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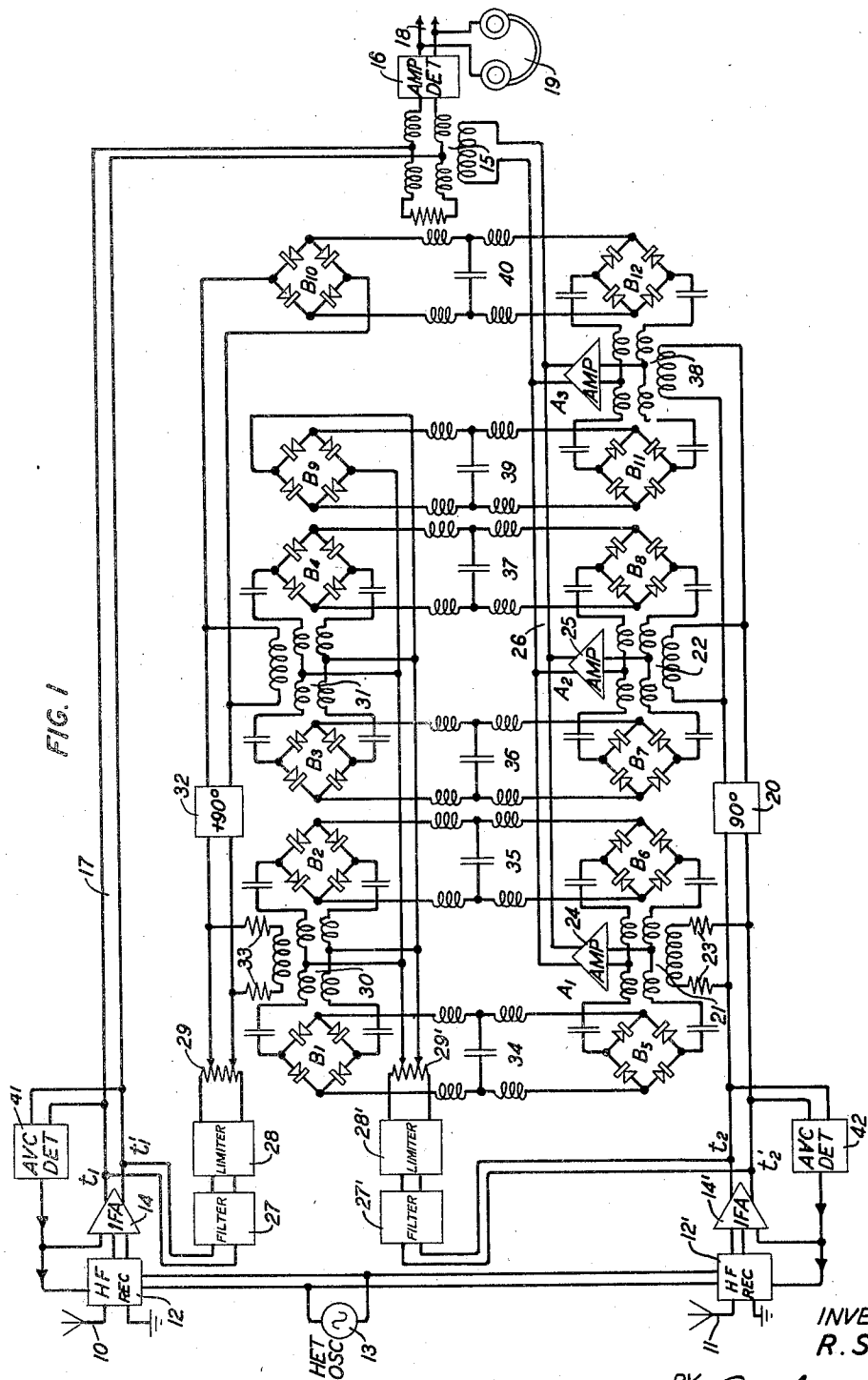
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2,089,409

