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(54) **COMPACT THREE-DIMENSIONAL ULTRA-WIDEBAND ANTENNA WITH IMPROVED CIRCULAR POLARIZATION PURITY**

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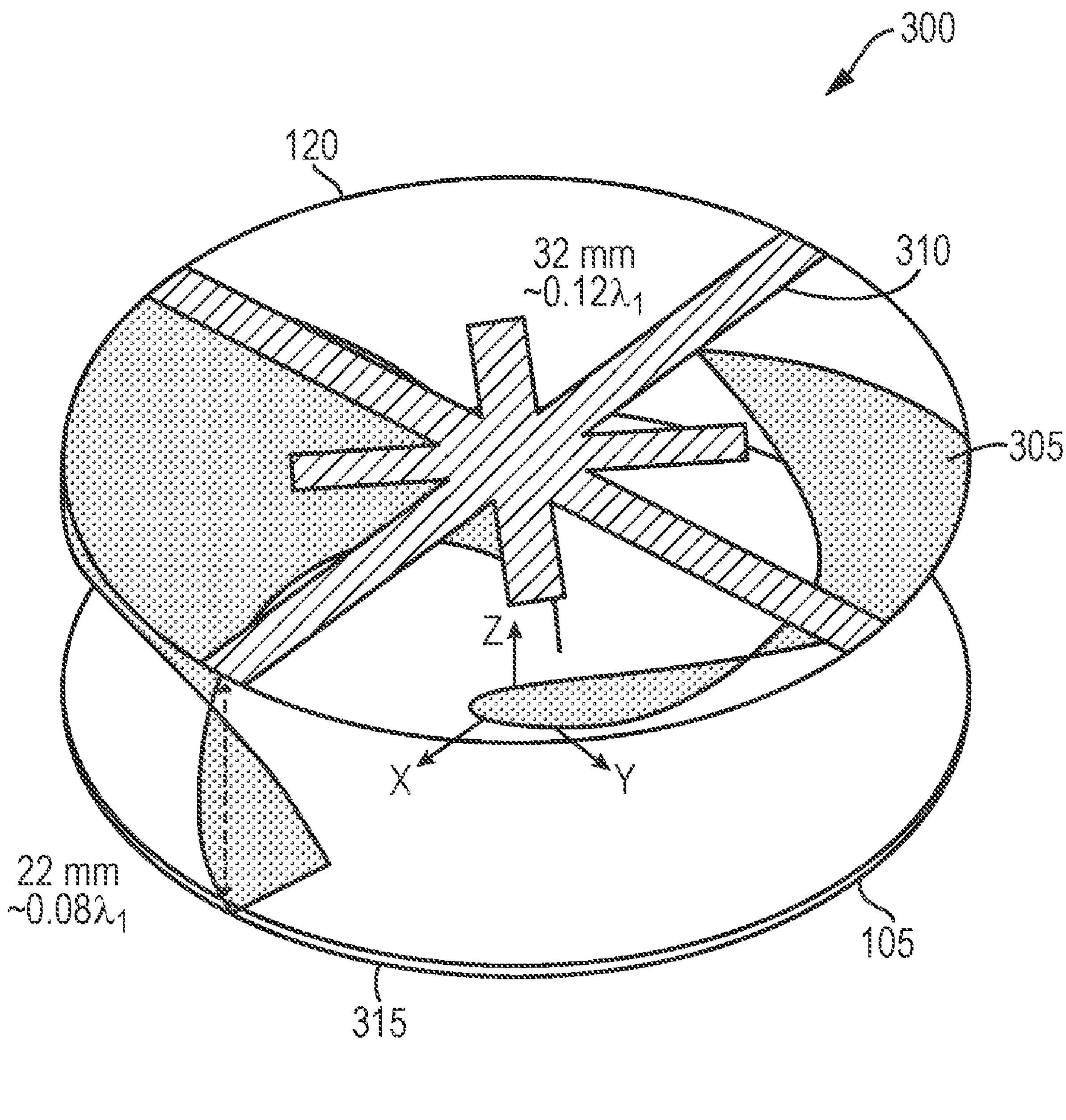
(57) **ABSTRACT**

A compact three-dimensional ultra-wideband antenna that provides improved circular polarization purity is provided. Short-circuited stubs located on a base are connected at the base of one or more radiators. The stubs and radiators are encased in a dielectric material. In an alternative embodiment, a pair of curved radiators extend from the base and are encased in a dielectric. Embodiments generate a quasi-traveling wave along the radiators.



