Sept. 15, 1936. A. LEIB 2,054,160

DIRECTIONAL RECEIVER

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Fig. 1

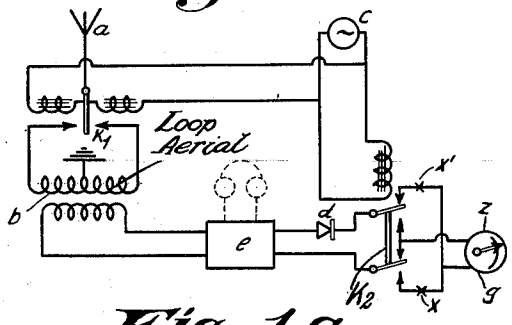


Fig. 1a

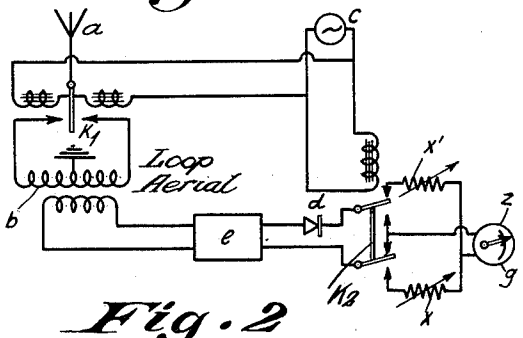


Fig. 2

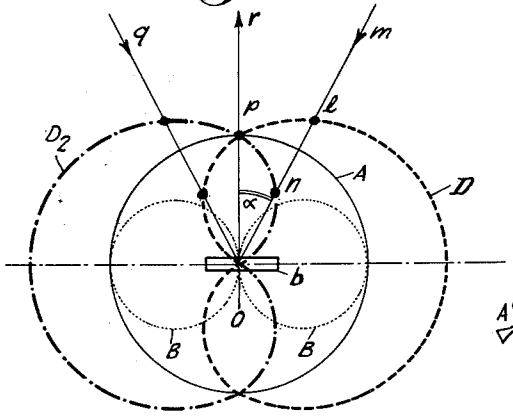


Fig. 3

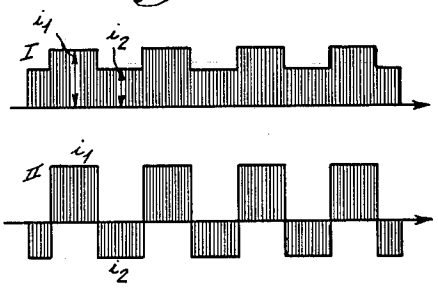


Fig. 6

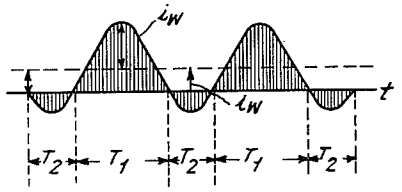


Fig. 4

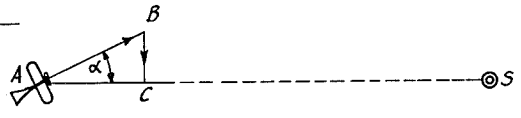
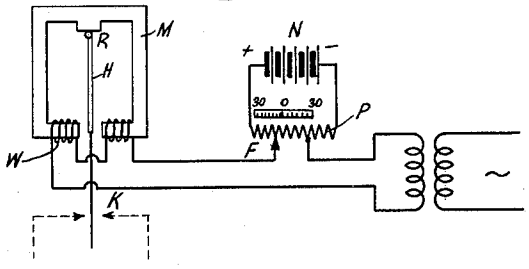


