Dec. 27, 1960 E. F. HARRIS 2,966,679

UNLOADED HELICAL ANTENNA

Filed Nov. 13, 1957

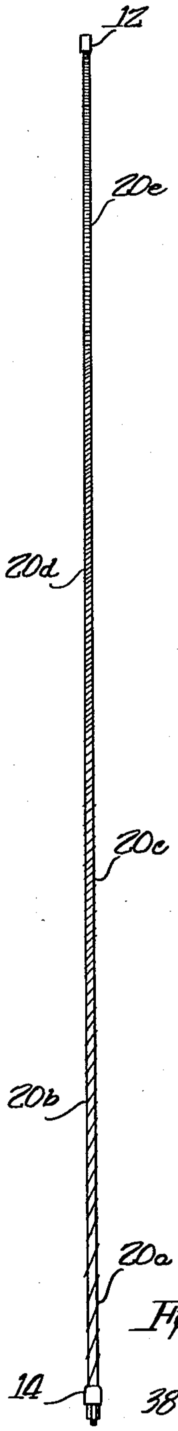

Fig.1

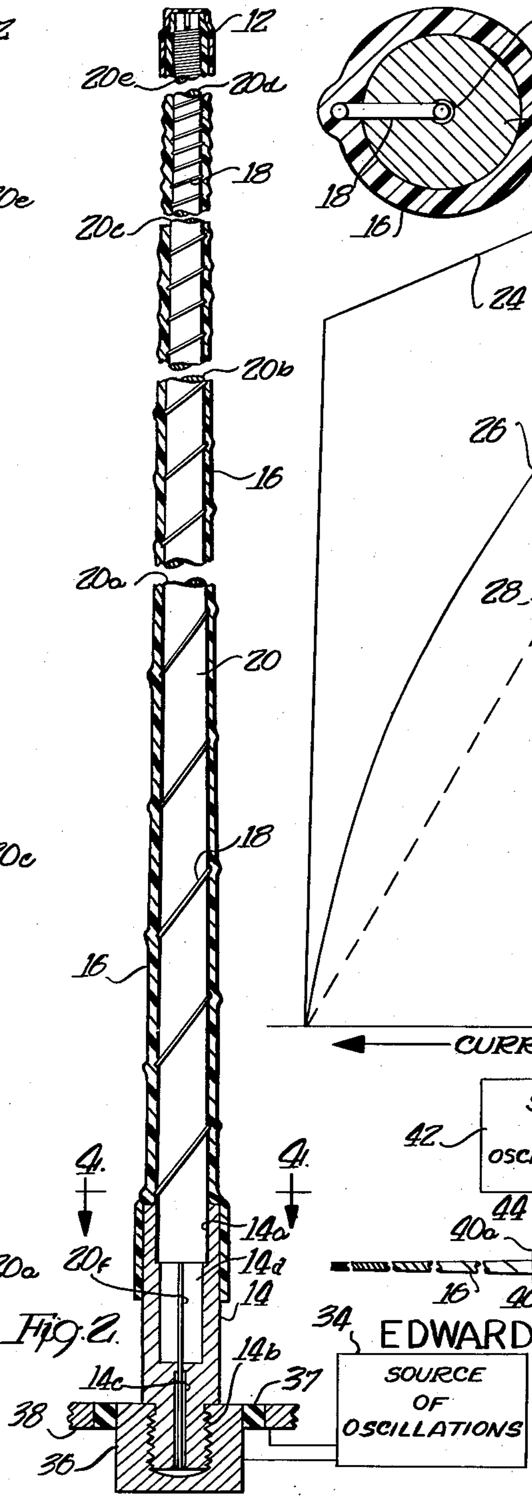

Fig.2

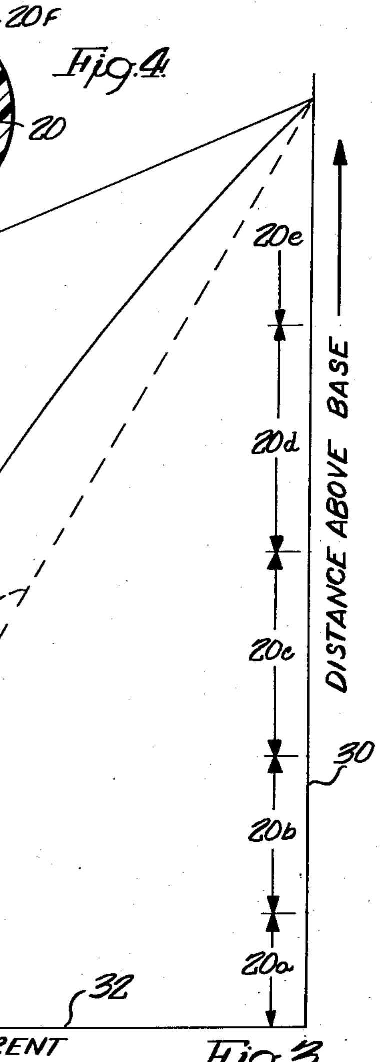

Fig.4

Fig.3

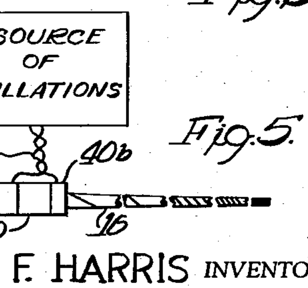

Fig.5

EDWARD F. HARRIS INVENTOR.

BY George E. Frost

ATTORNEYS

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UNLOADED HELICAL ANTENNA

Edward F. Harris, 4729 Farwell, Lincolnwood, Ill.

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2 Claims. (Cl. 343—895)

My invention relates to an improved helical antenna having small length in relation to the wave length of the radiated energy and characterized by a highly favorable current distribution and radiation resistance without the use of massive loading elements on the antenna structure.

In vehicles, boats, and other applications it is desirable to provide an efficient radiator or antenna of as small length in relation to the wavelength of the radiated signals as is possible. Moreover, for maximum utility such antennas should be free of loading coils, loading capacitors or other massive physical elements that must be supported during vehicle movement and under conditions of wind, icing, and the like. Also aesthetic considerations favor an antenna of the so-called "whip" type consisting of a single upstanding rod having its sleek appearance unmarred by other elements.

Efficient electrical performance in a short antenna demands operation in resonant fashion and with a maximum radiation resistance value. Resonant action at a shortened axial length can be achieved by the use of a helical construction, the antenna conductor being in the form of a wire wound helically about a straight or slightly tapered nonconducting core or rod at uniform pitch. Such arrangement is shown in my copending patent application, Whip Antenna and Process of Fabricating Same, Serial No. 687,286, filed September 30, 1957, now Patent No. 2,938,210. However, when such antenna is made with a very small axial length in relation to the wavelength, the radiation resistance falls to a low value. For example, such an antenna of one tenth wavelength axial physical length theoretically would have a radiation resistance of about six ohms. This resistance is small as compared