detector and yet be able to provide the same output voltages as in the Crosby system. Accordingly, it is one of the principal objects of my invention to provide discrimination and detection for FM reception on one frequency channel preferably with additive AVC voltage, and detection for AM reception on a different frequency channel without switching of any kind in the output of the detection stage.

When receiving FM signals with a receiver having a substantially flat-topped selectivity characteristic and no amplitude limiter is used, it is desirable to provide AVC voltage from the opposed diodes of the discriminator-detector circuit. Again, where such a receiver is provided with a separate signal channel for AM broadcast reception, it is desirable to use one of the opposed diodes for AM detection and AVC rectification without switching. It is an important object of my invention to provide such an FM-AM receiver with minimum circuit components and maximum detected voltage output.

Other objects of my present invention are to improve generally the efficiency of FM-AM receivers, and more especially to provide economical detector circuits for such receivers.

Other features 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, in partial schematic form, an FM-AM receiver employing one embodiment of my invention,

Fig. 1a shows an ideal selectivity characteristic of the FM signal channel,

Fig. 1b shows an ideal selectivity characteristic of the AM signal channel,

Fig. 1c illustrates the FM detection characteristic,

Fig. 1d shows the "frequency-AVC voltage" characteristic for FM reception,

Figs. 2, 3 and 4 show respectively different modifications of the detector network of Fig. 1.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, Fig. 1 shows an illustrative receiving system embodying a demodulator network adapted to provide audio voltage and AVC voltage in response to FM or AM signal reception. The receiver circuits prior to the demodulator are schematically represented. Those skilled in the art of radio reception are well acquainted with the nature of the circuits customarily employed in multi-band receivers. While my invention is readily adapted for FM and AM reception on respective bands of 42 to 50 megacycles (mc.) and 550 to 1700 kilocycles (kc.), it is to be clearly understood that the invention is not limited to such frequency bands. The 42 to 50 mc. band is presented by way of illustration, since it is the FM broadcast band presently assigned to such transmission. The 550 to 1700 kc. band is the present AM broadcast band assigned to transmission of AM signals.

It will further be understood that in the following description and claims the generic expression "angle modulated" is intended to include frequency modulation, phase modulation or hybrid modulations possessing characteristics common to either form of modulation. From a very general viewpoint my invention relates to a demodulator network having separate input circuits for carrier waves of different frequencies and of different modulation characteristics.

The numerals 1 and 2 in Fig. 1 denote respectively different sources of modulated carrier waves. Source 1 may be the usual signal collector, such as a dipole, employed for collecting FM waves. The FM waves are transmitted from FM transmitters at a mean, center or carrier frequency assigned to the particular transmitter. In the assumed FM band of 42 to 50 mc. the radiated carrier wave frequency would be in that range, and would be a wave of variable frequency

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and substantially uniform amplitude. As is well known, the frequency modulation of the carrier wave would be in accordance with the modulation signals at the transmitter. The extent of frequency deviation of the carrier frequency is a function of the modulation signal amplitude, while the rate of frequency deviation is dependent upon the modulation signal frequencies per se. The permissible extreme frequency deviation in the FM band of 42 to 50 mc. is 75 kc. to either side of the carrier frequency; the allotted FM channels are 200 kc. wide. These values are purely illustrative.

Source 2 may be the customary grounded antenna circuit employed in AM broadcast reception. The allotted channels are 10 kc. wide in this band. In AM transmission the carrier wave is modulated in amplitude in accordance with the modulation signals. The carrier frequency is maintained constant in value at the transmitter. The numeral 3 designates a tunable radio frequency amplifier having suitable signal selector circuits for FM or AM reception. Switching devices 4 and 5 respectively provide separate connection of the sources 1 and 2 to respective selector circuits of amplifier 3. It will be understood that when switch 4 is in closed position, collected FM signal energy will be applied to selector circuits of amplifier 3 capable of selectively amplifying the FM signals over a band at least 150 kc. wide. Upon closing of switch 5 and opening switch 4 the same amplifier 3 will have the FM selector circuits thereof operatively replaced by AM selector circuits. These latter circuits will select the collected AM signals and permit amplifier 3 to amplify the same over a 10 kc. band. Multi-band selector circuits and switching devices for suitable change-over are well known to those skilled in the art of radio communication. Switching devices 4 and 5 affect the demodulator circuit only in so far as they determine the character of the modulated wave to be delivered to the demodulator.

