

Oct. 21, 1930.

J. A. PROCTOR

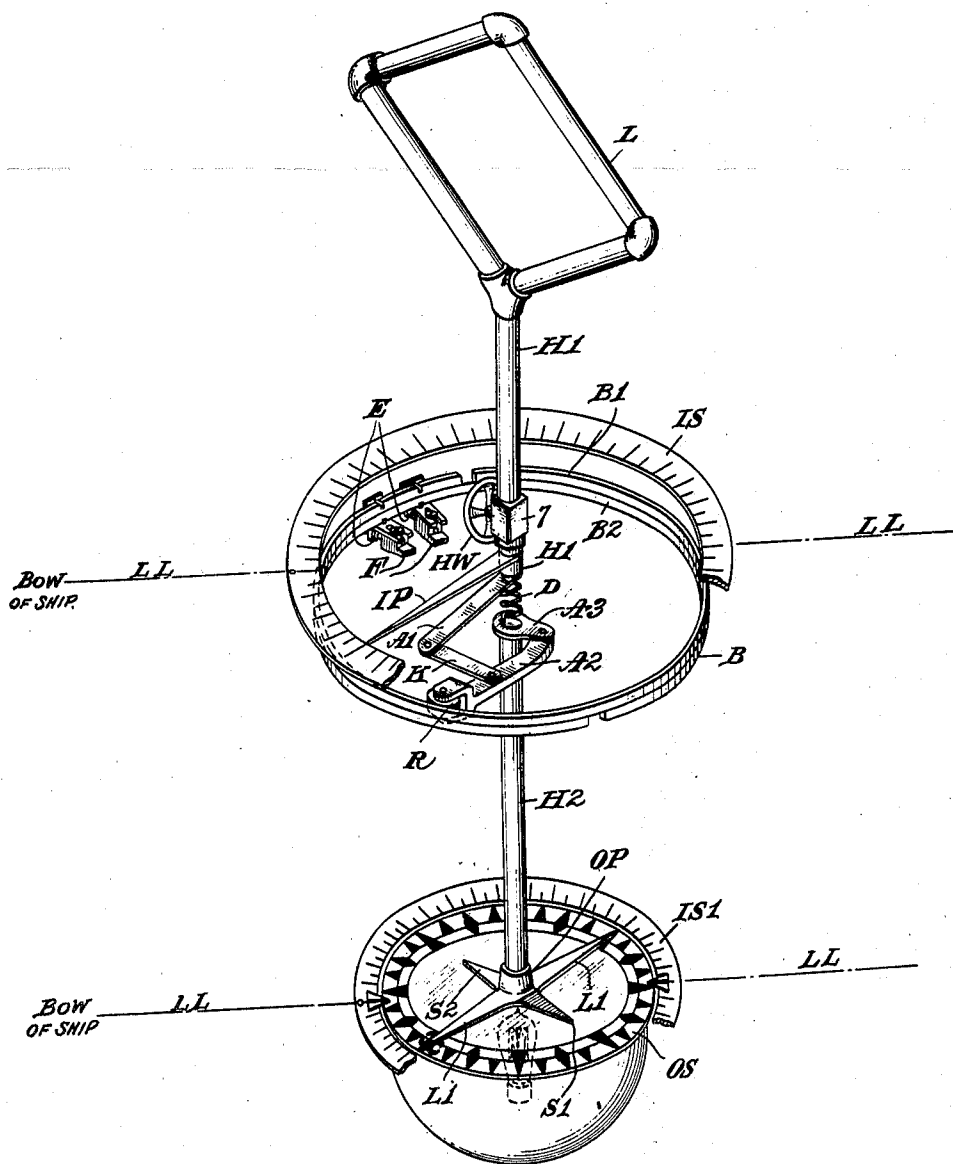
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RADIO LOOP AERIAL

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7 Sheets-Sheet 1

Fig. 1.



