Sept. 23, 1941. D. G. C. LUCK 2,256,619

DIRECTIONAL ANTENNA

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FIG. 2.

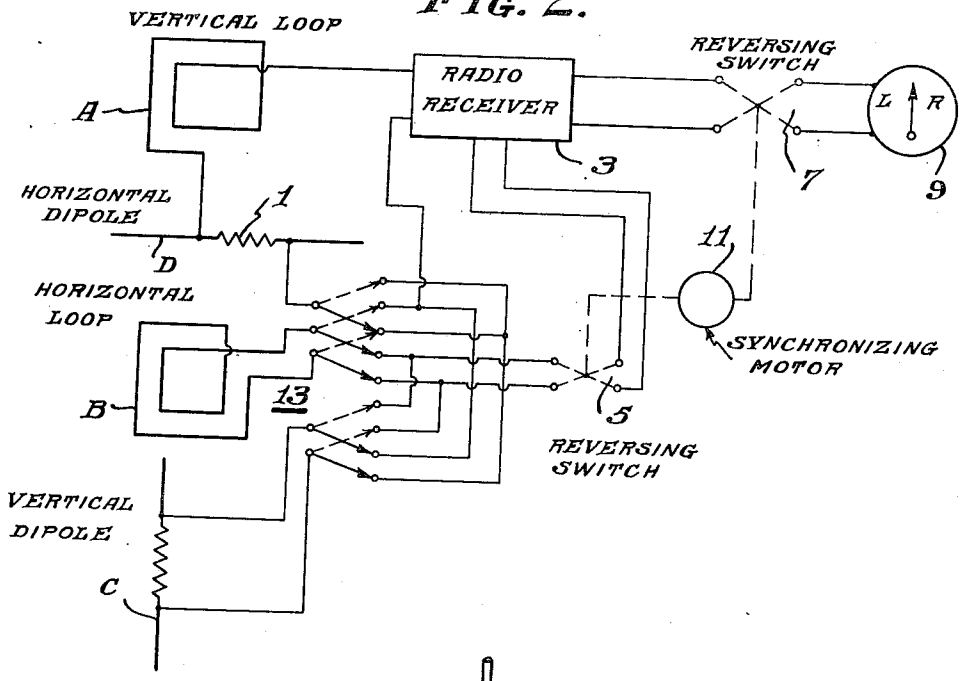
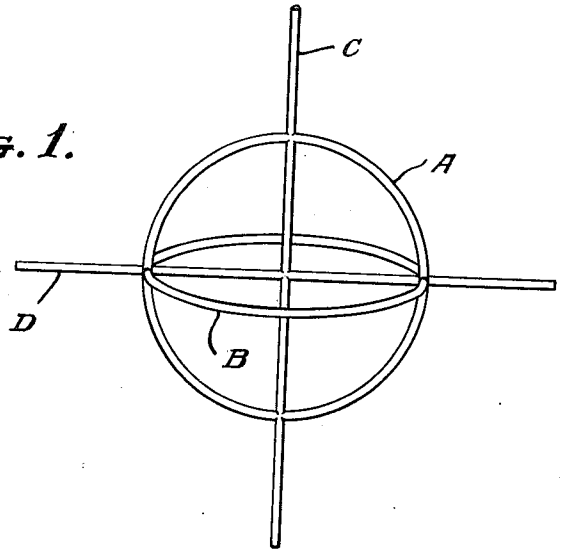


FIG. 1.



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DIRECTIONAL ANTENNA

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16 Claims. (Cl. 250—11)

This invention relates to directional antennas and especially to a radio compass antenna in which the deleterious effects of Heaviside layer reflections are eliminated or minimized.

It is well known that a radio compass antenna is not only responsive to the ground waves from a radio transmitter but the antenna is also responsive to unwanted waves. These unwanted waves are established by components of the transmitted waves which are reflected from the Heaviside layer. The radio compass errors caused by these and like reflections are called "night errors."

It is an object of this invention to minimize "night errors" in a radio compass by providing means for balancing out the unwanted components. Another object is to provide means in a directional antenna so that it will be responsive to ground waves but not to sky waves. Another object is to provide means for connecting a plurality of directional antennas so that the resultant directive pattern will lie only in a desired plane. An additional object is to provide means in a directional antenna system whereby the system may be used selectively for direction finding of either vertically or horizontally polarized waves.

