

June 13, 1944.

M. G. CROSBY

2,351,191

HETERODYNE ELIMINATION CIRCUIT

Filed Nov. 25, 1941

2 Sheets-Sheet 1

Fig. 1.

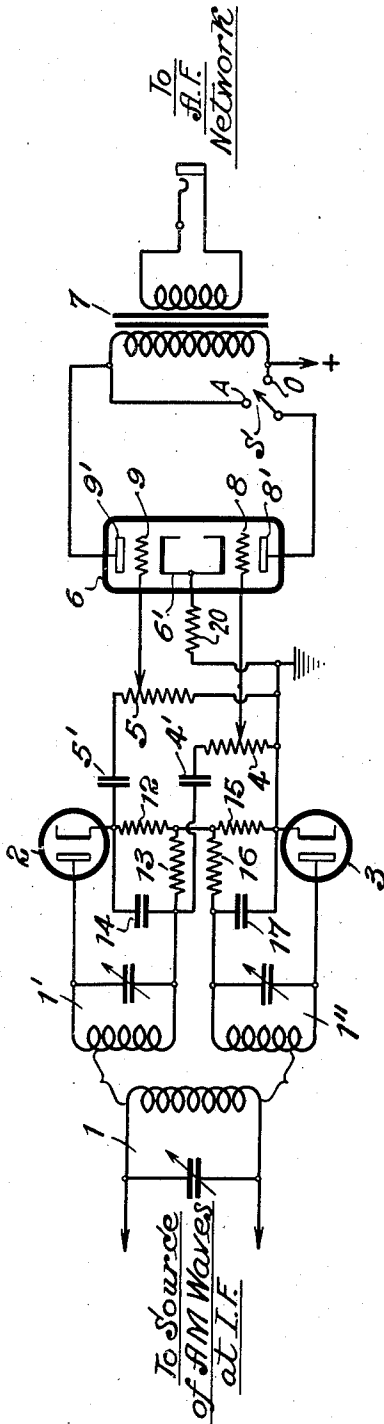


Fig. 1B.

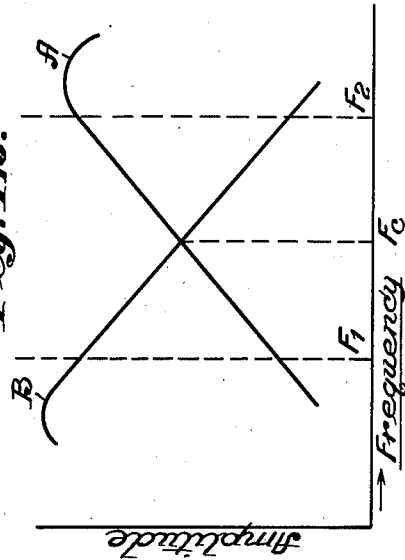
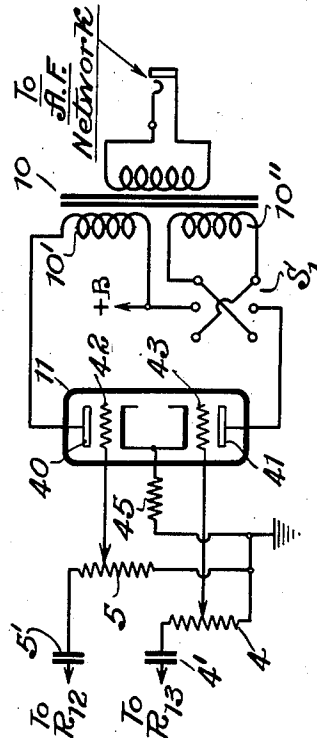


Fig. 1A.



