Dec. 1, 1959 S. RICEMAN 2,915,752

DIRECTIONAL ANTENNA

Filed Dec. 29, 1953 2 Sheets-Sheet 1

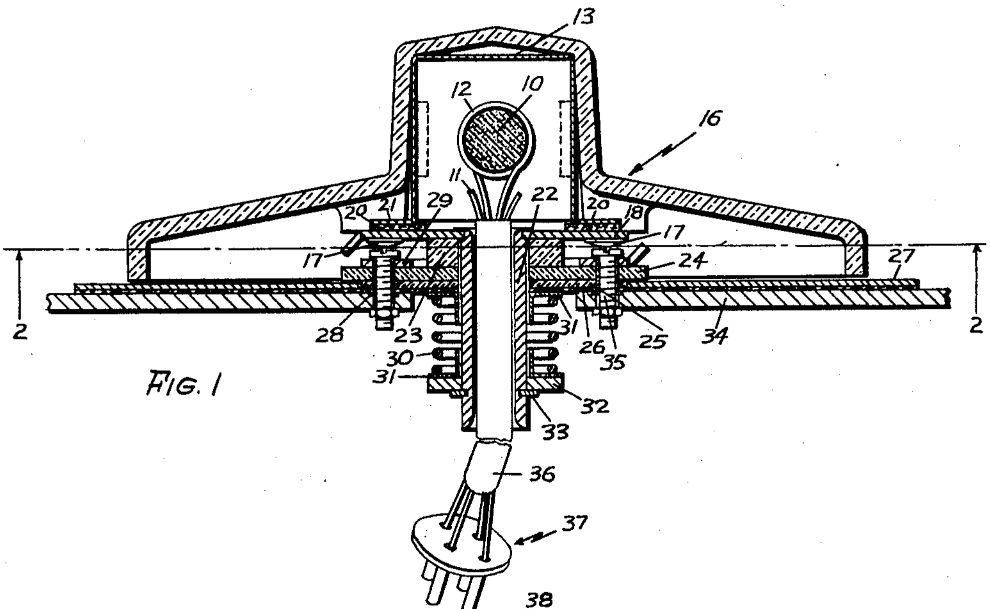

FIG. 1

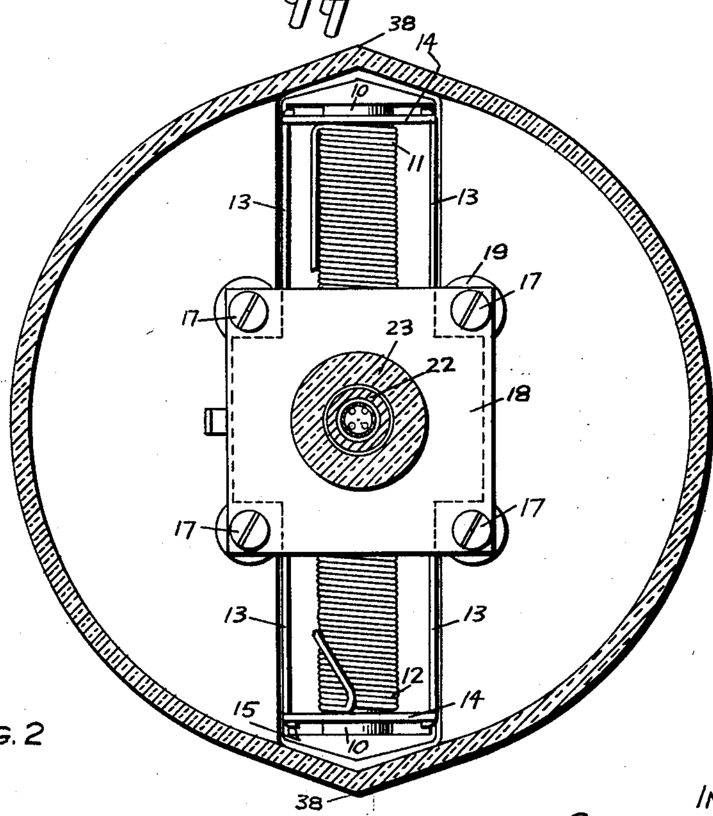

