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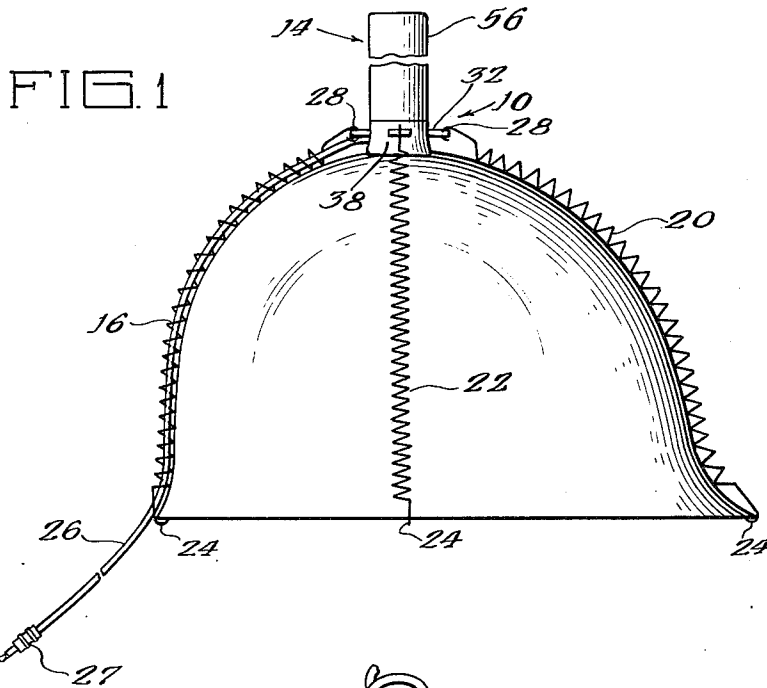
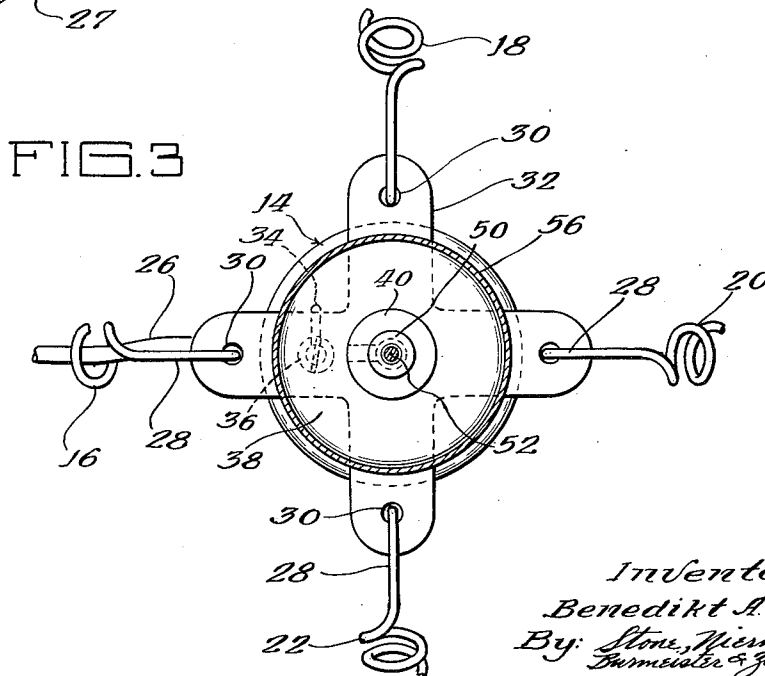
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3,199,108

