This invention relates to an antenna system and more particularly to a tuned antenna system utilizing a helical antenna.

In many applications, practical considerations require that the length of antenna associated with a radio transmitter be very small when compared to the desired operating wave length. Such conditions often arise in mobile radio system applications where the usual type of antenna utilized is a whip antenna. If the whip antenna is extremely small in length when compared to the emitted wave length its radiation resistance is quite small and it presents a very high capacitive reactance with a certain amount of loss to the antenna feed system, thereby limiting the proportion of power radiated by the antenna.

Another disadvantage of the usual whip antenna system is that due to the high reactance, a very high voltage is developed across the base insulator of the antenna system thus limiting the input power. Quite often the power losses in the base insulator of a whip antenna far exceed the radiated power.

In the past such vertical rod or whip antennas have been tuned by adding in series an inductive reactance such as a coil equal to the net capacitive reactance of the antenna system, including the base insulator, in order to bring the antenna system into a condition of resonance. By tapping the inductive reactance at predetermined locations and/or properly coupling the transmitter to the added inductance, power is fed to the antenna. Such a system radiates substantially the power output of the coupling device less losses due to the base insulator and the tuning coil.

One of the objects of this invention, therefore, is to provide an antenna system which has substantially no losses due to a base insulator or a separate tuning coil when the antenna's over-all height is small compared to the desired operating wave length.

Another object of this invention is to provide an antenna system which substantially eliminates any high voltage point at the base of the antenna.

A further object of this invention is to provide an antenna whose input reactance and over-all length will be small while its radiation resistance will be comparatively high.

In accordance with one feature of this invention the reduction or elimination of the input capacitive reactance of an antenna having a small over-all length compared to its wave length is achieved by the utilization of a resonant helical coil, a portion of a resonant helical coil, as the radiating antenna, thereby distributing the tuning coil without increasing the over-all height of the antenna.

Another feature of this invention is the novel coupling and tuning apparatus which are utilized in combination with a helical antenna in order to achieve a maximum tuning range of the antenna.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic diagram of the embodiment of a tuned antenna system having a helical element directly coupled to a transmitter; and

Figs. 2, 3, and 4 are schematic diagrams of alternate embodiments of a tuned antenna system and coupling arrangements in accordance with the principles of this invention.

Referring to Fig. 1, a schematic diagram of a tuned antenna system is shown comprising a supporting structure 1 and a conductive element 2. The supporting structure 1 comprises a plurality of vertical rods 3, 4, 5, and 6 composed of a dielectric material such as fiberglass wood, or polyurethane, or, alternatively, the supporting structure may be a dielectric cylinder, either solid or tubing. Conductive element 2 is wound in the shape of a helical radiator inside the area encompassed by the vertical rods 3, 4, 5, and 6 and is supported by the structure 1. The inner conductor 8 and an outer conductor 9, couples energy from a transmitter to the antenna system. The inner conductor 8 makes contact with the radiating structure 2 by means of a movable arm 10 and spring fingers 10a. The movable arm 10 is slidably mounted inside the inner conductor 8 by means of a telescoping joint 11. The outer conductor 9 is grounded to the base of the helix. The helical antenna may be tuned to any frequency above its natural resonant frequency by simply shortening its wire length. This may be easily done by shorting out turns above the coaxial line tap point. A shorting or tuning adjustment 12a has one end coupled to end 12 of the helix while the other end of adjustment 12a makes contact with the helix at point 12b thus shorting out all turns between 12 and point 12b. In order to tune the helical antenna over a wide range of frequencies, point 12b may be varied. The shorting adjustment 12a may be located anywhere along the helix and is not necessarily coupled to one end of the helix.

A helical antenna, having a height considerably less than a wave length, radiating predominantly vertical polarization in the normal mode, that is the peak of radiation pattern is normal to the helix axis, has been found to have several advantages over a conventional dipole when the antenna height must be considerably less than a quarter wave length. The radiation resistance of a helical radiating element is about 50% greater than a conventional dipole of same height and the input impedance can be made real and equal to the surge impedance of the coaxial feed line, so that the problem of matching to a transmission line is simplified.

