

Aug. 28, 1945.

M. G. CROSBY

2,383,847

FREQUENCY MODULATION RECEIVER

Filed March 20, 1942

4 Sheets-Sheet 1

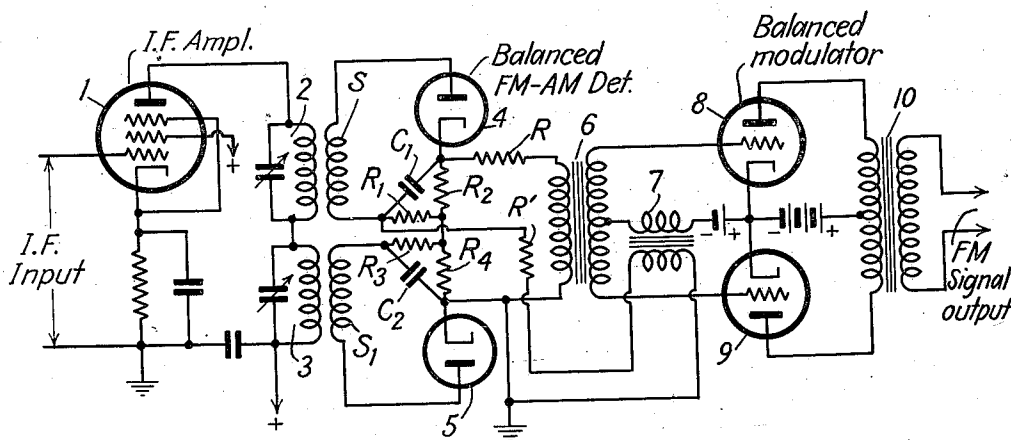
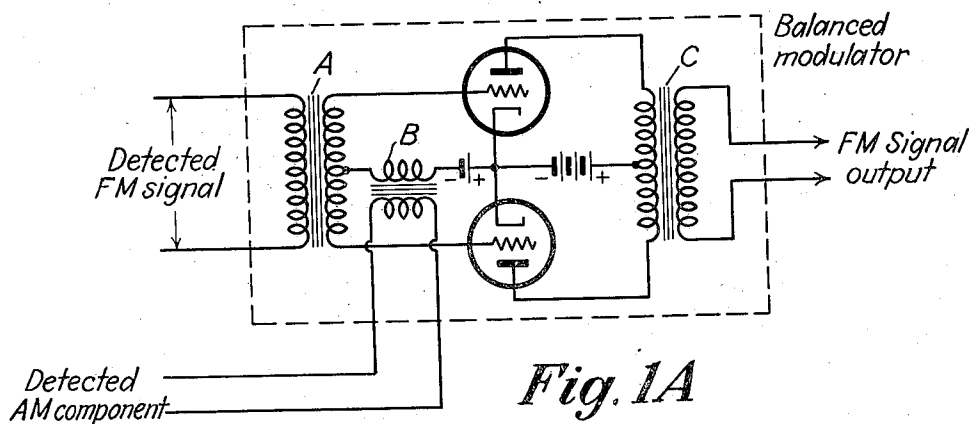
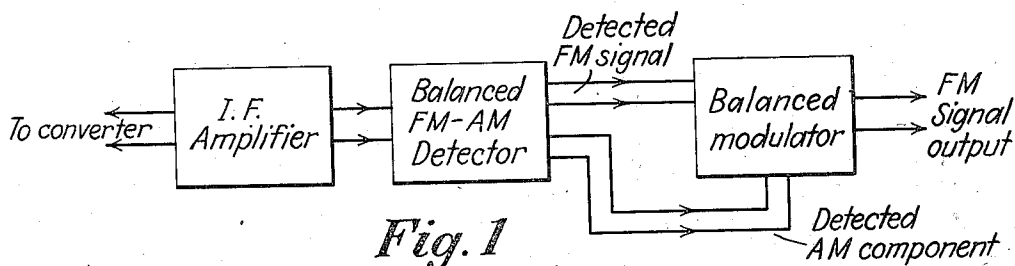


