

July 3, 1945.

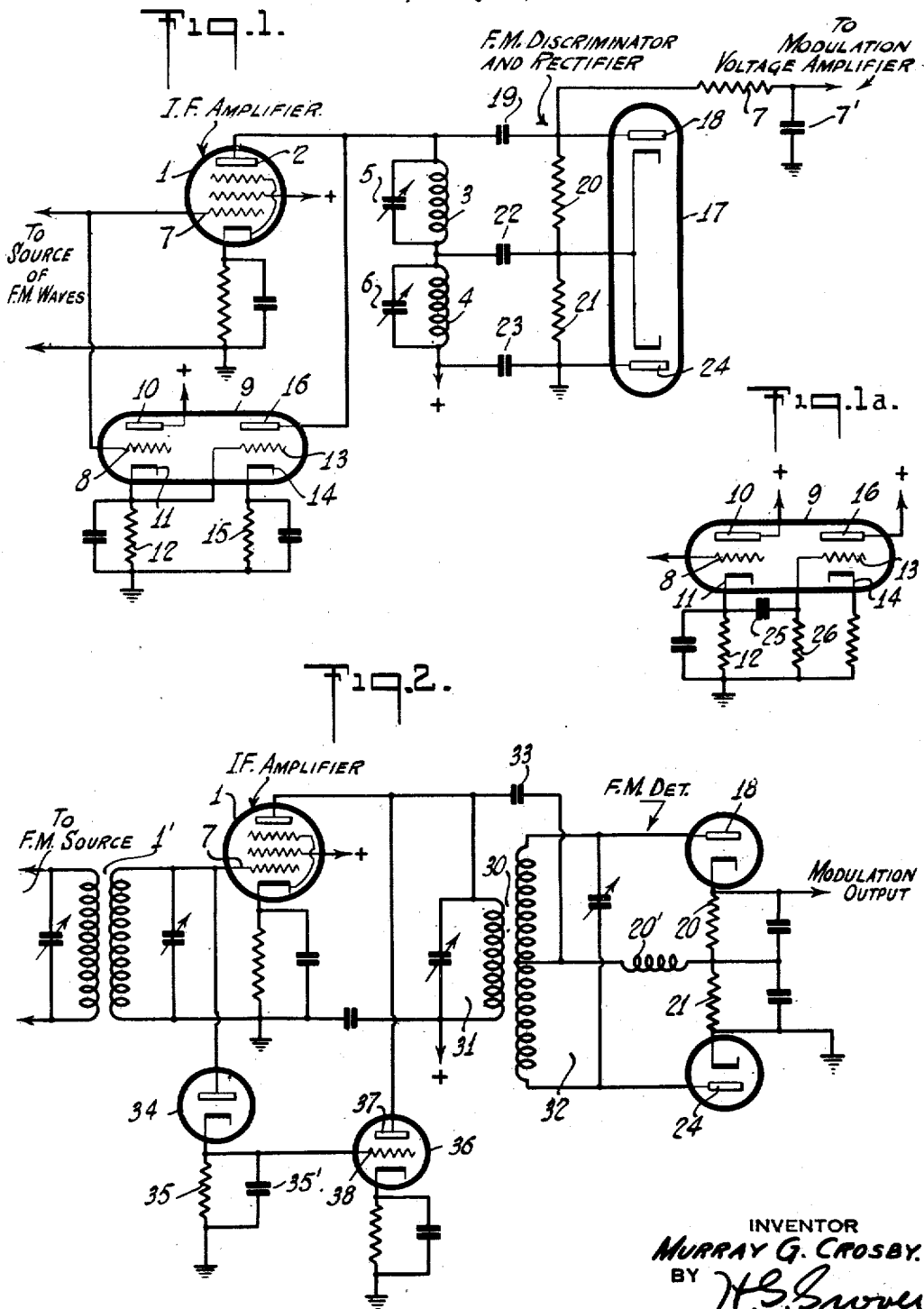
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2,379,688