Assuming the system is of the superheterodyne type, as is the usual practice at present, the converter 6 and intermediate frequency (I. F.) amplifier 7 will also be provided with suitable FM and AM signal selector circuits. At the converter 6 the FM signals will have the mean or center frequency thereof reduced to a value which may be chosen from a range of 1 to 20 mc., as for example 4.3 mc. The AM signals are reduced to an I. F. of 455 kc., as an illustrative frequency value, the latter being a commonly employed frequency in AM broadcast receivers of the superheterodyne type. The I. F. amplifier 7, which may consist of one or more separate stages of amplification, will have an ultimate output circuit from which may be derived, at separate points thereof, the amplified FM signals or AM signals.

The selective circuits 8 and 9 are to be understood as being arranged in series in the plate circuit of the last I. F. amplifier tube. Each of circuits 8 and 9 is resonated to its respective operating I. F. value for FM or AM reception. Thus, circuit 8 is tuned to 4.3 mc., while circuit 9 is tuned to 455 kc. There will be developed across tuned circuit 8 the FM signals at the 4.3 mc. mean frequency when switch 4 is closed, and all FM selector circuits of amplifier 3, converter 6 and I. F. amplifier 7 are in operative electrical connection. Conversely, when switch 5 is closed, and switch 4 is open, and all AM selector circuits are in operative electrical connection, there will

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be developed across circuit 9 AM signals at the I. F. value of 455 kc. The impedance of circuit 9 is negligible at 4.3 mc.; therefore, the insertion of circuit 9 in series with circuit 8 will not affect the development of FM signal voltage across circuit 8. Similarly, the impedance of circuit 8 is negligible at 455 kc., and circuit 8 will not affect development of AM signal voltage across circuit 9.

The demodulator comprises but two electron discharge devices, shown as diodes by way of illustration. The electrodes of the pair of diodes may be housed within a common tube envelope, or they may be in separate envelopes. By way of specific illustration the diodes 10 and 11 are shown as being separate tubes. The diode 10 is provided with a resonant input circuit 12 which is inductively coupled to the circuit 8. The anode of diode 10 is connected to one side of the input circuit 12, while the cathode of diode 10 is connected to the opposite side of input circuit 12 through the load resistor 13. Resistor 13 is bypassed by condenser 14 for high frequency currents.

Diode 11 has its cathode established at ground potential, while its anode is connected to the high alternating potential side of its resonant input circuit 15. Circuit 15 is also inductively coupled to the circuit 8. The low potential side of circuit 15 is connected to ground through the coil 16 and load resistor 17. Coil 16 is magnetically coupled to circuit 9, and condenser 18 shunts coil 16 to provide a resonant circuit 16-18 tuned to 455 kc. Condenser 19 shunts resistor 17 to bypass high frequency currents.

The input circuits 12 and 15 of diodes 10 and 11 respectively are oppositely and equally mistuned with respect to the operating I. F. value for FM reception. In other words, if the FM signals developed across circuit 8 have a center frequency of F_c (4.3 mc.), then circuits 12 and 15 will be detuned in opposite senses by equal predetermined frequency values relative to F_c . It will be recognized that circuits 8, 12 and 15 provide the well known discriminator network of Conrad U. S. Patent No. 2,057,640. The action of this form of discriminator circuit is well known to those skilled in the art. It functions to translate FM high frequency signals into corresponding AM high frequency signals.