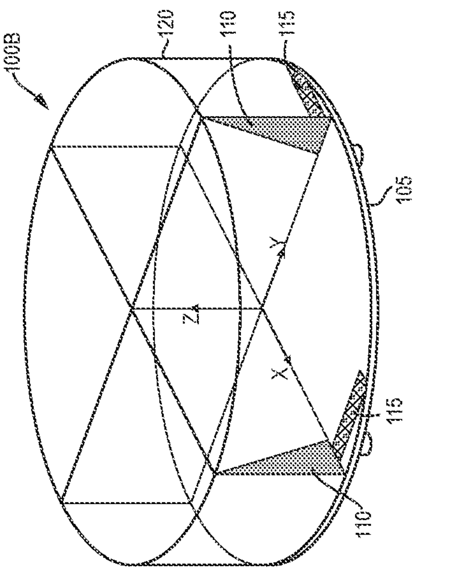

100B
120
110
115
105
Y
Z
X
115
110

FIG. 1B

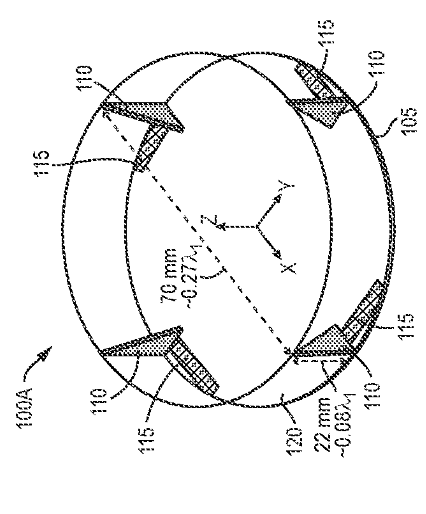

110
115
110
115
105
Z
Y
X
70 mm
~0.277λ1
100A
110
115
120
22 mm
~0.08λ1
110
115

FIG. 1A

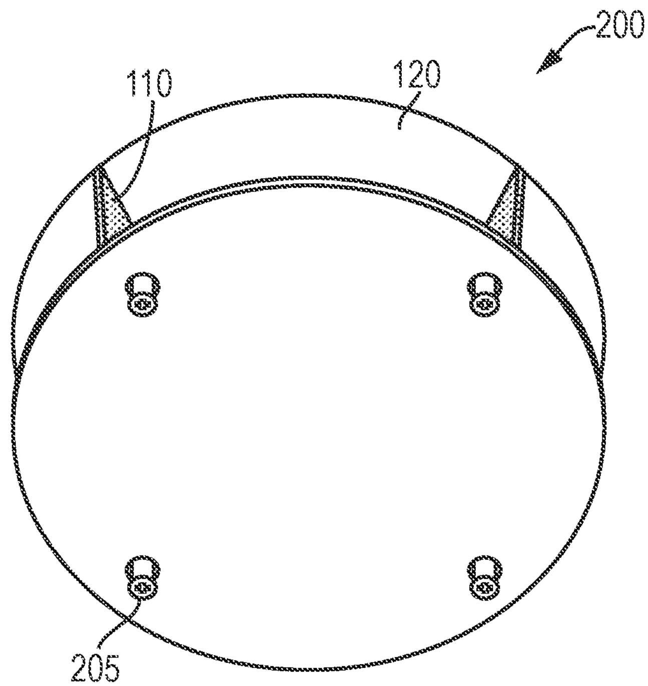


FIG. 2

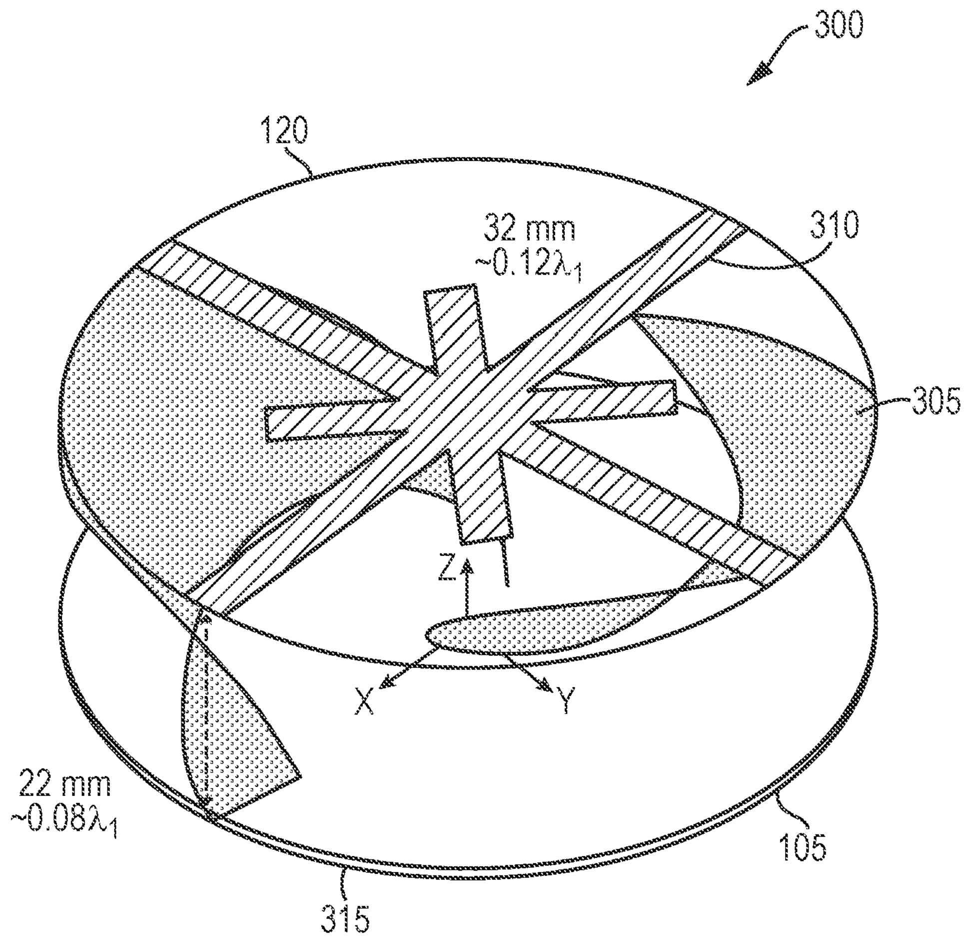


FIG. 3

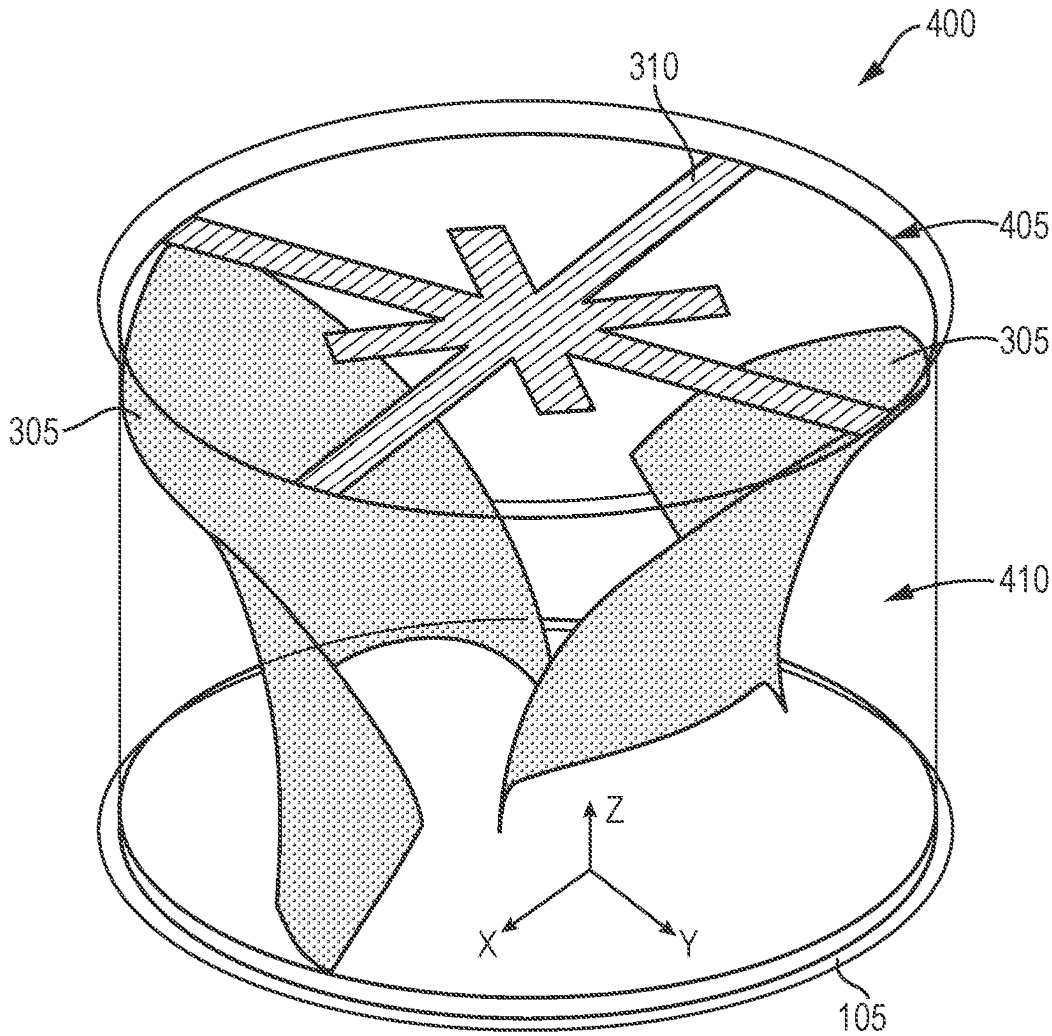


FIG. 4

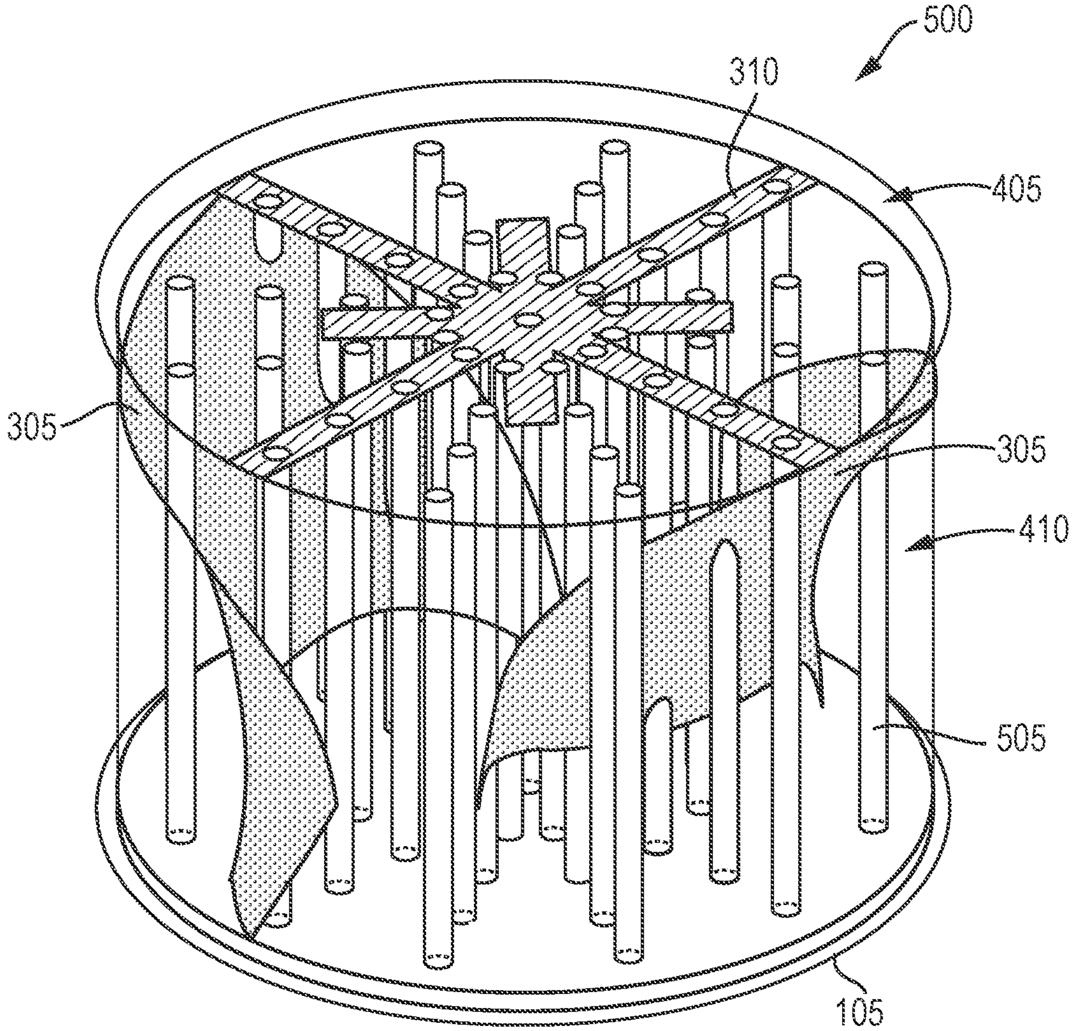


FIG. 5

600

Parameter	Specifications		
Frequency band	1545-1610 MHz (L1, G1, E1, B1, B1-2, L-Band Correction)	1217-1300 MHz (L2, G2, E6, B3)	1164-1214 MHz (L5, G3, E5a, E5, E5b, B2)
Return Loss	≥10 dB(≥9.2 dB)		
Rad. Efficiency	≥91 %	≥95 %	≥95 %