FREQUENCY MODULATION RECEIVER CIRCUIT

Filed July 13, 1942

3 Sheets-Sheet 1



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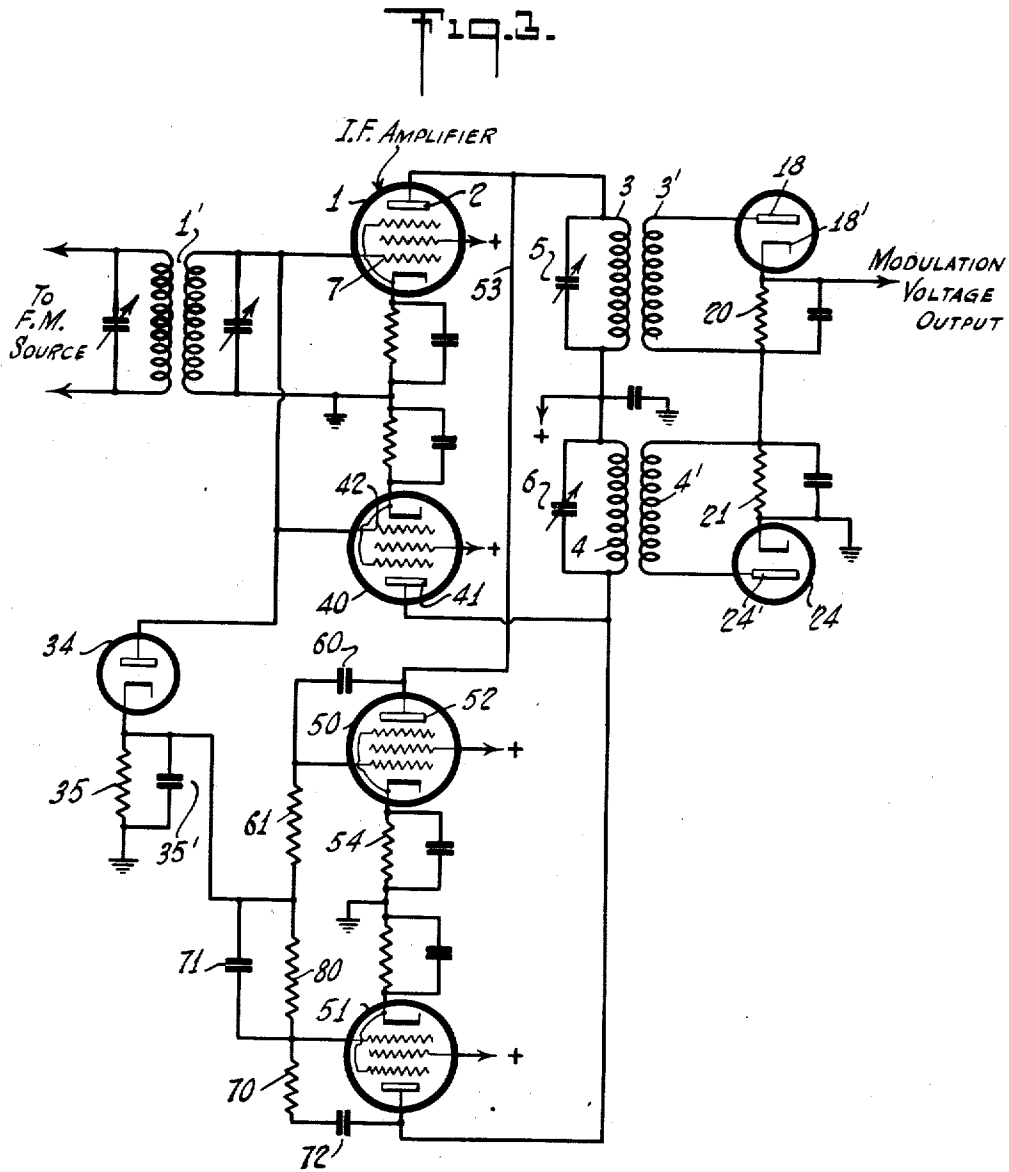
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

Fig. 4a.

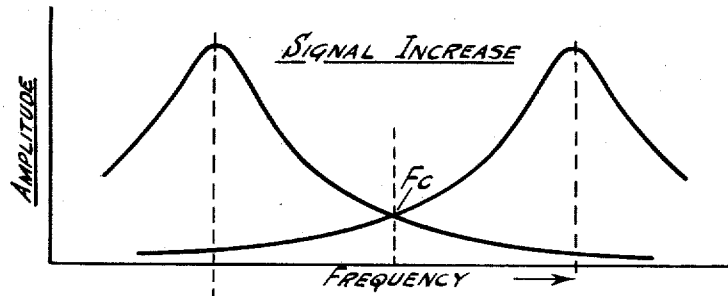


Fig. 4b.

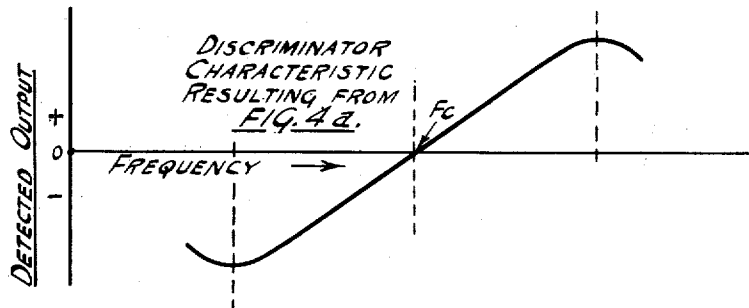


Fig. 4c.

