United States Patent

Felsenheld

[15] **3,689,928**

[45] **Sept. 5, 1972**

[54] **MULTI-BAND TUNABLE HALFWAVE WHIP ANTENNA**

[72] Inventor: **Robert A. Felsenheld,** Livingston, N.J.

[73] Assignee: **International Telephone and Telegraph Corporation,** Nutley, N.J.

[22] Filed: **Dec. 30, 1970**

[21] Appl. No.: **102,724**

[52] **U.S. Cl.** **343/703,** 343/745, 343/749, 343/752

[51] **Int. Cl.** **H01q 9/00**

[58] **Field of Search**......343/749, 750, 752, 858, 895, 343/703, 745

[56] **References Cited**

UNITED STATES PATENTS

2,875,443	2/1959	Kandoian 343/752
2,993,204	7/1961	Macalpine.................343/752
3,100,893	8/1963	Brueckmann 343/792

Primary Examiner—Eli Lieberman
Attorney—C. Cornell Remsen, Jr., Walter J. Baum, Paul W. Hemminger, Charles L. Johnson, Jr., Philip M. Bolton, Isidore Togut, Edward Goldberg and Menotti J. Lombardi, Jr.

[57] ABSTRACT

A physically shortened halfwave antenna of the whip type is disclosed. The antenna includes a main antenna rod, a pair of helices, one helix coupled to each end of the rod, and a capacitive top load coupled to the upper one of the helices. An RF terminal is inductively coupled to the lower one of the helices to supply RF energy to or remove RF energy from the antenna. A variable capacitance means is coupled between the lower helix and a capacitive bottom load, which may be ground, a small ground plane or an equivalent arrangement, to resonate the antenna. A plurality of lower helices and an associated variable capacitance means for each are selectively connected to the rod to enable the antenna to cover a relatively broadband frequency range. In one embodiment an inductive coupling to the lower helix is accomplished by a single tuned arrangement for the lower frequency band of the frequency range and by a doubled tuned arrangement for the middle and upper frequency band of the frequency range. Other embodiments may include all single tuned arrangements, all double tuned arrangements or a different combination of single and double tuned arrangements than that used for said one embodiment. A directional coupler and capacitance control arrangement are provided to adjust the capacitance of the variable capacitance means for reresonating the antenna when the resonance of the antenna is changed by an object coming into the proximity of the antenna.