Realized Gain (RHCP)	3.5-3.8 dB (≥1 dB)	2.2-2.4 dB (≥0 dB)	2.3-2.8 dB (≥ -2 dB)
HPBW	110-114°(~130°)	118-120°(~140°)	120-121° (~150°)
FTB	≥39.5 dB (≥30 dB)	≥39.7 dB(≥27 dB)	≥39.5 dB (≥30 dB)
Axial Ratio (Max. @ Zenith)	0.1 dB (~1.8 dB)	0.1 dB (~1.8 dB)	0.1 dB (~3 dB)
ARBW (3dB)	132-158°(~130°)	104-114°(~100°)	102-106°(~90°)
Cross-polar ratio (@ Zenith)	≥55.2 dB (~20 dB)	≥62.3 dB (~ 20 dB)	≥61.9 dB (~15 dB)
Group Delay Variation (≤90°)	≤75 ps	≤152 ps	≤242 ps

FIG. 6

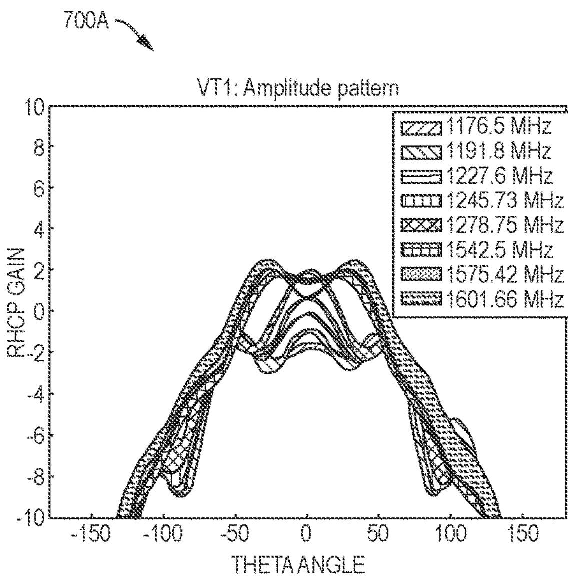

700A
VT1: Amplitude pattern
1176.5 MHz
1191.8 MHz
1227.6 MHz
1245.73 MHz
1278.75 MHz
1542.5 MHz
1575.42 MHz
1601.66 MHz
RHCP GAIN
THETA ANGLE

