June 8, 1937. R. H. WORRALL 2,082,812

SELECTIVE ANTENNAE

Filed Nov. 2, 1935

FIG. 1

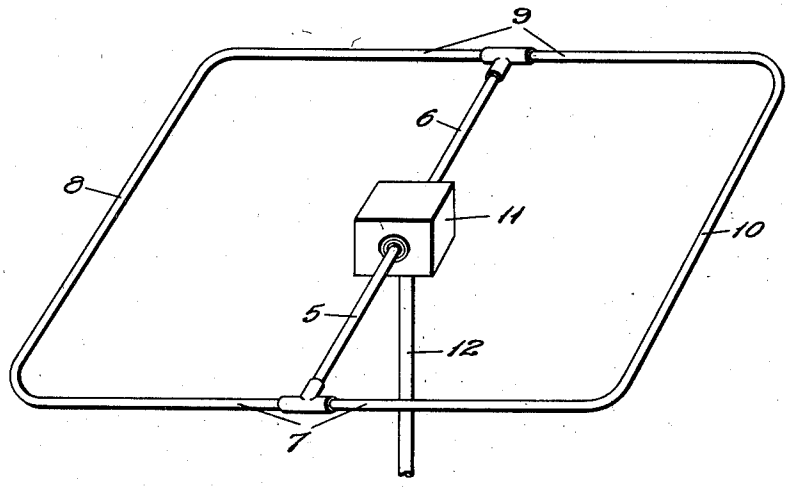


FIG. 2

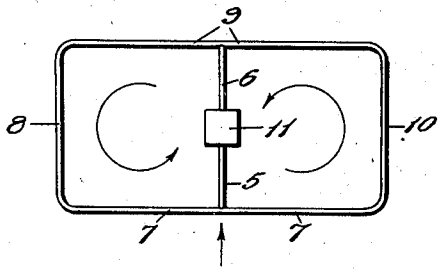


FIG. 3

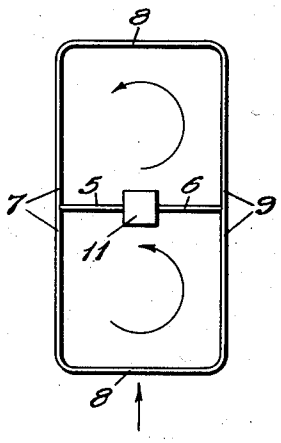
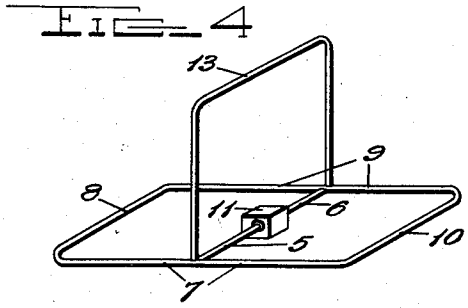


FIG. 4



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SELECTIVE ANTENNA

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10 Claims. (Cl. 250—11)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This invention relates to method and means for receiving radiant energy on special loop collectors.

One object of this invention is to provide a means for receiving only one component of a transmitted electric wave, and excluding all other components.

Another object of the invention is to provide a means for receiving simultaneously all components of a transmitted electric wave.

Another object of the invention is to provide a means for detecting the true direction of travel of a transmitted electric wave.

Other objects and uses will be apparent from the description which follows:

In the accompanying drawing, forming a part of this specification, and in which like numerals are used to denote like parts throughout the same:

Fig. 1 is a perspective view of one embodiment of the invention, consisting of a special loop referred to hereinafter as a "binocular loop".

Fig. 2 is a plan view of the binocular loop, in a horizontal plane, with the central common electrical path in a relatively north and south direction with respect to the paper;

Fig. 3 is a plan view of the binocular loop, in a horizontal plane, with the central common electrical path in a relatively east and west direction with respect to the paper;

Fig. 4 represents a perspective view of the binocular loop in a horizontal position, combined with a single vertical loop whose horizontal axis is parallel to the central, common electrical path of the binocular loop, and which is connected across this common path in such a manner that the common path forms one side of said vertical loop.

In the drawing wherein, for the purpose of illustration, is shown one embodiment of the invention, the numerals **7**, **8**, **9**, and **10** indicate the sides of a primary rectangular loop, whose sides are connected so as to form a continuous electrical path. At the midpoint of sides **7** and **9** the parts **5** and **6** are connected with electrically conductive joints. The free ends of these parts meet but are not directly connected together in a terminal box **11**, effectively dividing the primary loop into two equal rectangular loops, and forming a central conducting path parallel to the sides **8** and **10**. This path may contain one element of a coupling device for the purpose of transferring energy therefrom. The common path **5**, **6** is insulated from the terminal box **11** by suitable low loss bushings. The terminal box **11** is supported and grounded by the down shaft **12**, which extends from the box perpendicular to the plane of the loop. Within this terminal box the parts **5**, **6** are joined or coupled to the termination of a two-wire, or other type, non-receptive transmission line or other type of conductor which extends through the down shaft **12**, and is shielded thereby. The other end of this transmission line is connected to suitable radio receiving apparatus.

