

May 23, 1944.

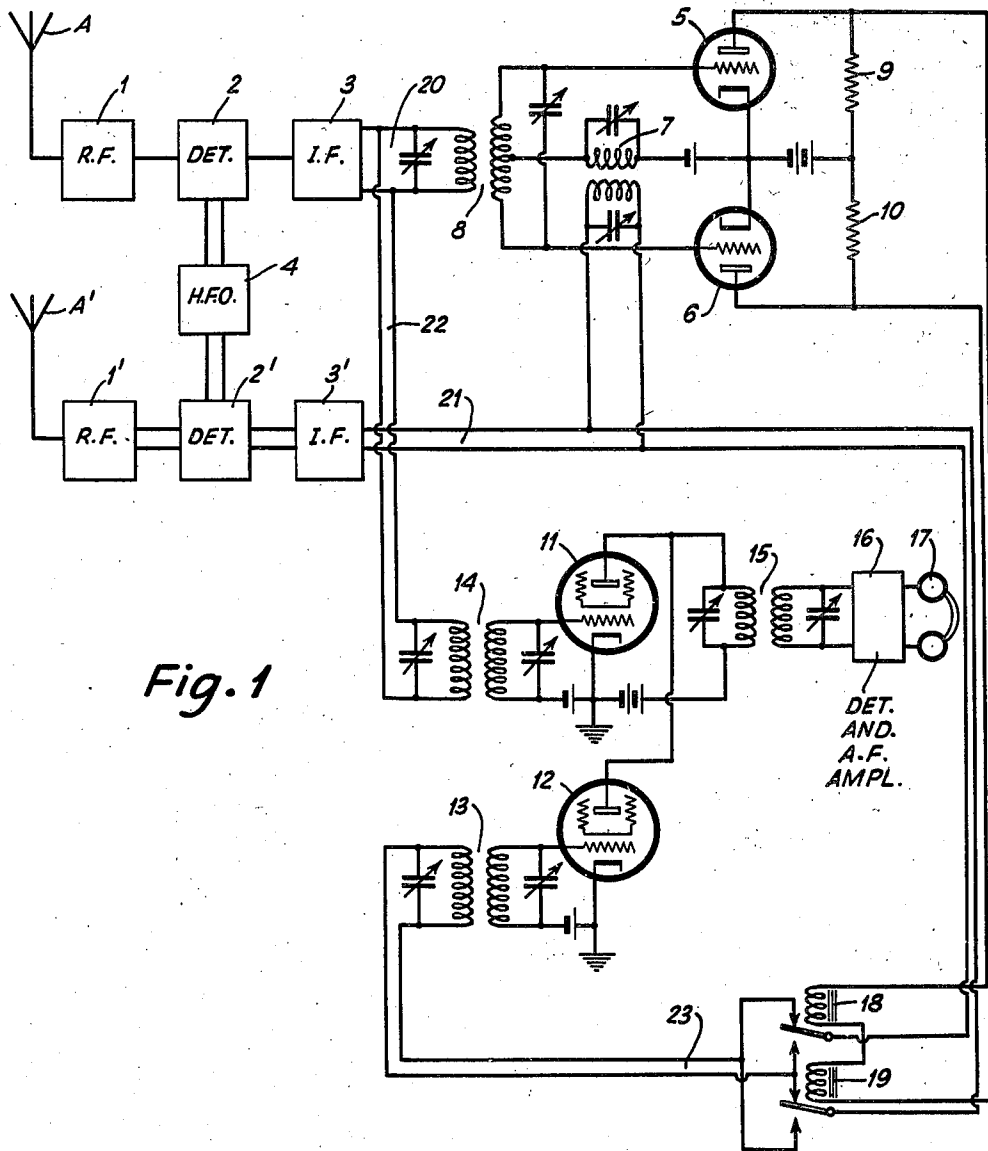
M. G. CROSBY

2,349,407

DIVERSITY RECEIVING SYSTEM

Filed Dec. 31, 1941

4 Sheets-Sheet 1



INVENTOR
MURRAY G. CROSBY
BY *H. G. Hoover*
ATTORNEY

M. G. CROSBY

DIVERSITY RECEIVING SYSTEM

Filed Dec. 31, 1941

Fig. 2

INVENTOR
MURRAY G. CROSBY
BY *H.B. Grover*
ATTORNEY

May 23, 1944.