FIG. 7A

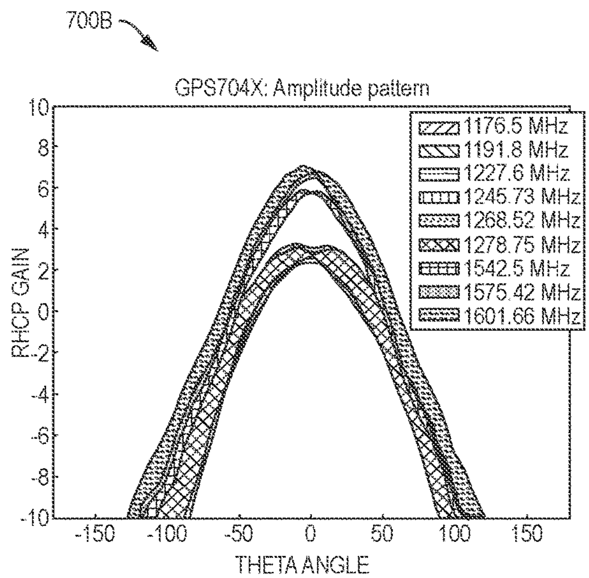

700B
GPS704X: Amplitude pattern
1176.5 MHz
1191.8 MHz
1227.6 MHz
1245.73 MHz
1268.52 MHz
1278.75 MHz
1542.5 MHz
1575.42 MHz
1601.66 MHz
RHCP GAIN
THETA ANGLE

FIG. 7B

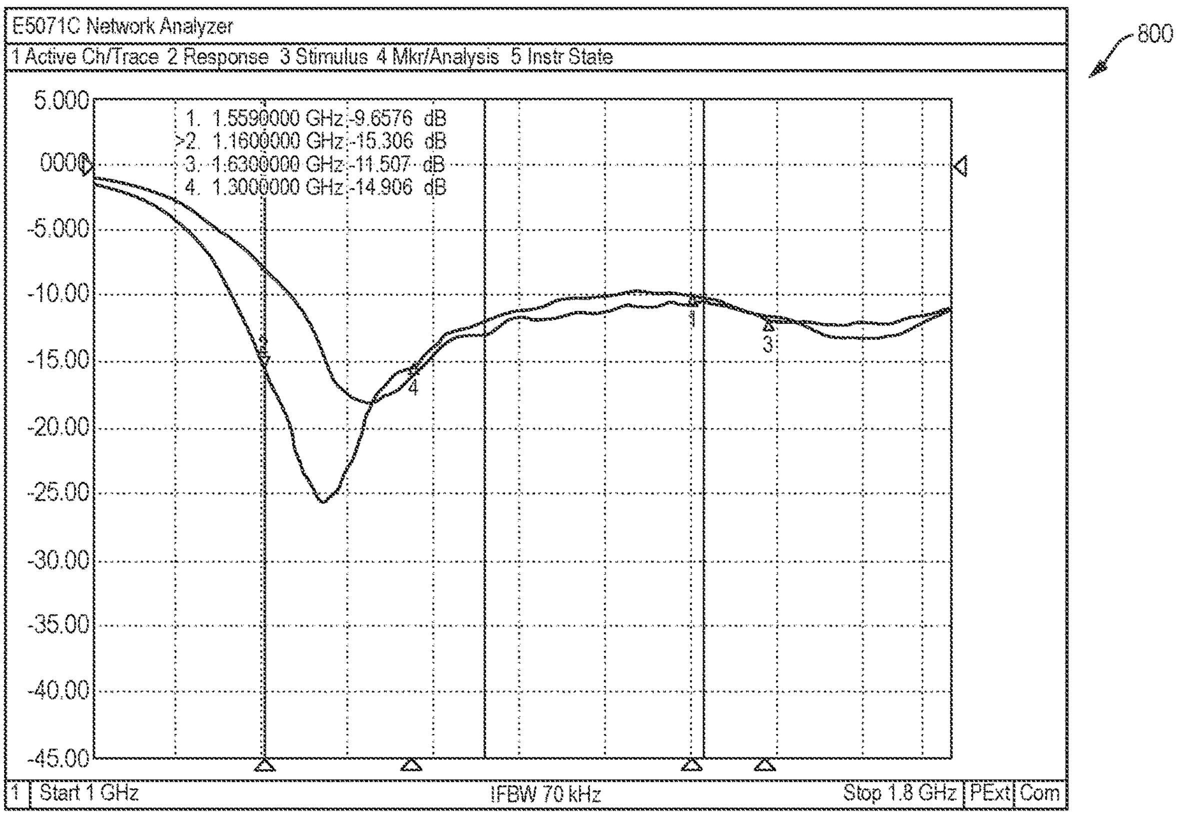

800
E5071C Network Analyzer
1 Active Ch/Trace 2 Response 3 Stimulus 4 Mkr/Analysis 5 Instr State
1. 1.5590000 GHz -9.6576 dB
>2. 1.1600000 GHz -15.306 dB
3. 1.6300000 GHz -11.507 dB
4. 1.3000000 GHz -14.906 dB
5.000
0.000
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
1 Start 1 GHz
IFBW 70 kHz
Stop 1.8 GHz
PExt
Com

FIG. 8

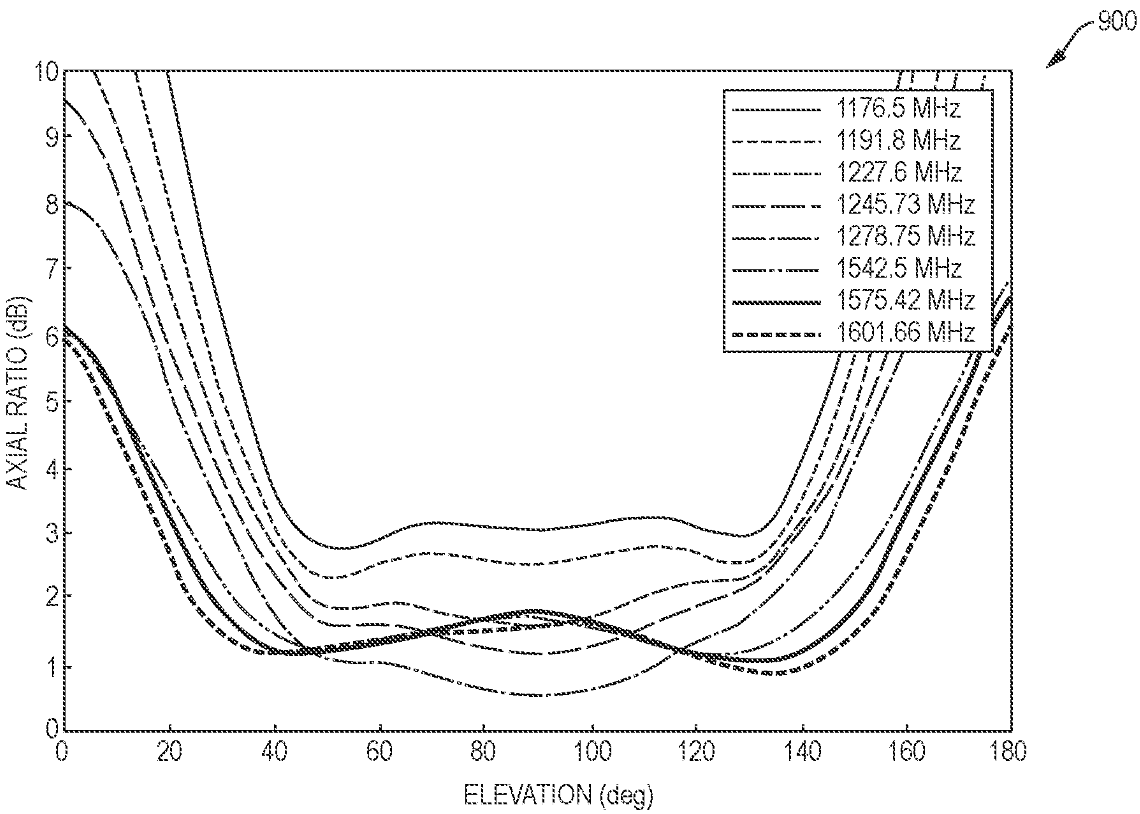

900
AXIAL RATIO (dB)
ELEVATION (deg)
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
120
140
160
180
1176.5 MHz
1191.8 MHz
1227.6 MHz
1245.73 MHz
1278.75 MHz
1542.5 MHz
1575.42 MHz
1601.66 MHz