17 Claims, 6 Drawing Figures

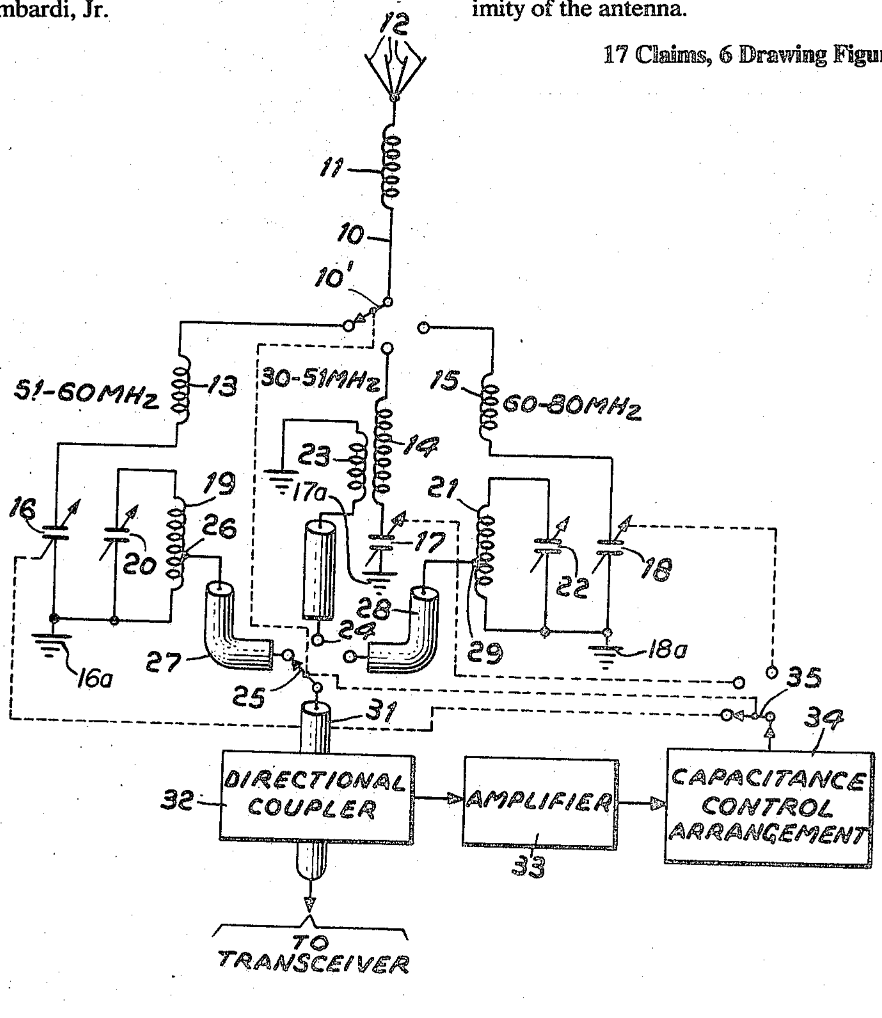


Fig. 1
(PRIOR ART)

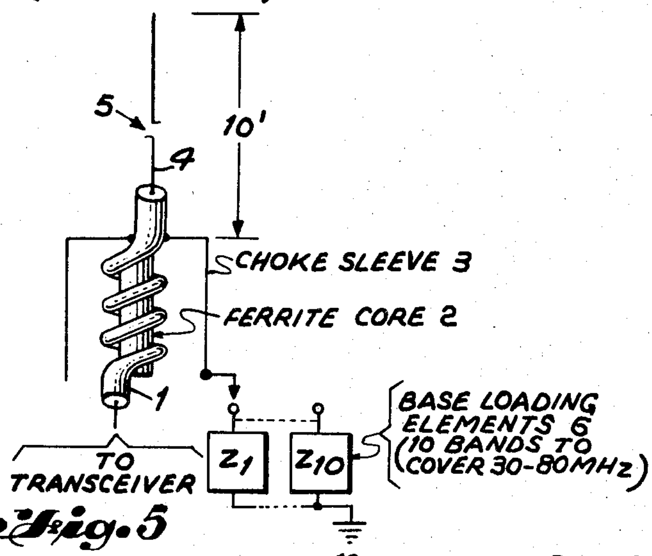


Fig. 2
(PRIOR ART)