Fig. 2

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4 Sheets-Sheet 2

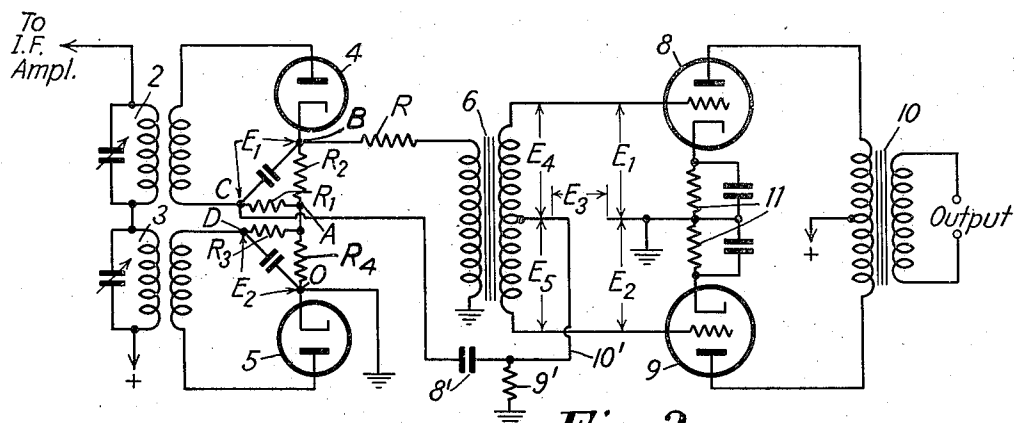


Fig. 3

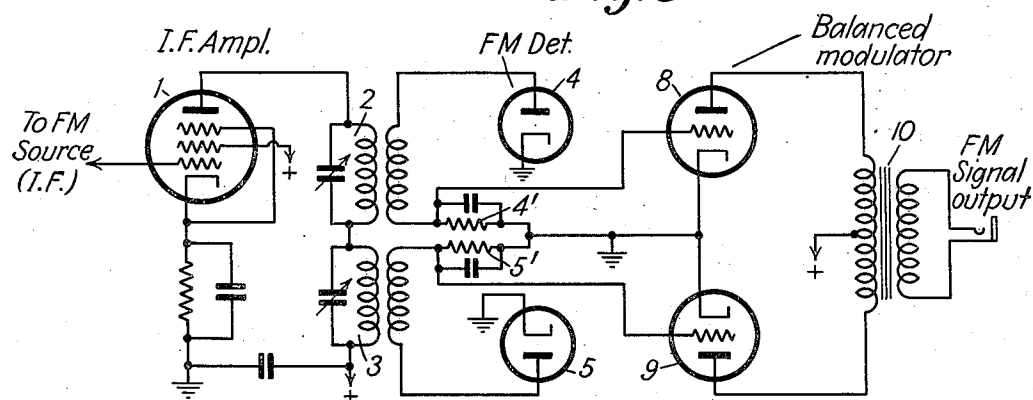


Fig. 4

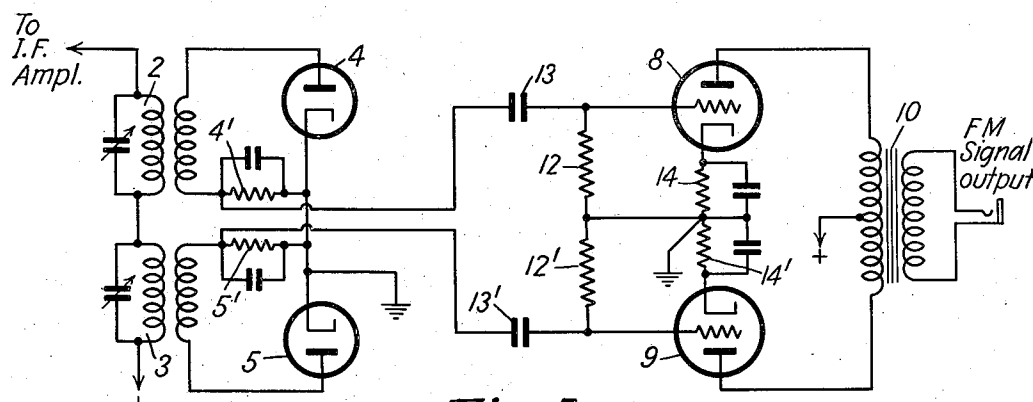


Fig. 5

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FREQUENCY MODULATION RECEIVER