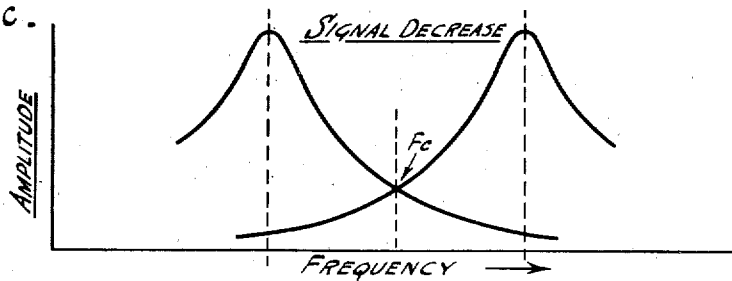
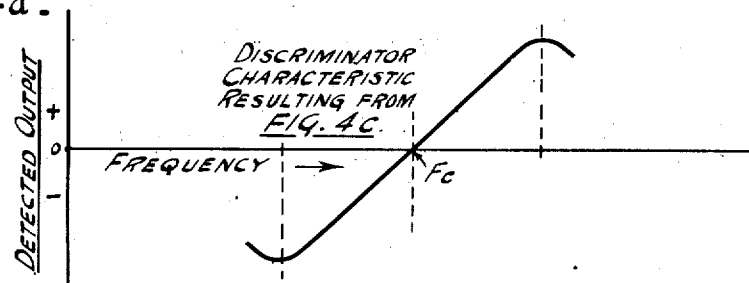


Fig. 4d.



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2,379,688

FREQUENCY MODULATION RECEIVER
CIRCUITSMurray G. Crosby, Riverhead, N. Y., assignor to
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Application July 13, 1942, Serial No. 450,656

17 Claims. (Cl. 250—20)

My present invention relates to frequency modulation receiver circuits, and more particularly to novel methods of, and means for, receiving frequency modulated carrier wave energy while simultaneously removing the effects of undesired amplitude modulation without the aid of a limiter per se.

One of the main objects of my present invention is to provide a system for receiving frequency modulated (F. M. for brevity hereinafter) carrier wave energy, the system including a circuit for separately detecting amplitude modulation when it exists on the received energy, the detected amplitude modulation being fed to the grid of a damping tube which functions to damp the tuned circuits of the discriminator in a manner such that the effective slope, or sensitivity, is reduced as the signal strength increases.

Another important object of the invention is to provide a method of modifying the sensitivity of the discriminator of a frequency modulation detector in inverse accordance to the amplitude modulation which may exist on the received carrier energy whereby amplitude modulation effects, which are undesired, are cancelled.

Another important object of the invention is to provide in a receiver of frequency modulated carrier wave energy a discriminator-rectifier network which functions to derive the modulation signals from the received energy, and means being employed prior to the discriminator for controlling the sensitivity of the discriminator in inverse accordance to amplitude modulation effects sought to be eliminated.

Yet another important object of the invention is to vary the efficiency of the discriminator section of a frequency modulation discriminator-rectifier in inverse accordance to undesired amplitude variations, and the efficiency being varied by varying the tuning of the individual tuned circuits of the discriminator.

Other objects of my invention are to improve generally the efficiency and simplicity of frequency modulation discriminator-rectifier networks, and more especially to provide discriminator-rectifier networks which are efficient and reliable in action and which are economically manufactured and assembled.

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 organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 shows one embodiment of the invention,

Fig. 1a shows an alternative embodiment of the discriminator control circuit,

Fig. 2 shows a further embodiment,

Fig. 3 shows another form of the invention

Figs. 4a to 4d inclusive show graphically the discriminator characteristics for different signal strengths in the circuit shown in Fig. 3.

Referring now to the accompanying drawings, and particularly Fig. 1, the numeral 1 designates an amplifier, for example one of the pentode type, which acts to feed the received modulated carrier wave energy to the discriminator. Where the receiver is of the superheterodyne type, and this type of receiver is used universally today, the amplifier 1 may be an intermediate frequency (I. F.) amplifier which precedes the discriminator. Since no limiter stage per se is employed in the present system, the I. F. amplifier 1 has its plate 2 connected to a point of positive potential through the coils 3 and 4 of the series-arranged tuned discriminator circuits. Each of coils 3 and 4 is shunted by a respective tuning condenser 5 and 6. The tuned circuits 5—3 and 6—4 are oppositely and equally mistuned relative to the center frequency; in this case the latter is the operating I. F. value. The input grid 7 of tube 1 may be connected to a source of frequency modulated wave energy. For example, the source could be the plate circuit of the converter, or it can be the plate circuit of a preceding I. F. amplifier. In any case, it is to be clearly understood that the received modulated carrier wave energy can be either frequency, or phase, modulated. The generic term "angular velocity-modulated carrier wave energy" includes frequency, and phase, modulated wave energy.