Fig. 5



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Fig. 7

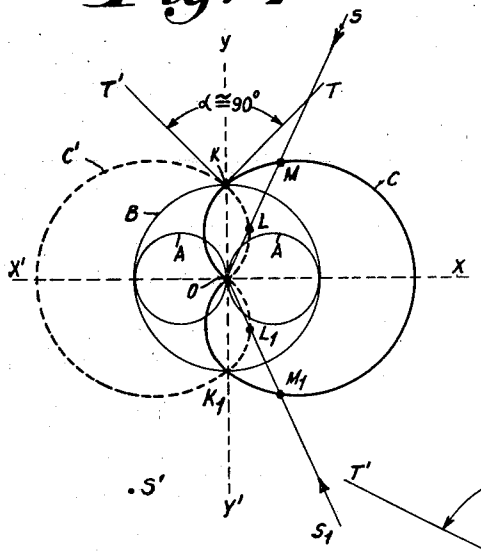


Fig. 8

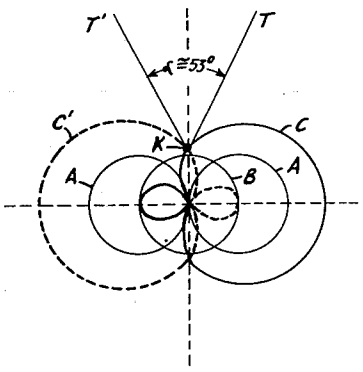
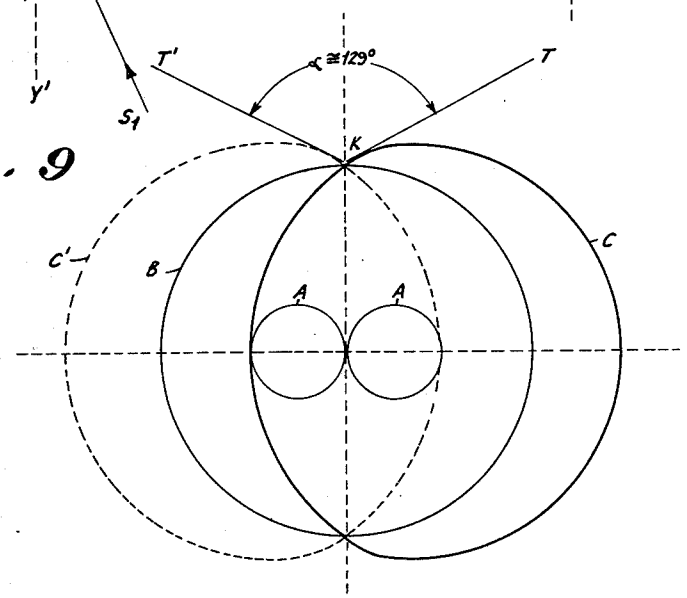


Fig. 9



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UNITED STATES PATENT OFFICE

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DIRECTIONAL RECEIVER

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Application June 14, 1932, Serial No. 617,159½
In Germany July 16, 1931

3 Claims. (Cl. 250—11)

This invention relates to radio direction-finder, especially adapted to aerial craft, comprising one directional and an additional (directional or non-directional) antenna and means insuring rhythmic change-over thereof.

In describing applicant's novel method of and means for determining the direction of a source of signalling energy reference will be made to the drawings attached to this application and forming a part thereof. In the drawings Figure 1 shows a directional receiver circuit arranged in accordance with the present invention; Figures 2, 3, and 4 illustrate the operation of the arrangement of Figure 1; Figure 1*a* and 5 illustrate modifications of the arrangement of Figure 1; Figure 6 illustrates the operation of the arrangement of Figure 5 and Figures 7 to 9 inclusive illustrate the mode of operation of the novel arrangements of Figs. 1, 1*a* and 5.

It has been previously suggested in the art to feed the receiver apparatus of the direction-finder from two aerials so as to insure a preciser determination of the direction of the incoming beam. The said two aerials may consist of two crossed loops which alternately, at a rapid rate or rhythm are connected with the receiver, or else one of the aerials may consist of a directional loop or coil antenna, and the other one of a non-directional linear antenna feeding the receiver at the same time though in such a manner that their sense of connection is reversed at a rapid rate.

A similar direction-finding scheme is reproduced in Fig. 1 of the attached drawings for the sake of affording a clearer understanding of what is set forth further below. Referring to Fig. 1, *a* denotes a non-directional straight antenna, *b* the winding of a directional loop aerial. k_1 is a reversing switch (double-pole switch) adapted to connect the antenna *b* at changing polarity in reference to the antenna *a*; *e* is a receiver, which may include signal demodulating means, *d* a suitable detector connected in the output circuit thereof and whose current is fed by way of a mechanical commutator (reverser) k_2 operating in synchronism with the change-over switch k_1 into a direct current indicator instrument *g* with central zero. The two synchronized throw-over switches k_1 and k_2 most suitably may be controlled from an A. C. generator *c* electrically. The operation of the arrangement is as follows:

