

[54] **CROSS LOOP ANTENNA**
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[57] **ABSTRACT**

Two orthogonal arrays of ferrite cores wound and connected in series. The arrays are insulated from each other to provide predictable inductance. The arrays preferably form a square inside of which a low-noise amplifier is connected directly to each array, the amplifiers forming a built-in part of the antenna assembly. A design for a small, narrow-band 10 KHz to 14 KHz antenna is described, having a large effective height.

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7 Claims, 3 Drawing Figures

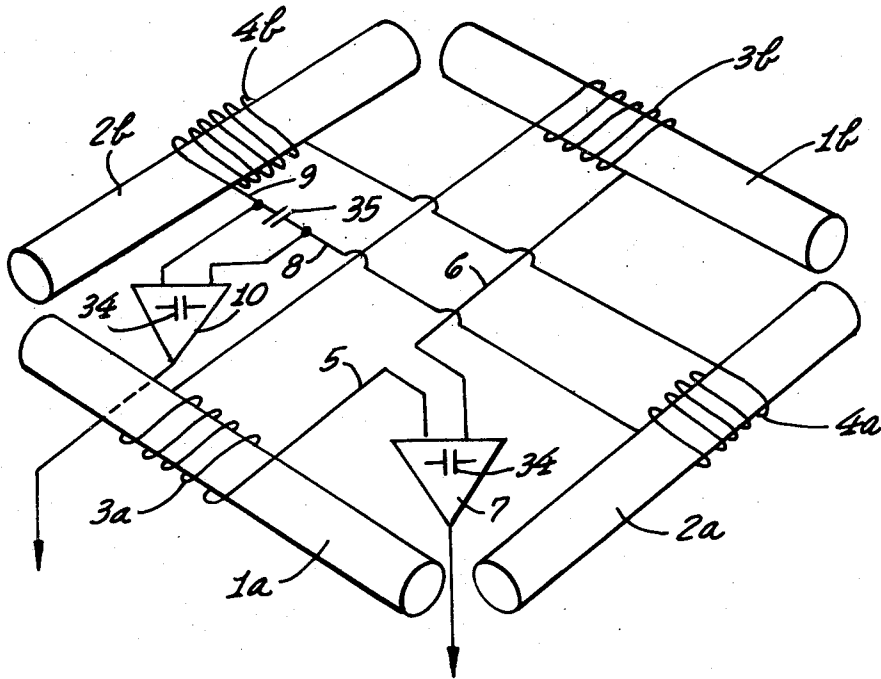


Fig. 1

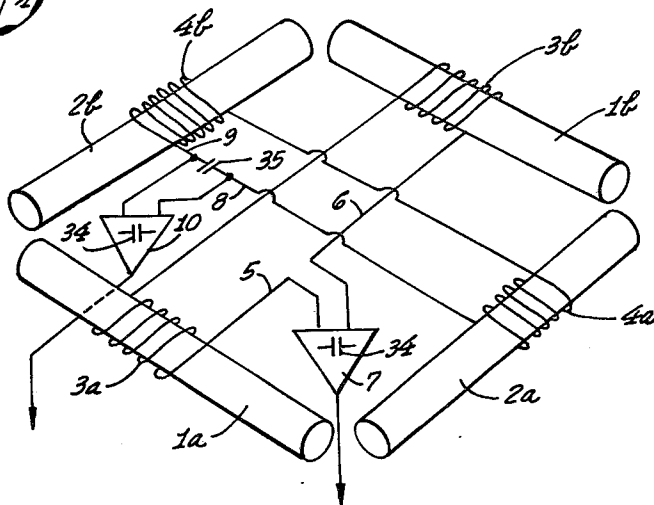
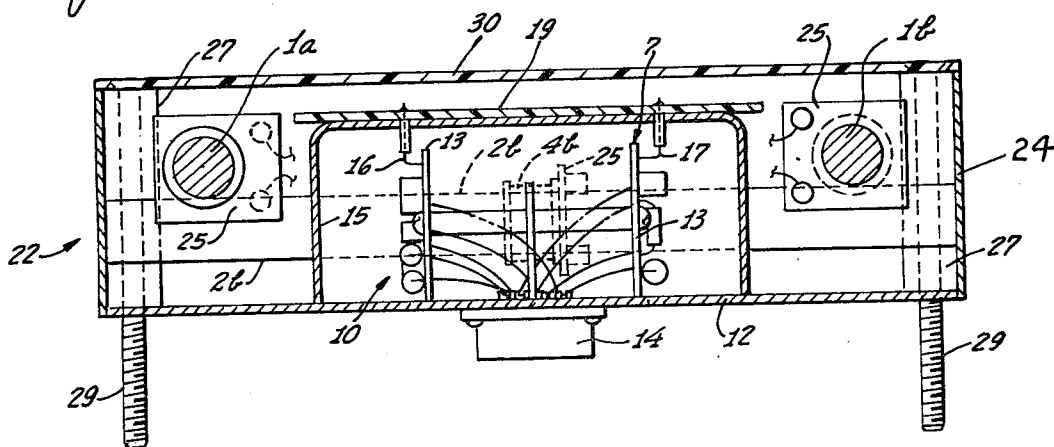
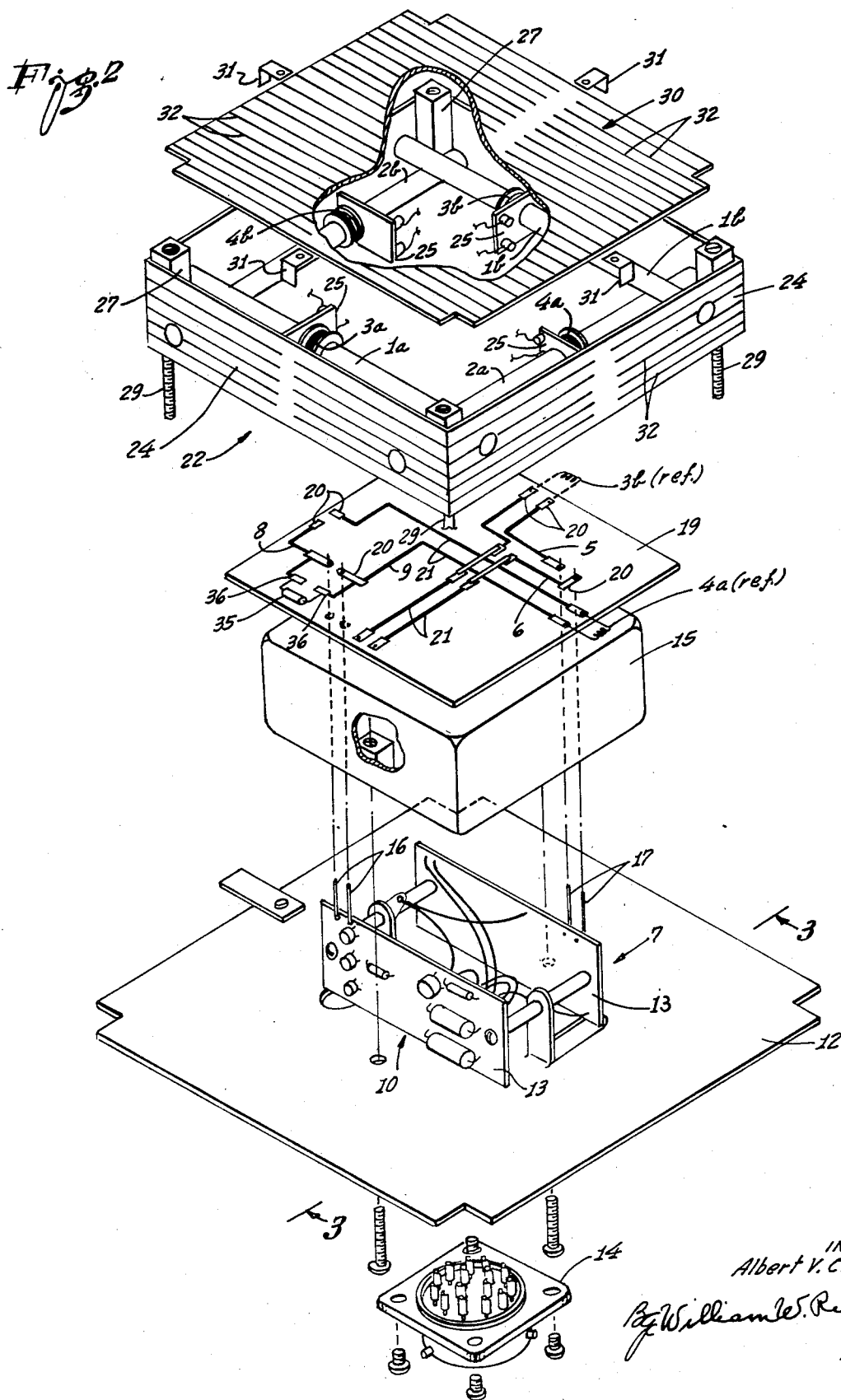