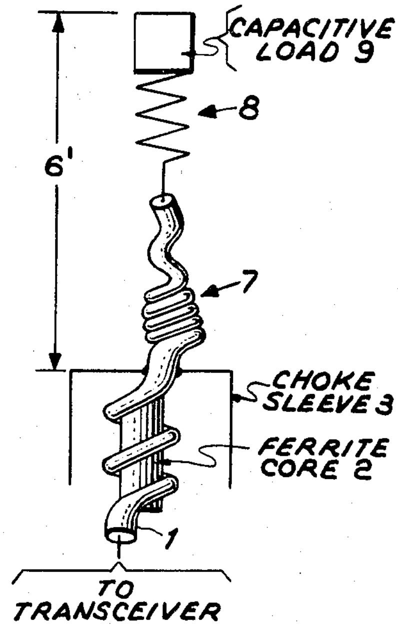


Fig. 5

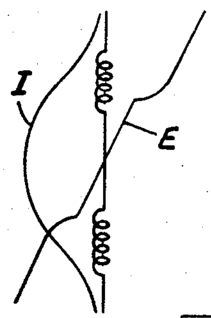


Fig. 3

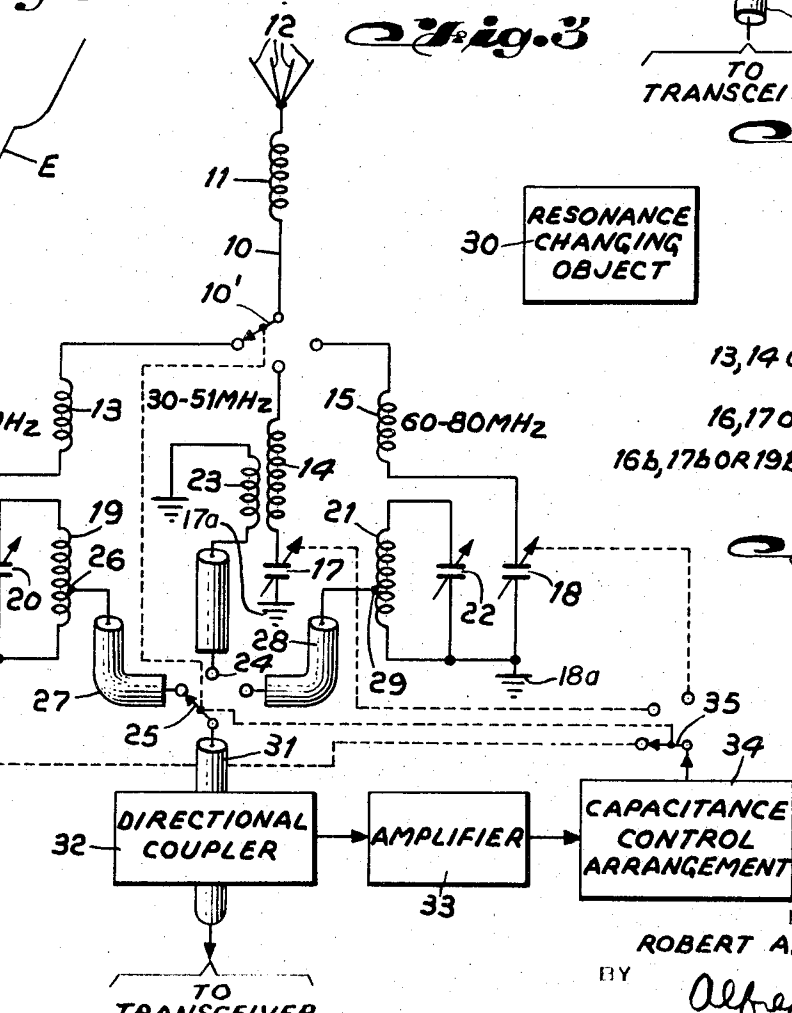


Fig. 4A

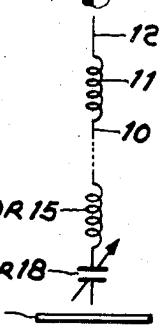
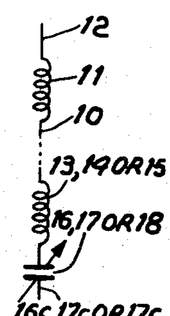


Fig. 4B



INVENTOR
ROBERT A. FELSENHELD
BY Alfred C. Hill
AGENT

MULTI-BAND TUNABLE HALFWAVE WHIP ANTENNA

BACKGROUND OF THE INVENTION

This invention relates to antennas and more particularly to antennas of the whip type for mounting on motor vehicles, ships, tanks, humans and the like.

Whip type antennas for motor vehicles and humans are known in the prior art that will cover a relatively broadband of frequencies, for instance, 30 to 80 megahertz (MHz). One such antenna is termed a center fed antenna. The center feed arrangement is provided by coupling radio frequency (RF) energy to a coaxial line which has the center conductor thereof broken in the middle of vertical length of the antenna. A physically shortened version of this type of antenna is also known wherein the coaxial line has helical configuration before reaching the middle of the vertical length of the antenna and having the center conductor in a helical configuration above the middle point of the antenna. In both of these versions of the center fed type antenna, the minimum current occurrs at the ends of the antenna and a high impedance transformer section is provided including the input coaxial formed into a helix about a ferrite core.