VERTICAL-RADIATOR ANTENNA

Filed March 25, 1963

2 Sheets-Sheet 1



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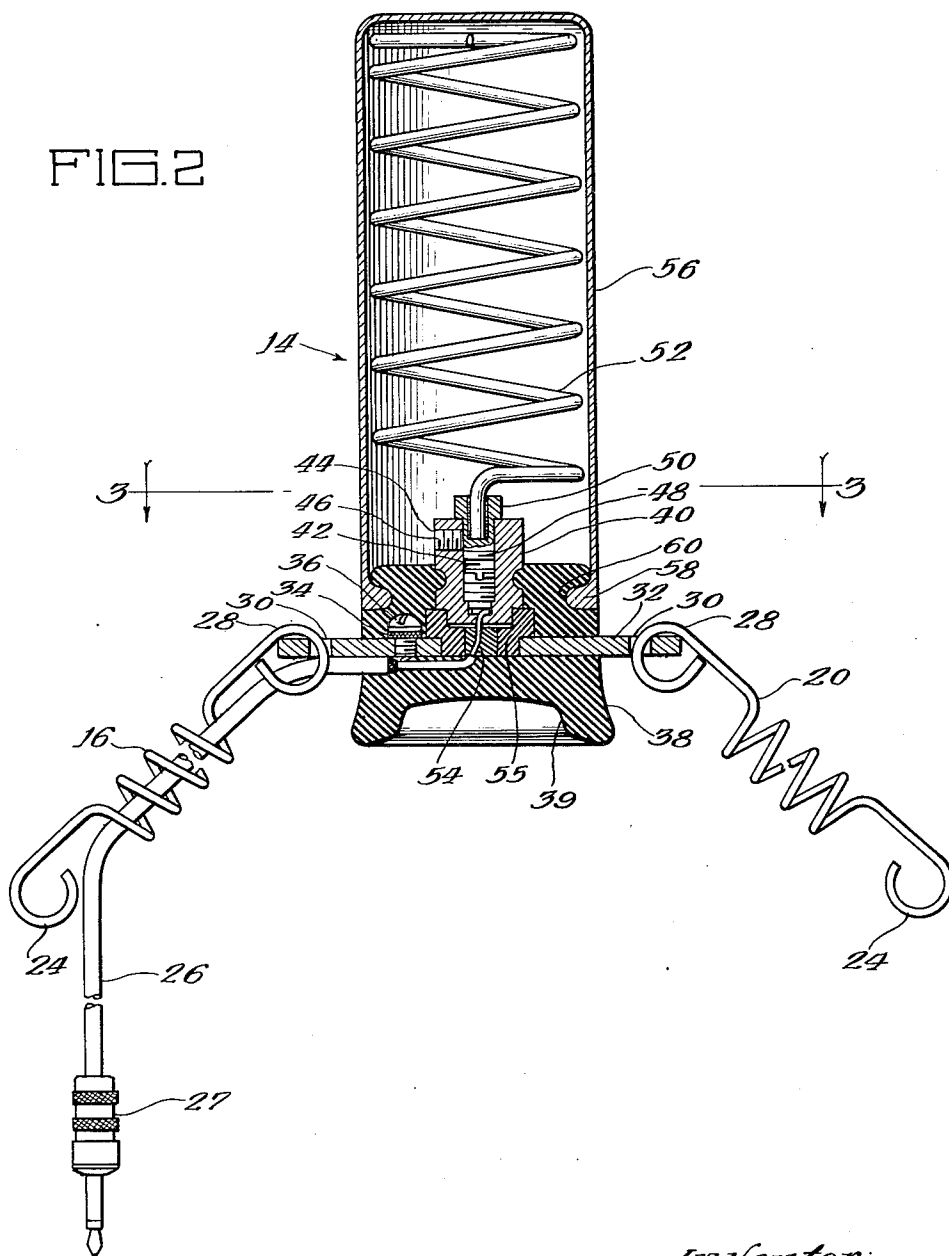
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2 Sheets-Sheet 2

FIG. 2



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VERTICAL-RADIATOR ANTENNA

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10 Claims. (Cl. 343-718)

This invention relates to antennas, and more specifically to vertical-radiator antennas employing a counterpoise or artificial ground-plane at the base of an elevated vertical radiator. The invention in its narrower aspects provides a novel form of mobile antenna for use with portable equipment such as communications transceivers carried on the person of the user, the antenna herein described being installed on a helmet or similar headpiece which is worn by the user. However, certain aspects of the invention, as will be seen, are readily adaptable to a variety of the other uses.

