



(51) International Patent Classification:
H01Q 5/01 (2006.01) *H01Q 13/08* (2006.01)
H01Q 1/38 (2006.01) *H01Q 9/04* (2006.01)

(21) International Application Number:
PCT/US2009/066786

(22) International Filing Date:
4 December 2009 (04.12.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PI 20090004 2 January 2009 (02.01.2009) MY

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

[Continued on next page]

(54) Title: MULTIBAND HIGH GAIN OMNIDIRECTIONAL ANTENNAS

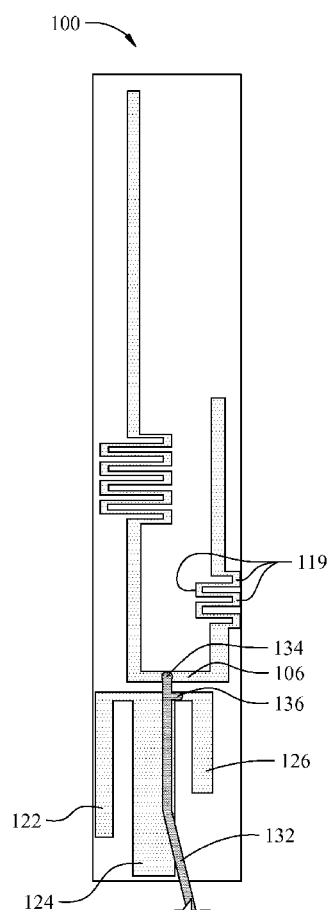


Fig. 1B

(57) Abstract: Exemplary embodiments are provided of multiband high gain omnidirectional antennas. In one exemplary embodiment, an antenna generally includes first and second radiating elements. The first radiating element is configured to produce a first radiation pattern at a first operating frequency. The second radiating element is configured to produce a second radiation pattern at a second operating frequency. Each of the first and second radiating elements includes a meandering or helical portion.





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Published:

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH,

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

MULTIBAND HIGH GAIN OMNIDIRECTIONAL ANTENNAS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a PCT International Application of (and claims priority to) Malaysian Patent Application No. PI 20090004 filed January 2, 2009. The entire disclosure of the above application is incorporated herein by reference.

FIELD

[0002] The present disclosure relates to multiband high gain omnidirectional antennas.

BACKGROUND

[0003] This section provides background information related to the present disclosure which is not necessarily prior art.

[0004] Omnidirectional antennas are useful for a variety of wireless communication devices because the radiation pattern allows for good transmission and reception from a mobile unit. Sometimes, printed circuit board omnidirectional antennas are used. Generally, an omnidirectional antenna is an antenna that radiates power generally uniformly in one plane with a directive pattern shape in a perpendicular plane, where the pattern is often described as "donut shaped."

SUMMARY

[0005] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0006] According to various aspects, exemplary embodiments are provided of multiband high gain omnidirectional antennas. In one exemplary embodiment, an antenna generally includes a first radiating element and a second radiating element. The first radiating element is configured to produce a first radiation pattern at a first operating frequency. The second radiating element is configured to produce a second radiation pattern at a second operating frequency. Each of the first and second radiating elements includes a meandering or helical portion. The meandering or helical portion may be disposed generally between straight portions of a radiating element. A connecting element may connect the first and second radiating elements.

[0007] In another exemplary embodiment, a multiband high gain omnidirectional antenna generally includes a first radiating element operable for producing a first radiation pattern at a first operating frequency. The first radiating

element includes at least one meandering portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a first signal at the first operating frequency. The antenna also includes a second radiating element operable for producing a second radiation pattern at a second operating frequency. The second radiating element includes at least one meandering portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a second signal at the second operating frequency.

[0008] In a further exemplary embodiment, a multiband high gain omnidirectional antenna generally includes a substrate having a radiation portion and a power feed portion. At least one power dissipation element is coupled to the power feed portion of the substrate. A first radiating element is coupled to the radiation portion of the substrate. The first radiating element is operable for producing a first radiation pattern at a first operating frequency. The first radiating element includes at least one meandering portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a first signal at the first operating frequency. A second radiating element is also coupled to the radiation portion of the substrate. The second radiating element is operable for producing a second radiation pattern at a second operating frequency. The second radiating element includes at least one meandering portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a second signal at the second operating frequency. A connecting element is connected to the $\lambda/4$ radiating portions of the first and second radiating elements. The first and second radiating elements are laterally spaced apart and extend generally perpendicular in a same direction from the connecting element.

[0009] An additional exemplary embodiment of a multiband high gain omnidirectional antenna generally includes first and second radiating elements comprising electrically-conductive wire. The first radiating element is operable for producing a first radiation pattern at a first operating frequency. The first radiating element includes at least one helical portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a first signal at the first operating frequency. The second radiating element is operable for producing a second radiation pattern at a second operating frequency. The second radiating element includes at least one helical portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a second signal at the

second operating frequency. A connecting element connects to the $\lambda/4$ radiating portions of the first and second radiating elements. The first and second radiating elements are laterally spaced apart and extend generally perpendicular in a same direction from the connecting element. Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0010] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure in any way.