These prior art antennas have been employed in the past to cover the approximate frequency range of 30 to 80 (MHz) by employing in conjunction therewith loading elements to cover 10 bands within this frequency ranged. These loading elements are coupled to the RF choke that is necessarily provided with the antenna in an attempt to reduce the radio frequency currents flowing on the motor vehicle carrying the transceiver with the antenna attached thereto.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved shortened halfwave antenna of the whip type which is ground insensitive.

Another object of the present invention is to provide in conjunction with the antenna of this invention an arrangement to reresonate the antenna when the capacity of the system is increased by objects coming into close proximity to the antenna.

Still another object of the present invention is to provide an energy coupling arrangement as part of the antenna which may be made broadband and thereby cover relatively broadband of frequencies.

Still another object of the present invention is to provide, by relatively simple components as compared to the impedance transformer section of the above mentioned prior art, a high impedance end fed antenna.

A feature of the present invention is the provision of a physically shortened halfwave antenna of the whip type comprising a main antenna rod having an upper and lower end; a first helix having one end connected to the upper end of the rod; a capacitive top load connected to the other end of the helix; a second helix having one end connected to the lower end of the rod; first means coupled to the other end of the second helix to resonate the antenna; and second means inductively coupled to the second helix to feed radio frequency to and remove radio frequency energy from the antenna.

Another feature of the present invention is a physically shortened halfwave antenna of the whip type as described hereinabove which further include a third means coupled between the second means and the first means, the third means responding to reflected power due to the resonance of the antenna being altered by an object that comes into the proximity of the antenna to reresonate the antenna.

Still a further feature of the present invention is the provision of a physically shortened halfwave antenna of the whip type which includes a plurality of the second helices; a plurality of the first means each coupled between an end of a different one of the plurality of the second helix and a capacitive bottom end load; first switch means to selectively couple the other end of each of the plurality of the second helix to the lower end of the rod; a plurality of the second means each inductively coupled to an associated one of the plurality second helix; a radio frequency terminal; and second switch means ganged to the first switch means to selectively couple each of the plurality of the second means to the terminal; the plurality of the second helix, the plurality of the first means and the plurality of the second means cooperating to resonate the antenna over a given broad frequency range, each of the plurality of the second helix, the first means and the second means covering a different given adjacent frequency band within the given broad frequency range.

BRIEF DESCRIPTION OF THE DRAWING

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 drawing, in which:

FIG. 1 is a schematic diagram of one form of the prior art antenna mentioned hereinabove under the heading "Background of the Invention;"

FIG. 2 is a physically shortened version of the antenna of FIG. 1;

FIG. 3 is a schematic diagram of an antenna system in accordance with the principles of the present invention capable of covering a relatively broadband frequency range in three different frequency bands;

FIGS. 4A and 4B illustrate schematically two alternatives for the capacitive bottom load that may be employed in the antenna system of FIG. 3; and

FIG. 5 illustrates the current and voltage distribution on the antenna of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is illustrated diagrammatically one of the center fed prior art antenna mentioned under the heading "Background of the Invention." This antenna includes a coaxial line 1 coupled to the transceiver which is configured to be helical in nature about a ferrite core 2 to form the necessary high impedance transformer to obtain the desired radiation characteristics. An RF choke sleeve 3 is coupled to the outer conductor of coaxial line 1 with the coaxial line 1 extending a given distance above sleeve 3. The center conductor 4 of coaxial line 1 is broken in the middle of its vertical height as shown at 5. This break 5 is the center feed point for the upper and lower portion of the antenna. The minimum voltage point is at the break 5 in the center conductor and the maximum current is at this location while the minimum current is at the ends of the antenna.

The antenna of FIG. **1** can be resonated over a relatively narrow frequency band as compared to the antenna of the present invention by each of a number of different base loading elements **6** which are coupled between ground and sleeve **3**. Selectively coupling ten appropriately selected elements **6** to shield **3** would enable the antenna to cover in 10 bands the frequency range of 30 to 80 MHz.