Referring to Fig. 2, let *b* be the position of the directional loop aerial, for example, loop *b* of Fig. 1, mounted in an aircraft and having directional characteristic BB, and circle A the characteristic of the non-directional antenna *a*. The resultant directional characteristic of the two aerials, for one sense of coupling, is represented by the curve D1 and for the other direction of coupling by curve D2. Suppose the direction of travel of the airplane is indicated by the arrow *or*. If the beacon to be received has the direction *mo* then the incoming signal volume, for one sense of coupling of the antenna will be measured by the distance *ol*, and for the opposite coupling by the distance *on*. This results in a detector current having a shape as shown by graph I in Fig. 3, the smaller values i_2 corresponding to the resulting current when the two antenna currents oppose, and the larger values i_1 to the resulting current when they add. Under the action of the reversing switch k_2 the current flowing through the direct current indicating instrument *g* has a shape as shown in curve *i i*, Fig. 3. Since i_1 is greater than i_2, the needle *z* of the indicating instrument will be kicked out of its central position, say, towards the right-hand side, and this the pilot interprets as meaning that the source of the signals is located on the right of his direction of travel. If the course is to be set for the source of the signals the pilot must steer to the right until the directions *or* and *om* coincide. In this instant the directional antenna is at right angles to the beam and becomes ineffective. Hence, the incoming volume independently of the reversing of the switch k_1, is measured by the distance *op*, and the needle of the direct current instrument *g* is returned to the zero position.

It can be similarly shown that when the direction of the incoming beam is *qo* the needle of the instrument *g* will be deflected to the left-hand side. Hence, when the pointer occupies the zero position this means that the transversal axis of the loop *b* points exactly at the transmitter.

The direction-finder arrangement as hereinbefore described and similar ones comprising two aerials and means for reversal of connection are thoroughly suited for checking up on the course of a trip in the absence of wind. But when there is a drift the following complication enters. If an airplane A (see Fig. 4) is to travel in the direction AS with course for the beacon S, and if the velocity of the wind is equal to BC then, in order to compensate for the drift BC, the pilot must set his course for AB. In order to maintain this course for wind of a certain strength, in an arrangement for direction-finding as before described, the pilot must so turn the loop aerial relative to the aircraft that its transversal axis is directed towards the transmitter S. This ro-

tatory mechanism tends to complicate the equipment, not to speak of the fact that it represents additional ballast, and this militates against the prevailing aim to reduce both weight and volume in aircraft, not to mention this further circumstance that in a rotatable loop the protective tube provided to surround its winding can not be made streamline in shape seeing that its orientation in reference to the direction of the wind changes in accordance with its angle of rotation.

In order to overcome these difficulties arrangements according to this invention are so made that the line of zero reception or volume i. e., for a direction of the beam where the indicating instrument shows no deflection, is made rotary relative to the transversal axis of the loop aerial *b*. According to this invention this is accomplishable by providing means whereby the relation between the current impulse produced upon the indicator instrument in one position of the antenna and the impulse in the opposite connection is made variable or adjustable. For this purpose two different ways and means may be applied: (1) the ratio between the impulses can be regulated by the adjustment of the ratio between the corresponding current strengths by inserting at the points *x* and *x'* of Figure 1 of the leads brought to the indicating instrument *g* suitable variable resistances X as shown in Figure 1*a*, with the resistances set at different values.

(2) The ratio between impulses may be regulated and made unequal by adjusting the duration of the current impulses, i. e., the relation between the length in time the switch K is in one position and the time that said switch is in the other. For instance, if in the case of a directional characteristic as shown in Figure 2 the zero indication of the instrument *g* is to correspond to the direction *mo* of the beam, arrangements could be made so that the connection where the incoming volume is measured by the distance *on* lasts some longer time, and the connection corresponding to volume *Oq* some shorter period of time. If the relationship between these periods has been so chosen that the products thereof are equal to the corresponding currents of the instrument *g* the opposite impulses occurring in rapid succession and coming to act upon the mobile part of the indicating instrument will neutralize one another, with the consequence that the needle stays in the middle or zero position.

An example to illustrate the desired effect in the case of using reversing contacts controlled by polarized relays is shown in Figure 5. Referring to the same M is the magnet system and H one of the keepers of a polarized relay R with reversing contact K as shown in the prior figures, the operating winding W thereof being energized from an alternating current source. Suppose that the positive direction of the alternating current corresponds to the throw of the reversing contact towards the left-hand side, and the negative sense of the controlling alternating current to the change of the contact towards the right-hand side. The periods of time T_1 and T_2 of the left- and the right-hand contact positions are alike, if the positive and the negative energization of the relay is symmetric as to time. If, as indicated in Fig. 6 an additional direct current energization is superposed upon the alternating current excitation, said supplemental excitation being taken, e. g., from a potentiometer P fed from a direct current source N, then, by suitable setting of the contact point F (Fig. 5) it is always feasible to obtain the desired ratio between the period T_1 of resultant positive excitation and the time T_2 of the resultant negative excitation of the relay. Hence, zero indication of the controlling instrument *g* can be insured at will no matter what the direction *no* of the beam for a directional characteristic as shown in Fig. 2. Since each and every direction *no* as the line of zero reception or volume of the check-up apparatus corresponds to a definite adjustment of the relation between the times or periods $T_1:T_2$ and since this ratio is absolutely a function of the position of the contact slide F of potentiometer P, it follows that the latter can be calibrated to read in terms of the angle of direction α (see Figs. 2 and 4), so that, in order to preserve direction or course all that is necessary to do is to shift the slide F into the corresponding position as indicated on the scale of the potentiometer P.