At the 4.3 mc. frequency used for FM reception the impedance of circuit 16-18 is negligible, and hence the load resistor 17 is effectively in series with input circuit 15 and diode 11. The upper end of resistor 17 is coupled to the lower end of resistor 13 through the condenser 20. Condenser 20 has a low impedance for the modulation frequencies developed during detection of the FM signals, but has a high impedance to high frequency currents. In other words, condenser 20 is a modulation frequency coupling condenser.

Assuming that the modulation signals on the received FM waves are of audio frequency, then the audio frequency amplifier of the receiver will have its input lead connected to the cathode end of load resistor 13. As already known, a de-emphasis network 21 may be employed in the audio frequency output connection in order to compensate for pre-emphasis of higher audio frequencies at the transmitter. In accordance with well-understood principles of FM signal detection, the alternating current components in the rectified signal voltage across each of resistors 17 and 13 will be combined in phase opposition due to the connection of the anode end of resistor 17 to the anode end of resistor 13 by coupling condenser 20.

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The differential voltage resulting from the phase-opposing voltages corresponds to the audio modulation signal voltage originally applied to the FM carrier wave at the FM transmitter. At the same time there is provided a conductive connection between the negative or anode end of resistor 17 and the cathode or positive end of resistor 13. This conductive connection includes resistor 22. Considered relative to ground the direct current voltage components of the rectified voltages appearing across resistors 13 and 17 are added in phase-aiding sense. In other words, the direct current voltage components of rectifiers 10 and 11 are combined in additive manner during FM signal reception, while the alternating current (audio) output of rectifiers 10 and 11 are combined in phase-opposing relation.

An AVC connection 23 is provided between the gain control electrodes, as for example the signals grids, of the various tubes in networks 3, 6 and 7 and the negative end of resistor 13. The AVC connection 23 includes a filter resistor 24, whose lower end is bypassed to ground by an audio frequency condenser 25, so as to prevent alternating current components from being transmitted over the connection 23. Network 24—25 therefore acts as a time constant network to produce "slow" AVC action.

The function of the AVC connection is well known to those skilled in the art. Should there be any carrier amplitude variation at the input terminals of each of rectifiers 10 and 11, such amplitude variation will be translated into a corresponding change in direct current voltage across the corresponding load resistors 13 and 17. The additive AVC voltage applied over connection 23 to the controlled tubes will reduce the gain of the tubes to counteract undesired carrier amplitude increase.

During AM signal reception the I. F. signal energy produced in the circuit 9 will be transferred to input circuit 16—18. Each of circuits 9 and 16—18 is tuned to the operating I. F. value of 455 kc. The circuit 15 and diode 11 are in a series circuit with tuned circuit 16—18 and load resistor 17. The circuit 15, resonant close to 4.3 mc., has no appreciable effect on the series circuit, since it acts as an extremely low impedance connection at the 455 kc. value. The modulation voltage component of the rectified I. F. energy developed across bypassed load resistor 17 is applied through condenser 20 and resistor 13 to the common modulation signal output circuit. The direct current voltage component across resistor 17 is applied over AVC path 23 to the prior tubes. The AVC line 23 connects to the ungrounded end of resistor 17, through a series path consisting of resistor 24, resistor 13 and resistor 22. Here, again, the network 24—25 acts to introduce time delay into the AVC action.

In Fig. 1a I have shown the form of selectivity characteristic which is preferred for use during FM signal reception. The curve is idealized, and represents a flat-topped characteristic at least 150 kc. wide. The characteristic represents the ideal pass band of the receiver circuits up to the opposed rectifiers 10—11 during FM reception. The flat-topped selectivity characteristic, if the FM carrier is correctly centered on it, insures against production of amplitude modulation on the FM wave as the latter passes through the cascaded resonant circuits to the FM detector circuit, and lessens the importance of the use of an amplitude limiter stage in FM reception. The AVC circuit acts effectively to reduce the gain

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of the receiver tubes in response to increases in amplitude of the FM carrier.