FIG. **2** illustrates diagrammatically the antenna of FIG. **1** in a physically shortened version. The coaxial line **1** has a helical configuration about a ferrite choke **2** to provide the high impedance transformer with an RF choke sleeve **3** being coupled to the outer conductor of coaxial line **1** substantially as illustrated in FIG. **1**. The coaxial line **1** is then configured in a tight helix **7** and will extend to the middle of the vertical height of the antenna. The center conductor of coaxial line **1** would then be extended by itself and formed into a helix **8**, the top of which has coupled thereto a capacitive load **9**.

Referring to FIG. **3**, there is illustrated diagrammatically an antenna in accordance with the principles of the present invention. The antenna of the present invention includes a main rod **10** having one end thereof coupled to a helix **11** and a capacitive top load in the form of one or more conductive elements **12**, such as wires or rods. The other end of rod **10** is coupled to one of the second helices **13**, **14** and **15** through switch means **10'**. Helix **13** is coupled to a variable capacitance means **16** which may be in the form of a physical capacitor, a varactor or a PIN diodes and capacitor arrangement. Capacitance means **16** has its other terminal connected to a capacitive bottom load, one form of which is ground **16*a*** as illustrated. Other illustrative forms of the capacitive bottom end load are illustrated in FIGS. **4A** and **4B**. FIG. **4A** illustrates a capacitive bottom end load formed by a small ground plane **16*b*** spaced from the lower terminal of capacitance means **16**. FIG. **4B** illustrates a capacitive bottom end load formed by a conductive element **16*c***, such as a wire or rod, directly connected to the lower terminal of capacitance means **16**. Secondhelix **14** has one end thereof connected to one terminal of variable capacitance means **17** which also may be in the form of a physical capacitor, a varactor or a PIN diodes and capacitor arrangement. The other terminal of capacitance means **17** is coupled to a capacitive bottom load as illustrated by **17*a***, FIG. **3**, **17*b***, FIG. **4A** and **17*c***, FIG. **4B**. Second helix **15** has one end coupled to one terminal of variable capacitance means **18**. The other terminal of means **18** is coupled to a capacitive bottom load as illustrated by **18*a***, FIG. **3**, **18*b***, FIG. **4A** and **18*c***, FIG. **4B**. Capacitance means **18** also may be in the form of a physical capacitor, a varactor or a PIN diodes and capacitor arrangement.

The purpose of capacitors **16**, **17** and **18** is to resonate the antenna in its particular band of frequencies. In one embodiment of the present antenna system, capacitance means **16** resonates the antenna system for the frequency band 51–60 MHz, capacitance means **18** resonates the antenna system for the frequency band 60–80 MHz, a capacitance means **17**, by varying the value thereof, can resonate the antenna of the present invention through the frequency band 30–51 MHz.

In accordance with one version of the antenna, the antenna system may be energized with radio frequency energy from the transceiver or radio frequency energy can be removed from the antenna for application to the transceiver by a parallel tuned circuit including an inductor **19** and a variable capacitor **20**. The combination of inductor **19**, helix **13**, capacitor **20** and capacitance means **16** forms a doubled tuned circuit which will provide both resonance and impedance matching over the frequency range 51–60 MHz. A similar arrangement is provided in conjunction with the second helix **15** wherein the inductor **21** and the variable capacitor **22** form a parallel tuned circuit which in combination with the helix **15** and the variable capacitance means **18** provides a double tuned circuit for resonating and providing an impedance match for the antenna system over the frequency range 60–80 MHz. Energy is coupled to and removed from the second helix **14** by means of a winding or inductor **23** having one end thereof connected to ground and the other end thereof connected to a terminal **24** associated with switch **25** which is ganged with switch **10'** so that the appropriate components will be provided for the frequency band being considered in the broadband frequency range. An appropriate impedance point **26** along inductor **19** has coupled thereto the inner conductor of a coaxial line **27** coupled to switch means **25**. Similarly the center conductor of coaxial line **28** is coupled to an impedance point **29** along inductor **21**. The impedance points **26** and **29** are selected to have an impedance to match the impedance of the associated coaxial line, such as 50 ohms if the coaxial line is a 50 ohm coaxial line.