FIG. 2

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DIRECTIONAL ANTENNA

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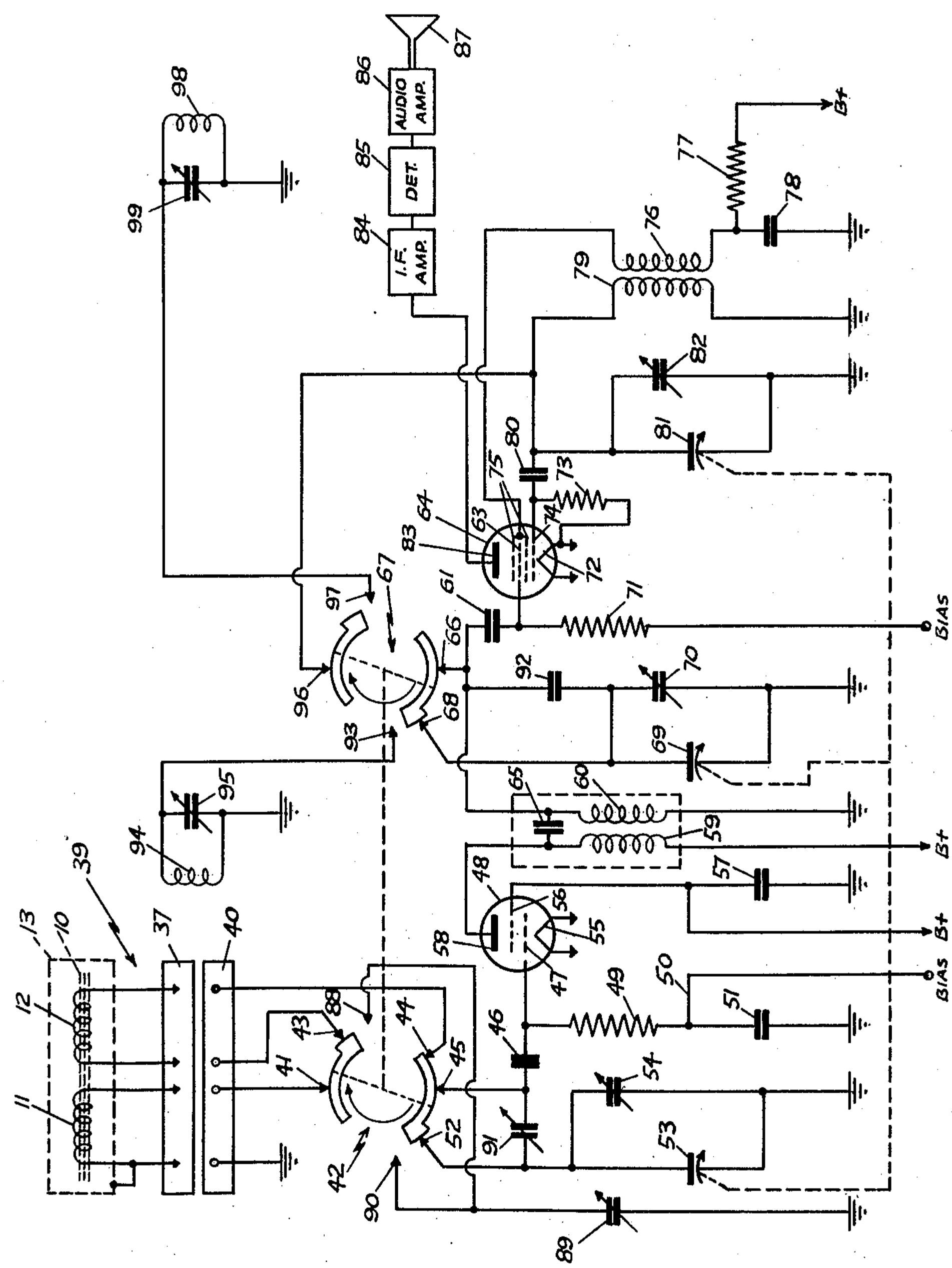