The invention will be described by referring to the accompanying drawing in which Figure 1 is a schematic perspective view of the directive antenna array of the invention; and Figure 2 is a schematic circuit diagram of the radio compass of the invention. Similar reference numerals will be applied to similar elements of the drawing.

Referring to Fig. 1 a vertically disposed dipole C is arranged symmetrically in the plane of a vertical loop antenna A along the vertical axis about which the loop rotates. A horizontal loop antenna B is positioned normal to the vertical loop so that the centers of the loops coincide. A horizontal dipole D is arranged symmetrically in the planes of both loops. To avoid unnecessary confusion, the connections from the loops and dipoles have not been shown in the perspective view. It should be understood that the several antennas are balanced with respect to ground and are symmetrically arranged to provide no mutual coupling, which condition might otherwise be obtained by electrical methods.

The schematic circuit diagram, Fig. 2, shows the connections of the several directive antennas. The vertical loop A is connected to the horizontal dipole D which includes a phasing resistor 1. The horizontal dipole D is connected to either the horizontal loop B or the vertical dipole C. The dipole C or loop B, whichever is not connected to the horizontal dipole, may be used as a sense antenna and is connected to the input of a radio receiver 3 by a reversing switch 5. The output of the radio receiver is connected through a reversing switch 7 to a left right indicator 9. The reversing switches 5, 7 are operated in synchronism by a motor 11.

The connections which connected the sense antenna, i. e. either the horizontal dipole D or the vertical loop B, to the receiver 3 and loop B or dipole C (as the case may be) to the vertical loop A and horizontal dipole D, respectively, may be made by means of a two position multipole switch 13. When the switch 13 is in the upper position, the directive antenna array includes the loop A, the dipole D, and the loop B; and the vertical dipole C serves as the sense antenna. When the switch 13 is in the lower position, the directive antenna array includes the loop A, the dipole D, and the dipole C; and the horizontal loop B serves as the sense antenna. The former connection is used for vertically polarized waves; the latter for horizontally polarized waves.

Inasmuch as the operation of a "left-right" radio compass indicator is well known to those skilled in the art, the present description will be limited to the operation of the directional array. In general, the "night errors" in a radio compass employing a loop antenna are the result of the sensitivity of the loop to waves which are reflected from the Heaviside layer and are therefore obliquely incident. In general, a wave obliquely incident on the receiving antenna may be resolved into four plane polarized components: (*a*) a horizontally incident wave having its electrical vector vertical, (*b*) a horizontally incident wave having its electrical vector horizontal (perpendicular to the plane of incidence), (*c*) a vertically incident wave having its electrical vector in the plane of incidence, and (*d*) a vertically incident wave having its electrical vector perpendicular to the plane of incidence. While the foregoing resolution is not absolutely rigorous, it is sufficiently exact for the purposes of the present invention. For our purposes, component (*d*) may be regarded together with component (*c*), simply as an unwanted vertically incident wave.

In the case of a wave initially plane polarized, all four components are in phase in time. In the limiting case of a circularly polarized original wave, the two components polarized in the plane of incidence are in time phase but are in phase quadrature with the other two components. The two horizontally incident components are of use for direction finding. In the case of a loop an-

tenna with a vertical axis of rotation only the vertically polarized of these two components is effective. In the case of a horizontal dipole, only the horizontally polarized component can act. With either type of antenna a vertically incident component may cause errors. The vertical component displaces the signal null as the antenna is rotated.