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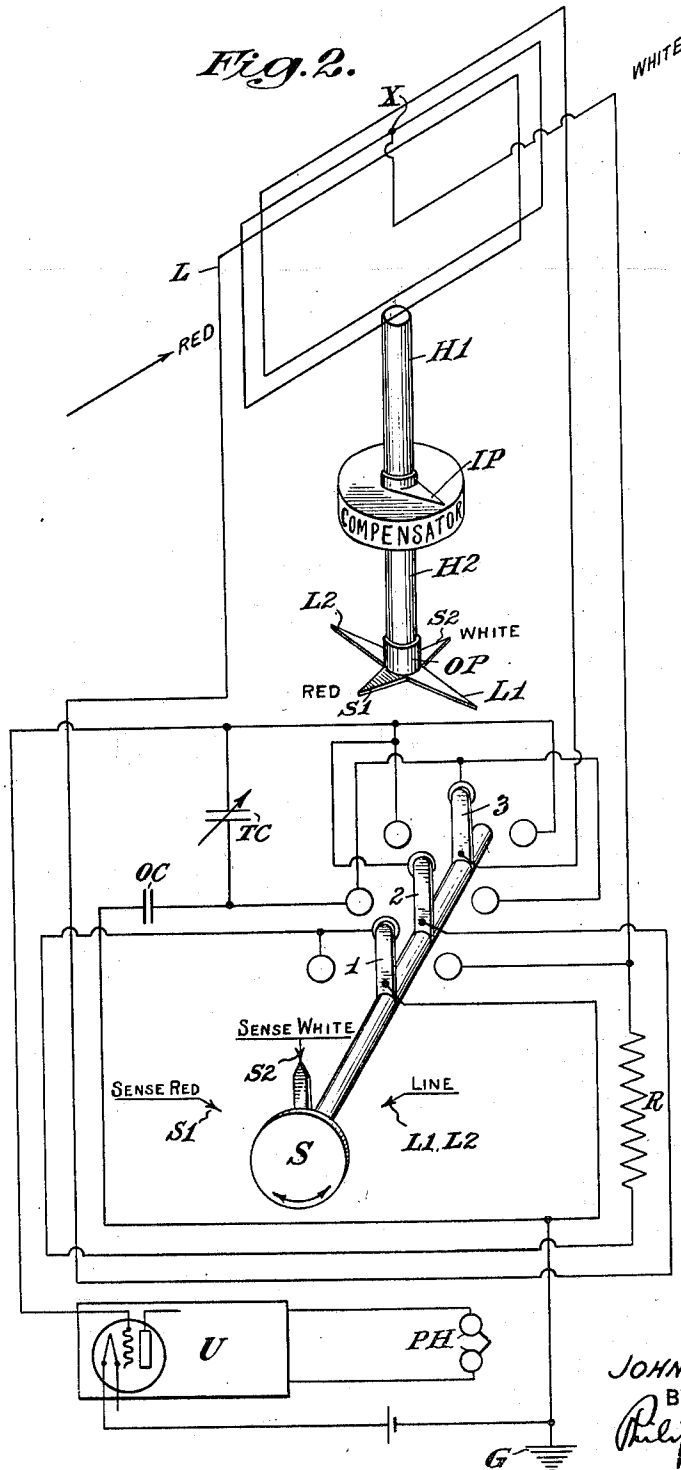
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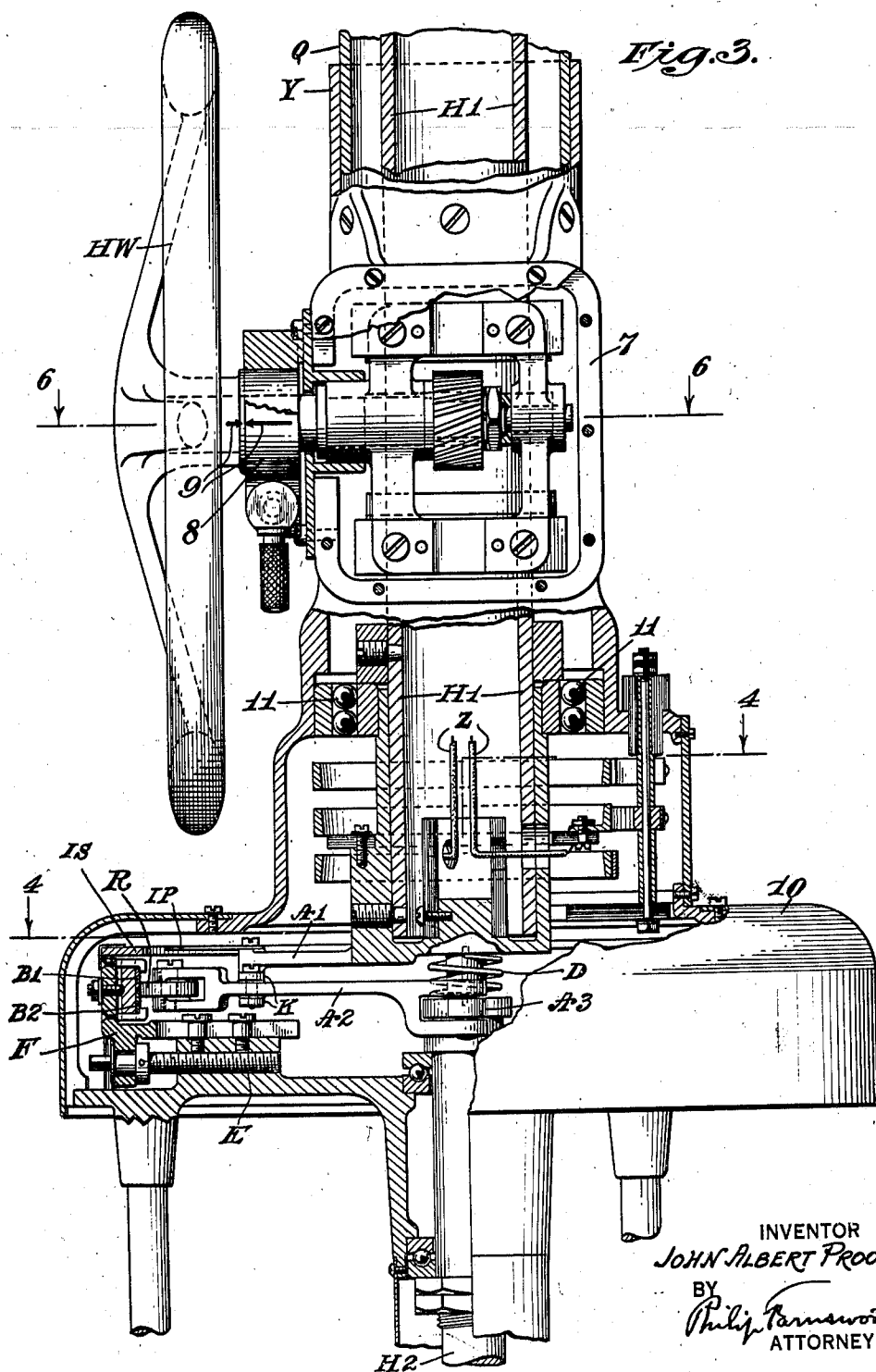
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Fig. 4.

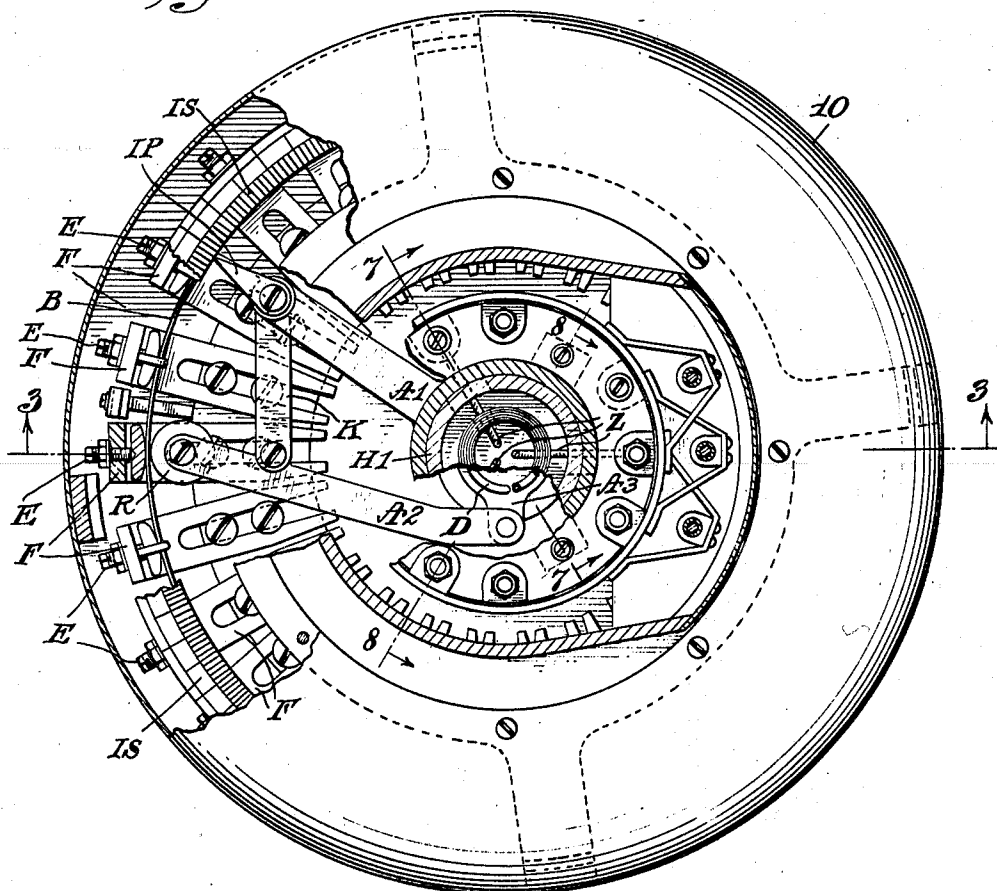
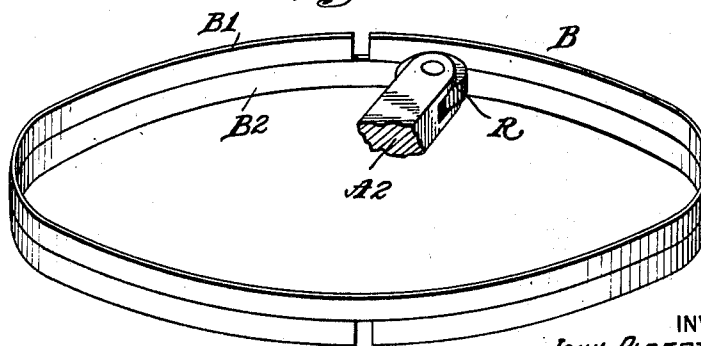


Fig. 5.



