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MAGNETIC ANTENNA SYSTEMS
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This invention relates generally to antenna systems and more particularly to improved arrangements of magnetic antennas which are suitable for use as antennas on mobile craft and other applications where protruding dimensions must be minimized or eliminated.

The art of signaling by means of electromagnetic radiation, in the past, has resulted in the advent of a wide variety of antenna arrangements for transmitting or receiving the wave energy signals. These antennas, while varying greatly in detail, are almost universally of the type which can be described as a conductivity discontinuity disposed in the transmission medium of free space and operating usually with reference to a conducting ground plane. For antennas in the form of a conducting electric element the distance between the element and the ground plane is required to be quite large for satisfactory operation and the effective height (i.e., the ratio of terminal voltage to field strength) rapidly approaches zero as this distance decreases. For antennas in the form of a slot in the ground plane efficient operation can be obtained without any physical extension from the ground plane. These latter antennas, however, are generally only practical for the relatively short wavelengths, such as in the microwave region.

The present invention is directed to the provision of flush mounted antennas which have no projection from the ground plane with which they operate and yet maintain a usable effective height as signal transmitters. This result may be achieved at any desired frequency including the relatively longer wavelengths, such as, for example, the aircraft beacon band in the neighborhood of 200 kilocycles and below, without undue physical size by employing a magnetic antenna element which is embedded in an opening in the conducting ground plane. The antenna so formed has been found to produce results which are at least as good as prior art electric antennas and by virtue of the physical arrangement thereof afford considerably improved structural features, such as the aerodynamic advantages in aircraft applications or the like.

A particular system in which the magnetic antenna of the present invention finds application occurs, for example, in the field of direction finding by which it may be employed to detect the direction from which radio frequency signals arrive at the aircraft location, thereby permitting the crew to determine which relative thereto. These systems have, in the past, incorporated a relatively large antenna structure which when mounted on an aircraft or other metal surface was required to be spaced away from such surface for effective reception of electromagnetic radiation. On high speed aircraft the protrusion of such antennas produces undesirable interference with the air flow over the aircraft surface and for increasingly higher speeds the size of protrusion that can be tolerated becomes vanishingly small. This requirement of smooth surfaces for uninterrupted air flow is in direct opposition to the requirement of a sensitive radio frequency electric antenna, inasmuch as the sensitivity of such antennas is, in general, a function of the projection thereof normal to the aircraft surface. The physical arrangements of such antennas are further restricted inasmuch as the protruding portion of the antenna in direction finder applications is, in general, required to be rotated.

It is, accordingly, a primary object of this invention to provide a new and improved antenna system which is operable when flush mounted in a conducting surface. Another object is to provide a directional antenna suitable for direction finding applications which may be operably located on an aircraft without protruding from the surface thereof.

Still another object is to provide a flush mounted magnetic antenna system which can be flush mounted on a conducting surface and which is simple and economical to construct and exhibits high sensitivity and reliability in operation.

These and other objects of the invention are accomplished according to the present preferred embodiment thereof by mounting a magnetic antenna element, such as a dust iron or ferrite bar, in a conducting surface or closely adjacent thereto and suitably coupling signals from the magnetic flux in the bar by means of, for example, a coil wound thereon. As utilized in a direction finder system the invention provides a plurality of radially disposed bars of powdered iron or other suitable high frequency permeable material. The radial bars are depressed in a conducting surface having incident thereon an electromagnetic radiation field. The coplanar bars and mounting surface thereof provide an ideal aerodynamic surface and such an arrangement, in accordance with the teaching of the present invention, is without deleterious effect on the electrical performance of the antenna. The bars are disposed with respect to a central opening in which a disc core member made of a similar permeable material is mounted for rotation. The disc core has wound thereon a coil which has a voltage induced therein in accordance with the flux induced in the radial bars and the relative position of the bars and the coil. The relative position at which a null is secured is indicative of the direction of arrival of the electromagnetic field.

For the purpose of this specification and the appended claims, "high-frequency high-permeability materials" and "magnetic antenna elements" are to be understood to mean materials which have high-resistivity and permeability, and magnetic antennas constructed with such materials. Such materials are those known, for example, as ferrites or such compositions as dust iron formed into suitable solid shape by a high-resistivity binder. It will further be understood that "conducting surface" or the like is hereby limited to mean non-magnetic conducting material surfaces which have low-permeability, for example, unity permeability.

The invention may be better understood by reference to the following detailed description taken in conjunction with the accompanying drawings wherein:

Fig. 1 is a perspective view of a magnetic antenna in a conducting sheet;