to the inevitable contact resistance, conductor resistance, and the resistance equivalent of other energy loss producing elements, so that the efficiency of such antenna is relatively low. When the antenna is made even shorter the radiation resistance falls to smaller values. Additionally, the low radiation resistance imposes a troublesome impedance matching problem with respect to the common transmission line impedance values, which are of the order of 50 ohms and more, In addition, the generally sinusoidal current distribution on an antenna or radiator of this type gives rise to low radiating efficiency.

In accordance with the present invention a helical antenna is provided with a varying pitch providing a nearly uniform current amplitude from the base to a point near the top. The current amplitude then rapidly drops to zero at the tip. It has been found that by so constructing the antenna the radiation resistance value is considerably more favorable than that of a simple helical antenna, and the efficiency of radiation is greatly enhanced over that associated with an equivalent helix of constant pitch. Moreover, this antenna—because of its short length—can be placed on a vehicle, such as a car, in a more favorable radiating position than a conventional

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"whip" antenna (even though loaded), achieving a maximum efficiency of operation.

It is therefore a general object of the present invention to provide an improved, short, unloaded whip type helical antenna.

A more specific object of the present invention is to provide an antenna of the above type which is characterized by a relatively large radiation resistance in relation to other unloaded antennas of equivalent length.

Still another object of the present invention is to provide a short helical antenna of the "whip" type having improved electrical characteristics.

Another object of the present invention is to provide an improved helical antenna wherein variations in pitch serve to provide improved radiation resistance and other performance despite the short axial length in relation to the resonant wavelength.

Yet another object of the present invention is to provide a helical antenna in which variation in pitch serves to provide improved electrical characteristics.

