

Nov. 28, 1944.

M. G. CROSBY

2,363,649

FREQUENCY MODULATION RECEIVER

Filed Oct. 25, 1941

4 Sheets-Sheet 1

**Fig. 1A.**

Balanced Detection

$f$  = FM Wave

$B$  = AM envelope due to undesired AM.

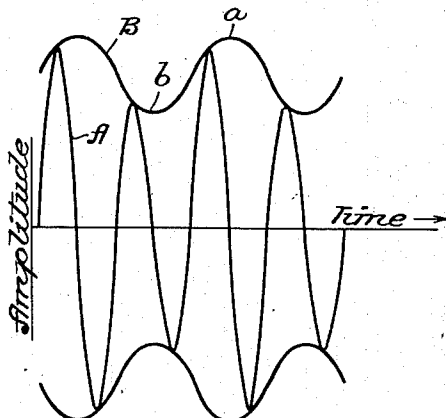


**Fig. 1B.**

Balanced Detection and Inverse Modulation

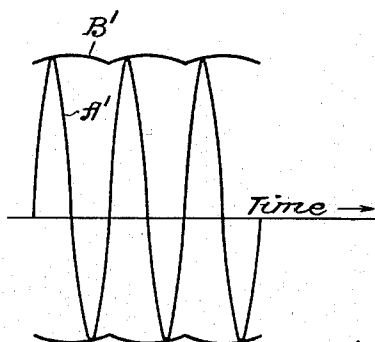
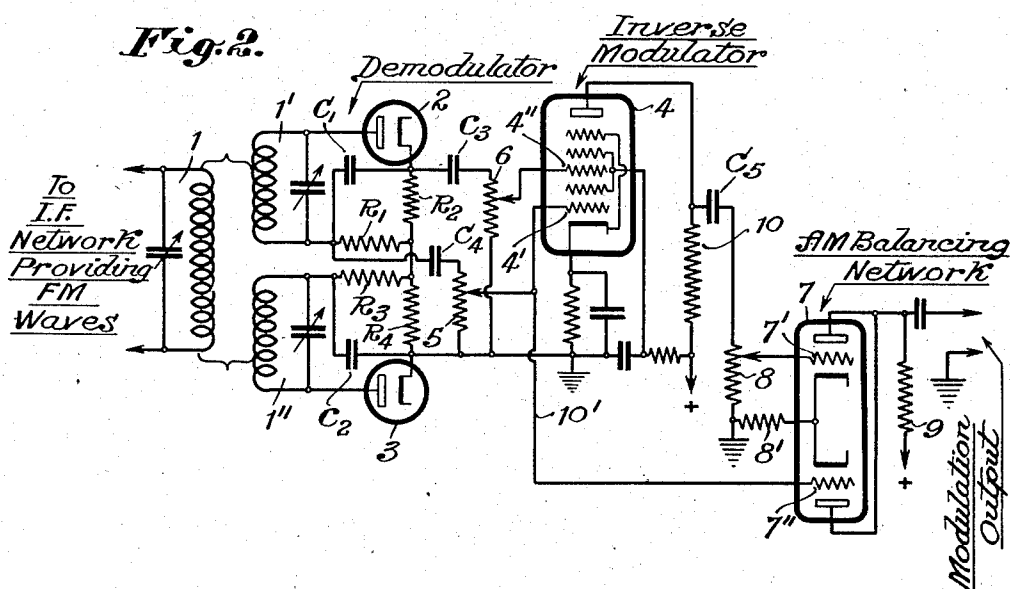


