

Dec. 12, 1944.

M. G. CROSBY

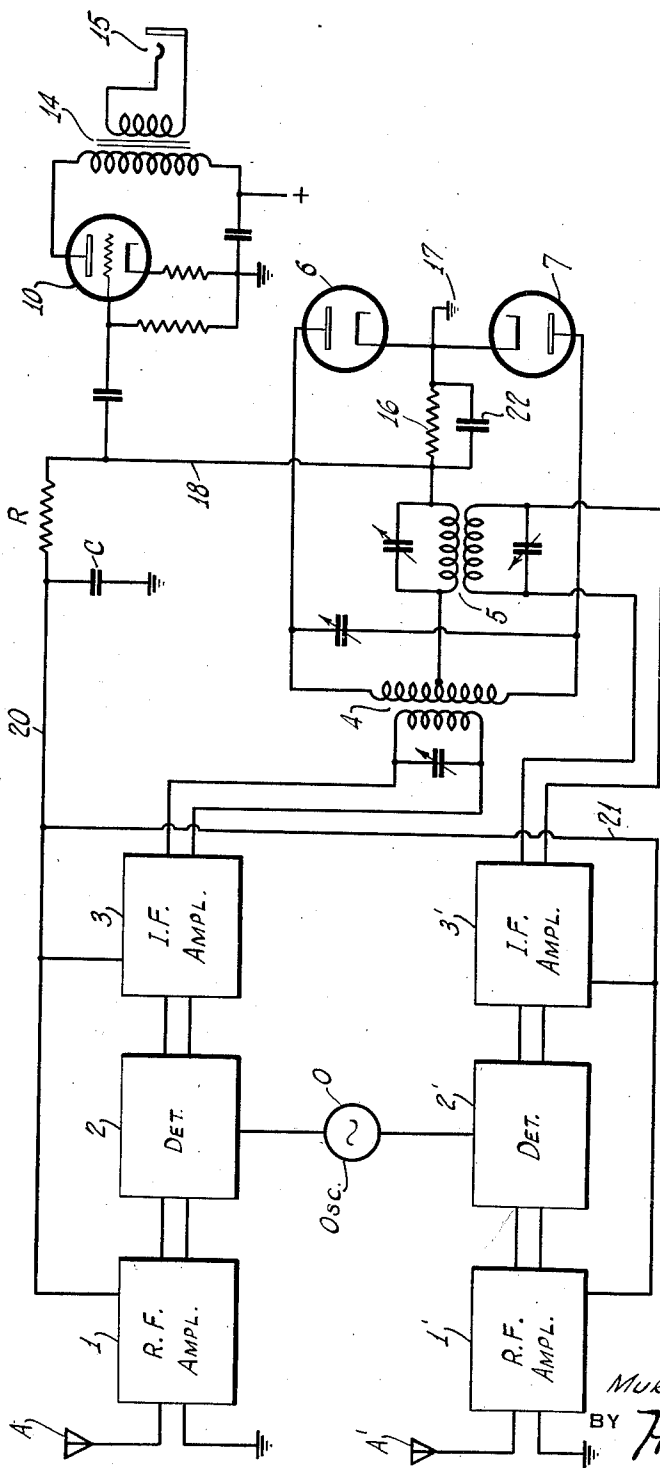
2,364,952

DIVERSITY RECEIVING SYSTEM

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2 Sheets-Sheet 1

Fig. 1.