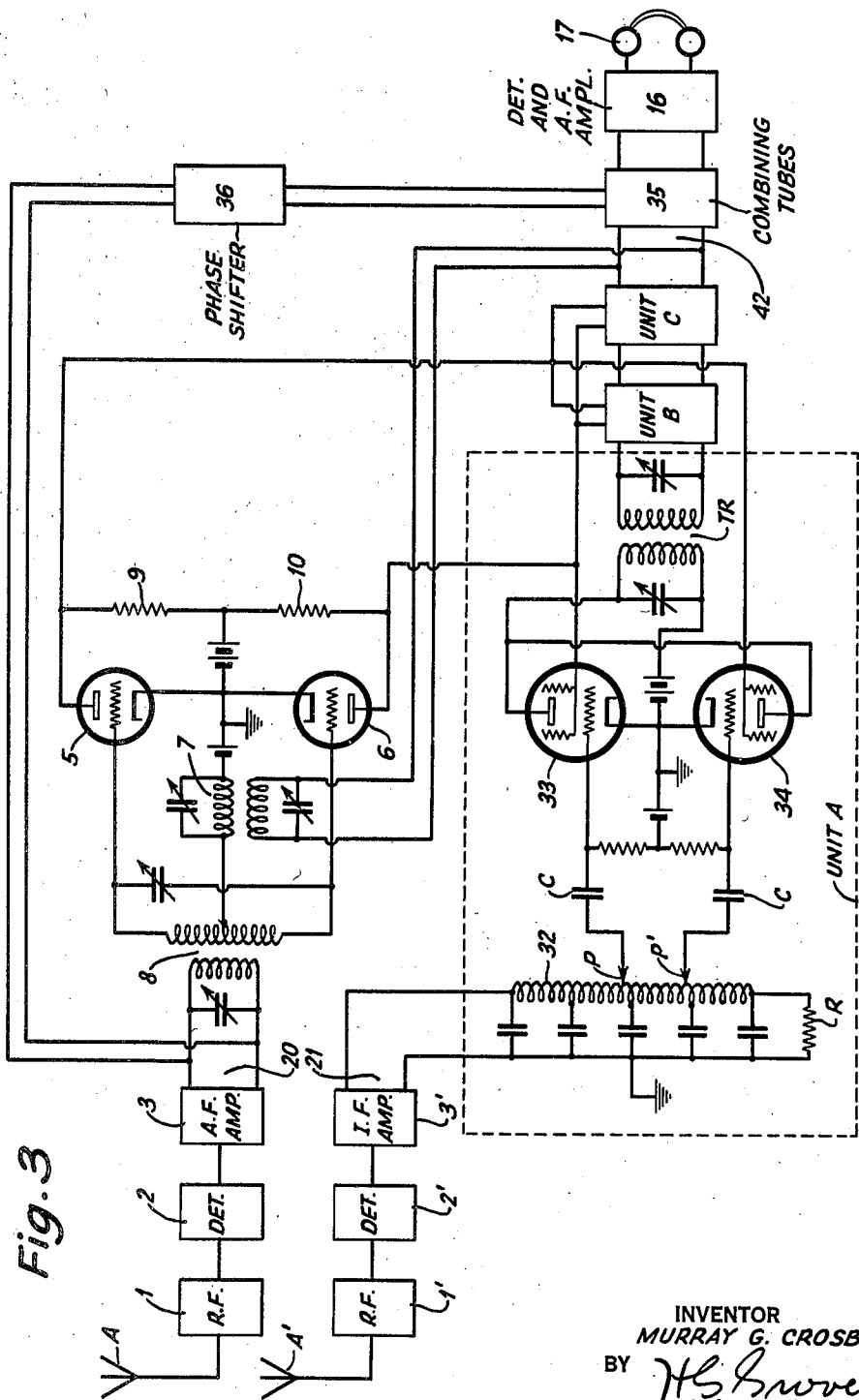
M. G. CROSBY

2,349,407

DIVERSITY RECEIVING SYSTEM

Filed Dec. 31, 1941

4 Sheets-Sheet 3



INVENTOR
MURRAY G. CROSBY
BY *H.S. Swover*
ATTORNEY

May 23, 1944.