[0011] FIG. 1A is a view of a multiband high gain omnidirectional printed circuit board antenna, according to an exemplary embodiment of the present disclosure;

[0012] FIG. 1B is a view of a multiband high gain omnidirectional printed circuit board antenna with a coaxial cable conductor attached thereto, according to an exemplary embodiment of the present disclosure;

[0013] FIG. 2A is an exemplary line graph of voltage standing wave ratio (VSWR) versus frequency from 2 gigahertz to 6 gigahertz for the exemplary antenna shown in FIG. 1B;

[0014] FIG. 2B is a table setting forth the VSWR and frequency (in Gigahertz) for the five data points shown in the line graph of FIG. 2A;

[0015] FIG. 3 is an exemplary radiation pattern illustrating gain (in decibels referenced to isotropic gain (dBi)) for the exemplary antenna shown in FIG. 1B at a frequency of 2.45 Gigahertz;

[0016] FIG. 4 is an exemplary radiation pattern illustrating gain (in decibels referenced to isotropic gain (dBi)) for the exemplary antenna shown in FIG. 1B at a frequency of 4.9 Gigahertz;

[0017] FIG. 5 is an exemplary radiation pattern illustrating gain (in decibels referenced to isotropic gain (dBi)) for the exemplary antenna shown in FIG. 1B at a frequency of 5.75 Gigahertz;

[0018] FIG. 6 is a view of the multiband high gain omnidirectional printed circuit board antenna shown in FIG. 1 with exemplary dimensions provided for purposes of illustration only according to exemplary embodiments;

[0019] FIG. 7 is a view of the multiband high gain omnidirectional printed circuit board antenna with the coaxial cable conductor attached thereto shown in FIG. 1B with exemplary dimensions provided for purposes of illustration only according to exemplary embodiments; and

[0020] FIG. 8 is a view of the multiband high gain omnidirectional printed circuit board antenna with the coaxial cable conductor attached thereto shown in FIG. 1B, and also illustrating the lengths ($\lambda/2$, $\lambda/4$) of various portions of the antenna with exemplary dimensions provided for purposes of illustration only according to exemplary embodiments; and

[0021] FIG. 9 is a view of a multiband high gain omnidirectional antenna including copper wire radiating elements with helical portions, a tubular member or sleeve, and a coaxial cable attached thereto, according to an exemplary embodiment of the present disclosure.

DETAILED DESCRIPTION

[0022] In the following description, numerous specific details are set forth such as examples of specific components, devices, methods, in order to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to a person of ordinary skill in the art that these specific details need not be employed, and should not be construed to limit the scope of the disclosure. In the development of any actual implementation, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints. Such a development effort might be complex and time consuming, but is nevertheless a routine undertaking of design, fabrication and manufacture for those of ordinary skill.

[0023] According to aspects of the present disclosure, antennas disclosed herein have a higher gain omnidirectional in multiband (*e.g.*, a first frequency bandwidth of 2.4 gigahertz to 2.5 gigahertz and a second frequency bandwidth of 4.9 gigahertz to 5.875 gigahertz). A general rule of thumb is that the collinear array can achieve a gain of between about 5 dBi to about 6dBi. Exemplary embodiments disclosed herein include antennas that can operate over more frequency bands and have higher gain.

[0024] FIG. 1A illustrates a multiband omnidirectional high gain antenna 100 embodying one or more aspects of the present disclosure. As shown, the antenna 100 includes radiating elements 102, 104 and a connecting element 106

connecting the radiating elements 102, 104. The radiating element 102 is configured to produce a first radiation pattern at a first frequency (*e.g.*, a frequency within a first frequency bandwidth of 2.4 gigahertz to 2.5 gigahertz), while the radiating element 104 is configured to produce a second radiation pattern at a second frequency (*e.g.*, a frequency within a second frequency bandwidth of 4.9 gigahertz to 5.875 gigahertz). The first radiating element 102 includes first and second straight portions 108, 112 (which may also be referred to as lower and upper radiating elements, respectively) with a bending or meandering portion 116 therebetween. The second radiating element 104 includes first and second straight portions 110, 114 (which may also be referred to as lower and upper radiating elements, respectively) with a bending or meandering portion 118 therebetween. In this particular example, each radiating element 102, 104 includes two straight portions with a meandering portion therebetween. The meandering portion 116 of the first radiating element 102 includes nine bending points 117, while the meandering portion 118 of the second radiating element 104 includes five bending points 119. During operation, the meandering portions 116 and 118 may be operable for phase-reversal and matching. Alternative embodiments may include one or more radiating elements having more or less than two straight portions, more than one meandering portion, and/or a meandering portion configured differently (*e.g.*, slanted portions, zigzags, etc.) with more or less bending points than what is shown in FIG. 1.

[0025] With continued reference to FIG. 1A, the antenna 100 also includes power dissipation elements 122, 124, 126. The power dissipation elements 122, 124, 126 reduce the impact of a power feed on the first radiation pattern and the second radiation pattern. Power dissipation elements 122, 124, 126 may have identical lengths and/or widths, or they may have varied lengths and/or widths as shown in FIG. 1A. For example, FIG. 6 illustrates exemplary dimensions in millimeters of the lengths and widths of the power dissipation elements 122, 124, 126 according to an exemplary embodiment, where these dimensions are provided for purposes of illustration only and not for purposes of limitation. As shown in FIG. 6, the power dissipation elements 122, 124, 126 (FIG. 1A) may have respective lengths of about 19 millimeters, 22 millimeters, and 13 millimeters and respective widths of about 2 millimeters, 5 millimeters, and 2 millimeters. With reference to FIGS. 1 and 8, the power dissipation elements 122 and 126 (FIG. 1) may each have a length (as shown in FIG. 8) of $\lambda/4$. In this example, the power dissipation element 122 may have a

length of $\lambda/4$ where λ is the wavelength of the first signal at the first operating frequency, such as within the frequency bandwidth of 2.4 gigahertz to 2.5 gigahertz, while the power dissipation element 126 may have a length of length of $\lambda/4$ where λ is the wavelength of a second signal at the second operating frequency, such as within the frequency bandwidth of 4.9 gigahertz to 5.875 gigahertz. While three power dissipation elements are shown in FIG. 1A, other embodiments may include more or less than three power dissipation elements and/or dissipation elements having a different configuration (e.g., shapes, sizes, locations, etc.).