Fig. 3



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CROSS LOOP ANTENNA

The present invention relates to antennas, and more particularly, to a small, high-performance cross loop antenna for detecting weak signals especially in the low frequency range and for airborne applications.

For use with low frequency radio navigation systems, conventional antennas are physically rather large yet have a low effective height. They require transformer coupling to raise the signal to a sufficient level for the amplifier. They are frequently untuned wide frequency-band units which use a core having a low permeability.

It is an object of the present invention to provide an antenna having a large effective height while minimizing size.

A further object of this invention is to provide a tuned antenna using a high permeability core material in order to increase the effective height.

Another object is to provide a low frequency antenna directly connectable to a pre-amplifier without incorporating a coupling transformer.

Other objects and features of advantage will be noted in the description of a preferred embodiment to follow.

Briefly, my invention comprises two orthogonal arrays of ferrite cores, each array having at least two separated parallel cores with windings connected in series, and each array connected directly to an amplifier adjacent to the cores. The arrays are preferably enclosed in an electrostatic shield to obtain sensitivity to the H field only, and the amplifier is preferably encased in a metal case to prevent coupling of the output into the input.

This invention will be more fully understood by reference to the following detailed description and to the accompanying drawings of a specific embodiment of the invention.

In the drawings,

FIG. 1 is a schematic pictorial diagram of the present antenna, showing the general arrangement of cores, windings and amplifiers.

FIG. 2 is an exploded isometric view of an actual antenna assembly built according to this invention, showing the order and construction of components.

FIG. 3 is a largely cross-section view through an assembled antenna, taken approximately as shown by the line 3—3 in FIG. 2, showing the final relative position of the various parts in FIG. 2.

Referring first to FIG. 1, the present antenna comprises two pairs of ferrite cores 1a, 1b, and 2a, 2b arranged substantially in a square. A first core pair 1a and 1b has a central winding 3a and 3b on each respective core, the windings being identical and connected in series in mutual inductance-cancelling fashion, thus reducing the total inductance which would be present if only one coil were provided or if the two were connected in mutual inductance-aiding fashion. A second set of identical windings 4a and 4b are provided at the centers of the second core pair 2a and 2b, and also connected in series the same way as windings 3a and 3b.

The cores 1a, 1b, 2a and 2b are selected from high initial permeability (μ_o) material in order to increase the effective antenna height for use in the 10 to 14 KHz frequency range for example. The windings are arranged only at the central portions of the cores so that substantially all the magnetic field lines of flux will go through the coil of wires.

The resulting two end coil wires 5 and 6 from windings 3a and 3b are directly connected in balanced input fashion to a first amplifier 7. Likewise, the two end coil wires 8 and 9 from windings 4a and 4b are directly connected to a second amplifier 10. Thus, actually two antennas are provided, which can be used separately.

