

June 10, 1947.

M. G. CROSBY

2,422,083

FREQUENCY MODULATION RECEIVER

Original Filed March 20, 1942 2 Sheets-Sheet 1

FIG. 1.

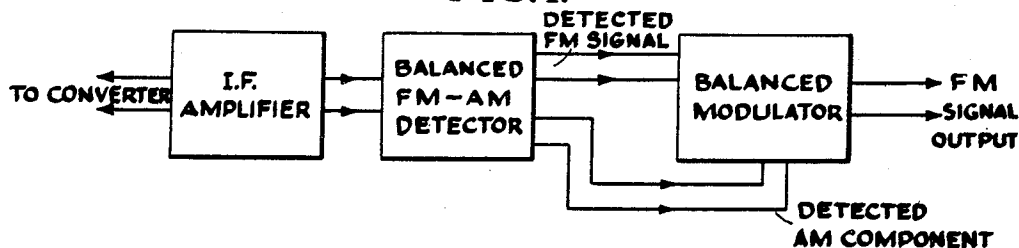


FIG. 1A.

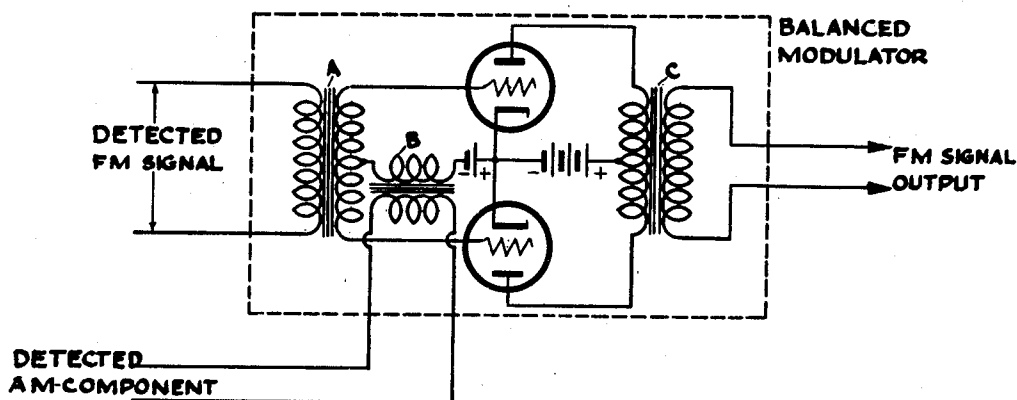
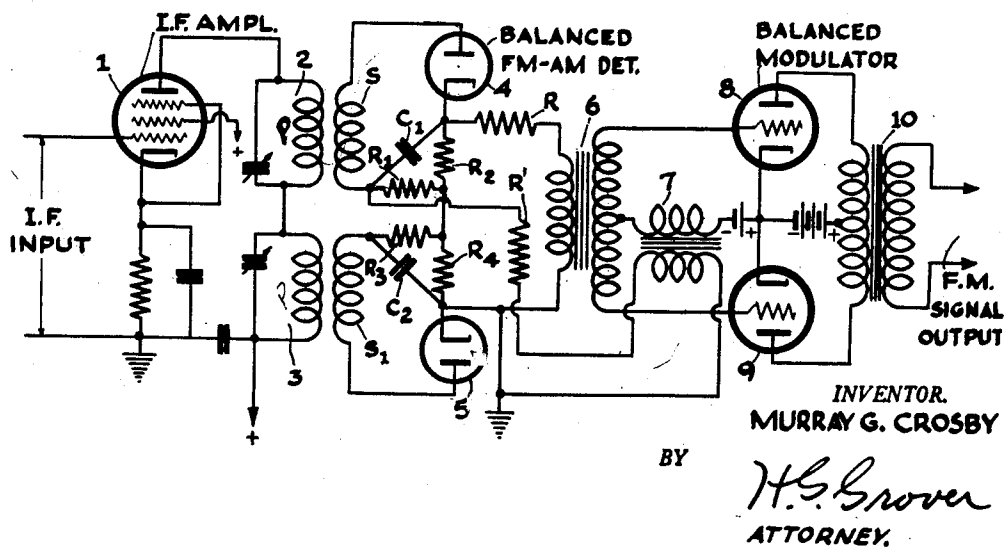


FIG. 2.



June 10, 1947.