INVENTOR  
**Murray G. Crosby**  
 BY *H. S. Snover*  
 ATTORNEY

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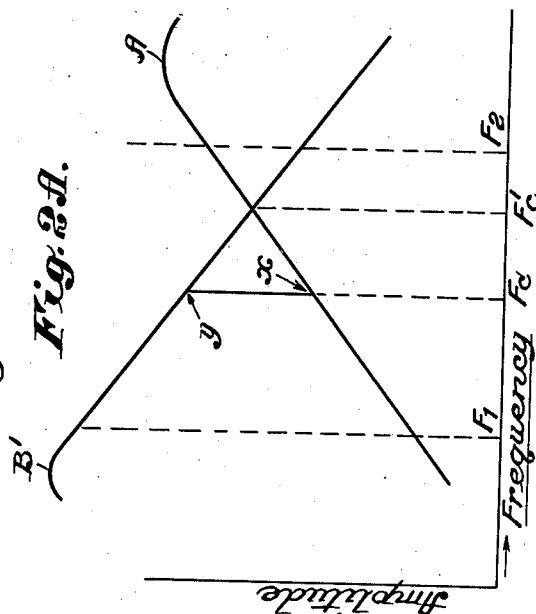
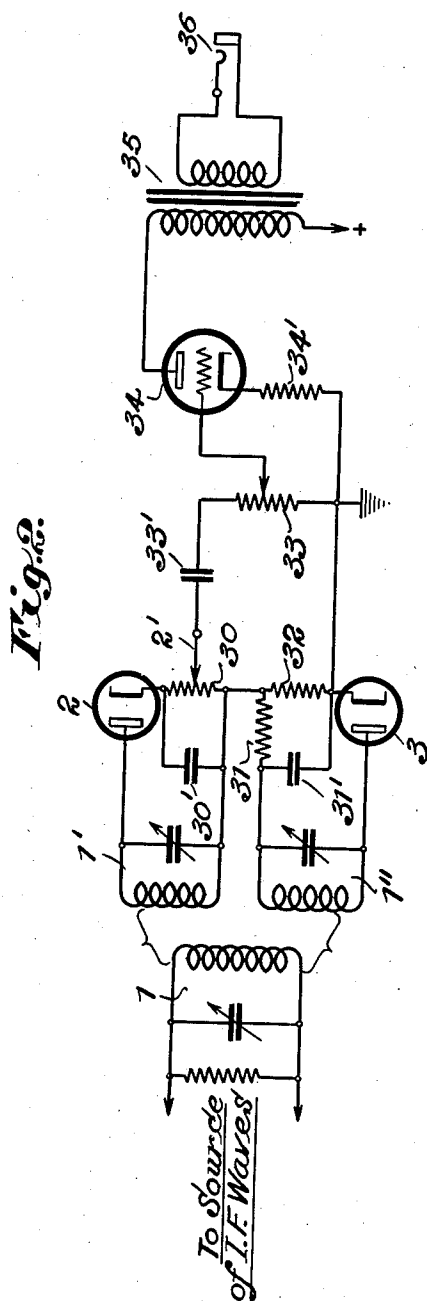
**M. G. CROSBY**

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## HETERODYNE ELIMINATION CIRCUIT

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2 Sheets-Sheet 2



INVENTOR  
*Murray G. Crosby*  
BY *H. S. Swover*  
ATTORNEY

## UNITED STATES PATENT OFFICE

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## HETERODYNE ELIMINATION CIRCUIT

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

Application November 25, 1941, Serial No. 420,362

12 Claims. (Cl. 250—20)

My present invention relates to modulated carrier receivers, and more particularly to a receiving system which includes means for eliminating the heterodyne obtained when an interfering carrier is located so near the desired carrier that an audible beat note is produced.

In the prior art undesired heterodyne currents have been reduced, or eliminated, by a selective circuit. For example, a band-elimination filter has been inserted in the intermediate frequency, or audio frequency, circuit so as to suppress the interfering carrier or audio beat note respectively. In another type of system a single side-band method of reception has been employed in which that side band is selected for detection which is free of interference.