By way of contrast to Fig. 1a I have shown the AM selectivity characteristic in Fig. 1b. This curve is idealized, and represents the flat-topped 10 kc. pass band of the receiver circuits up to the rectifier during AM signal reception. This enables faithful AM reception and permits the AVC action to function in the well understood manner. Fig. 1c shows the FM detection characteristic of opposed rectifiers 10 and 11 and their associated input circuits 12 and 15. It is desirable to have the spaced peaks of the ideal curve separated by a frequency value in excess of the 150 kc. band width. Further, the curve should be as linear as possible between the peaks thereof.

With a detection characteristic as shown in Fig. 1c, the AVC voltage-frequency characteristic during FM reception will be substantially of the form ideally represented in Fig. 1d. It will be noted that the AVC (negative in sign) voltage, with changes in carrier frequency but not in amplitude, becomes a maximum at spaced peaks of the curve, with a decrease towards the center frequency F_c . In other words, the AVC bias will be a maximum on each side of F_c thereby providing an audible aid in differentiation between exact tuning of the receiver and off-center tuning thereof.

The detection network of Fig. 1 may assume different forms. Figs. 2 to 5 inclusive show different modifications of the invention. In Fig. 2 the rectifier diode 10 has its cathode connected to the high potential side of input circuit 12, while the anode of the diode is connected to the upper end of load resistor 13, which is bypassed by condenser 14 for high frequency currents. Condenser 13' bypasses the anode end of resistor 13 to ground for both I. F. and A. F. currents. The anode of diode 11 is connected to the grounded cathode through a series path comprising circuit 15, circuit 16—18 and load resistor 17. The cathode end of resistor 13 is connected directly to the upper end of resistor 26, while the lower end of the latter is connected directly to the ungrounded end of load resistor 17. The modulation or audio output connection is made to an intermediate point on resistor 26. The AVC connection 23 is made to the anode end of resistor 13 through the time constant resistor 24.

The action of Fig. 2 is similar to that of Fig. 1. The AVC bias, during FM reception, is secured by additively combining the rectified direct current voltages across resistors 17 and 13 which are connected through resistor 26. The audio output voltage during FM reception is produced by combining in phase opposition the rectified voltages produced at audio frequency across resistors 13 and 17. The resultant audio voltage appearing between the center tap of resistor 26 and ground is used. For AM reception the diode 11 acts as the rectifier whose input circuit is 16—18. The audio voltage across resistor 17 is supplied to the audio network through resistor 26, while the AVC line 23 is connected to the negative end of resistor 17 through the path comprising resistor 24, resistor 13 and resistor 26.

In order to explain the function of center-tapped resistor 26 in this combination of elements, there will be considered what happens when signal amplitude changes on the one hand, and what happens due to signal frequency changes on the other hand. As the signal amplitude becomes larger with the frequency remaining constant, the end X of resistor 26 becomes more

positive relative to ground, it being understood that the anode end of resistor 13 is grounded for audio frequencies through condenser 13'. The other end Y of resistor 26 becomes more negative. Both of these effects follow from the direction of connection of diodes 10 and 11. The center tap of the resistor therefore remains at ground potential despite amplitude changes. This satisfies the requirement of a discriminator that it be balanced against amplitude modulation effects for a carrier tuned to the center of the band. As the signal frequency changes in one direction, however, the end X of resistor 26 becomes less positive while the other end Y becomes more negative. Hence, the center tap on the resistor assumes a negative voltage relative to ground. For changes in frequency of the carrier in the other direction, the end X of resistor 26 will become more positive and the other end Y less negative thereby causing the center tap to be positive. These last-mentioned changes occur at the audio modulation frequencies. This satisfies a second requirement of a discriminator that the output thereof shall follow frequency variation so as to derive the modulation frequencies. In the present discriminator circuit the outputs of the diodes are combined by approximately a parallel connection between the mid-point of resistor 26 and ground, which permits one side of each diode load resistor to be at ground potential for audio frequencies as well as for intermediate frequencies.