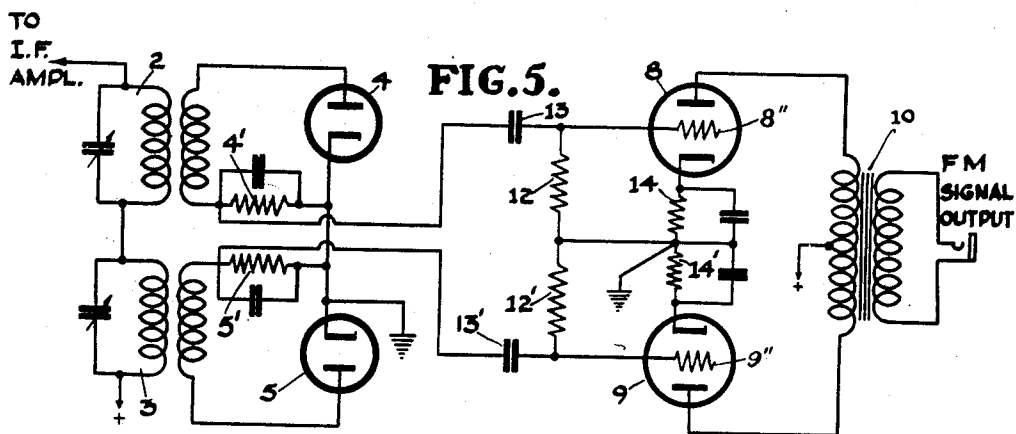
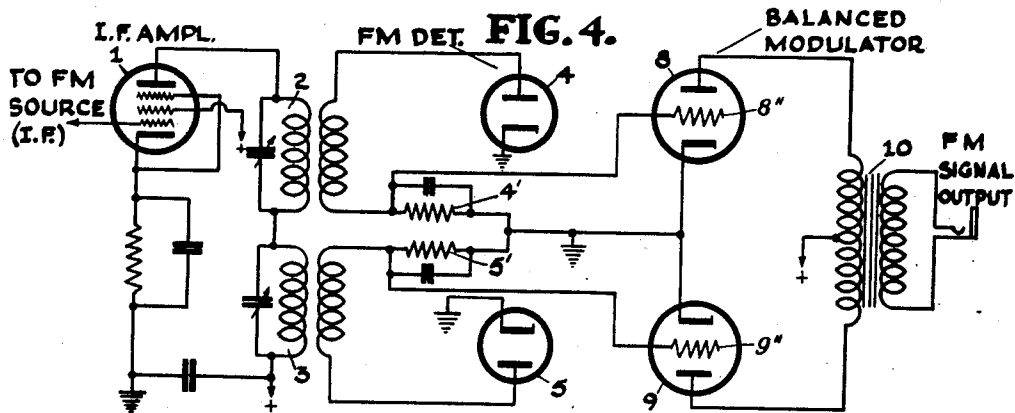
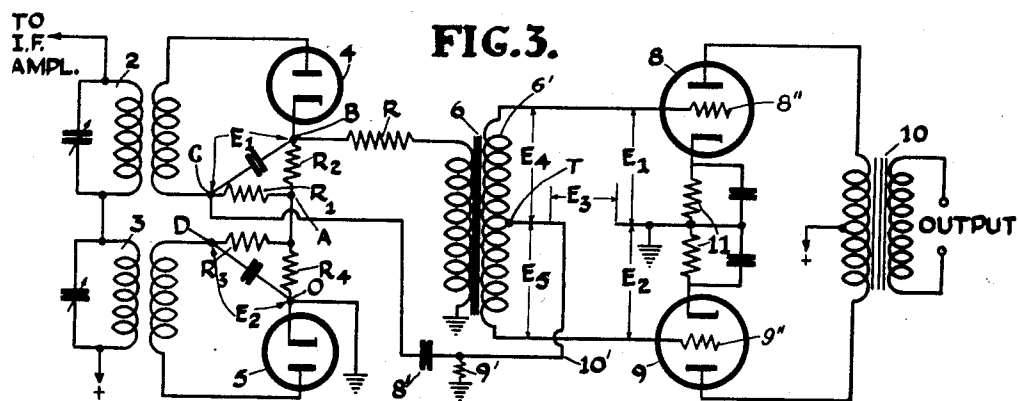
M. G. CROSBY

2,422,083

FREQUENCY MODULATION RECEIVER

Original Filed March 20, 1942

2 Sheets-Sheet 2



INVENTOR.
MURRAY G. CROSBY

BY

H. S. Grover
ATTORNEY

Patented June 10, 1947

2,422,083

UNITED STATES PATENT OFFICE

2,422,083

FREQUENCY MODULATION RECEIVER

Murray G. Crosby, Riverhead, N. Y., assignor to
Radio Corporation of America, a corporation
of Delaware

Original application March 20, 1942, Serial No.
435,467. Divided and this application January
5, 1944, Serial No. 516,999

3 Claims. (Cl. 250-27)

1

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. This application is a division of my parent application Serial No. 435,467, filed March 20, 1942, U. S. Patent No. 2,383,847, dated August 28, 1945.

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, patented 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.

An important object of my invention is to provide improved and simplified detectors which dif-

2

fer 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.

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 drawing 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.

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 aforesaid parent application. 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

3

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 parent patent application, and particularly in Figs. 1A and 1B thereof.

Fig. 1A of this application 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 the present 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 disclosed and claimed in my U. S. Patent No. 2,296,092, granted September 18, 1942. 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 detector 4-5 are preceded by the usual pre-modulator 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 to be understood as applied to the input electrodes of the I. F. amplifier. This invention is applicable to FM waves having a high or low frequency deviation ratio.

Diodes 4 and 5 are coupled to the respective series output circuits 2 and 3 of amplifier 1 by a network which has been disclosed and claimed in my aforesaid patent. 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

4

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 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 bypass 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 detected 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 split-resistor type of diode connection, a point C is available which gives the sum of the diode outputs for the amplitude modulation while point B provides 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 T of the secondary 6' of transformer 6. Resistor 9' is connected to ground from lead 10' to provide a direct current return path for the input grids 8'' and 9'' 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 summa-

5

tion of voltages is present in each diode resistor taken separately. Hence, the circuit of Fig. 4 is the electrical equivalent of the circuits of Figs. 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 8'' and 9'', 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 8'' and 9'' 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 its respective modulator grid 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 8'' of tube 8 by condenser 13, and condenser 13' couples the anode end of resistor 5' to the grid 9'' of tube 9.

It is to be clearly understood that the present invention is not limited to the utilization of the the oppositely-mistuned type of discriminator. As shown in Fig. 2 of my aforesaid patent there may be utilized a discriminator of the type disclosed by S. W. Seeley in U. S. Patent 2,121,103,

6

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 combination with a source of modulated carrier waves wherein the waves have a modulation component of a desired character and a second modulation component of a different character, means for detecting the waves to provide modulation voltage of the desired character and additional modulation voltage of the different character, a pair of electron discharge devices, each device having an input circuit and an output circuit, means to apply said input circuits in one phase relation, means to apply said different modulation voltage to said input circuits in a phase relation which is substantially different from the one phase relation, and said applying means consisting of common connections adapted additionally to apply negative gain control biases to said pair of devices thereby to reduce the gain of the latter in response to carrier wave amplitude increase, and means to connect said output circuits in phase relation to balance out said modulation of different character.

2. 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 modulation of a different character, at least two electron discharge devices, each device having a pair of input electrodes and a pair of output electrodes, means applying the timing modulation voltage to the input electrodes of said devices in push-pull relation, means applying the second voltage to said input electrodes in push-push relation, said applying means consisting of common connections adapted to negatively bias the input electrodes of said devices in a gain-reducing sense in response to carrier wave amplitude increase, and means connecting the output electrodes of said devices in push-pull relation thereby to cancel out said undesired modulation.

3. In a system for receiving timing modulated carrier waves, a pair of rectifiers, a discriminator input circuit connecting said rectifiers in opposed relation, a separate load resistor included in circuit with a respective one of the rectifiers, each load resistor having developed thereacross modulation voltages representative respectively of the timing modulation and an undesired amplitude modulation, each load resistor additionally having developed thereacross a direct current voltage representative of carrier wave amplitude variation, a balanced modulator comprising a pair of tubes, each tube having at least a cathode, control grid and anode, means con-

necting the anodes in a common push-pull output circuit, means connecting the tube cathodes in common to a junction of said load resistors, a separate direct current voltage connection from the respective control grid of each tube to a respective point of each load resistor of like negative polarity relative to said junction potential whereby said timing modulation voltages are applied in opposite phase to said control grids and said undesired modulation voltage in like phase while said direct current voltages are applied in gain-reducing senses to said control grids.

MURRAY G. CROSBY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,282,910	Thompson -----	May 12, 1942
2,351,212	Houghton -----	June 13, 1944
2,349,881	Peterson -----	May 30, 1944