PHASE CORRECTING MEANS AND METHOD

Filed April 14, 1936

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

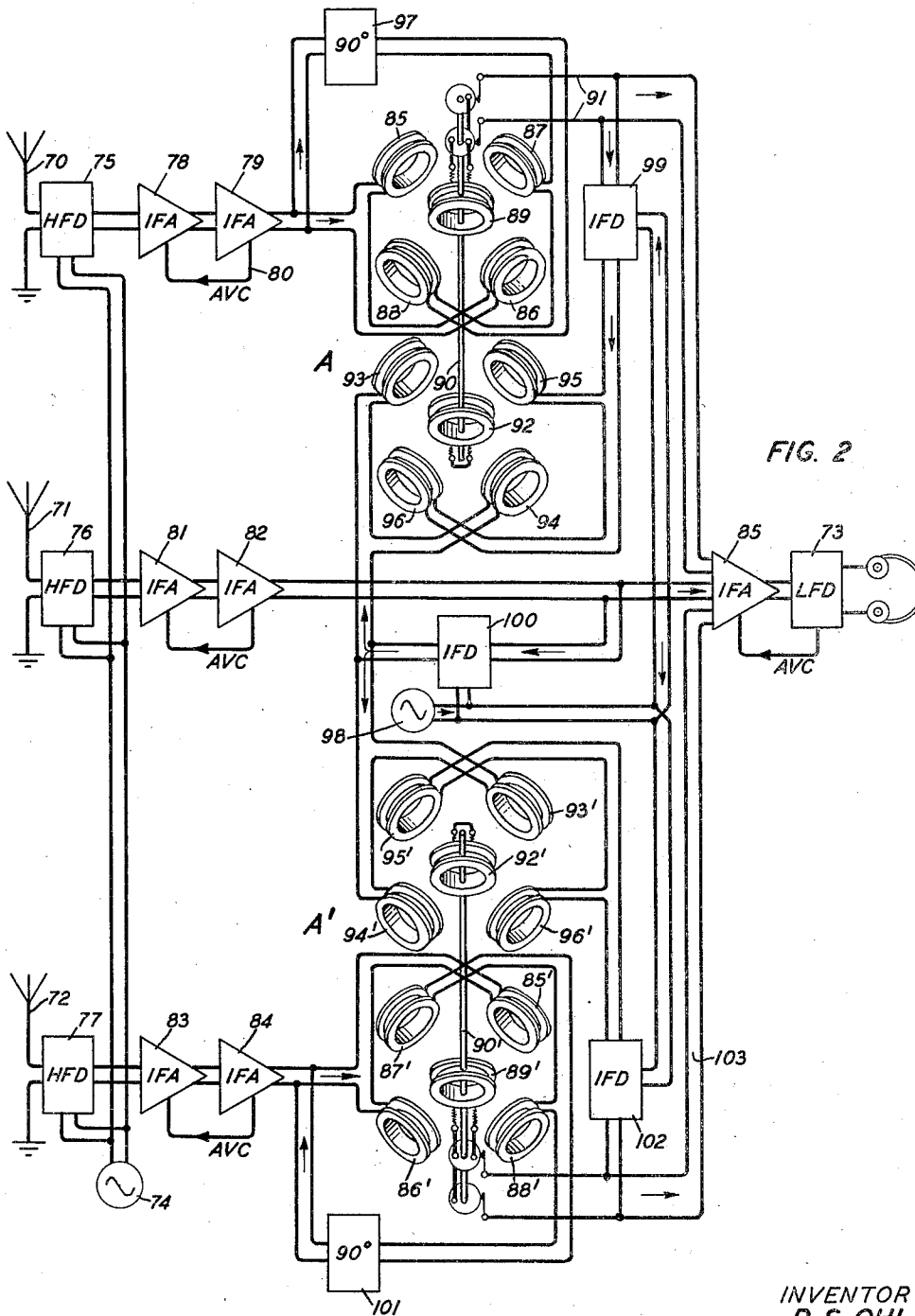


FIG. 2

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3 Sheets-Sheet 3

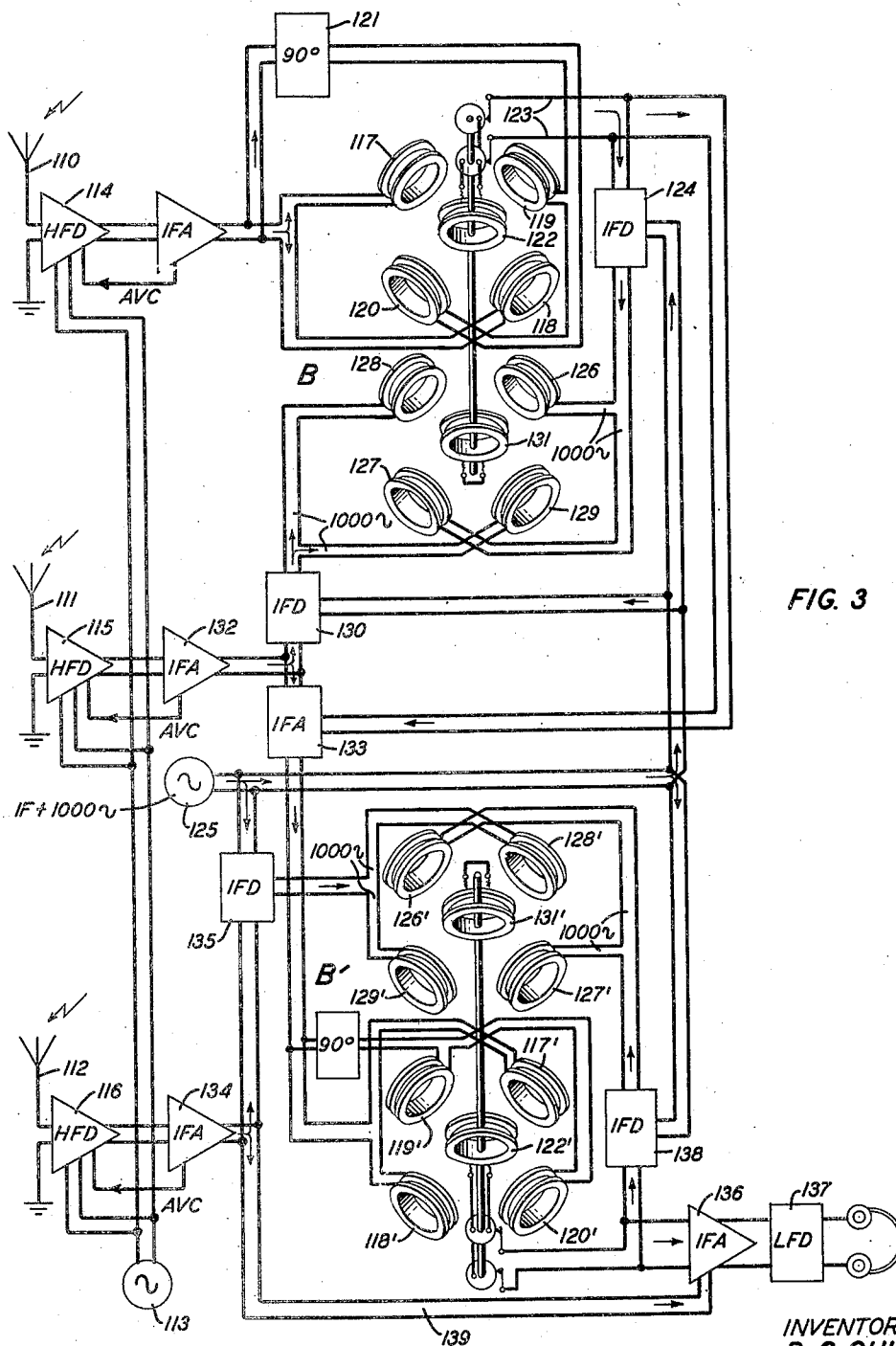


FIG. 3

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PHASE CORRECTING MEANS AND METHOD

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14 Claims. (Cl. 250-20)

This invention relates to phase correcting means and methods particularly for radio receiving circuits and, as applied to radio reception, has for an object to reduce the effects of fading, that is, variations in the intensity of the received wave.