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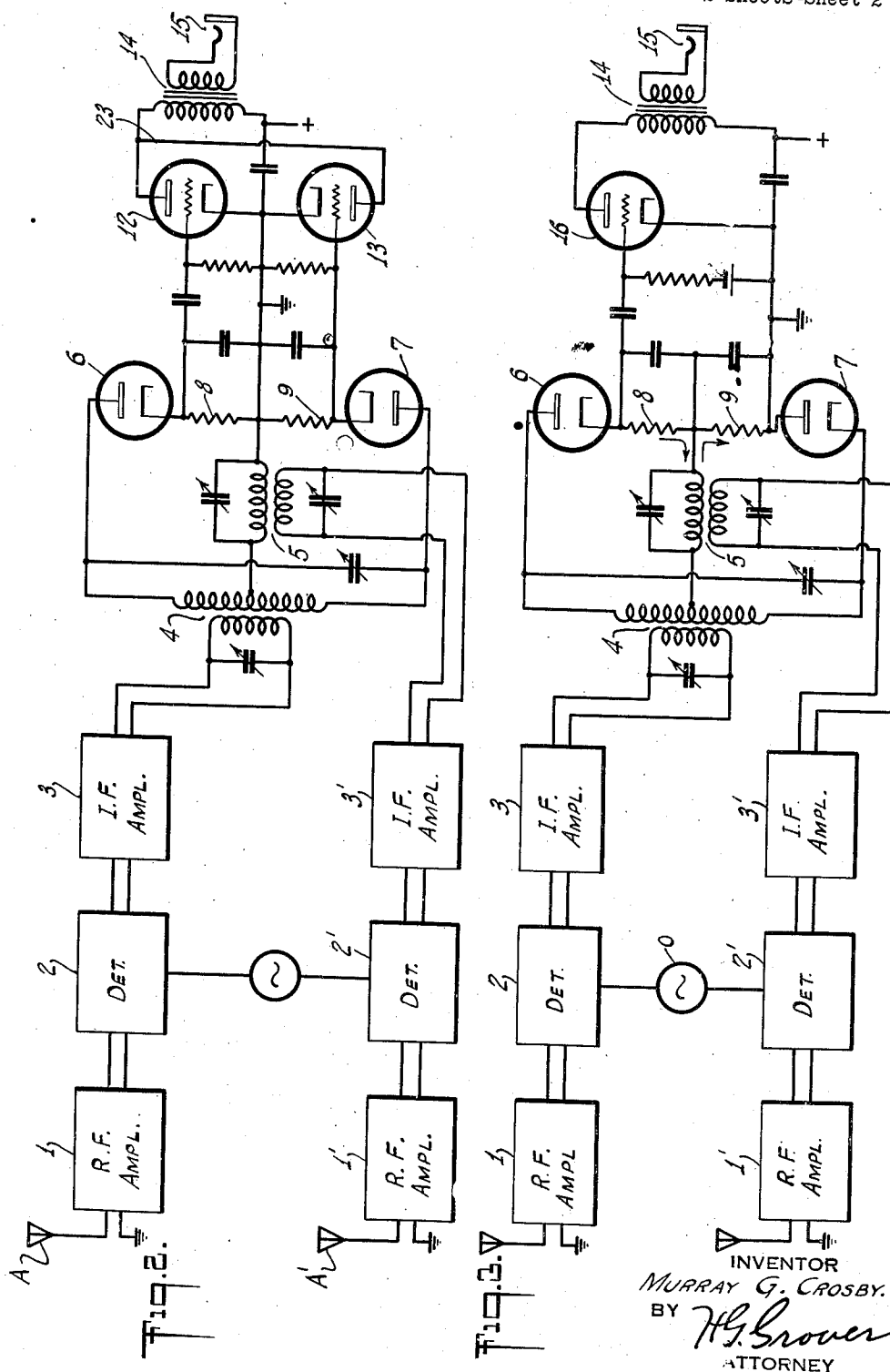
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DIVERSITY RECEIVING SYSTEM

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This invention relates to a signal receiving system employing a plurality of spaced antennas for reducing the effects of fading. Such a receiving system is known as a diversity system.

In such diversity receiving systems, the phases of the received energies at the different antennas do not remain constant but vary relative to one another with fading. The problem of overcoming the variability of the phase relations between the voltages from the different receiving antennas by automatically maintaining a predetermined phase relation, so that the radio frequency or intermediate frequency voltages may be combined before rectification, has been dealt with in my United States Patent 2,042,831, granted June 2, 1936. In my copending application filed December 31, 1941, Serial No. 425,021, I have disclosed a diversity receiving system in which, among other things, the receivers function to control the phase of one of the incoming signal voltages obtained from a receiver by varying a phase shifter or a reversing system. It is also known that in a diversity receiving system, the rectified energy from the various receivers may be combined and utilized to control the gain of the receivers. Such an arrangement is described, for example, in my United States Patent 1,835,761, granted December 8, 1931.