The above described double tuned arrangements provides antenna impedance match and antenna resonance over a relatively wide frequency band as compared to the above mentioned prior art arrangements and the single tuned arrangement of the present invention. Also the single tuned arrangement provides antenna impedance match and antenna resonance over a frequency band that is wider than the above mentioned prior art arrangements.

As is apparent from FIG. **5** the voltage is maximum at the ends of the antenna of FIG. **3**, while the current is maximum in the center of the antenna of FIG. **3** and the current is minimum at the ends of this antenna. Thus, there is an elimination or at least a substantial reduction in RF currents that may flow on the surface of the motor vehicle or in the body of the human carrying the transceiver and associated antenna. Thus, the feeding arrangement as illustrated and described with respect to FIG. **3** renders the antenna ground insensitive and, therefore, changes in configuration of the ground over which the motor vehicle travels, or the dielectric constant of the human body will not upset the desired characteristics of the antenna.

As is customary in all mobile and portable antennas, an object **30** such as a building, a tree, a mountain, a bridge or underpass coming into close proximity to the antenna will cause an increase capacitance in the antenna system and, hence, a detuning or a change of the resonance of the antenna. This is undesirable since the antenna characteristics are changed by the proximity of the object **30**. It is proposed in accordance with the present invention to couple the coaxial line **31** extending from switch means **25** to a directional coupler **32** such that when the resonance of the antenna is changed by object **30** a reflected standing wave is produced on coaxial line **31** which will be recovered by coupler **32** for application to amplifier **33**. The capacitance control arrangement **34** will respond to the magnitude of the reflected power, as represented by the reflected standing wave on coaxial **31**, to produce that amount of control voltage that is necessary to decrease the capacitance of capacitors **16**, **17** or **18**, depending upon the frequency band in operation, so as to reresonate the antenna system and thereby compensate for the resonance changing effect of object **30**. Arrangement **34** may be strictly mechanical to control a variable capacitor, it may be electro-mechanical to also control a variable capacitor or it may be completely electrical to control the capacitance of a varactor or a PIN diodes and capacitor arrangement.

For purposes of illustration switch **35** is provided which is ganged with switch means **10'** and **25** so that the control signal is coupled only to the one of the capacitive means **16**, **17** and **18** which have been selected by switch means **10'** and **25**. Better reliability, however, would be obtained if switch **35** were eliminated and the control output of arrangement **34** was coupled to all capacitance means **16**, **17** and **18** simultaneously. Reresonance would only be accomplished by that one of the capacitance means **16**, **17** and **18** coupled to the antenna by switches **10'** and **25**.

The antenna system of FIG. **3** has been reduced to practice in three forms, a five foot version for vehicle use and a four foot and one foot version for portable use by a human. These reductions to practice have a performance that exceeds the performance of the above-mentioned prior art arrangement.

The antenna system of the present invention will enable the achievement of a high impedance end coupled antenna by substituting the simple double tuned or single tuned arrangements of the present invention for the high impedance transformer of the above mentioned prior art of FIGS. **1** and **2** formed by coaxial line **1** having a helical configuration about ferrite core **2**.

In addition, the antenna system of the present invention covers the same frequency range as the above mentioned prior art antenna system using a fewer number of switched elements, or a greater frequency range can be covered by the antenna system of the present invention with the same number of switched elements as the above mentioned prior art antenna system.

The antenna system of FIG. **3** should not be considered as the only arrangement capable of covering a given frequency range in steps of a number of adjacent frequency bands. The given frequency range can be covered by a plurality of adjacent frequency bands greater or less in number than three and the energy coupling arrangements may be either all double tuned arrangements, all single tuned arrangements or a different combination of single and double tuned arrangements than that shown in FIG. 3.

