Feb. 20, 1940. R. KÜMMICH ET AL 2,190,717

RADIO DIRECTION FINDER

Filed Dec. 17, 1936

Fig. 1

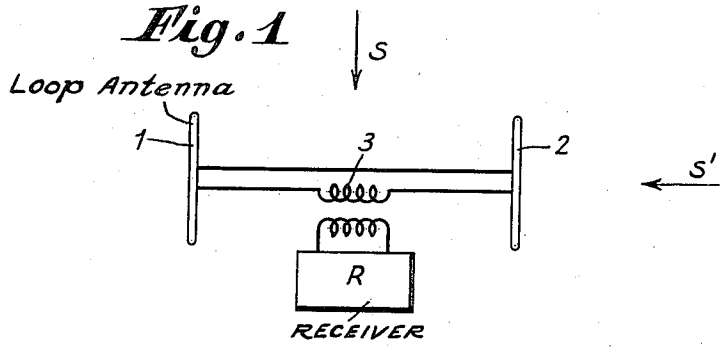



Fig. 2

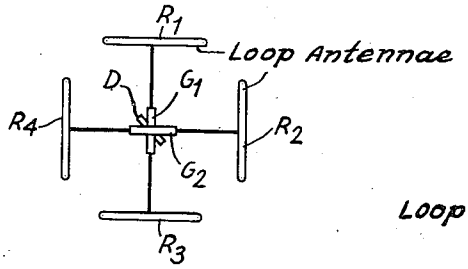



Fig. 3

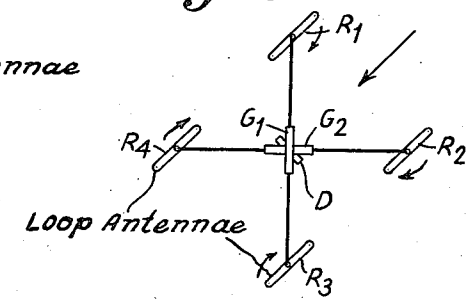



Fig. 4

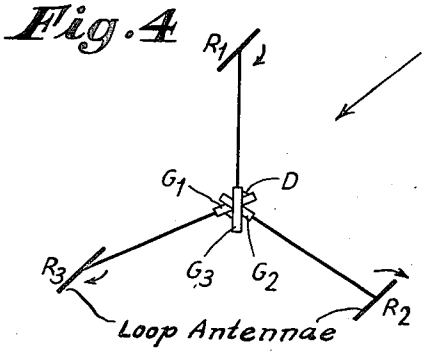
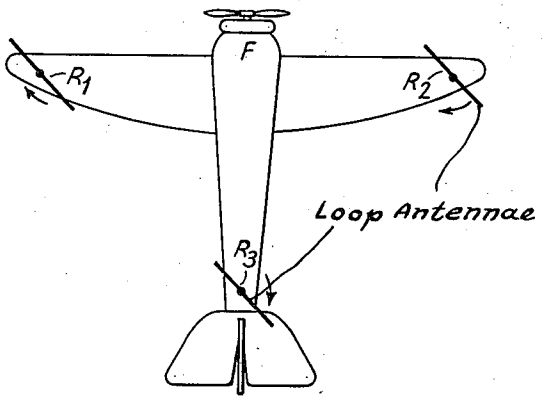



Fig. 5




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## RADIO DIRECTION FINDER

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In Germany October 19, 1935

2 Claims. (Cl. 250—11)

This invention is concerned with a radio goniometer in which several rotary frames or antenna loops are provided. An object of the invention is to overcome the adverse effects of waves reflected from the Kennely-Heaviside layer.

It is known from the art that a plain rotating frame antenna has two zero or minimum points for a vertically polarized wave whenever the plane through the frame is at right angles to the direction of propagation. In reference to a horizontally polarized wave coming in obliquely from above, the frame also exhibits two zero points, though these latter are shifted an angle of 90 degrees in reference to the former. Interference, or so-called "night-effects" are usually present whenever the plane in which the frame lies is at right angles to the direction of propagation.

The invention will now be explained in further detail, reference being made to the accompanying drawing in which

Fig. 1 represents a conventional system of two loop antennae spaced apart but lying in planes parallel to one another;

Fig. 2 represents another system employing four antenna loops arranged about a common center;

Fig. 3 shows one embodiment of our invention in which a plurality of frames is provided, each being rotatable about its own axis while maintaining parallelism between their respective planes;

Fig. 4 shows a modification in which only three frames are distributed over a circular arc; and

Fig. 5 shows a preferred arrangement of a three-frame goniometer system mounted on board an airplane.