FIG. 9

COMPACT THREE-DIMENSIONAL ULTRA-WIDEBAND ANTENNA WITH IMPROVED CIRCULAR POLARIZATION PURITY

BACKGROUND

[0001] Navigation systems, such as well-known global navigation satellite systems (GNSS) or terrestrial based navigation systems (TNS), typically utilize one or more radio frequency bands for transmission of navigation signals. In many applications, it is desirous for an antenna that is to be utilized with a navigation system receiver to be capable of receiving radio frequencies on a plurality of bands. By enabling such multi-band operation, the navigation system may be utilized with one or more differing GNSS constellations and/or terrestrial navigation systems.

[0002] Additionally, it may be desirous for an antenna to have an ultra-wideband range to enable reception of signals outside of conventional GNSS/TNS bands. One example is Xona Space Systems and their proposed Pulsar technology aiming at broadcasting navigation signals in L-band and C-band. Satellite navigation systems employ circular polarization to mitigate unpredictable Faraday rotation that occurs in the ionosphere for linearly polarized radiation. Ultra-wideband, i.e., those having a fractional bandwidth ≥20%, circularly polarized radiation antenna structures are commonly multi-feed or traveling wave. For multi-feed circularly polarized antennas, there is a requirement to separate the feed points to reduce mutual couplings between the points to yield the desired wider bandwidth. However, this separation compromises the size factor.

[0003] Compact size is often a necessary and/or desired feature of an antenna for use with navigation systems. Conventionally, stacked patch antennas or helical antennas have been utilized to achieve the necessary bandwidth without requiring a plurality of antennas. However, these types of antennas may not be as compact as required for particular applications. Furthermore, these designs are typically more sensitive to manufacturing tolerances and often require post assembly tuning. Wideband designs are normally not as compact as narrower band antennas as size and bandwidth are normally proportionally related. A compact wideband antenna is a very desirable feature but is challenging to achieve. Additionally, the manufacturing of these conventional antennas may not be economical, nor may they utilize the latest in manufacturing technologies.

[0004] Conventional antennas that utilize a travelling wave structure, such as the well-known Vivaldi antenna, typically have a well-defined phase center over an ultra-wide bandwidth. Further, they have a limited dispersion that yields minimal group delay variations over spatial distribution and frequencies. These features may be observable as controlled phase center offsets (PCO) and phase center variations (PCV) where, e.g., the PCO and PCVs are within 5 mm. Tighter PCOs and PCVs translated to higher precision positions for navigation systems, which is desirous for safety critical applications such as autonomous transportation.

SUMMARY

[0005] The above and other disadvantages are overcome by providing a compact three-dimensional ultra-wideband antenna that provides improved circular polarization purity in accordance with illustrative embodiments of the present invention. The antenna structures described herein illustratively generate a quasi-traveling wave and cover an ultra-wideband range. A three-dimensional structure enables the optimal use of volume to achieve wideband radiation through field configuration in the medium.

[0006] In accordance with an illustrative embodiment of the present invention, a set of radiators are arranged extending upward from the top of a base. Illustratively, the base is a printed circuit board, which enables ease of integration of the antenna into a larger system or sub-assembly. Each radiator has a short-circuited stub connected thereto along the base. The short-circuited stubs act as secondary radiators for improving bandwidth and circular polarization purity while preserving compactness. Illustratively, this is achieved by multi-resonance and forcing wave direction ("wave torquing") without the need to add additional volume to the antenna. A conventional feed circuit may be utilized at feed points located on the bottom of the base to connect to each of the radiators. The feed points are illustratively separated to reduce mutual coupling, thereby improving the antenna's bandwidth performance.

[0007] The radiators and stubs are encased in a dielectric material. When encased in a dielectric material with a high relative permittivity, the overall antenna size may be reduced, thereby promoting compactness.

[0008] In another illustrative embodiment of the present invention, a pair of three-dimensional curved radiators extend up from the top of a base. The radiators are encased in a dielectric and are fed from the bottom of the base. The three-dimensional curved radiators enable wave torquing in a dielectric medium for wideband circular polarization radiation. The curved radiators maximize the use of the volume of the antenna, while the use of a dielectric encasement helps to make the antenna compact.

[0009] The dielectric may be a solid, a fluid, such as a gas or liquid, a gel, a paste, or a combination thereof. The dielectric material may be chosen based on a variety of factors including, e.g., permittivity, operating temperature range, size considerations, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The above and further advantages of the present invention are described below in conjunction with the accompanying drawings in which like numbers indicate identical or functionally similar elements, of which:

[0011] FIG. **1**A is a perspective view of an exemplary antenna in accordance with an illustrative embodiment of the present invention;

[0012] FIG. **1**B is a perspective view of an exemplary antenna in accordance with an illustrative embodiment of the present invention;

[0013] FIG. **2** is a perspective bottom view of an exemplary antenna in accordance with an illustrative embodiment of the present invention;

[0014] FIG. **3** is a perspective view of an exemplary antenna in accordance with an illustrative embodiment of the present invention;

[0015] FIG. **4** is a perspective view of an exemplary fluid filled antenna in accordance with an illustrative embodiment of the present invention;

[0016] FIG. **5** is a perspective view of an exemplary fluid filled antenna in accordance with an illustrative embodiment of the present invention;

[0017] FIG. **6** is a chart detailing simulated and measured results of an antenna built in accordance with an illustrative embodiment of the present invention;

[0018] FIG. **7**A is a graph illustrating realized gain of an antenna built in accordance with an illustrative embodiment of the present invention;

[0019] FIG. **7**B is a graph illustrating realized gain of a conventional antenna;

[0020] FIG. **8** is a graph showing measured return loss of an antenna built in accordance with an illustrative embodiment of the present invention; and

[0021] FIG. **9** is a graph showing the axial ratio of an antenna built in accordance with an illustrative embodiment of the present invention.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

[0022] Embodiments of the present disclosure are directed to a compact antenna that is inspired from the well-known Vivaldi design. Illustrative embodiments described herein utilize a wave torquing technique to improve polarization purity for either right-hand circularly polarized (RHCP) or left-hand circularly polarized (LHCP) antennas. The antenna structure illustratively generates a quasi-traveling wave and covers an ultra-wideband range. In accordance with an illustrative embodiment described herein, the bandwidth covers approximately 1.16-1.6265 GHz, which covers the GPS L1-L5 bands as well as the Xona's Pulsar signal frequencies. As will be appreciated by those skilled in the art, by changing dimensions utilized, the antenna may be modified to cover alternative bandwidths. Therefore, the description of a particular set of ranges of frequencies covered by an illustrative embodiment of the antenna should be taken as exemplary only.