M. G. CROSBY

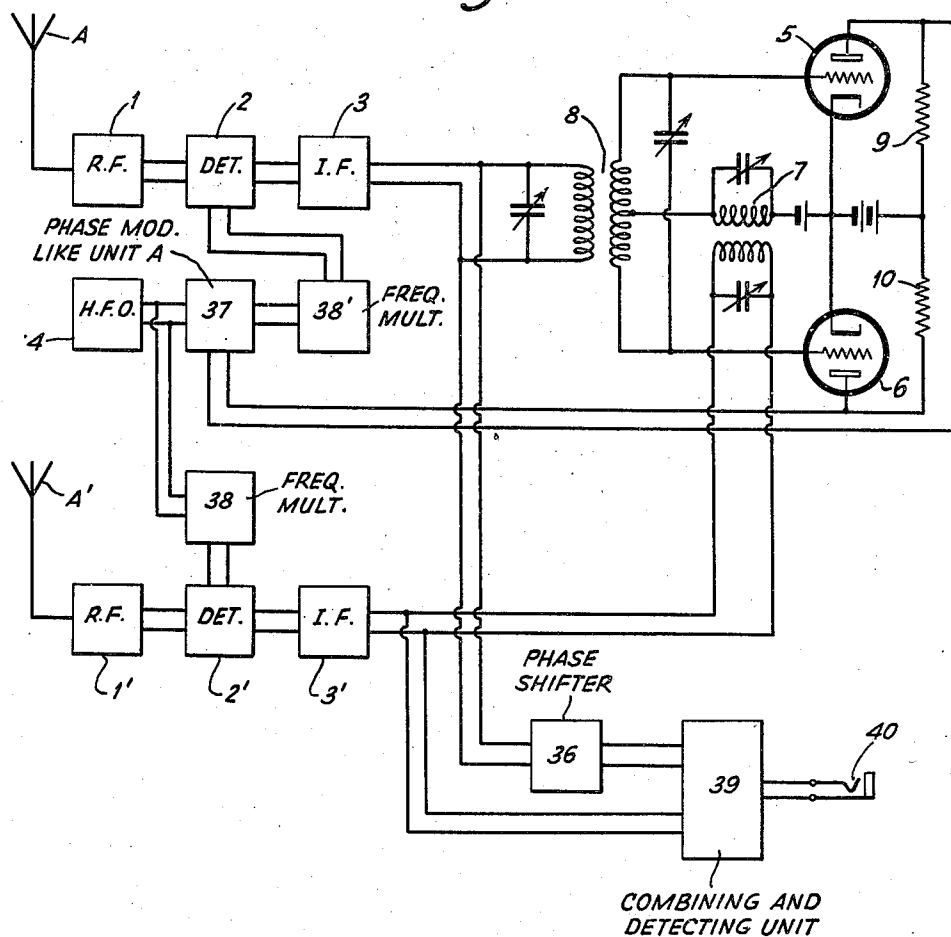
2,349,407

DIVERSITY RECEIVING SYSTEM

Filed Dec. 31, 1941

4 Sheets-Sheet 4

Fig. 4



INVENTOR
MURRAY G. CROSBY
BY *J. S. Grover*
ATTORNEY

UNITED STATES PATENT OFFICE

2,349,407

DIVERSITY RECEIVING SYSTEM

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

Application December 31, 1941, Serial No. 425,021

19 Claims. (Cl. 250—20)

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 relatively 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 No. 2,042,831, granted June 2, 1936.

The present invention provides improvements and refinements in the method of and apparatus for automatically controlling the relative phases of the energies from the different antennas of a diversity receiving system.

Although I have described in my United States Patent No. 2,042,831 a method of maintaining at a constant value the phase relations of the currents received from the diversity antenna system, which includes varying the frequency of the high frequency oscillator which heterodynes one of the signals, I have found it to be more desirable to control the phase of one of the incoming signal voltages by varying a phase shifter or a reversing system. The reason for this is that when the frequency is controlled as described in my United States patent supra, instead of the phase (in accordance with the present invention) proper phase synchronism is not obtained between the higher modulation frequencies of the signals received over the different antennas of the diversity system. That is, when the energy received from the phase detectors is applied to the high frequency oscillator in accordance with the disclosure in my United States patent, proper phase synchronism is obtained for the carrier frequencies but not for the side band frequencies. To obtain proper phase synchronism between both the carriers and the side bands of the signals received over the different antennas of the diversity system, the energy received from the phase detectors must be applied to effect a phase correction of one of the signal waves.

In the preferred embodiment of the invention, the receivers function to control the phase of one of the signal voltages obtained from a receiver by varying a phase shifter or a reversing system. In another embodiment of my invention, I am able to control the phase of one of the signal voltages by shifting the phase of the high fre-

quency oscillatory energy which beats with one of the signals to produce an intermediate frequency.

A more detailed description of the invention follows in conjunction with drawings, wherein Figs. 1 to 4, inclusive, show four different embodiments of the present invention. In the drawings, the same parts have been labeled by the same reference characters throughout the figures.

Fig. 1 shows a diversity receiving system comprising a pair of geographically spaced antennas A and A', respectively feeding identical heterodyne receivers 1, 2, 3 and 1', 2', 3'. A high frequency oscillator 4 furnishes beating energy to the detectors 2 and 2' of the two receivers so that the intermediate frequencies obtained in intermediate frequency amplifiers 3 and 3' are the same. Elements 1 and 1' which couple the antennas to the detectors represent radio frequency amplifiers. The output of intermediate frequency amplifier 3 is fed through line 20 directly to transformer 8 in circuit with differential phase detectors 5 and 6. The output of intermediate frequency amplifier 3' is fed through line 21 directly to transformer 7 of the differential detectors 5 and 6. It should be noted that the grids of detectors 5 and 6 receive cophasal energy impressed on transformer 7 and out-of-phase (antiphasal) energy impressed on transformer 8. In the outputs of the differential phase detectors 5 and 6 there are load resistors 9 and 10, and in series relation a pair of polar relays 18 and 19 which may be called reversing relays or a reversing switch, for reasons which appear hereinafter. The character of each polar relay is such that the armature will maintain its position in engagement with one of the contacts until such time as current through the winding of the relay in the opposite direction will cause the armature to be drawn to the oppositely disposed contact. Energy from the output of intermediate frequency amplifier 3 is also fed through line 22 to coupling transformer 14 for application to the grid of the coupling tube 11. Energy from intermediate frequency amplifier 3' is fed through line 21, not only to the transformer 7 but also to the armatures of polar relays 18 and 19 for application to line 23 and transformer 13, in order that this energy can be applied to the grid of coupling tube 12. Transformers 7, 8, 13, 14 and 15 are band pass tuned transformers of the conventional type, and tuned to pass the signal frequency range consisting of the carrier and side bands. It should be noted that when the armatures of polar relays 18 and 19 are simul-