It is well-known that when a vertical rod antenna is used and its over-all height is small compared to the transmitted wave length its radiation resistance is small and its input reactance is very high. The input impedance is given approximately by the formula:

\[ Z_{in} = \frac{400}{\lambda} \left( \frac{h^2}{2\pi} \right) \cot \left( \frac{2\pi}{\lambda} \right) \]  

wherein "Zin" equals the input impedance, "h" is the height of antenna, "r" is its characteristic impedance and \( \lambda \) is the operating wave length.

For example, a typical 35-foot vertical rod antenna has an input impedance of approximately 04-j5000 when operating at 300 kc. Thus, in order to radiate one watt approximately five amperes of antenna current is necessary, and this in turn, due to the high reactance, develops 25,000 volts R. M. S. at the base of the antenna resulting in a greater loss in the base insulator than is radiated by the antenna. If a coil having an inductive reactance of 5000 ohms (or whatever the net capacitance reactance is, taking the base insulator into account) is added, the an-
tenna may be thereby brought to resonance. By tapping the coil at the correct point or properly coupling to it, power may be fed into the antenna, but again the power actually radiated is less than the power available because of the losses in the base insulator and the tuning coil. Referring again to Fig. 1, if a helical coil 2 is constructed having a height of 35 feet so as to resonate at 300 kc. with its base grounded. This eliminates the base insulator and accompanying losses. By varying the position of movable arm 10 the antenna may be tuned to resonate at frequencies other than 300 kc. by having successive portions of the helical coil shunted for frequencies higher than 300 kc., thus enabling this antenna to be used over a relatively wide range of frequencies. By utilizing the antenna system of this invention, a high voltage point built up at the floating end 12 of the antenna and a low voltage point appears at the base portion of the antenna. The over-all height of the antenna is small when compared to the operating wave length.

The input impedance into a resonant helix, whether radiating or in a non-radiating circuit, is essentially a pure resistance given approximately by:

\[ R_{in} = Z_0 \theta \sin^2 \theta \]

(2)

where

- \( Z_0 \) = characteristic impedance of the helix;
- \( Q \) = loaded Q of the helix; and
- \( \theta \) = electrical length in degrees from the grounded end of the helix.

The effective height of a short dipole above a perfect ground plane is equal to one-half the actual height while the effective height of a resonant helical antenna is equal to twice the actual height divided by \( \pi \) due to the fact that the current distribution is sinusoidal rather than linear as in a dipole.

The radiation resistance of a short dipole is equal to

\[ \left( \frac{20h}{\lambda} \right)^2 \]

(3)

where \( h \) is the height of the antenna above ground. The radiation resistance of a resonant helical antenna is equal to

\[ \left( \frac{25.5h^2}{\lambda} \right)^2 \]

(4)

but for heights substantially equal to a quarter wavelength the factor of 25.5 in Equation 4 should be changed to 24 so the ohms resistance is obtained for a height equal to a quarter wave length.

Referring to Fig. 2, an alternate embodiment of the antenna system of this invention is shown wherein a conductive element 13 is wound in the form of a helix. No dielectric supporting structure is necessary if the conductive element 13 is of sufficient mechanical strength to be self-supporting or, alternatively, the supporting structure may be a dielectric cylinder, either solid or tubular. A coaxial cable 16 having an inner conductor 17 and outer conductor 18 couples energy from a transmitter 19 to a conductive element 13 by means of a direct coupling tap 20 connecting the inner conductor 17 to element 13. By means of sliding joint 15 the tuning adjustment 14 may be positioned along length of the helix 13 in such a manner that the effective length of helix radiating energy is made equal to one-quarter the wavelength. By coupling from a transmitter 19 in accordance with Formula 2. Tuning adjustment 14 shortens the bottom of the conductive element 13 that is all turns between the ground and adjustment 14 to the inner conductor 17 of the coaxial cable 16 in order to shorten and make ineffective the portion of the conductive element 13 between adjustment contact 14 and movable contact 20. The outer conductor 18 is grounded in the usual manner. Thus the effective portion of the helix can be made resonant at the frequency of the energy coupled from transmitter 19 through tap 20. Through use of movable adjustment contact 14 the antenna system of this invention may be made resonant over a relatively wide band of frequencies.