In the modification of Fig. 3 the AM circuits 9 and 16—18 are connected in common at the lower sides thereof. In place of the FM circuit 8, only the off-tuned circuits 12' and 15' are employed. These circuits 12' and 15' correspond to circuits 12 and 15 of Fig. 1. Circuit 12' tuned to a frequency somewhat above F_c is arranged in series with circuit 15' tuned to a frequency less than F_c by the same amount. The circuits 9, 12' and 15' are arranged in series in the I. F. amplifier output circuit. Diode 11 is arranged in series with circuits 16—18 and 12', the cathode of diode 11 being connected by radio frequency coupling condenser 27 to the high potential side of circuit 16—18. Condenser 28, an audio coupling condenser, connects the anode of diode 11 to the junction of circuits 12' and 15'. Load resistor 17 shunts the diode 11. Diode 10 has its cathode grounded, while its anode is connected by radio frequency coupling condenser 29 to the junction of circuits 12' and 15'. The audio coupling condenser 30 connects the lower side of circuit 15' to the grounded cathode of diode 10. Load resistor 13 shunts the diode 10. The AVC connection 23 is made through time constant resistor 26, associated with condenser 25, to the anode, or negative, end of resistor 17. The tapped resistor 26, from whose mid-tap the audio voltage is taken, connects the cathode end of resistor 17 to the anode end of resistor 13.

As in the previous modifications, rectifier 11 has AM signals applied thereto through the circuits 9 and 16—18. The circuit 12' acts as a low impedance connection relative to AM signal frequencies. The AVC bias is taken from the resistor 17, while audio voltage is taken from resistor 26. For FM reception circuit 9 has negligible impedance. Circuit 12' acts as the input circuit of diode 11, while circuit 15' functions to supply FM energy to diode 10. The action of the series discriminator 12'—15' in Fig. 3 is similar to that of Figs. 1 and 2 save that the primary circuit 8 is eliminated. The direct current voltages across

resistors 17 and 13 are added in phase aiding relation by connection through resistor 26, and the AVC connection 23 employs the additive voltage. The audio voltage components across resistors 17 and 13 are combined in opposition across resistor 26 in the same manner as in the circuits of Fig. 2. Condensers 28 and 30 of Fig. 3 ground the anode end of resistor 17 for audio frequencies in like manner to the action of condenser 13' in Fig. 2 in grounding the anode end of resistor 13.

The modification of Fig. 4 employs the principles of operation of Fig. 2, but differs therefrom in respects which adapt the audio output circuit of the network for push-pull operation. In the modification of Fig. 4, each of resistors 13 and 17 acts as the respective load resistor for rectifiers 10 and 11 during reception of FM signals. Furthermore, resistor 17 is the load resistor for rectifier 11 during reception of AM signals. The AVC connection 23 is made through filter resistor 24 to the anode end of resistor 17. Condenser 25 cooperates with resistor 24 to provide the time constant network for the AVC circuit. It will be seen that the direct current voltages developed across resistors 17 and 13 are additively combined, since the connection 23 is made to the negative end of resistor 17, and the positive end of the latter resistor is connected to the negative end of resistor 13 through resistor 31. The positive or cathode end of resistor 13 is connected to ground through a path including resistors 32 and 33 in series. The mid-taps on resistors 31 and 32 may act as opposed-phase input terminals for a following push-pull audio amplifier. The mid-tap on each of load resistors 13 and 17 is connected to ground through respective audio frequency bypass condensers 101 and 102.