As is well known to those skilled in the art, the selector circuits of the various stages of the receiver are tuned to the center, or midband, frequency of the received modulated energy. Due to extraneous noise effects, fading, and the cascading of the resonant circuits, amplitude modulation (AM) effects arise in the received modulated carrier energy. These undesired amplitude modulation effects must be eliminated, because they represent harmonics which cause distortion. The modulation signals vary solely the frequency of the carrier at the transmitter, while the amplitude of the carrier remains constant.

There are many ways in which undesired AM effects may be removed without using a limiter stage per se prior to the discriminator network. For example, in my application Serial No. 416,443, filed October 25, 1941, and application Serial No. 435,467, filed March 20, 1942, various arrangements are shown for eliminating undesired AM effects without using a special limiter stage. According to my present invention, the AM effects are eliminated without the use of a special limiter stage, but according to a method which generi-

cally differs from the methods of my aforementioned applications. A certain portion of the FM wave energy is applied to the grid 8 of the triode section of a twin triode tube 9. The plate 10 associated with grid 8 is connected to a point of positive potential of a direct current source (not shown). The cathode 11 is connected to ground through a carrier-bypassed biasing resistor 12 whose lower end is grounded. The grid 13 of the second triode section of tube 9 is connected to the cathode end of resistor 12. The cathode 14 is connected to ground through the carrier-bypassed biasing resistor 15. The plate 16 of the second triode section of tube 9 is connected to the plate 2 of the I. F. amplifier tube 1.

The rectifier network of the FM detector circuit comprises the double diode tube 17. The anode 18 of one diode section is connected through a coupling condenser 19 to the plate end of coil 3. The common cathode connection of the two diode sections of tube 17 is connected to the junction of load resistors 20 and 21. The junction of the load resistors is connected by coupling condenser 22 to the junction of discriminator circuits 5-3 and 6-4. The lower end of coil 4 is returned to the grounded end of load resistor 21 by coupling condenser 23. The anode 24 of the second diode section of tube 17 is connected to the grounded end of load resistor 21. Modulation voltage is taken off from the upper end of load resistor 20, and through resistor-condenser filter 7-7' the modulation signal voltage is fed to a modulation signal utilization network. The latter may comprise one or more amplifier stages followed by a reproducer.

In explaining the operation of the arrangement of the circuit shown in Fig. 1, it is pointed out that the incoming FM wave energy is fed concurrently to the control grids 7 and 8 of the I. F. amplifier and twin triode tube 9 respectively. The triode section 11-8-10 of tube 9 functions as an infinite impedance diode detector. It is not believed necessary to describe the nature of such a detector, since those skilled in the art are fully aware of the fact that it is a plate circuit rectification device which is degenerative by virtue of the degeneration across resistor 12.

The undesired AM component of the FM wave energy is detected by the infinite impedance diode detector device, and there appears across the cathode resistor 12 a voltage corresponding to the rectified AM component. This rectified AM voltage component is fed to the control grid 13 of the second triode section of tube 9. The second triode section functions as a damping tube. Of course, the triodes of tube 9 may be independently located in separate envelopes. The plate circuit of triode section 14-13-16 acts as a variable resistance which shunts the discriminator 5-3 and 6-4. It is pointed out that the discriminator tuned circuits have peak frequencies which are spaced apart by a frequency distance greater than the maximum frequency deviation range of the FM wave energy.

As the amplitude of the incoming FM wave energy increases, the detected voltage developed across resistor 12 becomes more positive. This voltage biases grid 13 of the damping triode more positive. The action lowers the plate resistance of the damping triode. Hence, the equivalent series resistance in each tuned circuit of the discriminator increases with the result that the sensitivity of the discriminator is reduced. Reducing the sensitivity of the discriminator causes a reduction in the detected audio output voltage,

so that there is produced a compensatory reduction in the audio output level as the signal carrier strength increases.