For novel construction details of the antenna assembly, reference is made to FIG. 2. A sheet metal base 12 has the two amplifiers 7 and 10 assembled on two circuit boards 13 which are mounted on edge and parallel to each other in the center portion of the base 12. An electrical connector plug 14 in the base 12 provides all the electrical connections to and from the amplifiers as required. Mounted over and enclosing amplifiers 7 and 10 is a metal can 15 fastened to the base 12, with only one pair of input leads 16 and 17 from each amplifier extending through small holes in the can 15. The actual position of all these parts can be seen in FIG. 3.

Directly on top of the can 15 is mounted a flat interconnect board 19 having solder connections 20 and printed circuit type conductors 21 for connection from the amplifier input leads 16 and 17 to the antenna windings 3a, 3b, and 4a, 4b. The solder connections for the antenna windings are located next to the center of each edge of the interconnect board 19 for nearness to the four windings.

FIG. 2 shows the mounting structure for the four cores and their windings. A square box 22 is made of sides 24 having mounting holes for the four cores 1a, 1b and 2a, 2b so the latter are in a substantial square larger than the interconnect board 19 and the can 15. The cores are not in contact with one another, so that the total inductance can be very closely predicted. The windings of the antenna are formed on four equal bobbin assemblies 25 which fit around the cores near or at the center thereof and may be secured thereto by a suitable cement for example. As illustrated herein, each winding is made in just one section, but they may be made in two (or more) adjacent sections separated by plastic rings if desired, to decrease the interwinding capacitance. Each of the two ends of the windings are soldered respectively to the four pairs of edge solder connections 20 on the interconnect board 19, and the resulting series windings ends 5, 6 and 8, 9 are thus connected to the amplifier input leads 17 and 16, respectively, by the conductors 21. As is evident, these conductors 21 form the proper series connections for the windings as shown in FIG. 1.

Four corner posts 27 of the box 22 carry fasteners such as screws 29 which extend perpendicularly outside the base 12, while the box sides 24 rest on the surface extremities of base 12. A shielding cover 30 fits over the box 22 and completes the assembly, being fastened to the sides 24 by four soldered straps 31.

The final assembly is thus very compact and appears as shown in FIG. 3. The cover 30 and box sides 24 are electrostatic shields being made of copper clad phenolic, for example, with surface etching 32 through the copper to break up eddy currents. The antenna is thus responsive to magnetic fields only. The metal can 15 can be seen to isolate the amplifiers 7 and 10 and their outputs from the input of the antenna as picked up by the cores and windings 3 and 4.

For attachment to a vehicle (not shown) such as an airplane, the base 12 fits against a flat outer skin while the screws 29 attach the assembly to the airplane structure, the latter having an opening at the center of the base 12 just large enough to accommodate the electrical plug 14. This antenna may also be installed in a depression in the outer airplane surface so that the cover 30 is substantially flush with the airplane skin.

The present antenna is preferably tuned to be operated at a desired small frequency band, such as 10 to 14 KHz for example. The center resonant point would be at approximately 12 KHz, therefore, and this is accomplished by a fixed capacitor 34 (FIG. 1) placed in each amplifier across its input circuit. To equalize each amplifier and coil resonant point in the actual final circuit, an additional small capacitor 35 may be connected across the series windings to one of the two amplifiers at two extra solder terminals 36 (FIG. 2) on the interconnect board 19, right near the windings.

It is thus seen that a very simple and inexpensive antenna has been provided which outperforms other, far more costly, antennas designed for the same purpose. A higher effective height is achieved by using a high μ_o core, increasing the number of coil turns, and increasing the Q at the input to the amplifiers. An array of cores is used instead of one core since this increases the inductance only linearly while inductance is increased as the square of the number of turns of one coil. Stray capacitance is minimized by placing the antenna amplifier as close to the windings as possible and is controlled by using printed circuit conductors to interconnect the amplifier to the windings. By using two cores per loop, the amplifiers can be placed within the square formed by the cores and thus reduce both antenna size and interconnection distance. The antenna and its amplifiers are produced in one package instead of two. Further, no coupling transformers are used or needed with the present antenna since the high efficiency cores and windings produce a high enough signal-to-noise ratio that no voltage step-up is required, and since no impedance matching problem exists. In comparison with a prior art antenna, the antenna of this invention optimized for the 10 to 14 KHz frequency range has an effective height of 30 or more times the former.