It has heretofore been proposed to reduce variations in the strength of the received signal at a short wave radio receiver by employing a number of geographically separated antennas arranged to receive waves from the same transmitter and selecting manually or automatically that antenna giving a signal of high volume for use in detecting the desired signal. This is based on the fact that if a number of receiving stations properly spaced apart are used to pick up a transmitted signal the signal does not fade similarly at each of the stations but will generally be of materially different intensities even when the stations are separated from each other a distance of the order of only a few wave-lengths. The possibility of the signal fading out equally at all of the receiving stations at the same time is, therefore, reduced with increase in the number of receiving stations.

The present invention distinguishes from these prior proposals in that the several receiving antennas are not made effective one at a time in accordance with their received signal strength, but all are simultaneously utilized and the signals therefrom combined additively. Such an arrangement, however, must take into consideration the phase relationships of the carrier frequencies received on the different antennas since serious interference effects within the speech band will be produced by component signals from different antennas unless the carriers or intermediate frequencies derived therefrom are brought into phase with each other. No fixed phase relation exists from instant to instant between the carriers received on different antennas, the phase variations being due primarily to the continually changing lengths of the transmission paths. This invention provides a relatively simple way of bringing the carriers from the different antennas into phase automatically and maintaining them in phase even when rapidly varying phase differences are taking place in the signals received from the different antennas. In one embodiment of this invention which may be taken as illustrative of its application to a short wave radio telephone system two separated receiving antennas are employed. The two carrier signals are received in different circuits after being beaten down in frequency in separate de-

tectors by a common beating frequency. One of the circuits containing the derived intermediate frequency may be taken as the master phase control circuit and the current therein may be impressed directly upon the final detector. The intermediate frequency in the other circuit must first be brought into phase with the intermediate frequency in the master circuit before the currents of the two intermediate frequencies may be combined.

In order to obtain this phase synchronism, currents from the two above-mentioned circuits are first separately led through narrow band-pass filters to substantially suppress the speech band and the outputs from these filters are passed through volume limiters to remove low frequency modulation and fading amplitude variations. The two smooth derived carriers are then impressed upon two pairs of full wave rectifiers each pair of which is interconnected by a hybrid coil, and the manner in which the two smooth carriers are impressed on these rectifiers is such that the resulting rectified direct currents define the phase relation between the two intermediate carriers. These direct currents after being filtered through suitable low-pass filters are employed to control the resistance of variable resistance devices forming branches of two Wheatstone bridges. The intermediate carrier to be corrected in phase is impressed upon the two bridges and the control of the variable resistance elements by the direct currents derived as described above is so arranged that the wave produced by combining the outputs of the bridges is in phase with the intermediate frequency in the master circuit and hence can be simultaneously impressed upon the final detector along with the intermediate frequency from the master circuit.

Referring to the drawings,

Fig. 1 represents an embodiment of the invention for bringing into the same phase components of the same carrier received on different antennas in which a static phase corrector is employed;

Fig. 2 discloses an arrangement for bringing into phase three separately received components of the same carrier in which rotary phase adjusting means are employed; and

Fig. 3 is a modification of Fig. 2.

Fig. 1 discloses a short wave radio receiving system in which the same high frequency carrier is received on two antennas 10 and 11 separated from each other by several wave lengths or differently polarized so that the received signals will not be subject to simultaneous fading. Be-

cause of their relative dispositions the currents in the two antennas will not in general be in phase with each other and due to the variations in the lengths of the transmission paths the phases of the two currents will vary at random. In order that they may be combined in a common detector in additive relation the currents must be brought approximately into phase.

The received high frequency waves are impressed on receivers 12 and 12' wherein they are amplified and then beat down in frequency by demodulation with a common heterodyne wave supplied by oscillator 13. The receivers and the oscillator may be of conventional types using vacuum tube elements. Preferably the receivers are located at a common receiving station and are connected to their respective antennas through concentric conductor transmission lines. The reduced frequency may be of any convenient value, for example, of the order of 300 kilocycles.

The reduced frequency oscillations are further amplified in intermediate frequency amplifiers 14 and 14', from the outputs of which they pass to hybrid coil 15 wherein they are combined and impressed upon amplifier-detector 16. The output of amplifier 14 goes directly to hybrid coil 15 through line 17 without change of phase. The output of amplifier 14' is passed through a phase changing device comprising the apparatus groups designated A₁ and A₂, the operation of which will be described later, and from thence to hybrid coil 15 in correct phase. The signal is detected from the combined intermediate frequency oscillations by detector 16 and is delivered to line 18 or to a local monitoring telephone 19.

It will be convenient to consider the current from antenna 10 as the master current and that from antenna 11 as the controlled current. The intermediate frequency voltage at the output terminals *t*, *t'* may be taken as a reference voltage of zero phase angle. Its value, denoted by *V_a*, may be expressed as

$$V_a = E_a \cos pt \quad (1)$$

where *E_a* is the amplitude, varying in accordance with signal modulations, and *p* is 2π times the intermediate carrier frequency. Likewise the voltage at output terminals *t₂*, *t₂'* of amplifier 15 may be expressed as

$$V_b = E_b \cos (pt + \Phi) \quad (2)$$

where *Φ* is the variable phase difference between the two sets of received oscillations.