It is known in the prior art that the night effect may be eliminated by the aid of two frames of like size, the planes of which have a common horizontal axis and are disposed some distance apart from each other and revoluble about an interposed vertical shaft or axis. A measurable difference of potential is then obtained in the two frames, except when the direction of transmission S is as shown in Fig. 1. The voltages obtained from the two loops 1 and 2 respectively are differentiated in the transformer 3 and observed in the receiver R. The minimum difference is obtained for the vertically polarized wave when each of the frames is positioned, in phase, in the maximum intensity position. For the horizontally polarized waves each of the frames is in the zero position. In other words, the zero or minimum point cannot be shifted as a result of night effect. For a wave coming in from the direction marked S', the system also occupies the zero position, but only for the vertically polarized wave, for which, as will be clear, each of the frames individually is in the zero position; but not so for the horizontally polarized wave inasmuch as the voltage in frame 1 presents a phase shift in relation to the voltage in frame 2. However, this second zero point is not free from night effect. If one observes the angle $\alpha$ between the direction of transmitted signals and the planes through the frames, reception for the vertically polarized wave as a general rule is proportional to sin $(2\alpha)$ and for the horizontally polarized wave it is proportional to sin $2\alpha$.

Hence, if night effect is present, only the first-named fixed zero places will be obtained. During the daytime, however, when normally only the vertically polarized wave exists, four fixed zero points will be found. It is known from practice that these two pairs of zero points may be distinguished by changing the polarity of the frame, for then the zero points which are free from night effect will be caused to disappear, but not the others.

The drawback of this arrangement consists of its extremely low sensitivity. For the incoming or signal amplitude is $\frac{\lambda}{\kappa d}$ times smaller than that of a single frame, where $\lambda$ is the wavelength and $d$ is the distance between the two frames. For reasons of manipulation, however, the distance cannot be made more than a few meters. For a distance of 3 meters and a wavelength of 1000 meters, for instance, the amplitude is 100 times less than that of a single frame.

In the case of a simple frame or a directional structure or system comprising two linear aerials (say, an Adcock antenna system) one is confronted with the further problem of obtaining satisfactory sensitiveness and ready rotatability. The remedy known in the art is to employ two structures mounted so as to be staggered or displaced an angle of 90 degrees. These are connected with a goniometer comprising a revolvable search or exploring coil. For example, instead of a rotary frame, two stationary frames crossing each other at right angles could be used, each of these frames being united with one of the field coils respectively of a goniometer. The field coils would likewise cross each other at right angles. Inside the magnetic field set up by the field coils is a rotatable search coil which

is connected with a receiver. The observed voltage represents the same function of the angle of rotation as obtained in a rotary frame. The device may also be built to comprise several fixed coils in cooperation with one or more rotatable field coils.

Now, this known goniometer principle is not readily applicable to a double or twin frame. For if, in analogy to a simple frame type goniometer two crossed double frames were connected with a goniometer as illustrated in Fig. 2, this arrangement in the four positions in which the goniometer coil is in coupling relation with only one of the two field coils would, to be sure, replace the rotatable double frame, but not in the intermediate positions. For instance, in the 45-degree direction the voltage in the search coil would be neutralized with respect to only one of the waves; that is to say, the vertically polarized or the horizontally polarized wave. In other words, in this direction, and likewise in all other directions apart from the four mentioned, no common zero point for the two waves could be obtained. The indications would not, therefore, be free from night effect. An arrangement in which four fixed double frames displaced 45 degrees are united with a (four-pole) goniometer is free from night actions only in some places for the reason that the voltage induced in the search coil by the vertically polarized wave varies with the angle of direction in accordance with another law than that of the voltage induced by the horizontally polarized wave.

According to this invention the difficulty is obviated thus: Three or more frames rotatable about their axes are mounted symmetrically on the circumference of a circle and are connected with a suitable goniometer arrangement.

An equipment of this kind designed for four frames is shown in Fig. 3. $R_1$—$R_4$ are four vertical frames whose centers are symmetrically distributed on the periphery of a circle. Pairs of diametrically opposite frames are differentially associated with the field coils $G_1G_2$ of a goniometer. All of the four frames are simultaneously rotated about the same angle. They may be motor driven, if desired. Their planes remain always in parallelism. At the same time, the goniometer search coil D always partakes of this rotation. It is so adjusted that in the presence of maximum and exclusive coupling with one field coil, the planes of the corresponding frames are at right angles to their connecting line. The currents flowing in the field coil are in phase for any desired position of the frames. The field coils are so connected that their magnetic fields induce currents in the search coil in an opposite sense.

For any direction of the transmitter S there is thus obtained a sharp and unequivocal zero point for the voltage in the search coil of the goniometer if the constituent frames are positioned for maximum pick-up in reference to the vertically polarized wave. For the horizontally polarized wave, all of the frames are then positioned in zero so that their difference again results in zero. Hence, the zero point is unaffected by night effect. It will thus be seen that, no matter what the direction of the signals, this goniometer arrangement behaves like the double frame, though it offers the merit that the various frames may be placed far apart so that high response or sensitivity is realized, while yet insuring handy manipulation and use.