While I have described above the principles of my invention in connection with specific apparatus it is to be more clearly understood that this description is made only by way of example 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 physically shortened halfwave antenna of the whip type comprising:
- a main antenna rod having an upper and lower end;
- a first helix having one end connected to the upper end of said rod;
- a capacitive top load connected to the other end of said first helix;
- a second helix having one end connected to the lower of said rod;
- first means coupled to the other end of said second helix to resonate said antenna; and
- second means inductively coupled to said second helix to feed radio frequency energy to and remove radio frequency energy from said antenna.

2. An antenna according to claim **1**, wherein said top load includes
at least one conductive element.

3. An antenna according to claim **1**, wherein said first means includes
- a capacitive bottom load, and
- a capacitance means coupled in series between the other end of said second helix and said bottom load.

4. An antenna according to claim **1**, wherein said second means includes
- a capacitive bottom load,
- a radio frequency terminal,
- an inductor having one end coupled to said bottom load and the other end coupled to said radio frequency terminal.

5. An antenna according to claim **1**, wherein said second means includes
- a capacitive bottom load,
- an inductor having one end coupled to said bottom load,
- a capacitance means coupled in parallel with said inductor, and
- a radio frequency terminal connected to a selected impedance point along said inductor.

6. An antenna according to claim **1**, wherein said first means includes
- a capacitive bottom load, and
- a variable capacitance means coupled in series between the other end of said second helix and said bottom load; and

said second means includes
- a radio frequency terminal,
- an inductor having one end coupled to said bottom load and the other end coupled to said radio frequency terminal;

said variable capacitance means, said second helix and said inductor providing a single tuned circuit to resonate said antenna and to provide a narrow band impedance match to said antenna;

the adjustment of said variable capacitance means enabling an impedance match and resonance of said antenna over a given frequency range.

7. An antenna according to claim **1**, wherein said first means includes
- a capacitive bottom load,and
- a first variable capacitance means coupled in series between the other end of said second helix and said bottom load; and

said second means includes
- an inductor having one end coupled to said bottom load;

a second variable capacitance means coupled in parallel with said inductor, and
a radio frequency terminal connected to a selected impedance point along said inductor;
said first and second variable capacitance means, said second helix and said inductor providing a double tuned circuit to resonate said antenna and to provide a broadband impedance match to said antenna.

8. An antenna according to claim 1, further including third means coupled between said second means and said first means, said third means responding to reflected power, due to an object altering the resonance of said antenna, to automatically control said first means and reresonate said antenna.

9. An antenna according to claim 8, wherein
said first means includes
a capacitive bottom load, and
a first variable capacitance means coupled in series between the other end of said second helix and said bottom load; and
said third means includes
a directional coupler coupled to said second means, and
a capacitance control means coupled to said directional coupler and said first variable capacitance means, said control means responding to said reflected power to alter the capacitance of said first variable capacitance means to reresonate said antenna.

10. An antenna according to claim 9, wherein
said second means includes
an inductor having one end coupled to said bottom load and the other end coupled to said directional coupler;
said first variable capacitance means, said second helix and said inductor providing a single tuned circuit to resonate said antenna and to provide a narrow band impedance match to said antenna;
the control of said first variable capacitance means enabling an impedance match and resonance of said antenna over a given frequency range.

11. An antenna according to claim 9, wherein
said second means includes
an inductor having one end coupled to said bottom load,
a second variable capacitance means coupled in parallel to said inductor; and
means to couple said directional coupler to a selected impedance point along said inductor;
said first and second variable capacitance means, said second helix and said inductor providing a double tuned circuit to resonate said antenna and to provide a broadband impedance match to said antenna.

12. An antenna according to claim 1, further including
a capacitive bottom load;
three of said second helix;
three of said first means each coupled between an end of a different one of said three of said second helix and said bottom load;
first switch means to selectively couple the other end of each of said three of said second helix to the lower end of said rod;
three of said second means each inductively coupled to an associated one of said three second helix;
a radio frequency terminal; and
second switch means ganged to said first switch means to selectively couple each of said three of said second means to said terminal;
said three of said second helix, said three of said first means and three of said second means cooperating to resonate said antenna over a given broad frequency range, each of said three of said second helix, said first means and said second means covering a different given adjacent frequency bands within said given broad frequency range.

13. An antenna according to claim 12, wherein
each of said three of said first means includes a first variable capacitance means;
one of said three of said second means includes a first inductor having one end coupled to said bottom load and the other end coupled to said second switch means;
said first inductor, the associated one of said first variable capacitance means and the associated one of said second helix providing a single tuned circuit, an adjustment of said associated one of said first variable capacitance means enabling the resonance of said antenna and an impedance match to said antenna over the lower one of said frequency bands; and
each of the other two of said three of said second means includes
a second inductor having one end coupled to said bottom load,
a second variable capacitance means coupled in parallel to said second inductor; and
means to couple said second switch means to a selected impedance point along said second inductor;
each of the associated one of said first variable capacitance means, each of said second variable capacitance means, the associated one of said second helix and each of said second inductor providing a double tuned circuit to resonate said antenna and to provide a broadband impedance match to said antenna over the associated one of the middle one and higher one of said frequency bands.

14. An antenna according to claim 1, further including
a capacitive bottom load;
a plurality of said second helix;
a plurality of said first means each coupled between and end of a different one of said plurality of said second helix and said bottom load;
first switch means to selectively couple the other end of each of said plurality of said second helix to the lower end of said rod;
a plurality of said second means each inductively coupled to an associated one of said plurality of second helix;
a radio frequency terminal; and
second switch means ganged to said first switch means to selectively couple each of said plurality of said second means to said terminal;
said plurality of said second helix, said plurality of said first means and plurality of said second means cooperating to resonate said antenna over a given broad frequency range, each of said plurality of said second helix, said first means and said second

means covering a different given adjacent frequency band within said given broad frequency range.

15. An antenna according to claim **14**, wherein
each of said plurality of said first means includes a first variable capacitance means;
certain ones of said plurality of said second means includes a first inductor having one end coupled to said bottom load and the other end coupled to said second switch means;
said first inductor, the associated one of said first variable capacitance means and the associated one of said second helix providing a single tuned circuit, an adjustment of said associated one of said first variable capacitance means enabling the resonance of said antenna and an impedance match to said antenna over certain ones of said frequency bands; and
others of said plurality of said second means includes
a second inductor having one end coupled to said bottom load,
a second variable capacitance means coupled in parallel to said second inductor; and
means to couple said second switch means to a selected impedance point along said second inductor;
each of the associated one of said first variable capacitance means, each of said second variable capacitance means, the associated one of said second helix and each of said second inductor providing a double tuned circuit to resonate said antenna and to provide a broadband impedance match to said antenna over others of said frequency bands.

16. An antenna according to claim **14**, wherein
each of said plurality of said first means includes a first variable capacitance means;
each of said plurality of said second means includes a first inductor having one end coupled to said bottom load and the other end coupled to said second switch means;
said first inductor, the associated one of said first variable capacitance means and the associated one of said second helix providing a single tuned circuit, an adjustment of said associated one of said first variable capacitance means enabling the resonance of said antenna and an impedance match to said antenna over each of said frequency bands.

17. An antenna according to claim **14**, wherein
each of said plurality of said first means includes a first variable capacitance means;
each of said plurality of said second means includes
an inductor having one end coupled to said bottom load,
a second variable capacitance means coupled in parallel to said inductor; and
means to couple said second switch means to a selected impedance point along said inductor;
each of the associated one of said first variable capacitance means, each of said second variable capacitance means, the associated one of said second helix and each of said inductors providing a double tuned circuit to resonate said antenna and to provide a broadband impedance match to said antenna over the associated one of said frequency bands.

* * * * *