Prior to the present invention, various attempts had been made to develop antennas suitable for use with "personal" radio transmitters. However, although such prior devices have appeared in laboratory measurements to be capable of satisfactory results, the radiation patterns obtained in actual use are found to be unsatisfactory. Upon analysis, it is found that the poor patterns obtained with such designs may be due primarily to the substantial conductivity of the human body, along with such factors as the effects of other metallic objects, such as the transmission line used for feeding the antenna. Upon analysis, it is found that the problem of producing the desirable pattern of circular symmetry in the horizontal direction is generally analogous to that encountered in producing such a pattern, with high gain in the horizontal direction, in the presence of a conducting vertical mast support, and other conducting bodies, in the case of a fixed-station installation for similar purposes. By the analogy thus found, it may be seen that great improvement in the radiation pattern of a vertical radiator carried on the person may be obtained by placing a vertical antenna atop the head of the wearer, and isolating the body of the wearer from the vertical radiator by the employment of a ground-plane or counterpoise formed by suitable radial ground rods extending from the base of the radiator. Such mounting is particularly suitable for use in field communications, in industrial uses in building-construction, oil and gas pipeline work, and a myriad of similar uses, including military uses, wherein plastic helmets are normally worn in any event, thus making the head-mounting of the antenna a mere minor addition as regards convenience and burden on the user.

By the present invention, there is provided an antenna of the type described which may readily be "snapped on" to any existing helmet structure of this type. The ground rods forming the counterpoise are of the general type described in the copending application of Marvel W. Scheldorf, Serial Number 861,610, filed December 23, 1959, i.e., they are helically coiled conductors extending downwardly and outwardly from the base of the vertical radiator. In the present construction, however, the coiled conductors are formed from a springy material such as stainless steel, and are provided at their outer ends with attachment means such as hooks engaging the rim of the helmet, the ground rod springs thus formed being free for tension expansion and flexing and serving the additional function of springs by means of which the entire antenna assembly is clipped to a plastic helmet.

As disclosed in the copending application mentioned above, the coiled ground rods are desirably of a length slightly greater than a quarter wavelength at the frequency of operation of the radiator element with which they are employed, an electrical length of from 0.35 to 0.5 wavelength being found to be highly effective for the present

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purpose of isolation of the "mast" (in this case the human body). The design of the coiled springs for production of the appropriate electrical length may readily be done for any particular frequency by the principles of design long known in connection with the design of helical radiators. The broad "tuning" or optimum length range (as compared with the criticality of the length of the radiator portion of such a ground-plane antenna), coupled with the relation between the dimensional changes which occur on extension of a coiled spring and the electrical length design parameters just mentioned, make such a structure of any given design usable both with a substantial frequency range of tuned radiators and with a substantial variety of helmet sizes and shapes, without change of the ground rod construction. Change of the physical length of the helical ground rod by changing the distance of the point of attachment of the outer end, and thus altering the degree of extension of the spring, is found to produce two opposite effects on the electrical length. The simultaneous occurrence of the alteration of the pitch of the helix and its physical length produces, at any given frequency, effects on the electrical length which are more or less self-cancelling, thus producing an electrical length change which is relatively small over a substantial range of physical length changes. Accordingly, the size and style of any particular plastic helmet upon which the ground-plane antenna is to be installed is a relatively unimportant factor, so that the antenna of the invention may be used as a general utility device for a large variety of applications, the design of the spring ground-rod being readily selected for the maintenance of the desired electrical length over a substantial range of physical lengths (extended lengths of the spring).