The present invention provides improvements in diversity receiving systems and has for one of its objects to prevent distortion in the final utilization circuit due to carrier cancellation when the carriers received on two or more antennas are in opposed phase and of substantially equal magnitude.

In accordance with one embodiment of the invention, the carriers are combined in aiding phase relation and also in opposing phase relation, and only those components which are in aiding phase relation made to contribute the major portion of the output for subsequent utilization.

Other objects and features of the invention will appear hereinafter from a reading of the following description, which is accompanied by drawings wherein Figs. 1, 2 and 3 illustrate three different embodiments of the present invention as applied to diversity receivers.

In the drawings, the same parts have been labeled by the same reference characters throughout the figures.

Referring to Fig. 1 in more detail, there is shown my preferred form of diversity receiving system for receiving amplitude modulated waves. This system includes a pair of geographically

spaced antennae A and A', respectively feeding identical heterodyne receivers 1, 2, 3 and 1', 2' and 3'. The high frequency oscillator O furnishes beating energy to the detectors 2 and 2' of the two receivers so that the intermediate frequencies obtained in band pass intermediate frequency amplifiers 3 and 3' are the same. Boxes 1 and 1', which couple the antennas to the detectors, represent radio frequency amplifiers. The output of intermediate frequency amplifier 3 is fed to the primary winding of transformer 4 whose secondary winding feeds opposed voltages to the anodes of diode rectifiers 6 and 7, while the output of intermediate frequency amplifier 3' is fed to primary winding of transformer 5 whose secondary winding is connected to the mid point of the secondary winding of transformer 4, to thereby feed cophasal voltages to the anodes of tubes 6 and 7. Transformers 4 and 5 are band pass tuned transformers which are tuned to pass the signal frequency range consisting of the carrier and side bands. Each winding of both transformers is tuned by means of a variable condenser, as shown. A common diode resistor 16 is placed between the cathodes of the diodes and one terminal of the secondary winding of transformer 5. This common diode resistor is shunted by a by-pass condenser 22 which provides a path of low impedance to energy of the operating frequency. The cathodes of the diodes are grounded by means of connection 17.

Rectified output from the diodes 6 and 7 is obtained by means of lead 18 which couples the high potential side of diode resistor 16 to the grid of audio frequency amplifier 10. Also connected to lead 18 is a time constant circuit RC which provides an automatic volume control for two receivers by way of AVC leads 20 and 21. Lead 20 is connected to the grids of apparatus 1 and 3 in one receiver, while lead 21 is connected to the grids of apparatus 1' and 3' in the other receiver, in order to vary the grid bias of these amplifiers in accordance with variations in signal strength, so as to maintain a constant signal level at the inputs of the devices. Time constant circuit RC has such values to assure that the automatic volume control will only remove slow variations of signal intensity in contradistinction to the fast variations of the modulation. The output of audio frequency amplifier 10 feeds into an audio frequency transformer 14, in turn coupled to a jack 15 for utilization by a headphone, loudspeaker, or other suitable apparatus (not shown). As an example, the apparatus which may be plugged into jack 15 may

be a broadcasting system for rebroadcasting the signals received on the diversity system.

