

April 30, 1935.

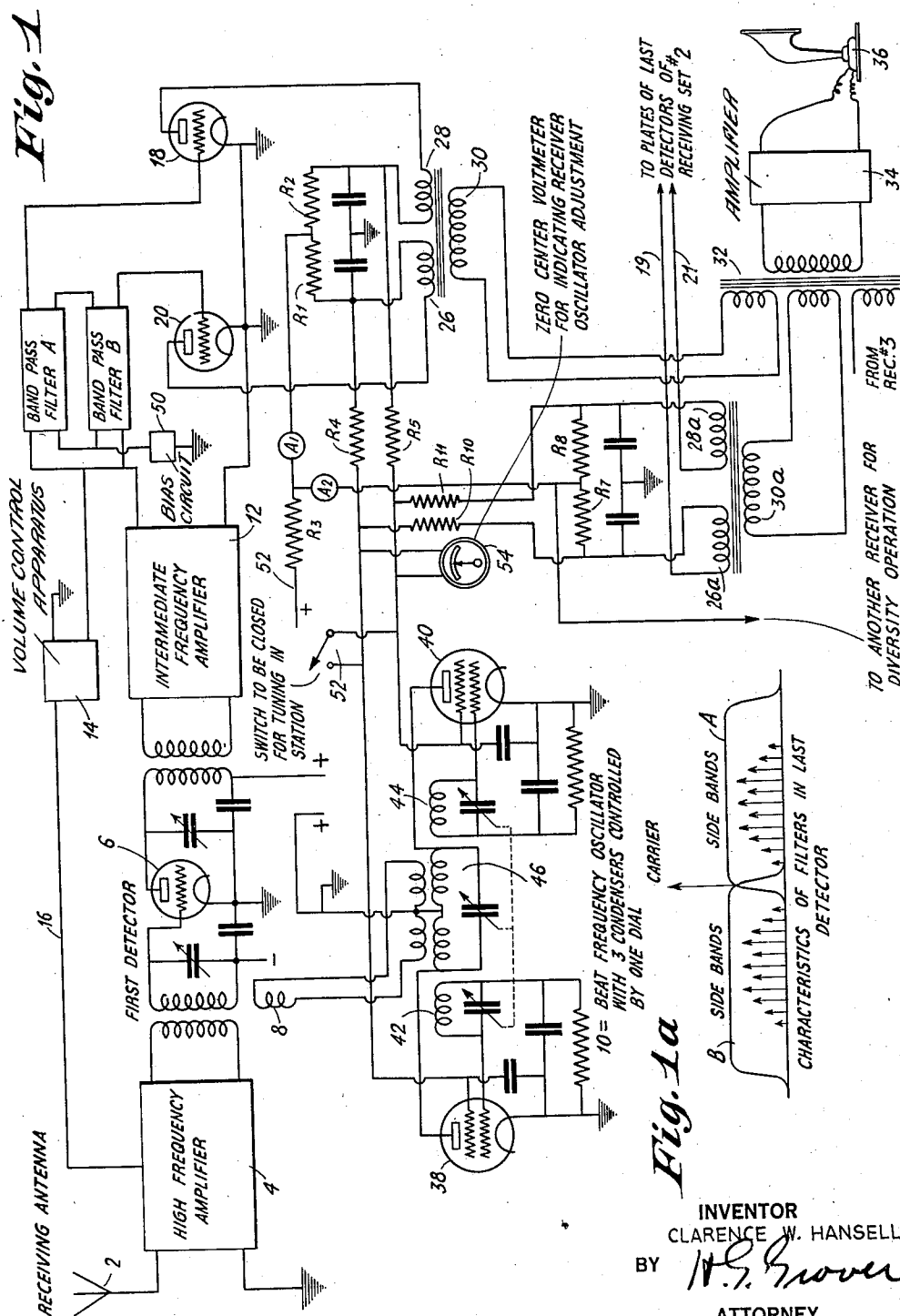
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1,999,902