The result of the increased damping action on the discriminator, or lower resistance of the plate circuit connected to plate 16, is to reduce the steepness of the slopes of the individual sloping filters of the discriminator without varying the peak frequency spacing the tuned circuits. The result is a decreased audio output. The decreased audio output compensates for the increase produced when the signal increases in amplitude. In other words, I have shown in Fig. 1 a method of varying the discriminating efficiency of an FM detector circuit, and the control of efficiency being effected in accordance with the amplitude of the undesired AM effects. The control of the discriminator efficiency is in such a direction that the undesired AM effects tend to be eliminated.

Fig. 1a shows an alternative method of coupling the detected AM voltage to the grid of the damping tube. A blocking condenser 25, in conjunction with grid resistor 26, blocks the slow variations so that they do not operate the damper tube. This type of arrangement allows the damper tube to work with a more fixed bias so that its operational characteristic may be controlled somewhat more accurately.

The discriminator of the oppositely mistuned type shown in Fig. 1 is not essential to the operation of the invention. There may be employed in place thereof a type of discriminator shown by S. W. Seeley in his U. S. Patent 2,121,103, granted June 21, 1938. Such a circuit is shown in Fig. 2. Here, the I. F. amplifier 1 has its input electrodes coupled to a prior I. F. input transformer 1'. The primary and secondary circuits of the latter are each tuned to the operating I. F. value which, of course, is the center frequency of the applied FM wave energy. The discriminator comprises the transformer 30 whose primary tuned circuit 31 is resonated to the center frequency. The secondary tuned circuit 32, reactively coupled to primary circuit 31, is also tuned to the center frequency. The diode anodes 18 and 24 are shown coupled in this case to the opposite sides of secondary circuit 32.

The load resistors 20 and 21 are arranged in series with the diode cathodes. The diodes are shown in separate tube envelopes. Each of the load resistors 20 and 21 is bypassed by its respective carrier bypass condenser, while the cathode end of resistor 21 is grounded. The junction of resistors 20 and 21 is connected by a radio frequency choke coil 20' to the midpoint of the coil of secondary circuit 32. The last named midpoint is also connected by the direct current blocking condenser 33 to the plate side of the primary circuit 31. The modulation output is taken from the cathode end of resistor 20. It is not believed necessary to describe the operation of the discriminator shown in Fig. 2. Those skilled in the art are fully acquainted with the manner in which the particular discriminator of Fig. 2 functions to transform the FM wave energy into corresponding AM wave energy, the latter being rectified by the opposed diodes.

In this case the undesired AM on the FM wave energy is detected, or rectified, by a diode 34 whose anode is connected to the grid 7 of tube 1. The cathode of diode 34 is connected to ground through a load resistor 35 which is bypassed by condenser 35' for I. F. currents. The damping tube is designated by numeral 36, and its plate 37 is connected to the plate of amplifier 1. The

grid 38 of damping tube 36 is connected to the cathode end of load resistor 35. The cathode circuit of damping tube 36 is grounded through a bypassed biasing resistor.

The plate circuit of damping tube 36 is connected across the primary circuit 31 of the discriminator. The damping that is applied to the primary circuit 31 is also reflected into the secondary circuit 32 so that the overall detection efficiency of the discriminator is varied. The remainder of the operation is the same as that explained in connection with Fig. 1. It will be understood that the coupling arrangement of Fig. 1a may also be applied to the circuit of Fig. 2.

The efficiency of discrimination may, additionally, be varied by regulating the tuning of the individual tuned circuits of the discriminator. In Fig. 3, I have shown the I. F. amplifier tube 1 connected in circuit with a second I. F. amplifier tube 40. The plate 2 of tube 1 and the plate 41 of tube 40 are connected to opposite sides of the discriminator tuned circuits. The junction of the coils of the discriminator tuned circuits is connected to a point of proper positive potential, while the said junction point is bypassed to ground for I. F. currents. The signal grids 7 and 42 respectively of tubes 1 and 40 are connected in parallel to the high potential side of the secondary circuit of the I. F. input transformer 1'. The cathodes of tubes 1 and 40 are connected through appropriately I. F.-bypassed biasing resistors to ground.

The coil 3 of the discriminator tuned circuit 5-3 is magnetically coupled to the input coil 3' of diode 18'. The load resistor 20 is in this case arranged in series with the coil 3' and the diode space current path. Similarly, the anode 24' of diode 24 is arranged in series with load resistor 21 and the secondary winding 4' of the transformer 4-4'. The cathode end of resistor 21 is grounded, while the modulation signal voltage is taken off from the cathode end of resistor 20. It will be noted that the discriminator-rectifier functions precisely as in the case of Fig. 1.