[0023] FIG. **1**A is a perspective view of an exemplary antenna **100**A in accordance with an illustrative embodiment of the present invention. The antenna **100**A illustratively comprises of a base **105** onto which the other components are layered. Base **105** is illustratively shown as circular, but in accordance with illustrative embodiments of the present invention, may have any shape. Therefore, the depiction of a circular base **105** should be taken as exemplary only.

[0024] Illustratively, base **105** serves to define an imaginary X-Y plane that will be used to describe the location of other elements of the antenna. However, it should be noted that base **105** does not need to be flat. Therefore, the depiction of base **105** as being flat should be taken as exemplary only. As used herein, the top of base **105** is the side wherein radiating elements, described below, are disposed, while the bottom of the base is the opposite side. Similarly, the axis extending away from the top side of the base shall be referred to as the positive Z-axis herein.

[0025] A set of radiators **110** are arranged around the base **105** and extend upwards from the base. Each radiator has a predefined shape, e.g., an equation based exponential taper, a right-angled triangle, etc. Illustratively, the radiators have a height that is sub-wavelength from the lowest operating frequency of the antenna. This three-dimensional profile of the illustrative antenna creates a quasi-traveling wave structure that provides enhanced bandwidth performance. In an illustrative embodiment, the radiators **110** are arranged equidistant around the base; however, in alternative embodiments they may be arranged in non-equidistant locations, such as that shown and described below in reference to FIG. **1**B.

[0026] Each radiator **110** has an associated stub **115** that lies on the base **105** and is operatively interconnected with the radiator. Illustratively, the stubs are short circuited; however, in alternative embodiments they may not be short-circuited. Therefore, the description of short-circuited stubs should be taken as exemplary only and to also include non-short-circuited stubs.

[0027] The short-circuited stubs act as secondary radiators and work to improve circular polarization purity and bandwidth of the antenna. The short-circuited stubs enable wave torquing to improve the circular polarization purity. As used herein the term wave torquing means generally providing wave guidance in a desired direction. The stubs are illustratively shown in a position that is counterclockwise (when viewed from above the top side of the base). In this configuration, right hand circular polarization is improved. If they are located on the clockwise side of radiator **110**, left hand circular polarization will be improved.

[0028] The radiators and short-circuited stubs may be made of any conductive material. In accordance with an illustrative embodiment, they are made of copper. However, it is expressly contemplated that other materials may be utilized. Therefore, the description of copper being used should be taken as exemplary only.

[0029] In accordance with an illustrative embodiment of the invention, the radiators **110**, short-circuited stubs **115**, and top of the base **105** are encased in a dielectric material **120**. Dielectric material **120** illustratively extends from the top of base **105** to the top of radiators **110**. In an illustrative embodiment, the dielectric material **120** has a permittivity greater than 2. The use of dielectric materials with higher permittivity allows the antenna to be reduced in size, but with a lowered gain.

[0030] Further, in accordance with illustrative embodiments, the dielectric material may comprise a solid, a fluid (liquid, gas, or gel), or a hybrid combination thereof. In an illustrative embodiment of the present invention, dielectric material **120** is ceramic. By utilizing certain materials as a dielectric, the antenna may be additively manufactured by the use of, for example, 3D printers. One example of such a material is ceramic infused thermoplastic. This capability of being additively manufactured works to reduce the overall cost, and ease-of-use and ease of manufacture of antennas as described herein. The description of any particular construction technique and/or material should be taken as exemplary only.

[0031] FIG. **1**B is a perspective view of an exemplary antenna **100**B in accordance with an illustrative embodiment of the present invention. Exemplary antenna **100**B is similar in design to antenna **100**A. However, only two radiators **110** and short-circuited stubs **115** are provided. As can be seen from antenna **100**B, the radiators and associated short-circuited stubs are not arranged equidistant around the edge of the base **105**. In this illustrative embodiment, the radiation pattern will be skewed as compared to antenna **100**A and will have a lower gain. In this exemplary embodiment, the phase angle between the two feed points will be 90°. While antenna **100**B is shown and described with two radiators that are offset 90°, the principles of the present invention may be utilized with other offsets. Therefore, the description of two radiators offset by 90° should be taken as exemplary only.

[0032] In accordance with alternative embodiments of the present invention, any number of radiators/short-circuited stub pairings may be utilized. Therefore, the depiction of antenna **100**A having four radiators and antenna **100**B having two radiators should be taken as exemplary only. Additionally, it should be noted that antenna **100**A may be converted to antenna **100**B by adjusting the feed network to only operate two of the radiators. This may occur due to an intentional decision or as the result of a failure of the feed network, damage to the antenna, etc. In this way, an antenna built in accordance with embodiments of the present invention may provide additional functionality and/or redundancy.

[0033] FIG. **2** is a perspective view **200** of a bottom side of an exemplary antenna in accordance with an illustrative embodiment of the present invention. As can be seen from exemplary view **200**, feed points **205** are aligned beneath each of the radiators **110** of the antenna **100**A. They are further placed a distance away from the geometric middle point of the base **105** X-Y plane to enable impedance matching and reduced mutual coupling among the ports. Illustratively, these feed points **205** are implemented as 50 Ohm coaxial feed points. However, it should be noted that in alternative embodiments of the present invention, differing types of feeds may be utilized. Therefore, the description 50 Ohm coaxial feeds should be taken as exemplary only.

[0034] In operation, a conventional quad feed circuit (not shown) is operatively connected to feed points **205** to provide the necessary phase differenced feeding to provide circular polarization.

[0035] FIG. **3** is a perspective view of an exemplary antenna **300** in accordance with an illustrative embodiment of the present invention. In exemplary antenna **300**, the radiators **110** have been replaced by curved radiating elements **305**. These curved radiating elements **305** are arranged to create wave torquing to improve circular polarity in accordance with an illustrative embodiment of the present invention. As noted above, the term wave torquing means generally providing wave guide in a desired direction as the wave propagates along a radiation (longitudinal) direction, setting up a quasi-traveling wave in the structure. This three-dimensional arrangement sets up the radiation fields with an optimized use of volume to yield a wideband circularly polarized radiation in a compact space.

[0036] Illustratively, the curved radiating elements **305** are equation-based exponential tapers that originate from their corresponding feed points located on the base **105** and taper exponentially away, at their inner edges, from the geometric central point of the base. This tapering occurs in the positive Z axis while its tapering inner-edges, where the radiation fields are set up, undergo a rotation to cause the antenna to have circularly polarized radiation. Should the rotation be clockwise (when viewed from above the antenna), the antenna will be left hand circularly polarized. Conversely, should the rotation be counterclockwise, the antenna will be right hand circularly polarized.