In fixed-station installations of the general type of antenna here used, the feed is normally through a coaxial cable which extends vertically downward from the base of the radiator (whether on the axis of a conducting support pole or otherwise), thus being isolated from the radiator by the ground-plane. In the present application, such a construction would require either that the coaxial feed extend within the plastic headpiece, or else that the ground rods be spaced from the outer surface of the headpiece in order to permit the coaxial feed to be in the region wherein it is beneath the more or less conical ground-plane or counterpoise. In the present construction, this difficulty is avoided by bringing the coaxial feed to the radiator and the inner ends of the ground rods through the interior of one of the ground rods. It is found that the shielding of the outer conductor of the feed from the radiator is thus made highly sufficient to prevent impairment of the pattern by re-radiation from the outer conductor, etc., thus minimizing the pattern distortion and producing the horizontal gain characteristic and omnidirectional radiation which is desired. By locating the ground-rod or spring through which the feed is brought at the back of the headpiece, the coaxial feed-line is not only made inconspicuous, but also produces a minimum of inconvenience to the user.

It will be observed that a number of the features of construction used in the antenna of the invention, which is designed for use with "personal" communications equipment, may be readily adapted to other uses of the type of vertical-radiator antenna generally known as the "ground-plane antenna." For example, the combination function of mechanical mounting and electrical counterpoise-formation of the coiled springs used for mounting the radiator by holding them in extension at their outer ends may be applied to semi-mobile fixed stations requiring fast installation and knock-down. Likewise, the simple operations involved in installation can advantageously be employed even in installations of a permanent type, as in the case of ground-plane antennas for amateur use. The

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formation of the ground rods by the springs held in extension makes it unnecessary to provide any rigid structure such as the plastic encapsulation heretofore normally associated with ground rods in the form of helical coils.

The nature and advantages of the invention in their broader aspects will be readily understood from what has already been stated. However, further details of the invention, together with their purpose and function, will be seen from the description of the embodiment of the invention illustrated in the attached drawing, in which:

FIGURE 1 is a view in elevation of an antenna-bearing helmet made in accordance with the invention;

FIGURE 2 is a view in side elevation, partially in vertical section, of the antenna which is shown in FIGURE 1 as installed on a helmet; and

FIGURE 3 is a plan sectional view of the antenna taken along the line 3—3 of FIGURE 2.

Referring now to the drawing, FIGURE 1 shows the antenna, generally designated by the numeral 10, as installed on a plastic helmet 12. Extending vertically upward from the crown of the helmet is a vertical radiator assembly generally designated by the numeral 14. Ground-rod springs 16, 18, 20 and 22, each terminating in a hook portion 24 at the outer end, extend outwardly and downwardly from the base of the radiator assembly 14, being hooked to the rim or lower edge of the helmet. A coaxial cable 26 extends up through the spring or ground-rod 16 which is located at the back of the helmet, a coaxial connector 27 on the end of the cable serving the usual function of connection of the antenna to the transmitter or transceiver (not shown) carried on the person of the wearer of the helmet.

Details of the antenna assembly are best seen in FIGURES 2 and 3. The inner ends of the springs 16, 18, 20 and 22 are formed with permanently fastened hooks 28 engaging apertures 30 in a cross-shaped ground plate 32. The coaxial cable, which extends through the spring 16 (but which of course does not short the turns of the spring because of the presence of the usual insulating jacket over the outer conductor of the cable) terminates at its inner end in appropriate connections of the inner and outer conductors to the radiator element and the ground-plane respectively. The end 34 of the braided outer conductor or sheath of the cable 26 is slitted and twisted in a manner normal for forming the "ground lead" at the end of such a cable, and mechanically and electrically connected to the ground plate 32 by a screw 36. The inner end of the cable is seated in a suitable well in a molded insulating base 38 formed with an inverted cup-shaped bottom 39 adapted to seat securely, when held by the springs, on the more or less spherical contour of the helmet. The upper end of the insulating base 38 has a conducting radiator support insert 40, provided with a threaded axial well. A radial bore 44 threadedly receives a set screw 46 which locks a connector 48 threaded into the well or bore 42 and provided with a stop head 50. The lower end of a helical radiator 52 is permanently attached to the connector 48, which serves as its support.