SIGNALING

Filed May 13, 1932

4 Sheets-Sheet 1



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Fig. 2

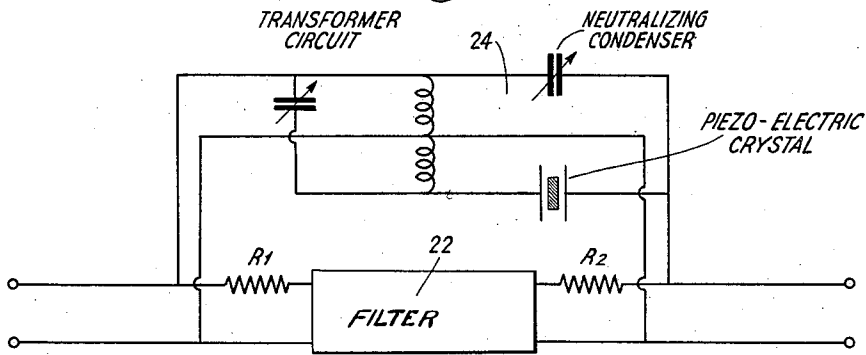


Fig. 3

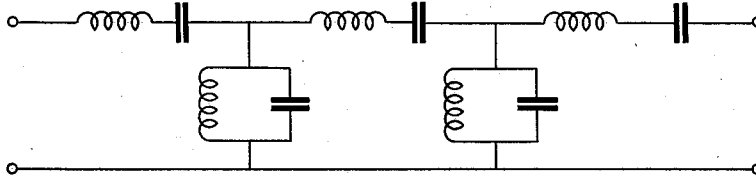
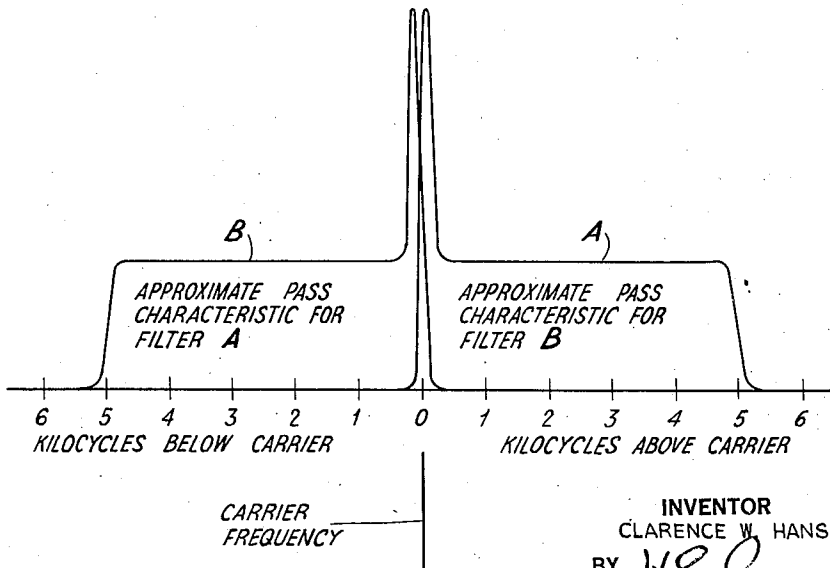


Fig. 4



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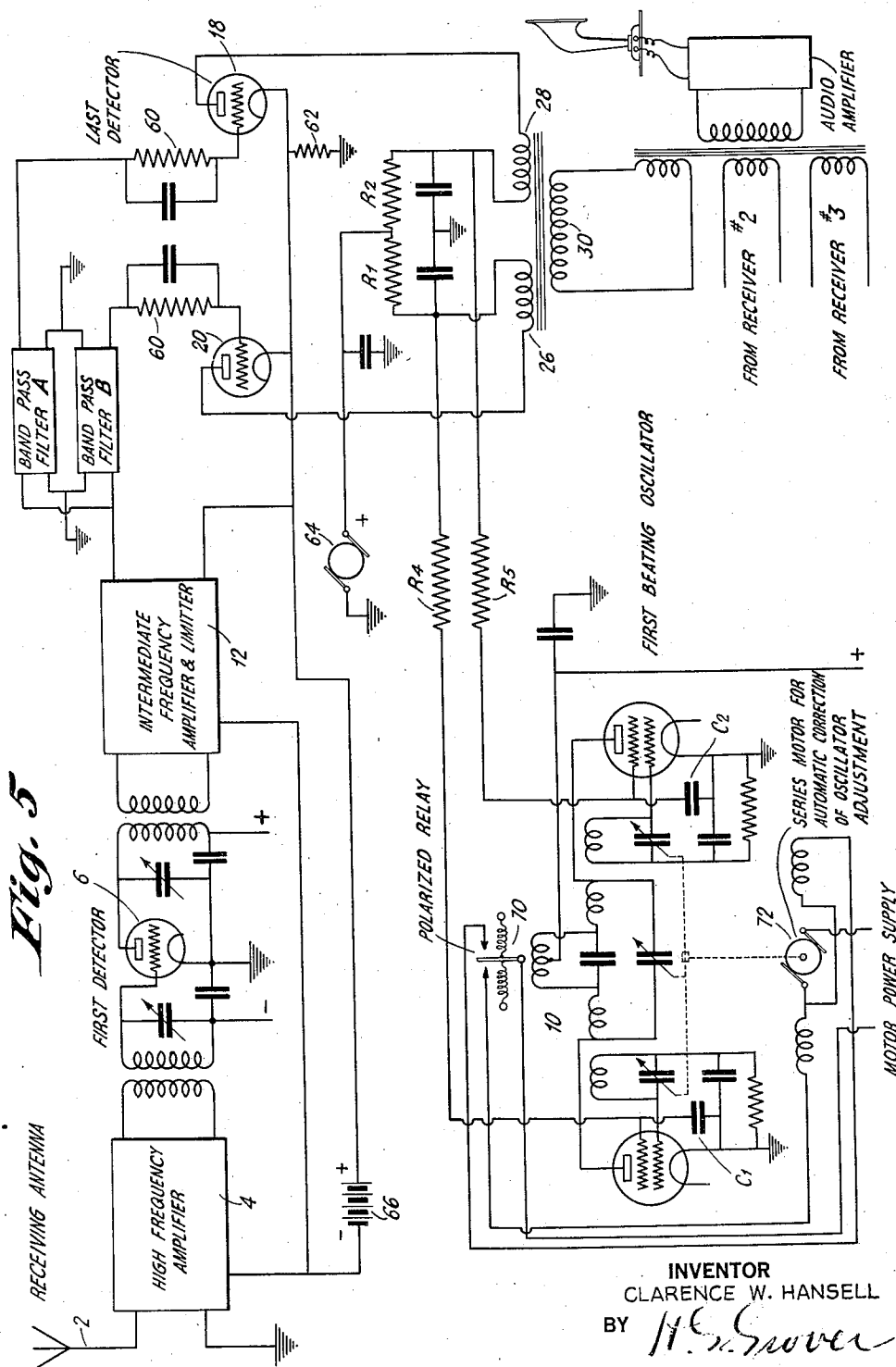
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4 Sheets-Sheet 4