In the reception of amplitude modulated (AM) carrier waves interference in the form of a heterodyne, or beat note, is produced when an undesired carrier is located so that its frequency is in the same channel as the desired carrier. The interference manifests itself in the form of a continuous whistle which is much stronger than the modulation which may be on the interfering carrier. If the heterodyne whistle is eliminated the resulting audible interference is small. The heterodyne itself is composed of two components i. e., an AM component and an FM (frequency modulation) component. If the detected currents resulting from rectification of these components are combined so that they cancel, the desired signal will remain free from heterodyne interference.

What comes in on an AM receiver is the desired AM plus the AM component of the beat note. In order to cancel out this undesired beat note, the FM component of the beat note is received and balanced against the AM component. The interference caused by the beat note consists of the combination of the desired carrier frequency and the interfering frequency. This combination causes a waxing and waning which appears as an amplitude modulation component of the beat note. In addition to the waxing and waning, there is a variation in the instantaneous phase of the resultant of the combination. This latter variation is a phase modulation which may be received on a frequency modulation receiver. Hence, by taking advantage of the presence of two types of modulation produced by the heterodyning of the interfering frequency, there can be produced an output from both modulations which may be arranged to cancel each other in the receiver output.

It is an important object of my invention, 55

therefore, to provide a network for balancing out a fundamental interference frequency, leaving only a weak harmonic component, in a case where an undesired carrier is located in the same channel as a desired carrier; the balancing network comprising rectifiers arranged to provide from applied desired and interference signals demodulated AM and FM voltages; the demodulated voltages being combined in such relative phases as to suppress the undesired carrier.

Still other objects of the invention are to improve generally heterodyne receiver operation, and to provide heterodyne interference suppression networks which are not only reliable and efficient in operation, but are economically manufactured and assembled.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 shows an embodiment of the invention, Fig. 1A shows a modification,

Fig. 1B illustrates the characteristics of the detectors of Fig. 1,

Fig. 2 illustrates a further modification of the invention,

Fig. 2A illustrates the detection characteristics of the network of Fig. 2.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, in Fig. 1 there is shown a tuned circuit 1 which may be a resonant output circuit of an intermediate frequency (I. F.) amplifier of a superheterodyne receiver. Since those skilled in the art are fully acquainted with the construction and operation of superheterodyne receivers, it is not believed necessary for a proper understanding of this invention to show more than the networks directly involved in the invention. The AM carrier waves, which may be for example in the broadcast range of 550-1700 kilocycles (kc.), may be reduced to an I. F. value of 175-500 kc. An I. F. value of 455 kc. is common practice. Of course, the invention is not limited to one frequency band, but may be utilized in the high frequency ranges such as the ultra-high frequency band.

The demodulator network itself comprises a

pair of rectifiers 2 and 3, each of the diode type. The anode of diode 2 is connected to the cathode thereof through a path comprising the tuned input circuit 1' in series relation with series-arranged resistors 13 and 12. The condenser 14 shunts the resistors 12 and 13, and acts to by-pass the I. F. currents. The anode of diode 3 is connected to its cathode through a path consisting of a second tuned input circuit 1'' arranged in series with the series-arranged resistors 16 and 15. The I. F. by-pass condenser 17 is connected in shunt with resistors 16 and 15. Resistors 12 and 15 are arranged in series relation with each other, and the cathode end of resistor 15 is established at ground potential.

The circuits 1' and 1'' are each separately magnetically coupled to circuit 1. Furthermore, they are oppositely and equally mistuned with respect to the operating I. F. value. It is not believed necessary to give any specific frequency values for the circuits 1' and 1'', as the mistuning magnitude will depend upon the circumstances encountered.

In general, and as shown in Fig. 1B, the circuits of the discriminator are off-tuned from the carrier by an amount which makes their sloping characteristic substantially linear in the I. F. channel from  $F_1$  to  $F_2$ . From the cathode end of resistor 12 there is derived the rectified voltage corresponding to the FM component of the heterodyne interference. From the anode end of resistor 13 there is derived the rectified voltage which corresponds to the combined desired signal and interference energies. In other words, there is developed between the cathode end of resistor 12 and ground a rectified FM voltage, whereas between the anode end of resistor 13 and ground there is developed a rectified AM voltage. This type of discriminator-rectifier circuit has been disclosed and claimed in my application Serial No. 402,784, filed July 17, 1941, granted September 15, 1942, as U. S. Patent No. 2,296,092. The potentiometer comprising condenser 5' and resistor 5 takes off the rectified FM component from the demodulator network, while the potentiometer comprising condenser 4' and resistor 4 takes off the rectified AM voltage. Of course, the AM voltage is the combined desired signal and interference energies in this case.