The inertia of the parts to be revolved may be diminished by replacing each one of the rotary frames by a crossed frame goniometer. Instead of the rotary double frame, there result in the instance here chosen, eight fixed frames and five goniometers.

In the absence of the horizontally polarized wave, that is to say, practically during daytime, just as with the plain double-frame arrangement, there are obtained with the arrangement here disclosed four precise non-shifting zero points. To distinguish the pair of zero points which is free from night effect from the pair of zero points that is not free presents no practical difficulty compared with the case of the double frame. It is true that one frame in each of the two pairs has been reversed, but this affords no absolutely safe criterion, seeing that in the 45-degree direction the zero point free from night effect is preserved. The action of the two pairs of frames upon the goniometer search coil is exactly alike. It will be understood, therefore, that the zero points will be exactly distinguishable if one frame is switched over after the other. At least in one of these reversal points, the zero point free from night effect must then disappear.

Another plan would be to superpose a voltage which is derived from a non-directional antenna in the center of the square upon the voltages otherwise derived from the directional loops. Thus, when the zero point free from night effect shifts to the right, the other one which is not free therefrom, is displaced to the left, and vice versa. After due calibration by the aid of a transmitter or beacon whose direction or position is known, the zero points may then be differentiated in the proper way.

After the direction of a transmitter or beacon has been ascertained by one of the methods hereinbefore disclosed, it may also be necessary to determine the sense of the same beacon. In addition to the goniometer and a centrally disposed frame adapted to make the direction-finding free from night effects and fix the zero points, there is associated with the input circuit of the receiver for the said purpose an eccentrically mounted frame, for instance, a frame which is parallel to the others and which in the direction of the beacon is moved somewhat out of the middle of the square formed by the four outer frames. Inasmuch as its energy pick-up presents a certain phase shift in reference to the voltage of the center (precision) frame, it follows that the zero point will experience a slight shift, the direction of the shift being a function of whether the phase is leading or lagging. This depends upon whether the sense-finder frame is closer to or remoter from the beacon than the center frame serving to make direction-finding more precise.

The arrangement hereinbefore disclosed may be developed in various ways. For example, it is possible to use three frames or more than four frames distributed over the circumference of the circle.

Fig. 4 shows a direction-finder scheme free from night effects which comprises only three frames distributed over a circular arc as indicated at $R_1$—$R_3$. In this case it would not do to combine two frames to form a pair and to unite them with a joint field coil of the goniometers, in fact, each frame must be provided with a distinct field coil ($G_1$—$G_3$) which are disposed at angles of 120 degrees to one another. The search coil D which is rotated conjointly with the frame is so adjusted that it is uncoupled in relation to each one of the

field coils when the frame associated therewith is so positioned that its plane passes through the center of the circle. The voltage induced in the search coil, in the presence of perfect symmetry, has a zero point free from night effect when the three planes through the frames are positioned in the direction of the beacon S.

All of the ways and means and methods hereinbefore described in connection with the four-frame arrangement may be applied, of course, in a similar way to the three-frame goniometer.

Fig. 5 finally shows a three-frame goniometer arrangement mounted on board an airplane. It is thus feasible to apply the methods adapted to insure navigation free from night effect on aircraft.

The arrangements hereinbefore disclosed are, of course, applicable on fixed land stations. But if these multi-frame goniometer outfits of this invention are used on airplanes, the goniometric error of the various frames will vary one from the other. In this case, in a way well known from the art, the error may be duly considered for each one of the frames.

The exemplified embodiments herein disclosed do not exhaust the basic idea of the invention. Various other embodiments may suggest themselves to those skilled in the art, and still they would be included in the scope of the invention.

We claim:

1. A direction finder system comprising three rotatable antenna loops having their axes of rotation parallel to one another and equidistant from the center of symmetry of said system, a goniometer having differently oriented magnetic field coils and a rotatable search coil, electrical connections between individual ones of said field coils and appropriately associated antenna loops, means common to said loops and to said search coil for rotating each of the same on its respective axis and with the same angular displacement, means for maintaining parallelism between the magnetic axes of said loops, and means for causing voltage variations to be induced in said search coil, which voltage variations are indicative of the directional axis of radiant energy collected by said antenna loops.

2. In the art of direction finding in which exactly three rotatable antenna loops and a goniometer are provided, said goniometer having differently oriented magnetic field coils and a rotatable search coil and electrical connections between individual ones of said field coils and appropriately associated antenna loops, the method of inducing a voltage in the search coil which has directional significance, which method comprises rotating each of said antenna loops and said search coil about its own axis, maintaining parallelism between the magnetic axes of said loops, and transferring the energy collected by said loops to associated ones of said magnetic field coils whereby the resultant voltage induced in said search coil is made commensurate with the amplitude of the energy collected by said antenna loops at different angles of orientation thereof.

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