A horizontal dipole in the plane of the turns of a vertical loop has, proportionally, exactly the same strength of response to the vertically incident waves as the loop for all rotational positions of the pair about a vertical axis. However, the voltages induced in the horizontal dipole will be in time quadrature with the voltages induced in the loop. If the horizontal dipole is short with respect to the wave length, so that it approximates a pure capacitance, and includes a suitable phasing resistance, this quadrature is removed and the dipole may be connected in series with the loop so that the vertically incident response of the two antennas may be made to neutralize for all frequencies for which the antennas are small in comparison to a wave length. This combination of loop and dipole will exhibit pairs of opposite null points 90° apart for waves horizontally incident and, respectively, vertically and horizontally polarized. If a horizontal loop is also serially connected with the vertical loop and horizontal dipole, its response to horizontally incident, horizontally polarized radiation will cause suppression of one null of the horizontal dipole and coincidence of the other null with a vertical loop null to give a usable directive system. While this system will have two null points spaced 180° for vertically polarized horizontally incident waves, a tilt of the polarization will cause the reciprocal null to shift toward the true null, being 90° from the true null for 45° plane polarization and coincident with it for horizontal polarization.

Antenna	Horizontally incident vertically polarized *a*	Horizontally incident horizontally polarized *b*	Vertically incident *c*
Vertical loop A	*Aa* Sensitive	*Ab* Insensitive	*Ac* Sensitive.
Horizontal loop B	*Ba* Insensitive	*Bb* Sensitive	*Bc* Insensitive.
Vertical dipole C	*Ca* Sensitive	*Cb* Insensitive	*Cc* Insensitive.
Horizontal dipole D	*Da* Insensitive	*Db* Sensitive	*Dc* Sensitive.

Instead of connecting a horizontal loop to the serially connected vertical loop and horizontal dipole, a vertical dipole may be connected so that the directive array may be used to suppress one null of the vertical loop and shift the other to coincide with one of the nulls of the horizontal dipole. Thus connected, the system is useful for horizontally polarized waves while the former system is used for vertically polarized waves.

While no type of incident wave will shift the true null in either system, the choice of the true null is simplified by a phase comparison in which a non-directive antenna may be used to obtain the reference phase. This arrangement corresponds to the well known use of a sense antenna. In the first described system, a vertical dipole is used to determine sense. In the second described system, which is responsive to horizontally polarized waves, a horizontal loop is used for sense determination. In the arrangement shown in Figs. 1 and 2 all four types of antennas are available, so that the switch places the two combinations at the disposal of the operator.

As an aid in understanding the invention reference is made to the accompanying table which indicates the sensitivity of the various types of antennas to the various types of waves. For the reception of vertically polarized waves the unwanted components are minimized or neutralized by serially connecting the antennas A, B and D. Thus connected, the vertical loop A is sensitive to horizontally incident, vertically polarized waves *a* and to verticalyl incident waves *c*. The vertically incidence response Ac is neutralized by the vertical incidence response Dc of the horizontal dipole D. However, the horizontal dipole D is sensitive to horizontally incident, horizontally polarized waves *b*. These waves are neutralized by the horizontal loop B which is only sensitive to the horizontally incident, horizontal polarized waves *b* and is insensitive to the other components.

In a similar manner, for horizontally polarized waves, the antennas A, C and D are serially connected. The horizontal dipole D is sensitive to the horizontally incident horizontally polarized waves *b* but it is also sensitive to the vertically incident waves *c*. This sensitivity is neutralized by the sensitivity of the vertical loop A to the vertically incident waves *c*. However, the vertical loop is also sensitive to horizontally incident, vertically polarized waves *a*. This sensitivity of the vertical loop A is neutralized by the vertical dipole C which is only sensitive to the horizontally incident, vertically polarized waves *a* and insensitive to the other components.

It should be understood that the foregoing response characteristics of the several types of antennas is based upon the antenna being so disposed with respect to the wave front that it will have a finite response. As the antenna array is rotated with respect to the wave front, responses of the several sensitive elements will be reduced occasionally to zero in accordance with the well known characteristic figure-of-eight. However, as the response of one of the neutralizing antennas, for example, the horizontal dipole D, falls off, the response of the antenna to be neutralized, say the vertical loop A, will also fall off so that there is no change in neutralization as the antennas are rotated about the common axis.

Thus the invention has been described as a directional antenna in which the undesired vertically incident wave components are minimized or eliminated. The elimination is effected by neutralizing the undesired response by connecting, in proper phase, an element equally responsive to the undesired component. Since the added element also has an additional undesired response, this second undesired response is in turn neutralized by connecting, in proper phase, an element equally responsive to the second undesired component but to no other undesired wave or component. The array may be used to indicate the direction of either vertically or horizontally polarized waves. Furthermore, a sense antenna may be added. The array may be used for transmission or reception, and may be arranged for uni-directional or bi-directional operation.