In the operation of Fig. 1, the signals received on antenna A are applied to transformer 4 which supplies them in opposing phase relation to the anodes of detectors 6 and 7. The signals received on antenna A', on the other hand, are applied to transformer 5 which applies them to the anodes of detectors 6 and 7 cophasally. Assuming that the signals received over the two antennas are at 180° phase relation, it will be evident that one of the diodes, for example diode 6, will receive a high effective carrier which is in effect the summation of the two carriers, while the other diode 7 will receive a low effective carrier which is the difference of the two received carriers. If, as an illustration, the signal from receiver 1, 2, 3 produces in each half of the secondary winding of transformer 4 a voltage of 1.2 volts, and signals received in receiver 1', 2', 3' produce in the secondary winding of transformer 5 a voltage of one volt, there will be applied to detector 6 a resultant voltage of 2.2 volts while there will be applied to detector 7 a resultant voltage of .2 volt. The resultant voltage of 2.2 volts applied to detector 6 will appear as a rectified voltage of 2.2 volts across diode resistor 16, which value is available in lead 18 for utilization by audio frequency amplifier 10, and also available for automatic volume control purposes. Because the resistor 16 is common to both diodes 6 and 7, the voltage appearing across this resistor serves to bias diode 7 so that its anode is negative by an amount which in this example is approximately 2.2 volts. Since the resultant intermediate frequency voltage applied to detector 7 is the resultant of the opposing carriers and is only .2 volt, the rectified voltage across common diode resistor 16 of a value of 2.2 volts will so bias detector 7 that it cannot draw current. It can be seen that with an opposite phase relation of zero degrees, the diode 6 will be biased by the direct current from diode 7, so that the diode 6 will not draw current.

The present invention thus provides an arrangement whereby only one diode detector or the other passes current when the phase relations between the carriers are either at zero or 180°. This detector which passes current is the one which receives the carriers in aiding phase relation. When the carriers impressed on transformers 4 and 5 from the receivers are at 90° phase relation, however, both diodes will draw current by virtue of the fact that at this particular phase relation the carriers do not buck or aid, and balanced resultant radio frequency voltages are fed to the anodes of the two detectors 6 and 7. This balancing condition for a 90° phase relation exists irrespective of the relative intensity or magnitude of the radio frequency carriers impressed on transformers 4 and 5. For intermediate values of phase relation between zero and 90° and between 90° and 180°, one diode will draw more current than the other, and the diode which passes the greater current will bias the diode passing the weaker current, so that the weaker current-passing diode does not contribute as much rectified output as the other.

Fig. 2 illustrates another form of the diversity receiving system in accordance with the invention in which there are employed separate diode resistors 8 and 9 for the respective diode rectifiers 6 and 7. Diode 6 has audio amplifier 12 coupled across the resistor 8, while diode 7 has an audio amplifier 13 coupled across its resistor 9, the outputs or anodes of both amplifiers 12 and 13

being connected in parallel by means of connection 23. The combined amplified outputs of tubes 12 and 13 pass through audio transformer 14 for utilization in jack 15 in the manner described above in connection with Fig. 1. Because of the use of separate diode resistors 8 and 9, both diodes will always pass current at all phase relations of the incoming carriers, although at a phase relation of zero or 180° between the two carriers, that detector which is receiving the opposed carriers will produce an inappreciable part of the output. For example, assuming that diode 6 is receiving a resultant radio frequency voltage which, in effect, is the summation of the two carriers, while diode 7 is receiving a resultant radio frequency voltage which is the difference of the two carriers, then there will be a large current flow through resistor 8 and a small current flow through resistor 9. The voltage across resistor 8 will be available for amplification by amplifier 12 and will produce the predominant output in transformer 14, while the voltage across resistor 9 (which in the condition assumed above is much smaller than that across resistor 8) will be amplified by tube 13 to produce an inappreciable part of the output available in transformer 14. Putting it in other words, the effectiveness of the combining system of Fig. 2 is dependent upon the fact that that detector receiving the energy from the two antennas combined out of phase has a low value of carrier and consequently a low audio output, whereas that detector receiving the carriers in phase has a high effective carrier and therefore a high output. When the carriers which are applied to transformers 4 and 5 are 90° out of phase, both detectors 6 and 7 will contribute the same amount of energy to the amplifiers 12 and 13, irrespective of the relative magnitudes of the carriers. But, since there is no distortion between the carriers for this particular phase relationship of 90°, as is the case for a zero or 180° phase relation condition, there is no necessity to have the output of one diode or the other predominate. The overall effect of the system of Fig. 2 is that when the carriers oppose or aid, the diode rectifier which is fed with the opposing carriers does not contribute enough output to allow distortion to become objectionable.