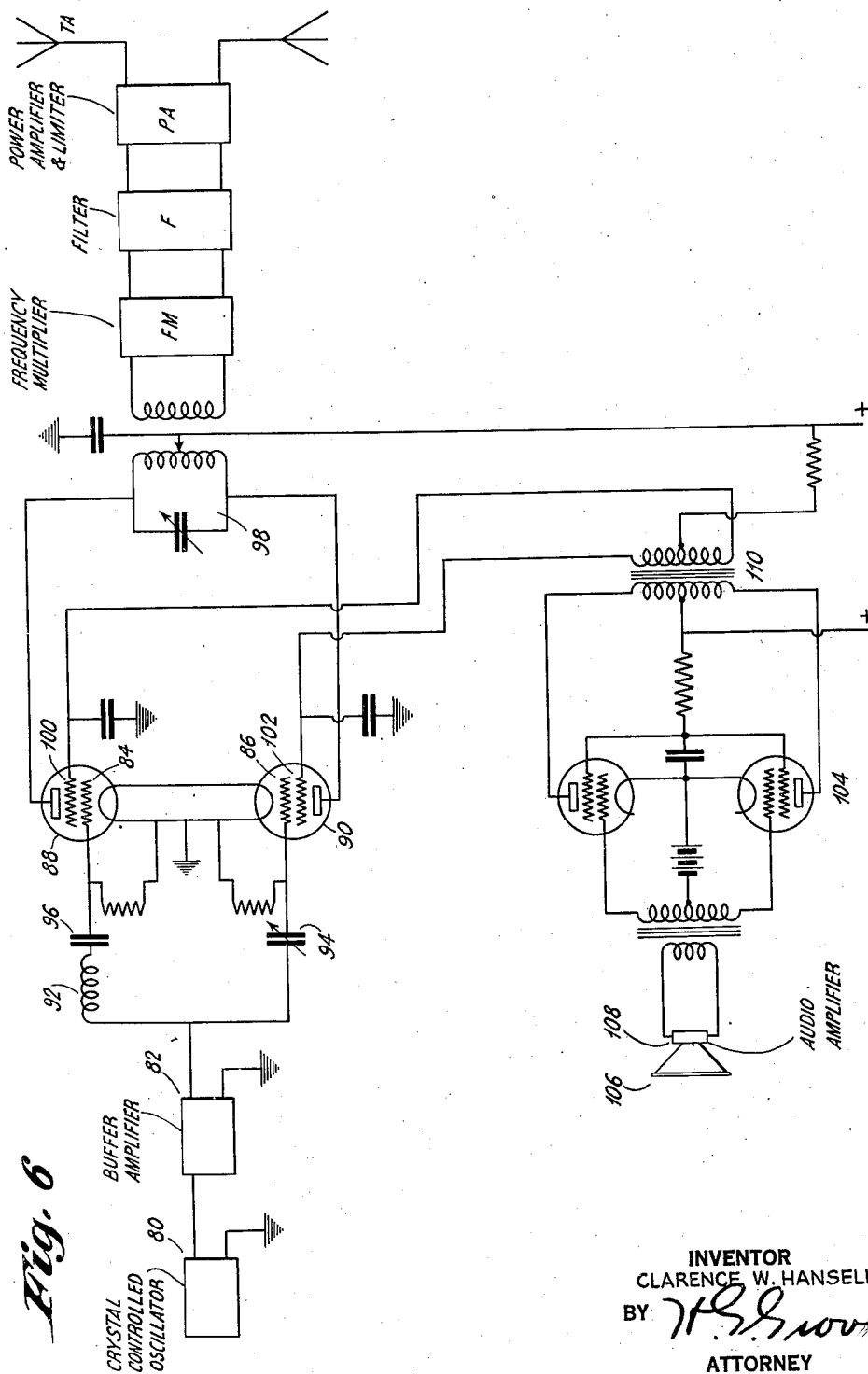


Fig. 6

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1,999,902

SIGNALING

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Application May 13, 1932, Serial No. 611,050

5 Claims. (Cl. 250—2)

This invention relates to signaling and is especially directed towards an improved method and means for signaling by phase modulating a carrier wave in accordance with intelligence to be transmitted from one geographically situated point to another. Although especially useful in connection with signaling by phase modulation, my present invention, however, is not limited thereto but as will be explained more fully hereinafter is also applicable to and gives beneficial results in signaling by frequency and amplitude modulation of a high frequency carrier wave. The signaling system disclosed herein is similar to the system disclosed in my copending application Ser. No. 670,846, filed May 13, 1933, which application is a division of the present application.

Fading at the higher frequencies or shorter wave lengths is still a troublesome factor which causes much signal variation and distortion. Not only does this phenomenon vary the intensity of a transmitted signal at receiving points, but also, broadly causes such effects as relative phase shifts between the component frequencies of a modulated signal, during transmission through space, which tend to cause dropping out of the signal at the receiver as well as producing distortion. The shift in relative phase of the side frequencies due to modulation, at differently located points, has offered the main obstacle in connection with diversity telephone reception schemes utilizing antennae situated at points spaced apart a considerable fraction of the received wave length. In amplitude modulation systems, for example, the resultant audio tones or frequencies due to the signal on each of the antennae would shift in phase in accordance with the relative phase shifts in the side frequencies at the separated antennae, causing an aggravated fading effect rather than as desired, increased signal strength and reduction of fading.

Beverage, Peterson and Moore have disclosed a system of diversity with phase modulation telephone reception for amplitude modulated waves in a paper entitled "Diversity Telephone Receiving System of R. C. A. Communications, Inc.," published in the April, 1931 issue of Proceedings of The Institute of Radio Engineers. Also I have described one system of diversity reception for frequency modulated waves in my U. S. Patent 1,803,504, filed October 5, 1928 and issued May 5, 1931. One object of my present invention is to apply diversity reception for reduction of fading effects on signals sent by modulating the phase of a carrier wave.

While I have mentioned in particular receiving antennae spaced apart a considerable distance relative to the received wave length, yet, it is to be clearly understood that my receiving system is not to be limited thereto but may consist of antennae located at approximately the same place arranged in different planes of polarization, or, the receiving system may include antennae diversified in space as well as in polarization, or, the antennae used may be arranged so as to have different directional characteristics.

I have further observed in connection with fading phenomena that horrible distortions in the detected signals occur when the strength of the received carrier current fades down to a value less than the peak strength of the side bands produced by modulation. To eliminate this difficulty is a further object of my present invention and in order to fulfill it, I provide a receiving system utilizing one or more detector tubes each of which is reached by only one side band of the received signal and the carrier. Consequently, there are no discontinuous distortions such as previously referred to when the carrier and both side bands reach a single detector tube and the maximum value of the side bands is greater than the carrier. That is to say, by allowing only the carrier and one side band to reach any one detector tube of my improved receiving system, it is possible to receive signals which have either been sent with, or which have been given by fading, more than 100% modulation, without producing the terrible distortion in the receiver output which would otherwise be the case.