FIG. 3

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DIRECTIONAL ANTENNA

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10 Claims. (Cl. 343—842)

This invention relates to electromagnetic wave energy reception systems and more particularly to directional antennas for use in devices such as radio direction finders.

Directional antennas having a very sharp null or directional zero sensitively are well known in the art and comprise, in general, a loop or coil of wire having a diameter many times the axial length of the coil. In such a device radiant energy incident on the coil from a direction at right angles to the axis thereof induces differential voltages in different portions of the loop causing currents to flow in the coil and, hence, producing a signal output from the coil to any desired device, such as to the input of a radio receiver. Energy incident on the coil from a direction substantially axial of the coil, on the other hand, induces substantially equal and opposite voltages in opposite portions of the coil, said voltages cancelling to produce a substantially zero output signal from the coil. The directional characteristic of such a loop antenna may be further increased by encasing the loop in a shield over the major portion thereof, said shield having a gap therein at one portion of the loop such that currents cannot flow around the shield in the same direction as currents in the loop. Such loop antennas had a relatively high shunt capacitance with the result that they could not be tuned by means of a variable condenser in parallel therewith over any substantial range of frequencies and, hence, were normally coupled through a broad band coupling network to an additional inductor which had a variable condenser in parallel therewith and which could be tuned over a relatively wide range of frequencies, for example over substantially the entire broadcast band.

This invention discloses that the size of loop antennas used for radio direction finding purposes may be reduced considerably by the use of ferrite cores for said coils and the sharpness of the directivity function, which normally depends on antenna diameter, may be retained by a shield surrounding the coil in the plane of the coil and exposing the end portions of the coil, said shield being non-reentrant whereby currents are prevented from flowing in directions parallel to the currents in the coil.

This invention further discloses that the capacitance of the loop may be further reduced by using a ferrite core for the coil, which is many times longer than its diameter. The loop coil may then be wound along the core with the conductive windings spaced, for example by an extra thick insulating covering, whereby the interwinding capacitances are considerably reduced but the electromagnetic lines link substantially all the turns of the coil due to the high permeability of the core with respect to the air. In such a structure, the shield extends along the full length of the core becoming an elongated cavity open at the ends to expose the end portions of the coil and having a slot or slots extending the full length thereof.

Other and further objects and advantages of this invention will become apparent as the description thereof

progresses, reference being had to the accompanying drawings, wherein:

Fig. 1 illustrates a longitudinal cross-sectional view of an antenna and housing structure embodying this invention;

Fig. 2 illustrates a transverse cross-sectional view of the device shown in Fig. 1 taken along the 2—2 line of Fig 1; and

Fig. 3 illustrates a schematic diagram of a radio receiver circuit in which the antenna structure of Figs. 1 and 2 is particularly useful.