Filed March 20, 1942

4 Sheets-Sheet 3

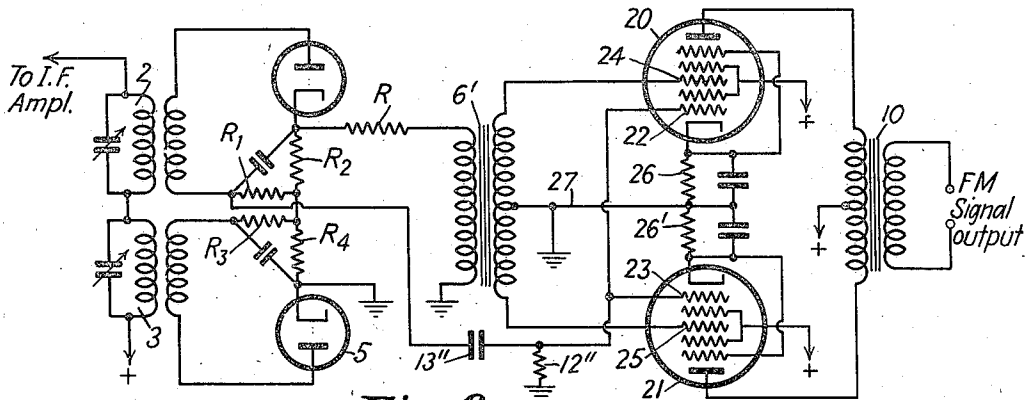


Fig. 6

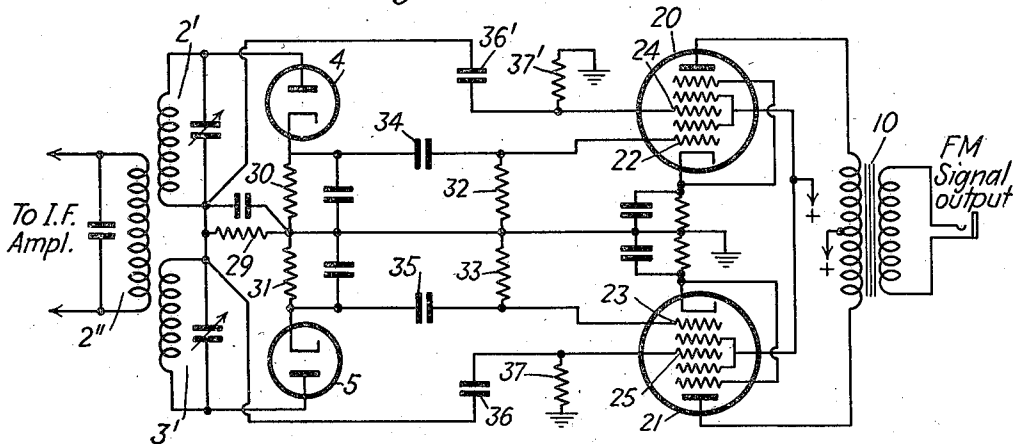


Fig. 7

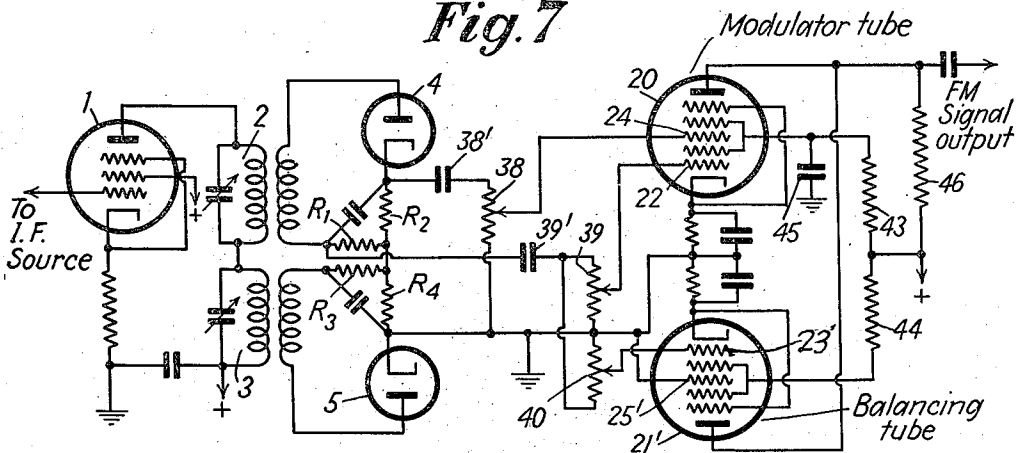


Fig. 8

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FREQUENCY MODULATION RECEIVER

Filed March 20, 1942

4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,383,847

FREQUENCY MODULATION RECEIVER

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Application March 20, 1942, Serial No. 435,467

9 Claims. (Cl. 250—20)

My present invention relates generally to angular velocity-modulated carrier wave receivers, and more particularly to a frequency modulation receiver wherein cancellation of amplitude modulation effects is effected without a limiter and at a point following the balanced detector.

In the past, undesired amplitude modulation effects existing on an angular velocity-modulated carrier wave have been removed by means of a special limiter device, a balanced detector, or by a combination of both devices. By "angular velocity-modulated carrier wave" is meant a phase, or frequency, modulated carrier wave. The expression "timing-modulated" may, also, be used hereinafter generically to designate such types of modulation. The limiter is effective in removing amplitude modulation at all times and even in the presence of frequency modulation, but the conventional balanced detector of frequency modulation signals is only completely balanced for the condition of no-frequency modulation present. Hence, when the balanced detector is depended upon to remove the undesired amplitude modulation the elimination is only complete in the absence of the desired frequency modulation, and becomes progressively poorer as the desired modulation is increased.

In my application Serial No. 416,443, filed October 25, 1941, granted November 28, 1944 as U. S. Patent No. 2,363,649, there has been disclosed the utilization of detected amplitude modulation existing on the angular velocity-modulated carrier wave to modulate the detected modulated carrier wave energy with such polarity that the undesired amplitude modulation is greatly reduced. Hence, if desired, the special limiter stage may be dispensed with, since the elimination of the amplitude modulation by the balanced detector is made more complete. By omitting the limiter the gain of the receiver may be decreased, since the large signal voltages required to saturate the limiter do not have to be provided. Economy of construction and simplification follow as a result of gain reduction prior to the demodulator.

One of the main objects of my present disclosure is to provide an improved type of inverse modulation circuit for eliminating undesired amplitude modulation in frequency modulation reception; by properly adjusting the operational characteristic of the inverse modulator tubes, a more complete inverse modulation may be effected so as more completely to remove the amplitude modulation.

Another important object of my invention is to

provide improved and simplified detectors which differ from the prior art detectors in that undesired amplitude modulation is removed by a compensating modulation instead of by means of a limiter per se; the compensating modulation being applied to the audio output so that amplitude variations which cause a variation of the audio output are compensated for.

Yet another important object of my invention is to provide a frequency modulation detector circuit using a compensating modulating process at a point subsequent to the detector for eliminating amplitude modulation effects, and the modulation characteristic being given a non-linear form thereby to secure a more complete elimination of the said amplitude effects.

Still other objects are to provide improved and efficient detectors of frequency and phase modulated carrier waves which need no limiter stage ahead of them, and which detectors are simple to construct and are reliable in operation.

The novel features which I believe to be characteristic of my invention are set forth with 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 is a schematic representation of the invention,

Fig. 1A shows a simple form of modulator, Fig. 2 illustrates one form of the invention, Fig. 3 is a modification of the system of Fig. 2, Fig. 4 is another modification, Fig. 5 shows still another embodiment,

Fig. 6 shows a modification of the arrangement in Fig. 3 wherein the modulator tubes use special modulating grids,

Fig. 7 illustrates a modification of the embodiment in Fig. 6,

Fig. 8 shows a different form of balanced modulator,

Fig. 9 shows a modification of the system of Fig. 8, and a preferred embodiment,

Fig. 10 graphically illustrates the various modulation characteristics which can be employed.