**Fig. 2.**



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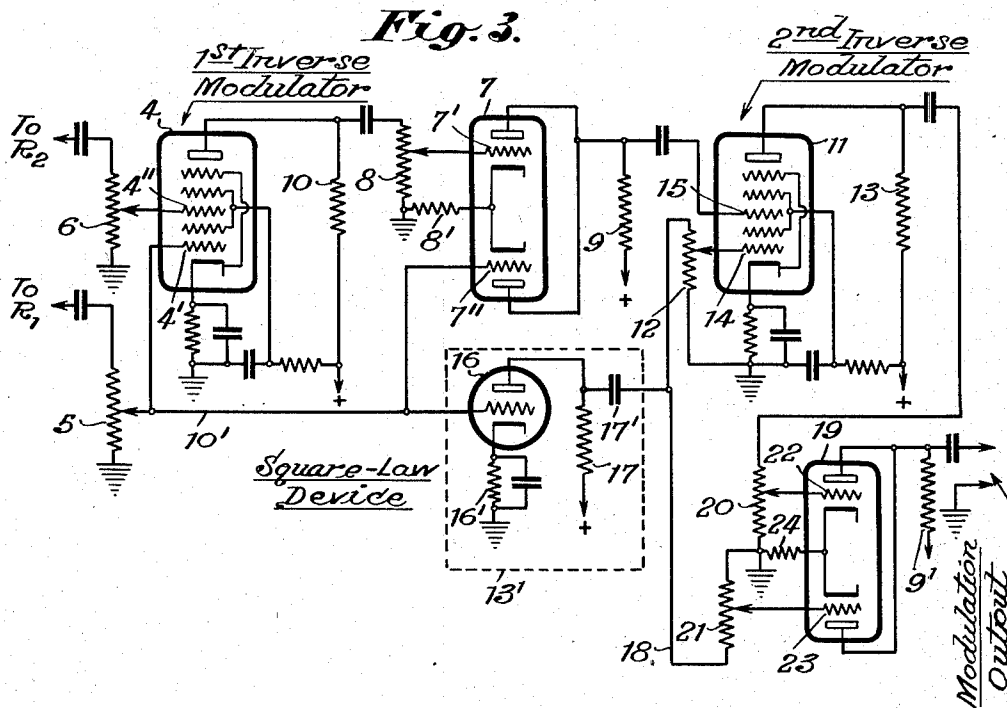
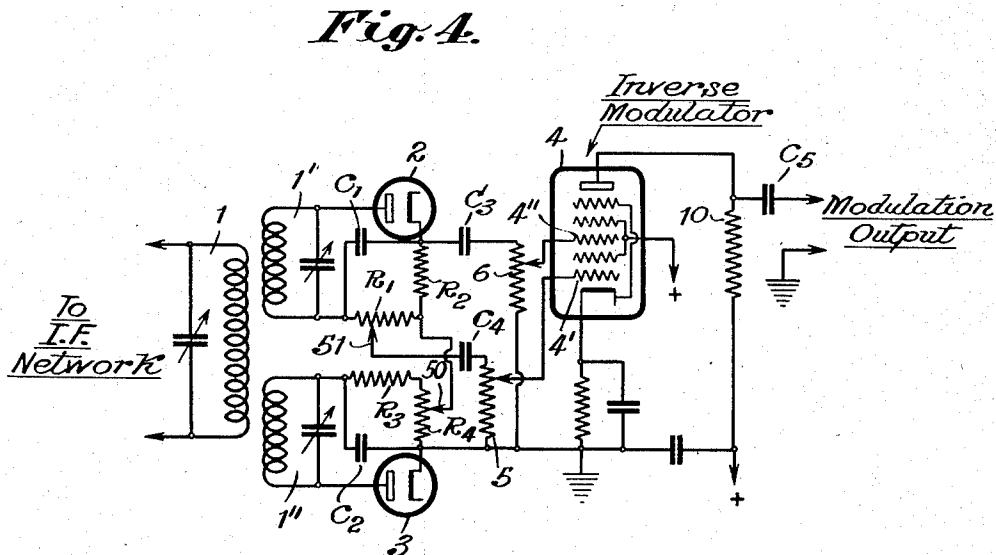
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4 Sheets-Sheet 2



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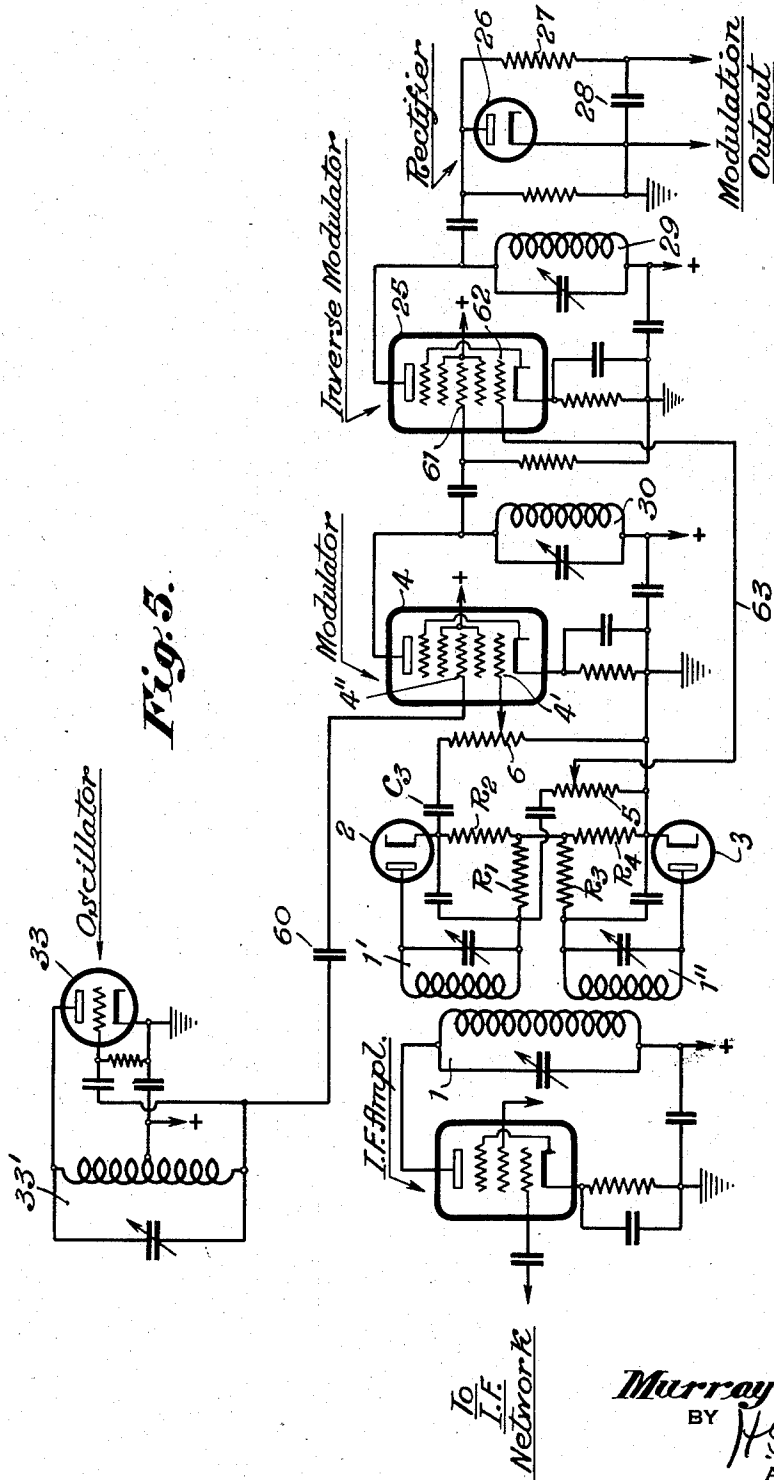
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FREQUENCY MODULATION RECEIVER