I claim as my invention:

1. A directive antenna array including a directional antenna having a desired response to horizontally incident waves and an undesired response to vertically incident waves, means connected to said antenna to minimize said undesired response, said minimizing means being responsive to both vertically incident waves and to waves polarized at substantially right angles to

said horizontally incident waves, and means connected to said first mentioned minimizing means for minimizing said response to said waves polarized at substantially right angles.

2. A directive antenna array of the character of claim 1 including a sense antenna non-directively responsive to said desired horizontally incident waves.

3. A directive antenna array including in combination a vertical loop, a horizontal loop, means connecting said loops in series, a horizontal dipole, phasing means connected to said dipole and means connecting said dipole in series with said loops.

4. A directive antenna including a loop antenna responsive to horizontally incident vertically polarized waves and to vertically incident waves, means serially connected to said loop antenna for neutralizing its response to said vertically incident waves, said neutralizing means being responsive to horizontally incident horizontally polarized waves, and means for neutralizing the response of said first mentioned neutralizing means to said horizontally incident horizontally polarized waves.

5. A directive antenna array including a horizontal dipole, said horizontal dipole including phasing means, a vertical dipole, said vertical dipole including phasing means, means serially connecting said dipoles, a vertical loop and means serially connecting said loop and said dipoles.

6. A directive antenna including a horizontal dipole responsive to horizontally incident horizontally polarized waves and to vertically incident waves, neutralizing means serially connected to said dipole antenna for neutralizing its response to said vertically incident waves, said neutralizing means being responsive to horizontally incident vertically polarized waves, and means for neutralizing the response of said first mentioned neutralizing means to said horizontally incident vertically polarized waves.

7. A directive antenna array including in combination a vertical loop, a horizontal loop, said loops having a common center, means connecting said loops in series, a horizontal dipole, arranged symmetrically in the planes of said vertical loops, phasing means connected to said dipole, and means connecting said dipole in series with said loops.

8. A directive antenna including a loop antenna responsive to horizontally incident vertically polarized waves and to vertically incident waves, means serially connected to said loop antenna for neutralizing its response to said vertically incident waves, said neutralizing means being responsive to horizontally incident horizontally polarized waves, and means for neutralizing the response of said first mentioned neutralizing means to said horizontally incident horizontally polarized waves, said loop antenna and each of said neutralizing means being arranged with a common center.

9. A directive antenna array including a horizontal dipole, said horizontal dipole including phasing means, a vertical dipole, said dipoles having a common center, said horizontal dipole including phasing means, means serially connecting said dipoles, a vertical loop having its center coincident with said common center, and means serially connecting said loop and said dipoles.

10. A directive antenna including a horizontal dipole responsive to horizontally incident horizontally polarized waves and to vertically incident waves, neutralizing means serially connected to said dipole antenna for neutralizing its response to said vertically incident waves said neutralizing means being responsive to horizontally incident vertically polarized waves, and means for neutralizing the response of said first mentioned neutralizing means to said horizontally incident vertically polarized waves, said dipole and each of said neutralizing means being arranged about a common center.

11. An antenna of the character of claim 3 including a sense antenna non-directionally responsive to horizontally incident vertically polarized waves.

12. An antenna of the character of claim 5 including a sense antenna non-directionally response to horizontally incident horizontally polarized waves.

13. A directive antenna array of the character of claim 1 in which the said antenna and first and second minimizing means are arranged to provide a minimum of mutual coupling.

14. An array of the character of claim 3 in which said horizontal loop, said vertical loop and said horizontal dipole are arranged to provide a minimum of mutual coupling.

15. An array of the character of claim 5 in which said horizontal dipole, said vertical dipole, and said vertical loop are arranged to provide a minimum of mutual coupling.

16. A directive antenna array of the character of claim 1, including a sense antenna non-directionally responsive to said desired incident waves and in which said directional and said non-directional antennas and said first and second minimizing means are arranged to provide a minimum of mutual coupling.

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