Referring to the accompanying drawings, wherein like reference characters in the various figures denote similar elements, the basic circuit of the inverse modulation system is shown in Fig.

1. This is the type of system shown in my afore-

said patent. The I. F. (intermediate frequency) channel of the FM (frequency modulation) receiver feeds a balanced frequency modulation detector which is capable of producing the detected frequency modulation and the detected amplitude modulation (AM). The detected frequency modulation signal is then fed to a balanced modulator in which the amplitude of this detected output is modulated (in proper inverse phase) by the detected amplitude modulation signal output. In this way as the undesired amplitude modulation swings the amplitude of the signal, and in turn the amplitude of the detected FM output, upward, the amplitude modulation detected output which is fed to the balanced modulator has such a polarity as to decrease the gain and thereby cancel the upward swing of the detected FM output. The downward swings of modulation are similarly cancelled. This process is more completely considered in my aforesaid patent, and particularly in Figs. 1A and 1B thereof.

Fig. 1A shows the conventional circuit of a balanced modulator as described by Carson. The usual and well known function of this type of modulator is to produce an amplitude modulation with the elimination of the carrier. However, its function in this inverse modulator circuit is to provide a modulation of the detected FM signal, and to balance out the modulating voltage consisting of the detected AM signal. For this arrangement, the detected AM signal is fed cophasally to the modulator grids so as to balance out in the push-pull output transformer C. The operation is somewhat in the manner of a push-pull amplifier, having input and output transformers A and C, which has its gain modulated in accordance with the detected AM signal applied at common grid transformer B. Since the modulating AM signal is fed in push-push, it is balanced out in the output C.

Fig. 2 shows how the balanced modulator of Fig. 1A is connected to a frequency modulation detector of the type employing the split-resistor connection of my application Serial No. 402,784, filed July 17, 1941, granted September 15, 1942, as U. S. Patent No. 2,296,092. In Fig. 2 there is shown only so much of an FM receiver as is essential to a proper understanding of the invention. Let it be assumed that the balanced detectors 4-5 are preceded by the usual pre-demodulator stages of a superheterodyne receiver adapted to operate in the ultra-high frequency band, say 42 to 50 megacycles (mc.), in which FM reception is had. As is well known, the received FM wave is produced by deviating the carrier frequency at the transmitter in accordance with the modulation amplitude, the rate of deviation being a function of the modulation frequencies per se.

A phase modulated wave (PM) may be considered as an FM wave which has been modulated with an input proportional to the modulating frequency. At present, a maximum carrier, or center, frequency (F_c) deviation of 75 kilocycles (kc.) is used for FM broadcasting. In the superheterodyne receiver the FM waves are reduced to an intermediate frequency (I. F.), although the same frequency deviation range is retained. The I. F. value may be chosen from a range of approximately 4 to 20 mc. The FM waves, with center frequency of the I. F. value, are applied to the input electrodes of the I. F. amplifier. This invention is applicable to FM waves having a high or low frequency deviation range.

Diodes 4 and 5 are coupled to the series out-

put circuits 2 and 3 of amplifier 1 by a network which has been disclosed in my aforesaid U. S. Patent No. 2,296,092. Such a detection network provides balanced detected FM voltage and a separate AM voltage. The anode of diode 4 is connected to its cathode through a series path comprising secondary coil S, resistor R_1 and resistor R_2 . The two resistors are shunted by the by-pass condenser C_1 . The anode of diode 5 is connected to its cathode through a series path comprising the secondary coil S_1 , resistor R_3 and resistor R_4 . The by-pass condenser C_2 shunts R_3-R_4 .

Each of tuned circuits 2 and 3 is magnetically coupled to its respective secondary coil S and S_1 . Circuits 2 and 3 are equally and oppositely mistuned relative to the operating I. F. value by any predetermined frequency separation. This provides FM discriminator action. Detected FM voltage is developed across resistors R_2 and R_4 which are arranged in polarity opposition, it being noted that the cathode end of resistor R_4 is at ground potential.

The detected AM voltage may be taken off at the anode end of resistor R_1 . The well known type of discriminator shown herein converts applied FM waves to AM waves with modulation envelopes 180 degrees out of phase. These modulation envelopes are rectified by diodes 4 and 5 which make the rectified outputs available across resistors R_1-R_2 and R_3-R_4 . The manner in which R_1-R_2 and R_3-R_4 are connected together makes the detected FM voltage available across R_2-R_4 . The detected AM voltage is taken from across resistors R_1 and R_4 . It will be noted that the two resistors R_1 and R_4 are connected so that they both have their ends which are towards the diode at high potential, and the combination of the detected AM voltage outputs is in phase. The normal adjustments of the resistors are to make them all equal in order to effect balanced conditions for both AM and FM reception. By-pass condensers will by-pass the I. F. currents fed to the discriminator, but allow the modulation frequencies to pass. There will, then, be derived from the upper end of R_2 the detected FM signal voltage, and the latter has superposed thereon the detected AM signal voltage to be eliminated. The detector AM signal voltage is derived from the anode end of R_1 .