The rectified FM and AM voltages are applied to separate electronic sections of a twin triode tube 6. The cathodes of the tube 6 are connected in common to ground through a resistor 20. The control grid 8 of the electronic section including plate 8' is connected by an adjustable tap to potentiometer resistor 4, and, therefore, the rectified combined desired and signal interference energies are applied to grid 8. The control grid 9 of the electronic section including plate 9' is connected by an adjustable tap to the potentiometer resistor 5. Accordingly, there is impressed upon grid 9 the rectified FM component of the interference signal energy.

Plate 8' is connected to an adjustable contact arm S. The plate 9' is connected to a source of positive voltage through the primary winding of an output transformer 7. The lower end of the primary winding of transformer 7 has a contact point marked O, whereas the opposite end of the winding is connected to a separate contact point designated A. Switch arm S is arranged for selective electrical connection to either of contacts A or O. It will, therefore, be seen that when switch S is connected to contact A, plates 8' and 9' are both connected to the high potential side

of the primary winding of transformer 7. The switch arm S may, therefore, be adjusted so as to provide a means for causing the plate currents of the independent electron sections of tube 6 to be either in phase addition, or in phase opposition.

Thus, when the switch arm S is on contact A, the triode sections are in parallel arrangement in so far as their plates are concerned. Hence, the currents flowing in the primary winding of transformer 7 are in aiding phase. On the other hand, when the switch arm S is on point O the section including grid 9 acts as a normal triode amplifier, but the triode section including grid 8 acts as a cathode driver which feeds the cathode of the other section. This cathode feed causes a phase reversal of the voltage fed to the grid 8. In other words, with this connection of the switch arm the outputs of the electronic sections are in phase opposition.

When the interference frequency is on one side of the desired carrier, the switch arm S is adjusted to point A. When it is on the other side of the carrier, the switch arm is adjusted to point O to secure the phase opposition relation. In operation, potentiometers 4 and 5 are adjusted so that the amplitude of the interference component on potentiometer 5 is equal to the interference component present with the desired signal on potentiometer 4. The switch arm S is adjusted to the proper position to produce cancellation of the interference. Stated differently, the rectified FM component of the incoming signal energies is combined with the rectified received energies in such relative phases as to cancel out the interference heterodyne.

In Fig. 1A there is shown a modification wherein the rectified voltages developed across resistors 5 and 4 are combined in a different manner. In this case the twin triode 11 has its common cathode lead connected to ground through a resistor 45. The slidable contact arm of potentiometer 5 is connected to grid 42 of one electron section including plate 40. The potentiometer slider of resistor 4 is connected to grid 43 of the other electron section. A switch  $S_1$  is provided so that the plates 40 and 41 of the triodes of tube 11 may be connected either in push-pull relation or in parallel relation. To accomplish this, the transformer 10 is provided with a pair of primary windings. The primary winding 10' has one end thereof connected to plate 40, while its opposite end is connected to a source of positive potential and one of the switch contact points. Plate 41 is connected to the opposite switch contact point. The second primary winding 10'' has its opposite ends connected to the contact points which are shown in Fig. 1A. Those skilled in the art are fully acquainted with the manner of constructing the schematically represented switch  $S_1$  so as to secure either push-pull or parallel arrangement of the electron sections of tube 11.