taneously drawn in the upward direction, the energy in line 21 is applied to line 23 in one sense, whereas if the armatures of polar relays 18 and 19 are simultaneously drawn in a downward direction, the energy in line 21 is applied to line 23 in an opposite sense. In other words, relays 18 and 19 function as reversal relays or as a reversing switch for reversing the direction of the current applied from line 21 to line 23 and coupling tube 12. The energy in the outputs of coupling tubes 11 and 12 are fed to a common transformer 15 and thence to a detector and amplifier unit 16 to be made available for utilization in 17 which may consist of headphones or a loudspeaker or a suitable recorder.

In the operation of Fig. 1, the phase detectors 5 and 6 supply a voltage across resistors 9 and 10, which is zero when the two carriers from the two receivers 1, 2, 3 and 1', 2', 3' are 90° or 270° out of phase, and is of a finite value with a polarity depending upon the phase relation when the two carriers are zero or 180° out of phase. Thus, if the signal voltages are in phase at any instant, a positive direct current voltage will appear across the resistors 9 and 10, and if they are out of phase at any instant, a negative direct current voltage will appear across these resistors; but if they are 90° out of phase, the voltage across one resistor opposes that across the other, so that no direct current voltage appears across the combination of the two. Putting it in other words, when the two signals from the receivers have a phase relation of 90°, the direct current outputs of the differential phase detectors 5 and 6 are equal and opposite and there is no change in the position of the armature of the reversing switch comprised of polar relays 18 and 19. In this condition of 90° phase difference between the two signal voltages, there is little or no distortion in combining the outputs of the receivers through the coupling tubes 11 and 12 for utilization in headphones 17. However, when the incoming signals are 180° apart, the combined energies tend to buck or oppose one another, and for this reason the reversing switch constituting polar relays 18 and 19 assures that the outputs of the receivers are always additive. If it were not for the reversing relays 18 and 19 operated by energy from the outputs of the phase detectors 5 and 6, the combined energies in the outputs of the coupling tubes 11 and 12 would alternately oppose (i. e., buck) and aid, depending upon the instantaneous phase relation between the energies from the two antennas. It has been found that this phase relation is very erratic and cannot be depended upon to maintain a constant value. The desired result of obtaining an additive effect from the outputs of the receivers is achieved by causing the phase detectors 5 and 6 to operate both of the polar relays 18 and 19 (whenever the carriers become out-of-phase) in the same direction so as to reverse the phase of the energy which is applied from line 21 to line 23 and coupling tube 12. In this way the energies received over the antennas A and A' are never allowed to oppose or buck each other but can combine when they are either in phase or 90° out-of-phase. As a consequence of this, the two signals from the spaced antennas are prevented from cancelling each other and there is obtained the full benefit of the different fading characteristics of the antennas, and a reduction of fading is achieved.

The system of Fig. 2 is quite similar to the system of Fig. 1, except that the reversing cir-