Fig. 3 is a modification of Fig. 2 and differs therefrom primarily in the method of combining the outputs of the two diodes 6 and 7. In Fig. 3, the cathode of diode 6 is connected through resistors 8 and 9 to the anode of diode 7 in a series arrangement. Thus, in effect, the connections of the anode and cathode electrodes of diode 7 to the secondary of transformer 4 and the resistor 9 are reversed with respect to the connections of the same diode to the same elements in Fig. 2. With the arrangement of Fig. 3, the currents through the resistors 8 and 9 are always in the same direction, and therefore it is possible to employ a single audio amplifier tube 16 whose input electrodes are connected across the two resistors 8 and 9. The arrows indicate the directions of the rectified current through resistors 8 and 9. It will be noted that the directions of current flow are the same so that this series connection applies the aiding combination of detected voltages to the grid of amplifier 16. Except for the foregoing difference, the operation of Fig. 3 is the same as that of Fig. 2.

What is claimed is:

1. The method of operating a diversity radio receiving system having a pair of antennas feeding energy to a pair of rectifiers which comprises

feeding signal energy from one antenna in opposed relation to certain electrodes of said pair of rectifiers, feeding signal energy from the other antenna and of the same frequency as said first signal energy to the same electrodes of said pair of rectifiers in cophasal relation, deriving rectified energy from both of said rectifiers in a common utilization circuit, causing one of said rectifiers to produce the predominantly useful alternating current output when the two carriers received by said antennas are at 180° phase relation, and causing the other of said rectifiers to produce the predominantly useful alternating current output when the two carriers received by said antenna are at zero degrees phase relation.

2. The method of operating a diversity radio receiving system having a pair of antennas feeding energy to a pair of rectifiers which comprises feeding signal energy from one antenna in opposed relation to certain electrodes of said pair of rectifiers, feeding signal energy from the other antenna and of the same frequency as said first signal energy to the same electrodes of said pair of rectifiers in cophasal relation, deriving rectified energy from both of said rectifiers in a common utilization circuit, causing both rectifiers to contribute equal values of useful output current when the two carriers received by said antennas are at a 90° phase relation, and causing one of said rectifiers to produce the predominantly useful output current when the two carriers received by said antennas depart from a 90° phase relation.

3. The method of operating a diversity radio receiving system having a pair of antennas feeding energy to a pair of rectifiers which comprises feeding signal energy from one antenna in opposed relation to certain electrodes of said pair of rectifiers, feeding signal energy from the other antenna and of the same frequency as said first signal energy to the same electrodes of said pair of rectifiers in cophasal relation, deriving rectified energy from both of said rectifiers in a common utilization circuit, causing both rectifiers to contribute equal values of useful output current when the two carriers received by said antennas are at a 90° phase relation, causing only one of said rectifiers to produce useful output current when the two carriers received by said antennas are at 180° phase relation, and causing only the other of said rectifiers to produce useful output current when the two carriers received by said antennas are at zero phase relation.

4. The method of operating a diversity radio receiving system having a pair of antennas feeding energy to a pair of rectifiers whose corresponding electrodes are connected together, which comprises feeding signal energy from one antenna in opposed relation to like electrodes of said pair of rectifiers, feeding signal energy from the other antenna and of the same frequency as the first signal energy to the same like electrodes of said pair of rectifiers in cophasal relation, deriving rectified energy from both of said rectifiers in a common utilization circuit, whereby one of said rectifiers receives a higher resultant high frequency voltage than the other when the two carriers depart from a 90° phase relation, and causing that rectifier receiving the higher resultant high frequency voltage to bias the other rectifier to reduce the tendency for current flow therethrough.

5. The method of operating a diversity radio receiving system having a pair of antennas feed-

ing energy to a pair of rectifiers which comprises feeding signal energy from one antenna in opposed relation to certain electrodes of said pair of rectifiers, feeding signal energy from the other antenna and of the same frequency as said first signal energy to the same electrodes of said pair of rectifiers in cophasal relation, deriving rectified energy from both of said rectifiers in a common utilization circuit, whereby one of said rectifiers receives a higher resultant high frequency voltage than the other when the two carriers depart from a 90° phase relation, and utilizing the rectified combined energies to bias negatively that rectifier which receives the lower resultant high frequency voltage.