Considering the action of the detection circuits in Figs. 1 and 1A in more detail, one of the secondaries of the discriminator, for instance 1', is tuned to give the curve A in Fig. 1B, and the other secondary to give the curve B.  $F_c$  is the carrier frequency, and  $F_1$  and  $F_2$  are the limits of the intermediate-frequency channel. These sloping filters convert the frequency modulation into amplitude modulation so that each detector resistor contains the detected frequency modulation component. Since the two sloping filters have opposite slopes, the two detected frequency modulation components are of opposite phase in

the resistors. Hence, in order to combine these two components in phase, one of the diode resistors 15 is connected with its cathode end grounded, and the other 12 with its cathode end high. This adds the two frequency modulation components in phase, and that part of the detected output is taken from blocking condenser 5' and potentiometer 5.

Although both of the diodes 2 and 3 are fed by sloping filters, this does not impair the ability of the detectors to detect the amplitude modulation component on the carrier. However, in the case of the amplitude modulation component, the detected outputs of each detector are of the same phase. Hence, to add them in phase the output is taken from a series combination of diode resistors in which the anode end is the high potential end for both resistors. The connection of resistors 15 and 13 gives this combination so that the amplitude modulation component is available from potentiometer 4.

Since the frequency modulation component of modulation on the carrier is detected by a series-opposing connection of the diode resistors, and the amplitude modulation component by a series-aiding connection, it is apparent that in the frequency modulation output the amplitude modulation component will be balanced out and in the amplitude modulation output the frequency modulation component will be balanced out. Consequently, potentiometers 5 and 4 present the outputs of a balanced frequency modulation detector and an amplitude modulation detector, respectively. The two outputs from potentiometers 4 and 5 are combined in either of tubes 6 or 11 to produce the heterodyne balance. The desired output appears on potentiometer 4, which gives the AM output plus the heterodyne beat note from an interfering signal. The FM component of this same combination gives an output consisting of substantially the beat note alone, since the amplitude modulation is balanced out. Hence, by combining in proper phase, the beat note may be cancelled and what remains is the desired AM component.

In Fig. 2 there is shown another modification of the invention. In this circuit a balanced discriminator circuit is arranged so that the degree of balance is controllable. As in the case of Fig. 1, the diode rectifiers 2 and 3 are provided with independent tuned input circuits 1' and 1'' which are oppositely mistuned with respect to the carrier frequency. The anode of diode 2 is connected to its cathode through input circuit 1' arranged in series with the load resistor 30, the latter being shunted by the I. F. by-pass condenser 30'. The anode of diode 3 is connected to its cathode through a path including input circuit 1'' in series with resistors 31 and 32, both resistors being shunted by the I. F. by-pass condenser 31'. The cathode end of resistor 32 is grounded, and resistors 30 and 32 are arranged in series relation.

The tube 34 has its cathode connected to ground through resistor 34' while the control grid of tube 34 is connected through an adjustable tap to any desired point on resistor 33. The latter is part of a potentiometer which includes resistor 33 and condenser 33'. An adjustable tap 2' connects condenser 33' to any desired point along resistor 30. It will, therefore, be seen that the potentiometer 2'—33'—33 is connected between the grounded end of resistor 32 and any desired point of load resistor 30. The plate of tube 34 is connected through

the primary winding of output transformer 35 to a source of positive potential. The secondary winding of transformer 35 may be connected to an output jack 36 to which may be coupled any type of utilization circuit such as an audio amplifier followed by a loud speaker.

The detected output from diode 3 is divided between resistors 31 and 32 so that only one half of the output from this diode is fed to the input electrodes of amplifier tube, 34. Diode 2 has the potentiometer 30 as its output load resistor so that the output thereof may be controlled from zero to about twice that contributed by diode 3. Hence, with the potentiometer arm 2' adjusted to the middle of resistor 30, the detection is a balanced FM detector. With the arm on either side of the mid-point the balance is off-set. The operation of this circuit depends upon an off-balancing of the detected outputs of the two detectors.

The carrier frequency is equal to the mid-frequency of the discriminator circuits 1' and 1''. In order to let amplitude modulation through, potentiometer 30 is adjusted so that the AM is not completely balanced out. The output of the detector then consists of the detected frequency modulation plus amplitude modulation. Hence, the desired combination of these two outputs is effective. By sliding the potentiometer arm 2' to each side of the balanced point, the phase of the detected amplitude modulation will be reversed. This provides a means for reversing the phase of combination of the two outputs. Potentiometer 33 controls the volume of the detected output which is amplified by tube 34.

In Fig. 2, the discriminator is tuned as shown in Fig. 1B, but the relative amplitudes of the detected outputs contributed by each detector are varied so as to vary the location of the balance point. This is shown in Fig. 2A in which the amplitude of the detected output from circuit B has been raised with respect to that of curve A. This raises curve B to the position of B' and shifts the point of balance to the frequency Fc'. The carrier is left tuned to its normal position Fc, so that the frequency modulation output of the detectors is no longer free from amplitude modulation, but has an amplitude modulation component corresponding to the distance  $x-y$ . This amplitude modulation component furnishes the desired AM output of the system. There will, also, be an undesired AM component of the beat note which comes through with the desired AM component. This undesired component is combined with the FM component of the beat note which is also present in the same output. The combination may be adjusted for cancellation of the beat note by an adjustment of the potentiometer 30. This potentiometer adjusts the degree of off-balance so that the amplitudes of the AM and FM components of the beat note may be adjusted to be equal. By adjusting the potentiometer so that the amplitude of curve B is made less than that of curve A, the AM component of detector A predominates instead of that of B. This causes a reversal of phase of the AM component which appears in the normal FM output. Consequently, when the required phase of combination reverses, as the interference shifts to the other side of the carrier, the phase of combination may be changed as was the case in Figs. 1 and 1A by means of switches S and S1, respectively.

The method by which the AM and FM detectors produce interference outputs which cancel

can be understood from the following analysis:

Let the desired carrier be represented by

$$e = E \sin \omega t \quad (1)$$

and the undesired interfering carrier by

$$e_1 = E_1 \sin \omega_1 t \quad (2)$$

These two carriers combine to form the resultant signal which is received by the amplitude modulation receiver. By vectorial combination, their resultant is:

$$e_3 = \sqrt{E^2 + E_1^2 + 2EE_1 \cos(\omega_1 - \omega)t} \sin \left( \omega t + \tan^{-1} \frac{E_1 \sin(\omega_1 - \omega)t}{E + E_1 \cos(\omega_1 - \omega)t} \right) \quad (3)$$

If the desired carrier is strong compared to the interfering carrier, (3) simplifies to

$$e_3 = E \left( 1 + \frac{E_1}{E} \cos pt \right) \sin \left( \omega t + \frac{E_1}{E} \sin pt \right) \quad (4)$$

where  $p = (\omega_1 - \omega) = 2\pi F_m$ , and  $F_m$  is the frequency of the heterodyne or beat note.

The amplitude modulation component of the resultant given by (4) is the envelope

$$\left( 1 + \frac{E_1}{E} \cos pt \right)$$

This can be seen to be an amplitude modulation with a modulation factor equal to the ratio  $E_1/E$ . When this envelope is detected on an amplitude modulation receiver, the output will be proportional to

$$\frac{E_1}{E} \cos pt$$

The frequency modulation component of the resultant may be determined from its phase angle

$$\left( \omega t + \frac{E_1}{E} \sin pt \right)$$

Since frequency is the rate of exchange of phase, the frequency is equal to the first derivative of the phase or,

$$f \text{ (radians per second)} = \frac{d \left( \omega t + \frac{E_1}{E} \sin pt \right)}{dt} \quad (5)$$

$$= \omega + p \frac{E_1}{E} \cos pt$$

Dividing by  $2\pi$  to obtain the frequency in cycles per second gives:

$$f = F_c + F_m \frac{E_1}{E} \cos pt \quad (6)$$

Thus the effective peak frequency deviation of the resultant is equal to

$$F_m \frac{E_1}{E}$$

and the output of a frequency modulation detector being fed by such a resultant will be proportional to