Referring now to Figs. 1 and 2, there is shown an antenna assembly comprising a ferrite core member **10** illustrated herein as cylindrical in shape and having a length many times its diameter. Core **10** may be made of any desired material which has a relatively high permeability and which has a relatively low loss at radio frequencies. Many types of materials having these properties are commercially available, one class of material being known as ferrites or ferramics and comprised essentially of iron compounds bonded together with plastics or ceramics. Other types of materials, such as powdered iron cores, could also be used. Core **10** has wound thereon two coils **11** and **12**, said coils being shown here, for example as single layer coils positioned end-to-end on core **10**. Coil **11** may be made to have forty-eight turns of wire and coil **12** may be made to have twenty-four turns of wire, said wire being, for example No. 24 wire wound along a total length of the core **10**, which is approximately five inches with the core **10** itself being approximately one-half inch in diameter. Positioned around core **10** and coils **11** and **12** is a shield **13** comprising a box having a substantially square cross section, for example one and one-quarter inches long on each side. Shield **13** is made of one piece around three sides of the square, preferably the two vertical sides and the top thereof, as illustrated herein, being made, for example of cadmium plated sheet copper or other highly conductive material. Core **10** is supported, with respect to shield **13**, by means of fiber spacers **14** positioned at either end of core **10**. Spacers **14** comprise planar members having apertures therein which snugly engage core **10** and having recesses in the edges thereof which engage tabs **15** bent inwardly from the ends of the side walls of the shield **13** thereby rigidly securing core **10** and coils **11** and **12** with respect to shield **13**.

The antenna structure and shield assembly may be mounted in any desired manner, and, as shown here, is placed in a case **16** made of dielectric material such as molded plastic. Case **16** preferably is made of material having a relatively low loss at radio frequencies such that radio frequency signals may pass therethrough to the antenna coils **11** and **12**. The external contour of the case member **16** may be of any desired shape and is shown here, by way of example, as having a cylindrical skirt with an upwardly extending portion conforming substantially to the shape of the shield **13**. However, it is to be clearly understood that the outside contour of the member **16** may be any desired shape such as cylindrical, hemispherical, or any other shape.

Member **16** is rigidly attached by means of screws **17** to a metal flange member **18**, shown here as being substantially square in shape, with the screws **17** extending through flange **18** and threadedly engaging thickened portions **19** of case **16** positioned adjacent each side of shield **13**. The flange member **18** is sufficiently large to extend beyond the sides of shield **13** and engage portions **19**. Flange **18** also engages fiber spacers **20** through which screws **17** extend and which, in turn, push against flange portions **21** at the lower edges of shield **13** thereby firmly urging shield **13** and its coil and core assembly into the recess provided for it in case 16. The purpose of the fiber spacers 20 is to prevent electrical contact of the plate 18 with the shield 13 and, hence, prevent completion of a conductive path in shield 13 around core 10. Flange 18 is rigidly attached to a hollow support shaft 22 which extends downwardly from the center of plate 18 and whose upper end extends through a hole in plate 18 and which is caused to rigidly engage said hole by upsetting or flaring the end of shaft 22 which extends through the hole in plate 18.

Surrounding shaft 22 below flange 18 is a spacing ring 23 of insulating material such as fiber or plastic. Ring 23 slidably engages shaft 22 and flange 18. Ring 23, in turn, rests on a plate 24 of insulating material having an aperture therein through which shaft 22 passes. Plate 24 likewise may be of any desired insulating material such as fiber or plastic. Plate 24, in turn, rests on a second plate 25 similar to plate 24, but somewhat smaller in diameter than plate 24, and plate 25, in turn, rests on a thin sheet of insulating material 26 which is somewhat larger in diameter than the diameter of the skirt of case 16. A metal disk 27 is provided having an aperture therein slightly larger than the diameter of plate 26, which is also a disk, and plate 27 is positioned surrounding plate 26. The entire assembly, including members 24, 25 and 26, is rigidly held together as a unit by means of hollow rivets or eyelets 28 extending through these members, for example at four points around the periphery thereof, rivets 28 also extending through an annular metal ring 29. The thickness of plate 26 is slightly less than the thickness of metal plate 27 such that the metal plate 27 is not tightly held between members 25 and 34 and hence rotates freely about the assembly comprising members 24 through 26. Plate 27 extends out beyond the skirt of case 16 and covers member 26.