Hence, in an arrangement of the invention as hereinbefore described, in order to check-up on the course to be kept in the presence of winds of varying velocities or strength, it is not necessary to turn the coil antenna relative to the aircraft; indeed, the same may be mounted stationary therein in such a way that its transverse axis of parallel to the longitudinal axis of the craft. Distinct mechanical means for rotation are dispensed with, and the protective sheet or tubing surrounding the turns of the loop aerial can be formed stream-line.

The direction finders as described above may, in accordance with the present invention, be operated to obtain sense of direction as well as line of direction. This operation has been illustrated in Figures 7, 8, and 9 of the drawings.

In Figure 7 the graph A denotes the directional characteristic of a coil antenna positioned at right angles to the axis *y, y'*, and B the characteristic of a non-directional antenna, the assumption being made that the radius of the circle B is equal to the diameter of each circle A, although this need not necessarily be true. If the loop and vertical antennae are connected in one sense by k_1, the resulting energy may be represented by cardioid C. If the direction of connection of one of the two aerials be reversed, then the cardioid C' will represent the characteristic of the system. If the beacon beam has the direction SO, then, in one connection of the antenna (cardioid C) there is obtained an electromotive force measurable by the distance OM and in the other connection of the aerials an electromotive force measurable by OL. These electromotive forces act alternately, at a very high rate of rhythm, upon a receiver outfit comprising a rectifier whose output direct current is reversed in synchronism with the antenna reversal, see Figure 1, and act upon an electrodynamic or an electromagnetic indicator instrument. These impulses may be measured by the distances OM and OL, respectively. The resultant effect is determinable by the distance LM. If the direction of the beam SO coincides with the direction *y, y'* of the transverse axis of the coil antenna, then the needle of the indicator instrument will not be deflected out of its middle position. But if the transmitter, as indicated in Figure 7, is on the right-hand side of the axis *y, y'*, then the indicator hand will be caused to kick towards the right. If the transmitter, however, happens to be located to the left of the axis *y, y'*, the indicator needle will be thrown towards the left-hand side.

The indicator needle will deflect towards the right also when the beacon beam has the direc-

tion S'O. In order to ascertain whether the beam comes in from the front, in the direction SO, or from the rear, direction S'O, all the pilot has to do is to turn his direction finder loop. If the loop is built stationary inside the craft, he must veer his plane towards the right-hand side. As a result the coordinate system x', x, and y', y with the directional characteristics referred thereto are turned in clockwise direction. If the beacon beam has the direction SO the length ML will approach the point K, in other words, it is reduced in size and the deflection of the indicator hand is diminished also. But, if the beam came in from the direction S'O the length M_1, L_1 will recede from the point K_1; in other words, it grows and the deflection of the indicator increases. In this way it is possible to tell whether the transmitter station is located in front or in the rear.

Electrodynamic or electromagnetic instruments for visible reading are less sensitive than the head 'phones of an auditory direction finder. Hence, direction finder equipment using visual indicators need higher amplification. Another point is that indicator instruments comprise deflection ranges or kicks which correspond only to certain intervals of the energy inputs. Hence, they must often be re-set in practice so as to adapt their sensitiveness to different field intensities of the beams, and these volumes are a function both of the distance and the power of the transmitter station. The telephone, on the other hand, responds to the whole energy range from the smallest up to the largest volumes. Hence, it can be used without being altered or adjusted for the greatest as well as the smallest distances for which direction finding is still required.

According to the invention the direction finder in which use is made of two symmetric cardioids by alternate change-over of two aerials may be rendered more serviceable by making the energies represented by the two cardioids acoustically identifiable so that they may be distinguished by use of the 'phones shown dotted in Figure 1 rather than by causing the impulses due to the two cardioids to act upon an integrating instrument. This may be accomplished by identifying one of the cardioids by a long dash, and the other one by means of two short dashes. For instance, if the volume of the long dashes corresponds to the length of OM, see Figure 7, and the volume of the subsequent pairs of short dashes to the length of OL, in other words, if the long dashes are louder than the short ones, this means that the transmitter is located towards the right of the axis y, y'. If the volume of the short dashes predominates, the transmitter is situated on the left. Moreover, if the pilot has ascertained that the transmitter is located on the right hand side then, if when he turns the loop or the whole plane to the right, the difference in the volume of the two signals or impulses diminish, this means that the transmitter is located in front, whereas when they increase the transmitter is in the rear.