[0037] In an illustrative embodiment, the amount of rotation of the inner edges of the curved radiating elements along the Z-axis is dependent on the electrical length of the waveguiding structure, i.e., the curved radiator. The rotation angle at any point of the inner edge corresponds to the instantaneous phase angle with respect to the guided wave's target frequency of operation. Illustratively, the feed point is utilized as the signal phase origin for reference.

[0038] The curved radiating element's surface that extends from the inner edge towards the circumferential edge of the dielectric material encasing the radiators undergoes a rotation of twice the angular rate of rotation of the inner edge at any point along the Z-axis. To choke (phase) the return currents, to improve the antenna's bandwidth, the curved radiating elements each have a section removed at the edges contacting the top side of the base **105**. Illustratively, the section that is removed is a half torus. Illustratively, the half torus is centered along the Z-axis with an outside radius that is less than the base. This allows the radiating elements to be in contact with the base.

[0039] A pair of crossed arms **310** may be located on top of the dielectric material to enhance polarization purity. The crossed arms **310** also causes the structure to act as a loop-dipolar structure that helps in impedance matching for a higher bandwidth. Illustratively, the crossed arms **310** may be made of the same material as radiators. In alternative embodiments, the crossed arms may be made of a differing material.

[0040] Illustratively, the side edge of base **105** has side plating **315** to provide a current path continuity from the outer edges of radiators **305** to the ground plane of base **105**.

[0041] FIG. **4** is an exemplary perspective view of an exemplary antenna **400** in accordance with an illustrative embodiment of the present invention. Antenna **400** is of a similar configuration as antenna **300** but utilizes a fluid dielectric **410**. To accommodate the fluid dielectric **410**, an outer shell **405** is required to contain the fluid. Outer shell **405** may be made of a dielectric, such as a plastic casing. The use of a plastic casing should be taken as exemplary only.

[0042] The fluid, which may be a liquid, gas, gel, paste, or combination thereof, may vary depending on the operating environment of the antenna. For example, a liquid may be utilized in environments where there is not a chance of the liquid freezing, while a gas may be used in alternative embodiments where extremely low temperatures are expected. A reference liquid dielectric is water. However, water freezes at a relatively high temperature, i.e., zero degrees Celsius. A mixture of water and alcohol may be utilized in environments where the temperature may be significantly below zero degrees Celsius.

[0043] The material of the fluid dielectric may be dielectric itself or may be conductive and then be mixed with suitable materials to create a desired permittivity. For example, solutes could be added to water (or another liquid) to create a desired dielectric. Examples of solutes that may be utilized with water include, e.g., Sodium Chloride ($NaCl$).

[0044] In alternative embodiments of the present invention, ionic liquids may be utilized as fluid dielectric. One exemplary ionic liquid that may be utilized is choline L-alanine; however, other ionic liquids may be utilized in alternative embodiments. Therefore, the description of choline L-alanine should be taken as exemplary only.

[0045] FIG. **5** is a perspective view of an exemplary antenna **500** in accordance with an illustrative embodiment of the present invention. Exemplary antenna **500** is of a similar configuration as antenna **400** but utilizes a hybrid dielectric. That is, a fluid dielectric **410** is utilized in conjunction with dielectric rods **505**. Dielectric rods **505** may be made of ceramic or any other material that has the desired dielectric properties, such as graphene oxide. The description of ceramic and graphene oxide being used as the dielectric rods **505** should be taken as exemplary.

[0046] By combining both a fluid dielectric **410** and dielectric rods **505**, the desired permittivity of the combined (hybrid) dielectric may be obtained. In accordance with an illustrative embodiment, customized permittivity values may be obtained by adjusting the mixture ratio of one or more fluid dielectrics **410**. It should be noted that while circular rods are shown, in accordance with alternative embodiments of the present invention other shapes may be utilized. Therefore, the depiction of circularly shaped dielectric rods **505** should be taken as exemplary only. Further, while FIG. **5** depicts the dielectric rods **505** extending from the base to the same height as the radiators, in alternative embodiments, they may have differing heights.

[0047] FIG. **6** is a chart **600** detailing simulated and measured specifications for an antenna constructed in accordance with the principles of the present invention. These specifications are for an antenna constructed in accordance with the embodiment shown and described in connection with FIG. **1**. The constructed antenna had a diameter of 69.2 mm±0.4 mm and a height of 20.95 mm±0.1 mm and utilized PREPERM® ABS1000, as the dielectric. The radiators were 0.08 times the wavelength of the lowest frequency. Using the selected dielectric material, the antenna was additively manufactured by use of a 3-D printer. The constructed antenna weighed 176.4 grams.

[0048] The values in parentheses in the chart are the measured values and the other values were those generated via simulation. As can be seen from the measured results, the exemplary antenna achieves the desired goal of providing ultra-wide bandwidth in a compact form factor.

[0049] FIGS. **7**A-B show the realized gain from the antenna constructed according to the principles of the present invention **700**A and the gain from using a conventional GPS-**704**-X antenna **700**B, available from NovAtel, Inc. of Calgary, Alberta, Canada. The GPS-**704**-X antenna has a diameter of 185 mm, a height of 69 mm, and a weight of 468 grams, which is substantially larger than the antenna built in accordance with an illustrative embodiment of the present invention.

[0050] As can be seen from charts **700**A and **700**B, the novel antenna of the present invention compares favorably in realized gain to a conventional antenna. These charts also highlight the stability of the radiation patterns as compared to the GPS-**704**-X antenna over azimuth angles. It has a very wide bandwidth and a very compact size. Further, as it may be additively manufactured, total costs may be lower as compared to a conventionally made antenna.

[0051] FIG. **8** is a graph illustrating the measured return loss of an antenna built in accordance with an illustrative embodiment of the present invention. FIG. **9** is a graph illustrating measured axial ratio of an antenna built in accordance with an illustrative embodiment of the present invention. As can be seen from FIGS. **8** and **9**, antennas constructed in accordance with embodiments of the present invention have excellent broadband circularly polarized performance.

[0052] While the present invention has been shown and described using various dimensions, radio frequency bandwidths, materials, shapes, number of radiating elements, etc., it should be noted that the principles of the present invention may be utilized in differing configurations. Therefore, the description contained herein should be taken as exemplary only.

What is claimed is:

1. An antenna comprising:

a base with a first side and a second side, the base having a first shape and a geometric central point;

a set of N radiators on the first side of the base, the N radiators lying in a plane substantially perpendicular to the base are arranged in a rotation manner about the geometric central point, wherein each of the N radiators has a second shape;

wherein each of the N radiators has a stub attached thereto along the first side of the base, the stubs acting as secondary radiators for improving circular polarization purity and the bandwidth of the antenna;

wherein the N radiators and the stubs are encased in a dielectric material; and

a set of N feed points having, each of the N feed points having a first electrical connection connected to one of the set of N radiators, spaced at a distance away from the geometric central point, with each of the N feed points having a second electrical connection connected to the second side of the base, wherein each of the N feed points has a difference in phase of its input signal relative to an adjacent feed point's input signal, the difference in phase being an angle to the adjacent radiator for generating circularly polarized radiation.