While this object may be carried out by the use of one detector tube, as I have already indicated, I prefer to use two detector tubes and allow only one side band to reach one tube and the other side band to reach the other tube, while at the same time the carrier is made to act upon both tubes. In this manner there is more efficient utilization of the side bands, in fact both side bands may be used in producing useful signal output as will be described more fully in connection with the receiving systems illustrated on the attached drawings.

From what I have stated before, and considering the known characteristics of detectors, it should be apparent that, in order to obtain the best quality reproduction of the modulation or transmitted signal, it is desirable to have the carrier reach the detectors with its strength much higher than the maximum resultant of the

side bands. In other words the harmonic distortion in detectors is reduced by keeping the effective percentage modulation low. To do so forms a further object of my present invention.

5 To accomplish this purpose, I place ahead of my detectors, band pass filters having such a characteristic, that for very narrow frequency bands around the carrier frequency, or preferably, in the event that heterodyning is used, around the
10 intermediate frequency carrier, they pass energy of the carrier frequency with much lower attenuation than in the main portions of the passed bands.

These narrow bands of very low attenuation in
15 the two filters may be made identical but preferably they are made slightly different but overlapping in the same manner as the normal pass band in order to allow making the automatic control of the frequency of the first beating oscillator more positive, a feature which will be described more fully hereinafter.

To further "exalt", so to speak, the intermediate or carrier frequency relative to the other frequencies of the passed bands, I may increase the
25 attenuation of the said frequencies by the use of impedances or resistors, and increase the intermediate carrier frequency by means of a bypassing crystal filter which also will be more fully described later.

30 I have already stated that I prefer to use, in the receiving end of my improved signaling system, receivers of the heterodyne type. In the ordinary superheterodyne type of receiver it is common practice to take the incoming signal
35 picked up by a receiving antenna and amplify it through one or more stages of a high frequency amplifier. The output of the amplifier is then applied to a heterodyne detector, and commonly supplied with beat frequency energy
40 from a separate oscillator. The output of the heterodyne detector is usually an intermediate frequency which is still further amplified. The intermediate frequency amplifier which has a relatively narrow frequency pass band, permits
45 the desired signal to pass with, due to its narrow pass band, a minimum of accompanying undesired signals and noise. When the signal being received is an amplitude modulated phone signal, the output of the intermediate frequency amplifier is applied to a rectifying type of detector
50 and produces variations in the detector plate current which are substantially a true copy of the useful modulation.

When a receiver of this type is used for receiving very high frequencies, towards which my
55 present invention is particularly directed, difficulty is encountered due to the fact that it is impossible to maintain absolutely accurate frequencies in the transmitted carrier and in the beat frequency oscillator for the first detector of
60 the receiver. The variations in frequency of the transmitter and receiver oscillators increase about in proportion to the carrier frequency used, and cause variations in the intermediate
65 frequency energy of the receiver. For this reason it is found necessary to allow a sufficiently wide frequency band in the intermediate frequency amplifier so that the desired signal does not move outside the received frequency band, if the receiving system is to function satisfactorily in
70 commercial service. The breadth of the band necessary, however, adversely effects to an unwanted degree, the design of commercial receiving equipment. For example, in an inter-island
75 telephone circuit set up in the Hawaiian Islands

partly under my supervision, in order to make it possible for the signal to be always within the receiver frequency band, it was necessary to widen the frequency band of the intermediate frequency receiver circuits to about 60,000 cycles
5 whereas the maximum band required for the useful signal was only about 6,000 cycles. As a result, this receiver allows through it an amount of noise energy substantially 10 times as great
10 as would be the case were there no necessity to allow for variations in transmitter and receiver oscillators in setting the frequency selectivity of the receiver.

Another example of the deleterious effect of frequency variations is to be found in commercial short wave telegraph receivers in long distance short wave circuits wherein the receivers
15 require a frequency band of only about 250 cycles to accommodate the side bands produced by telegraph keying at speeds of 200 words per minute. However, due to the necessity for allowing for frequency variations in transmitter and receiver,
20 the intermediate frequency filter circuits must be designed with a band width approximately 2,500 cycles wide. Here again, approximately 10
25 times as much interfering energy is admitted as would be necessary if the effect of frequency variations in the output of the receiver could be eliminated.

Accordingly, a further prime object of my present invention is to eliminate the foregoing defects arising from variations in frequency of the transmitted carrier and variations in frequency in the locally generated heterodyning wave. Briefly to
30 do so, I eliminate variations in the intermediate frequency by utilizing signal energy applied to two detector or demodulator tubes, or electron discharge devices to cause differential variations
35 in potential which are utilized to correct the frequency of, say, the first beating oscillator. In this manner, the first beating oscillator is always
40 made to follow the frequency of the transmitter with a substantially constant frequency difference and therefore in the intermediate frequency amplifier circuits, there is no necessity to pass a
45 frequency band wider than that necessary to pass the useful modulation.

With my automatic tuning arrangement in simplified form, some difficulty may be encountered
50 in actual operation during times of extremely bad fading when the incoming signal may practically cease altogether for appreciable periods. Thus, if the amount of correction being applied to the first beating oscillator were quite great, in the event that the incoming signal dropped out the
55 oscillator would change greatly in frequency in returning to its natural frequency, so that when the signal came in again, the local oscillator might cause an intermediate frequency after the first detector beyond the pass bands of either of
60 the filters for the last detector. To avoid this possibility which would require attention from an operator to manually tune in the signal again, since under the circumstances outlined, the signal cannot control the first beating oscillator, I
65 further provide means, which will be described more fully later on, to keep the receiver circuits always closely adjusted to the correct value so that in the case of absence of signal the first beating oscillator does not change greatly in frequency.

It is undesirable to have the automatic frequency controlling feature just referred to in operation while initially tuning in a station, since
75 once tuned to a station, the receiver would auto-

matically hold its own condition to receive that station and render the operator powerless to turn into some other desired station, I provide as a further feature of my present invention, means for rendering the automatic frequency controlling apparatus inoperative during tuning periods.

There are additional objects in my invention of a more specific nature which will appear in connection with more detailed descriptions of equipment hereinafter.