To regulate the sharpness or clarity of identification and obtain a more precise determination of the direction of the beam it is possible to use weaker signals where smaller distances between the receiver and the transmitter are dealt with. Regulation of the electromotive forces which are derived from one of the two receiving antennae, say, the non-directional, insures either greater working range, in which case the electromotive force from the non-directional aerial must be made large, or else a greater clarity of identification of the signal. In the latter case the electromotive force from the non-directional aerial should be chosen small. Since the two cardioids C and C' then will change their shape in a similar manner and remain also symmetric in relation to each other it follows that where great variations of the electromotive forces of the two aerials are concerned the characteristic y', y, will invariably preserve its position in reference to the direction finder.

The influence of the regulation of the electromotive forces of the aerials on the clearness of identification may be explained in the following way:

As the radio beacon or beam SO approaches the direction y, y' of the characteristic, the length of LM becomes smaller and smaller and finally shrinks to a point K when the transmitter falls in the line y', y. Inversely will the same distance and its length be found to grow in proportion as the beam deviates from the line y', y, and such departure will be identifiable so much more sharply the faster this growth takes place; in other words, the acuter the angle TKT' between the tangents of the two cardioids at point K as the apex becomes. Under conditions as shown in Figure 7 the said angle amounts to 90 degrees. The electromotive force due to the non-directional antenna (radius of circle B) is equal to the crest electromotive force due to the loop or coil antenna (diameter of the circles AA). Now, if for smaller distances from the radio beacon station the electromotive force due to the non-directional aerial is adjusted to, say, one-half of the previous amount, the two cardioids will assume a form as shown in Figure 8. The angle TKT' between the tangents at point K becomes smaller (approximately 53 degrees), and the sharpness of identification grows.

For great distances where sharp identification direction finding is unnecessary it is possible to raise the electromotive force due to the non-directional antenna, as shown in Figure 9. The radius of the circle B is chosen twice as large as the diameter of the circles AA. The cardioids CC' approach the shape of a circle, their areas become increasingly larger, and the range is correspondingly extended, but the sharpness is smaller seeing that the angle TKT' has here grown to 127 degrees.

The direction finder here disclosed is useful both for the waves of relatively great length that have heretofore been used in practice as well as for short and ultra-short waves.

What is claimed is:

1. A device for indicating the direction of a source of radiant energy comprising a loop aerial including an inductance having a grounded tap intermediate its terminals, a polar relay having a movable contact and two stationary contacts disposed on opposite sides of said movable contact thereby to make contact therewith first in one position and then the other, one of said stationary contacts being connected to one terminal of said loop aerial and the other stationary contact being similarly connected to the other terminal of said loop aerial, a connection between said vertical aerial and said movable contact, a receiver coupled to said inductance, a utilization circuit including indicating means for differentiating between the relative intensities of said radiant energy when received during certain intermittent time intervals in respect to such energy when received during intervening

time intervals, means including a potentiometer having a movable contact member thereon and a wind drift correction scale member cooperating with said contact member for applying to said indicating means a correction due to wind drift, a current reversing switch in circuit between said receiver and said indicating means, and means including a source of alternating current for actuating said polar relay and said reversing switch synchronously.

2. A device for indicating the direction of a source of radiant energy comprising, a loop aerial, a vertical aerial, means including a switch for coupling said vertical aerial alternately to opposite terminals of said loop aerial, a receiver, a current intensity indicating device, a circuit coupling said receiver to said current intensity indicating device, said circuit including means for reversing the connections between said receiver and said indicating device, and means for so adjusting said reversing means as to cause said indicating device to be compensated for a bearing angle due to wind drift, the last said means comprising a polar relay, a potentiometer in circuit with the windings of said polar relay and a biasing source across which said potentiometer is connected.

3. A radio direction finder including a directional and a non-directional antenna, a magnetic relay including an armature connected with said non-directional antenna, contacts connected with the terminals of said directional antenna whereby movement of said armature will connect said non-directional aerial alternately to the terminals of said directional aerial, a receiver coupled to said aerials, indicating means, circuits including switching means for connecting said indicating means to said receiver, a magnetic relay for actuating said last named switching means to reverse said connections, a source of alternating current, a circuit connecting said source to each of said magnetic relays, and a potentiometer and a source of direct current potential in parallel in the circuit between said source and said first named magnetic relay, said potentiometer being calibrated to read in terms of bearing angles.

AUGUST LEIB.