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Fig. 6.

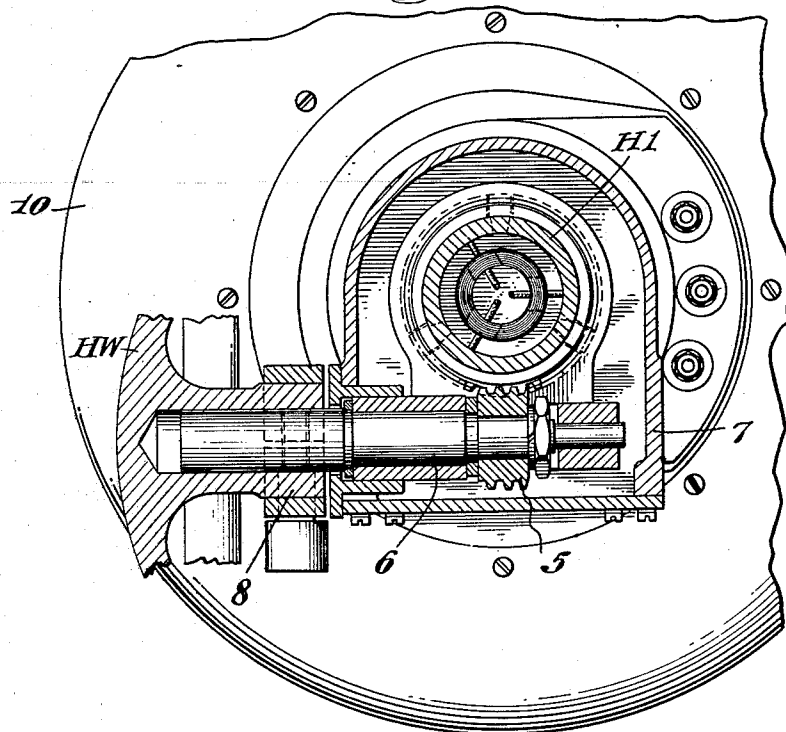


Fig. 7.

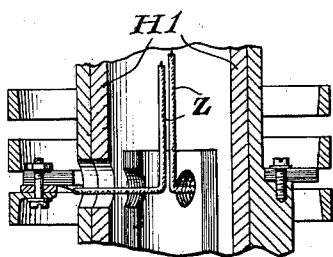
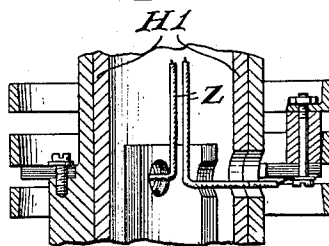


Fig. 8.



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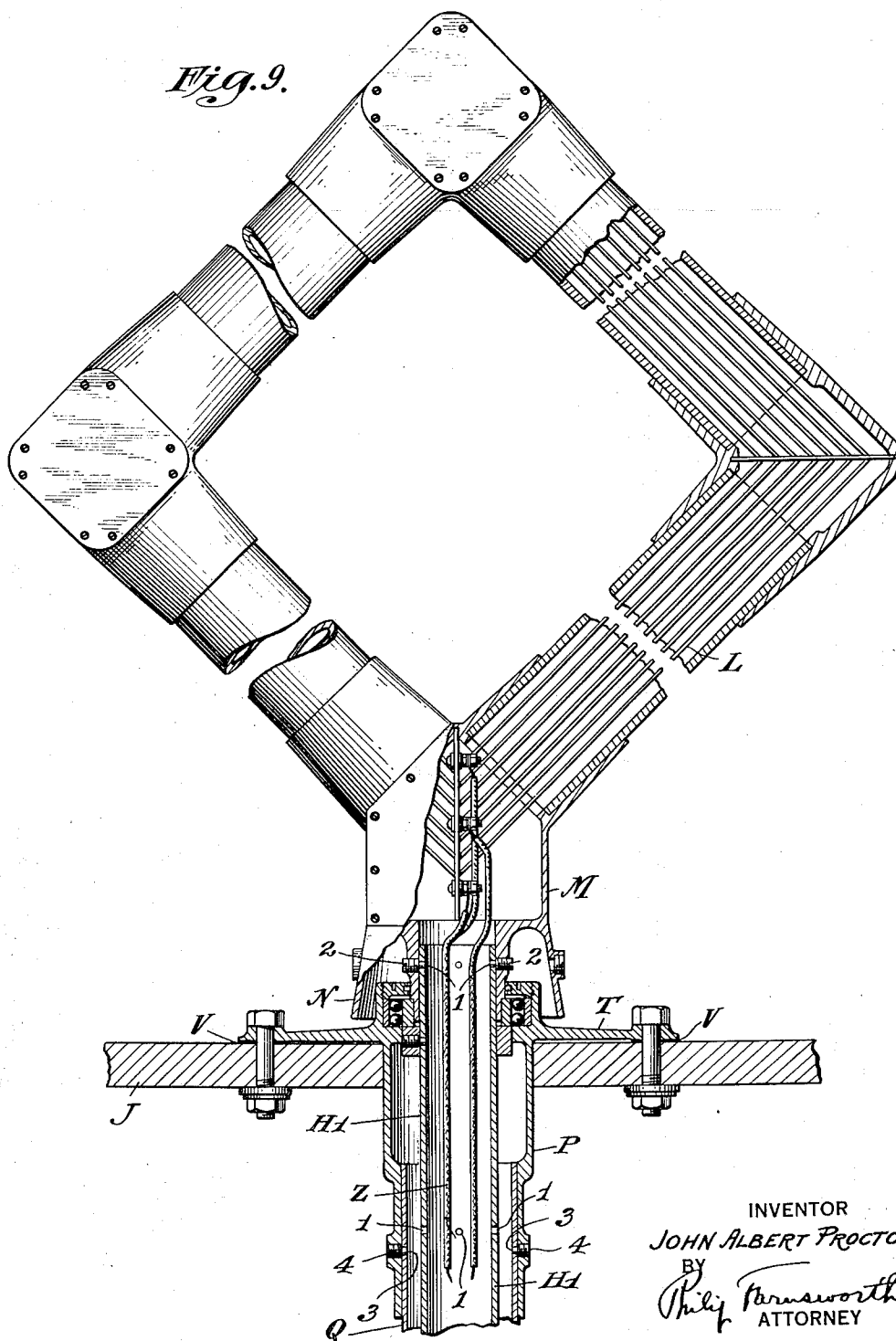
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Fig. 9.