In the accompanying drawings wherein I have illustrated preferred embodiments for carrying into effect the various features of my present invention, Figure 1 illustrates a diversity receiving system particularly adapted for reception of phase modulated waves and having the feature of automatic frequency control for the heterodyning oscillator;

Figure 1a is a graph illustrating the frequency characteristics of band pass filters to be used ahead of the second or last detectors of the receiving system shown in Figure 1;

Figure 2 illustrates a preferred filtering arrangement to be used in connection with my improved receiving system wherein the carrier frequency may be exalted above the side frequencies in order to reduce the effective percentage modulation at the detectors and so reduce their distortion;

Figure 3 illustrates a band pass filter which may be utilized in connection with the arrangement shown in Figure 2;

Figure 4 illustrates graphically, the characteristic of a pair of band pass filters such as illustrated in Figure 2 for my improved receiving system;

Figure 5 illustrates an improved modification of the receiving arrangement shown in Figure 1 having in addition to the arrangement shown in Figure 1, means for preventing ill effects due to dropping out of a signal entirely; and,

Figure 6 illustrates a preferred form of phase modulation transmitter to be used in connection with my improved receiving system.

Referring to Figure 1, which illustrates a preferred form of receiving system having many features of my present invention, the receiving antenna 2 feeds energy to a high frequency amplifier 4, preferably of the cascaded vacuum tube type having tuned coupling circuits. The output of the high frequency amplifier 4 is fed to a first detector 6 preferably of the power type. The first detector 6 is also supplied with locally generated heterodyning waves through an inductive link 8. This link 8 is not essential for, in the event that the beat frequency oscillator 10 is not shielded, coupling to the detector is obtained unavoidably. In fact no special coupling circuit under those circumstances need be added. Best design, however, would require the oscillator to be thoroughly shielded and placed in a separate compartment and in this case some form of adjustable coupling such as conductive link 8 may be added to good advantage.

The output of the first detector, by a suitable choice of oscillation frequency of the oscillator 10, is of some relatively low radio frequency. The value of this intermediate frequency fed to the intermediate frequency amplifier 12 should be sufficiently low to permit the desired degree of selectivity in the intermediate frequency amplifier. However, the value of the intermediate frequency in cycles per second should always be greater than half the width of the pass band of the high frequency amplifier and preferably it

should be greater than the width of the pass band of the high frequency amplifier in order that the noise energy in the intermediate frequency circuits may be made a minimum. In receiving very high frequency, or short wave signals, it may sometimes be necessary to pass through two or more stages of heterodyne detector, each preceded by amplifiers and frequency selective circuits, in order to permit carrying out this requirement for obtaining minimum noise. It should be understood that, where necessary this would be done.

In receiving phase modulated signals the intermediate frequency amplifier is operated preferably as a limiter, that is to say, it amplifies the minimum amount of energy fed to it so as to bring its output at all values of input to a constant value. In other words, the intermediate frequency amplifier is designed and adjusted in such a way that the minimum excitation applied to the first tube of the amplifier is more than that required to produce saturation of the last tube. To assist in this action, or in place of it, a portion of the intermediate frequency amplifier output may be fed to a volume control or further detector 14 of any well known type, whose unidirectional output is utilized to control the grid bias through conductor 16 of the tubes forming the high frequency amplifier such that the high frequency amplifier is made to furnish substantially sufficient constant input to the intermediate frequency amplifier through the intermediary of the first detector. Although, in Figure 1 I have shown detector 14 supplied with energy from the final output of the intermediate frequency amplifier it should be understood that the energy might be taken from any of the intermediate frequency amplifier stages.

The intermediate frequency energy is passed through the intermediate frequency amplifier and the constant amplitude intermediate frequency energy (due of course to the limiting action of the intermediate frequency amplifier together with the volume control circuit 14, 16) is fed to two band pass filters A B having overlapping characteristics as illustrated in Figure 1a. The wiring diagram of each of the filters A and B may be as indicated in Figure 3 which, of course, is only illustrative of many of the forms which the band pass filters A and B may take. The overlapping characteristic of the two filters should be such as illustrated in Figure 1a so that the intermediate frequency carrier may be allowed to reach both of the second or last detector tubes 18, 20. By adjusting the local oscillator 10 the intermediate frequency carrier is made to fall within the band common to both detector filters A B. It should be understood, however, that the amount of overlapping frequency band in the two filters should be small so that substantially only the carrier and one side band can reach each of the final detector tubes 18, 20.

However, I prefer to make each of the band pass filters in the form illustrated in Figure 2 such that the combined characteristic of both filters will be that illustrated in Figure 4. Thus, referring to Figure 2 by shunting in parallel with any type of electrical circuit band pass filter 22 which may be of the type illustrated in Figure 3, a neutralized piezo-electric crystal circuit 24 which passes only a very narrow band of frequencies, this narrow band is increased in value relative to the other side frequencies. This predominant passing action for the very narrow

band may be further increased by the use of attenuating impedances or resistors R_1 R_2 as illustrated in Figure 2. These attenuating resistors serve to further attenuate the side frequencies passed by the band filters 22 or filters A and B of Figure 1. This particular arrangement of filtering circuit giving a filter a desired characteristic is more fully described in my copending application, Serial Number 547,770, filed September 24, 1931, any of the arrangements of which may, of course, be used here. The neutralizing feature is more fully described in my copending application, Serial Number 203,901, filed July 7, 1927.

The carrier and one side band which reaches each detector of the last detectors 18, 20 produces beats in the outputs of the detectors corresponding to the modulation introduced at the transmitter. Since these beats from the two detectors will be 180 degrees out of phase with one another if phase modulation is used, the plate output coils 26, 28 should be coupled magnetically to the common audio output coil 30 in pushpull relationship so that their outputs add rather than cancel. In the event that the transmitter has its carrier wave amplitude modulated, the outputs of the two detectors should be coupled with like polarities or effectively in parallel which may be done by reversing the connections from one of the coils relative to the other so that the output in the output coil 30 is cumulative. For frequency modulated waves, the connections should be made similar to those for phase modulated waves, that is to say, the coils 26, 28 should be coupled effectively in pushpull relationship or substantially to the two detector tubes 20, 18. Insofar as the operation of the receiver shown in Figure 1 is concerned, the only change necessary to modify reception from phase or frequency modulation to amplitude modulation is merely the reversal of the connections to one primary winding of the output transformer comprising primary windings 26, 28 and secondary winding 30.