cuit composed of polar relays of Fig. 1 has been replaced by a different form of reversing circuit composed of a vacuum tube arrangement 27 and 28. In order to simplify the drawings, only that portion of the system is shown which extends to the right of lines 20 and 21 which are respectively coupled to the outputs of the receivers 1, 2, 3 and 1', 2', 3'. The antennas and receiver elements of Fig. 1 which couple to the lines 20 and 21 have not been shown in Fig. 2, because this portion of the circuit is the same in the systems in both figures. In Fig. 2, the energy from the output of receiver 1', 2', 3' (applied to line 21) is fed to transformer 29 and to the coupling tube 15 26. The anode of tube 26 is joined to the anodes of the tubes 27 and 28, and the combined energies fed to transformer 15 and detector 16 for subsequent utilization in headphone, loudspeaker or recorder 17. The differential phase detectors are constituted by diode detectors 22 and 23 instead of the triode vacuum tubes shown in Fig. 1. Differential energy in the outputs of the diode detectors, dependent upon the phase difference between the two signals from the receivers, appears across diode resistors 24 and 25 and is fed to the suppressor grids of reversing tubes 27 and 28. Vacuum tubes 27 and 28 function as a reversing switch in a manner similar to the polar relays 18 and 19 of Fig. 1, except that the reversing action is obtained in Fig. 2 by biasing the suppressor grid of that tube 27 or 28 which receives a 180° voltage on its control grid from transformer 29 so that it does not amplify, and biasing the other tube 28 or 27 receiving a zero degree voltage on its control grid from transformer 29 so that it does amplify. The grid of tube 27 is fed signal voltage which is 180° out of phase with that fed to the grid of tube 28 from transformer 29. Consequently, the phase of the voltage appearing in the common anode circuit of the two vacuum tubes 27 and 28 may be reversed by causing one tube to be conductive, that is, to do the amplifying, and rendering the other tube non-conductive. If the two signal voltages from the receivers are 90° out-of-phase, both vacuum tubes 27 and 28 furnish energy to the common anode circuit which is available for utilization in unit 17, because in this condition the balanced voltages from the diode detectors do not affect the suppressor grids of the tubes 27 and 28 differently. At this phase relation of 90°, there will be no opposing or bucking effect of the energies combined in the detector 16. The polarity of the voltage received by the reversing tubes 27 and 28 from the diode resistors 24 and 25 as applied to the suppressor grids, is set so that the proper tube 27 or 28 is turned on to form an in-phase relation between the voltages from vacuum tube 26 and either vacuum tube 27 or 28, depending upon which of the last two tubes is conducting. The combined voltages appearing in transformer 15 are rectified and combined in the same manner as in Fig. 1. Transformers 29 and 30 are band-pass tuned transformers which are tuned to pass the signal frequency range consisting of the carrier and side bands.

Figs. 3 and 4 show different systems for continuously maintaining the phase of the combination of the signal waves at a constant value.

In Fig. 3 the energy from the phase detectors 5 and 6 is utilized to vary the phase of one of the signal waves in a continuous manner. Whereas the systems of Figs. 1 and 2 merely reverse the phase of one of the signal waves when the two voltages begin to buck (that is,

oppose or cancel), the system of Fig. 3 maintains a predetermined phase relation at all times between the voltages from the two receivers. The intermediate frequency energy from the superheterodyne receiver 1', 2', 3', fed over line 21, is applied to the input terminals of an artificial line 32 which is terminated by a surge impedance or resistor R equal in value to the surge impedance or resistance of the line 32. By virtue of the termination of line 32 at the desired intermediate frequency, only traveling waves appear in the inductive portion of the line. A pair of electron discharge device modulators 33 and 34 have their control electrodes tapped through blocking condensers C, C to points P and P' on the inductance coil of the line 32, which points supply voltages to the control grids approximately 90° apart. Accordingly, voltages of the same or like frequency as that supplied from line 21 are fed to the control grids of the modulator tubes 33 and 34 ninety degrees apart. The anode circuits of both modulator tubes are joined together and to a tuned circuit forming part of the transformer TR. Transformer TR is a band-pass tuned transformer which is tuned to pass the signal frequency range consisting of the carrier and sidebands. In accordance with the invention, it is proposed to oppositely vary the output of the modulator tubes 33 and 34 in order to vary the phase of the resultant voltage from the two tubes between two limits. This shift in phase of the resultant constituting the output of the modulator tubes 33 and 34 is accomplished by relatively decreasing the amplified voltage appearing in the output of one of the modulator tubes 33 or 34 and relatively increasing the amplified voltage from the other modulator tube 34 or 33 appearing in the output circuit. In order to cause this opposite variation in output voltage in modulator tubes 33 and 34, the anode circuits of the phase detectors 5 and 6 are connected to the screen grids of the modulator tubes to apply to these screen grids the differential voltage from the phase detectors. It will thus be seen that there is employed a differential modulation of the two phase differentiated voltages taken from phase shifters 32 so that the resultant varies in phase but only slightly in amplitude. When the phase relation between the two signal waves obtained from the two receivers of the diversity system varies from the desired 90° relation, and causes the voltage across resistor 9 to go up and that across resistor 10 to go down, the amplitude of the energy from modulator tube 33 is increased and that from 34 decreased, as a consequence of which the phase of the energy in the common anode circuit of the two modulator tubes will change.

The phase shifter 32 and the modulator tubes 33 and 34 with their common output circuit have been indicated in dotted lines and labeled as unit A. This unit is identical in construction with the apparatus in units B and C, all of which, it should be noted, are connected together to the same leads extending to the resistors 9 and 10 in the outputs of the phase detectors 5 and 6. The same process previously described as taking place in unit A will simultaneously take place in units B and C which are cascaded with unit A so as to produce a greater phase variation than is obtainable in only one of the units. This greater phase variation occurs because all the phase changes in units A, B and C add up together to produce a resultant which is fed via

line 42 to the combining circuit 35, after which the energies are fed to detector and audio frequency amplifier 16 for utilization in headphones, loudspeaker or recorder 17. Combining circuit 35 may comprise coupling tubes such as 11 and 12 of Fig. 1. By using proper connections with a suitable adjustment of the polarities, the energy from the phase detectors 5 and 6 will cause phase modulator units A, B and C to apply a phase correction to the energy from line 21, so that the voltages fed to detectors 5 and 6 via transformers 8 and 7 will be brought back to the desired 90° relation. In this way the voltages fed to the phase detectors will be continuously maintained at or near the 90° desired phase relation position. The energy from receiver 1, 2 and 3 and line 20 is fed to a suitable phase shifter 36, in order that it may be combined by apparatus 35 with the energy from line 42, the last energy being obtained from receiver 1', 2', 3' and line 21. Phase shifter 36 may take the form of the artificial line type of phase shifter 32, or any other suitable form such as that described in my United States Patent No. 2,247,941. Apparatus 35 constitutes suitable vacuum tube apparatus for combining energies in known manner. The combined energy is then detected in unit 16 and made available for utilization.

One advantage of the system of Fig. 3 over known methods of maintaining continuous control of the phase relation between the voltages from the two receivers is that I employ electronic control whereas I previously described (in my United States Patent No. 2,042,831, Fig. 1 thereof) a motor control arrangement. The electronic control scheme of the present invention is much faster in operation than the motor control method of accomplishing a similar result.

The system of Fig. 4 obtains a continuous and automatic control of the phase relations between the outputs of the two superheterodyne receivers of the diversity system by shifting the phase of the high frequency oscillator energy instead of that in the intermediate frequency energy as shown in Figs. 1, 2 and 3. In Fig. 4, the energy from the high frequency heterodyne oscillator 4 is phase modulated at a relatively low frequency by modulator unit 37, which is like apparatus A of Fig. 3. More specifically, unit 37 is a phase modulator employing two vacuum tubes and a phase shifter of the type shown in Fig. 3. This phase modulator 37 is controlled from the output of differential phase detectors 5 and 6 in the same manner as described hereinabove in connection with Fig. 3. The output of the phase modulator 37 is frequency multiplied by frequency multiplier unit 38' so as to increase the degree of phase modulation effected by unit 37. A similar frequency multiplier 38 is located in the line feeding high frequency oscillator energy from unit 4 to the detector 2' of receiver 1', 2', 3'.

In the operation of the system of Fig. 4, the differentially detected output from 5 and 6 is fed to the phase modulator unit 37 so as to correct the phase of the high frequency oscillator energy fed thereto by unit 4, and in turn correct the phase relation between the two signal waves in the two receivers so as to maintain a 90° phase relation between the energizes from the two antennas A and A'. These two energies with constant phase relation are then fed to combining and detecting units 39, one of them being phase shifted to the desired relationship by means of

phase shifter 36. The coupling tubes of unit 39 are the same as coupling tubes 11 and 12 of Fig. 1. Instead of showing (in Fig. 4) the usual detectors 16 and 17 as illustrated in Figs. 1, 2 and 3, I show a jack 40 to indicate that any suitable utilization circuit may be linked thereto. This feature may also be used in any one of the systems of the other figures of the drawings.

In the diversity receiving system of Fig. 4, the phase modulator unit can be arranged, if desired, to correct the phase of the second intermediate frequency oscillator in a triple detection superheterodyne receiver, instead of the high frequency oscillator as is shown. By correcting the second oscillator, there is obtained the advantage of an increase in the flexibility of the receiver, since the phase modulator and the frequency multipliers would not then have to be tuned to tune in different signals.

Although the drawings show only two antennas in a diversity system, it will be understood that the circuits are not limited to two antennas and that if desired a third antenna with an associated third receiver can also be used. If such a third antenna is employed, the collected energy from the third antenna can be combined with the collected energy from the first two antennas by considering the combined output of the first two antennas as a single output and then combining the energy from the third antenna with the combination of the first two. This is a type of family tree arrangement which can be extended to combine the energies from any number of antennas in a diversity receiving system. Another method of combining the energies collected from more than two antennas would be to consider one of the receivers associated with an antenna as the standard to which the receivers of the other two antennas are to be combined; thus, such an arrangement would make two of the antennas in phase with the third one, so that they would be in phase with each other. What is claimed is:

1. The method of operating a diversity receiving system which includes collecting signal energy at two spaced points, combining the energies collected, producing a single voltage responsive to relative variations in phase of the two collected energies and utilizing said voltage to produce fixed changes of 180° in the phase relation of the combined energies.

2. A radio receiving system comprising a pair of antennas, a differential detector, means for feeding energy collected upon one antenna cophasally to said detector, means for feeding energy collected upon the other antenna antiphasally to said detector, an energy combining circuit, separate paths coupling each of said antennas to said energy combining circuit, and means responsive to an unbalance in the output of said differential detector for reversing the connections of one of the paths to said combining circuit, whereby the polarity of the energy in said one path applied to said combining circuit is also reversed.