Filed Oct. 25, 1941

4 Sheets-Sheet 3



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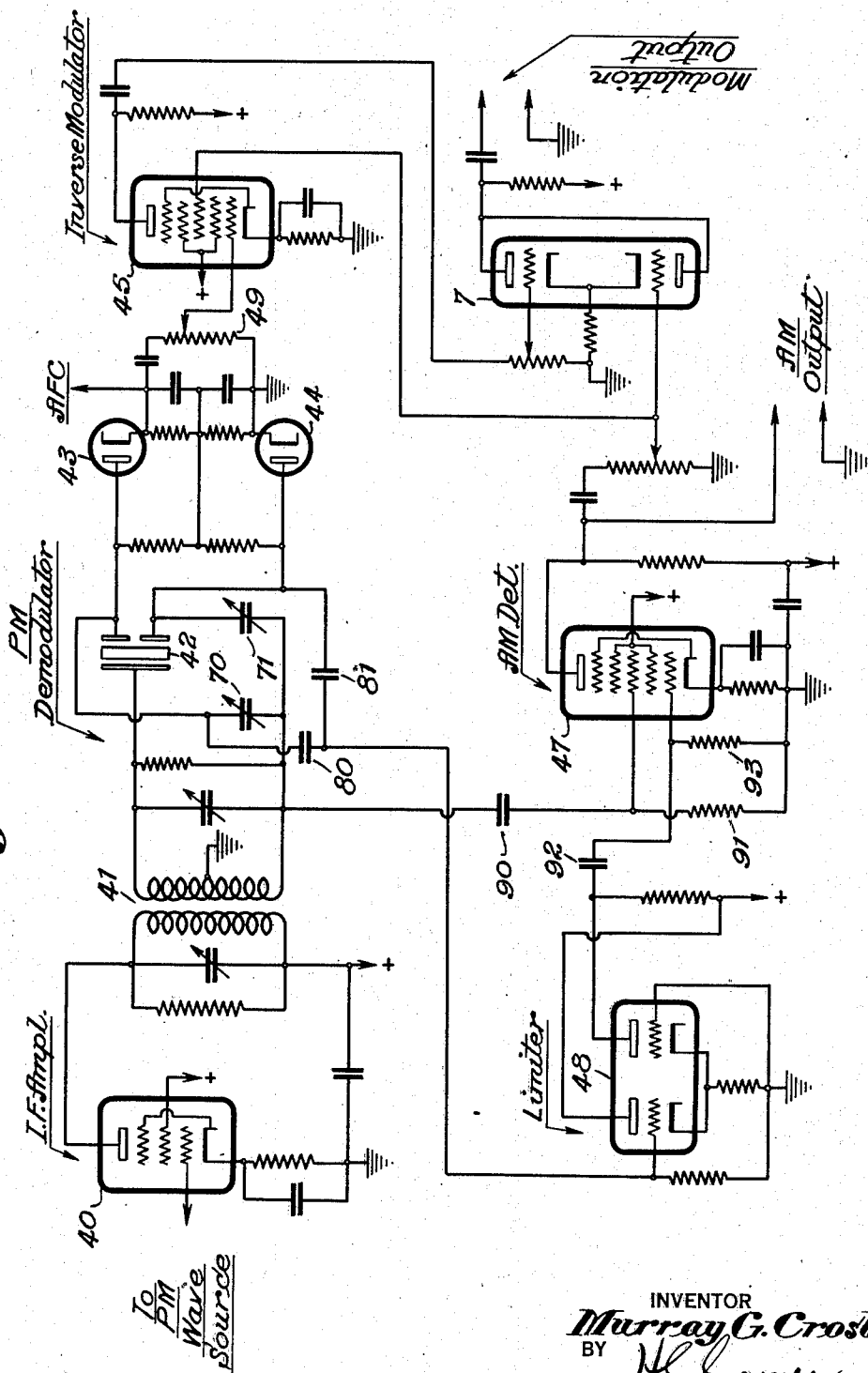
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FREQUENCY MODULATION RECEIVER

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4 Sheets-Sheet 4

Fig. 6.



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## UNITED STATES PATENT OFFICE

2,363,649

## FREQUENCY MODULATION RECEIVER

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Delaware

Application October 25, 1941, Serial No. 416,443

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 limiter, 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 even in the presence of frequency modulation, but the balanced detector 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 modulation, and becomes progressively poorer as the desired modulation is increased.

Basically, my present invention involves 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 limiter 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.

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.

Fig. 1A shows the wave form of the detected output of a frequency modulated carrier wave (FM).

Fig. 1B illustrates the same wave form when using the present invention.

Figs. 2 to 6 inclusive show respectively different embodiments of the invention.

Referring to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, there will first be considered the manner in which my inverse modulation method effects substantial suppression of the amplitude modulation (AM) existing on the carrier. Fig. 1A shows the manner in which the presence of amplitude modulation is manifested in the frequency modulation receiver demodulator output. Wave A is the desired detected frequency modulation output which is assumed to have a higher frequency than the undesired amplitude modulation frequency. The undesired amplitude modulation appears as an amplitude envelope as shown by wave B of Fig. 1A. The undesired amplitude modulation is assumed to produce a 25 percent modulation of the incoming signal.