To bring the two currents into phase, the controlled oscillations must be shifted through the angle *Φ*. This is done by splitting the controlled current into two components, one an in-phase component and the other a quadrature component, and automatically adjusting the relative amplitudes of the two components in accordance with the phase difference *Φ*. When the components are recombined their resultant has the required phase. The quadrature component is obtained from a 90 degree phase shifting network 20 connected to terminals *t₂* and *t₂'* and the in-phase component is obtained directly from the amplifier output.

The in-phase component is impressed on hybrid coil 21, the secondaries of which are connected to variable resistor groups B₅ and B₆, the combination forming a Wheatstone's bridge circuit. The quadrature component is impressed upon a similar bridge circuit comprising hybrid coil 21 and resistor groups B₇ and B₈. Resistors 23 in series with the primary of coil 21 serve to com-

pensate for any voltage drop that may occur in phase shifter 20, thereby insuring that the input voltages of the two coils will be equal. Resistor groups B₅ to B₈ each comprise four elements connected in bridge formation, but for the present each group may be regarded as a single resistance. The output terminals of the two coils are connected respectively to vacuum tube amplifiers 24 and 25 which in turn are connected in parallel to line 26 leading to hybrid coil 15. The purpose of amplifiers 24 and 25 is to provide high impedance output circuits for the two bridges. In many cases they may be omitted without noticeably affecting the operation of the system.

The resistance elements constituting resistor groups B₅ to B₈ are of a type which exhibit a resistance variation when subject to a direct current biasing voltage. They may consist of plates of crystal agglomerate material such as described in U. S. Patent 1,822,742, issued September 8, 1931, to K. B. McEacheron and commercially known as Thyrite, or they may be constituted by dry contact copper-oxide rectifier elements. Such resistors are characterized by resistances to alternating current which diminish rapidly in the presence of an increasing D. C. biasing voltage. It is desirable to have all of the elements in the several groups closely matched in respect of their normal resistance values and their variation characteristics.

Assuming that the coils 21 and 22 are of efficient design and construction, the output voltages of the two bridges will be in phase with their respective inputs, but will have magnitudes and signs dependent upon the degree and sense of the bridge unbalances. The proper degree and sense of the unbalance is obtained by superimposing D. C. voltages on the resistor groups, the magnitudes of which are controlled in accordance with the phase difference to be corrected. The arrangements for producing these voltages are as follows:

Branch paths from the outputs of the intermediate frequency amplifiers lead to band-pass filters 27 and 27' which have sufficiently narrow bands and sharp discrimination to suppress most of the signal modulations of the carrier waves. From these filters the substantially smoothed carriers pass to voltage limiters 28 and 28' which serve to remove any residual modulations and to furnish output voltages which remain constant even in the presence of large amounts of fading. These limiters may consist of vacuum tube devices operated at plate current saturation. They may be adjusted so that their outputs are substantially equal or, alternatively, the output amplitudes may be controlled by potentiometers 29 and 29'. The filters and the limiters in the two paths should be carefully equalized with respect to their phase characteristics so that the phase difference of their outputs may be the same as that of their inputs.

The smoothed carrier oscillations from the two paths are combined to produce voltages representing their sum and their difference and also voltages representing the sum and difference when one of the oscillations is shifted 90 degrees in phase. The four resultant voltages are such that their relative magnitudes are different for all values of the phase angle *Φ* up to 360 degrees.

The two oscillations are combined directly in hybrid coil 30, to the secondary winding terminals of which are connected full wave rectifiers B₁ and B₂. As the result of the combination a voltage equal to the sum of the two applied

voltages appears at the terminals of rectifier B₁ and the difference voltage at the terminals of B₂. The two oscillations are similarly combined in hybrid coil 31, but in this case the oscillations from limiter 28 are shifted 90 degrees by phase shifter 32 before being impressed on the coil windings. The sum of the two voltages is impressed on rectifier B₃ and the difference on rectifier B₄. Resistances 33 in the primary circuit coil 30 serve to compensate for any resistance drop in network 32. Rectifiers B₁ to B₄ may comprise copper-oxide dry contact rectifying elements. In the figure each rectifier consists of four elements arranged in bridge formation to form balanced full wave rectifiers. The rectified D. C. voltages are transmitted through low-pass smoothing filters 34 to 37, inclusive, to resistors B₅ to B₈ on which they are impressed as bias voltages.

The operation of the circuit will be most readily understood from the following mathematical analysis:

The smoothed carrier voltages at the outputs of the limiters 28 and 28' may be expressed as

$$E_1 \cos (pt + \Psi)$$

and

$$E_2 \cos (pt + \Psi + \Phi)$$

respectively, where Ψ represents the phase change suffered in passing through the equalized filters and limiters. These voltages have the same phase difference as exists between the master and the controlled voltages, but are of constant amplitude. By proper adjustment of potentiometers 29 and 29' they may be made to produce equal components in the secondaries of coils 30 and 31, in which case the A. C. voltages impressed on rectifiers B₁ to B₄ are, respectively,

$$V_1 = E \cos (pt + \Psi) + E \cos (pt + \Psi + \Phi)$$

$$V_2 = -E \cos (pt + \Psi) + E \cos (pt + \Psi + \Phi) \quad (3)$$

$$V_3 = E \cos \left(pt + \Psi + \frac{\pi}{2} \right) + E \cos (pt + \Psi + \Phi)$$

$$V_4 = -E \cos \left(pt + \Psi + \frac{\pi}{2} \right) + E \cos (pt + \Psi + \Phi)$$

where E denotes the common amplitude of the two components.

