

May 30, 1944.

H. O. PETERSON

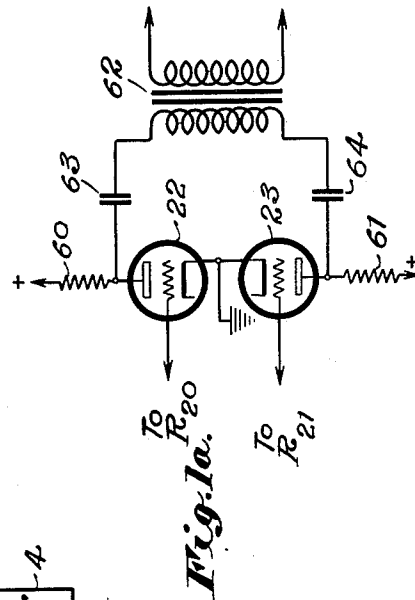
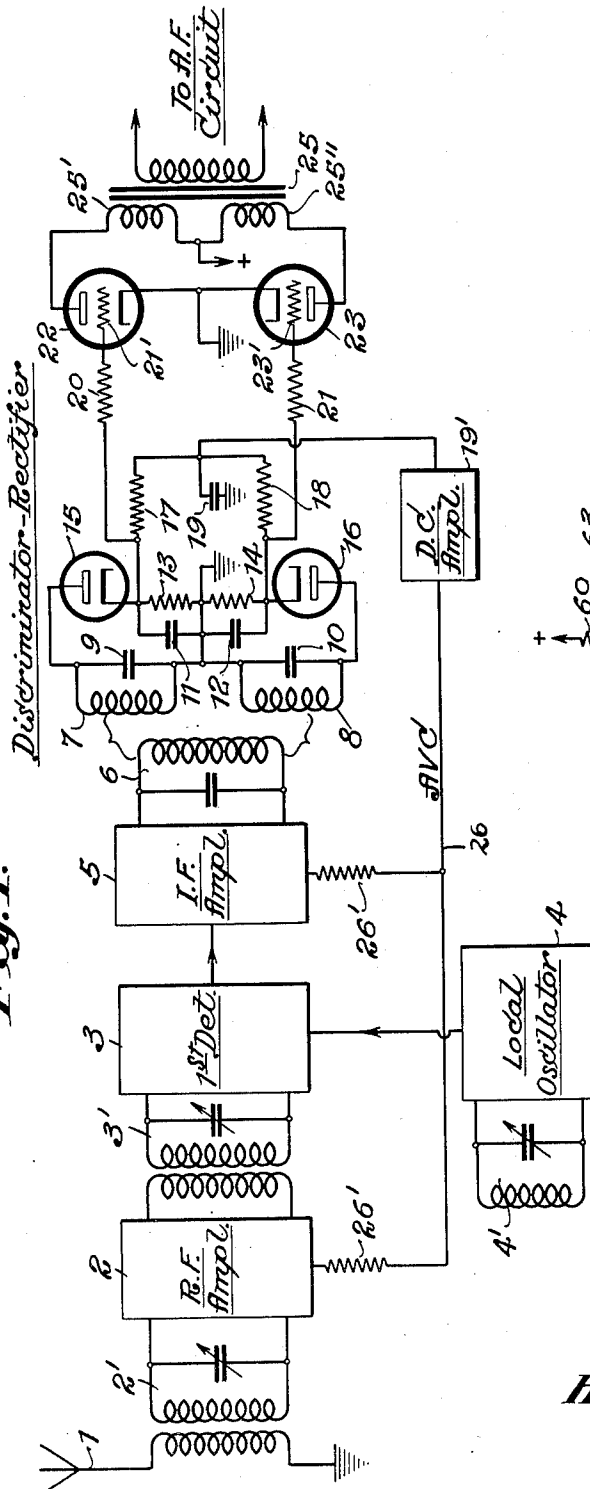
2,349,881

FREQUENCY MODULATION RECEIVER

Filed Nov. 27, 1941

2 Sheets-Sheet 1

Fig. 1.



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Fig. 2.