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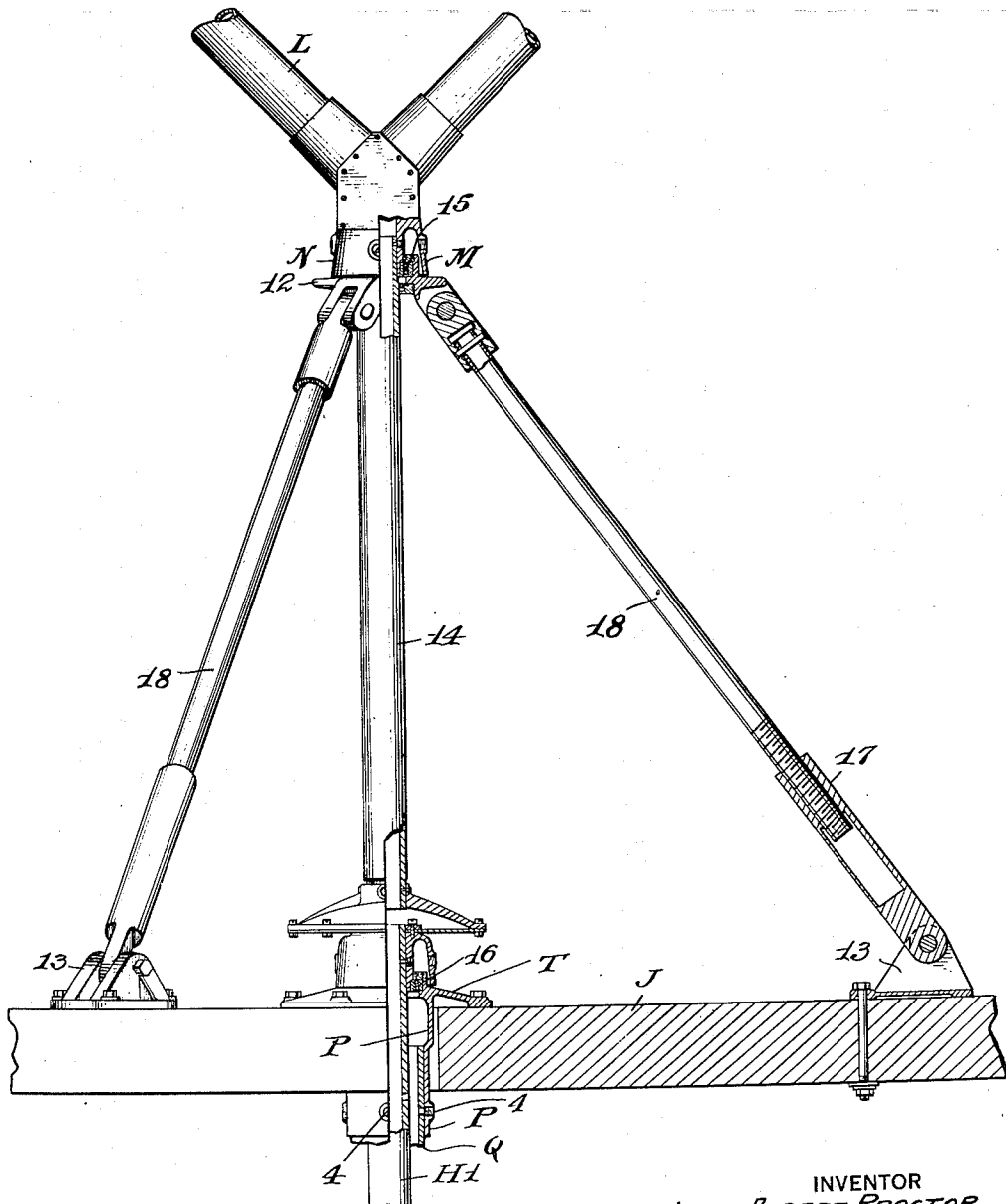
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Fig. 10.



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RADIO LOOP AERIAL

Application filed May 13, 1925. Serial No. 29,919.

This invention relates to radio loop aerials and radio direction finding, including radio compass structures and methods.

An object of the invention is to increase the accuracy, facility and speed of determination, at a radio receiving station, of the direction therefrom of a distant point at which a radio transmitter is located, which distant point may be out of other than radio communication.

The invention consists of the apparatuses and methods pointed out as to novelty in the appended claims, and described by way of example in the following specification, in connection with the drawings of which

Fig. 1 is a schematic perspective view of my direction finder, including the compensating apparatus;

Fig. 2 is a diagrammatic view of the electrical circuits and of various instruments constituting parts of the completely operative direction finder;

Fig. 3 is an enlarged detail front elevation, partly in section, of the loop-rotating means, the compensator and adjacent parts;

Fig. 4 is a horizontal section on the line 4—4 in Fig. 3, and shows in particular various details of the compensating apparatus;

Fig. 5 is a detail perspective of the adjustable band, roller and roller arm of the compensating apparatus;

Fig. 6 is a horizontal section on the line 6—6 in Fig. 3, and shows certain details of the loop-rotating and locking mechanism; also means by which the position of the loop is made known visually to the operator;

Figs. 7 and 8 are detail vertical sections on the lines 7—7 and 8—8 respectively in Fig. 4, and show details of the collector rings for the electrical circuits;

Fig. 9 is an enlarged detail elevation partly in section, of the loop, showing the mechanical construction of the loop housing bearing and supporting flange; and,

Fig. 10 is an elevation, partly in section, of the tripod device by which the loop can be elevated above the roof of the radio-operator's cabin.

Heretofore radio direction finding in practice has involved the employment of a rotatable

closed-circuit, condenser-tuned aerial, (Pickard Patent 876,996), the closed-circuit aerial or loop being rotated as a bi-lateral functioning loop to obtain the line-bearing, and then mechanically rotated as a unilateral loop to obtain the sense-bearing. The apparatus has been such as to result in such serious errors as to the line-bearing as not only to result in an inaccurate line bearing, but in some cases to cause the sense-bearing based thereon to be of little or no value. The reason why the bearings obtained by prior apparatus and methods were not the true bearings is that the operation of the receiving loop is affected by electrical conductors in the vicinity of the radio receiving station, which cause distortion of the wave-front approaching the loop; such distortion-causing conductors being especially vertical conductors, such as shrouds, stays and funnels of a steamship, but also other conductors, even underground pipes in the vicinity of land radio stations.

It is important that the direction-determination be not only accurate but speedy, as in cases of location of a ship at sea in storm, and it is desirable that the determination be made with the minimum of movement of the heavy slow-moving loop structure itself. Heretofore it has been the practice not only to rotate the loop in the process of determining the sense-bearing, as well as in the process of determining the line-bearing, but it has been the practice for the operator after the determination of the line-bearing to correct the same for distortion errors, such correction having been made with the assistance of a curve sheet, chart or table previously prepared for the particular direction finding apparatus in the conditions of its installation environment. This correction, however, made by the radio receiving operator, not only consumed considerable time, frequently vitally important, but permitted errors of personal observation involved in the making of the corrections themselves.

In accordance with the present invention, the distortion-errors are corrected by the operation of the apparatus itself in determining the line-bearing prior to the deter-

mination of the sense-bearing; and the sense-bearing is determined thereafter on the basis of a true line-bearing, not requiring correction by the operator, and by a method which makes unnecessary the mechanical rotation of the loop for the determination of the sense-bearing, such new method being extremely effective, in connection with the automatic error-correction, in increasing the accuracy of determination of the sense-bearing.

In Fig. 1 is shown somewhat diagrammatically for clearness the assembled self-compensating radio compass or direction finder; and Fig. 2 is a diagram showing the electrical apparatus and connections employed with the direction finder of Fig. 1 in connection with the novel method for the accurate determination of the sense-bearing without mechanical rotation of the loop.

In Fig. 1, the loop L is fixed mechanically on the upper end of a rotatable vertical hollow metal (as brass) shaft H^1 , down thru which the insulated loop-leads extend (Fig. 9) and from the lower end of which said leads exit (Figs. 3, 7 and 8) to the electrical apparatus of the diagram of Fig. 2.