6. In a radio receiving system, a pair of antennae feeding separate receivers, a pair of detectors having their corresponding electrodes connected together, means for feeding energy from one receiver to the anodes of said detectors in opposed phase relation, means for feeding energy from the other receiver to the anodes of said detectors in cophasal relation, a common bias resistor through which flows the detected currents from both detectors, and means for utilizing the voltage drop across said resistor.

7. In a radio receiving system, a pair of antennae feeding separate receivers, each receiver having an amplifier, a mixer circuit for producing an intermediate frequency output, and an intermediate frequency amplifier; a pair of rectifier circuits each including a discharge device having anode and cathode electrodes, a pair of like resistors connected in series between the cathodes of said devices, a transformer having a primary winding coupled to the intermediate frequency amplifier of one receiver and a secondary winding coupled to the anodes of said devices for applying opposed voltages thereto, another transformer having a primary winding coupled to the intermediate frequency amplifier of the other receiver and a secondary winding coupled between the electrical center of the first secondary winding and the junction point of said resistors for applying in-phase voltages to the anodes of said devices, a condenser for each of said windings of said transformers for tuning the same to pass the signal frequency range of carrier and side bands, and a pair of audio frequency amplifiers one of which has its input electrodes across one of said resistors while the other has its input electrodes across the other of said resistors, and a connection between the output electrodes of said audio amplifiers for combining the outputs thereof.

8. In a radio receiving system, a pair of antennae feeding separate receivers, each receiver having an amplifier, a mixer circuit for producing an intermediate frequency output, and an intermediate frequency amplifier; a pair of rectifier circuits each including a discharge device having anode and cathode electrodes, a band pass transformer having a primary winding coupled to the intermediate frequency amplifier of one receiver and a secondary winding coupled to the anodes of said devices for applying opposed voltages thereto, another band pass transformer having a primary winding coupled to the intermediate frequency amplifier of the other receiver and a secondary winding coupled between the electrical center of the first secondary winding and the cathodes of said devices for applying in-phase voltages to the anodes of said devices, and audio frequency amplifier means having its input electrodes coupled to said devices.

9. In a radio receiving system, a pair of antennae feeding separate receivers, each receiver having an amplifier, a mixer circuit for producing an intermediate frequency output, and an intermediate frequency amplifier; a pair of rectifier circuits each including a discharge device having anode and cathode electrodes, a pair of like resistors connected in series between the cathodes of said devices, a by-pass condenser across each resistor of said pair, a connection from ground to the junction point of said resistors, a transformer having a primary winding coupled to the intermediate frequency amplifier of one receiver and a secondary winding coupled to the anodes of said devices for applying opposed voltages thereto, another transformer having a primary winding coupled to the intermediate frequency amplifier of the other receiver and a secondary winding coupled between the electrical center of the first secondary winding and the junction point of said resistors for applying in-phase voltages to the anodes of said devices, a condenser for each of said windings of said transformers for tuning the same to pass the signal frequency range of carrier and side bands, and a pair of audio frequency amplifiers one of which has its input electrodes across one of said resistors while the other has its input electrodes across the other of said resistors, and a connection between the output electrodes of said audio amplifiers for combining the outputs thereof.

10. In a radio receiving system, a pair of antennae feeding separate receivers, each receiver having an amplifier, a mixer circuit for producing an intermediate frequency output, and an intermediate frequency amplifier; a pair of rectifier circuits each including a discharge device having anode and cathode electrodes, a resistive connection between the cathode of one device and the anode of the other device, a band pass transformer having a primary winding coupled to the intermediate frequency amplifier of one receiver and a secondary winding coupled to the anode of said one device and the cathode of said other device for applying opposed voltages to said last electrodes, another band pass transformer having a primary winding coupled to the intermediate frequency amplifier of the other receiver and a secondary winding coupled between the electrical center of the first secondary winding and the electrical center of said resistive connection for applying in-phase voltages to said last electrodes, and an audio frequency amplifier having its input electrodes connected across said resistive connection.