3. A radio receiving system comprising a pair of spaced antennas, a receiver for each of said antennas including an oscillator in common to said receivers for heterodyning with the waves collected by said antennas to produce an intermediate frequency, a differential phase detector comprising a pair of vacuum tubes, a connection between the cathodes of said vacuum tubes, a first transformer having a pair of tuned circuits

one of which is connected between like electrodes of said vacuum tubes for applying out-of-phase potentials thereto and the other of which is connected to the intermediate frequency output of one receiver, a second transformer having a pair of tuned circuits one of which is connected between the cathodes of said vacuum tubes and the electrical center of said one tuned circuit of said first transformer for applying in-phase potentials to said like electrodes and the other circuit of which is connected to the intermediate frequency output of the other receiver, an energy combining circuit, separate paths from the intermediate frequency outputs of said receivers to said energy combining circuit, each of said paths including a coupling vacuum tube, and a circuit coupled to said differential phase detector and responsive to an unbalance in the output of said detector for reversing the connections of one of said paths.

4. A radio receiving system comprising a pair of spaced antennas, a receiver for each of said antennas, a differential phase detector comprising a pair of vacuum tubes, a connection between the cathodes of said vacuum tubes, a first transformer having a pair of tuned circuits one of which is connected between like electrodes of said vacuum tubes for applying out-of-phase potentials thereto and the other tuned circuit of which is connected to one receiver, a second transformer having a pair of coils one of which is connected between the cathodes of said vacuum tubes and the electrical center of the first tuned circuit of said first transformer for applying in-phase potentials to said like electrodes and the other tuned circuit of which is connected to the other receiver, an energy combining circuit, separate paths from said receivers to said energy combining circuit, each of said paths including a coupling vacuum tube, and a circuit coupled to said differential phase detector and responsive to an unbalance in the output of said detector for reversing the connections of one of said paths.

5. A system in accordance with claim 6, characterized in this that said circuit coupled to the differential phase detector and responsive to an unbalance in the output of the detector for reversing the connections of one of the paths includes a pair of polar relays whose windings are in series and connected to like electrodes of the detector, said one path including the armatures of said polar relays and certain contacts thereof.

6. A system in accordance with claim 4, characterized in this that said circuit coupled to the differential phase detector and responsive to an unbalance in the output of the detector for reversing the polarity of one of the paths includes a multi-grid tube whose suppressor grid is connected to the detector circuit and whose control grid is coupled to said one path.

7. A radio receiving system comprising a pair of antennas, like receivers for said antennas, a differential phase detector comprising a pair of vacuum tubes, a circuit from one receiver to said detector to feed energy in out-of-phase relation to said vacuum tubes, a circuit from the other receiver to said detector to feed energy in cophasal relation to said vacuum tubes, whereby no differential voltage appears in the output of said detector when the signal waves from the two receivers applied to said detector are 90° out-of-phase, an energy combining circuit, separate paths from said receivers to said energy combining circuit to apply high frequency energy there-

to, and a polarity reversing circuit located in one of said paths, said reversing circuit being coupled to said phase detector and responsive to an unbalance in the output of said detector caused by a departure of the signal waves from said 90° relation for reversing the connections of said one path.

8. In a radio receiving system, a pair of antennas, like receivers for said antennas, a differential phase detector comprising a pair of vacuum tubes, a circuit from one receiver to said detector to feed energy in out-of-phase relation to said vacuum tubes, a circuit from the other receiver to said detector to feed energy in cophasal relation to said vacuum tubes, whereby no differential voltage appears in the output of said detector when the signal waves from said two receivers applied to said detector are 90° out-of-phase, one of said circuits including a pair of thermionic discharge devices, each having anode, cathode, control grid and screen grid electrodes, there being provided means for feeding the energy in said one circuit to said control grids 90° out-of-phase relative to each other, a direct connection between the anodes of said devices for combining the outputs of said devices to obtain resultant energy of like frequency as the frequency of the waves in said one circuit, connections from the output of said differential phase detector for applying potentials in phase opposition to said screen grids whenever there is an unbalance in the output of said phase detector, an energy combining circuit, a path from one receiver to said energy combining circuit, said path including a phase shifter, a path from the outputs of said thermionic devices to said energy combining circuit, and translating means coupled to the output of said energy combining circuit.

9. In a radio receiving system, a pair of antennas, like receivers for said antennas, a differential phase detector comprising a pair of vacuum tubes, a circuit from one receiver to said detector to feed energy in out-of-phase relation to said vacuum tubes, a circuit from the other receiver to said detector to feed energy in cophasal relation to said vacuum tubes, whereby no differential voltage appears in the output of said detector when the signal waves from said two receivers applied to said detector are 90° out-of-phase, one of said circuits including a pair of thermionic discharge devices, each having a plurality of electrodes, a transmission line having its input terminals connected to the receiver associated with said one circuit and its output terminals terminated by an impedance of such a value as to cause only traveling waves to appear in said line, connections between points on said line which are 90° apart to the control electrodes of said devices, a direct connection between the output electrodes of said devices, connections from the output of said differential phase detector for applying potentials in phase opposition to other like electrodes of said devices whenever there is an unbalance in the output of said phase detector, an energy combining circuit, a path from one receiver to said energy combining circuit, said path including a phase shifter, a path from the outputs of said thermionic devices to said energy combining circuit, and translating means coupled to the output of said energy combining circuit.