In the case of diversity reception, the output conductors of, say, receiver number 2, are connected as illustrated at 26a, 28a and 30a, corresponding to the connections for coils 26, 28 and 30. For simplicity only the final detector connections of the other receivers are shown. The conductors 19, 21 lead, of course, to the plates of the second detectors for receiving set number 2, which detectors would correspond to detectors 18, 20. The final output of each antenna from each receiver may then be fed as shown to a common transformer 32, the primaries of which are connected to the respective coils of each radio receiver such as coils 30 and 30a. In the secondary of transformer 32, there will appear, of course, the combined output which may be amplified by a suitable amplifier 34 and fed to a suitable translating device 36.

The constants of the detector output and combining circuits should be such that, when the signal has completely faded out of all but one receiver, the impedance of the output circuit is such as to take approximately maximum power from the one receiver. Then, when all receivers are working, their mutual reaction upon one another changes their output impedances, lowering the output from each receiver and so tending to give the same output as if only one receiver were working. Thus the combined power output of the group of receivers tends to remain constant.

In addition to the output transformer 26, 28,

30 of each receiver, or more simply in the receiving set number 1 completely illustrated in Figure 1, two resistances R_1 , R_2 may be connected as shown. The amount of direct current through these two resistances varies differentially as the intermediate frequency carrier varies in frequency towards one or the other of the pass bands of the two band pass filters A, B. This differential variation in current is used to cause differential variations in the adjustments of the oscillator 10 for the first detector 6 and these variations in adjustments move the frequency of the oscillator in such a direction as to tend to keep the currents through R_1 R_2 equal or in other words, to maintain the constant frequency difference between the output of the local oscillator 10 and the received high frequency carrier.

To accomplish this I may use any oscillator capable of having its frequency controlled. In the circuits shown in Figure 1 I make use of a form of oscillator quite similar to my improved variable oscillator described in my copending applications Serial Number 336,772, filed February 1, 1929, and Serial Number 463,614, filed June 25, 1930. As illustrated here my variable oscillator 10 consists of two screen grid oscillator tubes 38, 40 having separate tuned grid circuits 42, 44 with a common tuned plate circuit 46. The two grid circuits are tuned to different frequencies, one being tuned to a frequency higher than the desired heterodyning frequency, while the other is tuned to a frequency lower than the desired frequency of operation of the oscillator 10. The plate circuit 46, however, is tuned substantially to the desired beating frequency which is intermediate to the frequencies for which the grid circuits or control electrode circuits are tuned. As explained in my copending applications, in an oscillator of this type the frequencies of the oscillations produce a compromise between the frequencies which each of tubes 38, 40 would produce if oscillating alone.

By differentially varying the outputs of the tubes 38, 40 by applying the voltage variations across resistances R_1 and R_2 to the screen grids thereof as shown, one tube or the other predominates in producing oscillations in the common output circuit 46. As a result, the output frequency of oscillator 10 may be varied back and forth between the limits set by the frequencies of oscillation of each tube when used alone.

Consequently, the output frequency of the oscillator 10 is put under control of the detector tube plate currents since the voltage variations across resistances R_1 and R_2 are proportional to the detector plate currents and the frequency of the local oscillator 10 is automatically adjusted to such a value that the detector plate currents are always substantially balanced across resistors R_1 and R_2 and the intermediate frequency of the receiver is substantially in the center of the receiver pass band.

If for any reason the transmitter frequency varies or the circuits of the local oscillator vary their tuning due to changes in temperature humidity and so forth, in such a way as to produce a variation in the intermediate frequency of the receiver, the variations are automatically compensated for by the methods shown. For example, if desired, the transmitter frequency might be varied over a considerable range and the receiver adjustments would automatically follow the transmitter so that the desired signal might be received always with maximum efficiency and a minimum of undesired noise.

In addition, this arrangement also provides for the retention of a receiver in tune with a transmitter whose frequency is varied for secret signaling. That is to say, my present receiver may be applied to a secret signaling system without the need of any complicated synchronizing arrangements at the receiving end as now required in such systems. The transmitter frequency may be varied through wide limits and the receiver with my receiving apparatus would always follow the transmitter frequency so that there is a constant intermediate frequency which may be detected as shown.

In the circuits shown in Figures 1 and 5 I have assumed that each receiver has its own separate beating oscillator for its first heterodyne detector. However, if desired, a common beating oscillator may be used for all receivers in which case it is preferable that all the detectors contribute to the control of the common beating oscillator. Thus I may utilize the drop in resistors R_7 , R_8 , as well as R_1 , R_2 , through resistors R_{10} , R_{11} , and R_4 , R_5 , to control the frequency of the beating oscillator, as shown in the dotted connections of Figure 1. In this case, so long as carrier energy reaches either receiver the oscillator frequency remains under control. Of course, any number of receivers may be connected up in the same way to contribute to the oscillator control and the probability of control being lost, due to fading of the carrier, is greatly reduced. Also, for the other receivers similar coupling units 8 may be used for supplying the local frequency thereto, or, if desired, the output of the local oscillator 10 may be radiated or carried by wire line to each receiver. Or, receiving apparatus may be placed together and exposed to the fields of the oscillator 10 which is left unshielded.