The shaft 22 is urged downwardly through plates 24, 25 and 26 by means of a coil spring 30 surrounding shaft 22 with the upper end of spring 30 engaging a metal bearing ring 31 which engages the lower surface of plate 26 and the lower end of spring 30 engaging a metal bearing ring 31 which engages a washer 32 surrounding shaft 22 and held in place by a horse-shoe shaped spring clip retainer 33 resiliently urged into a groove in shaft 22 adjacent the lower end thereof. During assembly the members 24 through 29 are bolted to the desired support for the antenna assembly, for example, as shown here to the top surface 34 of a metal cabinet for a radio receiver proper, by means of bolts 35 extending through the hollow eyelets or rivets 28. The shaft 22 is then inserted in the apertures in the members 24 through 26 and also through a somewhat larger corresponding aperture in the upper metal surface 34 which assists shield 13 in shielding coils 11 and 12. The elements 30 through 33 are then assembled on to the shaft 22 from inside the cabinet. If desired, the bolts 35 could be rigidly attached to the metal ring 29, for example by soldering and the entire antenna assembly could be put together outside the receiver case and the bolts 35 could then be attached to the cabinet by threading the nuts on inside the cabinet.

The terminal wires for the coils 11 and 12, as shown here, extend down through hollow shaft 22 surrounded by a suitable plastic sleeve 36 and terminate in a plug assembly 37, which may be plugged in the chassis of the radio receiver inside the cabinet. The metal plate 27 extends out beyond the skirt of the antenna case 16 sufficiently to allow compass bearing marks to be visibly inscribed on the upper surface thereof. Plate 27 may be oriented to any desired direction relative to the actual physical position of the receiver case, for example with north pointing to the bow of a craft on which the direction finder is situated. The antenna case 16 may then be rotated manually and any desired indicator point on the core, such as pointed protuberances 38, may be used as reference points to read off the desired bearing of the received signal on the scale 27. Since, with the antenna illustrated herein, the null direction is axial with the core 10, the protuberances 38 are made axial with core 10.

Referring now to Fig. 3, there is illustrated, by way of example, a radio receiver circuit with which the antenna illustrated in Figs. 1 and 2 may be used. The antenna is illustrated here diagrammatically at 39 with the coils 11 and 12 wound on the core 10 and the entire assembly surrounded by the shield 13. The coils 11 and 12 are separately connected through jack plug 37 to a terminal strip 40 such that the end of the coil 11 adjacent the end of the core 10 is connected to ground and also is connected to a shield 13. The other end of coil 11 is connected to a sliding contact 41 of one section of a rotary switch 42 which is used to switch the frequency bands over which the radio receiver can be tuned. As shown here, the switch section 42 is in the low frequency band position which covers substantially the entire broadcast band. In this position, the contact 41 is connected through the switch section 42 to another contact 43, which is connected to the end of coil 12 adjacent coil 11, said coils being both wound in the same direction on the core 10 such that this connection produces a series aiding connection of coils 11 and 12. The other end of coil 12 is connected through to a contact 44 on another portion of switch section 42, which, in the position shown, makes contact with another contact 45 which is connected through a coupling condenser 46 to the grid 47 of an RF amplifier pentode 48. Grid 47 is connected through a grid load resistor 49 to a bias bus 50 to which a fixed negative bias is normally applied for direction finder work. Bus 50 is by-passed to ground through a filter condenser 51. Contacts 44 and 45 are also connected, in the position shown, to a contact 52, which is connected through a tuning condenser 53 to ground, said tuning condenser having a trimming condenser 54 in shunt therewith for tracking adjustment purposes. Thus it may be seen that the tuning condenser 53 is actually in parallel with the coils 11 and 12 in series and is designed to resonate with said coils over the desired range of tuning frequencies, for example the broadcast band. The signals developed across the tank circuit, comprising condenser 53 and coils 11 and 12, is fed through the coupling condenser 46 to the grid 47 of the RF amplifier. The filament 55 of tube 48 shown here, by way of example, is a directly heated cathode and is connected to a suitable source of heater current, not shown, and through said source to ground. The screen grid 56 of tube 48 is connected to a suitable cource of B+ voltage and to ground through a suitable by-pass condenser 57. The suppressor grid, not shown in the interest of clarity, is connected to the filament 55 as is conventional. The anode 58 of pentode 48 is connected, through the primary winding 59 of an interstage RF coupling transformer, to B+. The secondary winding 60 of the interstage coupling transformer is connected from ground through a coupling condenser 61 to the injection grid 62 of pentagrid converter 64. An RF coupling condenser 65 is connected between upper ends of windings 59 and 61 to improve the coupling at the higher RF frequency.