In Fig. 4 of the drawing is shown a modification of the invention, in simplified form, in which a vertical loop **13**, with one side removed, is connected across the points where the parts **5** and **6** join the principal loop. The loop **13** has its vertical axis perpendicular to the plane of the binocular loop. In actual use for its designed purpose, the vertical loop **13** must be shielded, or sufficiently removed from the binocular loop, so that there is no coupling or mutual inductance between them.

All the above-mentioned parts, except the terminal box and the transmission line, are made of thin walled, hard drawn copper tubing, or similar electrically conductive material.

The terminal box may be made of bakelite, hard rubber, or the like, or of appropriate metallic shielding material. The transmission line may be of any material suitable for the type of line employed.

The operation of the invention is as follows, considering the binocular loop located in a horizontal plane:

Each transmitted electrical wave above a certain frequency (about 6000 kcs.) may be considered as composed of three components, viz: the "A" component, which is the ground wave, and which has its electric vector polarized perpendicular to and its magnetic vector polarized horizontal to the earth's surface; the "B" component, which is one part of the reflected sky wave, and which is polarized in the same manner as the "A" component; and the "C" component, which is the other part of the reflected sky wave, and which has its electric vector polarized horizontal to and its magnetic vector polarized perpendicular to the earth's surface.

In Figs. 2 and 3 the arrows outside the loops indicate the direction of wave travel.

Any current induced in **5**—**6** will result in a received signal.

Referring to Figs. 1, 2, and 3, with the binocular loop horizontal in every case, consider the effect of the "A" component. Since the magnetic field of the "A" component is horizontal and travels parallel to the earth's surface, and since the loop is also horizontal and parallel to the earth, no

magnetic lines are cut and no E. M. F. is induced in the loop, so that no signal is received.

Referring to Fig. 2, consider the "B" component's effect on the binocular loop. "B" component also has a horizontal magnetic field, but its travel instead of being parallel to the earth's surface, is downward from the heaviside layer. Consequently, the magnetic field would cut the opposite loop members simultaneously.

Thus, the field will cut the members **5—6, 8,** and **10** simultaneously inducing exactly equal E. M. F.'s in these members. Since no E. M. F. is induced in **7** and **9**, the E. M. F.'s are exactly balanced and no current will flow in any member; therefore, no signal will be received.

Referring to Fig. 3, the same reasoning as above applies except that different members are cut; viz., **7** and **9**. In intermediate positions, between that shown in Fig. 2 and that shown in Fig. 3, a similar balance exists.

Consider the "C" component, referring to Fig. 2. The magnetic field, being vertically polarized, cuts the near side **7** and, a fraction of an instant later, the far side **9**. The effective voltages on the opposite sides of both secondary loops are equal, but slightly different in phase. A resulting round-the-loop voltage exists in each half, as shown by arrows. The current flow is around the loop but there is no flow in **5—6** because the two individual loop voltages are in direct phase opposition and produce cancellation in the common electrical path. Hence, there is no signal received.

Now let us rotate the loop 90 degrees in the horizontal plane (Fig. 3), so as to receive the signal upon the end of the loop. The wave motion is no longer parallel to **5—6** but has a component parallel to **7** and **9**. This results in a slight departure from perfect phase opposition in the two round-the-loop voltages, proportional to the time required for the wave to pass from the center of the first secondary loop to the center of the second secondary loop. This time interval is proportional to the sine of the angle of rotation from the position of Fig. 2, and is a maximum in the position of Fig. 3. This represents a maximum phase difference (from opposition) of the E. M. F.'s in **5—6**, and a maximum of current flows, producing a maximum signal.

This device, therefore, gives the same type of bi-lateral directional characteristics on the "C" component alone as the ordinary vertical direction finder loop gives on the combined "A" and "B" components. Since the "A" and "B" components do not produce a signal with the binocular loop horizontal, the true direction of wave travel will be indicated, regardless of the varying proportions or phases of the wave components, failing only when the "C" component is too weak to be detected.

In order to increase the phase differential and, as a result, the magnitude of the current flowing in the common path **5—6**, the dimensions of the sides **7** and **9** may be greatly extended. This has the effect of increasing the time interval between passage of an electric wave at the centers of the two loops. (See Fig. 3.)