Referring to Fig. 3, an alternate embodiment of the antenna system of this invention is shown utilizing inductive coupling wherein the radiating element 23 is constructed in a manner similar to the radiating element shown in Fig. 1. The coaxial cable 24 coupling energy from transmitter 25 has its inner conductor 26 terminated in a sliding joint 24a which is electrically connected to an arm 27 terminated in an inductive coupling coil 28 connected between the outer conductor 25a and the inner conductor 26 of cable 24, which is coaxial to and inside the radiating element 23. The point of coupling between tuning contact 27a and the helix may be adjusted so that effective length of helix can be made resonant with the frequency to be transmitted.

Referring to Fig. 4, an alternate embodiment of the antenna system of this invention is shown wherein the supporting structure 29 is surrounded by the radiating element 30. Coupling is accomplished by utilizing a coupling tap 31 connected to the helix structure 30 and connected to inner conductor 32 of coaxial cable 33 through the use of movable joint 34. As in the other embodiments of this invention, the effective radiating length of the helix may be varied so that the effective length of the radiating element is substantially equal to one-quarter of the wave length at the radiating frequency and the point of coupling may be adjusted so that the helical structure may be made to resonate over a wide band of frequencies. This is accomplished by projecting a variable portion of the helix above the ground plane. While I have described above the principles of my invention in connection with specific apparatus and examples, it is to be clearly understood that this description is by way of example only and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. A radio antenna system comprising a conductive element disposed in the form of a helical radiator, a source of radio frequency energy, means to couple said radio frequency energy directly to predetermined turns of said helical radiator, means to vary the position of said coupling means to vary the turns of said radiator to which said direct coupling occurs, and means to shorten the effective electrical length of said radiator to render said helical radiator resonant at said radio frequency to radiate said energy normal to the axis of said helix.

2. A radio antenna system comprising a conductive element disposed in the form of a helical radiator having a diameter a fraction of a wavelength of the energy to be radiated, means to couple energy at a predetermined frequency directly to predetermined turns of said helical radiator, means to adjust said coupling means to vary the turns of said helical radiator to which said direct coupling occurs, and means to shorten the effective electrical length of said radiator to render said helical radiator resonant at said predetermined frequency.

3. A radio antenna system comprising a conductive element disposed in the form of a helical radiator having a diameter a fraction of a wavelength of the energy to be radiated, a source of radio frequency energy, means to couple energy from said source at a predetermined frequency within a relatively broad frequency range directly to predetermined turns of said helical radiator, said coupling means including a coaxial transmission line coupled to said source of energy and having its outer conductor grounded, a coupling element coupled to the inner conductor of said line and to a portion of said helical radiator, means to adjust said coupling element to vary the turns of said helical radiator to which said direct coupling occurs, and means to shorten the effective electrical length of said radiator to render said heli-
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5. A radio antenna system comprising a dielectric supporting structure, a conductive element wound in the form of a helix around said supporting structure, a source of radio frequency energy, means to couple energy at a predetermined frequency from said source directly to said helical radiator, said helix having a diameter a fraction of a wavelength at said predetermined frequency, means to adjust said coupling means to vary the turns to which said direct coupling occurs, and means to shorten the effective electrical length of said radiator to cause a portion of said helical radiator to resonate at said predetermined frequency.

6. A system according to claim 5 wherein said means to couple energy from said transmitter to said helical radiator further includes a coil in inductive coupling relation with selected turns of said helical radiator.

7. A system according to claim 6 wherein said coil is coaxial with said helical radiator.

8. A radio antenna system comprising a dielectric supporting structure, a conductive element disposed in the form of a helix inside said supporting structure, a source of radio frequency energy, a coaxial transmission line having an outer conductor grounded and an inner conductor with one end thereof coupled to said source, means to cause the second end of said inner conductor to couple energy from said source directly to a portion of said helix to radiate said energy normal to the axis of said helix, variable means coupling said outer conductor to said helix to short out a selectable portion of said helix, and means to move said inner conductor to vary the portion to which said direct coupling occurs.

References Cited in the file of this patent

UNITED STATES PATENTS
1,517,570 Manborgne Dec. 2, 1924
1,575,824 Eiffert Mar. 9, 1926
1,684,009 Brown Sept. 11, 1928
1,933,941 Taylor Nov. 7, 1933
2,119,692 Voigl June 7, 1938
2,158,271 Buschbeck May 16, 1939
2,503,010 Tiley Apr. 4, 1950
2,781,514 Sichak et al. Feb. 12, 1957

FOREIGN PATENTS
391,077 Great Britain Apr. 20, 1933

OTHER REFERENCES