[0026] As also shown in FIG. 1A, the antenna 100 includes a substrate 120 that supports the radiating elements 102, 104. For descriptive purposes, the substrate 120 may be considered as having a radiation portion 128 and a power feed portion 130. The first and second radiating elements 102, 104 are located in the radiation portion 128, such that the first and second radiating elements 102, 104 are laterally spaced apart from each other on the board 120. The first and second radiating elements 102, 104 extend generally perpendicular in a same direction (upward in FIG. 1A) from the connecting element 106. The power dissipation elements 122, 124, 126 are located in the power feed portion 128. The substrate 120 may be made from a number of different materials. In various exemplary embodiments, the substrate 120 comprises a flex material or dielectric or electrically non-conductive printed circuit board material. In embodiments in which the substrate 120 is formed from a relatively flexible material, the antenna 100 may be flexed or configured so as to follow the contour or shape of the antenna housing profile. For example, having a flexible substrate 120 may allow the antenna 100 to be flexed or configured into a generally cylindrical shape (or at least a portion thereof) so as to follow the contour or shape of a cylindrical antenna housing in which the antenna 100 may be housed. The substrate 120 may be formed from a material having low loss and dielectric properties. According to some embodiments the substrate 120 is a printed circuit board. In such embodiments, the radiating elements 102, 104 may be traces on the printed circuit board. The substrate 120 may be sized differently depending, for example, on the particular application as varying the thickness and dielectric constant of the substrate may be used to tune the frequencies. For example, FIG. 7 illustrates exemplary dimensions in millimeters of the substrate 120 according to an exemplary embodiment, where these dimensions are provided for purposes of illustration only and not for purposes of limitation. As shown in FIG. 7,

the substrate 120 may have a length of about 132 millimeters, a width of about 21 millimeters, and a thickness of about .80 millimeters. Alternative embodiments may include a substrate with a different configuration (*e.g.*, different shape, size, material, etc.). Still other embodiments may not include a printed circuit board substrate, such as the antenna 200 shown in FIG. 9 and described below.

[0027] In exemplary embodiments, the radiating elements 102, 104 may have lengths as shown in FIGS. 6, 7, and/or 8. In this regard, FIGS. 6, 7, and 8 illustrate exemplary dimensions of the radiating elements 102, 104 according to exemplary embodiments, where these dimensions are provided for purposes of illustration only and not for purposes of limitation. As shown in FIG. 6, the radiating elements 102, 104 may have respective lengths of 103 millimeters and 43 millimeters. Also shown in FIG. 6, the first radiating element's first and second straight portions 108, 112 may have respective lengths of about 23 millimeters and 66 millimeters, while the second radiating element's first and second straight portions 110, 114 may have respective lengths of about 8 millimeters and 23 millimeters. With reference to FIGS. 1 and 8, the first radiating element's first and second straight portions 108, 112 (FIG. 1) may be configured to be $\lambda/4$ and $\lambda/2$ radiating elements (as shown in FIG. 8) where λ is the wavelength of a first signal at the first operating frequency, such as within the frequency bandwidth of 2.4 gigahertz to 2.5 gigahertz. The second radiating element's first and second straight portions 110, 114 (FIG. 1) may be configured to be $\lambda/4$ and $\lambda/2$ radiating elements (as shown in FIG. 8) where λ is the wavelength of a second signal at the second operating frequency, such as within the frequency bandwidth of 4.9 gigahertz to 5.875 gigahertz. As one of ordinary skill in the art will recognize on reading this disclosure, the operating bands may be tuned by varying the length of radiating element 102 (and the lengths of its first and/or second straight portions 108, 112), the length of radiating element 104 (and the lengths of its first and/or second straight portions 110, 114), or a combination thereof. While two radiating elements 102 and 104 are shown, more or less than two radiating elements are possible. Varying the thickness and dielectric constant of the substrate may also be used to tune the frequencies.

[0028] Radiating elements 102, 104, and power dissipation elements 122, 124, 126 may be made of metallic material, such as, for example, copper, silver, gold, alloys, combinations thereof, other electrically-conductive materials, etc. Further, radiating elements 102, 104, and power dissipation elements 122, 124, and

126 may be made out of the same or different materials. Still further, radiating element 102 may be made of a different material than the material from which the radiating element 104 is formed. Similarly, power dissipation elements 122, 124, 126 may each be made out of the same material, different material, or some combination thereof.

[0029] FIG. 1B illustrates the antenna 100 with a power feed 132 attached thereto. The power feed 132 supplies power to the antenna 100. In the example shown in FIG. 1B, the power feed 132 is a coaxial cable conductor. Alternative embodiments however, may include any other suitable type of power feed structure as is known in the art.

[0030] With continued reference to FIG. 1B, the power feed 132 has a center conductor 134 and an outer jacket 136. The center conductor 134 is attached to the connecting element 106 to supply power to radiating elements 102, 104. The outer jacket 136 is coupled to the power dissipation elements 122, 124, 126 to dissipate power from the outer jacket 136. Optionally, the power feed 132 may be attached to the length of the power dissipation element 124 or directly to the substrate 120, for example, to provide additional strength and/or reinforcement to the power feed 132. Generally, the connections may be accomplished using solder connections, but other types of connections are possible, such as, for example, snap connectors, press fit connections, or the like.