The control over the discriminator efficiency is accomplished in this case by varying the tuning of the individual tuned circuits 5-3 and 6-4. To accomplish this the diode 34, as in the case of Fig. 2, has its anode connected to the input circuit of amplifier tube 1. The detected AM voltage developed across load resistor 35, appropriately bypassed for I. F. currents by condenser 35', is applied as a biasing voltage to the control grids of a pair of reactance tubes 50 and 51. Each of these reactance tubes may be of the pentode type. Each reactance tube is associated with a respective one of the discriminator tuned circuits. Thus, the plate 52 of tube 50 is connected by lead 53 to the plate side of tuned circuit 5-3. The cathode of tube 50 is connected to ground through a carrier-bypassed biasing resistor 54. Hence, the plate to cathode impedance of tube 50 is shunted across the tuned circuit 5-3.

In order to vary the reactive magnitude of the plate to cathode impedance of tube 50 there is used a feedback phase shifter composed of condenser 60 and resistor 61. These elements are arranged in series between the plate 52 and detector load resistor 35. Condenser 60 has a high reactance, while the resistor 61 has a relatively low resistance. Under these conditions, and as is well known to those skilled in the art, there will be applied to the grid of tube 50 alternat-

ing current voltage which is in phase quadrature with the alternating voltage at the plate 52. Hence, the plate to cathode impedance of tube 50 will simulate a capacitive reactance, and the magnitude of the capacitive reactance will be a function of the direct current voltage of the control grid of tube 50. This direct current voltage depends upon the voltage developed across rectifier load resistor 35.

The reactance tube 51 has a feedback phase shifter composed of resistor 70 and condenser 71. These two elements are arranged in series between the direct current blocking condenser 72 and the load resistor 35. The resistor 80 acts as a grid return resistor for the control grid of tube 51. In the case of the reactance tube 51 the quadrature voltage is taken off from across condenser 71, and therefore, the plate to cathode impedance simulates an inductive reactance whose magnitude is a function of the direct current voltage of the grid of tube 51. The reactance of condenser 71 is low compared to the resistance of resistor 70. It will be observed that direct current voltage developed across rectifier load resistor 35 is applied through resistors 80 and 61 respectively to the grids of reactance tubes 51 and 50. This acts to control the biases of the grids, and, hence, the capacitive and inductive effects of tubes 50 and 51 respectively.

In order to explain the operation of the circuit shown in Fig. 3, attention is directed to Figs. 4a to 4d inclusive. In Fig. 4a there is shown the relation between "frequency" and "amplitude." One of the single peak response curves is the resonance curve of one of the discriminator tuned circuits, while the other single peak curve is the response curve of the second discriminator tuned circuit. The cross-over point of the two curves represents the center frequency F_c . The frequency spacing between the peaks of the response curves should be at least as wide as the maximum frequency deviation range of the incoming FM energy. Preferably, the frequency spacing exceeds the maximum frequency deviation range. An increase in signal carrier amplitude is detected by rectifier 34, and the positive voltage developed across resistor 35 is applied as a positive bias to each of the grids of reactance tubes 50 and 51. These reactance tubes are arranged so that the positive bias on each grid acts to shift the reactive effects of these tubes so as to tune the discriminator circuit farther away from the carrier, or center, frequency F_c . In other words, in Fig. 4a there is shown the relation between the response curves of the discriminator tuned circuits for a condition of signal carrier amplitude increase.

In Fig. 4b there is shown the discriminator characteristic which results from the relationship of Fig. 4a. In the case of Fig. 4b "frequency" is plotted against "detected output" of the rectifiers. This is the well known S-shaped characteristic of the FM detector. It will be noted that there is a definitely lowered steepness of the characteristic for signal amplitude increases. The detected audio output of the discriminator-rectifier network is consequently lower, so that the effect of the increased signal strength is compensated for. This is essentially the same result which is secured in each of the systems shown in Figs. 1 and 2, although in those figures a damping action is relied upon rather than a resonance action as in the case of Fig. 3. Further, whereas the peak spacing is varied in the case of Fig. 3, in the systems of Figs. 1 and 2

the spacing between the discriminator peaks is not varied.

If, now, there occurs a decrease in modulated carrier amplitude, the reactive effects of tubes 50 and 51 are varied in opposite senses so as to tune the discriminator circuits 5-3 and 6-4 closer to the center frequency F_c . This is depicted in Fig. 4c. It will be noted that the resonance peaks of the individual discriminator tuned circuits are considerably closer as a result of a signal carrier amplitude decrease. Fig. 4d shows the discriminator characteristic which results from the relationship in Fig. 4c. It will be noted that the sensitivity of the discriminator characteristic has now been increased, because the steepness of the overall slope is increased. The result is a variation of detection efficiency in inverse accordance with carrier amplitude variations. Consequently the undesired AM effects, which may otherwise occur in the output circuit of the opposed rectifiers, are effectively eliminated.