In a manner similar to the operation of resistor 26 in Fig. 2, a connection may be traced from the mid-tap of resistor 32 to ground through the upper end of resistor 32, upper half of load resistor 13, and condenser 101, and a second connection in parallel therewith may be traced from the mid-tap of resistor 32 to ground through the lower end of resistor 32, condenser 25, lower half of load resistor 17 and condenser 102. These connections will cause the potential at the mid-tap of resistor 32 to change with variations in the signal frequency in the same manner in which the potential of the mid-tap of resistor 26 changes in the operation of Fig. 2. In like manner two parallel connections are established between the mid-tap of resistor 31 and ground, one through the upper half of resistor 31, lower half of resistor 13, and condenser 101 and the other through the lower half of resistor 31, upper half of resistor 17 and condenser 102. It will be apparent to those skilled in the art without further explanation that the potential of the mid-tap of resistor 31 also changes with variations in the signal frequency, and in opposite phase to the potentials on the mid-tap of resistor 32. The condensers 101 and 102 may also act to improve the response at the higher audio frequencies by providing a good path to ground for such frequencies. During AM signal reception, it being understood that circuit 15 has negligible impedance, rectifier 11 is fed with AM signals by input circuit 16—18. The direct current voltage developed across resistor 17 is employed for AVC bias, whereas the audio voltage across resistor 17 is used for push-pull operation since the input terminals, or the center-

taps on resistors 31 and 32, are connected to points of opposite polarity on resistor 17 relative to audio frequency ground at condenser 102.

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.

What I claim is:

1. In combination with a frequency discriminator, a pair of opposed rectifiers each having an input electrode coupled to said discriminator, a separate load impedance in circuit with each rectifier, resistive means connecting said load impedances in series relation, means grounding the positive potential end of one impedance a first connection to the negative potential end of the series-connected second impedance for deriving from said impedances in additive polarity sense rectified voltages thereacross thereby to provide a negative voltage relative to ground, a second connection to an intermediate point on said resistive means for deriving a voltage resulting from said rectified voltages being combined in polarity opposition.

2. In combination with a frequency discriminator, a pair of opposed rectifiers each having an input electrode coupled to said discriminator, a separate load impedance in circuit with each rectifier, a first resistor connecting a first pair of opposite polarity points of said load impedances, a second resistor connecting a second pair of opposite polarity points of said load impedances in reversed sense relative to the first resistor, a first connection for deriving from said impedances in additive polarity sense direct current voltages thereacross, respective output connections to an intermediate point on said resistor means for deriving a push-pull modulation signal voltage resulting from rectified voltages being combined in opposition, a source of amplitude modulated carrier wave energy coupled to one of the rectifiers and including its respective load impedance in circuit therewith, and said output connections deriving from said last load impedance rectified voltage corresponding to amplitude modulation.

3. In combination with a frequency discriminator consisting of a pair of oppositely mistuned resonant circuits, a pair of opposed diode rectifiers each having its electrodes coupled to a respective resonant circuit of said discriminator, a separate load impedance in circuit with each diode rectifier, a resistor connecting said load impedances in series relation, means grounding the cathode end of one of said load impedances, a gain control connection to the anode end of the series-connected second impedance for deriving from said impedances in additive polarity sense rectified direct current voltages thereacross thereby to provide a gain control voltage which is negative relative to ground, a second connection to the midpoint of said resistor for deriving a modulation voltage resulting from said rectified voltages being combined in polarity opposition.

4. In combination with a frequency discriminator, means for impressing frequency modulated signal waves thereon, a pair of opposed diode rectifiers each having an input electrode coupled to said discriminator, a separate load impedance in circuit with each of said diode rectifiers for deriving a rectified voltage therefrom, a resistance, a modulation frequency connection from one end

of said resistance to ground through a condenser connected to an intermediate point on one of said load impedances, a modulation frequency connection from the other end of the resistance to ground through a second condenser connected to an intermediate point on the other of said load impedances, and a connection substantially to the midpoint of said resistance for deriving a modulation voltage resulting from said rectified voltages being combined in opposition.