The end of the inner conductor 54 of the cable 26 is suitably mechanically and electrically connected to the insert 40 at the bottom of the bore or well 42, the central portion of which is apertured to pass the end of the cable into the interior of the insert. Plastic assembly inserts 55, employed for fixing the relative position of the parts, including the ground plate 32, in the molding of the base 38, are shown in the drawing for purposes of completeness.

In order to prevent hazard due to power lines and similar conditions encountered in use, in addition to reducing the likelihood of deformation of the helical radiator, a cover 56 is fitted over the radiator and is provided with an internal lip 58 at the bottom for snap-on engagement in a groove 60 provided for this purpose at the upper end of the base 38.

As will be seen, the hooks 24 at the outer ends of

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the springs are formed to provide simple hook-on attachment of the antenna assembly to a helmet or similar head covering. Typically, the dimensions of helmets used in industrial fieldwork, as well as in military work, require an extended spring length (from the region of the crown to the rim) of the order of from 9 to 13 inches. Using a suitable resilient stainless steel, an overall length of spring of approximately $7\frac{1}{2}$ inches with apertures 30 in the ground plate about 2 inches apart, provides a structure usable with most industrial and military headwear. The number of helical turns, and the length of the end portions terminating in the hooks 24 and 28, and the diameter and pitch of the helical portion, depend of course upon the frequency of operation of the radiating element. The latter is designed in accordance with the well-known principles of design of helical radiating elements. The design of the helical portion of the ground rods accords generally with the same principles, but exact calculation is not easily made because of the curvature produced by the conformity to the surface of the helmet, the effective electrical length of this curved configuration being somewhat shorter than would be the case with a straight structure of the same helical configuration. However, the use of ordinary design parameters applicable to helical radiating elements gives sufficiently close approximation to permit easy experimental determination for any given frequency, the factors mentioned above then permitting the use of the same ground-rod construction with a fairly substantial variety of radiating elements in the same general frequency range without substantial impairment of results.

As an example of the utilization of the illustrated construction, replaceable helical radiators 52, varied in design to produce operating frequencies from approximately 145 to 175 megacycles, were found to produce satisfactory results without changing of ground rods. The structure may be used at frequencies somewhat lower than this, but the system is of course limited to use at fairly high frequencies (normally 100 megacycles or more) by the dimensional limitations which fix a practical lower limit of frequency at which such an antenna may be used on a headpiece. Of course, the same principles may be applied at lower frequencies in other utilizations of the invention. It is of course possible to use the invention at substantially higher frequencies than those mentioned by elongating the uncoiled ends of the ground rods and reducing the helical portion to a relatively short length just sufficient to produce adequate spring force. However, it will be observed that this structure somewhat reduces the overall general utility by reason of the limits thus imposed on the range of helmet or headpiece sizes or configurations accommodated. For extremely high frequencies, of course, the structure may be modified in such a manner that the ground-rods do not extend all the way to the rim of the headpiece. However, in general, the invention as applied to employment with headpieces is best utilized in the region from about 100 megacycles to about 250 megacycles.

It will be observed that the relative stability of electrical length of a helical conductor under varying conditions of elongation, for the reasons described above, may also be applied in certain instances of advantage to helical radiators as well. For example, a helical radiator, suitably designed for the purpose, may be mounted under tension between supports at its ends which may be selected for merely approximate spacing, without greatly changing its resonant frequency as the degree of extension is altered in successive installations. Furthermore, where extremely precise tuning to a frequency is required, such a radiator may be very finely adjusted in frequency by fairly coarse adjustment of the physical length, the variation in resonant frequency with change of length being much smaller than in the case of, for example, a telescoping straight radiator, where resonant frequency is proportional to length. It will of course be understood

that the helical conductor must be of a material of much better spring characteristics than the copper or aluminum normally employed in the active elements of antennas, whether radiators or ground rods, a yield strength substantially greater than 25,000 pounds per square inch generally being required for production of adequate spring tension, and stainless steels of high conductivity being particularly desirable.