The voltage from limiter 28' is applied to all of the rectifiers in the same phase while that from limiter 28 is reversed in phase in rectifier B₂ with respect to B₁ and in rectifier B₄ with respect to B₃.

The rectified D. C. voltages corresponding to V₁ to V₄ have the values respectively,

$$V_5 = K_1 E \sqrt{1 + \cos \Phi}$$

$$V_6 = K_1 E \sqrt{1 - \cos \Phi} \quad (4)$$

$$V_7 = K_1 E \sqrt{1 + \sin \Phi}$$

$$V_8 = K_1 E \sqrt{1 - \sin \Phi}$$

where K₁ is a numerical constant which may be taken as having the same value for all of the rectifiers. Since the rectifiers are unidirectional devices only the positive values of Equations (4) need be considered. The D. C. voltages V₅ to V₈ are impressed on resistors B₅ to B₈, respectively, and provide the bias voltages therefor. It will be observed that the voltages V₅ to V₈ have different relative magnitudes for all values of Φ from zero to 360 degrees.

Returning now to the apparatus groups A₁ and A₂, if the elements of the bridge groups B₅ to B₈ are all similar, the resistance of each bridge will

be equal to that of its component elements and, as the resistances of the elements to superimposed A. C. voltages varies under the influence of the D. C. voltage bias so also will the resistance of the bridge group vary.

Denoting the resistances of the bridge groups by R₅ to R₈, respectively, it may be shown that the output voltage, denoted by V_{a1}, of the system A₁ has the value

$$V_{a1} = K_2 \frac{R_5 - R_6}{R_5 + R_6} E_b \cos (pt + \Phi) \quad (5)$$

and the output voltage, V_{a2}, of the system A₂, has the value

$$V_{a2} = K_2 \frac{R_7 - R_8}{R_7 + R_8} E_b \cos \left(pt + \Phi - \frac{\pi}{2} \right) \quad (6)$$

where K₂ is a constant multiplier having the same value for both systems.

For the types of variable resistor described, the typical resistance variation under a variable D. C. bias voltage is expressed by

$$\frac{1}{R} = a + bV^2 \quad (7)$$

V denoting the bias voltage and a and b being constants. Assuming the resistor elements all to have similar characteristics and making appropriate substitutions in Equations 5 and 6 leads to the final values

$$V_{a1} = K_3 E_b \cos \Phi \cos (pt + \Phi) \quad (8)$$

and

$$V_{a2} = K_3 E_b \sin \Phi \sin (pt + \Phi) \quad (9)$$

where K₃ is a third constant multiplier involving K₁, K₂ and the quantities a and b.

When the voltages V_{a1} and V_{a2} are combined additively the resultant has the value

$$V_{a1} + V_{a2} = K_3 E_b \cos pt \quad (10)$$

and if the two components are equally amplified in amplifiers 24 and 25 before combining the resultant will be simply increased in proportion without change of phase.

The combined output of systems A₁ and A₂ is thus in phase with the master voltage and may therefore be combined directly therewith in hybrid coil 15. The accuracy of this result is dependent upon the balance of the various parts of the system and the matching of the various elements included. These factors can be taken care of by careful design and construction. It is also dependent upon the use of variable resistances following the law expressed by Equation (7). However, it is not necessary that this law obtain accurately and considerable deviations therefrom will result in errors of phase correction of only a few degrees at most.

The unbalance of the systems A₁ and A₂ which give the required correction requires the presence of carrier frequency components from both of the receivers 12 and 12'. If the carrier from receiver 12' should momentarily be reduced to zero by excessively deep fading the signals from receiver 12 may still be received since they go directly to the output coil 15. However, if the carrier from receiver 12 is reduced to zero, systems A₁ and A₂ assume a balanced condition and signals from receiver 12' cannot be passed. Such deep fading of the carrier waves is of comparatively rare occurrence and ordinarily the amplitude variations are not great enough to prevent the production of constant carrier components for control purposes by limiting devices 28 and 28'.

To guard against extreme fading of the master

carrier a by-pass circuit is provided for the controlled carrier which is normally blocked and is opened only when the master carrier is abnormally reduced. This by-pass circuit comprises a bridge system A_3 similar to A_1 and A_2 and including hybrid coil 38 and resistance bridges B_{11} and B_{12} . The input of the hybrid coil is connected to the output of amplifier 14 either directly or through phase shifter 20 as illustrated. The output of the hybrid coil goes directly to coil 15. Biasing voltages for the resistance bridges are supplied through filter 39 and rectifier B_9 connected to limiter 28' and through filter 40 and rectifier B_{10} connected to limiter 28. So long as the outputs of the two limiters remain constant the biasing voltages are equal and system A_3 remains balanced. When a deep fade of the master carrier occurs, the corresponding biasing voltage is reduced and the system becomes unbalanced permitting the transmission of the signals by the controlled carrier.

Automatic volume control circuits may be included in the system of the invention. These may be of any well-known type, the application of a feedback type of control being illustrated in the drawings. From the output of amplifier 14 the intermediate frequency voltage is picked off and applied to a detector or rectifier 41. The rectified voltages are then fed back to control the vacuum tubes of receiver 12 and amplifier 14 in the usual manner. A similar circuit including rectifier 42 controls the volume output of receiver 12'. These automatic volume controls also assist the limiters 28 and 28' in maintaining constant phase control voltages.

Fig. 2 discloses the phase synchronization of three carrier components by an arrangement involving mechanical displacement to cause phase variations. The three antennas 70, 71 and 72 are adapted to receive the same high frequency carrier but with no fixed phase relation, and the purpose of the disclosed arrangement is to bring the three components into the same phase before they are impressed upon a common low frequency detector 73.