As mentioned, the square array of four cores allows the direct-connected amplifiers to be located within the square and thus permit a very compact package. However, the invention also comprises a larger number of cores in each array, the coils of each array of cores being connected in series. For instance, two orthogonal arrays of four spaced cores each may be provided in two closely adjacent planes, no cores touching each other, and the amplifiers mounted in the same package closely adjacent one coil array.

While in order to comply with the statute, the invention has been described in language more or less specific as to structural features, it is to be understood that the invention is not limited to the specific features shown, but that the means and construction herein disclosed comprise the preferred form of putting the invention into effect, and the invention is therefore claimed in any of its forms or modifications within the legitimate and valid scope of the appended claims.

What is claimed is:

1. A cross loop antenna comprising:

- a. a first array having a plurality of winding cores spaced apart in parallel relation;
 - b. a second similar array mounted in a closely adjacent plane parallel to that of said first array but the winding cores of said second array being perpendicular to the first cores, the cores of said second array being spaced from the cores of said first array;
 - c. an antenna winding on each of said cores, the windings of each array being connected in series, alternate windings connected in mutual inductance-cancelling fashion;
 - d. a pair of amplifiers, the input of each said amplifier connected directly to the two ends of one of the respective series combinations of windings of said arrays;
 - e. a first electrostatic shield around said antenna and a second electrostatic shield separating said amplifiers from said windings; and
 - f. said antenna being contained in a single package.
2. A cross loop antenna comprising:
- a. a first array having two winding cores spaced apart in parallel relation;
 - b. a second array of two winding cores mounted in a closely adjacent plane parallel to that of said first array but the winding cores of said second array being perpendicular to the first cores, the cores of said second array being spaced from the cores of said first array;
 - c. an antenna winding on each of said cores, the windings of each array being connected in series, alternate windings connected in mutual inductance-cancelling fashion, each said winding being concentrated at a small central portion of its respective core;
 - d. a pair of amplifiers located inside the square formed by said four cores, the input of each said amplifier connected directly to the two ends of one of the respective series combinations of windings of said arrays; and
 - e. said antenna being contained in a single package.
3. An antenna assembly comprising:
- a. a substantially square box having a height substantially less than the length of each of its four sides;
 - b. a first array of two parallel cores mounted between two opposite sides at substantially opposite ends thereof, and a second array of two parallel cores similarly mounted between the other two opposite sides;
 - c. an antenna coil winding on each said core concentrated at substantially the central portion of its core;
 - d. a lower base of said box having a pair of amplifiers mounted thereon in the central portion thereof and extending upward within the space formed in the center of the four said cores;
 - e. the windings of each said array being connected in series and in mutual inductance-cancelling fashion, the ends of each series - connected array being connected to the input of a respective one of said amplifiers by substantially as short a length of leads as necessary;
 - f. a cover over the top of said box; and
 - g. an electrical connector in an opening of said base for carrying amplifier output and operating leads through said base.

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4. Apparatus in accordance with claim 3 including a circuit board having printed circuit conductors thereon mounted over the top of said amplifiers, said conductors forming the electrical connections of paragraph (e) between said windings and said amplifier inputs.

5. Apparatus in accordance with claim 3 including shielding means between said amplifiers and said windings.

6. Apparatus in accordance with claim 3 wherein said box forms an electrostatic shield.

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7. Apparatus in accordance with claim 3 including shielding means around the sides and top of said amplifiers, means defining small openings in the top of said shielding means, amplifier input leads passing through said openings, a circuit board having printed circuit conductors thereon mounted over the top of said shielding means, said conductors forming the electrical connections as recited in paragraph (e) between said windings and said amplifier input leads.

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