It is not necessary, of course, to use the form of oscillators 40, 38 illustrated, but any other type of oscillators such as referred to in my copending applications may be used. Also detector 14 and control circuit 16 may be omitted for receiving phase or frequency modulation or a common detector 14 may be used and the conductor 16 be used to control the bias on all of the high frequency amplifiers or detector 14 may be duplicated at each receiver and the detector outputs paralleled to obtain a common volume control which will tend to make the output from the receiver with the strongest received carrier predominate in giving output. For receiving amplitude modulation with my system I would not use limiting in the intermediate frequency amplifier system, because that would remove the modulation. Instead I would rely chiefly on the automatic volume control through 14 and 16 and upon the characteristic of the detectors 18, 20 in conjunction with voltage drop in resistor R_3 to obtain relatively constant output from each receiver. The biasing means for the detectors illustrated diagrammatically at 50 may be batteries or any other negative polarizing source. The common resistor R_3 may be inserted in the plate supply lead 52, the voltage drop across which in the event of a good signal on receiver 1 will be sufficient to more than proportionally reduce the outputs of receivers numbers 2 and 3 so that the noise level may be reduced. In other words, with R_3 in circuit, usually only one antenna supplies a useful energy output while the other antennae are effectively disconnected from the circuit. In principle the action of the circuit, in this case, is similar to that described by Beverage, Peterson

and Moore in the reference previously cited. However, resistor R_3 is not essential and may be omitted. In that case all of the antennae are coupled into circuit.

In other words, with resistor R_3 in circuit, as the strength of the incoming carrier picked up by the various receiving antennae and delivered to the various receivers varies, there would be produced a potential drop across resistor R_3 to cause the receiver with the strongest carrier to predominate over the other receivers furnishing audio output. This action is more fully described in the copending application of Harold O. Peterson, Serial Number 319,938, filed November 16, 1928. Or, in my improved receiving system a mechanical relay switching arrangement such as disclosed by John B. Moore in his United States application, Serial Number 319,768, filed November 16, 1928, may be used; or if desired for this purpose, as will be apparent to those skilled in the art, successive antenna selection by change of grid bias such as described by Harold O. Peterson in his copending application, Serial Number 309,877, filed October 2, 1928, may also be used to good advantage here. However, the system which I have shown here has marked advantages over others in that there need be no time delay in the action of the voltage drop in resistor R_3 so that a more perfect final output results.

I have stated that in receiving phase and frequency modulation limiting may be used in the intermediate frequency amplifier 12, but it is to be clearly understood that such action may also be used in addition in the high frequency amplifier 4 to reduce the effect of fading upon the strength of output from each receiver.

Also, the potential variations across the resistors R_1 and R_2 may be used as will be apparent to those skilled in the art to vary the plate potentials on the local oscillator tubes 38, 40 or, to vary their control grid potentials in order to vary their outputs differentially. In fact any system in which frequency variations may be produced by variations of potential might be used.

Obviously, it would be almost impossible to tune the receiving system from one station to another with the frequency controlling arrangement in circuit, for, under such circumstances, or if the receiver happened to be tuned into an undesired station inadvertently, the receiver would automatically hold its own condition to receive the undesired transmitter and no other. Consequently, to allow change in tuning from one station to another, the local oscillator 10 is provided with a switch 52 which, when closed, short circuits voltage variations across resistors R_1 , R_2 away from the screen grids of tubes 38, 40. The resistors R_4 , R_5 are in circuit in order to reduce the D. C. voltage applied to the screen grids of tubes 38, 40 to a suitable value. With the switch 52 closed, the receiver can be tuned to any desired station, and, once tuned, opening of the switch 52 will cause automatic frequency controlling action of the receiving system.

In addition to the switch 52 I have provided a zero center voltmeter 54 which may be used to indicate the condition of tuning adjustment of the receiver at all times. With this voltmeter, the operator may adjust the circuits of the beat frequency oscillator to put a minimum demand upon the automatic frequency correction equipment, which is another feature of my present invention. To facilitate tuning and to allow the outputs from the receivers to be initially equalized I have added

ammeters A₁ and A₂ which normally should show equal average currents. Of course the usual jack plugs, switching, metering, monitoring and other features common to receivers may be used, though omitted in the diagrams for simplicity.

In general all of the remarks applied to the system of Figure 1 apply with equal force to the arrangement of Figure 5. As the grid bias connections of the last detectors shown in Figure 5 are illustrated in the form of grid leak and condenser arrangement 60, for volume control a resistor 62 is inserted in series with the ground and filament connection of the detector tubes 18, 20. Consequently, with strong signals, the output plate currents of the last detectors 18, 20 are relatively small allowing a high negative bias from source 66 to be impressed upon the control grids of the high frequency amplifier 4 and intermediate frequency amplifier 12. However, with weak signals, the detector output currents are increased and the voltage arising across resistor 62 will be in such a direction as to compensate the source 66 and make the bias upon the high frequency amplifier and intermediate frequency amplifier tubes less negative thereby increasing the output of the intermediate frequency amplifier 12. In view of the reversed current action in the detector tubes care must then be taken so that the differential voltage variations across resistors R₁, R₂ cause the correct variation in output frequency of the local oscillation generator 10.

This local oscillation generator 10 of Figure 5 is a little different from the one described in connection with Figure 1 and has the refinement that the local oscillator will not greatly vary in frequency when the signal drops out at the antenna 2. That is to say, if the amount of correction being applied to the first beating oscillator 10 were quite great and should the incoming signal drop out at antenna 2, the oscillator would change greatly in frequency in returning to its natural frequency so that when the signal came in again it might cause an intermediate frequency after the first detector 6 entirely outside of the pass bands of either of the filters A, B, for the last detectors 18, 20. In this case, the signal cannot regain control of the first beating oscillator where one antenna is used and the attention of an operator is required to tune in the signal again.

To avoid such a difficulty, a polarized relay 70 is added to the local oscillator 10 of Figure 5 which in turn is operated by the unbalanced currents through the detector tubes of the receiver. The relay is used to control a small motor 72 in one direction or the other to keep the receiver always near the exactly correct adjustment. In effect, therefore, the voltage variations applied to the screen grids as illustrated in Figure 5, compensate the relatively rapid frequency fluctuations while the motor operated control follows the slow variations.

By tracing the circuits shown in Figure 5, it will be found that the polarized relay is operated by differential variations of plate currents of the oscillator tubes. This relay, of course, could also be operated by potential differences across resistors R₁, R₂.

To simplify adjustment of the local oscillator 10, unicontrol is provided for all of the tuning condensers as in the case of the beating oscillator 10 of Figure 1.