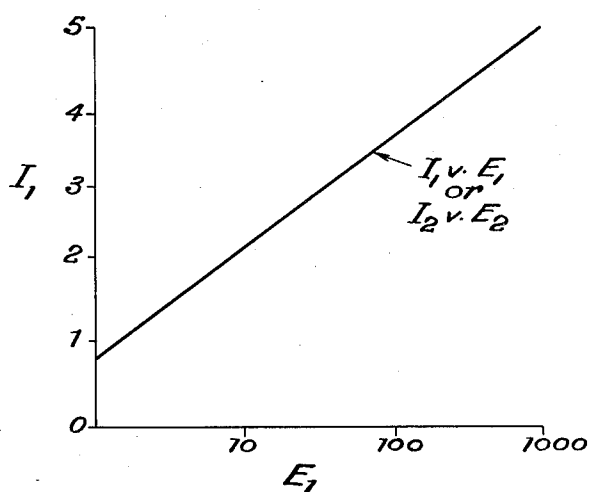
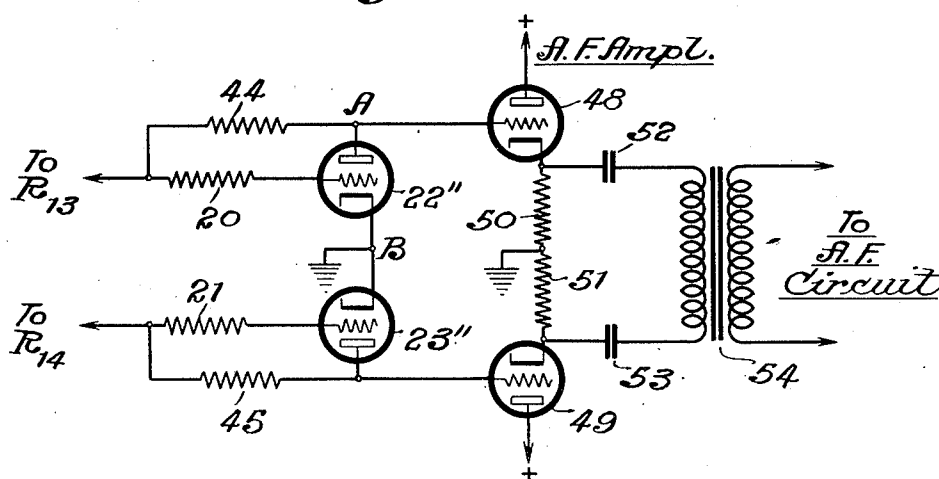


Fig. 3.



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FREQUENCY MODULATION RECEIVER

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12 Claims. (Cl. 250—27)

My present invention relates to receivers of angular velocity-modulated carrier waves, and more particularly to frequency modulation receivers having reduced noise and amplitude modulation output without the use of limiters.

One of the advantages of operating a frequency modulated carrier wave (FM) receiver without a limiter resides in the fact that the high carrier amplification usually required prior to a limiter may be dispensed with. In place of a special stage devoted solely to minimizing amplitude modulation (AM) effects on the carrier, in my invention there is secured a balance in the modulation voltage utilizing network such that the AM effects are balanced out.

It is therefore, an important object of this invention to provide in a receiver of angular velocity-modulated carrier waves a discriminator-rectifier network capable of producing demodulated carrier voltages corresponding to both the frequency and amplitude modulation on the received carrier, and means being employed at the modulation voltage utilization network to balance out the amplitude modulation voltage.

Other objects are to improve generally the simplicity and efficiency of FM receivers, and to provide FM receivers which are not only free of a limiter but are economical to manufacture and assemble.

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:

Figure 1 illustrates in schematic form an FM receiver embodying an audio circuit in which AM balancing is secured.

Figure 1a shows a modification of the audio circuit of Figure 1.

Figure 2 illustrates an operating characteristic of the balancing circuit.

Figure 3 shows a modified form of the audio balancing network.

Referring, now, to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, the networks shown in Figure 1 which appear prior to the discriminator-rectifier are schematically represented. Those skilled in the art are fully

acquainted with the construction of the present type of superheterodyne receiver constructed to receive angular velocity-modulated carrier waves, such as FM waves. At the present time the assigned FM band is in the 42-50 megacycle (mc.) band; and the permissible frequency deviation in each channel is 100 kilocycles (kc.) on either side of the carrier. However, the present invention is not limited to that particular frequency band, nor is it limited to the reception of FM waves of a high carrier frequency deviation ratio.