10. Apparatus for reducing the fading of received radio waves comprising a pair of antennas for collecting transmitted waves, a differential detector, means for feeding energies collected

upon one antenna cophasally to the differential detector, means for feeding energies collected upon the other antenna antiphasally to said differential detector, purely electronic means for maintaining a predetermined phase displacement between the energies respectively fed to said differential detector, the last said means being responsive to an unbalancing of the output from said detector, and means for translating and utilizing the outputs of said antennas.

11. Apparatus for receiving radio waves comprising a pair of antennae, a receiver for each antenna, a differential detector, means for feeding energy from one receiver cophasally to said differential detector, means for feeding energy from the other receiver antiphasally to said differential detector, means including a differential modulator coupled between the output of said detector and the output of one receiver for maintaining a predetermined phase displacement between the energies fed to said differential detector, and means for combining and translating the outputs of said receivers.

12. A receiving system comprising a pair of antennas, a receiver for each antenna, a local heterodyne oscillator having a connection to one receiver and a connection to the other receiver for causing the energies collected by said antennas and impressed on said receivers to be converted to an intermediate frequency, a phase modulator in one of said connections for shifting the phase of the oscillator energy therein, a differential phase detector, a circuit from one receiver for feeding intermediate frequency energy cophasally to said detector, a circuit from the other receiver for feeding intermediate frequency energy antiphasally to said detector, and a circuit from the output of said detector to said phase modulator, whereby an unbalance in the outputs of said detector affects said phase modulator to correct the phase of the oscillator energy supplied to one of the receivers to thereby correct the phase relation between the energies supplied to said detector to maintain a substantially 90° phase relation therebetween.

13. A receiving system comprising a pair of antennas, a receiver for each antenna, a local heterodyne oscillator having a connection to one receiver and a connection to the other receiver for causing the energies collected by said antennas and impressed on said receivers to be converted to an intermediate frequency, a phase modulator in one of said connections for shifting the phase of the oscillator energy therein, a differential phase detector, a circuit from one receiver for feeding intermediate frequency energy cophasally to said detector, a circuit from the other receiver for feeding intermediate frequency energy antiphasally to said detector, and a circuit from the output of said detector to said phase modulator, whereby an unbalance in the output of said detector affects said phase modulator to correct the phase of the oscillator energy supplied to one of the receivers to thereby correct the phase relation between the energies supplied to said detector to maintain a substantially 90° phase relation therebetween, and separate means for combining and detecting the outputs of said receivers.

14. A receiving system in accordance with claim 13, including a frequency multiplier connected to the output of said phase modulator in order to increase the degree of phase modulation affected by said modulator.

15. A receiving system in accordance with

claim 13, including a frequency multiplier connected to the output of said phase modulator in order to increase the degree of phase modulation affected by said modulator, and also including a like frequency multiplier in the other connection from the local oscillator to the other receiver.

16. The method of operating a diversity receiving system which includes collecting signal energy at two spaced points, detecting in one circuit a part of the signal energies thus collected, diverting to another circuit the remaining part of the energies thus collected, producing a voltage whose polarity changes in response to relative variations in the phase of the energies detected in said one circuit, and utilizing said voltage to produce a relative change in the phase of the signal energies diverted to said other circuit.

17. The method of reducing fading of radio signals which includes collecting the signal energy at two spaced points, combining the collected energies, producing a single voltage responsive to relative variations in phase of the two collected energies, and utilizing said voltage to produce fixed changes of predetermined amount in the phase relation of the combined energies.

18. A radio receiving system comprising a pair

of antennas, a differential detector, means for feeding energy collected upon one antenna cophasally to said detector, means for feeding energy collected upon the other antenna antiphasally to said detector, an energy combining circuit, separate paths coupling each of said antennas to said energy combining circuit, and means responsive to an unbalance in the output of said differential detector for changing the relative phase of the energies in said separate paths.

19. Apparatus for reducing the fading of received radio waves comprising a pair of antennas for collecting transmitted waves, a differential detector, means for feeding energies collected upon one antenna cophasally to the differential detector, means for feeding energies collected upon the other antenna antiphasally to said differential detector, purely electronic means for maintaining the phase difference between the voltages respectively fed to said differential detector not greater than 90° , the last said means being responsive to an unbalancing of the output from said detector, and means for translating and utilizing the outputs of said antennas.

MURRAY G. CROSBY.