The upper end of secondary winding 60 is also connected to a contact 66 of a second switch section 67 ganged to operate with switch section 42. Contact 66 in the position shown is for broadcast band coverage and in this position is connected to a contact 68 which is connected through a tuning condenser 69, ganged to tuning condenser 53, to ground. Tuning condenser 69 has a trimmer condenser 70 connected in parallel herewith for tracking adjustment purposes. The injection grid 63 of tube 64 is connected through a grid load resistor 71 to the negative bias supply which may be on the order of —1 or —2 volts. The filamentary cathode 72 of tube 64 is connected through a heater current source, not shown, to ground and through a grid load resistor 73 to the control grid 74 of tube 65. The screening grids 75 of tube 64 are connected through the primary winding 76 of a local oscillator radio frequency coupling transformer and through a decoupling resistor 77 to B+. The junction between winding 76 and resistor 77 is by-passed to ground through a by-pass condenser 78. The secondary winding 79 coupled to winding 76 is connected from ground through a coupling condenser 80 to control grid 74. Winding 79 has, connected in parallel therewith, a tuning condenser 81, mechanically ganged to condensers 53 and 69, and having a trimmer condenser 82 connected in parallel therewith. The windings 76 and 79 are so poled that oscillations will occur in the tank circuit comprising condenser 81 and winding 79 according to well-known practice. The anode 83 of tube 64 is connected through a suitable intermediate frequency coupling transformer, not shown, to B+ according to well-known practice and is illustrated herein as feeding an IF amplifier 84. The output of IF amplifier 84 feeds a detector 85, which, in turn, feeds an audio amplifier 86 driving a loud speaker 87, all according to well-known practice.

An automatic gain control voltage may be derived from the detector 85 in accordance with well-known practice and may be fed back to the bias bus feeding grids 63 and 47 to provide automatic volume control. This is desirable when the device is used for ordinary reception of broadcast intelligence which is feasible since the antenna is relatively sensitive in all the directions, except those very close to the axis of the magnetic core 10.

However, if it is desired to use the device for direction finding purposes, the automatic gain control voltage would be switched off and a fixed bias substituted therefor so that the exact null or zero signal direction of any signal could be determined. The RF amplifier and mixer stage, described herein in some detail, illustrate only one example of the many types of circuits that could be used with the antenna structure. For example, the RF amplifier stage 48 could be eliminated entirely along with one gang of the ganged tuning condensers 63, 69 and 81, and the signal derived from the antenna fed directly into the mixer 64, as is done in many of the less expensive battery operated receivers commercially available. If desired, the antenna could be used with the tuning condenser and one or more RF amplifier stages to produce a tuned radio frequency receiver or to feed any other desired type of receiver.

When the switch sections 42 and 67 are switched into their other position, contacts 43 and 44 are disconnected from the circuit thereby leaving coil 12 out of the circuit and, hence, lowering the inductance presented by the induction. The contact 41 is now connected to a contact 88, which is connected through a band frequency adjustment trimming condenser 89 to ground and to a contact 90, which is now connected to contact 45. A series trimming or padding condenser 91 is connected between condenser 46 and tuning condenser 53 and is now connected in the circuit due to disconnection of contact 52 from contact 45. Contact 68 of switch section 67 is disconnected from contact 66 and introduces into the circuit a series padding condenser 92 between contact 66 and tuning condenser 69. Contact 66 is now connected to a contact 93, which is connected through an indicator 94 to ground, said inductor being by-passed by a trimmer condenser 95, which may be adjusted along with trimmer condenser 89 and 91 to produce tracking in the high band. Another portion of switch section 67 connects oscillator tuning condenser 81 to a contact 96, which is now connected to a contact 97, which, in turn, is connected through an inductor 98 to ground, said inductor being by-passed by a trimmer condenser 99. Trimmer condenser 99 is used to adjust the oscillation frequency for tracking on the upper band, which, as shown here by way of example, may be the band from 1700 to 3400 kilocycles immediately above the broadcast band.