The detected FM signal voltage is applied to the modulator tubes 8 and 9 in push-pull relation. Push-pull transformer 6 has its primary ends connected to the cathode ends of R_2-R_4 . The detected amplitude modulation voltage is applied to tubes 8 and 9 by the common-leg transformer 7. Isolating resistors R and R' prevent the respective transformers 6 and 7 from shunting the diode resistors. Isolating, or blocking, condensers may be substituted for resistors R and R'. The output transformer 10 balances out the amplitude modulation component which is amplified by the modulator tubes, and delivers the FM component which has been modulated so as to remove its undesired amplitude variations.

Fig. 3 shows another arrangement of the type of circuit of Fig. 2. It will be noted that the transformer 7 for feeding the AM component to the common leg of the modulator input circuit has been eliminated, and the common-leg circuit is fed directly from the diode resistors. This is possible since with the slip-resistor type of diode connection, a point is available which gives the sum of the diode outputs for the amplitude

modulation as well as the difference output for frequency modulation. In the circuit of Fig. 3 the tubes 8 and 9 are biased by biasing resistors 11, each bypassed for audio frequency currents. The point C of resistor R_1 is connected by condenser 8' and lead 10' to the midpoint of the secondary of transformer 6. Resistor 9' is connected to ground from lead 10' to provide a direct current return path for the input grids of tubes 8 and 9.

Study of the circuits of Figs. 2 and 3 will reveal that the voltage applied to the modulator grids is in each case the summation of the detected FM and AM components. Such a summation of voltages is present in each diode resistor taken separately. Hence, the circuit of Fig. 4 is the electrical equivalent of the circuits of Fig. 2 and 3. That this equivalence is true may be seen from the following analysis.

Referring to Fig. 3, the voltages fed to the two modulator grids are E_1 and E_2 . E_1 is equal to the summation $E_3 + E_4$ and E_2 is equal to the summation $E_3 - E_5$. The voltage E_3 is equal to the summation of the voltages across OA and AC. The voltages E_4 and E_5 (assuming a one-to-one transfer through transformer 6 and resistance R) are equal to the summation OA plus AB. Thus:

$$E_1 = E_3 + E_4 \text{ and } E_2 = E_3 - E_5, \text{ or } E_3 - E_4 \quad (1)$$

$$E_3 = OA + AC \quad (2)$$

$$E_4 = OA + AB \text{ and since } AB = -AC \quad (3)$$

$$E_4 = OA - AC \quad (4)$$

Adding relations (2) and (4) to give E_1 , we find that E_1 is equal to $2(OA)$. Similar reasoning will show that the voltage E_2 is equal to $2(AB)$. Hence, if the separate diode voltages from each diode are fed directly to the modulator grids, the same voltage distribution will be obtained as is obtained in Fig. 3, or in Fig. 2.

In the circuit of Fig. 4, the bias for the modulator grids of tubes 8 and 9 is obtained by connecting the respective grids directly to the anode side of the diode resistors 4' and 5'. The anode side of each of the diode resistors must be connected to the grids so as to produce a negative bias which increases when the modulated carrier voltage increases. The common junction of resistors 4' and 5', each properly bypassed for I. F., is grounded, and each diode cathode is grounded. With this connection an increase in carrier strength, as would be caused by an upward swing of amplitude modulation, produces an increase in negative bias to the grids of the two modulator tubes 8 and 9. This reduces the gain of the modulator tubes so as to compensate for the increase in FM output caused by the increase in carrier strength. The opposite change in gain occurs when the carrier amplitude decreases. The resultant effect is a smoothing out of the amplitude variations of the FM detected output. The FM output of the detectors appears as a push-pull voltage on the diode resistors, and is combined in push-pull output transformer 10. The amplitude variations appear cophasally, and are therefore balanced out by the push-pull transformer 10.

The circuit of Fig. 4 may be connected so as to prevent the modulator bias from being varied by the carrier variations by using the circuit of Fig. 5. Blocking condensers 13 and 13' and respective grid-return resistors 12 and 12' are inserted so as to eliminate the direct biasing connection to the diode resistors 4' and 5'. This blocks the permanent direct current component, and allows the audio variations to pass. Proper bias is applied

to the modulator grids of tubes 8 and 9 by means of the conventional bypassed cathode resistors 14 and 14'. The anode end of resistor 4' is coupled to the grid of tube 8 by condenser 13, and condenser 13' couples the anode end of resistor 5' to the grid of tube 9.

In the above-described circuits the type of modulation used in the balanced modulator is grid modulation. This type of modulation has various disadvantages with respect to the auxiliary-grid type of modulators about to be described. With grid modulation the operational characteristic must be adjusted non-linear to effect modulation. Consequently, the characteristics of the modulator tubes as amplifiers of the detected FM component are non-linear, and distortion is encountered. The even harmonics of this distortion are cancelled by the balancing action of the push-pull circuits. The distortion may also be reduced by designing the slopes of the input discriminator network 2-3 to be gradual. As a consequence the detected FM component will be small, and will swing the modulator tubes over a small range of their characteristics thereby to produce low distortion. This feature of utilizing low-slope discriminator curves in the detection circuit is a feature of the invention as embodied in Figs. 2 to 5.

In the auxiliary-grid type of modulator circuit of Fig. 6 the functions of amplification of the FM component, and modulation by the AM component, are separated. Hence, each may be adjusted to be best suited to its function. As will be shown later, in order to effect a more complete degree of inverse modulation, the modulation characteristic must be adjusted so as to cause distortion if the same characteristic is used for amplification. Hence, a separation of these two functions prevents introduction of distortion to the FM component.