The antenna 1 may be of any desired type, such as for example a dipole, and it feeds an amplifier 2. The latter is the carrier amplifier having a tunable input circuit 2' which functions to select the desired mid-band carrier frequency. The following first detector 3 is, also, provided with a tunable selector circuit 3'. The local oscillator 4, provided with the tunable tank circuit 4', is utilized to feed oscillations to the converter stage. The latter functions to reduce the center frequency of the received FM waves to the desired operating intermediate frequency (I. F.) value. The operating I. F. value may be chosen from a range of 3 to 8 mc., assuming that reception is in the 42 to 50 mc. band. Amplification at I. F. is performed by the I. F. amplifier 5, whose output circuit 6 is fixedly tuned to the I. F. value.

The discriminator-rectifier is of a well known form, and comprises a pair of diode rectifiers 15 and 16 having oppositely mistuned input circuits. Thus, the coil 7 and shunt condenser 9 provide an input circuit for diode 15. The circuit 7-9 is tuned by a predetermined frequency value to one side of the center frequency, which in this case is the operating I. F. value. The load resistor 13 is shunted by the I. F. by-pass condenser 11, and is arranged in series between the cathode and low potential side of the input circuit 7-9. Similarly, coil 8 and shunt condenser 10 provide the input circuit of diode 16. Circuit 8-10 is fixedly tuned to the opposite side of the I. F. center frequency by a frequency amount which is equal to the amount by which 7-9 is mistuned. The numeral 14 designates the load resistor for diode rectifier 16, I. F. by-pass condenser 12 shunting load resistor 14.

The junction of condensers 11 and 12 is connected to the grounded junction of resistor 13 and 14, as well as to the junction of coils 7 and 8. As stated previously, the discriminator-rectifier network shown in Figure 1 is very well known. In the present case it is found desirable

to tune the discriminator circuit so that its overall characteristic is substantially linear over a range considerably wider than the frequency modulation channel being received. For example, if the frequency deviation is 50 kc., the overall width will be 100 kc. plus modulation frequencies multiplied by 2, or about 130 kc. for a high fidelity program service. In such a case the input circuit 7-9 is tuned to a frequency on the order of 300 kc. different from the frequency to which input circuit 8-10 is tuned.

The rectifiers 15 and 16 function to rectify the I. F. energy developed across each of the respective diode input circuits thereby producing rectified signal voltage across load resistors 13 and 14. As is well known to those skilled in the art, there would be developed across each of load resistors 13 and 14 a rectified carrier voltage when the carrier frequency at circuit 6 instantly deviates from the predetermined I. F. value. The FM wave consists of a wave whose center frequency is deviated in accordance with the amplitude of the modulation frequencies, whereas the rate of deviation corresponds to the modulation frequencies per se. Hence, as the carrier frequency swings to different frequency points beyond the center frequency value, and on either side of the center frequency, there will be developed rectified carrier voltages across each of load resistors 13 and 14 the amplitude of which corresponds to the modulation originally applied to the carrier at the transmitter.

As is well known, the FM wave energy at circuit 6 will acquire amplitude modulation by virtue of noise impulses, fading and even because of the effect of the cascaded resonant circuits prior to the demodulator stage. This amplitude modulation evidences itself as a variation in the amplitude of the frequency modulated carrier. In the prior art a special limiter stage has been utilized prior to the demodulator to minimize such carrier amplitude variation. To operate the limiter stage it has been necessary to increase the level of the modulated carrier waves to a relatively high magnitude. This was necessary because the limiter network functions in the manner of a saturated amplifier.

According to my present invention the limiter stage is eliminated. Hence the gain of the networks prior to the demodulator need not be as high as would be necessary in the case of using a special limiter stage. It is, also, pointed out that even with the use of a special limiter stage a certain amount of amplitude modulation develops in the discriminator-rectifier network per se due to imperfect balancing. According to my present invention, such amplitude modulation effects are balanced out in the modulation voltage utilization network.

The control grid 21' of tube 22 is connected by resistor 20 to the cathode end of load resistor 13. The control grid 23' of tube 23 is connected by resistor 21 to the cathode end of load resistor 14. The cathode ends of resistors 13 and 14 are connected together through a path consisting of resistors 17 and 18 arranged in series. The junction of resistors 17 and 18 is connected to ground through condenser 19. The direct current voltages developed across load resistors 13 and 14 are conducted through resistors 17 and 18 respectively to the time constant condenser 19. The latter connects through lead 26 to the control grid circuits of the controlled amplifier tubes. The lead 26 is designated "A. V. C." to represent the fact that it is the automatic vol-

ume control circuit. The A. V. C. connection is made from the junction of resistors 17 and 18 to each of the signal control grids of the ultra-high frequency amplifier 2 and I. F. amplifier 5.