The signals received on the three antennas are beaten down in frequency by the same beating oscillator 74 so as to retain their phase relationships. The frequency of oscillator 74 may be such as to bring the frequency output of the high frequency detectors 75, 76, 77 down to a frequency, say of 300 kilocycles. Intermediate frequency amplifiers 78 and 79 with an automatic volume control 80 serve to maintain the intermediate carrier frequency derived from antenna 70 at a substantially constant level. Similar intermediate frequency amplifiers 81, 82 are provided for the output of detector 76 and intermediate frequency amplifiers 83, 84 are provided for the output of detector 77.

The intermediate frequency derived from antenna 71 may be termed the master control frequency and is impressed through another amplifier 85 directly upon the low frequency detector 73 without phase modification, while the intermediate carrier frequencies derived from antennas 70 and 72 must first be brought into phase with the output from amplifier 82 before they can be supplied to the same low frequency detector 73.

In order to obtain this phase correction for the output of amplifier 79 a phase correction instrument A is provided. One portion of this instrument is a two-phase induction motor comprising four fixed coils 93 to 96 and a rotor which may

be a short-circuited coil 92 wound as a squirrel-cage for two-phase induction motor operation. The other portion of the instrument A may be termed the phase adjuster and comprises a rotor coil 89 mounted on the same shaft 90 as rotor 92 and surrounded by four fixed coils 85 to 88. Windings 85 to 88 are shielded from each other but are in inductive relation to the rotatable coil 89. Slip rings serve to connect rotatable coil 89 to the outgoing leads 91. The output of amplifier 79 is supplied directly to coils 85, 86 without phase modification and is supplied to coils 87, 88 after a phase shift of 90 degrees produced by phase shifter 97. It will be apparent that the phase of the current induced in rotatable coil 89 will depend upon the angular position of coil 89 with respect to the fixed coils and it is, therefore, necessary to adjust the position of coil 89 until the phase of the intermediate frequency from amplifier 79 is the same as the phase of the intermediate frequency from amplifier 82.

In order to provide the turning torque for shaft 90 another beating oscillator 98 is provided such that when its frequency is combined with the intermediate frequency from amplifiers 79, 82 and 84 the resulting difference frequency will be of the order of 1000 cycles. Part of the intermediate frequency output from rotatable coil 89 is impressed upon the intermediate frequency detector 99 along with current from oscillator 98. Detector 99 preferably includes in its output a narrow band-pass filter to suppress substantially all frequencies except the desired difference frequency of 1000 cycles and also a suitable volume limiter to maintain a constant output amplitude. The thousand cycle frequency from the output of detector 99 is supplied to fixed coils 95, 96. A similar detector 100 is supplied with current from amplifier 82 and current from beating oscillator 98 to also produce a difference frequency of 1000 cycles which is supplied to coils 93, 94. It will be apparent that the phase relation between the thousand cycle current supplied to coils 95, 96 and the thousand cycle current supplied to coils 96, 97 will be the same as the phase relation between the two high frequency carrier components received by antennas 70, 71. The coil 92 will, therefore, be rotated due to this phase difference until the currents in coils 95 and 96 are in phase with the current in coils 93, 94 which will mean that coil 89 will also be rotated until the current induced therein is in phase with the current output from amplifier 82. The current output from coil 89 which carries the signaling component from antenna 70 may then be impressed upon intermediate frequency amplifier 85 and the low frequency detector 73.

Phase induction instrument A' is of the same type as instrument A previously described and is used in a similar manner to bring the signaling component from antenna 72 into phase with the signaling component from antenna 71. The output from amplifier 84 is supplied to fixed coils 85', 86' without phase modification and is supplied to fixed coils 87', 88' with a 90-degree phase shift due to phase shifter 101. The current induced in rotatable coil 89' is fed into intermediate frequency amplifier 85 but a portion thereof is branched into intermediate frequency detector 102 along with current from the beating oscillator 98. Detector 102 being similar to detectors 99 and 100, it follows that the thousand cycle current output from detector 102 has a phase depending upon the phase of the signaling

output from antenna 72. The thousand cycle current from detector 102 is supplied to fixed coils 95', 96' while coils 93', 94', are supplied with the thousand cycle current from detector 100. Coil 92' will then be rotated until the current in coils 95', 96' is in phase with the current in coils 93', 94'. This will, therefore, place coil 89' in such an angular position that the current induced therein will be in phase with the signaling component from amplifier 82 and may be led by conductors 103 to intermediate frequency amplifier 85 to be detected in detector 73 simultaneously with the signaling component from the other receiving antennas.

As the signaling components received by antennas 70 and 72 vary in phase from the signaling component due to antenna 71 it follows that shafts 99 and 90' will be rotated to bring all three components into phase before they are impressed upon the common low frequency detector 73. Intermediate frequency amplifier 85, if desired, may be provided with an automatic volume control to maintain a substantially constant output.

In Fig. 2 where three receiving antennas are employed the signal from one antenna is regarded as the master phase and each of the other two signals is brought into the same phase as the master phase. In Fig. 3 the arrangement is somewhat similar except that two of the signals are first combined in phase and their combined output is then united in phase with the third signal.