As an alternative arrangement for the motor of Figure 5, which as shown has series field wind-

ings, only one of which is used at a time and which is so connected as to reverse the field and direction of rotation depending upon which is energized, a shunt motor may be used and the relay arranged to reverse the direction of the armature current. Still another alternative method, rather than the one illustrated, may be to allow the motor to run always in one direction and engage electrically operated reversing clutches operated by the relay.

The relay 70 should be so designed magnetically, or preferably should be so equipped with springs as to hold the contacts open unless the tube current unbalance exceeds a chosen value. Adjustable springs are preferred so the relay can be biased to compensate for tube and circuit characteristics.

As illustrated in Figure 5, the final output coils of the detectors are coupled for giving an audio output from either phase or frequency modulated waves. For amplitude modulated waves one of the primary coils 26, 28 may be reversed in polarity relative to the other. The secondary audio output appearing in coil 30 may be combined with audio outputs from similar receiving systems utilizing energy from the local oscillator 10. The other receiving systems, preferably, have independent antennae separated apart a considerable fraction of the operating wave length.

As I have already indicated, I prefer to use phase modulation in combination with my receiving system either utilizing a single receiver or preferably a plurality of receivers arranged in diversity fashion. The phase modulation transmitter which I prefer to use is illustrated in Figure 6.

By means of a very constant oscillator such as a crystal controlled oscillator 80, described in my copending application, Serial Number 540,310, filed May 27, 1931, or in the copending application of James L. Finch, Serial Number 531,684, filed April 21, 1931, constant frequency oscillations are fed to a buffer amplifier and/or frequency multiplier 82. The output of the buffer amplifier is fed in parallel to the control grids 84, 86 of tubes 88, 90 through the inductor 92 and condenser 94. Condenser 96 is merely a direct current blocking condenser offering no appreciable reaction and having practically no effect upon the inductance of inductor 92. The parallel tuned circuit 98 connected to the plates of tubes 88 and 90 is tuned to the output frequency of the buffer amplifier 82.

By rendering one of the tubes more conductive than the other, for example, by increasing the potential on the screen grid of one of the tubes 88, 90, relative to the potential on the other screen grid of that pair of tubes, the current appearing in the output circuit 98 will be caused to lag or lead dependent upon whether or not control is by tube 88 or tube 90, in other words, whether or not the feed is through inductor 92 or condenser 94. Consequently by applying modulating potentials to the screen grids 100, 102 from the audio amplifier 104, the currents in circuit 98 will be phase shifted in accordance with the modulation supplied by the microphone or modulating source 106.

These phase modulated waves may then be fed to a suitable frequency multiplier and amplifier FM to augment the degree of phase modulation and then fed to a power amplifier and limiter PA and subsequently radiated over a suitable transmitting antenna TA. I prefer to place ahead of

the power amplifier a suitable filter F in order to control the side band width of the energy radiated and maintain it within a prescribed frequency.

In the event that secret signaling is used the oscillator 80 should preferably be of the regenerative control type having a tuning condenser for either the input or output circuit or both which controls the frequency of oscillations generated. This tuning condenser may be varied through limits either in oscillating fashion or continuously rotated to alter the frequency of the transmitted wave. In that case the filter F would require a somewhat larger pass band.

Having thus described my invention, what I claim is:

1. The method of signaling for overcoming fading at short wave lengths which includes at the transmitter generating a constant frequency carrier wave, generating modulating potentials, shifting the phase of the constant frequency carrier wave in accordance with the modulating potentials generated, transmitting the resultant phase modulated carrier waves, and at the receiver, collecting the radiated phase modulated energy at a plurality of separated points, at each of the collection points separating the collected energies into two portions comprising carrier energy and energy of one side band only and carrier energy and only the other side band energy, separately detecting each of the portions so collected, combining the detected portions in opposed phase, and combining the combined detected energies and translating the resultant energy.

2. The method of eliminating fading effects at short wave lengths which includes phase modulating a carrier wave in accordance with intelligence to be transmitted, transmitting the carrier energy so modulated in phase and at the receiver collecting the radiated energy at a plurality of points separated apart an appreciable fraction of the transmitted wave length, separately amplifying the collected energies, varying the amplification of the collected energies in response to the volume of the energies collected at each of the separated points so as to maintain the amplified energy constant, separately detecting side bands of the constant volume amplified energy with energy of carrier frequency, combining the separately detected portions of energy from each antenna in phase opposition, combining all of the energies combined in phase opposition, co-phasally, and translating the cophasally combined energies.

3. In a system for reducing fading of propagated short waves, the combination of a transmitter for transmitting waves modulated in phase in accordance with intelligence to be transmitted, and, a receiving system comprising a plurality of separated antennae, separated apart an appreciable fraction of the transmitted wave length, means to separately limit the collected energies to constant value to eliminate the effects of fading at each of the antennae, means for separately detecting each of the side bands of the limited energies with carrier energy, means for combining the separately detected energies of each antenna in opposed phase relationship, means for combining the energies so combined cophasally, and means for translating the combined energy.

4. A system for eliminating fading of short waves which waves are modulated in phase in accordance with signals to be transmitted comprising a plurality of antenna collecting the transmitted phase modulated short waves, means individual to each of a plurality of said antenna separating the energies collected thereon into two portions comprising carrier energy and energy of one side band only and carrier energy and only energy of the other side band, separate detectors separately detecting each of the portions so separated, means combining the combined detected energies and means translating the resultant energy.

5. In a system for effecting fading effects of short waves continually modulated in phase in accordance with signals to be transmitted a plurality of antenna spaced apart an appreciable fraction of the transmitted wave length, amplifiers individual to each antenna for amplifying the energies collected thereby, means varying the amplification of the energies collected on each antenna in response to the total volume of the energies collected upon the antenna so as to maintain the amplified energy substantially constant, detectors separately detecting side bands of the constant volume amplified energy with energy of carrier frequency, means combining the separately detected portions of energy derived from each antenna in phase opposition, means combining the energies combined in phase opposition, cophasally, and translating means translating the co-phasally combined energies.

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