Fig. 6 is the same as Fig. 3 in all respects, except that the detected amplitude modulation component is fed to a separate modulating grid of each modulator tube. Hence, the tubes 20 and 21 may be adjusted so that the grids 24 and 25, which are fed the FM component by transformer 6', are operated on the linear portion of their characteristics, while the modulator grids 22 and 23 may be adjusted with high bias so as to produce the proper modulation characteristic to be described later.

Specifically, the primary winding of transformer 6' has its ungrounded end connected by resistor R to the cathode end of resistor R₂. The tubes 20 and 21, each of which may be of the pentagrid type 6SA7 for example, have the cathodes thereof connected by biasing resistors 26 and 26'. Each biasing resistor is properly bypassed for audio currents, and the junction of the resistors is connected to the grounded midpoint of the secondary of transformer 6'. Auxiliary grids 22-23 are connected in common, through coupling condenser 13'', to the anode end of R₁. Resistor 12'' provides a grid return path for the grids 22-23. The grids 24 and 25, each located in a positive shielding field, are connected to opposite ends of the secondary of transformer 6'.

Fig. 7 shows another modification of the auxiliary-grid type of modulator. In this circuit, the midpoint of the diode series resistors 30-31 is grounded, and a common resistor 29 is inserted to obtain the detected AM component. Resistors 30 and 31 furnish detected FM signals in push-pull to the inner grids 22 and 23 of the modulators. The detected AM component will, also, be present on these resistors, but since it appears cophasally

transformer 10 will balance it out in the output circuit. The inner grids 22 and 23 are adjusted to be linear so that there is no intended modulation taking place on these grids. The outer grids 24 and 25 are inversely modulated by the detected AM voltage of the common resistor 29 in the diode circuits.

Considering the circuit of Fig. 7 in detail, the I. F.-tuned output circuit 2'' of the prior amplifier is magnetically coupled to each of input circuits 2' and 3'. The circuits 2' and 3' are oppositely and equally mistuned by equal frequency values to provide a proper discriminator action. This has been explained in connection with Fig. 2. Common resistor 29, properly bypassed for I. F. currents, is connected between the junction of 30—31 and the junction of circuits 2'—3'. The cathode end of resistor 30 is connected to grid 22 by coupling condenser 34, grid return resistor 32 connecting the grid to the grounded junction of the usual biasing resistors. Similarly, condenser 35 couples the cathode end of resistor 31 to grid 23, grid return resistor 33 connecting to ground. The outer grid 24 is coupled by condenser 36' to the anode end of common resistor 29. The outer grid 25 is connected by condenser 36 to the anode end of resistor 29. Resistors 37 and 37' act as grid return paths for grids 25 and 24 respectively.

In the type of circuit shown in Fig. 8, the effect of a balanced modulator is obtained by using a single modulator tube and a balancing tube. The balancing tube is arranged so that it causes a cancellation of the undesired detected AM component which is amplified by the modulator. This circuit is a modification of the type of circuit disclosed in my aforesaid U. S. Patent No. 2,363,649. Tube 20 is the modulator tube which is of the two-grid type with the detected FM component fed from potentiometer 38 to the outer grid 24, and the detected AM component fed to the inner grid 22 by means of potentiometer 39. The detected AM component is fed to the inner grid 23' of a balancing tube 21' by means of a potentiometer 40. Tube 21' is shown of the negative transconductance type which is described in my application Serial No. 420,500, filed November 26, 1941. By leaving the screen resistor 44 unbypassed the phase of the amplified voltage is reversed with respect to what it would be if the screen did not contain an impedance. Thus, the detected AM component amplified by the modulator tube has the usual phase reversal effected by an amplifier tube, but the balancing tube 21' does not. Consequently, equal voltages fed to their two inner grids 22 and 23' will balance in the common output circuit consisting of resistor 46.

The plates of tubes 20 and 21' are connected in parallel to the upper end of load resistor 46. The screen grid of tube 20 and that of tube 21' are connected to the positive potential supply by series resistors 43 and 44, the resistor 43 being bypassed by condenser 45 to ground. Potentiometer 38 has its ungrounded end coupled to the cathode end of R₂ by condenser 38'. The adjustable tap of potentiometer 38 is connected to outer grid 24 of modulator tube 20. The ungrounded ends of potentiometers 39 and 40 are connected in common, and coupling condenser 39' connects the common ends to the anode end of R₁. The outer grid 25' of balancing tube 21' is grounded, while the inner grid 23' is connected to the adjustable tap of potentiometer 40. The inner grid 22 of modulator tube 20 is connected to the adjustable tap of potentiometer 39. The usual bypassed

biasing resistors, in the cathode circuits of tubes 20 and 21', provide negative grid bias for the inner and outer grids of each of tubes 20 and 21'.

Fig. 9 shows a further modification of Fig. 8. The same principle of using a modulator and a balancing tube is used, but instead of using a negative transconductance tube with a common output resistor, duplicate tubes 20 and 20' are used in conjunction with a push-pull output transformer 10. The detected AM component is fed directly to the inner grid 22 of the modulator tube 20, and through potentiometer 50 to the inner grid 23'' of the balancing tube 20'. Hence, the detected AM component may be balanced out by varying potentiometer 50.

Considering the circuit of Fig. 9 more specifically, it will be observed to be quite similar to that shown in Fig. 8, except for the differences which have been described. The potentiometer 38 is connected at its upper end, and through coupling condenser 38', to the cathode end of resistor R₂. The lower end of the potentiometer is connected to the grounded end of resistor R₄. The outer grid 24 of modulator tube 20 is connected to the adjustable tap of potentiometer 38. The outer grid 25'' of balancing tube 20' is connected to the grounded junction of the cathode biasing resistors of each of tubes 20 and 20'. The ungrounded end of potentiometer 50 is coupled by condenser 51 to the anode end of resistor R₁. The adjustable tap of potentiometer 50 is connected to the inner grid 23'' of balancing tube 20'.