$$F_m \frac{E_1}{E} \cos pt$$

The above analysis shows that both the detected amplitude and frequency modulation components of the resultant are proportional to the quantity

$$\frac{E_1}{E} \cos pt$$

Hence the two outputs have such a phase that by properly polarizing them, they can be adjusted to cancel. The amplitude of the frequency modu-

lation component is also proportional to the beat note frequency,  $F_m$ . This means that for a low beat note frequency, the relative amplitude of the output of the AM detector will have to be lowered to obtain oscillation. Hence there must be some sort of control on the relative amplitudes of the two outputs so that they can be adjusted equal in magnitude.

In Equations 1 to 6, it was assumed that  $\omega_1$  was higher in frequency than  $\omega$  so that their difference,  $p$ , would be positive. If  $\omega_1$  was the lower of the two,  $p$  would become negative. Inserting this negative value of  $p$  in the resultant given by (4) would not effect the amplitude envelope since  $\cos(-pt)$  is equal to  $\cos pt$ . The sign between the two parts of the phase angle, however would be made negative. Hence the phase of the frequency modulation component of the resultant is reversed, but that of the amplitude modulation component is not. Consequently, interference on one side of the desired carrier requires one phase of combination for cancellation, while interference on the opposite side requires the opposite phase.

The above analysis was carried out for the condition of no modulation on both the desired and undesired carriers. However, it is apparent that the balance will still hold in the presence of modulation on either or both of the carriers, since a change in the amplitude of one of the carriers affects the degree of modulation of both components an equal amount. That is, if the desired carrier is modulated upward, both the AM and FM components of the interference are modulated upward the same amount so that the balance remains. The same holds true if the undesired carrier is modulated.

It is pointed out that in the case of frequency modulated wave reception, heterodyne elimination may be secured in a circuit similar to that shown in Fig. 1 by removing the usual limiter which precedes the FM detector. That is, if the limiter is removed so that the AM component is fed to the balanced detectors, heterodyne interference on an FM signal may be removed. This elimination is effected by detuning the receiver slightly so that enough AM component comes through to balance out the frequency component of the beat note.

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 amplitude modulated carrier waves which include a heterodyne interference frequency, means for rectifying the combined amplitude modulated carrier wave energy and interference energy to produce rectified modulation voltages corresponding thereto, a second means for rectifying the frequency modulation component of the interference energy to provide a second rectified modulation voltage corresponding to the frequency modulation component, and means for combining said two rectified modulation voltages in a predetermined phase relation such as to balance out said frequency modulation component thereby to provide cancellation of the heterodyne interference.

2. In combination with a source of amplitude modulated carrier waves which include a hetero-

dyne interference frequency, means for rectifying the combined amplitude modulated carrier wave energy and interference energy to produce rectified voltages corresponding thereto, a second means for rectifying the frequency modulation component of the interference energy to provide a second rectified voltage corresponding to the frequency modulation component, means for combining said two rectified voltages thereby to provide cancellation of the heterodyne interference, and additional means for controlling the phase relation between the combined rectified voltages.

3. In combination with a source of amplitude modulated carrier waves which include a heterodyne interference frequency, means for rectifying the combined amplitude modulated carrier wave energy and interference energy to produce rectified voltages corresponding thereto, a second means for rectifying the frequency modulation component of the interference energy to provide a second rectified voltage corresponding to the frequency modulation component, means for combining said two rectified voltages thereby to provide cancellation of the heterodyne interference, and means for adjusting the aforesaid combination of rectified voltages so that they can be in either phase-aiding or phase-opposing senses.

4. A method of receiving amplitude modulated carrier waves which include a heterodyne interference signal due to an undesired carrier in the same channel as the desired carrier, which includes rectifying the combined desired modulated carrier energy and interference energy to provide a first rectified voltage, rectifying the frequency modulation component of the interference energy to provide a second rectified voltage, and combining the two rectified voltages in such phase relations as to balance out said frequency modulation component whereby the said heterodyne interference is eliminated.