A second vertical rotatable hollow shaft H^2 (Figs. 1, 3 and 9) is located below and in line with upper shaft H^1 . To a lower portion of shaft H^2 is keyed (Fig. 1), to rotate therewith, an operator's indicator OP (Figs. 1 and 2), which revolves over the manually rotatable compass card OS and scale IS^1 . Said card and scale may be illuminated from below to facilitate accurate observation, because this indicating means provides direct accurate readings for the line-bearing and sense-bearing respectively.

Operator's indicator OP has not only the long pointer L^1 usually employed in determining the line-bearing, but also a short pointer S^1 , S^2 used thereafter in determining the sense-bearing. Indicator OP preferably, as shown, is fixed to lower shaft H^2 , so that its line-pointer L^1 is more or less at right angles to loop L, depending on the actions of the compensating mechanism now to be described.

A flexible metal band B (Fig. 1) is fixed in a horizontal plane between the adjacent ends of the two shafts H^1 and H^2 .

Shafts H^1 and H^2 are connected together to permit joint rotation, but at dissimilar rates, by mechanism which includes (Figs. 1, 3, 4 and 5) a roller R acting on the inside of band or curve B, the roller being pressed against the band B by a suitable spring D (Figs. 1, 3 and 4). This is an improved embodiment of the inventions in my application for patent Serial No. 408,291, filed September 4, 1920.

The shape of band B and the operation of roller R on the side thereof control the angular movement of shaft H^2 for a given angu-

lar movement of loop L and shaft H^1 . Shaft H^1 is the one which usually is rotated by the operator as by hand-wheel HW (Figs. 3 and 6) in the determination of the line-bearing. Band B may be substantially circular when the entire apparatus is first installed in its place of use, as on a steamship. As part of the final process of installation, band B, in preparations for future operations, is given a distorted setting in accordance with distortion errors observed in the operation of the apparatus to result from the conductors in the vicinity of the given apparatus being installed. The band is then sealed or locked by the installer. Thereafter, flexible band B, so set as to discount errors, and as a part of the apparatus including the mechanism connecting shafts H^1 and H^2 , itself serves automatically to correct the distortion errors. The observing radio operator, to determine the line-bearing, simply rotates loop L mechanically and reads the true line-bearing by the position of operator's pointer L^1 on the scale IS^1 . Pointer L^1 fixed to shaft H^2 (and more or less at right angles to loop L of shaft H^1) then will indicate the true line-bearing notwithstanding that the position of loop L itself does not indicate the true line-bearing.

The mechanism connecting shafts H^1 and H^2 and including roller R is important and is as follows: (Figs. 1, 3 and 4). An arm A^1 fixed at its inner end to loop-shaft H^1 to be revolved thereby has its outer end pivotally connected to one end of a link K, the other end of which is pivotally connected to a second arm A^2 at a point intermediate the ends of the latter. One end of second arm A^2 is pivotally connected with the outer end of a third arm A^3 . The inner end of third arm A^3 is fixed to lower or pointer-shaft H^2 at the upper end thereof to rotate said shaft H^2 when, as preferred, the rotation of the system is effected by the application of torque to upper shaft H^1 , as by hand-wheel HW, Fig. 3. The free end of second arm A^2 carries roller R, and spring D forces roller R yieldingly against band B.

The general operation of this compensating apparatus connecting shafts H^1 and H^2 is as follows, it being assumed that curve-band B has been set by the installer (see later for description thereof): in accord with distortion errors due to the environment of a particular loop L and/or its circuits of Fig. 2. The operator or observer (band B previously having been set by the installer) mechanically rotates loop L to determine the line-bearing of the location of the distant radio transmitter (pointer L^1 on scale IS^1). Shaft H^1 , via the compensating mechanism above described, rotates shaft H^2 at rates which slightly differ from its own rates, depending upon the departures of parts of curve-band B from a perfect circle centering

on shaft H^1 and H^2 . Thus, for any given angular position of loop L , the operator's pointer L^1 will either be at right angles to the loop or at more or less slight departures from such right angle, depending upon the errors corrected by the compensator; or else, if pointer L^1 be fixed (initially before setting of band B) in line with the loop (which is not preferred), said pointer, in the bearing-determining operation, will be either directly in line with the loop, or at more or less departures from line, depending on said errors and the corresponding departures of parts of curve B from the periphery of a perfect circle. When, as preferred, pointer L^1 initially is fixed to shaft H^2 at right angles to loop L , the line-bearing of the distant transmitter is determined by aural observation of minimum or null telephone response, when loop L is at right angles to the line-bearing; and the position of pointer L^1 will be substantially in exact line with the distant radio transmitter, and therefore, will indicate on the scale of degrees of a circle (OS) and at null loop response, the true line-bearing of said transmitter, and what is of importance, the line-bearing of the ship or the shore station on or at which said transmitter is located.

In effect, therefore, there is incorporated within the loop-apparatus itself the curve of distortion errors which heretofore has been in the form of an independent diagram or chart but which curve now is made a functioning part of the loop-apparatus itself.

There are two customary methods of taking a line-bearing. One is by reading the compass card OS and scale IS^1 in degrees off the keep or ship's head, and the other is reading from the ship's course at that instant. Either method may be used with the apparatus hereof. In both methods (referring to Fig. 1), the operator's scale IS^1 is fixed in position so that the pointers therein (arrowheads, Fig. 1) are in line with the keel of the ship (keel-line LL , Fig. 1). Compass card OS is manually rotatable.

In case it is desired to employ the first method, i. e., to take a reading direct from the ship's head (i. e. from keel-line LL), then compass card OS is used in a position where its zero and 360 degree marks lie on keel line LL . The position of operator's pointer L^1 then will indicate the line-bearing of the distant radio transmitter, in degrees from keel-line LL .

In case it is desired to employ the second method, i. e., to obtain a line bearing figured in degrees from the ship's course at any instant, then compass card OS is rotated by the operator to a point which coincides with the course in degrees from the ship's head as given by the navigator to the radio operator at that instant.

The compass card OS shown as forming

part of the operator's indicator in Fig. 1, ordinarily is supplied with the direction finder hereof; but it may be replaced by a magnetic compass suspended below operator's pointer L^1 in a similar manner; or a gyroscopic repeater may be employed in like manner. With either of these instruments, line-bearings indicated by the position of operator's pointer L^1 will be direct with respect to the ship's course and will coincide with the master navigating compass.

The circuit diagram (Fig. 2) shows the coordination with the mechanical apparatus of Fig. 1, of the electrical circuits of the loop L and its associated radio apparatus. The lower shaft H^2 , shown in Fig. 1, is omitted from Fig. 2 for clearness.

The general method of operation and the novel method for determination of the sense-bearing now will be described in connection particularly with the diagram of Fig. 2, it being first assumed as follows. Short operator's pointers S^1 , S^2 (Figs. 1 and 2) are indicators of the sense-bearing; long operator's pointer L^1 permanently at right angles to S^1 , S^2 being, as stated, an indicator of the line-bearing. Either S^1 or S^2 is pointed ninety degrees off from the distant transmitter when pointer L^1 is in line-bearing position.