2. The antenna of claim **1** wherein the stubs are short-circuited.

3. The antenna of claim **1** wherein the first shape and a parallel cross-section of the dielectric material encasing the N radiators and the stubs are identical.

4. The antenna of claim **3** wherein the first shape and the dielectric material have their extents containing fully the radiators and stubs.

5. The antenna of claim **1** wherein the second shapes are equation-based exponential tapers originating from a predefined point on the base and tapering exponentially away from the geometric central point towards straight edges along the planes substantially perpendicular to the base.

6. The antenna of claim **5** wherein a height of the second shapes is a sub-wavelength with respect to a lowest frequency of operation.

7. The antenna of claim **1** wherein the dielectric has a relative permittivity of greater than two.

8. The antenna of claim **7** wherein the dielectric material is a ceramic.

9. The antenna of claim **8** wherein the ceramic is a variant capable of being additively manufactured.

10. The antenna of claim **9** wherein the ceramic is a ceramic infused thermoplastic.

11. The antenna of claim **7** wherein the dielectric material is a fluid substrate contained in a dielectric shell.

12. The antenna of claim **11** wherein the fluid substrate is dielectric.

13. The antenna of claim **11** wherein the fluid substrate is partially conductive.

14. The antenna of claim **11** wherein the fluid substrate has solutes dissolved in the liquid to alter its electrical properties.

15. The antenna of claim **7** wherein the dielectric material is a combination of one or more solid substrates and one or more liquid substrates.

16. The antenna of claim **1** wherein the stubs are arranged in a clockwise direction of each of the N radiators to cause the antenna to have improved left hand circular polarization purity and bandwidth.

17. The antenna of claim **1** wherein the stubs are arranged in a counterclockwise direction of each of the N radiators to cause the antenna to have improved right hand circular polarization purity and bandwidth.

18. The antenna of claim **1** wherein the second side of the base is metalized to act as a ground plane.

19. The antenna of claim **1** wherein the N radiators create a quasi-traveling wave, having sub-wavelength, with respect to a lowest frequency of operation, dimension along an axis perpendicular to the top side of the base.

20. The antenna of claim **1** wherein the antenna has a fractional bandwidth of at least 20%, thereby qualifying the antenna as ultra-wideband.

21. The antenna of claim **1** wherein the dielectric and N radiators are additively manufactured.

22. The antenna of claim **1** wherein extents of the base and a cross-section of the dielectric material encasing the N radiators and the stubs are within sub-wavelength with respect to a lowest frequency of operation.

23. An antenna comprising:

a circular base having a top side and a bottom side and a geometric central point;

two or more radiators contacting top side traces of the base, wherein the radiators have a first shape, the first shape being a three-dimensional structure extending from the top side surface of the base, each radiator of first shape arranged in a sequential rotation manner about the geometric central point at an angle of 180° apart for a pair;

wherein the two or more radiators create a quasi-traveling wave and circularly polarized radiation through wave guiding;

wherein the two or more radiators and the top side of the base are encased in a dielectric material having a top side; and

two or more feed points having first electrical connections connected to the two or more radiators at the top side traces of the base, separate from the geometric central point for improved bandwidth, with second electrical connections connected to the bottom side of the base, wherein each of the feed points has a phase difference of its input signal to its other feed point's input signal of 180° for a pair, and sequentially rotated phases for more radiators.

24. The antenna of claim **23** wherein the base has side plating to provide continuity of current from the edges of the radiators to the bottom side of the base.

25. The antenna of claim **23** wherein the height of the first shapes, and a height of the dielectric material encasing the radiators, are a sub-wavelength with respect to a lowest frequency of operation.

26. The antenna of claim **23** wherein the dielectric material has a relative permittivity of greater than two.

27. The antenna of claim **23** wherein the dielectric material is a ceramic.

28. The antenna of claim **27** wherein the ceramic is a variant that can be additively manufactured.

29. The antenna of claim **28** wherein the ceramic is a ceramic infused thermoplastic.

30. The antenna of claim **23** wherein the second side of the base is metalized to act as a ground plane.

31. The antenna of claim **23** wherein the antenna has a fractional bandwidth of at least 20% thereby qualifying the antenna as ultra-wideband.

32. The antenna of claim **23** wherein the dielectric and radiating shapes are additively manufactured.

33. The antenna of claim **23** wherein the dielectric material is a fluid substrate contained in a dielectric shell.

34. The antenna of claim **33** wherein the fluid substrate is dielectric.

35. The antenna of claim **33** wherein the fluid substrate is partially conductive.

36. The antenna of claim **33** wherein the fluid substrate has solutes dissolved in the liquid to alter its electrical properties.

37. The antenna of claim **33** wherein the dielectric material is a combination of one or more solid substrates and one or more liquid substrates.

38. The antenna of claim **23** wherein a diameter of the circular base and a cross-section of the dielectric material encasing the radiators are within a sub-wavelength with respect to a lowest frequency of operation

39. The antenna of claim **23** further comprising a widened cross metallic trace connecting ends of the two or more radiators is located on the top surface of the dielectric material encasing the radiators and top side of the base.

40. The antenna of claim **23** wherein the first shapes are equation-based exponential tapers originating from the corresponding feed points and tapering exponentially away, at inner edges, from the geometric central point along a longitudinal direction while its tapering inner-edges, where the radiation fields are setup, undergo a clockwise rotation to cause the antenna to have left hand circularly polarized radiation;

wherein the amount of rotation of the inner-edges along the longitudinal direction is dependent on the electrical length of the radiator, where the rotation angle at any point of the inner-edge corresponds to the instantaneous phase angle with respect to a guided wave's target frequency of operation referencing from the feed point as the signal phase origin;

wherein the surface extending from the inner edge of a first shape towards the circumferential edge of the dielectric material encasing the radiators undergo a clockwise rotation of twice the angular rate of rotation of the inner-edge at any point along the longitudinal direction;

wherein the rotating surfaces of the first shapes has a section removed at the edges contacting the top side of the base, where the section of the surfaces removed constitute a half torus, for the purpose of phasing the return currents to improve the bandwidth.

41. The antenna of claim **23** wherein the first shapes are equation-based exponential tapers originating from the corresponding feed points and tapering exponentially away, at the inner edges, from the geometric central point along the longitudinal direction while its tapering inner-edges, where the radiation fields are setup, undergo a counterclockwise rotation to cause the antenna to have right hand circularly polarized radiation;

wherein the amount of rotation of the inner-edges along the longitudinal direction is dependent on the electrical length of the waveguiding structure, where the rotation angle at any point of the inner-edge corresponds to the instantaneous phase angle with respect to a guided wave's target frequency of operation referencing from the feed point as the signal phase origin;

wherein the surface extending from the inner edge of a first shape towards the circumferential edge of the dielectric material encasing the radiators undergo a counterclockwise rotation of twice the angular rate of rotation of the inner edge at any point along the longitudinal direction;

wherein the rotating surfaces of the first shapes has a section removed at the edges contacting the top side of the base, where the section of the surfaces removed constitute a half torus, for the purpose of phasing the return currents to improve the bandwidth.

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