On the upper band the disconnection of the coil 12 entirely from the circuit eliminates losses which would lower the Q of the antenna circuit and, hence, lower the gain of the receiver on this band. However, if desired, the coil could remain with one end connected to the circuit. It is clearly understood that any number of coils could be wound on the core 10 and switched in or out to produce coverage of a large number of bands of the radio frequency spectrum.

This completes the description of the specific embodiment of the invention illustrated herein. However, many modifications thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this invention. For example, the antenna core is not necessarily limited to a cylindrical shape, but could have a cross section which is rectangular, triangular, or any other desired shape and the core could be bent to lie along a curved path, and any desired type of shielding could be used to produce the desired directional characteristics. Accordingly, it is desired that this invention be not limited by the particular details of the embodiments illustrated herein, except as defined by the appended claims.

What is claimed is:

1. A directive loop antenna comprising a coil of conductive material, and a shield secured relative to said coil whereby said shield and said coil maintain a stationary disposition with respect to each other, said shield comprising an elongated cavity of highly conductive material substantially surrounding said coil and extending along the entire length of said coil, said shield being substantially spaced from said coil and having open opposite ends to expose the end portions of said coil, said shield further having at least one slot extending along the full length thereof whereby a complete discontinuity is provided in the surface of said shield so that no conductive path exists in said shield around said coil.

2. A directive loop antenna comprising a coil of conductive material, the length of said loop being substantially greater than the diameter thereof, and a shield secured relative to said coil whereby said shield and said coil maintain a stantionary disposition with respect to each other, said shield comprising an elongated cavity of highly conductive material substantially surrounding said coil and extending along the entire length of said coil, said shield being substantially spaced from said coil and having open opposite ends to expose the end portions of said coil, said shield further having at least one slot extending along the full length thereof whereby a complete discontinuity is provided in the surface of said shield so that no conductive path exists in said shield around said coil.

3. A directive loop antenna comprising a coil of conductive material wound on a core having a magnetic permeability substantially greater than that of free space, and a shield secured relative to said coil whereby said shield and said coil maintain a stationary disposition with respect to each other, said shield comprising an elongated cavity of highly conductive material substantially surrounding said coil and extending along the entire length of said coil, said shield being substantially spaced from said coil and having open opposite ends to expose the end portions of said coil, said shield further having at least one slot extending along the full length thereof whereby a complete discontinuity is provided in the surface of said shield so that no conductive path exists in said shield around said coil.

4. A directive loop antenna comprising a coil of conductive material wound on a core having a magnetic permeability substantially greater than that of free space, the length of said coil being substantially greater than the diameter thereof, and a shield secured relative to said coil whereby said shield and said coil maintain a stationary disposition with respect to each other, said shield comprising an elongated cavity of highly conductive mate-

rial substantially surrounding said coil and extending along the entire length of said coil, said shield being substantially spaced from said coil and having open opposite ends to expose the end portions of said coil, said shield further having at least one slot extending along the full length thereof whereby a complete discontinuity is provided in the surface of said shield so that no conductive path exists in said shield around said coil.