[0031] FIG. 2A is an exemplary line graph of voltage standing wave ratio (VSWR) versus frequency from 2 gigahertz to 6 gigahertz for the exemplary antenna 100 shown in FIG. 1A. The data depicted in the line graph (FIG. 2A) generally demonstrates that the performance of the antenna 100 is relatively good and well matched. The performance will depend, at least in part, on the PCB material. In regard to the data shown in FIG. 2A, the PCB material was Rogers.

[0032] FIG. 2B is a table of VSWR at specific data points, i.e. specific frequencies, derived from the graph of FIG. 2A. By way of background, VSWR may be used to indicate reception quality of an antenna. The VSWR indicates interference caused by reflected waves and may serve as an indicator of reflected waves bouncing back and forth within a transmission line of the assembly. In theory, a 1:1 VSWR represents a perfect match of antenna components. But in practice, a 2:1 VSWR is typically acceptable. Higher VSWR may indicate a degradation of signal reception by an antenna assembly.

[0033] FIG. 3 is an exemplary radiation pattern illustrating gain (in decibels referenced to isotropic gain (dBi)) for the exemplary antenna 100 shown in FIG. 1A at a frequency of 2.45 Gigahertz. In this example, the antenna 100 had a maximum or peak gain of about 5.1 dBi, an average gain of about 2.8 dBi, and a maximum angle of about 127.9 degrees. The data depicted in the FIG. 3 generally demonstrates that the antenna 100 achieved higher peak gain with omnidirectional at 2.45 GHz and smaller physical size. The performance will depend, at least in part, on the PCB material. In regard to the data shown in FIG. 3, the PCB material was Rogers. With continued reference to FIG. 3, “Free Az” refers to the measurements of the antenna in free space and the position is Azimuth, whereas “Total Field (V+H)” refers to the field of Vertical Polarization and Horizontal Polarization.

[0034] FIG. 4 is an exemplary radiation pattern illustrating gain (in decibels referenced to isotropic gain (dBi)) for the exemplary antenna 100 shown in FIG. 1A at a frequency of 4.9 Gigahertz. In this example, the antenna 100 had a maximum or peak gain of about 4.6 dBi, an average gain of about 3.1 dBi, and a maximum angle of about 190.0 degrees. The data depicted in the FIG. 4 generally demonstrates that the antenna 100 achieved higher peak gain with omnidirectional at 4.9 GHz and smaller physical size. The performance will depend, at least in part, on the PCB material. In regard to the data shown in FIG. 4, the PCB material was Rogers.

[0035] FIG. 5 is an exemplary radiation pattern illustrating gain (in decibels referenced to isotropic gain (dBi)) for the exemplary antenna 100 shown in FIG. 1A at a frequency of 5.75 Gigahertz. In this example, the antenna 100 had a maximum or peak gain of about 4.7 dBi, an average gain of about 2.0 dBi, and a maximum angle of about 266.0 degrees. The data depicted in the FIG. 5 generally demonstrates that the antenna 100 achieved higher peak gain with omnidirectional at 5.75 GHz and smaller physical size. The performance will depend, at least in part, on the PCB material. In regard to the data shown in FIG. 5, the PCB material was Rogers.

[0036] FIGS. 6 and 7 illustrate exemplary dimensions in millimeters that may be used for the antenna 100 shown in FIGS. 1A and 1B, respectively, for purposes of illustration only and not for purposes of limitation. In the particular embodiment shown in FIGS. 6 and 7, the PCB is a Rogers PCB. The materials and dimensions provided herein are for purposes of illustration only as a contact may be configured from different materials and/or with different dimensions. For example,

the dimensions may slightly change depending on which materials are selected for the various components of the antenna, the dielectric constant of the PCB, the coaxial cable length, etc.

[0037] FIG. 8 is a view of the antenna 100 shown in FIG. 1B, and also illustrating the lengths ($\lambda/2$, $\lambda/4$) of various portions of the antenna with exemplary dimensions provided for purposes of illustration according to exemplary embodiments. With continued reference to FIG. 8, a general rule of thumb is that the collinear array has $\lambda/2$, $\lambda/4$ and phase-reversal or matching (e.g., via meander sections 116, 118 in FIG. 1B), but other embodiments may include dimensions that may slightly change due to the selection of materials, dielectric constant of PCB, cable length, etc.

[0038] FIG. 9 illustrates an alternative embodiment of a multiband high gain omnidirectional antenna 200 embodying one or more aspects of the present disclosure. As shown in FIG. 9, the antenna 200 includes radiating elements 202, 204 and a connecting element 206 connecting the radiating elements 202, 204. In this example, the radiating elements 202, 204 may be formed from an electrically-conductive material, such as copper wire, etc. By way of comparison, the radiating elements 102, 104 of antenna 100 shown in FIGS. 1A and 1B may be traces on a printed circuit board.

[0039] With continued reference to FIG. 9, the antenna 200 includes an electrically-conductive tubular member 220, which is shown as a metal tube or sleeve in this example. The radiating elements 202, 204 and tubular member 220 may be made of metallic material, such as, for example, copper, silver, gold, alloys, combinations thereof, other electrically-conductive materials, etc. Further, the radiating elements 202, 204 and tube 220 may be made out of the same or different materials. Still further, the radiating element 202 may be made of a different material than the material from which the radiating element 204 is formed.