Referring to Fig. 3 the first step in the phase synchronization is to unite in phase the signals from antennas 110 and 111 by means of a phase adjusting instrument B similar to instrument A of Fig. 2. The carrier components from antennas 110 and 111 are stepped down in frequency, say to a carrier of 300 kilocycles by common beating oscillator 113 in the respective high frequency detectors 114 and 115. The reduced carrier from detector 114 after amplification is supplied directly to fixed coils 117 and 118 of the phase adjusting instrument and is supplied to fixed coils 119 and 120 after a 90-degree phase shift due to phase shifter 121. It follows that the phase of the carrier current in leads 123 connected to rotatable coil 122 depends upon the angular position of coil 122 relative to the fixed coils. A portion of the output of coil 122 is branched into intermediate frequency detector 124 along with a beating frequency from oscillator 125, the frequency of source 125 being such that the output from detector 124 is a relatively low frequency, 1000 cycles, for example, detector 124 including a narrow band-pass filter and a volume limiter to limit its frequency output to the desired 1000 cycle current. This 1000 cycle output from detector 124 is impressed upon fixed coils 126, 127.

Due to the beating oscillator 113 the high frequency carrier from antenna 111 is stepped down in frequency in high frequency detector 115 and after amplification a portion of the intermediate carrier is impressed upon detector 130 along with a beating frequency from oscillator 125 to produce a thousand cycle frequency output of substantially constant volume and this thousand cycle current is impressed upon the fixed coils 128, 129. The thousand cycle current from detector 130 bears the same phase relation to the thousand cycle current from detector 124 as exists between the two carrier components received by antennas 110, 111. Hence under the action of the currents in the fixed coils 126 to 129 the short-circuited rotor coil 131 which is mounted

on the same shaft as coil 122 will be rotated until the thousand cycle current in coils 126, 127 is in phase with the thousand cycle current in coils 128, 129 and under such a condition it follows that the intermediate frequency current from coil 122 will be in phase with the intermediate frequency current from amplifier 132. The output from amplifier 132 derived from antenna 111 and the output from coil 122 derived from antenna 110 may then be combined in the same intermediate frequency amplifier 133 since they are now in the same phase.

The next step is to bring the intermediate frequency output from amplifier 133 into phase with the intermediate frequency output of amplifier 134. The output from amplifier 133 is supplied without phase modification to fixed coils 117', 118' and with a phase shift of 90 degrees to the fixed coils 119', 120' of phase adjusting instrument B'. The intermediate frequency current induced in rotatable coil 122' is fed to amplifier 136 and also to the low frequency detector 137 for securing the desired signal. A part of the output from coil 122' is branched to intermediate frequency detector 138 along with the beating frequency from source 125 to produce a thousand cycle current which is impressed upon the fixed coils 126', 127'. Similarly a portion of the output from amplifier 134 derived from antenna 112 is impressed upon intermediate frequency detector 135 along with frequency from the beating source 125 to provide a thousand cycle current which is supplied to fixed coils 128', 129'. Rotatable coil 131' will, therefore, be rotated until the intermediate frequency current from coil 122' is in phase with the output from amplifier 134. Current from coil 122' due to the signaling current from antennas 110 and 111 is supplied to intermediate frequency amplifier 136 and detected in low frequency detector 137 along with the signaling component derived from antenna 112 since the output of amplifier 134 by leads 139 is also connected to amplifier 136. The arrangement described is such that the three signaling components derived from the three antennas 110, 111 and 112 are brought into the same phase before they are detected by the low frequency detector 137. It will be apparent that the apparatus of Fig. 3 is not blocked even when there are deep fades in the signal received by one or two of the receiving antennas.

It is to be understood that the automatic volume controls shown in Figs. 2 and 3 are preferably slow operating and may be of the same general type as used in the system of Fig. 1.

While this invention has been described in connection with a short wave radio receiving system it is to be understood that the invention has utility in other fields. For example, it may be employed for synchronizing power control currents and standard frequency currents with or without modulation.

What is claimed is:

1. In a radio receiving system, a plurality of antennas each receiving the same high frequency signal and so related that the received signals vary differently in phase, and means for bringing the phase of the signal derived from a first antenna into phase with the signal derived from a second antenna, said means comprising a first Wheatstone bridge arrangement and a second Wheatstone bridge arrangement each balanced and each having input and output terminals in conjugate relation, means for impressing a signal current derived from said first antenna upon the

input terminals of said first bridge, means for impressing the signaling current derived from said first antenna on the input terminals of said second bridge with a 90 degree phase shift, means responsive to the phase difference between the signals derived from said first antenna and from said second antenna for unbalancing both of said bridges to cause the combined output current from the output terminals of both bridges to be in phase with the signal current derived from said second antenna, and a receiver responsive to the signal derived from said second antenna and to the phase corrected signal derived from said first antenna.

2. In a high frequency receiving system, a first antenna and a second antenna so related that the same carrier is received by said antennas in variable phase relationship, a Wheatstone bridge arrangement having as one arm a full wave rectifier and having in an adjacent arm a second full wave rectifier, a second Wheatstone bridge arrangement having as one arm a third full wave rectifier and having in an adjacent arm a fourth full wave rectifier, each of said rectifiers acting as a resistance whose value depends upon the magnitude of the direct current impressed thereon, a hybrid coil for connecting said first and second rectifiers in a normally balanced relation, a second hybrid coil for connecting said third and fourth rectifiers in a normally balanced relation, means for impressing on the first rectifier to vary its effective resistance a direct current derived from the rectification of current from said second antenna unchanged in phase and current from said first antenna shifted 90 degrees in phase, means for impressing on the second rectifier to vary its effective resistance a direct current derived from the rectification of current from said second antenna unchanged in phase and a current from said first antenna shifted 270 degrees in phase, means for impressing on the third rectifier to vary its effective resistance a direct current derived from the rectification of current from the second antenna unchanged in phase and current from the first antenna unchanged in phase, means for impressing on the fourth rectifier to vary its effective resistance a direct current derived from the rectification of current from said second antenna unchanged in phase, and current from the first antenna shifted 180 degrees in phase, means for impressing upon the input terminals of said first hybrid coil the signal from said first antenna shifted in phase by 90 degrees, means for impressing upon the input terminals by said second hybrid coil the signal derived from said first antenna with no phase modification, and a receiver responsive to the signal derived from said second antenna and responsive to the combined output from the output terminals of said hybrid coils.