Still another object of the present invention is to provide an improved unloaded helical antenna in which the current sharply increases in value from the free end to reach a substantially uniform value that is effective for the major proportion of the length.

It is another object of the present invention to provide an improved short helical whip antenna or antenna element having features of construction, combination, and arrangement rendering it easily and inexpensively manufactured, readily installed on a vehicle for effective operation, efficient and reliable in operation even under adverse conditions, readily adjusted to accommodate varying frequencies, of attractive appearance, and of maximum commercial utility.

It is yet another object of the present invention to provide a resonant helical antenna element suitable for use as an individual element, as part of a dipole, as part of a directional array, or for other purposes in which variations of pitch serve to provide improved radiation resistance and other performance despite the short axial length in relation to the resonant wavelength.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention, itself, together with further objects and advantages thereof, will best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

Figure 1 is an elevational view of a helical whip antenna constructed in accordance with the present invention;

Figure 2 is an enlarged, fragmentary, elevational cross-sectional view of the antenna of Figure 1, with portions broken away to shorten the overall length;

Figure 3 is a graph showing the current distribution along the length of various types of antennas; and

Figure 4 is a view through section 4—4 of Figure 1;

Figure 5 is a somewhat schematic view of a multi-element array incorporating the radiator of the present invention.

In the antenna of Figures 1 and 2, the conducting wire 18 is wound about flexible core 20. A ferrule or base member 14 is connected to the base end of the core, as described hereafter. A protective insulating covering 16 envelopes both the conducting wire 18 and the core 20, and a cap 12 is telescoped over the free end of the core, as shown.

The base end of the wire 18 extends radially inwardly through the core 20 and downwardly through the axial hole 20*f* of the core and axial hole 14*c* of the ferrule, as shown in Figures 2 and 4. Connection is made to a source of radio frequency oscillations indicated at 34. The latter source is also connected as shown to the conducting support socket **36**. This socket is insulatingly supported on the vehicle (or other support) by insulating washer **37** or by other suitable means which is in turn supported by the body **38** of the vehicle or by other appropriate support. The source of oscillations **34** is connected as shown to the conducting socket **36** and to the body **38**, the latter acting to define a ground plane with respect to which the antenna radiates.

The other end of wire **18** is received in slot **22** as the free end of core **20**. The conducting wire **18** and flexible core **20** are preferably fabricated with a protective covering in the same manner as that described in my co-pending application Whip Antenna and Process of Fabricating Same, Serial No. 687,286, filed September 30, 1957.

Core **20** is made of resilient material capable of holding an erect shape when supported at one end and which is light weight and dielectric. Any resilient core with these characteristics may be used, but preferably the core is of a plastic impregnated glass composition, such as is commonly used in fishing rods, and may, for example, be made of molded glass fibers mechanically bound with a polyester resin. The diameter of core **20** progressively decreases from the base end (received in ferrule **14**) to the free end topped with cap **12**, although this is not necessary to the practice of the present invention.

Ferrule or base member **14** is tightly received on the base end of core **20**. The exposed outer face of the ferrule is of hexagonal conformation. The ferrule has a cylindrical bore **14*a*** in one end into which core **20** is cemented. The ferrule has an extending threaded stub **14*b*** at its base end to be threadedly received in socket **36** and establish a conducting connection therewith. The socket **36** may, for example, be the top or engine hood of a car. Because the structure of the present invention permits the efficient use of a relatively short antenna, some latitude in the choice of the mounting location is permitted and the antenna may be mounted on a flat conducting surface such as the engine hood or the body which defines an effective ground plane from which radiation takes place. Passage **14*c*** extends through stud part **14*b*** of ferrule **14** and connects to a hollowed center portion **14*d*** of the ferrule. Conducting wire **18** extends radially upwardly, passes through the end of core **20**, and is received in the ferrule to extend into the passage **14*c*** where it is soldered to ferrule **14**.

Wire **18** is wound helically along the core **20**. The wire is wound in a series of segments **20*a***, **20*b***, **20*c***, **20*d*** and **20*e***, each having turns of like pitch or spacing. The top segment **20*c*** has the turns wound against each other to provide minimum pitch. As shown, the turns in segments **20*d***, **20*c***, **20*b***, and **20*a*** each have greater pitch than those of the preceding segment. The purpose and effect of the variation in pitch is described in detail hereafter.

The antenna specifically shown in Figures 1 and 2 is intended for use in the 15 meter (20 megacycle) range. In this antenna the conductor **18** is of #20 A.W.G. enameled copper wire. The antenna totals 47.5 inches in axial core length. With the form shown, the total length of the conductor **18** is about 398 inches, and the respective conductor lengths in the portions **20*a*** to **20*e***, inclusive, are 9, 10, 13, 14 and 353 inches. The effect of this distribution is to provide a current distribution along the axial length of the antenna of approximately the form shown at curve **24**, Figure 3, where axis **30** represents distance from the base and axis **32** represents current amplitude. It will be noted that the current increases from zero value at the antenna tip to almost maximum value at the lower end of section **20*e***. Below this point, the current has a substantially constant value.

The current distribution of curve **24**, Figure 3, should

be compared with that of curve **26**, Figure 3, for a uniformly wound helix, and curve **28**, Figure 3, for a base loaded antenna. Curve **26** is in the form of a sine wave, with continuously decreasing value as the top of the antenna is approached. The curve **28** is essentially a straight line decreasing current curve due to the near straight line conformation of the first portions of a sine curve and the fact that the base loading coil accounts for the remainder of the standing current wave.

It has been found that the nearly rectangular current distribution curve of curve **24**, Figure 3, provides highly desirable antenna characteristics. In the first place, essentially the entire length of the antenna operates at high current density and hence a relatively high radiated energy. This same high radiated energy is reflected in an increased radiation resistance, which means that the efficiency and the amount of the radiation is increased. Alternatively, if a predetermined radiation efficiency is desired, an antenna such as that of Figures 1 and 2 and having the current distribution of curve **24** may be made shorter than an antenna having the current distribution of curve **26** or **28**.

Computations indicate that for a given axial antenna length that is short in relation to a quarter wavelength, the antenna of Figures 1 and 2 has about twice the radiation resistance of a helix of like length and a uniform pitch (curve **26**), and more than three times the radiation resistance of a short base loaded antenna of like length (curve **29**).

In use, the antenna should be trimmed to a length providing resonant action at the driven frequency. This can be readily accomplished by removing cap **12**, and cutting the length of the antenna until the reactive impedance cancels out at that frequency. The use of a matching network (not shown) between the source of oscillations (or antenna energizing cable) and the antenna provides some adjustment for error in actual length and for matching the actual complex antenna impedance to the cable or source termination.

One of the advantageous features of the antenna lies in the short axial length that may be used. One of the problems in mounting vertical antennas on automobiles is that of avoiding excessive vertical height. With such conventional antennas it is often necessary to mount them on the vehicle bumper. This is highly undesirable because no efficient and uniform ground plane is defined, the vehicle body often parallels the lower part of the antenna, and such field as is developed is highly distorted. The antenna of the present invention—because of the short length possible—may more readily be mounted on the metallic roof or engine hood where a relatively good ground plane is established, radiation is directionally uniform, and the vehicle body does not parallel the antenna in any substantial respect.

Another advantage of the antenna of the present invention is that it requires no elevated loading coil or capacitor. This is highly important because such elements are necessarily massive, are unslightly, and impose troublesome tuning and support problems.

In a practical antenna constructed in accordance with the present invention for use on an automobile in the 15 meter amateur band, the following dimensions were used:

Core—plastic impregnated rod of glass fiber, 48″ long ⅜″ diameter at base tapering to 0.275″ at tip.

Conductor—#20 A.W.G. enameled copper wire.

Segment **202**—11.5 inches long, 26 turns per inch, 299 turns, total wire length 353 inches, wires wound for minimum pitch.

Segment **20*d***—11.5 inches long, ⅛ inch pitch, total wire length 13.7 inches.

Segment **20*c***—10.5 inches long, ¼ inch pitch, total wire length 12.7 inches.

Segment **20*b***—8 inches long, ½ inch pitch, total wire length 10.2 inches

Segment **20a**—6 inches long, 1 inch pitch, total wire length 9.11 inches.

Total axial length of winding on core—47.5 inches.

Jacket **16**—vinyl tubing dilated, to slip over antenna and dilator thereafter permitted to evaporate.

Ferrule or base **14**—approximately 2 inches long.

In the design of antennas pursuant to the present invention, the current value should be made to increase as rapidly as possible from the tip end down, and below the top segment, the conductor should be wound to provide a practically constant current value. This means that the pitch at the top of the antenna should be as small as the diameter of the conductor (and insulation) permits, and that this portion should continue until at least half of the total wire, and preferably substantially more than half of the wire, is used along a comparatively short axial length, preferably less than a quarter of the antenna length. Below this closely wound section, the pitch should increase progressively and substantially, so that a configuration similar to that of Figures 1 and 2 is obtained. In theory a uniformly increasing pitch from turn to turn is desirable. For production reasons, however, it is desirable to wind the conductor in a series of adjacent segments, each having a constant pitch. Preferably these should be of progressively shorter length as the base end of the antenna is approached and the pitch of each such segment should be about twice that of the preceding segment as the base is approached.

While the above description relates to a unit where the helical element radiates in relation to a ground plane, the element may also be applied to various kinds of multi-element antennas. It may, for example, be used in a dipole construction, such as is shown in Figure 5. Here, an insulating support **40** has a pair of conducting end members **40a** and **40b**, each of which is threaded to receive stud **14b**, Figures 1 and 2, to define a dipole with two elements of the type shown in Figures 1 and 2. The dipole is energized from source **42** through the transmission line **44**. This construction is especially useful for a horizontal antenna structure, particularly in a directional unit mounted on a rotatable structure.

The antenna element of the present invention may be used for reception as well as transmission, in which case a receiver is connected in the same manner as the oscillation sources **34** and **42**. The term radiant energy apparatus is used in the appended claims and denotes both transmitting and receiving apparatus.

While I have shown and described specific embodiments of the present invention, it will, of course, be understood that other modifications and alternative construction may be used without departing from the true spirit and scope of this invention. I therefore intended by the appended claims to cover all such modifications and alternative constructions as fall within their true spirit and scope.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A normal mode resonant antenna characterized by relatively high radiation resistance in relation to axial length and resonant frequency and suitable for radiating action in relation to a plane of uniform potential, said antenna comprising in combination: a lengthy insulating whip-like support means extending in direction normal to said plane with one end substantially in said plane and the other end remote therefrom, the support means extending in its lengthy direction substantially less than a quarter wavelength at said frequency and having its largest cross-sectional dimension less than one-fiftieth wavelength at said frequency and a uniform low resistance conductor wound helically about said support means in a series of at least four axially spaced segments each having a uniform pitch, the turns of the segment adjacent said other end of the support means incorporating at least a major proportion of the total length of the conductor in not more than the quarter of the length of the support means adjacent said other end, the remaining segments having progressively shorter axial lengths as the end of the supporting means adjacent said plane is approached, the pitch of the segment adjacent said first mentioned segment being substantially greater than the pitch of said first mentioned segment, and each successive segment as said first end of the supporting means is approached having substantially greater pitch than the preceding segment, the total number of turns on the helix being such as to provide resonant quarter wave action in normal mode at said frequency, and the total length of the conductor being approximately one-fourth wave at said frequency.

2. A normal mode resonant antenna characterized by relatively high radiation resistance in relation to axial length and resonant frequency and suitable for radiating action in relation to a plane of uniform potential; said antenna comprising in combination: a lengthy insulating whip-like support means extending in direction normal to said plane with one end substantially in said plane and the other end remote therefrom, the support means extending in its lengthy direction substantially less than a quarter wavelength at said frequency and having its largest cross-sectional dimension less than one-fiftieth wavelength at said frequency; and a uniform low constant resistance conductor wound helically about said support means with progressively decreased pitch as said other end of the support means is approached, the length of the conductor wound about the quarter of the support means adjacent said other end constituting at least 80 percent of the total length of the conductor, said conductor being resonant in normal mode at said frequency and of total length approximately one-fourth wave at said frequency.

References Cited in the file of this patent

UNITED STATES PATENTS

2,681,412	Webster	June 15, 1954
2,682,608	Johnson	June 29, 1954
2,712,602	Hallen	July 5, 1955
2,850,732	Kandoian et al.	Sept. 2, 1958
2,875,443	Kandoian	Feb. 24, 1959

FOREIGN PATENTS

810,325	France	Dec. 28, 1936

OTHER REFERENCES

"Antennas," by J. D. Krause, copyright 1950, pp. 213 to 216.