[0040] The antenna 200 includes a power feed 232 that supplies power to the antenna 200. In the example shown in FIG. 9, the power feed 232 is a coaxial cable conductor that extends or passes through the electrically-conductive tubular member 220. The power feed 232 has a center conductor 234 attached to the connecting element 206 to supply power to radiating elements 202, 204. The outer portion or jacket (e.g., metallic braid) of the power feed 232 may be coupled to the electrically-conductive tubular member 220 to dissipate power from the outer jacket

of the power feed. Generally, the connections may be accomplished using solder connections, but other types of connections are possible, such as, for example, snap connectors, press fit connections, crimping, or the like. By way of example, the outer portion of the power feed 232 may be coupled to the sleeve 220 by way of soldering or a crimping process. The sleeve 220 acts as the ground of the antenna 200 with the length of quarter wavelength of the low operating frequency band (*e.g.*, a first frequency bandwidth of 2.4 gigahertz to 2.5 gigahertz). Alternative embodiments however, may include any other suitable type of power feed and grounding structures known in the art.

[0041] The radiating element 202 is configured to produce a first radiation pattern at a first frequency (*e.g.*, a frequency within a first frequency bandwidth of 2.4 gigahertz to 2.5 gigahertz), while the radiating element 204 is configured to produce a second radiation pattern at a second frequency (*e.g.*, a frequency within a second frequency bandwidth of 4.9 gigahertz to 5.875 gigahertz). The first radiating element 202 includes first and second straight portions 208, 212 with a helical or coiled portion 216 therebetween. The second radiating element 204 includes first and second straight portions 210, 214 with a helical or coiled portion 218 therebetween. In this particular example, each radiating element 202, 204 includes two straight portions with a helical portion therebetween. During operation, the coils of the helical portions 216 and 218 may be operable for phase-reversal and matching. Alternative embodiments may include one or more radiating elements having more or less than two straight portions, more than one helical portion, and/or a helical portion configured differently than what is shown in FIG. 9.

[0042] In exemplary embodiments, the radiating elements 202, 204 may have respective lengths of 103 millimeters and 43 millimeters. As an example, the first radiating element 202 may include first and second straight portions 208, 212 having respective lengths of $\lambda/4$ and $\lambda/2$ where λ is the wavelength of a first signal at the first operating frequency, such as within the frequency bandwidth of 2.4 gigahertz to 2.5 gigahertz. Continuing with this example, the second radiating element 204 may include first and second straight portions 210, 214 having respective lengths of $\lambda/4$ and $\lambda/2$ where λ is the wavelength of a second signal at the second operating frequency, such as within the frequency bandwidth of 4.9 gigahertz to 5.875 gigahertz. The operating bands may be tuned by varying the length of radiating element 202, the length of radiating element 204, or a combination thereof. While

two radiating elements are shown, more or less than two radiating elements are possible.

[0043] Terms such as “upper,” “lower,” “inner,” “outer,” “inwardly,” “outwardly,” and the like when used herein refer to positions of the respective elements as they are shown in the accompanying drawings, and the disclosure is not necessarily limited to such positions. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context.

[0044] When introducing elements or features and the exemplary embodiments, the articles “a,” “an,” “the” and “said” are intended to mean that there are one or more of such elements or features. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements or features other than those specifically noted. It is further to be understood that the method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0045] The foregoing description of the embodiments of the present invention has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described.

CLAIMS

What is claimed is:

1. A multiband high gain omnidirectional antenna comprising:
 - a first radiating element including at least two generally straight portions and at least one meandering portion generally between the at least two straight portions, and configured to produce a first radiation pattern at a first operating frequency;
 - a second radiating element including at least two generally straight portions and at least one meandering portion generally between the at least two straight portions, and configured to produce a second radiation pattern at a second operating frequency; and
 - a connecting element connected to at least one straight portion of each of the first and second radiating elements, thereby connecting the first radiating element and the second radiating element;
 - the first and second radiating elements laterally spaced apart and extending generally perpendicular in a same direction from the connecting element.
2. The antenna of claim 1, wherein the meandering portions are configured to be operable for phase-reversal and matching.
3. The antenna of claim 1 or 2, wherein:
 - the at least two generally straight portions of the first radiating element include a $\lambda/4$ radiating portion between the at least one meandering portion and the connecting portion, and a $\lambda/2$ radiating portion disposed on a side of the at least one meandering portion opposite that of the $\lambda/4$ radiating portion, where λ is a wavelength of a first signal at the first operating frequency; and
 - the at least two generally straight portions of the second radiating element include a $\lambda/4$ radiating portion between the at least one meandering portion and the connecting portion, and a $\lambda/2$ radiating portion disposed on a side of the at least one meandering portion opposite that of the $\lambda/4$ radiating portion, where λ is a wavelength of a second signal at the second operating frequency.
4. The antenna of claim 1, 2, or 3, further comprising at least one power dissipation element.