The A. V. C. connection includes appropriate filter resistors 26' which function to remove pulsating voltage components from the uni-directional control voltage. The function of the A. V. C. circuit is to minimize the effects of fading thereby to reduce one of the factors which creates amplitude modulation effects at the input network of the demodulator. It will be noted that the A. V. C. connection is made to the cathode ends of load resistors 13 and 14. Accordingly, a network 19' which may be a direct current voltage amplifier is inserted in the A. V. C. connection 26 so as to reverse the polarity of the voltage in a sense such that the A. V. C. bias becomes increasingly negative as the carrier amplitude increases. Of course, the I. F. energy from the amplifier 5 could be transmitted through a parallel network into a special rectifier used exclusively to develop the A. V. C. voltage.

The rectified signal voltages appearing across load resistors 13 and 14 are transmitted through the resistors 20 and 21 respectively to the control grids 21' and 23'. The plates of tubes 22 and 23 are connected in push-pull relation. These plates are connected to the opposite ends of the primary winding of the transformer 25. The mid-tap of the primary winding is connected to a point of proper positive potential, while the common cathode lead of the push-pull tubes is connected to ground. The secondary winding of the transformer 25 may be connected to the subsequent audio voltage utilization circuit.

It will be noted that the rectified carrier wave delivers positive voltage to both resistors 20 and 21. When the carrier frequency of the received FM waves deviates instantaneously in one direction, the direct current voltage across resistor 13 will increase and the direct current voltage across resistor 14 will decrease by an equal amount. Thus, the current in the plate circuit of tube 22 will increase while the plate current of tube 23 will decrease. The primary windings of transformer 25 are so connected that a voltage will be induced in the secondary of transformer 25. In other words, for the frequency modulation component of the modulated carrier waves the plate current through one of the primary windings 25' will vary in magnitude in one sense, while the plate current through the opposite primary winding 25'' will vary in magnitude in the opposite sense. As the carrier deviates in frequency in accordance with the modulation, the plate current flowing through the primary windings of transformer 25 will induce a voltage in the secondary winding which is representative of the frequency modulation on the carrier.

However, as far as the amplitude modulation is concerned the positive voltage across resistors 13 and 14 will increase simultaneously, since the amplitude modulation of the carrier affects the input circuits of both diodes in an equal manner. Such positive voltage will cause the plate current of amplifiers 22 and 23 to increase simultaneously. If the circuit characteristics are so chosen that these two currents are increased by an equal amount, no effect will appear in the secondary of transformer 25 due to the amplitude modulation component. In other words, the amplitude modulation component is balanced out by the push-pull arrangement of the plate circuits

of tubes 22 and 23. It will, therefore, be seen that the currents due to the FM component of the modulated carrier waves add to provide a differential voltage which is utilized in subsequent utilization networks, whereas the amplitude modulation component is balanced out.

A preferred arrangement of the output circuit of tubes 22 and 23 would be to feed the plate current thereto through equal resistors 60 and 61, and then connect a simple transformer 62 from plate to plate through coupling condensers 63 and 64. This is shown in Figure 1a. This preferred modification will avoid magnetic saturation effects which are sometimes experienced when direct current is passed through the windings of a transformer.

In order to secure the aforementioned balancing action for the amplitude modulation component of the modulation carrier wave, it is desirable to have a circuit characteristic such that a given percentage modulation of the voltage across resistor 13 will produce the same change of plate current of amplifier 22 as that same percentage of modulation of voltage across resistor 14 produces in the amplifier tube 23. This should be so even though the voltage drop across resistor 13 may not be the same as the voltage drop across resistor 14. For that reason the circuit is arranged so as to have a logarithmic relationship between the voltages E_1 and E_2 and currents I_1 and I_2 , as is depicted in Figure 2.