Before the determination of the sense-bearing, but after the line-bearing has been determined by the reading indicated by pointer L^1 at minimum or no loop response, the rotatable loop system is turned ninety degrees so that the sense pointers S^1 , S^2 point to the same readings of operator's scale IS^1 as those which have just been indicated by pointer L^1 . This, of course, can be done with perfect accuracy.

In this operation loop L will be rotated mechanically 90° from its broadside front to the distant transmitter, so that its plane will be brought in line with the distant transmitter, more or less, depending upon the distortion errors. Up to this time loop L has been acting as a bilateral loop, the switch S of Fig. 2 having been pointed at the point marked "Line," i. e., in a position where the switch established pure or bilateral loop conditions, for the purpose of determining the line-bearing; the loop as a bilateral loop thus having two points of maximum response (either end) and two points of minimum response (either side); altho the critical observation of line-bearing at null response was in the loop position broadside on the distant transmitter. Now, sense pointers S^1 , S^2 are provided for the purpose of cooperating with the electrical switching means of Fig. 2 for the purpose of determining the sense-bearing, i. e., determining whether S^1 or S^2 is pointing at the distant transmitter, by observation and comparison of the loudest signals with the weakest or minimum, the loop acting uni-

laterally, i. e., with a blind spot at one end. At this time, when the sense-bearing is about to be determined, the operator moves switch S to one or the other of the two "sense" positions, i. e., either "red" or "white," as shown, Fig. 2. At either "red" or "white" position, the loop L is changed (see later for how) from a bilateral to a unilateral loop for the purpose of causing it to have only one point of maximum (only one end) and only one point of minimum (the other end) response. The operator's sense pointers, S^1 , S^2 of Fig. 1 are colored red and white, respectively, to correspond with the red and white sense positions of switch S of Fig. 2. That is, they are adapted (pursuant to a manufacturer's test to be described) to indicate correspondence to a sense (as vision) of the observer.

At this moment pointers S^1 , S^2 are more or less in line with loop L, their departures from line depending on automatic correction of distortion error by the compensator. The loop L itself has one of its ends pointing more or less toward the distant radio transmitter, the departures from exact pointing thereat depending on the distortion errors. The question now is which end of the loop, i. e., which of the two sense pointers S^1 , S^2 , is pointing at the distant radio transmitter, the red pointer S^1 or the white pointer S^2 . This is determined by the aural sense of the observer via phones PH in the diagram of Fig. 2, while switch S is moved by him successively to the "red" or "white" (S^1 or S^2) positions; and this without any mechanical rotation of loop L to change the physical relation of its parts to the distant transmitter. The result of the operation of switch S is, so to speak, an electrical rotation of loop L. The advantage of this electrical rotation is twofold, for it not only obviates the need of actual and slow movement of a comparatively heavy loop structure by the operator while he is making visual or aural observations, but, what is of greater importance, it obviates the time lag between different loop positions and corresponding presentation of different sound intensities to the operator's ears for his judgment as to differences in intensity. That is, the operator can move switch S from "red" to "white" positions very rapidly indeed, as compared with mechanical rotation of the loop structure, and such rapid operation of the switch permits the two sounds of different intensities to be compared or contrasted by him with minimum time interval, thereby permitting very greatly increased accuracy of aural observation.

The above "electrical rotation" of loop L results from the following conditions. In either the "red" or "white" (sense) positions of switch S, its blade 1 connects resistance R in the grounded open antenna circuit between ground G and a mid-point X of loop L. This results in producing the cor-

rect amount of antenna-current component to cause loop L to act uni-laterally, with one point of maximum response and one point of minimum response (in sense switch positions S^1 , S^2) instead of two points of each, as when switch S is in position marked "Line". When switch S is moved from "red" to "white" or from "white" to "red" positions, the operation of its blades 2 and 3 is to reverse the terminals of loop L and, therefore, is to reverse the true loop currents with respect to said antenna-currents. Thus, the maximum and minimum points of the uni-lateral loop are shifted through 180° ; in other words, loop L is turned electrically end for end.

Now, assume switch S to be in the "white" sense position, as shown in the diagram of Fig. 2, and that in fact the distant transmitter is at the left end of loop L marked "red" in Fig. 2, the direction of waves from the distant transmitter being indicated by the arrow. Assume, also, that the maximum of the uni-lateral characteristic of the loop (switch S being, as stated, in the "white" position) is in line with the loop and at its right or end marked "white", due to the direction of winding of the loop and the poling of the various circuits connected to the loop and its amplifying apparatus U. Then the minimum of uni-lateral characteristic will come in line with the loop and at the left or loop-end marked "red". The observer, listening at phones PH with switch S in "white" sense position, will hear nothing or a faint signal; but when he moves switch S over to the "red" position, he will hear a strong or much stronger signal, because in that position of the switch the loop circuits are such as to give a maximum response to signals coming toward the "red" end of the loop. The receipt of maximum signals at the "red" position of the switch (Fig. 2) and the sense-to-operator correspondence of the "red" switch position with the "red" sense pointer S^1 (Fig. 1), and the automatic error-discounting of the apparatus, will indicate to the operator the fact that the distant transmitter is exactly in the direction toward which red pointer S^1 of Fig. 1 is pointing. Thus, the sense-bearing is determined without mechanical rotation of the loop, and with absolute accuracy based upon the accurate predetermination of the line-bearing.

In the process of manufacture, the operator's sense pointers S^1 , S^2 of Fig. 1 are oppositely colored in correspondence with the opposite coloring of the positions of switch S, Fig. 2, pursuant to test with a distant transmitter, the true direction of which already is known. This test made either by factory man or installer, consists in determining (by loop sense-bearing readings, Fig. 1, relative to a known distant radio transmitter), the fact that white pointer S^2 is pointing toward the distant transmitter when switch S (Fig. 2) is

is in the white sense-position, and at minimum or zero response of phones PH. If white pointer S^2 is not so pointing, then the terminals of loop L are reversed, (as a step of manufacturing or installing) either at the receiving apparatus or at the collector rings shown in Fig. 3; such reversal resulting in coordinating the operator's sense-indicators S^1 , S^2 of Fig. 1 with the switch positions of Fig. 2.

The mechanical apparatus and the loop aerial of Fig. 1 may be employed with electrical circuits other than those of Fig. 2, i. e., as in the prior method of mechanically rotating the loop 180° after determining the sense-bearing. In the latter case there will be only one position of switch S of Fig. 2, i. e., only one unilateral position. In this case the apparatus is installed as follows. The installer, receiving from a known distant transmitter, will mechanically rotate loop L, observing thru 180° the increase or decrease of sound in phones PH. All is well if the sound is minimum or zero when the pointer which is to be used to indicate the sense-bearing (as either S^1 or S^2 reaches the position in which it points at the known distant transmitter. If the minimum or zero response does not occur in such position of such pointer, the installer will reverse the terminals of loop L, as above described, and that will result in fixing conditions so that such pointer thereafter will act as the sense pointer.