5. The antenna of claim 4, further comprising:
 - a power feed coupled to the first radiating element and the second radiating element; and
 - a ground coupled to the at least one power dissipation element.
6. The antenna of claim 5, wherein the power feed comprises at least one coaxial cable.
7. The antenna of claim 4, 5, or 6, wherein the at least one power dissipation element comprises first, second, and third power dissipation elements, and the second power dissipation element is disposed generally between the first and third power dissipation elements.
8. The antenna of claim 4, 5, 6, or 7, wherein the antenna includes:
 - at least one power dissipation element having a length of about 19 millimeters and a width of about 2 millimeters;
 - at least one power dissipation element having a length of about 22 millimeters and a width of about 5 millimeters; and
 - at least one power dissipation element having a length of about 13 millimeters and a width of about 2 millimeters.
9. The antenna of any of the preceding claims, further comprising:
 - at least one $\lambda/4$ power dissipation element where λ is a wavelength of a first signal at the first operating frequency; and
 - at least one $\lambda/4$ power dissipation element where λ is a wavelength of a second signal at the second operating frequency.
10. The antenna of any of the preceding claims, wherein:
 - the first radiating element has an overall length of about 103 millimeters;
 - the at least two generally straight portions of the first radiating element include a first radiating portion between the at least one meandering portion and the connecting portion having a length of about 23 millimeters, and a second radiating portion disposed on a side of the at least one meandering portion opposite that of the first radiating portion and having a length of about 66 millimeters;
 - the second radiating element has an overall length of about 43 millimeters; and
 - the at least two generally straight portions of the second radiating element include a first radiating portion between the at least one meandering portion and the connecting portion having a length of about 8 millimeters, and a second radiating

portion disposed on a side of the at least one meandering portion opposite that of the first radiating portion and having a length of about 28 millimeters.

11. The antenna of any of the preceding claims, further comprising a substrate supporting the first radiating element, the second radiating element, and the connecting element.

12. The antenna of claim 11, wherein the substrate has a length of about 132 millimeters, a width of about 21 millimeters, and a thickness of about .80 millimeters.

13. The antenna of claim 11 or 12, wherein:
the substrate comprises a printed circuit board; and
the first radiating element, the second radiating element, and the connecting element comprise at least one trace on the printed circuit board.

14. The antenna of any of the preceding claims, wherein:
the meandering portion of the first radiating element includes nine bending points; and
the meandering portion of the second radiating element includes five bending points.

15. The antenna of any of the preceding claims, wherein:
the first operating frequency is between about 2.4 gigahertz and about 2.5 gigahertz; and
the second operating frequency is between about 4.9 gigahertz and about 5.875 gigahertz.

16. The antenna of claim 15, wherein the antenna is configured such that peak gain is between about 4.6 dBi and 6 dBi for the first and second operating frequencies.

17. The antenna of claim 15 or 16, wherein the antenna is configured such that voltage standing wave ratio is less than about 2:1 for the first and second operating frequencies.

18. The antenna of any claims 1, 2, 3, 4, 5, 6, 10, 15, 16, or 17, wherein the first and second radiating elements comprise electrically-conductive wires including the at least two generally straight portions and at least one meandering portion, wherein the electrically-conductive wires include helical portions defining the meandering portions.

19. The antenna of claim 18, wherein the electrically-conductive wire comprises copper.

20. The antenna of claim 18 or 19, further comprising an electrically-conductive tubular member and a coaxial cable coupled to the electrically-conductive tubular member, whereby the electrically-conductive tubular member is operable for grounding the antenna.

21. A system including the antenna of any of the preceding claims.

22. A multiband high gain omnidirectional antenna comprising:

a first radiating element operable for producing a first radiation pattern at a first operating frequency, the first radiating element including at least one meandering portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a first signal at the first operating frequency; and

a second radiating element operable for producing a second radiation pattern at a second operating frequency, the second radiating element including at least one meandering portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a second signal at the second operating frequency.

23. The antenna of claim 22, further comprising a connecting element connected to the $\lambda/4$ radiating portions of the first and second radiating elements.

24. The antenna of claim 22 or 23, wherein the first and second radiating elements are laterally spaced apart and extend generally perpendicular in a same direction from the connecting element.

25. The antenna of any of claims 22 to 24, wherein the meandering portions are configured to be operable for phase-reversal and matching.

26. The antenna of any of claims 22 to 25, further comprising at least one power dissipation element.

27. The antenna of claim 26, further comprising:

a power feed coupled to the first radiating element and the second radiating element; and

a ground coupled to the at least one power dissipation element.

28. The antenna of claim 27, wherein the power feed comprises at least one coaxial cable.

29. The antenna of claim 26, 27, or 28, wherein the at least one power dissipation element comprises three power dissipation elements of different lengths.

30. The antenna of claim 26, 27, or 28, or 29, wherein the antenna includes:

at least one power dissipation element having a length of about 19 millimeters and a width of about 2 millimeters;

at least one power dissipation element having a length of about 22 millimeters and a width of about 5 millimeters; and

at least one power dissipation element having a length of about 13 millimeters and a width of about 2 millimeters.

31. The antenna of any of claims 22 to 30, further comprising:

at least one $\lambda/4$ power dissipation element where λ is a wavelength of a first signal at the first operating frequency; and

at least one $\lambda/4$ power dissipation element where λ is a wavelength of a second signal at the second operating frequency.

32. The antenna of any of claims 22 to 31, wherein:

the first radiating element has a length of about 103 millimeters;

the $\lambda/4$ radiating portion of the first radiating element has a length of about 23 millimeters;

the $\lambda/2$ radiating portion of the first radiating element has a length of about 66 millimeters;

the second radiating element has a length of about 43 millimeters;

the $\lambda/4$ radiating portion of the second radiating element has a length of about 8 millimeters; and

the $\lambda/2$ radiating portion of the second radiating element has a length of about 28 millimeters.

33. The antenna of any of claims 22 to 32, further comprising a substrate supporting the first and second radiating elements.