The voltages E_1 and E_2 are the voltages developed across load resistors 13 and 14 respectively, while the currents I_1 and I_2 are the plate currents of tubes 22 and 23 respectively. With a relationship such as is shown in Figure 2, a given percentage change in E_1 will result in a fixed number of milliamperes change in current I_1 irrespective of the value of E_1 . While it is appreciated that it would be difficult to produce a circuit having a perfect logarithmic characteristic over as large a range of E_1 as indicated in Figure 2, it has been found possible to produce a logarithmic characteristic over a sufficiently wide range to make the performance of the overall circuit satisfactory. Furthermore, the automatic gain control of the receiver will serve to keep the average value of E_1 and E_2 at approximately the desired level. Additionally, by making the characteristic of the discriminator circuit considerably wider than the band width of the FM wave the overall modulation range of voltages E_1 and E_2 is effectively limited.

Resistors 13 and 14 of Figure 1 would normally be equal for sake of simplicity. Possibly in some cases an adjustment of their relative values would be provided to afford a means for balancing up the system to give the desired overall effect. The logarithmic characteristic is brought about by the fact that the grids of tubes 22 and 23, being at positive potential, draw current which has to flow through relatively high resistances 20 and 21. Generally resistors 20 and 21 would be of values considerably higher than resistors 13 and 14, optimum relationships being readily determined for a given choice of tube types by experimentation. Resistors 20 and 21 will reduce the voltage transferred to the grids of tubes 22 and 23, but there will remain usable amounts of the modulation components. Resistors 17 and 18 of Figure 1 would normally be about equal. They would generally be of values high compared to the values of 13 and 14. They cooperate with condenser 19 to provide the appropriate A. V. C. time constant network.

In Figure 3 there is shown an alternative arrangement which has been found to give the desired logarithmic characteristics over a considerable operating range. As in the case of Figure 1, tubes 22'' and 23'' have their control grids connected to the cathode ends of load resistors 13 and 14 respectively through resistors 20 and 21 respectively. The plate of tube 22'' is connected through resistor 44 to the furthest end of resistor 20, while the plate of tube 23'' is connected through resistor 45 to the far end of resistor 21. Two additional tubes 48 and 49 are provided. The cathodes of tubes 48 and 49 are connected through series resistors 50 and 51, the junction of the two resistors being connected to ground. The plates of each of tubes 48 and 49 are connected to sources of direct current for energizing these tubes, and the audio output transformer has its primary winding connected to the cathode ends of each of resistors 50 and 51 through independent coupling condensers 52 and 53. The control grids of tubes 48 and 49 are connected to the plate ends of resistors 44 and 45 respectively.

In the arrangement of Figure 3, the rectified signal current passes through load resistors 13 and 14 as in the case of Figure 1. The A. V. C. circuit is energized by the direct current voltages transmitted through resistors 17 and 18. The direct current voltages are applied through resistors 44 and 20 and through resistors 45 and 21. Tubes 22'' and 23'' operating in conjunction with resistors 20—44 and 21—45 respectively perform the function of establishing a logarithmic relationship between the voltages across each of the diode load resistors and the currents flowing in resistors 50 and 51 of amplifier tubes 48 and 49. Tubes 48 and 49 function as the audio frequency amplifier, the amplified audio voltage being taken off from the cathode load resistors through the coupling condensers 52 and 53. The audio voltage, corresponding to the FM component on the modulated carrier waves, is fed through transformer 54 to the succeeding utilization network which may include an audio power amplifier and loud speaker.

While not being desirous of limiting myself to the following explanation of the theoretical action of the system of Figure 3, it is given to clarify the circuit operation.

If no current flowed in the grid circuits of tubes 22'', 23'', 48 and 49, then the voltage applied to the grids of 48 and 49 would be the same as the voltage across resistors 13 and 14. This voltage would be approximately a linear function of the applied I. F. carrier voltage, which is not the desired logarithmic relationship. Now, if we simply connected a diode across the circuit between points A and B of Figure 3, it would draw current through resistor 44, reducing the voltage applied to the grid of tube 48. This current would increase faster than linearly proportional to the applied voltage. Therefore, the shunting action would increase with increase of applied voltage, which is the effect that tends to arrive at the logarithmic response characteristic shown in Figure 2. This variation of shunting action with increase of applied voltage was found to be more nearly that required to give a good logarithmic characteristic (with the tubes at hand) than if the circuit was set up as shown in Figure 3. It is quite probable that a different arrangement, or at least a different choice of constants, would be used for a different choice of tube types. In Figure 3 only tubes 48 and 49 act

as audio amplifiers in the general sense of the word, while tubes 22' and 23' in cooperation with resistors 20, 21, 44, 45, and in some instances the grids of tubes 48 and 49, serve to produce the desired logarithmic characteristic.