5. In combination with a source of amplitude modulated carrier waves including an interference frequency, means for rectifying the combined amplitude modulated carrier wave energy and interference energy to produce a modulation voltage corresponding thereto, a second means for rectifying the combined energies to provide a second modulation voltage corresponding to a frequency modulation component of the resultant of the modulated wave and interference, and means for combining said two modulation voltages in such relative phases as to balance out said frequency modulation component thereby to provide a cancellation of an effect of said heterodyne interference.

6. In combination with a source of amplitude modulated carrier waves affected by interference, means for rectifying the modulated carrier wave energy to produce a first rectified voltage, further means for rectifying the modulated wave energy to provide a second rectified voltage corresponding to the frequency modulation component of the resultant of the modulated wave and interference, means for combining said two rectified voltages thereby to provide cancellation of the interference, and additional means for controlling the phase relation between the combined rectified voltages.

7. A method of receiving amplitude modulated carrier waves which include an interference signal due to an undesired carrier in the same channel as the desired carrier, which includes recti-

fying the combined desired amplitude modulated carrier energy and interference energy to provide a first rectified voltage, rectifying the combined energies to provide a frequency modulation component of the resultant of the modulated waves and interference, and combining the two rectified voltages in such phase relations as to balance out said frequency modulation component thereby to eliminate the said interference.

8. In combination with a source of amplitude modulated carrier waves which include an interference frequency, opposed diode means for rectifying the combined amplitude modulated carrier wave energy and interference energy to produce rectified voltages corresponding thereto, said means rectifying said combined energies to provide a second rectified voltage corresponding to the frequency modulation component of the resultant of the modulated waves and interference, means for combining said two rectified voltages thereby to provide cancellation of the interference, said combining means including a pair of electron discharge devices, and means for adjusting the output currents of said devices so that the output currents can be in either phase-aiding or phase-opposing senses.

9. In combination with a source of amplitude modulated carrier waves which include a heterodyne interference frequency, means for rectifying the combined amplitude modulated carrier wave energy and interference energy to produce rectified voltages corresponding thereto, a second means for rectifying the frequency modulation component of the interference energy to provide a second rectified voltage corresponding to the frequency modulation component, a modulation amplifier having input electrodes, means applying the two rectified voltages to said input electrodes in such relative phases as to cancel out said frequency modulation component thereby to provide cancellation of the heterodyne interference in the amplifier output.

10. A method of receiving amplitude modulated carrier waves which include a heterodyne interference signal due to an undesired carrier in the same channel as the desired carrier, which includes rectifying the combined desired amplitude modulated carrier energy and interference energy to provide a first modulation voltage, rectifying the frequency modulation component of the interference energy to provide a second modulation voltage, and combining the two modulation voltages in such phase relations as to balance out said frequency modulation component thereby to eliminate the said heterodyne interference.

11. In combination with a source of amplitude modulated carrier waves including an interference frequency, means for rectifying the combined amplitude modulated carrier wave energy and interference energy to produce a rectified voltage corresponding thereto, a second means for rectifying the combined energies to provide a second rectified voltage corresponding to a frequency modulation component of the resultant of the modulated wave and interference, a pair of amplifier tubes having separate input electrodes, means for applying each rectified voltage to a respective input electrode in such relative phases as to cancel out said frequency modulation component thereby to provide a cancellation of an effect of said heterodyne interference.

12. In combination with a source of amplitude modulated carrier waves which include an interference frequency, opposed rectifiers for rectify-

ing the combined amplitude modulated carrier wave energy and interference energy to produce rectified voltages corresponding thereto, said rectifiers rectifying said combined energies to provide a second rectified voltage corresponding to the frequency modulation component of the resultant of the modulated waves and interference, electronic means for combining said two rectified

voltages in such relative phases as to cancel said frequency modulation component thereby to provide cancellation of the interference, and means for adjusting the output currents of said electronic means so that the output currents can be in either phase-aiding or phase-opposing senses.

MURRAY G. CROSBY.