The sense pointers S^1 , S^2 of Fig. 1 are useful during periods of occurrence of what is known as night effects, when it is not practicable to distinguish nul loop points in bi-lateral working on account of the fact that responses of more or less equal intensity result from all angular positions of the loop. Under such conditions, however, there is good loop-working under uni-lateral arrangement. In such cases, therefore, pointers S^1 , S^2 , fixed more or less in the plane of the loop L, (the loop being more or less in line with the distant transmitter), may be used not only for determination of sense-bearing, but also initially for determination of line-bearing, by the operator's observation of the signal minimum or nul loop response. Hence, the sense-bearing may be determined, as above described, but without the preliminary 90° mechanical rotation of loop L. In fact, this operation can be effected not merely at times of night effect, but at any time, including times of heavy static. Usually, however, in the day time it is preferable, for determination of line-bearing, to use pointer L^1 in connection with bi-lateral loop-working (with switch S of Fig. 2 in "line" position) and observation of minimum or nul response of loop at right angles to the distant transmitter. This preference is due to the far greater accuracy of bi-lateral working in direction finding, due to the fact that the nuls or minimums are far sharper in

bi-lateral working than in uni-lateral working, save under the night or static conditions above referred to.

The following are the important details of the apparatus of the diagram of Fig. 2. TC is the loop tuning condenser, used for all positions of switch S. Resistance R is in circuit with loop L only when the latter is in condition for uni-lateral reception (switch S at positions "sense red" or "sense white"). The function of resistance R is to add an open-antenna component to the true loop-current. OC is a condenser of small capacity, which transmits the open-antenna current (with R in circuit) to amplifier U. Condenser OC always is in circuit; but when switch S is in position marked "Line" (for bi-lateral loop-working), there is no open-antenna E. M. F. across condenser OC as there is when switch S is in a sense position. The values of resistance R and of condenser OC are determined by test for each designed embodiment of the invention. Initially, during manufacture, these values are varied until with signals from a known distant transmitter and with switch S in positions S^1 , S^2 , respectively, there is maximum different intensity of sound in phones PH in said two switch positions. The value of resistance R is of the general order of 1,000 ohms, say from 500 to 1,500 ohms, more or less. The value of condenser OC is of the general order of .0001 microfarad, more or less.

The apparatus can be used for ordinary reception when switch S is in either of the three positions of Fig. 2.

After sense-bearing as well as line-bearing of a given distant transmitter has been determined and reported to an inquirer, and when the line-bearing of another distant radio transmitter is to be determined, then switch S is moved to its position marked "Line" (Fig. 2). This results in short-circuiting resistance R from the circuit X—G, leaving that good grounding circuit from mid-point X of loop L for the purpose of eliminating all open-antenna action, and leaving the possibility of only true loop currents for bi-lateral loop-working, preferably with minimum or nul loop response, this being the optimum condition for determination of line-bearing.

Summing up, the action of switch S is as follows. Blade 1 cuts resistance R out of circuit or shorts it, when switch is moved to "line" position from either "red" or "white" position. Each of blades 2 and 3, when moved either from "red" to "white" or "white" to "red", reverse the terminals of loop L with respect to variable loop-tuning condenser TC, amplifier U, and the ground-path X—G through small fixed condenser OC.

The operations in installing the apparatus, with particular reference to the setting of band B of the compensating apparatus, are as

follows. It is to be assumed that the installation is complete save for such band adjustment, and that flexible metal band B is substantially circular. Fig. 5 shows the preferred duplex construction of the band, which comprises two bands B¹ and B², arranged edgewise one above the other, and each with disconnected ends (i. e., each band is split), the two disconnected ends being located at different portions of the circle, thereby permitting the radial deformation of band B as a whole, without completely interrupting the continuity of the inner band surface over which roller R operates. Each band is about 3/8th of an inch wide, so that the two provide a total vertical width of about 3/4ths of an inch for roller R of more or less corresponding width, so that the roller R travels over both bands. Each band B¹, B² of band B is of thin phosphor-bronze about 3/64th inch thick, so that band B is flexible. The object of this part of the installation is to deform band B in accord with previously observed distortion errors, thereby causing band B itself to be in effect an error-chart or diagram embodied as a functioning part of the apparatus. With this construction and otherwise complete installation, the final installation operations are as follows. (1) The installer selects a known radio transmitting station, as one in sight. (2) He arranges for it to transmit test signals for a sufficiently long time. (3) If the installation is being made on a ship, the ship is then swung slowly around thru a circle of short radius. (4) At frequent intervals during such movement of the ship (a) the installer observes the apparent bearings of the known distant transmitter by the aid of loop L, and (b) simultaneously the ship's navigator makes pelorus observations of the bearing of the transmitter, and (c) they either transmit their observations to one another at the time, or (d) record them for subsequent comparison. (5) For accuracy, these observations of the installer and navigator are repeated several times to check errors. If the direction finding apparatus is being installed on land, then the land operator arranges for the distant radio transmitter, say on a ship, to sail a course covering all desired angles with respect to the land direction finder; then the land installer makes simultaneous observations, by pelorus and radio direction finder. Then the errors are observed and recorded as by tabulation or by correction curves, and finally embodied in corresponding distortion of band B, as described later.

In making the above observations by radio compass, the installer does the following. (1) Rotates loop L until he hears minimum or no response in phones PH. (2) Reads the position of installer's pointer IP on installer's scale IS. The zero of scale IS is in line with the ship's keel or lubber line

LL as indicated. Scale IS usually is fixed to the ship in position so that the zero is toward the bow, as shown, although it could be toward the stern.

The installer, now equipped with the data of observation, proceeds as follows. He sets his pointer IP at zero or other point of scale IS. As yet, while band B is substantially circular, the lower or operator's pointer OP (as L¹ thereof) points to the same number of degrees on the lower or operator's scale IS¹ as does upper installer's pointer IP on the upper installer's scale IS,—the two scales being fixed alike as to the ship's lubber line LL. With the two pointers IP (above) and L¹ (below) at say zero degrees on their respective scales, the installer looks at his record of distortion errors of this apparatus for zero degrees reading and finds, for example, that the true bearing of the known distant transmitter at zero degrees setting of the loop L was actually 5°. The installer then observes the position of roller R, which may be at any angular position against roller band B. He then (Figs. 1, 3 and 4) turns screw E on one of the adjusting devices F which is located in the vicinity of roller R, thereby bending band B inwardly or outwardly until the resulting movement of spring-pressed roller R moves lower shaft H² so that operator's pointer L¹ moves from zero degrees toward and to 5° on operator's scale IS¹. When this position is attained, the adjusting screw E is fixed for permanent installation for this particular part of band B. If roller R happens to lie between two adjusting screws, the installer adjusts both screws. It is preferable to provide about 24 adjusting devices with their adjusting screws around the circle of band B of about ten inches (Fig. 4). The above adjusting of band B is repeated thruout its circumference and in accordance with the table of errors prepared as the result of the above observations of the installer and the navigator.

The change in amount of error, in traversing the entire scale, is gradual, i. e., there is usually no large change of error for a small change in degree of arc. The flexible metal band B and its adjusting devices are of such constituency as to give only smooth and gradual departures from a circular arc, thereby conforming to the above fact as to the errors. Thus, consequently, while there may be several bulges in the resulting adjusted band, B, the result is more likely to be what might be termed a "smoothly bumpy" circle. That is, the adjusting movement of one screw is not very greatly different from that of the screws adjacent to it, even where the error changes sign, i. e., where the band is bent inwardly and outwardly respectively. In adjusting around the circle, the successive adjustments may be made at no more frequent intervals than 10° apart, although the adjusting de-

vices and adjustments may be made closer, if desired. The result is an installation which is permanent so long as there is no substantial change in the matter of electrical conductors in the vicinity of the direction finder. In case of any such change, it is desirable to repeat the above portion of the installation including the observation of errors and the resetting of band B.