What I claim is:

1. In combination with a pair of rectifiers each having its individual resistive load impedance, means for simultaneously applying to said rectifiers modulated carrier waves whose modulation includes a frequency modulation component and an amplitude modulation component of substantial magnitude whereby rectified voltages are developed across each of said load impedances corresponding to said modulation components, a pair of electron discharge tubes each having input and output electrodes, means connecting the output electrodes of said tubes in polarity opposing relation, means impressing the rectified voltage developed across one of the rectifier load impedances upon the input electrodes of one of said tubes, means impressing the rectified voltage developed across the second rectifier load impedance upon the input electrodes of the second tube, said rectified voltages being applied to the separate input electrodes of said pair of tubes in like polarity with respect to both said modulation components, but in opposing magnitude senses with respect to said frequency modulation component, means for causing the output currents of said tubes to vary by substantially equal amounts in response to the rectified voltages whereby currents in the common output circuit of said pair of tubes corresponding to said amplitude modulation component are effectively balanced out and means coupled solely to the output electrodes of said pair of tubes for deriving therefrom currents corresponding to said frequency modulation component.

2. In combination with a pair of rectifiers each having its individual resistive load impedance, means for simultaneously applying to said rectifiers modulated carrier waves whose modulation includes a frequency modulation component and an amplitude modulation component of substantial magnitude whereby rectified voltages are developed across each of said load impedances corresponding to said modulation components, a pair of electron discharge tubes each having input and output electrodes, means connecting the output electrodes of said tubes in polarity opposing relation, means impressing the rectified voltage developed across one of the rectifier load impedances upon the input electrodes of one of said tubes, means impressing the rectified voltage developed across the second rectifier load impedance upon the input electrodes of the second tube, said rectified voltages being applied to the separate input electrodes of said pair of tubes in like polarity with respect to both said modulation components, but in opposing magnitude senses with respect to said frequency modulation component whereby currents in the common output circuit of said pair of tubes corresponding to said amplitude modulation component are effectively balanced out, and the constants of said load impedances and said pair of tubes being so chosen that a logarithmic relation exists between the rectified voltage developed across each of said load impedances and the output currents of each of said pair of tubes whose input electrodes are fed from the last named load impedance.

3. In combination with a pair of rectifiers each having its individual resistive load impedance, means for simultaneously applying to said rectifiers modulated carrier waves whose modulation includes a frequency modulation component

and an amplitude modulation component of substantial magnitude whereby rectified voltages are developed across each of said load impedances corresponding to said modulation components, a pair of electron discharge tubes each having input and output electrodes, means connecting the output electrodes of said tubes in polarity opposing relation, means impressing the rectified voltage developed across one of the rectifier load impedances upon the input electrodes of one of said tubes, means impressing the rectified voltage developed across the second rectifier load impedance upon the input electrodes of the second tube, said rectified voltages being applied to the separate input electrodes of said pair of tubes in like polarity with respect to both said modulation components, but in opposing magnitude senses with respect to said frequency modulation component whereby currents in the common output circuit of said pair of tubes corresponding to said amplitude modulation component are effectively balanced out over appreciable ranges of frequency and amplitude, said means for applying rectified voltage to said pair of tubes comprising a second pair of electron discharge tubes each having coupling paths between the output and input electrodes thereof so as to provide a logarithmic relation between the rectified voltage developed across each load impedance and the output current produced thereby in each of the respective one of said first pair of tubes.

4. In a receiver of angular velocity-modulated carrier waves, a discriminator-rectifier of the type utilizing a pair of rectifiers connected in opposed relation through a pair of series-related load resistors, a pair of modulation voltage utilization tubes having their output electrodes connected in a common push-pull output circuit, means for establishing the junction of said series load resistors at a relatively invariable potential whereby separate rectified voltages are developed across the load resistors, separate means for applying the rectified voltages to a respective one of said modulation utilization tube input electrodes, said separate means applying said rectified voltages to said input electrodes of each of said modulation tubes in like polarity and magnitude senses for amplitude modulation components of received modulated carrier waves, and in like polarity but opposing magnitude senses, for the angular velocity-modulation component, means for causing the output currents of said tubes to vary by substantially equal amounts in response to said rectified voltages whereby currents flowing in said common push-pull output circuit corresponding to said amplitude modulation component are effectively balanced out thereby eliminating the need for a limiter network per se prior to the discriminator-rectifier, and additional means coupled to solely said push-pull output circuit for deriving therefrom currents corresponding to said angular velocity-modulation component.

5. In combination with a pair of rectifiers each having its individual resistor load, means for simultaneously applying to said rectifiers modulated carrier waves whose modulation includes a timing modulation component and an amplitude modulation component of substantial magnitude whereby rectified voltages are developed

across each of said resistors corresponding to said modulation components, a pair of electron discharge tubes each having input and output electrodes, means connecting the output electrodes of said tubes in polarity opposing relation, resistor means of predetermined value impressing the rectified voltage developed across one of the rectifier load resistors upon the input electrodes of one of said tubes, resistor means of predetermined value impressing the rectified voltage developed across the second rectifier load resistor upon the input electrodes of the second tube, said rectified voltages being applied to the separate input electrodes of said pair of tubes in like polarity with respect to both said modulation components, but in opposing magnitude senses with respect to said timing modulation component whereby currents in the common output circuit of said pair of tubes corresponding to said amplitude modulation component are effectively balanced out without the need for a limiter device prior to the rectifiers, and additional means coupled solely to said common output circuit for deriving therefrom currents corresponding to said timing modulation component.

6. In combination with a pair of rectifiers each having its individual resistive load impedance, means for simultaneously applying to said rectifiers modulated carrier waves whose modulation includes a timing modulation component and an amplitude modulation component whereby rectified voltages are developed across each of said load impedances corresponding to said modulation components, a pair of electron discharge tubes each having input and output electrodes, means connecting the output electrodes of said tubes in polarity opposing relation, electronic means impressing the rectified voltage developed across one of the rectifier load impedances upon the input electrodes of one of said tubes, electronic means impressing the rectified voltage developed across the second rectifier load impedance upon the input electrodes of the second tube, said rectified voltages being applied to the separate input electrodes of said pair of tubes in like polarity with respect to both said modulation components, but in opposing magnitude senses with respect to said timing modulation component, whereby currents in the common output circuit of said pair of tubes corresponding to said amplitude modulation component are effectively balanced out, and the constants of said load impedances and said pair of tubes being so chosen that a logarithmic relation exists between the rectified voltage developed across each of said load impedances and the output currents of each of said pair of tubes whose input electrodes are fed from the last named load impedance.

7. In combination with a pair of rectifiers each having its individual resistive load impedance, means for simultaneously applying to said rectifiers modulated carrier waves whose modulation includes a frequency modulation component and an amplitude modulation component whereby rectified voltages are developed across each of said load impedances corresponding to said modulation components, a pair of electron discharge tubes each having input and output electrodes, means connecting the output electrodes of said tubes in polarity opposing relation, means impressing the rectified voltage developed across one of the rectifier load impedances upon the input electrodes of one of said tubes, means impressing the rectified voltage developed across the second rectifier load impedance upon the input

electrodes of the second tube, said rectified voltages being applied to the separate input electrodes of said pair of tubes in like polarity with respect to both said modulation components, but in opposing magnitude senses with respect to said frequency modulation component, whereby currents in the common output circuit of said pair of tubes corresponding to said amplitude modulation component are effectively balanced out, said means for applying rectified voltage to said pair of tubes comprising a second pair of electron discharge tubes each having resistive coupling paths between the output and input electrodes thereof so as to provide a logarithmic relation between the rectified voltage developed across each load impedance and the output current produced thereby in each of the respective one of said first pair of tubes.

8. In a receiver of angular velocity-modulated carrier waves, a discriminator-rectifier of the type utilizing a pair of rectifiers connected in opposed relation through a pair of load resistors, a pair of modulation amplifier tubes having their output electrodes connected in a common push-pull output circuit, means for establishing the junction of said load resistors at a relatively invariable potential whereby separate rectified voltages are developed across the load resistors, separate means for applying the rectified voltages to a respective one of said modulation amplifier tube input electrodes, said separate means applying said rectified voltages to said input electrodes of each of said modulation amplifier tubes in like polarity and magnitude senses for amplitude modulation components of received modulated carrier waves, and in like polarity but opposing magnitude senses for the angular velocity-modulation component, said separate means causing the amplifier tube output currents to vary by substantially equal amounts in response to said rectified voltages whereby currents flowing in said common push-pull output circuit corresponding to said amplitude modulation component are effectively balanced out thereby eliminating the need for a limiter network per se prior to the discriminator-rectifier, and an output circuit coupled to solely said push-pull output circuit for utilizing currents corresponding to said angular velocity-modulation component.

9. In combination with a pair of opposed diode rectifiers each having its individual resistive load impedance, means for simultaneously applying to said rectifiers modulated carrier waves whose modulation includes a frequency modulation component and an amplitude modulation component whereby rectified voltages are developed across each of said load impedances corresponding to said modulation components, said load impedances being connected in series relation, a pair of electron discharge tubes each having input and output electrodes, said tubes functioning as amplifiers for solely said frequency modulation component, means connecting the output electrodes of said tubes in polarity opposing relation, resistive means of predetermined value impressing the rectified voltage developed across one of the rectifier load impedances upon solely the input electrodes of one of said tubes, resistive means of predetermined value impressing the rectified voltage developed across the second rectifier load impedance upon solely the input electrodes of the second tube, said rectified voltages being applied to the separate input electrodes of said pair of tubes in like polarity with respect to both said modulation components, but in op-

posing magnitude senses with respect to said frequency modulation component whereby currents in the common output circuit of said pair of tubes corresponding to said amplitude modulation component are effectively balanced out, and said means connecting the output electrodes of said tubes being entirely independent of said load impedances.

10. In combination with a pair of rectifiers each having its individual resistive load impedance, means for simultaneously applying to said rectifiers modulated carrier waves whose modulation includes a frequency modulation component and an amplitude modulation component whereby rectified voltages are developed across each of said load impedances corresponding to said modulation components, a pair of amplifier tubes each having input and output electrodes, means connecting the output electrodes of said tubes in polarity opposing relation, said last means being independent of said load impedances, a first resistor impressing the rectified voltage developed across one of the rectifier load impedances upon the input electrodes of one of said tubes, a second resistor impressing the rectified voltage developed across the second rectifier load impedance upon the input electrodes of the second tube, said rectified voltages being applied to the separate input electrodes of said pair of tubes in like polarity with respect to both said modulation components, but in opposing magnitude senses with respect to said frequency modulation component whereby currents in the common output circuit of said pair of tubes corresponding to said amplitude modulation component are effectively balanced out, and the constants of said load impedances and said pair of tubes being so chosen that a logarithmic relation exists between the rectified voltage developed across each of said load impedances and the output currents of each of said pair of tubes whose input electrodes are fed from the last named load impedance.

11. In a receiver of angular velocity-modulated carrier waves, a discriminator-rectifier of the type utilizing a pair of rectifiers connected in opposed relation through a pair of series-related load resistors, a pair of modulation voltage amplifier tubes having their output electrodes connected in a common push-pull output circuit which is independent of the load resistors, means

for establishing the junction of said series load resistors at a relatively invariable potential whereby separate rectified voltages are developed across the load resistors, separate resistors for applying the rectified voltages to a respective one of said modulation tube input electrodes, said separate resistors applying said rectified voltages to said input electrodes of each of said modulation tubes in like polarity and magnitude senses for amplitude modulation components of received modulated carrier waves, and in like polarity but opposing magnitude senses, for the angular velocity-modulation component and causing the amplifier tube output currents to vary by substantially equal amounts in response to said rectified voltages whereby currents flowing in said common push-pull output circuit corresponding to said amplitude modulation component are effectively balanced out.

12. In combination with a frequency modulation detector comprising a pair of diode rectifiers each having its individual resistor load, a signal input circuit for simultaneously applying to said rectifiers modulated carrier waves whose frequency modulation includes an amplitude modulation component whereby rectified voltages are developed across each of said resistors, a pair of modulation amplifier tubes each having input and output electrodes, means independent of the resistor loads connecting the output electrodes of said tubes in polarity opposing relation in a common output circuit, resistor means impressing the rectified voltage developed across one of the rectifier load resistors upon the input electrodes of one of said tubes, resistor means impressing the rectified voltage developed across the second rectifier load resistor upon the input electrodes of the second tube, said rectified voltages being applied to the separate input electrodes of said pair of tubes in like polarity with respect to both said modulation components, but in opposing magnitude senses with respect to said frequency modulation whereby currents in the common output circuit of said pair of tubes corresponding to said amplitude modulation component are effectively balanced out, and a substantial logarithmic relation existing between the rectified voltage across each resistor load and the output current of the amplifier tube connected thereto.

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