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 system for receiving angular velocity-modulated carrier wave energy, a discriminator comprising a pair of frequency responsive circuits having sloping filter characteristics which are oppositely related, a pair of opposed rectifiers operatively associated with said pair of frequency responsive circuits, means for applying to said frequency responsive circuits said modulated carrier wave energy, and means, responsive to carrier amplitude variations in the received energy, for automatically varying the steepness of said sloping filter characteristics.

2. In a system for receiving angular velocity-modulated carrier wave energy, a discriminator comprising a pair of frequency responsive circuits having sloping filter characteristics which are oppositely related, a pair of opposed rectifiers operatively associated with said pair of frequency responsive circuits, means for applying to said frequency responsive circuits said modulated carrier wave energy, a rectifier coupled to the input of said frequency responsive circuits for developing a uni-directional voltage whose magnitude is proportional to amplitude variations in the received carrier, and means, responsive to said uni-directional voltage, for automatically varying the steepness of said sloping filter characteristics.

3. In a system for receiving angular velocity-modulated carrier wave energy, a discriminator comprising a pair of frequency responsive circuits having sloping filter characteristics which are oppositely related, a pair of opposed rectifiers operatively associated with said pair of frequency responsive circuits, means for applying to said frequency responsive circuits said modulated carrier wave energy, means, responsive to carrier amplitude variations in the received energy, for automatically varying the steepness of said sloping filter characteristics, said last means comprising a rectifier having an input connection to the input circuit of said frequency responsive circuits, a pair of electronic reactances, each of said reactances being separately associated with

a corresponding one of said frequency responsive circuits thereby to control the tuning thereof, and means responsive to the rectified voltage output of said last rectifier for varying the magnitudes of said electronic reactances.

4. In a system for receiving angular velocity-modulated carrier wave energy, a discriminator comprising a pair of frequency responsive circuits having sloping filter characteristics which are oppositely related, a pair of opposed rectifiers operatively associated with said pair of frequency responsive circuits, means for applying to said frequency responsive circuits said modulated carrier wave energy, a rectifier coupled to the input of said frequency responsive circuits for developing a uni-directional voltage whose magnitude is proportional to amplitude variations in the received carrier, means, responsive to said uni-directional voltage, for automatically varying the steepness of said sloping filter characteristics, and said means responsive to said uni-directional voltage consisting of an electronic impedance device arranged in circuit with said frequency responsive circuits.

5. A method of receiving frequency modulated carrier wave energy which includes converting said energy into corresponding amplitude modulated carrier wave energy, rectifying the converted modulated energy subsequent to said conversion step thereby to provide modulation signal voltage, deriving a control voltage from the frequency modulated carrier wave energy in response to carrier amplitude variations, and controlling the efficiency of solely said conversion step in inverse relation with the magnitude of said control voltage and without affecting said rectification.

6. In a system for receiving angular velocity-modulated carrier wave energy, a discriminator comprising a pair of frequency responsive circuits, a pair of opposed rectifiers operatively associated with said pair of frequency responsive circuits, means for applying to said frequency responsive circuits said modulated carrier wave energy, a rectifier coupled to the input of said frequency responsive circuits for developing a uni-directional voltage whose magnitude is proportional to amplitude variations in the received carriers, means responsive to said uni-directional voltage for automatically varying the steepness of the discriminator characteristic, and said means responsive to said uni-directional voltage consisting of an electronic impedance device arranged in circuit with said frequency responsive circuits.

7. A method of receiving angular velocity-modulated carrier wave energy which includes transforming said energy into corresponding amplitude modulated carrier wave energy, deriving from the transformed modulated energy subsequent to said rectification step modulation signal voltage, deriving a control voltage from the modulated carrier wave energy in response to carrier amplitude variations, and controlling the efficiency of solely said transformation step in inverse relation with the magnitude of said control voltage and without affecting said derivation step.

8. In a system for receiving angular velocity-modulated carrier wave energy, a discriminator comprising a pair of oppositely mistuned frequency responsive circuits having sloping characteristics which are oppositely related, a pair of opposed rectifiers operatively associated with said pair of frequency responsive circuits, means for applying to said frequency responsive circuits said modulated carrier wave energy, and means, re-

sponsive to carrier amplitude variations in the received energy, for automatically varying the steepness of said sloping characteristics.

9. In a system for receiving angular velocity-modulated carrier wave energy, a discriminator comprising an input circuit and a pair of opposed rectifiers, means for applying to said input circuit said modulated carrier wave energy, a rectifier coupled to the input circuit for developing a uni-directional voltage whose magnitude is proportional to amplitude variations in the received carrier, and means, responsive to said uni-directional voltage, for automatically varying the steepness of the S-shaped discriminator characteristic.