In my aforesaid U. S. Patent No. 2,363,649, I described the modulator tubes of this inverse modulator system as being linear modulators. The theory developed in that application showed that this type of modulator was capable of reducing the undesired modulation, but that there was a residual amount left which consisted mostly of second harmonic of the undesired component. In the improvement about to be described it will be shown that by adjusting the modulators to have a certain type of nonlinearity, the degree of removal of the undesired AM component will be considerably increased.

The reason that the linear type of modulator cannot remove all of the undesired amplitude modulation may be seen when it is realized that as the amplitude modulation swings the amplitude of the signal down towards zero, the compensating inverse modulation must swing the gain of the modulator towards infinity. Obviously infinite gain is not realizable, so that 100 percent amplitude modulation may not be removed. However, limiters and other similar devices are, also, not capable of removing 100 percent modulation. On the other hand, for degrees of modulation that are less than 100 percent, an approximation of this ideal modulator characteristic with a gain rising towards infinity may be realized. At any rate, an improvement over the linear modulator is possible.

Let it be assumed that an incoming frequency modulated carrier is modulated 50 percent by the undesired amplitude modulation. The output of the balanced detector will then be the desired detected FM signals with a 50 percent amplitude modulation envelope superimposed upon it. Such a wave is shown as Fig. 1A in my aforesaid U. S. Patent No. 2,363,649. Let it, also, be assumed that the amplitude of the detected FM output is equal to unity, so that the amplitude modulation swings it up to a peak amplitude of 1.5 and down to an amplitude of 0.5. In order for the inverse modulator to remove this amplitude envelope, it

must have a gain of 2.0 at the instant when the FM signal drops to its amplitude of 0.5, and it must have a gain of 1/1.5, or 0.666, when the FM signal is amplitude modulated up to 1.5.

It is, also, known that the modulator must have a gain of unity at the instant that the AM component goes through zero. Likewise, at the instant the amplitude is at 1.25, the modulator gain must be 1/1.25, or 0.8, and at the instant it is at 0.75, the gain must be 1.333. In this way the ideal modulation characteristic may be plotted as shown by the solid line curve in Fig. 10. "Modulating voltage" is plotted as the horizontal axis. For 100 percent amplitude modulation, the peaks of this modulating voltage would be plus and minus 1.0. "Gain of modulator" is plotted on the vertical axis. The curve would rise towards infinity at the 100 percent modulation peak of +1.0. It would drop to 0.5 at the peak of -1.0. Only the range for 50 percent modulation is plotted.

The curve for linear modulation is shown by the dashed line. It can be seen that the ideal modulation characteristic departs considerably from the linear characteristic. The dotted line curve shows how the ideal characteristic may be approximated by the use of a type 6SK7 tube biased at -15 volts. The tube would be used as a grid modulator to obtain this characteristic. Grid modulation circuits are shown in Figs. 2, 3, 4, and 5.

The auxiliary-grid modulator circuit of Figs. 6, 7, 8, and 9 may be adjusted to have the desired modulation characteristic of the solid line of Fig. 10. This can be done by adjusting the bias on the grid to which the detected amplitude modulation component is applied. Proper choice of other element voltages, as well as choice of tubes, will also be required. In general, bias which places the operating point near negative cut-off will give the desired curvature to the characteristic.

An interesting, and highly important, effect observed in an actual experimental embodiment of the circuit of Fig. 9 was the removal of distortion caused by the selectivity of the I. F. amplifier preceding the discriminator. Such an amplifier has a round-topped response curve, and of necessity introduces amplitude modulation into the FM wave. Of course, it would be desirable to have the I. F. amplifier provided with a flat top response curve, but this is difficult to secure by the usual and known methods. In the absence of the presently disclosed inverse modulation, or of a special limiter stage, distortion as high as 12% is found introduced by the usual I. F. amplifier response curve. The distortion, when employing the present invention, or a special limiter stage, can be reduced to 2.5%. In other words, the present invention is capable of equaling the performance of a special limiter stage in respect of compensating for AM effects introduced by virtue of the round-topped selectivity of the I. F. amplifier.

It is to be clearly understood that the present invention is not limited to the utilization of the oppositely-mistuned type of discriminator. As shown in Fig. 2 of my U. S. Patent No. 2,296,092, there may be utilized a discriminator of the type disclosed by S. W. Seeley in U. S. Patent 2,121,103, granted June 21, 1938. In this type of discriminator the diodes are coupled in opposition to the secondary circuit of the discriminator, and both primary and secondary circuits are tuned to the same carrier frequency value. In general,

it is only required to secure separate detected FM and AM components from the detector circuit regardless of the construction thereof.

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 frequency modulated carrier wave system, a detector for such waves constructed to produce a first modulation voltage corresponding to the frequency modulation component of the modulated waves and a second voltage corresponding to an amplitude modulation component of said waves, means for inversely modulating said first modulation voltage with said second voltage, said last means comprising a first tube having at least two spaced control elements and an output electrode, means for applying said two voltages separately to respective ones of said two control elements, a second tube having at least two spaced control elements and an output electrode, means applying at least said second voltage to one of the second tube control elements, means for biasing at least said one control element of said second tube sufficiently negative to place the tube operating point near negative cut-off thereby to provide a desired curvature in the tube operating characteristic, and means connecting the output electrodes of both tubes in a sense to balance out said second voltage.