3. A high frequency receiving system in accordance with claim 2 provided with means for impressing the signal current from said first antenna upon said receiver when the signal from said second antenna fades to substantially zero.

4. A radio receiving system comprising a plurality of receiving antennas so related that the same incoming signal is received in different phase relations by respective antennas, and means for bringing the phase of the signal received by a first antenna into phase with the signal received by a second antenna, said means comprising a rotatable coil, a plurality of fixed coils angularly disposed with respect to said rotatable coil, means for impressing on one of said fixed coils

a signal current derived from said first antenna with no phase shift and for impressing upon a second of said fixed coils a signal current derived from said first antenna after a 90 degree phase shift, a second rotatable coil mounted for rotation with said first rotatable coil, a second plurality of fixed coils surrounding said second rotatable coil, means for supplying to one of said second fixed coils a control current of a definite frequency of a phase controlled by the phase of the signal current in said first rotatable coil, means for supplying to a second of said second fixed coils a current of said definite frequency and of a phase controlled by the phase of the signal current from said second antenna and a detector responsive to the signal current derived from said first rotatable coil and from said second antenna.

5. In a high frequency radio receiving system, a plurality of receiving antennas so related that the same signal is normally received in different phase by the respective antennas, and means for bringing the phase of the signal received from a first antenna into phase with the signal received from a second antenna, said means comprising a two-phase induction motor having stator windings and a rotor winding, means for impressing on one of said stator windings an alternating current having a phase controlled by the phase of the signal received from said first antenna, means for impressing upon another stator winding an alternating current having a phase controlled by the phase of the signal received from said second antenna, a 360 degree phase adjuster comprising a rotatable coil driven by said rotor and a plurality of stator windings non-inductively related to each other but inductively related to said rotatable coil, means for supplying said last mentioned stator windings with signal bearing current derived from said first antenna, and a receiver responsive to the signal current from said second antenna and responsive to the signal current from said rotatable coil.

6. A high frequency receiving system in accordance with claim 5 in which the alternating current which has its phase controlled by the phase of the signal received from said first antenna and which is impressed upon one of the stator windings of said motor is a current derived from the current induced in said rotatable coil.

7. In a high frequency receiving system comprising a plurality of receiving circuits each receiving the same high frequency signal and so related that the signals received therein are subject to variations in phase with time, a signal translating device, and separate transmission paths for oscillatory currents coupling said device to each of said receiving circuits, means in a first of said paths for producing two component currents substantially in phase quadrature with each other from signal currents received therein, means responsive to the phase difference between signal currents in said first path and signal currents in a second of said transmission paths for controlling the relative amplitudes and signs of said component currents, whereby the resultant of the modified quadrature components is substantially in phase with the currents in said second path, and means for combining said modified components and impressing the resultant thereof upon said signal translating device.

8. In a high frequency receiving system com-

prising a plurality of receiving circuits each receiving the same high frequency signal and so related that the signals received therein are subject to variations in phase with time, a signal translating device, and separate transmission paths for oscillatory currents coupling said device to each of said receiving circuits, means in a first of said paths for producing two component currents substantially in phase quadrature with each other from signal currents received therein, means responsive to the phase difference between signal currents in said first path and signal currents in a second of said transmission paths for maintaining the relative amplitudes of said quadrature components substantially in the ratio of cosine ϕ to sine ϕ , where ϕ denotes the angular phase difference between the currents impressed upon said first and second transmission paths from the receiving circuits connected thereto, and means for combining said component currents and impressing the resultant thereof upon said signal translating device.

9. In a radio receiving system comprising two antennas each receiving the same high frequency signal and so related to each other that the signal oscillations received therein are subject to variations in phase with time, a common signal translating device, and separate transmission paths for oscillatory currents coupling said device and said antennas, means in one of said paths for producing from signal currents received therein two component currents substantially in phase quadrature with each other, means responsive to the phase difference between the currents received in said antennas for controlling the relative amplitudes and signs of said components, whereby the resultant of the modified components is substantially in phase with the currents in the second of said paths, and means for combining said modified components and impressing the resultant thereof upon said signal translating device.

10. In a high frequency receiving system comprising a plurality of receiving circuits each receiving the same high frequency signal and so related that the currents received therein are

subject to variations in phase with time, means for deriving from a first of said receiving circuits two current components substantially in phase quadrature with each other, two variable transducers, means for impressing said component currents upon said transducers respectively, means for producing a plurality of control currents in accordance with the phase difference between the currents in said first receiving circuits and the currents in a second of said receiving circuits, and means for controlling said variable transducers by said control currents whereby the relative amplitudes and signs of the output currents thereof are so modified that their resultant is substantially in phase with the currents in said second circuit.

11. A system in accordance with claim 10 in which the said transducers comprise differential bridge circuits, each bridge circuit having a pair of adjacent arms constituted by non-linear resistance elements.

12. A system in accordance with claim 10 in which the said transducers comprise differential bridge circuits, each bridge circuit including non-linear resistance elements in adjacent arms, and which includes means for superimposing said control currents upon said non-linear elements whereby the resistances thereof are varied in accordance with the magnitudes of said control currents.

13. A system in accordance with claim 10 in which the said two transducers are constituted by a variometer system comprising two separate fixed primary windings and a single movable secondary winding, and which includes means operated by said control currents for moving said secondary winding relatively to said primaries.

14. The combination with a system as set forth in claim 7 of an auxiliary transmission path paralleling said first transmission path, means normally blocking said auxiliary path, and means operative in response to substantially complete suppression of the current in said second path for disabling said blocking means.

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