5. The combination with a frequency discriminator, means for impressing frequency modulated signal waves thereon, a pair of opposed diode rectifiers each having an input electrode coupled to said discriminator, and a separate load impedance in circuit with each of said diode rectifiers for deriving a rectified voltage therefrom, the improvement comprising an output impedance, a modulation frequency connection from one end of said output impedance to an intermediate ground point on one of said load impedances, a modulation frequency connection from the other end of the output impedance to an intermediate point on the other of said load impedances, and a connection substantially to the midpoint of said output impedance for deriving a modulation voltage resulting from said rectified voltages being combined in opposition.

6. The combination with a frequency discriminator, means for impressing frequency modulated signal waves thereon, a pair of opposed diode rectifiers each having an input electrode coupled to said discriminator, and a separate load impedance in circuit with each of said diode rectifiers for deriving a rectified voltage therefrom, all of which are known; of an output impedance, a modulation frequency connection from one end of said output impedance to ground through a portion of one of said load impedances, a modulation frequency connection from the other end of the output impedance to ground through a portion of the other of said load impedances, a second output impedance, a modulation frequency connection from one end of said second output impedance to ground through another portion of said one of said load impedances, a modulation frequency connection from the other end of the second output impedance to ground through another portion of the other of said load impedances, and connections substantially to the midpoints of said output impedances for deriving push-pull modulation voltages from said rectified voltages.

7. The combination with a frequency discriminator, means for impressing frequency modulated signal waves thereon, a pair of opposed diode rectifiers each having an input electrode coupled to said discriminator, and separate, substantially equal load impedances in circuit respectively with each of said diode rectifiers for deriving a rectified voltage therefrom, condensers of low impedance to modulation frequencies respectively connecting substantially the midpoints of the load impedances to ground, output impedances connected to different terminals of the load impedances and each to terminals of opposite modulation voltage, and connections substantially to the midpoints of said output impedances for deriving push-pull modulation voltages from said rectified voltages.

8. The combination with a frequency discriminator, means for impressing frequency modulated signal waves thereon, a pair of opposed diode rectifiers each having an input electrode coupled to said discriminator, and separate, substantially

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equal load impedances in circuit respectively with each of said diode rectifiers for deriving a rectified voltage therefrom, connections having low impedance to modulation frequencies between substantially the midpoints of the load impedances and ground, output impedances connected to different terminals of the load impedances and each to terminals of opposite modulation voltage, connections substantially to the midpoints of said output impedances for deriving push-pull modulation voltages from said rectified voltages, and means for deriving automatic volume control voltage from said load impedances in aiding phase.

9. In combination with a frequency discriminator, a pair of opposed rectifiers each having an input electrode coupled to said discriminator, a separate load impedance in circuit with each rectifier, a first resistive means connecting a first pair of points of opposite polarity of said load impedances, a second resistive means connecting a second pair of points of opposite polarity of said impedances, and a separate output connection to an intermediate point on each of said two resistive means for push-pull modulation voltage resulting from said rectified voltages being combined in opposition.

10. In combination with a frequency discriminator comprising at least two resonant circuits, a pair of opposed diode rectifiers each having an input electrode coupled to a respective resonant circuit of said discriminator, a separate load im-

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pedance in circuit with each rectifier, first resistive means connected between ends of said load impedances in series relation, a second resistive means connected between the opposite ends of said load impedances in series relation a first connection for deriving from said impedances in additive polarity sense rectified voltages thereacross, push-pull output connections to midpoints of said two resistive means for deriving a voltage resulting from said rectified voltages being combined in opposition, a source of amplitude modulated carrier wave energy coupled to one of the rectifiers and including the respective load impedance in circuit therewith, one of said discriminator circuits being in circuit with said source but not affecting rectification of said amplitude modulated wave energy, and said output connections deriving from said last load impedance rectified voltage corresponding to amplitude modulation.

WINFIELD R. KOCH.

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