2. In a frequency modulated carrier wave system, a detector for such waves constructed to produce a first modulation voltage corresponding to the frequency modulation component of the modulated waves and a second voltage corresponding to an amplitude modulation component of said waves, means for inversely modulating said first modulation voltage with said second voltage, said last means comprising a first tube having at least two spaced control elements and an output electrode, means for applying said two voltages separately to respective ones of said two control elements, a second tube having at least two spaced control elements and an output electrode, means applying said two voltages separately to respective ones of the second tube control elements, means for biasing close to cut-off the respective control elements of said two tubes to which said second voltage is applied, and means connecting the output electrodes of both tubes in a sense to balance out said second voltage.

3. In combination with a transmission circuit for angular velocity-modulated carrier waves, said circuit having a round-topped selectivity response characteristic thereby introducing an amplitude modulation effect on said waves, means detecting the transmitted waves, means to provide from the detected waves a voltage component corresponding to the angular modulation and a second voltage corresponding to the amplitude modulation, at least two electron discharge devices, one device having at least two spaced input electrodes and an output electrode, the second device having at least one input electrode and an output electrode, means to apply said two voltages separately to said spaced electrodes of said one device, means to apply said second voltage to the input electrode of said second device, means for biasing said second device input electrode suffi-

ciently negative to impart a desired degree of non-linearity to the operating characteristic of the second device, and means for connecting the output electrodes of said two devices in a sense to balance out the effect of said amplitude modulation voltage.

4. In a timing modulated carrier wave system, a detector for such waves constructed to produce a first modulation voltage corresponding to the timing modulation component of the modulated waves and a second voltage corresponding to an amplitude modulation component of said waves, a first tube having at least two spaced control elements, means for applying said two voltages separately to respective ones of said two control elements, a second tube having at least two spaced control elements, each tube having a respective output electrode, means applying at least said second voltage to one of the second tube control elements, means for negatively biasing each control element of said two tubes to which said second voltage is applied close to cut-off, and means connecting the output electrodes of both tubes in a sense to balance out said second voltage.

5. In a frequency modulated carrier wave system, means to derive from such waves a first modulation voltage corresponding to the frequency modulation component of the modulated waves and a second voltage corresponding to an amplitude modulation component of said waves, a first tube having at least two spaced control grids, means for applying said two voltages separately to respective ones of said two control grids, a second tube having at least two spaced control grids, means applying at least said second voltage to one of the second tube control grids, each tube having a respective output electrode, means for applying a relatively high negative bias to said one control grid of the second tube, and means connecting the output electrodes of both tubes in a sense to balance out said second voltage.

6. In combination with a transmission circuit for angular velocity-modulated carrier waves, said circuit having a round-topped selectivity response characteristic thereby introducing an amplitude modulation effect on said waves, means to derive from the waves a voltage component corresponding to the angular modulation and a second voltage corresponding to the amplitude modulation, at least two electron discharge devices, one device having at least two spaced input electrodes and an output electrode, the second device having at least one input electrode and an output electrode, means to apply said two voltages separately to said spaced electrodes of said one device, means to apply said second voltage to the input electrode of said second device, biasing means connected to the input electrode of said second device for applying a high negative bias thereto, and means for connecting the output electrodes of said two devices in a sense to balance out the effect of said amplitude modulation voltage.

7. In combination with a transmission circuit for angular velocity-modulated carrier waves, said circuit having a round-topped selectivity response characteristic thereby introducing an amplitude modulation effect on said waves, means to derive from the waves a voltage component corresponding to the angular modulation and a second voltage corresponding to the amplitude modulation, at least two electron discharge devices, one device having at least two spaced input electrodes and an output electrode, the second device having at least one input electrode and an output electrode, means to apply said two voltages separately to said spaced electrodes of said one device, means to apply said second voltage to the input electrode of said second device, means for biasing the latter input electrode near cut-off, and means for connecting the output electrodes of said two devices in a sense to balance out the effect of said amplitude modulation voltage.

8. In a system for receiving timing modulated carrier waves, a detection circuit having an input network upon which is impressed said waves, means in said circuit for deriving from the detected waves a modulation voltage corresponding to the timing modulation and a second voltage corresponding to an undesired amplitude modulation, a pair of electron discharge tubes, each tube having a pair of control electrodes and an output electrode, means applying the timing modulation voltage to like control electrodes of said tubes, means applying the second voltage to the second pair of like control electrodes, means connecting the output electrodes of said tubes in push-pull relation thereby to cancel out said undesired modulation, means biasing said first like electrodes whereby they are operated at the linear portions of their characteristics, and means biasing the second pair of like control electrodes highly negative.

9. In a frequency modulated carrier wave system, means to derive from such waves a first modulation voltage corresponding to the frequency modulation component of the modulated waves and a second voltage corresponding to an amplitude modulation component of said waves, a first tube having at least two spaced control grids, means for applying said two voltages separately to respective ones of said two control grids, a second tube having at least two spaced control grids, means applying at least said second voltage to one of the second tube control grids, and means to apply a high negative bias to the grid of the first tube and the said one grid of the second tube to which said second voltage is applied, each of said tubes having a respective output electrode, means connecting the output electrodes of both tubes in a sense to balance out said second voltage.

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