34. The antenna of claim 33, wherein the substrate has a length of about 132 millimeters, a width of about 21 millimeters, and a thickness of about .80 millimeters.

35. The antenna of claim 33 or 34, wherein:

the substrate comprises a printed circuit board; and

the first and second radiating elements comprise at least one trace on the printed circuit board.

36. The antenna of any of claims 22 to 35, wherein:

the meandering portion of the first radiating element includes nine bending points; and

the meandering portion of the second radiating element includes five bending points.

37. The antenna of any of claims 22 to 35, wherein:

the first operating frequency is between about 2.4 gigahertz and about 2.5 gigahertz; and

the second operating frequency is between about 4.9 gigahertz and about 5.875 gigahertz.

38. The antenna of claim 37, wherein the antenna is configured such that peak gain is between about 4.6 dBi and 6 dBi for the first and second operating frequencies.

39. The antenna of claim 37 or 38, wherein the antenna is configured such that voltage standing wave ratio is less than about 2:1 for the first and second operating frequencies.

40. The antenna of any claims 22, 23, 24, 25, 26, 27, 28, 32, 37, 38, or 39, wherein the first and second radiating elements comprise electrically-conductive wires including the at least two generally straight portions and at least one meandering portion, wherein the electrically-conductive wires include helical portions defining the meandering portions.

41. The antenna of claim 40, wherein the electrically-conductive wire comprises copper.

42. The antenna of claim 40 or 41, further comprising an electrically-conductive tubular member and a coaxial cable coupled to the electrically-conductive tubular member, whereby the electrically-conductive tubular member is operable for grounding the antenna.

43. A system including the antenna of any of claims 22 to 42.

44. A multiband high gain omnidirectional antenna comprising:

a substrate including a radiation portion and a power feed portion;

at least one power dissipation element coupled to the power feed portion of the substrate;

a first radiating element coupled to the radiation portion of the substrate and operable for producing a first radiation pattern at a first operating frequency, the first radiating element including at least one meandering portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a first signal at the first operating frequency;

a second radiating element coupled to the radiation portion of the substrate and operable for producing a second radiation pattern at a second operating frequency, the second radiating element including at least one meandering portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a second signal at the second operating frequency;

a connecting element connected to the $\lambda/4$ radiating portions of the first and second radiating elements;

the first and second radiating elements laterally spaced apart and extending generally perpendicular in a same direction from the connecting element.

45. The antenna of claim 44, wherein:

the substrate comprises a printed circuit board; and

the first and second radiating elements and connecting element comprise at least one trace on the printed circuit board.

46. The antenna of claim 44 or 45, wherein:

the meandering portion of the first radiating element includes nine bending points; and

the meandering portion of the second radiating element includes five bending points.

47. The antenna of any of claims 44 to 46, wherein:

the first operating frequency is between about 2.4 gigahertz and about 2.5 gigahertz; and

the second operating frequency is between about 4.9 gigahertz and about 5.875 gigahertz.

48. The antenna of any of claims 44 to 47, wherein the antenna is configured such that peak gain is between about 4.6 dBi and 6 dBi for the first and second operating frequencies.

49. The antenna of claim 47 or 48, wherein the antenna is configured such that voltage standing wave ratio is less than about 2:1 for the first and second operating frequencies.

50. A system including the antenna of any of claims 44 through 49.

51. A multiband high gain omnidirectional antenna comprising:

a first radiating element comprising electrically-conductive wire and operable for producing a first radiation pattern at a first operating frequency, the first radiating element including at least one helical portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a first signal at the first operating frequency;

a second radiating element comprising electrically-conductive wire and operable for producing a second radiation pattern at a second operating frequency, the second radiating element including at least one helical portion disposed between a $\lambda/4$ radiating portion and a $\lambda/2$ radiating portion, where λ is a wavelength of a second signal at the second operating frequency;

a connecting element connected to the $\lambda/4$ radiating portions of the first and second radiating elements, the first and second radiating elements laterally spaced apart and extending generally perpendicular in a same direction from the connecting element.

52. The antenna of claim 51, further comprising:

an electrically-conductive tubular member; and

a coaxial cable coupled to the electrically-conductive tubular member.

53. The antenna of claim 51 or 52, wherein:

the first operating frequency is between about 2.4 gigahertz and about 2.5 gigahertz; and

the second operating frequency is between about 4.9 gigahertz and about 5.875 gigahertz.

54. The antenna of claim 53, wherein the antenna is configured such that peak gain is between about 4.6 dBi and 6 dBi for the first and second operating frequencies.

55. The antenna of any of claims 51 to 54, wherein the antenna is configured such that voltage standing wave ratio is less than about 2:1 for the first and second operating frequencies.