11. In a radio receiving system, a pair of antennae feeding separate receivers, each receiver having an amplifier, a mixer circuit for producing an intermediate frequency output, and an intermediate frequency amplifier; a pair of rectifier circuits each including a discharge device having anode and cathode electrodes, a resistive connection between the cathodes of said devices, a band pass transformer having a primary winding coupled to the intermediate frequency amplifier of one receiver and a secondary winding coupled to the anodes of said devices for applying opposed voltages thereto, another band pass transformer having a primary winding coupled to the intermediate frequency amplifier of the other receiver and a secondary winding coupled between the electrical center of the first secondary winding and the electrical center of said resistive connection for applying in-phase voltages to the

anodes of said devices, a by-pass condenser across each half of said resistive connection, and audio frequency translation means coupled to said rectifier circuits for utilizing the currents rectified thereby.

12. The method of combining signals having the same intelligence and which are varying in relative phase and amplitude, which comprises producing a first combination of the energies of a pair of said signals having the same frequency, producing a second combination of said same energies with a phase of combination opposite to that of said first combination, and causing the stronger of said two combinations to contribute a major portion of the output for utilization.

13. In a radio receiving system, a pair of energy collectors feeding separate receivers, a pair of detectors having their corresponding electrodes connected together, means for feeding energy from one receiver to like electrodes of said detectors in opposed phase relation, means for feeding energy from the other receiver to the same like electrodes of said detectors in cophasal relation, a common bias resistor through which flows the detected currents from both detectors, and means for utilizing the voltage drop across said resistor.

14. In a radio receiving system, a pair of energy collectors feeding separate receivers, a pair of detectors having their corresponding electrodes connected together, a circuit for feeding signal energy from one receiver to like electrodes of said detectors in opposed phase, a circuit for feeding signal energy of the same frequency as said first signal energy to the same like electrodes in cophasal relation, a common bias resistor through which flows the detected currents from both receivers, and an audio frequency utilization circuit coupled to said resistor for utilizing the voltage drop across the resistor.

15. In a radio receiving system, a pair of energy collectors feeding separate receivers, a pair of detectors having their corresponding electrodes connected together, a circuit for feeding signal energy from one receiver and of a frequency lower than that impressed upon said one receiver to the anodes of said detectors in opposed phase relation, a circuit for feeding signal energy from the other receiver and of the same lower frequency mentioned above to the anodes of said detectors in cophasal relation, a common bias resistor through which flows the detected currents from both receivers connected between the cathodes and the anodes of said detectors, and an electron discharge device translation circuit coupled to said resistor for utilizing the voltage drop thereacross.

16. In a radio receiving system, a pair of energy collectors feeding separate receivers, each receiver having means for producing an intermediate frequency output, a pair of rectifier circuits each including a discharge device having anode and cathode electrodes, a band pass transformer having a primary winding coupled to the intermediate frequency output of one receiver and a secondary winding coupled to the anodes of said devices for applying opposed voltages thereto, another band pass transformer having a primary winding coupled to the intermediate frequency output of the other receiver and a secondary winding coupled between the electrical center of the first secondary winding and the cathodes of said devices for applying in-phase voltages to the

anodes of said devices, and audio frequency utilization means coupled to said devices.

17. In a radio receiving system, a pair of energy collectors feeding separate receivers, each receiver having means for producing an intermediate frequency output, a pair of rectifier circuits each including a discharge device having anode and cathode electrodes, a resistive connection between the cathode of one device and the anode of the other device, a band pass transformer having a primary winding coupled to the intermediate frequency output of one receiver and a secondary winding coupled to the anode of said

5 one device and the cathode of said other device for applying opposed voltages to said last electrodes, another band pass transformer having a primary winding coupled to the intermediate frequency output of the other receiver and a secondary winding coupled between the electrical center of the first secondary winding and the electrical center of said resistive connection for applying n-phase voltages to said last electrodes, and an 10 electron discharge device translation circuit connected across said resistive connection.

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