5. An electromagnetic wave energy reception system comprising a directive loop antenna comprising a coil of conductive material, a tuning condenser coupled in parallel with said coil, and a shield secured relative to said coil whereby said shield and said coil maintain a stationary disposition with respect to each other, said shield comprising an elongated cavity of highly conductive material substantially surrounding said coil and extending along the entire length of said coil, said shield being substantially spaced from said coil whereby the coil capacity is kept to a minimum in order to retain a wide tuning range, said shield having open opposite ends to expose the end portions of said coil, said shield further having at least one slot extending along the full length thereof whereby a complete discontinuity exists in the surface of said shield so that no conductive path is present in said shield around said coil.

6. An electromagnetic wave energy reception system comprising a directive loop antenna comprising a coil of conductive material, a tuning condenser coupled in parallel with said coil to the input of an electron discharge device, and a shield secured relative to said coil whereby said shield and said coil maintain a stationary disposition with respect to each other, said shield comprising an elongated cavity of highly conductive material substantially surrounding said coil and extending along the entire length of said coil, said shield being substantially spaced from said coil whereby the coil capacity is kept to a minimum in order to retain a wide tuning range, said shield having open opposite ends to expose the end portions of said coil, said shield further having at least one slot extending along the full length thereof whereby a complete discontinuity exists in the surface of said shield so that no conductive path is present in said shield around said coil.

7. An electromagnetic wave energy reception system comprising a directive loop antenna comprising a coil of conductive material wound on a core having a magnetic permeability substantially greater than that of free space, the length of said coil being substantially greater than the diameter thereof, a tuning condenser coupled in parallel with said coil to the input of an electron discharge device, and a shield secured relative to said coil whereby said shield and said coil maintain a stationary disposition with respect to each other, said shield comprising an elongated cavity of highly conductive material substantially surrounding said coil and extending along the entire length of said coil, said shield being substantially spaced from said coil whereby the coil capacity is kept to a minimum in order to retain a wide tuning range, said shield having open opposite ends to expose the end portions of said coil, said shield further having at least one slot extending along the full length thereof whereby a complete discontinuity exists in the surface of said shield so that no conductive path is present in said shield around said coil.

8. An electromagnetic wave energy reception system comprising a directive loop antenna comprising a coil of conductive material wound on a core having a magnetic permeability substantially greater than that of free space and a relatively low loss at radio frequencies, the length of said coil being substantially greater than the diameter thereof, a tuning condenser coupled in parallel with said coil to the input of an electron discharge device, and a shield secured relative to said coil whereby said shield and said coil maintain a stationary disposition with respect to each other, said shield comprising an elongated cavity of highly conductive material substantially surrounding said coil and extending along the entire length of said coil, said shield being substantially spaced from said coil whereby the coil capacity is kept to a minimum in order to retain a wide tuning range, said shield having open opposite ends to expose the end portions of said coil, said shield further having at least one slot extending along the full length thereof whereby a complete discontinuity exists in the surface of said shield so that no conductive path is present in said shield around said coil.

9. A directive loop antenna comprising a coil of conductive material, and a shield secured relative to said coil whereby said shield and said coil maintain a stationary disposition with respect to each other, said shield comprising an elongated cavity of conductive material substantially surrounding said coil and extending along the entire length of said coil, said shield being substantially spaced from said coil and having at least one slot extending along the full length thereof whereby a complete discontinuity is provided in the surface of said shield so that no conductive path exists in said shield around said coil.

10. A directive loop antenna comprising a coil of conductive material wound on a core of ferrite material, and a shield secured relative to said coil whereby said shield and said coil maintain a stationary disposition with respect to each other, said shield comprising an elongated cavity of conductive material substantially surrounding said coil and extending along the entire length of said coil, said shield being substantially spaced from said coil and having at least one slot extending along the full length thereof whereby a complete discontinuity is provided in the surface of said shield so that no conductive path exists in said shield around said coil.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,915,752 December 1, 1959

Sumner Riceman

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 7, for "the 2—2 line" read -- line 2—2 --; column 4, line 10, after "through" insert -- the --; line 49, for "cource" read -- source --.

Signed and sealed this 14th day of June 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents