

[54] **BROADBAND TUNABLE ANTENNA**

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[51] Int. Cl. **H01q 1/36**

[58] Field of Search 343/895, 843, 750, 751, 343/725, 729, 730, 745, 722

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[57] **ABSTRACT**

This invention relates to antennas and more particularly to broadband tunable antennas especially suitable for use on moving vehicles, such as submarines, ships and aircraft.

13 Claims, 7 Drawing Figures

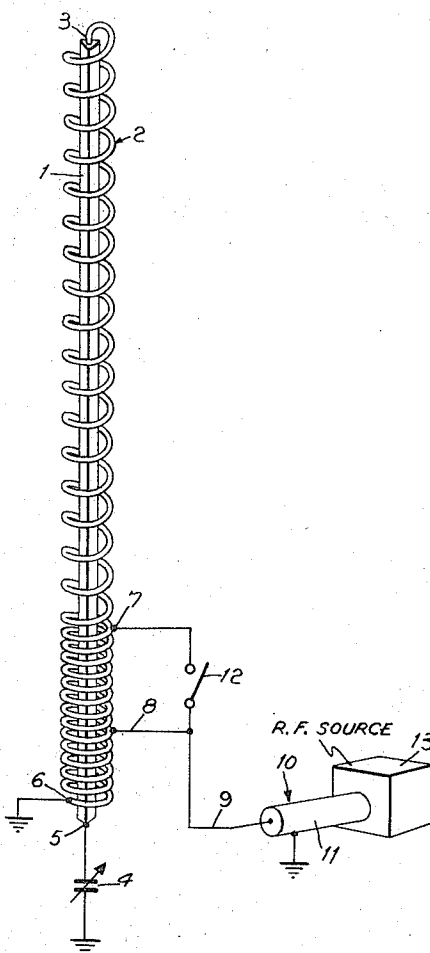


Fig. 1

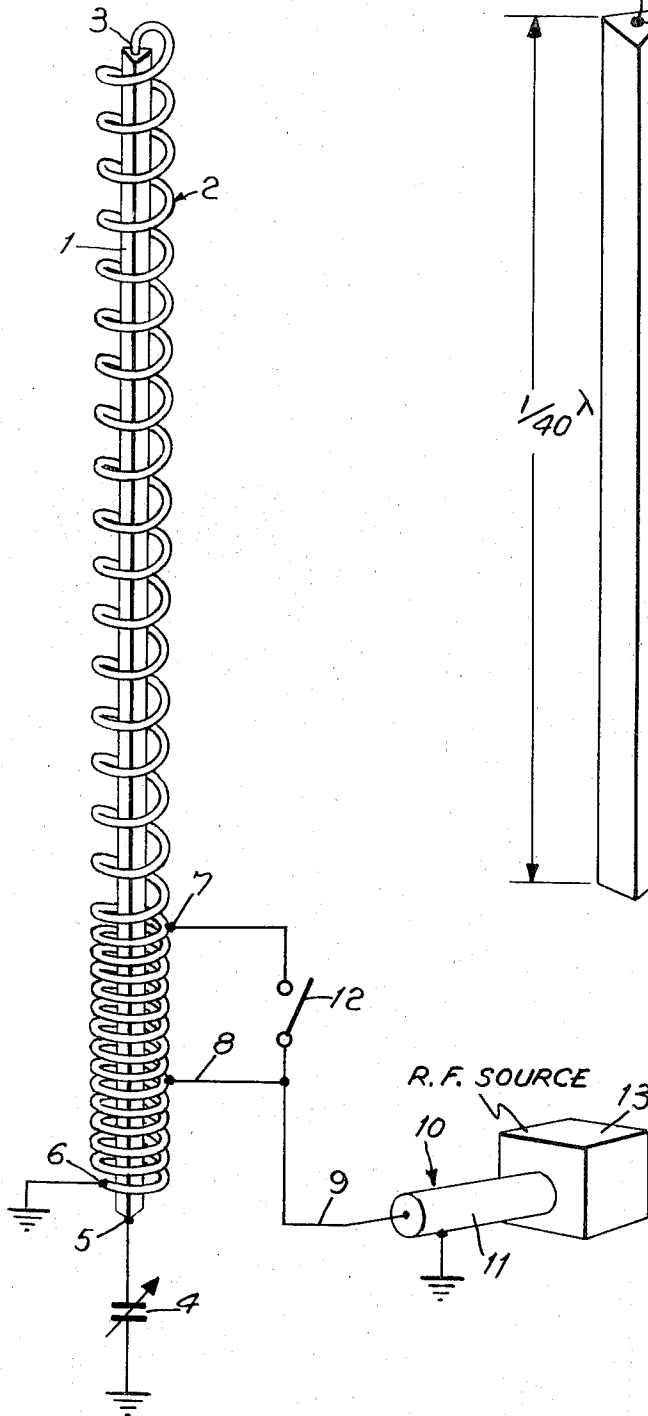
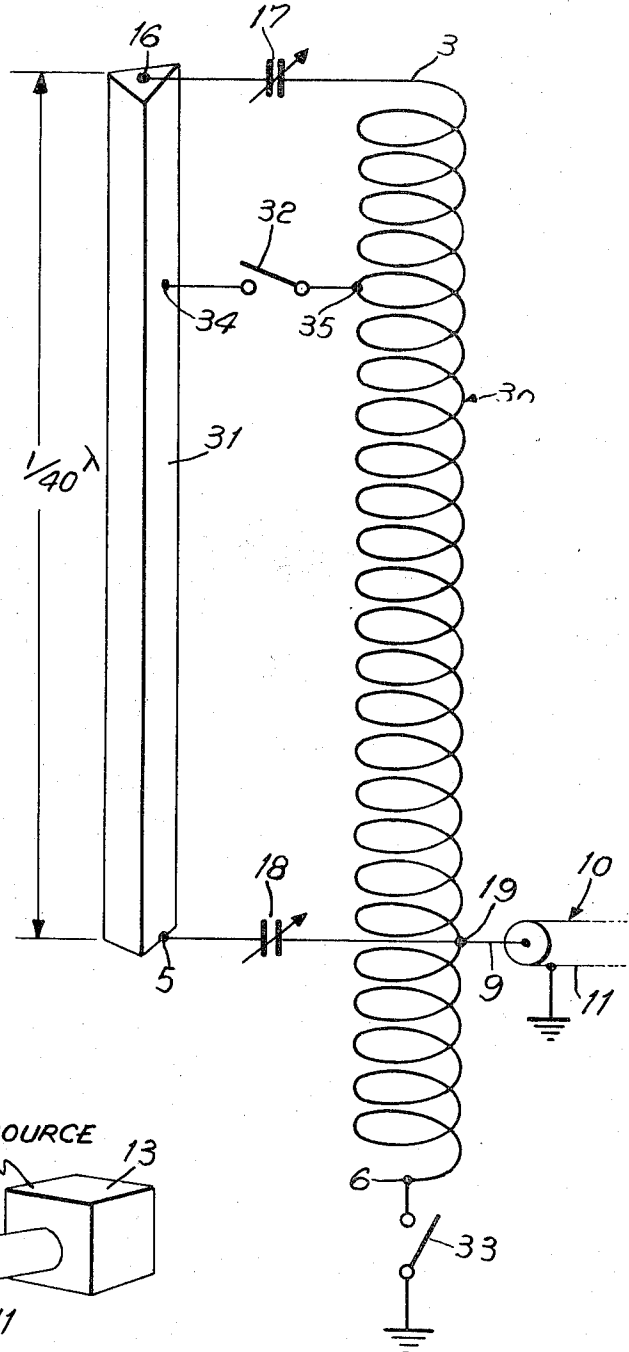


Fig. 4



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Fig. 2

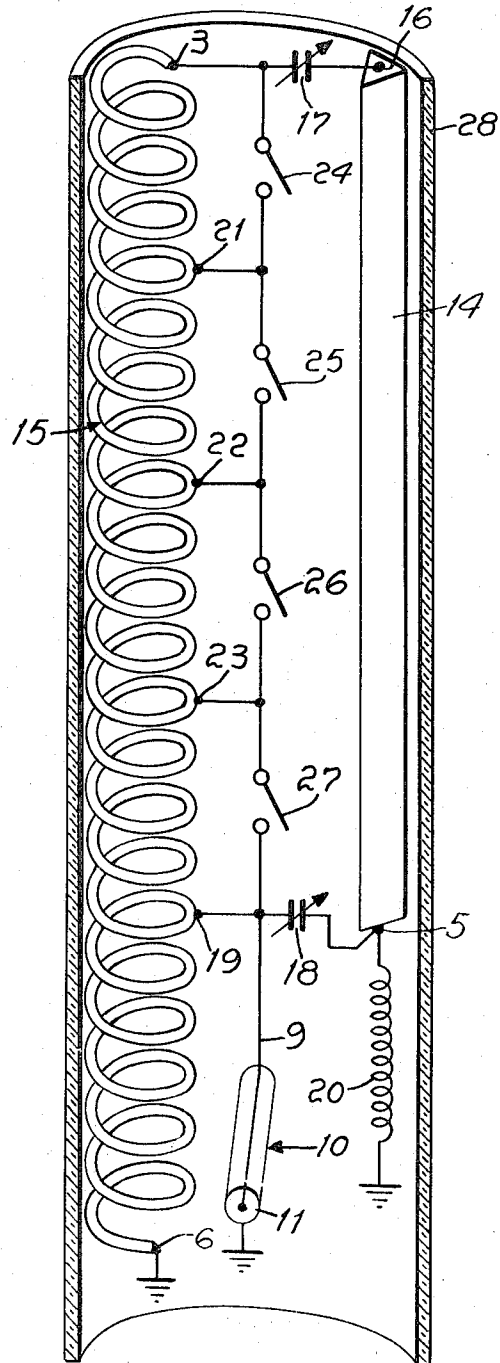
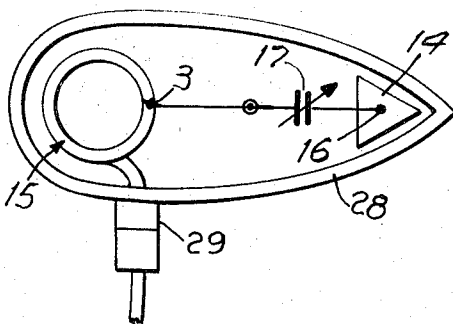


Fig. 3



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Fig. 5

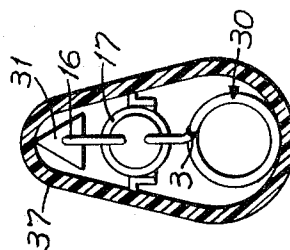
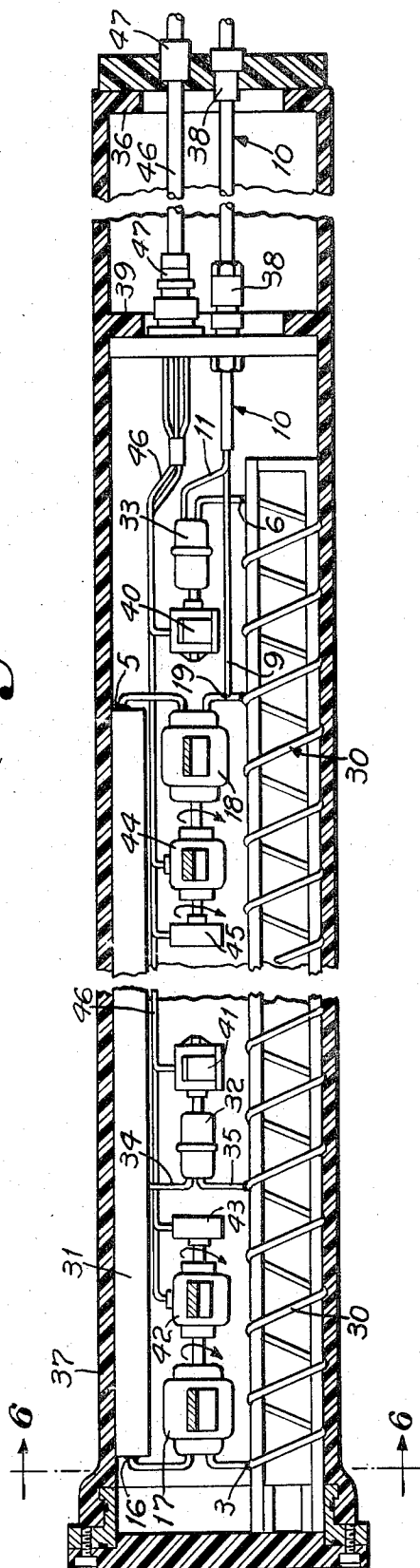


Fig. 6

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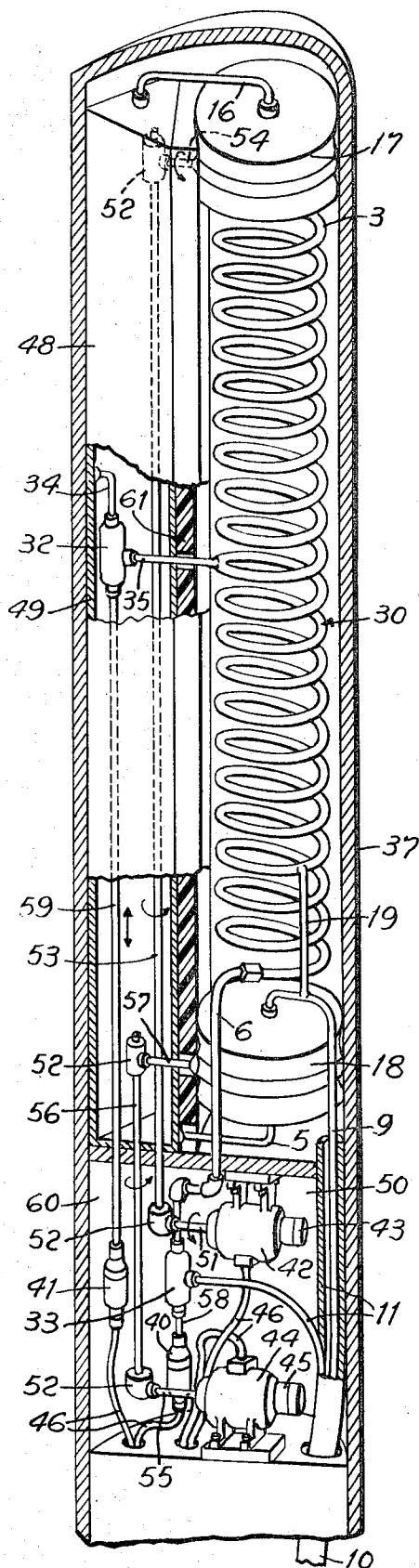


Fig. 7

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BROADBAND TUNABLE ANTENNA

A number of techniques for tuning antennas have been developed in the past. In some of these techniques, in order to tune the antenna, it is necessary to change the physical dimensions of the radiating members of the antenna structure. As the operating frequency is changed, the physical dimensions of the radiating members are changed to keep the dimensions equal to the same number of wavelengths at the new frequency. In other schemes, the physical position of the antenna members are changed with respect to each other. These techniques which utilize physical movement of the radiating members typically suffer problems inherent in sliding contacts and fragile moving insulators. The problems introduced by the necessity for movement of the antenna radiating members result in antennas which leave much to be desired in the way of ruggedness and durability. In many cases antennas are used in locations on aircraft and vessels which put considerable mechanical stress on the antenna due to streaming pressure, air flow and shock due to maneuvers. Under the past state of the art, broken antennas have often resulted. Other classes of antennas do not change in physical dimension but utilize variation in electrical circuit components, such as variable inductors and variable capacitors, to achieve change in tuning. One important disadvantage of such antennas is that the frequency range over which the tuning can be accomplished is not very large; hence, such antennas are not as broadband as would be desirable. A typical tuning range might be plus or minus ten per cent of the center frequency of the antenna, for example.

Therefore, one of the objects of the present invention is to provide an antenna which can be tuned over a very broad frequency range without any changes in physical dimensions of the radiating structure.

Another object of this invention is to provide a simple, compact antenna structure with great physical ruggedness and reliability.

It is a further object of this invention to provide a streamlined antenna which can be completely enclosed within a protective housing to isolate the antenna members from unfavorable environments and, at the same time, to provide an antenna which will be aerodynamically suitable for fluid flow past the antenna structure.

Briefly, a feature of this invention is to provide a bar-shaped element which serves as both a radiating element to propagate the electrical waves into space and which serves as a return lead to connect the antenna tuning capacitor to a helical radiating element of the antenna. The bar-shaped conductive element may be placed either within the helical radiating element and along the axis thereof or it may be placed entirely outside of the helical radiating element. The bar-shaped element may take on any convenient cross-sectional shape and may have cross-sectional size depending on convenience and the frequency band which it is desired to cover with the antenna.

Another feature of this invention is to provide two radiating elements which are integrated into one compact antenna structure. The first radiating element is a conductor formed in the shape of a helix. The second radiating element is a straight bar-shaped conductor which has a relatively large cross-sectional dimension. Each of these two radiating elements is inherently reso-

nant at a different band of frequencies. The present invention is arranged so that these two elements cooperate to provide a range of frequencies over which the antenna may be tuned which is much broader than would result by the use of such elements singly.

Still another feature of this invention is the use of capacitors as means to tune the antenna and also as coupling devices to link the helical radiating conductor to the bar-shaped radiating conductor. The arrangement of the capacitors allows the helical radiator to be used alone or the bar-shaped radiator can be used alone or both the helix and the bar can be used to radiate at the same time. The capacitors serve the dual function of infinitely variable tuning means and as impedance isolation members. Thus, the capacitors serve as tuning adjustments for the antenna and also to couple or decouple the two cooperating radiating elements, the helix and the bar.

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

FIG. 1 is a view in side elevation which is partly diagrammatic and partly schematic showing one embodiment of this invention;

FIG. 2 is a side elevational view with some of the structure broken away showing another embodiment of a broadband tunable antenna;

FIG. 3 is a top view of FIG. 2;

FIG. 4 is a schematic circuit diagram showing a preferred embodiment.

FIG. 5 is a side elevation in cross-section view of the embodiment of the antenna according to the circuit diagram of FIG. 4; and

FIG. 6 is a cross-sectional view taken along the lines 6-6 of FIG. 5.

FIG. 7 is a side elevation in cross-section view of another embodiment of the invention.

FIG. 1 shows a bar-shaped conductive and radiating element 1 around which is constructed a conductor and radiator formed in the shape of a helix 2. The bar-shaped radiating element 1 and the helical radiating element 2 are electrically insulated from each other by the air space in between them. The top of the bar-shaped element 1 is connected to the top of the helical element 2 at point 3. The bottom of the element 1 is connected to variable capacitor 4 at point 5. The other side of capacitor 4 is connected to radio frequency (RF) ground. Element 2 is wound in 2 uniform sections, that section from points 6 to 7 is closely wound with a small pitch angle, and the section from points 7 to 3 being wound with a larger pitch angle. More than 2 sections and different pitch angles may be used for performance over more frequencies. The input to the helical element 2 is either at point 8 or point 7 and RF ground is at point 6. At point 8, the center conductor 9 of coaxial cable 10 is connected to part of the closely spaced portion of helical element 2. The outer conductor 11 of coaxial cable 10 is connected to RF ground. Point 7 on the element 2 represents the point where the helix changes from a closely spaced winding to a more widely spaced winding. Switch 12 is connected across terminals 7 and 8. The switch 12 is shown in the open position. The source of RF energy 13 represents a transmitter or other device which will supply electromagnetic energy through the coaxial cable 10 to the an-

tenna. With switch 12 in the open position, as shown, the operation is as follows: Electromagnetic energy is fed into the antenna at point 8. The electric field propagates both up and down the helical radiating element 2. All of the helix 2 radiates the energy out into space. A portion of the helix 2 from the RF ground point at 6 up to the input point at 8 represents an impedance transformer to match the line impedance of coaxial cable 10. This impedance might be in the order of 50 ohms for typical coaxial cable terminations. The upper end of the helix 3 must be provided with a complete conductive path for proper tuning. The bar-shaped radiating element 1 provides this return connection to tuning capacitor 4. However, bar 1 in addition radiates energy itself. The tuning of this antenna is accomplished by varying capacitor 4. The capacitance of capacitor 4 at low frequencies is relatively large. If it is desired to operate at higher frequencies, the capacitance of capacitor 4 is gradually reduced in value. As a result, the antenna structure is resonant at higher frequencies as the capacitance of capacitor 4 is reduced. Thus, in this antenna, both helix 2 and bar 1 radiate energy into space. In addition, the bar 1 has a double function of both radiating and providing a conductive return path to the tuning element, capacitor 4. When switch 12 is closed, the portion of the helix 2 between terminals 7 and 8, i.e., part of the closely wound portion of the helix 2, is shorted out. As a result, the inductance of the helix is reduced and a further higher band of frequencies is obtained. As before, capacitor 4 provides tuning over this higher frequency band.

FIGS. 2 and 3 show another embodiment of this invention. In this embodiment there are also two cooperating radiating elements, the bar-shaped conductor 14 and the helical-shaped conductor 15. The bar-shaped radiating element 14 is now outside of the helix 15. Helical radiator 15 is wound uniformly throughout its entire length. But several sections could be readily wound with different pitch angles for more flexible operating performance. The top of bar-shaped element 14 at 16 is connected to one terminal of a variable capacitor 17. The top of helix 15 at point 3 is connected to the other terminal of variable capacitor 17. The bottom of bar 14 at point 5 is connected to one terminal of a variable capacitor 18. The other terminal of variable capacitor 18 is connected at point 19 to the lowest tap point on helix 15. Similarly, the section of helix from point 19 down to point 6, the bottom of the helix, where the helix is returned to RF ground, represents a suitable impedance termination for the coaxial cable 10 whose center conductor 9 is connected to point 19. The other end of conductor 9 is connected to an RF source (not shown). The outer conductor 11 of coaxial cable 10 is also returned to RF ground. The bottom of bar 14 at point 5 is also connected to inductor 20. The other terminal of inductor 20 is returned to RF ground. Helix 15 is provided with connections at various points along its length, such as points 21, 22, 23 and input 19. These connection points divide the helix 15 into a number of sections. Shorting switch 24 is connected between the top of helix 15 at point 3 and connection point 21. Shorting switch 25 is connected between terminal 21 and terminal 22. Shorting switch 26 is connected between terminals 22 and terminal 23, and shorting switch 27 is connected between tap connection point 23 and input point 19. These shorting switches 24, 25, 26, and 27 perform a similar function to shorting switch

12 of FIG. 1, as will be explained later. The entire antenna assembly is surrounded and enclosed within protective radome 28 which is made of a suitable dielectric material and has top and bottom covers which are not shown here for clarity. Radome 28 is a pressure-proof, water-tight enclosure completely protecting the radiating elements of the antenna structure from any hostile environment. Coaxial cable 10 is brought inside of radome 28 by a suitable pressure-proof and water-tight fitting, such as indicated at 29 in FIG. 3.

The operation of the antenna is as follows. At low frequencies all of the switches 24, 25, 26 and 27 are in the open position as shown. Variable capacitor 18 is tuned to its lowest value of capacitance. Variable capacitor 17 is tuned to its largest value of capacitance. Operation is initially at the lowest frequency for which the antenna is designed. When it is desired to use the antenna at higher frequencies, capacitor 17 is made smaller and smaller in capacitance value to tune the antenna at higher frequencies. Radiation takes place from both helix 15 and bar 14. In addition, bar 14 acts as a return lead to return one terminal of capacitor 17 to RF ground through the coil 20. At relatively low frequencies, the inductive reactance of coil 20 is relatively small so that for practical purposes it provides an effective return path to RF ground for capacitor 17. Thus, the antenna is tuned by the adjustment of capacitor 17. Capacitor 18, on the other hand, because it is tuned to its lowest value, has a relatively large capacitive reactance and effectively isolates the input connection of the helix at point 19 from the bottom of the bar at 5. Consequently, a resonant circuit is constituted by the helix from point 19 up through point 3 through capacitor 17 down through the bar 14 and through coil 20 to ground. When capacitor 17 has been tuned to its smallest value, the upper limit of the first frequency band has been reached. To tune the antenna to still higher frequency bands, the first shorting switch 27 is closed. This shorts out the section of the helix between connection points 19 and 23. Hence, the inductance of the helix is lowered and capacitor 17 can again be used to tune the radiating antenna over another higher frequency band. After switch 27 has been closed, capacitor 17 can be tuned from its largest value to its smaller value of capacitance thereby tuning the antenna into the higher frequency region. Likewise, when capacitor 17 has again reached its smallest value of capacitance, shorting switch 26 is closed and the process is repeated over a still higher frequency band. When all four of the shorting switches 27, 26, 25 and 24 have been closed, the helix 15 is shorted out entirely and the sole radiator is the bar 14 being fed through the capacitor 17 which serves to tune the bar. The relatively broad cross-sectional area of the bar itself makes the bar 14 a relatively broadband device. Hence, with the use of capacitor 17 the bar itself will radiate over a substantially wide frequency band.

When still higher frequencies of operation are desired, the following procedure is used. All the four shorting switches 24, 25, 26 and 27 are again returned to their open position as shown. Capacitor 17 is now turned to its smallest value of capacitance. In this mode of operation, the bar 14 is the principal radiating element although some radiation takes place from the helix 15. Helix 15 does not contribute as much to the radiation strength because the inductance of helix 15 is relatively much larger at higher frequencies. Capacitor

tor 17, by being tuned to its smallest value of capacitance, acts as an effective impedance isolation between the top of helix 15 at point 3 and the top of the bar 14 at point 16. The tuning of the antenna in this mode is accomplished by varying capacitor 18. The bar 14 is fed from coaxial conductor 9 to point 19 through capacitor 18 and the radiation propagates upwards through the bar 14 and out into space. In this mode of operation, coil 20 acts like a filter section, being used to match coaxial cable 10 into the antenna, consisting of capacitor 18 and bar 14. The use of coil 20 provides much better voltage standing wave ratios (VSWR) along the radiating bar 14. In addition, it allows a broader frequency range to be covered by the use of capacitor 18. As capacitor 18 is decreased in value, the operating frequency can be made higher. With capacitor 18 at its smallest value of capacitance and all the shorting switches open and capacitor 17 turned to its smallest value of capacitance, the highest possible operating frequency of the antenna has been reached. The adjustments of variable capacitors 17 and 18 and the opening and closing of the shorting switches 24, 25, 26 and 27 can be made by hand before operation of the antenna or they can be performed by use of remote control means while the antenna is in operation. Such remote means for controlling the switches and capacitors are not shown in FIG. 2.

FIG. 3 is a top view of FIG. 2, showing some of the details of the location of the radiating elements of the antenna of FIG. 2. The adjustable capacitors 17 and 18 in diagrammatic form as in FIG. 2 are shown between the bar 14 and the helix 15. The streamline shape of the radome 28 is now clearly shown. This is of particular utility in applications where wind resistance or streaming pressure due to water in the case of submarines might cause drag in the vessel or vehicle which is carrying the antenna. Note that the streamlined design of the antenna is aided by the shape and location of bar 14. The triangular cross section of bar 14 allows it to fit snugly into the rear space of the tapered radome 28. Also, the solid bar 14 provides a rigid member that adds to the strength of the entire antenna assembly.

FIG. 4 shows a preferred embodiment of this broadband tunable antenna which combines many of the desirable features of FIGS. 1, 2 and 3 in one unique structure. As in the embodiment of FIG. 2, adjustable capacitor 17 is connected between the top of helix 30 at point 3 and the top of the bar 31 at point 16 and adjustable capacitor 18 is connected between the input connection to the helix 30 at point 19 and the bottom of the bar at point 5. However, shorting switch 32 operates somewhat differently than the shorting switches shown in FIG. 2. Moreover, a grounding switch 33 performs a unique function not found in any other embodiment of this invention. One terminal of shorting switch 32 is connected to connection point 34 in an inner portion of bar 31. The other terminal of single-pole, single-throw switch 32 is connected to connection point 35 in an inner middle portion of helix 30. Single-pole, single-throw grounding switch 33 is connected between the bottom of the helix at point 6 and radio frequency ground. The length of radiating bar-shaped element 31 is approximately one-fortieth of a wavelength at the lowest frequency. However the radiation efficiency of the antenna is a function of the length of the antenna and various lengths may be used by compromising some radiation efficiency in exchange for shorter

length for convenience. At low frequencies, grounding switch 33 is in the closed position, and shorting switch 32 is open. At low frequency, operation is quite similar to the embodiment shown in FIG. 2. With switch 33 closed, the portion of helix 30 between input connection 19 and the bottom 6 of helix 30 which is connected to RF ground with switch 33 closed, acts as an impedance transformer to match the antenna to coaxial cable 10 into which the RF energy is sent by the transmitter (not shown). Both capacitor 17 and capacitor 18 enter actively into the network at both low and high frequencies. At low frequencies, the operation is very similar to that of a resonant series RLC circuit. The helix radiates electromagnetic waves into space and, at the same time, bar 31 both radiates and acts as a connecting lead between the terminals of capacitor 17 and capacitor 18. To tune the antenna, capacitor 18 is gradually reduced in value as the desired operating frequency is increased. When capacitor 18 has reached its lowest value of capacitance, capacitor 17 is then decreased to allow operation at even higher frequencies. Capacitors 17 & 18 can also be adjusted in the reverse order with no detrimental effects. Also under some circumstances it is desirable to adjust capacitors 17 & 18 simultaneously. At intermediate range of frequencies, the unique function of grounding switch 33 becomes evident. If there were no switch between the bottom 6 of helix 30 and ground, the helix would always remain connected directly to RF ground. As the frequency is increased, the impedance of the section of the helix 30 between the input connection at 19 and RF ground at point 6 will gradually change. More precisely, as the frequency is increased the antenna more nearly approaches a one-quarter wavelength radiator and the impedance approaches that of a one-quarter wavelength dipole with a ground plane, namely 37 ohms. Finally, a mismatch would be produced between the coaxial cable 10 and the antenna if the tap point 19 on the helix 30 were not moved. This would greatly reduce the radiation efficiency of the antenna. One method would be to provide a sliding movable connection at point 19 so that point 19 could be moved from turn to turn on the helix. Switch 33 provides a much simpler expedient, however. At intermediate frequencies and higher frequencies, switch 33 is simply put into the open position as shown since the impedance transformation is no longer correct. The antenna structure then has no direct ground connection but instead the inherent capacitance between the structure and its surrounding ground planes, such as metal surfaces of supporting elements, etc., are used to provide the return path to RF ground. This causes a good match to be made between connection point 19 and the coaxial line and the antenna even though the frequency is changed, without necessitating the use of any sliding contacts. When both capacitor 17 and capacitor 18 have been turned to the lowest value of capacitance and it is desired to operate at still higher frequencies, then shorting switch 32 is put into the closed position. Now capacitor 17 can be turned up to its largest capacitive value and then gradually reduced to produce even higher operating frequencies. In this very high frequency mode of operation, the antenna structure acts like a one-quarter wavelength broadband dipole, which can be tuned somewhat by changing the capacity with respect to the helix. The shorting switch changes the current distribution in an advantageous manner. Both the helix 30 and

the bar-shaped element 31 contribute to the radiation of the antenna, and fine precision tuning can be obtained by adjusting the loop formed by shorting switch 32, helix 30 between points 35 and 3 and capacitor 17 and bar-shaped element 31 between points 16 and 34. This loop can be separately tuned by adjustment of capacitor 17. Likewise, the loop formed by shorting switch 32, helix 30 from connection point 35 to input point 19, capacitor 18 and the bar-shaped element 31 from point 5 to point 34 can be separately tuned by adjusting capacitor 18. Thus a very broad range of frequencies can be tuned by the antenna. At any selected operating frequency, the antenna can be brought to a very high degree of accuracy in frequency tuning and impedance match with the input coaxial cable. This produces an antenna which has very high radiating efficiency for its physical dimensions.

FIG. 5 shows an embodiment of the invention which is suitable for use on submarines or naval vessels or other mobile craft. The structure of FIG. 5 follows the circuit diagram given in FIG. 4. In addition to the radiating helix element 30 and the radiating bar element 31 and tuning and coupling capacitors 17 and 18, FIG. 5 shows all the elements illustrated in FIG. 4. In addition, FIGS. 5 and 6 show means for remotely varying and controlling capacitors 17 and 18 and switches 32 and 33. In FIG. 5 the electrical circuit corresponding to FIG. 4 can be traced out as follows: Coaxial cable 10 is brought through the first bulk head 36 of the radome 37 by a pressure-proof, water-tight fitting 38. The coaxial cable 10 is then brought through the second bulk head 39 by another pressure-proof, water-tight fitting 38. The coaxial cable then separates into two conductors, one connected to the outer or ground conductor 11 of the coaxial cable which is connected to RF ground and the other inner conductor 9 which is connected to the center conductor of the coaxial cable 10. Ground conductor 11 enters switch 33 which is normally in the open position when the solenoid 40 is unoperated. Solenoid 40 is the means for remotely opening or closing switch 33. The other terminal of switch 33 is connected by an RF lead to the bottom of helix 30 at point 6. The inner conductor 9 of the RF lead of coaxial cable 10 is connected to the common point 19 which is connected to helix 30 and to one terminal of adjustable capacitor 18. The other terminal of capacitor 18 is connected to the bottom of bar 31 at point 5 by an RF lead. Capacitors 17 and 18 are shown here as high voltage vacuum capacitors, but other types could be used. A portion of the helix between connection point 19 and the ground point 6 at the bottom of the helix again represents a proper impedance termination for coaxial lead 10. Adjustable capacitor 17 has one terminal connected at point 16 to the top of bar 31. The other terminal of capacitor 17 is connected to the top of the helix at point 3. Shorting switch 32 has one of its terminals connected to bar 31 at point 34 by an RF lead and the other terminal of switch 32 is connected to the helix at point 35 as shown. Solenoid 40 provides means for remotely actuating switch 33. Switch 33 is a plunger type vacuum switch, but other types may be used. Likewise, solenoid 41 provides motive means for remotely actuating switch 32. Capacitors 17 and 18 are adjustable by rotating the shafts which are connected to them. Connected to the adjustment shaft of capacitor 17 is motor 42 and also connected to this drive shaft is potentiometers and limit

stops indicated at 43. The motor 42 in conjunction with the potentiometers and limit stops 43 provide means allowing the use of a closed loop servo mechanism or controller to remotely control the positioning of the drive shaft of capacitor 17. Hence, the value of capacitor 17 can be remotely adjusted to cause remote tuning of the antenna. In a similar manner, motor 44 and potentiometer and limit stops indicated at 45 provide motive means for adjusting capacitor 18 from a remote position. The control leads for the motors and potentiometers are shown as a cable 46. The cable 46 passes through the first bulk head 36 of the radome 37 through pressure-proof and water-tight fittings 47 and then passes through the second inner bulk head 39 by pressure-proof, water-tight fittings 47. From there the various control leads are connected to the motors, potentiometers and limit stops as required. Thus, radome 37 can be completely sealed and enclosed as a water-proof, pressure-tight structure to protect the radiating and electrical elements of the antenna structure.

FIG. 6 helps to show the relative location of the helix 30, the bar 31 and the capacitors and motors and their respective supports. The electrical operation of the embodiment shown in FIGS. 5 and 6 is the same as that described in the discussion concerning FIG. 4. The streamlined shape of radome 37 is clearly shown.

A variation of FIG. 5 which has some extremely practical and effective features can be made rather simply. In FIG. 5, under certain conditions, the low voltage control leads 46 extending to the motors and potentiometers may have some tendency to pick up RF radiation. Under most conditions, this is of no importance. However, if the transmitter or receiver and other associated electronic equipment which are supplying the antenna are extremely sensitive, it may be desirable to insure that no RF leakage can occur through the control leads 46 out of the antenna enclosure. There are two expedients which can be used to eliminate any RF leakage out of the leads 46. One is to place RF chokes in series with the leads 46 within the radome 30, and the other is to place RF chokes outside of the radome at the terminals of the leads 46 beyond pressure-proof connector 47. This technique will effectively eliminate whatever small amount of RF radiation that might possibly be present on the control leads 46.

In some other situations, two effects may be present. Within the vessel or aircraft which is carrying the antenna there may be other electronic equipment which produces RF radiation used for other purposes not connected with the antenna shown in this invention. It is possible that undesired RF energy might be coupled into the control leads 46 and pass into the radome 30; and by being in close proximity to the helix 30 and the bar 31, this RF energy might cause some slight degree of modulation on the output of this antenna. Likewise, such RF leakage into the antenna might be picked up by the helix 30 and the bar 31 and returned to any receiving apparatus which might be connected to this antenna. Again, there is the possibility that the RF energy radiated from the helix 30 and the bar 31 may leak onto the control leads 46 and thence out of the radome and cause interference with other equipment in proximity to the antenna equipment. Both of these undesirable possibilities can be easily avoided by a modification of the structure shown in FIG. 5.

FIG. 7 shows a modification of the invention which follows the R.F. circuit diagram of FIG. 4 and which

possesses particularly good R.F. shielding characteristics to avoid the pickup problems described above. The electrical operation of the embodiment of FIG. 7 is the same as that described in connection with FIG. 4, but FIG. 7 has a number of additional features. The bar radiating element 48 serves the same function as the bar radiating element 31 of FIG. 5. However, bar element 48 is made hollow as shown in FIG. 7. Vacuum shorting switch 32 is now placed entirely within the hollow bar element 48. The conductive walls 49, of bar 48 act as a shielding structure to completely eliminate any R.F. radiation from being conducted to any mechanisms located within hollow bar 48. Capacitors 17 and 18 are now located at the ends of helix 30. This insures that the structure of the capacitors will have no effect on the radiation pattern of the antenna by intercepting directly radiation from the antenna. Capacitors 17 and 18 perform the same tuning and coupling functions described in connection with FIG. 4. A motor 42 is similarly used to mechanically adjust capacitor 17 and likewise motor 44 is used to mechanically adjust capacitor 18. Also solenoid 40 is used to operate grounding switch 33 as before and solenoid 41 is used to operate shorting switch 32 which is now located within the hollow bar 48. It will be seen by reference to FIG. 7 that motors 42 and 44, solenoids 40 and 41 and switch 33 are now all located entirely within a closed chamber 50. The walls 60 of chamber 50 are lined with a conductive material to completely shield this chamber from either receiving or emitting radiation from any structures outside the chamber 50. Thus radiation from bar 48 and helix 30 cannot be picked up by the control leads 46 which run to the motors and solenoids within RF shielded chamber 50. The potentiometers 43 and 45 are shown as integral members with motors 42 and 44, respectively, and are also located within RF shielded chamber 50. Again, the control leads 46 for the motors and potentiometers and the solenoids are brought into shielded chamber 50. RF energy is brought to the antenna structure by coaxial cable 10 which passes through shielded chamber 50. The outer conductor 11, of coaxial cable 10 is at ground potential and the ground connection to grounding switch 33 is made to the outer case of switch 33 which serves as the ground terminal for the switch 33. The inner conductor 9 of coaxial cable 10 is entirely shielded by the outer conductor 11 at ground potential within chamber 50. Hence, all structures within shielded chamber 50 are at no more than RF ground potential and there is no possibility of radiation being transmitted to, or emitted from, the structures within chamber 50. The center conductor 9 of coaxial cable 10 is connected to helix 30 and capacitor 18 at the common point 19 as in FIGS. 4 and 5. To enable all of the motors, potentiometers and solenoids to be located within one shielded chamber 50, it is necessary to provide mechanical drive shafts and gear trains to transmit the rotary motion or plunger-type motion to the capacitors 17 and 18 and switch 32. Thus, rotary motion of the shaft 51 from motor 42 is transmitted to bevel gear unit 52 which transmits the rotary motion to shaft 53. Shaft 53, in turn, is coupled to upper bevel gear unit 52 whose other shaft 54, is coupled to capacitor 17. Thus, motion is transmitted from motor 42 to shaft 51 to bevel gear unit 52 through shaft 53 to upper bevel gear unit 52 through shaft 54 to capacitor 17. In a similar manner, the rotary motion of motor shaft 55 is transmitted to

bevel gear unit 52 which is coupled by shaft 56 to another bevel gear unit 52 whose output is coupled to shaft 57 and hence into capacitor 18. Thus, motion from motor 44 transmitted by shaft 55 through bevel gear unit 52 through shaft 56 to another bevel gear unit 52 to shaft 57 which adjusts capacitor 18. Solenoid 40 is coupled to grounding switch 33 by rod 58. Likewise, solenoid 41 is connected to shorting switch 32 by rod 59. Thus, plunger-type motion is transmitted from solenoid 41 to switch 32 by means of rod 59. All of the shafts and gearing units 51, 52, 53, 54, 55, 56 and 57 and all of the rods 58 and 59 are made of a dielectric material, such as plastic, to further reduce any possibility that they might transmit stray and undesired RF radiation. Note also that the RF leads in coaxial cable 10 and the control leads 46 are physically separated at opposite sides of radome 37 to prevent any interaction. The lead 35 from switch 32 to helix 30 passes thru an insulated hole 61 in the wall 49 of bar 48. Other useful variations of the invention can be made by placing one or both capacitors 17 and 18 as well as switch 32 inside of hollow bar 48. If the capacitors are placed within bar 48, the bar 48 can be made somewhat larger in cross section and smaller sized capacitors can be used. Hollow bar 48 will, as in FIG. 7, completely shield any structures within the bar from picking up any undesired RF radiation. This will prevent stray radiation from propagating over the leads and surfaces of the capacitors when they are enclosed within hollow bar 48. As in FIG. 7, mechanical coupling to capacitors 17 and 18 and switches 32 and 33 can be made by means of dielectric shafts and rods running from the motors 42 and 44 and the solenoids 40 and 41. In addition, by placing both capacitors and switches entirely within hollow bar 48 a further saving in space is effected. Thus, FIG. 7 and the technique just presented provide two means of reducing undesired RF leakage — (1) by shielding the components involved within hollow bar element 48 and (2) by placing motors and solenoids and potentiometers within an RF sealed chamber, such as 50. This invention has been reduced to practice. An embodiment in the form of FIG. 1 has been built and tested. The following list gives the electrical parameters and the physical dimensions of the antenna structure:

Title	Value
Capacitor (element 4)	10 mmf
D, the diameter of helix (element 2) (center of conductor to center of conductor)	4.15 inches
Length of close wound section (from point 6 up to point 7)	1.0 feet
Diameter of conductor	¼ inch
S ₁ , spacing between turns	0.242 inches per turn
Pitch angle (equal to arctan (S ₁ /TTD))	1.06 degrees
Length of open wound section (from point 7 up to point 3)	10.0 feet
Diameter of conductor	¼ inch
S ₂ , spacing between turns	1.695 inches per turn
Pitch angle (equal to arctan (S ₂ /TTD))	7.4 degrees
Length of bar (element 1)	11.5 feet

Testing was conducted over a 2MC to 6MC band with excellent results.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claims.

We claim:

1. A broadband tunable antenna comprising a first radiating element resonant at a first band of frequencies, a second radiating element resonant at a second band of frequencies disposed parallel to and coextensive with said first radiating element, means coupling one end of said first radiating element to one end of said second radiating element and adjustable capacitive tuning means connected to the other end of said second radiating element.

2. A broadband tunable antenna comprising a helix resonant at a first band of frequencies, a bar-shaped element resonant at a second band of frequencies disposed parallel to said helix, means coupling one end of said helix to one end of said element and adjustable capacitive tuning means connected to the other end of said element.

3. A broadband tunable antenna comprising a helical radiating element resonant at a first band of frequencies connected to a bar-shaped radiating element resonant at a second band of frequencies, adjustable capacitive tuning means connected to said bar radiating element, said helical radiating element comprising at least two sections, the first section of said helical element being more closely wound than said second section and switching means connected between the middle portion of said first section of said helical radiating element and the junction of said first and second sections.

4. A broadband tunable antenna comprising a helical radiating element resonant at a first band of frequencies, a bar-shaped radiating element resonant at a second band of frequencies and disposed parallel to said helical element and within said helical radiating element, adjustable capacitive tuning means connected to one end of said bar-shaped element, the other end of said bar-shaped element being connected to one end of said helical element, said helical element comprising at least two sections, the first section of said helical element being more closely wound than said second section of said helical element and switching means coupling the midpoint of said first section and the junction of said first and second sections.

5. A broadband tunable antenna comprising a first radiating element resonant at a first band of frequencies, a second radiating element resonant at a different band of frequencies and adjustable capacitive coupling and tuning means connecting said first radiating element to said second radiating element.

6. A broadband tunable antenna comprising a helical radiating element resonant at a first band of frequencies, a bar radiating element resonant at a different band of frequencies, first adjustable capacitive coupling and tuning means connecting the upper part of said helical radiating element to one end of said bar radiating element and second adjustable capacitive coupling and tuning means connecting the lower part of said helical radiating element to the other end of said bar radiating element.

7. An antenna comprising an enclosure, a broadband tunable antenna disposed within said enclosure, said broadband tunable antenna comprising a helical radiating element resonant at a first band of frequencies, a bar radiating element resonant at a different band of frequencies and disposed parallel to said helical element, first adjustable capacitive coupling and tuning means connecting the upper part of said helical radiating element to one end of said bar radiating element and second adjustable capacitive coupling and tuning means connecting the lower part of said helical radiating element to the other end of said bar radiating element, an inductor connected between said other end of said bar element and ground, a plurality of switching means connected between points on said helical radiating element, said points being located along the length of said helical element so as to divide said helical element into a plurality of portions.

8. A broadband tunable antenna comprising a helical radiating element resonant at a first band of frequencies, a bar radiating element resonant at a different band of frequencies and located parallel to said helical element and outside of said helical element, said bar element having a triangular cross-sectional shape, first adjustable capacitive coupling and tuning means connecting the upper part of said helical element to the upper end of said bar element and second adjustable capacitive coupling and tuning means connecting the lower part of said helical element to the lower end of said bar element, first switching means coupling the middle portion of said helical element to the middle portion of said bar element, and second switching means coupling the lower end of said helical element to ground.

9. An antenna comprising an enclosure, a broad band tunable antenna disposed within said enclosure, said broadband tunable antenna comprising a helical radiating element resonant at a first band of frequencies, a bar radiating element resonant at a different band of frequencies, said bar element being disposed parallel to said helical element, first adjustable capacitive coupling and tuning means connecting one end portion of said helical radiating element to one end portion of said bar radiating element and second adjustable capacitive coupling and tuning means connecting the other end portion of said helical radiating element to the other end portion of said bar radiating element, first switching means coupling the middle portion of said helical element to the middle portion of said bar element, second switching means coupling one end of said helical element to ground, first motive means coupled to said first and second adjustable capacitive coupling means and second motive means coupled to said first and second switching means.

10. An antenna comprising a streamlined pressure-proof, water-tight radome, said radome being elongated vertically and having one side portion thereof tapered laterally with respect to the vertical axis of said radome, a broadband tunable antenna disposed within said radome, said broadband tunable antenna comprising a helical radiating element resonant at a first band of frequencies and a bar radiating element resonant at a different band of frequencies, means disposing said bar element parallel and adjacent to said helical element with the said bar element located in the tapered portion of said radome, first adjustable capacitive coupling and tuning means connecting the upper part of

said helical radiating element to the upper part of said bar radiating element, a second adjustable capacitive coupling and tuning means connecting the lower part of said helical radiating element to the lower part of said bar radiating element, first switching means coupling the middle portion of said helical element to the middle portion of said bar element, second switching means coupling the lower end of said helical element to ground, a first motor coupled to said first adjustable capacitive coupling and tuning means, a second motor coupled to said second adjustable capacitive coupling and tuning means, a first solenoid connected to said first switching means and a second solenoid connected to said switching means.

11. An antenna according to claim 10 wherein said bar radiating element is hollow and said first switching means is disposed in said hollow bar element and further including an electrically shielded chamber, said first and second motors being disposed within said electrically shielded chamber.

12. A broadband tunable antenna comprising a first radiating element resonant at a first band of frequencies, a second radiating element resonant at a different

band of frequencies, adjustable capacitive coupling and tuning means connecting said first radiating element to said second radiating element, one of said radiating elements being hollow and driving means disposed in said hollow radiating element for operation of said adjustable coupling and tuning means.

13. A broadband tunable antenna comprising a helical radiating element resonant at a first band of frequencies, a bar radiating element resonant at a different band of frequencies and located parallel to said helical element, said bar element being hollow, first adjustable capacitive coupling and tuning means connecting one end portion of said helical element to one end portion of said bar element and second adjustable capacitive coupling and tuning means connecting the other end portion of said helical element to the other end of said bar element, first switching means coupling the middle portion of said helical element to the middle portion of said bar element, and second switching means coupling one end portion of said helical element to ground, said first switching means being disposed in said hollow bar element.

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