Fig. 2 is a plan view of an antenna system in accordance with the invention shown mounted in a fragmentary portion of an aircraft surface, for use in direction finding;
3 Fig. 3 is a sectional view along the line 3-3 of Fig. 2; and Fig. 4 is a sectional view along the line 4-4 of Fig. 2. Referring now to Fig. 1, there is shown a conducting surface 8 having secured in an opening therein a magnetic rod 9 which has a coil 10 wound thereon. The rod 9 has a high-permeability and is non-conducting and may have a dielectric constant greater than unity, if desired. One ferromagnetic material which has given satisfactory results is that known in the trade as "Stackpole Ceramag 4." The antenna may be utilized for transmission or reception by connecting the terminals of the coil 10 to appropriate circuits in a conventional manner. In Fig. 2 is shown an aircraft surface 11, which has embedded therein three bars 12 which are made of a high-permeability high-resistivity material or iron dust held together with a suitable non-conducting binder. The bars 12 are long in comparison to their cross-sectional dimensions and are retained in the recesses in the surface 11 by being embedded in low loss plastic 13 or like material which may be molded and hardened. Rotatably mounted in a circular opening 14 in the surface 11 and in a hub position with respect to the poles 12 is a disc 15 of high-frequency permeable material similar to that of the bars 12. The disc 15 has a coil 16 wound thereon which may be center-tapped, if desired. Connections to the coil 16 are made by means of slip rings as will be hereinafter described. The rods 12 may have shaped pole shoes 20 which are adjusted to reduce a sextant error in the null voltage position of the coil 16 resulting from the three rod arrangement. In Fig. 3 the bar 12 is shown embedded in plastic 13 thus forming a substantially continuous surface between the portions of the aircraft surface 11 adjacent the recess. If desired, an exactly flush surface construction could be used.

4 Fig. 4 shows the core 15 rotatably mounted in a bearing 17 coaxial with the opening 14. The end and center terminals of the coil 16 are connected to slip rings 18 which are contacted by brushes 19. The coil and core assembly may be rotated by manual or power means, not shown, depending upon the particular system into which the antenna is incorporated. In order to obtain a suitable inductance value it may be desirable to provide the core 15 of a thickness somewhat greater than that of the rods 12. This may be achieved without undue loss in the flux transferred from the rods 12 to the core 15 by providing suitably shaped pole shoes 21. The opening 14 may be closed by a suitable cover plate 22 which may be flush mounted in a recess, if desired.

5 What is claimed is:

1. A magnetic antenna system comprising, a plurality of magnetic rods radially disposed in a conducting plate having circular openings therethrough, a plurality of high-frequency cores rotatably mounted in said plate adjacent said openings, and a plurality of conductors connected to the ends of said rods and to said cores for transmitting and receiving electromagnetic signals.

2. A direction finding magnetic antenna system for electromagnetic radiation comprising, three rods formed of high-frequency magnetic material radially disposed in a conducting plate, a high-frequency core rotatably mounted centrally in said plate, said core being of such a thickness and dimensions as to cause the magnetic flux generated by said core to be substantially greater than the magnetic flux generated by said rods, and means for determining the direction of the field of said core relative to said plate.

3. A magnetic antenna system comprising, a plurality of magnetic conductors radially disposed in a conducting plate having circular openings therethrough, a plurality of high-frequency cores rotatably mounted in said plate adjacent said openings, and means for determining the direction of said cores relative to said plate by means of a detecting circuit connected to said cores.

6 The operation of the magnetic antenna system of the present invention is qualitatively explained by analogy with the well known electric antennas. As hereinbefore described, conductive antennas, such as the half-wave dipole, represent a conductivity discontinuity and the performance of such antennas is markedly affected by the proximity of other conductors such as the ground plane. The magnetic antenna represents a magnetic discontinuity of high permeability and in accordance with the present teaching the performance thereof is not seriously impaired by the proximity of the conducting ground plane. In the case of the electric antenna the analogous question of the effect of the presence of non-conductive permeable bodies has apparently been of insufficient practical interest to warrant investigation; whereas, the present teaching of the utility of a magnetic antenna located in a conducting surface is eminently practical as, for example, in high speed aircraft installations.

7 In the operation of the direction finder of Fig. 2 the antenna system of the present invention picks up radio frequency signals with an effective height equivalent to that of many prior art protruding antennas. The effective height of the antenna increases with physical dimensions for dimensions much smaller than a wavelength and in a particular application it will be understood that the maximum physical size and weight of an antenna will be limited by other considerations. For example, a satisfactory directional finder antenna similar to that of Fig. 2 for the frequency range of 100-1750 kilocycles per second had the bars 12 each of length 14 inches, and 0.75 inch in diameter, thereby providing a physical arrangement well adapted for mounting in the wing of an aircraft. The bars 12 may be designed as magnetic or non-magnetic antenna elements in a manner similar to that described in an article entitled, "The Magnetic Antenna" by Leigh Page, published in Physical Review, June 1946. For this purpose, the bars 12 should be as long as is practicable and the transverse dimensions as smallably chosen. By making the air gap between the ends of the rods 12 and the core 15 small, substantially all of the flux from the rods 12 will pass through the core 15 and induce a voltage in the coil 16. The voltage induced in the coil 16 will have a pattern with respect to rotation of a figure 8 similar to well known loop patterns, which may be utilized in any conventional manner for indicating the direction of arrival of the electromagnetic waves. By virtue of the absence of any projection into the air-stream, the antenna system of the present invention produces no aerodynamic disturbances.

8 Many modifications of the antenna system here described will be apparent to those skilled in the art in the light of the above teaching. Various core and coupling arrangements are possible by analogy to various other magnetic circuits. In the direction finder antenna, changes may be made, such as a greater number of radial rods, members may be used to improve the symmetry of the antenna aperture relative to direction. In some applications, it may be desirable to adjust the angular positions of one or more of the radial bars relative to the others to compensate for quadrantal errors of the aircraft.
high-frequency high-permeability antenna elements, means for radially disposing said elements essentially in a conducting surface, a rotatable core centrally located with respect to said elements, a coil covering substantially the full width of said core, and signal frequency means coupled to said coil, the air gaps between the adjacent ends of said elements being substantially greater than the air gaps between said elements and said core, whereby shunting of flux and inductance variations are minimized.

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