In the receiver of this invention, an amplitude modulation output is provided having the wave form of the amplitude envelope B. This output is used to modulate the amplitude of wave A in a sense which causes a reduction of amplitude when the wave is at point *a* on the envelope; and an increase in amplitude when the wave is at point *b*. The inverse modulation thus applied, therefore, opposes the undesired amplitude modulation which is present, and tends to cancel it. Fig. 1B shows the result of applying the inverse amplitude modulation to the FM wave of Fig. 1A. The resulting AM envelope B' is of double frequency and greatly reduced amplitude.

Before evaluating the degree of reduction of AM effects possible by the present reverse modulation process, one embodiment of the invention will be explained. 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 2—3 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 FM wave is produced by deviating the carrier frequency 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 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 FM waves, with center frequency of the I. F. value, are to be understood as applied to the resonant

primary circuit 1 tuned to the I. F. value. This invention is applicable to FM waves having a high or low frequency deviation ratio.

Diodes 2 and 3 are coupled to the input circuit 1 by a network which has been disclosed in my application Serial No. 402,784, filed July 17, 1941 patented September 15, 1942, as 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 2 is connected to its cathode through a series path comprising secondary circuit 1', resistor R<sub>1</sub> and resistor R<sub>2</sub>, the two resistors being shunted by the by-pass condenser C<sub>1</sub>. The anode of diode 3 is connected to its cathode through a series path comprising the secondary circuit 1'', resistor R<sub>3</sub> and resistor R<sub>4</sub>, the by-pass condenser C<sub>2</sub> shunting R<sub>3</sub>—R<sub>4</sub>.

Each of circuits 1' and 1'' is magnetically coupled to tuned circuit 1, but circuits 1' and 1'' are equally and oppositely mistuned relative to the I. F. value of circuit 1 by any predetermined frequency separation. As explained in the aforesaid patent, detected FM voltage is developed across resistors R<sub>2</sub> and R<sub>4</sub> which are arranged in polarity opposition, it being noted that the cathode end of resistor R<sub>4</sub> is at ground potential.

The detected AM voltage may be taken off at the anode end of resistor R<sub>1</sub>. This type of discriminator converts applied FM waves to AM waves with modulation envelopes 180 degrees out of phase. These modulation envelopes are detected by diodes 2 and 3 which make the detected outputs available across resistors R<sub>1</sub>—R<sub>2</sub> and R<sub>3</sub>—R<sub>4</sub>. The manner in which R<sub>1</sub>—R<sub>2</sub> and R<sub>3</sub>—R<sub>4</sub> are connected together makes the detected FM voltage available across R<sub>2</sub>—R<sub>4</sub>. The detected AM voltage is taken from across resistors R<sub>1</sub> and R<sub>4</sub>. It will be noted that these two resistors R<sub>1</sub> and R<sub>4</sub> 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<sub>2</sub> the detected FM voltage which, also, has superposed the detected AM effects which are to be eliminated. From the anode end of R<sub>1</sub> there is derived the detected AM voltage per se.

The cathode end of R<sub>2</sub> is connected to ground through a series path comprising condenser C<sub>3</sub> and resistor 6. An adjustable tap is provided to take off from the potentiometer 6 any desired magnitude of voltage thereacross. In the same way the series path C<sub>4</sub>—5 acts as a potentiometer connected between the anode end of R<sub>1</sub> and ground. The tap slidable along resistor 5 provides an adjustment for feeding a desired magnitude of detected AM voltage to tube 4. The latter acts as a modulator tube, and may be of the pentagrid type.

It includes a cathode, a plate and five successive control grids. Grid 4'' is connected to the resistor 6, and has the detected FM voltage applied thereto. Grid 4' is connected to resistor 5, and has the detected AM voltage impressed thereon. The plate of tube 4 is connected to a source of positive voltage through load resistor 10, the screen grids on either side of grid 4''

being connected to the same source through a voltage reducing resistor.

In a modulator of the type shown at tube 4 the carrier is usually fed to the third grid 4'', and appears across a tuned circuit in the plate circuit. The modulation applied to the first grid is normally of a frequency such that the tuned circuit does not pass it. However, in this type of audio modulator a resistor 10 is employed in the plate circuit, and there appears across the resistor in amplified form the detected AM voltage originally applied to grid 4'. There, also, appears across the resistor 10 the inversely modulated detected FM voltage.

In other words, at tube 4 the detected AM voltage is applied to grid 4' in such a phase relation to the detected FM voltage at grid 4'' that the wave form of the resultant inversely modulated, detected FM voltage is as shown in Fig. 1B. The inverse modulation causes a rise in the gain of modulator tube 4 when the undesired AM causes a reduction of the incoming signal amplitude, and a decrease in gain when the signal amplitude is modulated upward.

The amplified AM voltage appearing as such across resistor 10 may be removed from the modulator output by means of a balancing system embodying tube 7. The latter, for example, may be a twin triode tube. The common cathode connection of tube 7 is connected through a resistor 8' to the grounded end of potentiometer resistor 8. The upper end of the latter is connected to the plate end of resistor 10 by a condenser C<sub>5</sub>. The grid 7' of one of the triodes of tube 7 is connected by an adjustable tap along resistor 8, while the grid 7'' of the other triode is connected by lead 10' to the adjustable tap which feeds the detected AM voltage to grid 4'. The plates of tube 7 are connected in parallel to a common source of positive direct current voltage through load resistor 9.

As the detected AM voltage is amplified by the modulator tube 4 its phase is reversed. When combined in-phase, as is done by tube 7, bucking results. Potentiometer 8 may be adjusted so that the undesired detected AM voltage transmitted through the modulator just cancels that fed to the grid 7'' of tube 7. The output voltage appearing across resistor 9 is, then, the pure modulated output which consists of an inverse amplitude modulation applied to the detected FM wave form. That is, the output appearing across resistor 9 has the wave form A'—B' of Fig. 1B.

At first it might be assumed that the undesired amplitude modulation may be completely cancelled by this present modulation process. However, that this is not possible will be realized when the condition of 100% amplitude modulation is considered. It is obvious that when the amplitude modulation modulates the carrier to zero amplitude, it would take an infinite amount of gain to bring it back to normal amplitude.

On the other hand, for the upward peaks of amplitude modulation the condition of 100 percent upward modulation may be compensated for by a reduction in gain of 2:1. Thus, the upward and downward swings of the modulation do not follow a linear law which allows complete cancellation by a simple application of reverse modulation. The degree of reduction possible by this reverse modulation process will now be evaluated in the following analysis:

The incoming signal is frequency modulated,

and also, has an amplitude envelope; hence, it is given by:

$$e = E(1 + m \sin pt) \sin \left( \omega t - \frac{F_d}{F_m} \cos qt \right) \quad (1)$$

in which  $m$  is the amplitude modulation factor,  $p$  is the angular velocity of the amplitude modulating wave,  $\omega$  is the carrier angular velocity,  $F_d$  is the peak frequency deviation,  $F_m$  is the modulation frequency of the applied frequency modulation, and  $q$  is the angular velocity of the applied frequency modulation. This signal is passed through the two sloping filters of the balanced discriminator. The first of these filters causes the frequency modulated wave to have an amplitude envelope which is in accordance with the frequency modulation.

This results in:

$$e = E(1 + m \sin pt)(1 + kF_d \sin qt) \sin \left( \omega t - \frac{F_d}{F_m} \cos qt \right) \quad (2)$$

where  $k$  is a constant which is determined by the steepness of the sloping filters. When the wave given by (2) is detected, the output is proportional to the amplitude envelope. The amplitude envelope consists of the two quantities in parentheses which multiply out to give:

$$e_o = EK(1 + m \sin pt + kF_d \sin qt + kF_d m \sin pt \sin qt) \quad (3)$$

in which  $K$  is the constant of proportionality of the detectors.

The second of the two sloping filters has a slope which is opposite to that of the first so that  $k$  is negative. The output of the second detector is thus:

$$e_o = EK(1 + m \sin pt - kF_d \sin qt - kF_d m \sin pt \sin qt) \quad (4)$$

The output of the balanced frequency modulation detector is a differential combination of (3) and (4), so that it is merely the difference between (3) and (4), or:

$$e_f = 2EK(kF_d \sin qt + kF_d m \sin pt \sin qt) \quad (5)$$

which may be rewritten:

$$e_f = 2EKkF_d(1 + m \sin pt) \sin qt \quad (6)$$

From (6) it can be seen that the detected frequency modulation output is modulated in amplitude by the envelope  $(1 + m \sin pt)$ . It, thus, conforms to the amplitude modulated shape shown in Fig. 1A. It may, also, be seen that the ratio of the desired signal to the undesired amplitude modulation interference is equal to the ratio between the first and second terms in parentheses in (5). This ratio is  $1/m \sin pt$ . The signal-to-interference ratio is thus inversely proportional to the modulation factor of the amplitude modulation, and, therefore, increases as the amplitude modulation factor decreases.

The amplitude modulation output from the balanced detectors is the result of additive combination of the detected outputs. It is, therefore, the sum of (3) and (4), or:

$$e_o = EKm \sin pt \quad (7)$$

in which the direct current term has been neglected. It is apparent that the amplitude modulation output is a true rendition of that output undisturbed by the presence of the frequency modulation which has been balanced out.

In the inverse modulation method of this invention the amplitude modulation output given

by (7) is applied as modulation, with the wave given by (6) as the carrier. Thus, (6) is given the amplitude envelope  $(1 - m \sin pt)$ . The levels are adjusted so that the modulation factor of the resulting modulation is equal to that of the original amplitude modulation on the incoming wave so that  $EK$  is made equal to unity. Multiplying this envelope by (6) to obtain the resulting output, gives:

$$e = 2EKkF_d(1 - m^2 \sin^2 pt) \sin qt \quad (8)$$

From a comparison of Equations (6) and (8), it can be seen that the result of the inverse modulation is to square the term  $m \sin pt$  in the envelope produced by the amplitude modulation. The new signal-to-interference ratio is hence  $1/m^2 \sin^2 pt$ . The ratio is, therefore, increased since the quantity  $m$  is less than unity. Thus, if  $m$  is 0.5, the signal-to-interference ratio would be 2.0 without inverse modulation, but would be 4.0 with inverse modulation. If  $m$  is 0.25, the ratio is increased from 4.0 to 16.

It is apparent that the improvement in signal-to-interference ratio, expressed as a number larger than unity, is equal to the ratio of  $m \sin pt$  to  $m^2 \sin^2 pt$ , or  $1/m \sin pt$ . The improvement is, therefore, inversely proportional to  $m$ , and consequently rises rapidly as  $m$  is made smaller.

This process of inverse modulation may be carried to an unlimited extent depending upon the degree of amplitude modulation reduction desired. Thus, a second stage of modulation may follow this first one. The second stage would be fed by the output of the first one which is the wave given by (8). The amplitude modulation output which is to modulate this second stage should be passed through a square-law device before feeding to the second modulator. This causes the modulating wave to have the amplitude  $m^2 \sin^2 pt$  so that the envelope applied by the second modulator is  $(1 + m^2 \sin^2 pt)$ . The second modulator output is, therefore:

$$e + 2EKkF_d(1 - m^2 \sin^2 pt)(1 + m^2 \sin^2 pt) \sin qt \quad (9)$$

or,

$$e = 2EKkF_d(1 - m^4 \sin^4 pt) \sin qt \quad (10)$$

The resulting envelope is thus proportional to the fourth power of the modulation factor,  $m$ . This increases the improvement factor to  $1/m^3 \sin^3 pt$ . Hence, the improvement for the case of 50 percent modulation is 8:1, for 25 percent modulation 64:1, and so on.

The circuit arrangement of Fig. 3 shows how a second stage of inverse modulation may be added to the circuit shown in Fig. 2. Tube 11 is a second modulator tube which is fed by the output voltage of the first modulator tube 4 as a source of voltage to be modulated. The modulation voltage itself is taken from the detected AM voltage across potentiometer resistor 5, and the AM voltage is fed to the tube 16 of the square-law device which is shown in the dotted box 13'. Tube 16 has a high negative bias developed across the self-bias resistor 16' so that the tube is operated near plate current cut-off, and, therefore, has a square law input-output characteristic. In other words, there is fed to the grid of tube 16 the detected AM voltage which is also applied to the grid 7' of tube 7.

The grid 15 of the second modulator tube 11 has applied to it the modulation voltage developed across resistor 9. The first grid 14 has applied to it the modulating voltage developed

across resistor 17. The latter is arranged in the plate circuit of tube 16. The voltage across resistor 17 is applied to grid 14 through a path which includes the coupling condenser 17' of the potentiometer resistor 12. The lower end of the latter is connected to the grounded end of the grid biasing resistor of tube 11. The potentiometer is provided with an adjustable tap so that any desired magnitude of modulation voltage may be applied to grid 14. The modulation voltage fed to the grid 14 of tube 11 is squared by virtue of the effect of device 13'. The resulting amplitude modulation envelope will have the desired fourth-power characteristic as given by the aforesaid Equation (10). The box 13' may be replaced by any other square-law device. It is only essential that the characteristic of the latter be of a square law, and that voltage of proper polarity is fed to the modulating grid 14. Potentiometer 12 adjusts the degree of modulation of tube 11. The inversely modulated output of tube 11 is developed across resistor 13, and the output voltage may be treated in the same manner as in the case of the voltage developed across resistor 10 in the case of the first modulator tube.

In other words, a tube 19, which is similar to the tube 7, is employed, and the grid 22 of one of its triode sections may have applied to it by means of potentiometer 20 the voltage developed across resistor 13. The common cathode lead of tube 19 is connected to the grounded end of resistor 20 through the resistor 24. The grid 23 of the second triode section of tube 19 is connected to the potentiometer resistor 21 which has applied to it the voltage developed across resistor 17 of the square-law tube 16. The final output voltage is developed across resistor 9' which is arranged in the common plate circuit of tube 19. It will, therefore, be seen that the amplified amplitude modulation component developed across resistor 13 is eliminated in the same manner as was done in the case of the first modulator tube 4.

It is apparent that more stages of modulation may be added, if it is desired to reduce the amplitude modulation component still further. A third stage of inverse modulation will require a modulating voltage raised to the fourth power, and this may be done by applying a second square-law network to the output of device 13'. The resulting improvement factor for this system will be inversely proportional to the seventh power of the modulation factor  $m$ . While multiple stages of modulation may be used to reduce the amplitude modulation to extremely low values, for most purposes the use of a single stage will be sufficient. The reason for this is that for signals which are normally used the percentage of amplitude modulation effected by the noise is relatively low, so that the system is operating in a condition which produces a high degree of improvement by the inverse modulation.

In Fig. 4 there is shown another arrangement for securing a single stage of inverse modulation. However, in this case the balancing tube 7 of Fig. 2 is dispensed with. This is accomplished by employing an adjustable connection between the junction of resistors  $R_1$ — $R_2$  and resistor  $R_4$ . It will be observed that an adjustable tap 50 is provided between the last-named junction point and resistor  $R_4$ . Furthermore, an adjustable tap 51 is provided between the left-hand terminal of condenser  $C_4$  and resistor  $R_4$ . The cir-

cuit arrangement of Fig. 4 is similar to that shown in Fig. 2, with the exception that tube 7 and its associated circuits are omitted. The tap 50 is adjusted along resistor  $R_4$  so that the detected FM voltage contains a component of amplitude modulation which is not balanced out. In other words, the balanced detector is adjusted so that it does not completely balance out the amplitude modulation. This applies a component of amplitude modulation to the third grid 4'' of tube 4 which cancels that amplified by the first grid 4'. In this way the undesired amplification of the amplitude modulation by the first grid is eliminated.

When this off-balance of the detected FM output is effected by adjusted tap 50 there is also produced an off-balance of the detected AM output. This must not take place since it would then allow the detected FM components to appear in the detected AM output. Hence, a pure AM signal would not be available for the inverse modulation process. In order to compensate for this effect, potentiometer tap 51 is adjusted in the same manner as tap 50. This brings the amplitude modulation component back into balance, and thereby eliminates the FM component from the detected AM output.

In the receiving arrangement of Fig. 4 discriminator 1—1'—1'' must be adjusted so that each sloping filter of the discriminator is linear when taken separately. That is, the push-pull action of the discriminator must not be depended upon too strongly for linearity. The reason for this is that the detecting system is adjusted by means of tap 50 to a condition of fixed off-balance of the two detectors. This reduces somewhat the push-pull effect of the detecting system.

It is possible to provide inverse modulation at radio frequency instead of at audio frequency. In Fig. 5 there is shown an arrangement for utilizing a single stage of inverse modulation, but modulation being accomplished at radio frequency so that there is no amplification of the detected AM voltage by the modulator tube. In the arrangement of Fig. 5 the demodulator diodes 2 and 3 are shown coupled to a prior I. F. amplifier by means of the discriminator network shown in Fig. 2. The detected FM voltage is applied to the grid 4' of modulator tube 4 through the potentiometer resistor 6. The AM voltage is taken off from the potentiometer resistor 5. The grid 4'' of modulator tube 4 has applied to it unmodulated radio frequency oscillations from the oscillator 33. The latter includes a tank circuit 33' which couples the plate and grid circuit of the oscillator tube in well known fashion. The tank circuit 33' is adjusted to a predetermined radio frequency value. The radio frequency oscillations are transmitted through coupling condenser 60 to the grid 4''. The oscillator 33 may be the local oscillator of the superheterodyne receiver. If this is done provision must be made in circuits 30 and 29 to pass the full range of tuning of the oscillator. This could be done by damping circuits 30 and 29 with proper shunt resistance.

The tuned circuit 30 is arranged in the plate circuit of tube 4 and is fixedly resonated to the frequency of oscillation of oscillator 33. The voltage developed across circuit 30 is derived from the voltage produced by oscillator 33 with an amplitude envelope consisting of the detected FM wave voltage applied to grid 4'. In other words, at modulator tube 4 the output energy of

oscillator 33 functions as a carrier which is modulated by the detected FM voltage applied to grid 4'.

The FM wave voltage developed across circuit 30 is applied to the grid 61 of the inverse modulator tube 25. The first grid 62 of tube 25 has applied to it the AM voltage developed across resistor 5 and transmitted to grid 62 by lead 63. The plate circuit of inverse modulator 25 includes a tuned circuit 29 which is fixedly resonated to the frequency of oscillator 33. At tube 25 the frequency modulated carrier voltage applied to grid 61 is modulated with an amplitude modulation voltage applied to grid 62 which is in opposite phase to that of the undesired AM voltage existing on the FM wave voltage applied to grid 61.

Hence, it will be seen that the output energy developed across circuit 29 consists of an AM carrier which has an envelope in accordance with the desired FM wave form and with the AM envelope substantially reduced. This resultant FM carrier envelope is then detected by diode rectifier 26 to obtain the desired modulation voltage which was originally applied to the carrier at the transmitter. The resistor 27 and condenser 28 provide a time constant network which functions to eliminate the radio frequency carrier, which was produced at oscillator 33, from the output terminals of rectifier 26.

The method employed in the present invention may be applied to the reception of phase modulated carrier waves (PM). In phase modulation reception the presence of amplitude modulation produces the same kind of modulation of the output as in the case of FM waves. Consequently, the same type of circuits may be used for reducing the undesired component. Referring to Fig. 6 which shows a receiving system for PM waves, the tube 40 is an I. F. amplifier on which are impressed PM waves reduced to the I. F. value. The I. F. transformer 41, whose primary and secondary circuits are each fixedly resonated to the operating I. F. value, is adjusted to be of the band pass type.

The coil of the tuned secondary circuit is mid-tapped to ground for the purpose of providing neutralizing voltage for the piezo-electric crystal 42. The crystal is included in a crystal filter network, and provides a phase modulation discriminator of the over- and under-neutralized type as described in my U. S. Patent 2,204,575. The neutralizing condensers 70, 71 are adjusted so that an over-neutralized characteristic is fed to one of the two diodes 43, 44, while an under-neutralized characteristic is provided with respect to the other of the diodes. This produces a balanced phase modulation detector which delivers AFC (automatic frequency control) voltage at the terminal designated AFC. Detected PM voltage is developed across the potentiometer resistor 49.

Tube 47 is a separate multi-grid detector for amplitude modulation detection. For this detection, filtered carrier is obtained by combining the over- and under-neutralized outputs by means of condensers 80 and 81. This combination produces a neutralized filter output which is fed to the grid of limiter tube 48; the construction of the latter is disclosed in application Serial No. 275,151, filed May 23, 1939. The output of the limiter tube is fed to one of the grids of detector tube 47, while the other grid is fed by the unfiltered signal energy from the secondary of transformer 41. This combination of filtered

and unfiltered signal energy is adjusted for amplitude modulation detection by means of phase shifters 90-91 or 92-93.

The proper phase relation for amplitude modulation detection is either zero or 180 degrees. The detected AM voltage may be taken from the output circuit of detector tube 47. It is, also, fed to the third grid of modulator tube 45 so that it amplitude modulates the detected PM voltage which is fed to the first grid by potentiometer 49. In other words, the tube 45 functions as the inverse modulator tube in this case. The modulation occurring at tube 45 is adjusted to have the right polarity to oppose the undesired AM envelope which exists on the detected PM voltage envelope. The polarity may be adjusted by reversing the phase of either the carrier or unfiltered signals fed to the grids of detector tube 47. The tube 7 operates, as disclosed in Fig. 2 for example, to balance out the amplification of the detected AM component in the output circuit of the inverse modulator tube 45.

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 pair of rectifiers, a source of timing modulated carrier waves subject to amplitude modulation of the carrier waves, means for deriving from the waves a pair of radio frequency voltages whose relative amplitudes are equal at the mean frequency of the modulated carrier waves and vary relatively in accordance with the timing modulation of the carrier waves, means separately applying each radio frequency voltage to a respective one of said rectifiers, means for deriving from said rectifiers in opposition a modulation voltage comprising a component corresponding to said timing modulation and a component corresponding to said amplitude modulation, means for deriving from said rectifiers in aiding phase a modulation voltage corresponding essentially to said amplitude modulation, and means for combining said two modulation voltages in such relation that said amplitude modulation component of the first modulation voltage is in opposition to the second modulation voltage thereby to provide a resultant timing modulation voltage with amplitude modulation component substantially reduced.

2. In a receiver of timing-modulated carrier waves, a single means for detecting the waves to provide a first modulation voltage corresponding to the timing-modulation and undesired amplitude modulation on the carrier waves, said single means providing a second modulation voltage corresponding to said undesired amplitude modulation, means for utilizing the first modulation voltage, and additional means subsequent to said detecting means for substantially reducing the effects of undesired amplitude modulation which may exist on said waves applied to said single detecting means, said additional means comprising modulator means for combining said first modulation voltage from said detecting means with said second modulation voltage in such a sense to produce said reduction, and an auxiliary device for further combining said second modulation voltage with the resultant

of said last combined modulation voltages to balance out any residual amplitude modulation which may exist on said resultant.

3. In a receiver of timing-modulated carrier waves, means for detecting the waves to provide modulation voltage corresponding to the timing-modulation on the carrier waves, means for utilizing the modulation voltage, and additional means subsequent to said detecting means for substantially reducing the effects of undesired amplitude modulation which may exist on said waves applied to said detecting means, said additional means comprising means for deriving a second modulation voltage from said waves which corresponds to said undesired amplitude modulation, and means for combining said first modulation voltage from said detecting means with said second modulation voltage in such a sense as to produce said reduction, a square-law device, means to apply said second modulation voltage to said square-law device, means to combine the resultant output of said combining means with the output voltage of said square-law device in a sense to still further reduce said undesired amplitude modulation.

4. In a frequency modulated carrier wave system, a common detector for such waves consisting of a pair of rectifier networks connected in opposition to produce a first modulation voltage corresponding to both the frequency modulation component and an amplitude modulation component of the modulated waves and connected in aiding phase to produce a second modulation voltage corresponding solely to the amplitude modulation component of said waves, and means for inversely modulating said first modulation voltage with said second voltage thereby to cancel out modulation effects due to the said amplitude modulation component.

5. In a frequency modulated carrier wave system, a common detector for such waves consisting of a pair of rectifier networks connected in opposition to produce a first modulation voltage corresponding to the frequency modulation component of the modulated waves and connected in aiding phase to produce a second voltage corresponding to an amplitude modulation component of said waves, and means for inversely modulating said first modulation voltage with said second voltage to cancel out any amplitude modulation effects on the carrier, said last means comprising a tube having at least two spaced control elements, and means for applying said two voltages separately to respective ones of said two control elements.

6. A method of reducing undesired amplitude modulation existing on frequency modulated carrier waves which includes deriving a first voltage from the waves corresponding to the frequency modulation, modulating a high frequency carrier of constant amplitude with said first voltage to produce a modulated carrier whose amplitude is varied in accordance with the first voltage, deriving a second voltage from the said

waves corresponding to said undesired amplitude modulation, inversely modulating the modulated carrier with said second voltage, and rectifying the inversely modulated carrier.

7. In a receiver of frequency modulated carrier wave energy, a demodulator circuit constructed and arranged to provide a first modulation voltage consisting of a component corresponding to the frequency modulation on the carrier wave and a component corresponding to undesired amplitude modulation, means to provide a second modulation voltage corresponding solely to said undesired amplitude modulation, means for combining said two modulation voltages in relative phases substantially to reduce any undesired amplitude modulation component which may exist in said first modulation voltage, and at least one auxiliary means for combining the resultant output of said combining means with a predetermined portion of the second modulation voltage thereby further to reduce said undesired amplitude modulation component.

8. In a receiver of frequency modulated carrier wave energy, a demodulator circuit constructed and arranged to provide a first modulation voltage composed of one component corresponding to the frequency modulation on the carrier wave and a second component corresponding to undesired amplitude modulation, means to provide a second modulation voltage corresponding solely to said undesired amplitude modulation, means for combining said two modulation voltages in relative phases substantially to reduce any undesired amplitude modulation component which may exist in said first modulation voltage, and at least one auxiliary means for combining the resultant output of said combining means with a predetermined portion of the second modulation voltage thereby further to reduce said undesired amplitude component, an inverse modulator following said last combining means, means applying the output of the last combining means to said modulator, and a square law device coupling an input electrode of the modulator to said second modulation voltage means.

9. In combination with a first source of voltage representative of a desired form of modulation and an undesired different form of modulation, means to provide a second voltage representative of solely said undesired form of modulation, an inverse modulator coupled to said first source and said means and arranged to provide a resultant output voltage wherein said desired form of modulation predominates over said undesired form of modulation, and a balancing network having at least two input connections, one of said connections being made to said modulator, the second connection being made to said means whereby the balancing network output voltage is representative of substantially said desired form of modulation.

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