Referring to Fig. 4, with the principal loop horizontal as before, the horizontal portion will respond only to the "C" component as previously described. The vertical loop **13** will however respond only to the "A" and "B" components, according to the theory herein previously discussed. The composite loop will therefore respond simultaneously to and give bilateral bearings upon all the components of an electric wave. As previously stated the vertical loop must be so shielded or removed from the principal loop that no coupling nor mutual inductance shall exist between them. The purpose of the composite loop is to obtain a bearing on the direction of an electric wave under any and all circumstances. This arrangement is based on the fundamental direction finder theory that refraction, commonly known as night effect, is caused by interference at the point of reception between the "A" and "C" components, and that ordinary fading is caused by like interference between the "A" and "B" components. Unless these two phenomena occur simultaneously, the composite loop will always give an indication of the direction of travel of an electric wave, through use of the portion which is responsive to the component or components unaffected by the refraction or fading.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

Having thus described my invention, I claim:

1. A directional receiving antenna system responsive to wave energy of a single polarization only, comprising a closed loop in a horizontal plane, a pair of conductors lying within the plane of said loop connected to and extending from the center of opposite sides thereof toward the center of said system, and a non-receptive transmission line or other type of conductor, adapted to be connected to a radio apparatus, extending to the center of said antenna system and having the wires thereof connected or coupled to said pair of conductors.

2. A bi-directional receiving antenna system responsive to wave energy of a single polarization only, comprising a horizontally disposed closed loop, a pair of conductors lying within the plane of said loop connected to and extending from the center of opposite sides thereof toward the center of said system and a non-receptive, balanced transmission line or other type of conductor, adapted to be connected or coupled to a radio apparatus, extending to the center of said antenna system and having the wires thereof connected to the termination of said pair of conductors.

3. A directional receiving antenna system responsive only to the vertically polarized magnetic vectors of electro-magnetic wave energy comprising a closed horizontal loop, a pair of conductors lying within the plane of said loop connected to and extending from the center of opposite sides thereof toward the center of said system, a non-receptive transmission line or other type of conductor, adapted to be connected to a radio apparatus, extending to the center of said antenna system and having the wires thereof connected or coupled to the termination of said pair of conductors, and means for shielding said transmission line or conductor.

4. A bi-directional antenna system responsive to wave energy of a single polarization only, comprising a pair of oppositely disposed symmetrical half loop sections occupying a single horizontal plane, said half loop sections being joined together to form a closed loop, conductors joined to and extending from both of the points of juncture of said half loops into a terminal box or other type of junction at the center of said system, and a balanced transmission line or other type of non-receptive conductor having the wires thereof connected or coupled to the termination of said conductors.

5. A directional antenna system responsive to wave energy of a single polarization only, comprising a pair of oppositely disposed symmetrical half loop sections occupying a single horizontal plane, said half loop sections being joined together to form a closed loop, symmetrical conductors joined to and extending from both of the points of juncture of said half loops into a terminal box or other type of junction at the center of said system, a non-receptive balanced transmission line or other type of conductor having the wires thereof connected or coupled to the termination of said conductors, and means for shielding said transmission line or conductor.

6. A directional antenna system responsive only to sky wave energy with magnetic vectors vertically polarized, comprising a pair of oppositely disposed half loop sections occupying a horizontal plane, said half loop sections being connected together to form an electrically closed loop, conductors joined to and extending from the electrical centers of two opposite sides of said closed loop into a terminal box or other type of junction at the electrical center of said system, and a balanced transmission line or other type of conductor connected or coupled to the termination of said conductors.

7. An apparatus consisting of a horizontally disposed, rotatable, primary loop of electrically conducting material, subdivided by a common electrical path into two similar secondary loops, having the terminals of said common electrical path connected at the outer ends to opposite sides of the primary loop and at the inner ends, through a terminal box or other type of junction, to a non-receptive transmission line or other type of conductor leading to any convenient form of receiving apparatus, in combination with a rotatable vertical half loop connected across the outer terminals of the common electrical path, but shielded or separated therefrom, for the purpose of receiving all components of an electric wave, and determining therefrom the direction of travel of the electric wave in space.

8. An apparatus consisting of a horizontally disposed, rotatable, primary loop of electrically conducting material, subdivided by a common electrical path into two similar secondary loops, having the terminals of said common electrical path connected at the outer ends to opposite sides of the primary loop and at the inner ends, through a terminal box or other type of junction, to a balanced transmission line or other type of conductor leading to any convenient form of receiving apparatus; for the purpose of receiving only the component of electro-magnetic wave energy whose magnetic vectors are polarized vertically, and determining therefrom the direction of travel of the electric wave in space.

9. A directional antenna system responsive to wave energy of a single polarization only, comprising a pair of oppositely disposed part loop sections occupying a single horizontal plane, said sections being joined together to form an electrically closed loop, conductors joined to and extending from opposite sides of said closed loop, connected or coupled to a transmission line or other type of conductor adapted to be connected or coupled to a radio apparatus, and forming with said line and apparatus an electrical path common to both said part loops, and means for shielding all connecting means so as to render them non-receptive.

10. A directional antenna system responsive to all components of electro-magnetic wave energy, comprising a pair of oppositely disposed part loop sections occupying a single horizontal plane, and connected together to form an electrically closed primary loop, conductors joined to and extending from opposite sides of said primary loop connected or coupled to a transmission line or suitable conductor adapted to be connected or coupled to a radio apparatus, a vertical part loop widely separated or shielded from said primary loop, whose extremities are connected to the points of juncture of aforesaid conductors with said primary loop, and means for shielding all connecting means so as to render them non-receptive.

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