10. In a system for receiving angular velocity-modulated carrier wave energy, a discriminator comprising a pair of frequency responsive circuits having sloping filter characteristics which are oppositely related, a pair of opposed rectifiers operatively associated with said pair of frequency responsive circuits, means for applying to said frequency responsive circuits said modulated carrier wave energy, a third rectifier having an input connection to the input circuit of said frequency responsive circuits, a pair of electronic reactances of opposite sign, said reactances being separately associated with a corresponding one of said frequency responsive circuits thereby to control the tuning thereof in opposite senses, and means responsive to the rectified voltage output of said third rectifier for varying the magnitudes of said electronic reactances thereby to control the frequency spacing between the peaks of said pair of circuits.

11. In a system for receiving angular velocity-modulated carrier wave energy, a discriminator comprising a pair of frequency responsive circuits having sloping filter characteristics which are oppositely related, a pair of opposed rectifiers operatively associated with said pair of frequency responsive circuits, means for applying to said frequency responsive circuits said modulated carrier wave energy, a third rectifier having an input connection to the input circuit of said frequency responsive circuits, at least one damping tube associated with said frequency responsive circuits thereby to control the damping thereof, and means, responsive to the rectified voltage output of said third rectifier, for varying the magnitude of the damping characteristics of said damping tube.

12. In a system for receiving frequency modulated carrier wave energy, a frequency discriminator circuit having a pair of sloping filter characteristics which are mutually opposed with respect to a predetermined reference frequency, a pair of opposed rectifiers operatively associated with said discriminator circuit, means for applying to said discriminator circuit said modulated carrier wave energy, and means, responsive to carrier amplitude variations in the received energy, for varying the steepness of said sloping filter characteristics in a like sense to compensate for the amplitude variations.

13. In a system for receiving angular velocity-modulated carrier wave energy, a discriminator comprising a pair of resonant circuits having sloping filter characteristics which overlap at the mean frequency of said modulated wave energy, a pair of opposed rectifiers operatively associated with respective ones of said pair of resonant cir-

cuits, means for applying to said resonant circuits said modulated carrier wave energy, a third rectifier coupled to the input of said resonant circuits for developing a uni-directional voltage whose magnitude is proportional to amplitude variations in the received carrier, and means, responsive to said uni-directional voltage, for automatically varying the damping of said resonant circuits in a sense to reduce the effect of said carrier amplitude variation.

14. In combination, a discriminator comprising a pair of frequency responsive circuits having sloping filter characteristics which are oppositely related relative to a predetermined reference frequency, a pair of opposed rectifiers operatively associated with said pair of frequency responsive circuits, means for applying to said frequency responsive circuits angular velocity-modulated carrier wave energy, means, responsive to carrier amplitude variations in said modulated wave energy, for automatically varying the steepness of said sloping filter characteristics, said last means comprising a rectifier having an input connection to the input circuit of said frequency responsive circuits, a pair of electronic reactances of opposite reactive sign, each of said reactances being separately associated with a corresponding one of said frequency responsive circuits thereby to control the tuning thereof, and means responsive to the rectified voltage output of said last rectifier for varying the magnitudes of said electronic reactances.

15. A method which includes converting frequency modulated carrier wave energy into corresponding amplitude modulated carrier wave energy, rectifying the converted amplitude modulated energy, deriving a control voltage from a portion of the unconverted frequency modulated carrier wave energy in response to carrier amplitude variations occurring in said frequency modulated wave energy, and controlling the efficiency of solely said conversion in inverse relation with the magnitude of said control voltage.

16. In combination, a discriminator comprising a pair of oppositely mistuned frequency responsive circuits having sloping filter characteristics which are mutually opposed relative to the center frequency of said mistuned circuits, a pair of opposed rectifiers operatively associated with said pair of frequency responsive circuits, means for applying to said frequency responsive circuits angular velocity-modulated carrier wave energy, and means, responsive to carrier amplitude variations in the latter energy, for automatically varying the steepness of said sloping filter characteristics.

17. In an angular velocity-modulated carrier wave energy system, a frequency discriminator comprising an input circuit and a pair of opposed rectifiers, said input circuit having a frequency vs. response characteristic which is an inclined line of substantial linearity, means for applying to said input circuit said modulated carrier wave energy, a rectifier coupled to the input circuit for developing a uni-directional voltage whose magnitude is proportional to amplitude variations existing in said angular-velocity modulated carrier, and means, responsive to said uni-directional voltage, for automatically varying the steepness of said inclined characteristic.

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