Many other applications of the invention, in addition to those already mentioned, will readily be made. Although the embodiment herein described is of particular advantage, persons skilled in the art will readily adapt the invention to structures far different in appearance, but nevertheless utilizing, when closely scrutinized, the basic teachings of the invention. Accordingly, the scope of the invention should not be limited to any particular embodiments herein illustrated or described, but should extend to all structures as described in the appended claims, and equivalents thereof.

What is claimed is:

1. A ground-plane antenna comprising a vertical radiator and a ground-plane structure comprising:

- (a) a ground conductor secured to the base of the radiator,
- (b) a plurality of helically coiled spring conductors having their inner ends secured to the ground conductor and their outer ends insulatedly secured in fixed relative positions outward of the radiator and held in expanded tension,
- (c) said spring conductors extending from the ground conductor in generally opposite directions,
- (d) the base of the radiator being horizontally positioned substantially solely by the tension of the spring conductors,
- (e) the spring conductors being of an electrical length slightly in excess of a quarter wavelength at the operating frequency of the radiator.

2. A helmet antenna comprising:

- (a) a vertical radiator, and
- (b) a ground-plane structure at the base of the radiator comprising a plurality of helically coiled spring members free for tension expansion and extending in an at least partially radial direction from the base of the radiator,
- (c) the spring members having attachment means on the ends thereof adapted for securing said ends to the lower edge of a helmet and being of electrical length slightly in excess of a quarter wavelength at the operating frequency of the radiator.

3. A ground-plane antenna comprising:

- (a) a vertical radiator,
- (b) helically coiled ground rods extending downwardly and outwardly from the base of the radiator,
- (c) insulating means for supporting the ground rods on a conducting body over which they may be placed, and
- (d) a coaxial transmission line extending through one of said ground rods within the helical coil and having the inner ends of its inner and outer conductors respectively connected to the radiator and the ground rods.

4. An antenna-bearing headcovering comprising:

- (a) an insulating headpiece adapted to fit the human head and having an exterior contour generally conforming thereto,

(b) a vertical radiator at the crown of the headpiece, and

(c) helically coiled spring members forming a counterpoise for the radiator and extending substantially from the crown to the rim of the headpiece and conforming to the contour of the headpiece,

(d) the spring members bearing attachment means on their outer ends engaging the rim and being thereby held in tension to position the radiator at the crown.

5. The antenna-bearing headpiece of claim 4 having:

(e) a coaxial transmission line extending along the interior of one of the spring members for connection of the antenna.

6. A ground-plane antenna comprising:

- (a) a vertical radiator,
- (b) an insulating support member at the base of the radiator bearing a ground conductor insulated from the radiator, and
- (c) a plurality of helically coiled springs free for tension expansion having their inner ends secured to the ground conductor and having attachment means on their outer ends adapted for securing the antenna in position with the springs in tension, the springs being of electrical length slightly greater than a quarter wavelength at the operating frequency of the radiator.

7. The antenna of claim 6 having a coaxial transmission line extending through one of the springs.

8. An antenna assembly for use with transmitting equipment carried on the person comprising:

- (a) an insulating headpiece adapted to be worn on the head of the user and generally conforming to the shape thereof,
- (b) a vertical helically coiled radiator extending from the crown of the headpiece, and
- (c) coiled ground conductors extending outwardly and downwardly from the base of the radiator along the surface of the headpiece and forming a counterpoise for the radiator to isolate the body of the user from the radiator,
- (d) the ground conductors being resilient springs extending along the exterior surface of the headpiece and secured thereto at the lower edge.

9. The antenna assembly of claim 8, wherein:

(e) such securing of the outer ends of the ground conductors constitutes the sole attachment of the radiator and counterpoise assembly to the headpiece.

10. The antenna assembly of claim 8 having:

(e) a coaxial feed line extending through one of the coiled conductors.

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HERMAN KARL SAALBACH, *Primary Examiner*.