The mechanical operation of the compensator including band B is as follows. Motion of the main operating shaft H^1 (Figs. 1 and 3) is transmitted to indicator shaft H^2 by means of the link motion. Torsion spring D keeps roller R always in close contact with the inner surface of band B. In order that a given bulge of band B inwardly or outwardly from its original circular configuration will register equal degrees and correction from the pointer (L^1) attached to shaft (H^2), the center of roller R is designed to move in and out on a radius passing thru the center of shafts H^1 and H^2 . It is also desirable to have the included angle, formed by A^1 and K, equal to 90 degrees when the band B is a perfect circle of mean diameter. It is likewise desirable to have the included angle between the links (A^2 and A^3) 90 degrees under similar conditions. By maintaining the angles given, the most variable mechanical leverage systems are possible, that is, the links are always as far as possible from their dead center position.

The various more or less important further features of an actual embodiment of the inventions hereof are shown in Figs. 3-10, according to the general descriptions of such figures first above stated.

In order to place the apparatus in its desired place of operation (as with the structure of loop L above the cabin roof and with the rest of the structure in doors), it is only necessary to provide an opening in the roof J (Figs. 9-10) to permit passage of the longitudinal portion of the roof-casting P. The horizontal flange portion T of such roof-casting then is bolted to roof J, a rubber or other gasket V (Fig. 9) being interposed between roof J and flange T. Thus vertical hand-wheel HW (Fig. 3) inside the cabin or pilot house can be operated to rotate the loop structure enclosing loop wires L, outside the cabin for the determination of the line-bearing; yet the apparatus inside the cabin is protected from the weather. In Fig. 9 are shown the practical features of the top ball-bearing for the rotatable loop structure inside the upper part of flange T (a lower ball-bearing is shown at 11, Fig. 3). In Fig. 9 also are shown the loop leads Z (Fig. 4) from loop L extending down thru hollow shaft H^1 to the collector rings of Figs. 7-8. Also in Fig. 9 is shown the hollow metal loop structure enclosing loop wires L.

The following adjustment construction is

provided to permit installation of standard apparatus in cabins or pilot houses of varying height, permitting the location of the compensating apparatus and indicating scales of Fig. 1 (carried with shaft H^2 by any suitable supports bolted to the floor) at substantially the same distance above the floor in every instance. In manufacturing, the hollow shaft H^1 (Fig. 9) is made of maximum length and is formed with a vertical series of horizontal rows of jig-located holes 1. In installation the top of this shaft H^1 is cut off (if the head room is less than maximum) so that lower holes 1 of the vertical series of holes may receive screws 2 securing shaft H^1 to the rotatable hollow loop structure. Similarly fixed metal tube Q (Fig. 9) in manufacture is made of maximum length and is formed with jig-located holes 3 in horizontal rows and in similar vertical series of rows, so that in installation the top of this tube Q may be cut off, and yet bring one horizontal set of holes 3 in position to receive screws 4 which secure tube Q to fixed supporting tube P depending from flange-member T. Thus the rotatable and fixed parts between the floor and the compensating apparatus and scale-indicators may be made substantially the same, irrespective of the height of the cabin, and notwithstanding the fixing of a part of the structure of the roof of the cabin, and thereby bringing the apparatus and indicators at substantially the same height in all cases relative to the operator.

In Figs. 3, 4 and 6 are shown the details of the mechanism for rotating the loop structure and for locking it against wind-pressure. Gear teeth are located on the loop-rotating shaft and a worm gear 5 is keyed on horizontal shaft 6 to engage said teeth, hand wheel HW lying inside the cabin on the end of shaft 6 so as to be arranged vertically for the greatest convenience of the operator reading the indicating scales. (If desired, hand-wheel HW may be mounted horizontally directly on shaft H^1 , but the above gear reduction is preferred.) The reduction gearing is enclosed in a casing 7. Between casing 7 and hand wheel HW is located a friction lock 8 which clamps the latter in any desired position, thereby fixing the loop from rotation by wind or otherwise. On wheel HW and lock 8 are marked arrows 9 (Fig. 3) indicating to the operator inside the cabin a given desired normal fixed position of the loop outside on the roof, such position being that for example of minimum wind resistance such as a fore and aft position on a steamship.

The compensating apparatus is enclosed in a casing 10 as shown in detail in Fig. 3.

In Fig. 10 is shown lateral supporting means for the loop structure above the cabin roof J in a case where it is desired to have the loop structure more elevated above the roof than in Fig. 9. This means comprises

legs or links 18 pivoted at their upper ends to a stationary head or support 12 supported by them and in turn supporting top bearing 15 for the rotatable structure. Legs 18 are pivoted at their lower ends to feet 13 bolted thru roof J. In this case the loop is centrally supported by a metal tube 14, which is rotatable by being secured at its top, as shown, to the bottom of the hollow loop structure L (rotating on top bearing 15) and secured at its bottom as shown to a structure rotating on lower bearing 16; shaft H¹ being secured to the hollow loop structure L to rotate therewith. Tube 14, therefore, constitutes an upward extension of loop-rotating shaft H¹. Legs 18 preferably, as shown, have a turn-buckle construction 17 (Fig. 10), so that, in combination with their pivots, the loop may be very securely positioned at a substantial distance above cabin roof J. All this construction is optionally additional to that involving roof-flange T above described.

As to the compensator and band B, while the latter is shown stationary, the part rotated by the operator being shaft H¹, yet it is to be understood that various other arrangements are within the scope of the invention. That shown, however, is preferred on account of various practical considerations. With this construction, for example, it is the heavier part of the structure (the loop structure which also frequently is subject to wind-pressure) which is rotated and it in turn rotates the lower shaft H² via the compensator, the parts of which, therefore, may be of lighter construction than in the case where the operator rotated the lower shaft H¹ in the first instance. Also as contrasted with a modification wherein a rotation of band B (against a roller R fixed relative to loop L, band B and the indicating scales), the band B here may be much lighter in construction and, therefore, more readily adjustable by the installer to distortion errors.

The loop structure as to general dimensions is standard, being a coil about 4 feet square and having a suitable number of spaced turns, or otherwise, all as well known.

While this invention is embodied in the preferred form, which comprises a single rotatable loop-coil, yet the various features may be employed with various other forms of radio loops, including the form comprising a plurality of fixed loops and a rotatable search-coil; in such a case, the compensating apparatus hereof being combined with such rotatable search-coil.

All the uses of the invention are included within the scope of the claim, as for example its use for ordinary reception, including reduction of interference (by radio transmitters or static), due to the directional and/or unilateral properties of the loop; and various other features for any desired purpose

may be combined with the disclosures hereof.

I claim:

In radio loop aerial apparatus, the combination with a rotatable loop and a shaft-
ing rotating therewith, of a second shaft and
an indicating device for the second shaft;
and compensating mechanism connecting the
two shafts and comprising a band adjustable
to loop-distortion errors and arranged in a
plane at right angles to the axis of said
shafts; an arm fixed to the loop-shaft; an arm
fixed to said second shaft; a link pivoted to
said loop-shaft arm; a third arm pivoted
at a point intermediate its ends to said link;
said third arm being pivoted at one end to
said arm of the second shaft and having its
other end in operative engagement with said
band.

JOHN ALBERT PROCTOR.