56. The antenna of any of claims 51 to 55, wherein the electrically-conductive wire comprises copper.

57. A system including the antenna of any of claims 51 to 56.

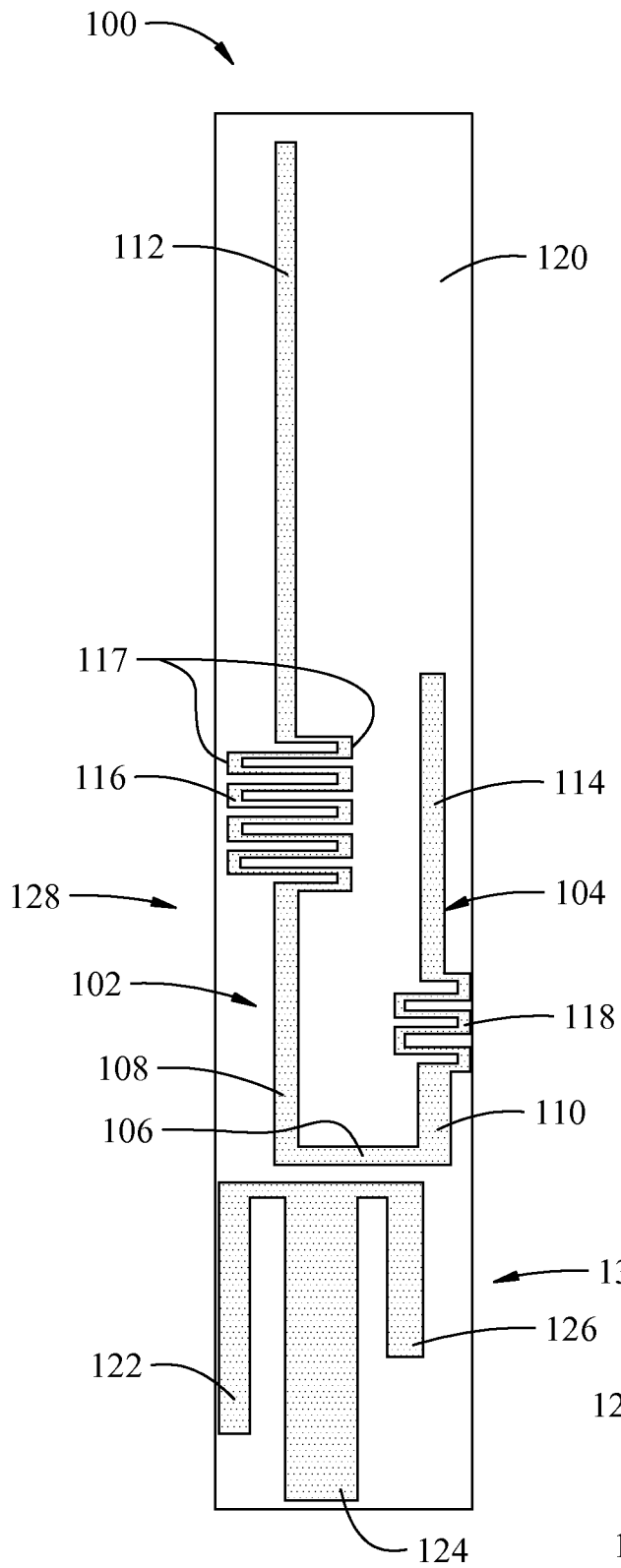


Fig. 1A

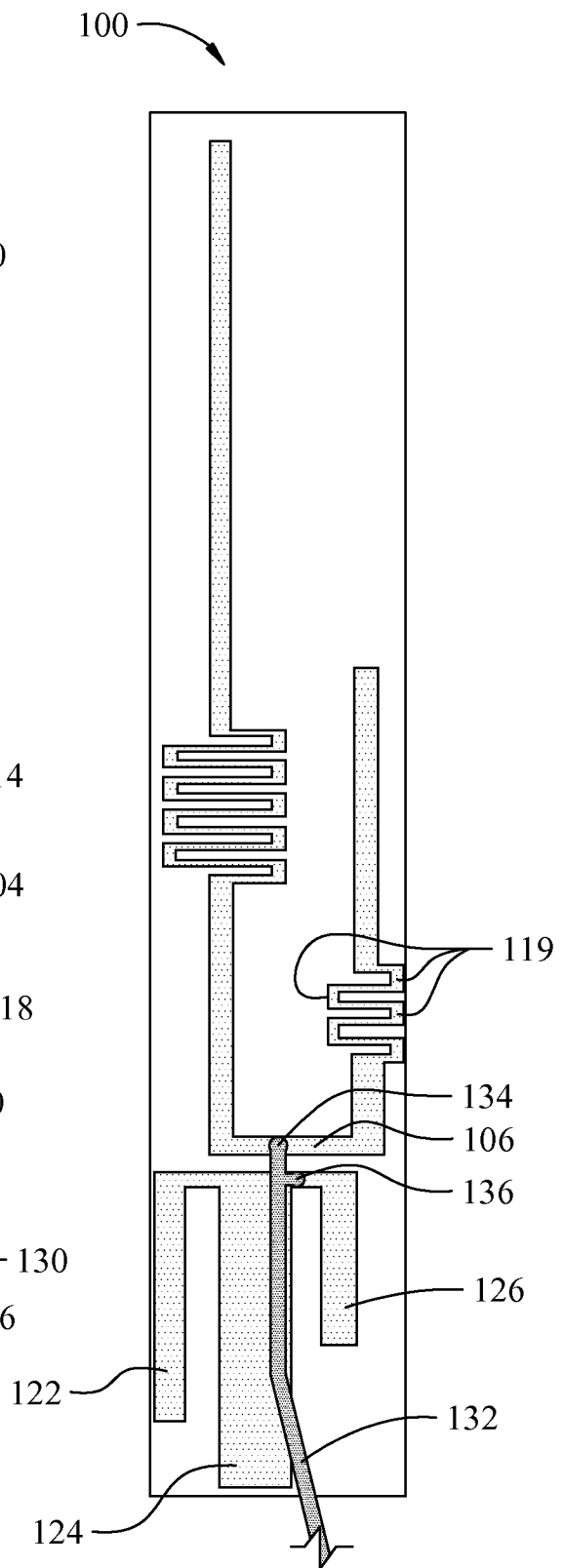


Fig. 1B

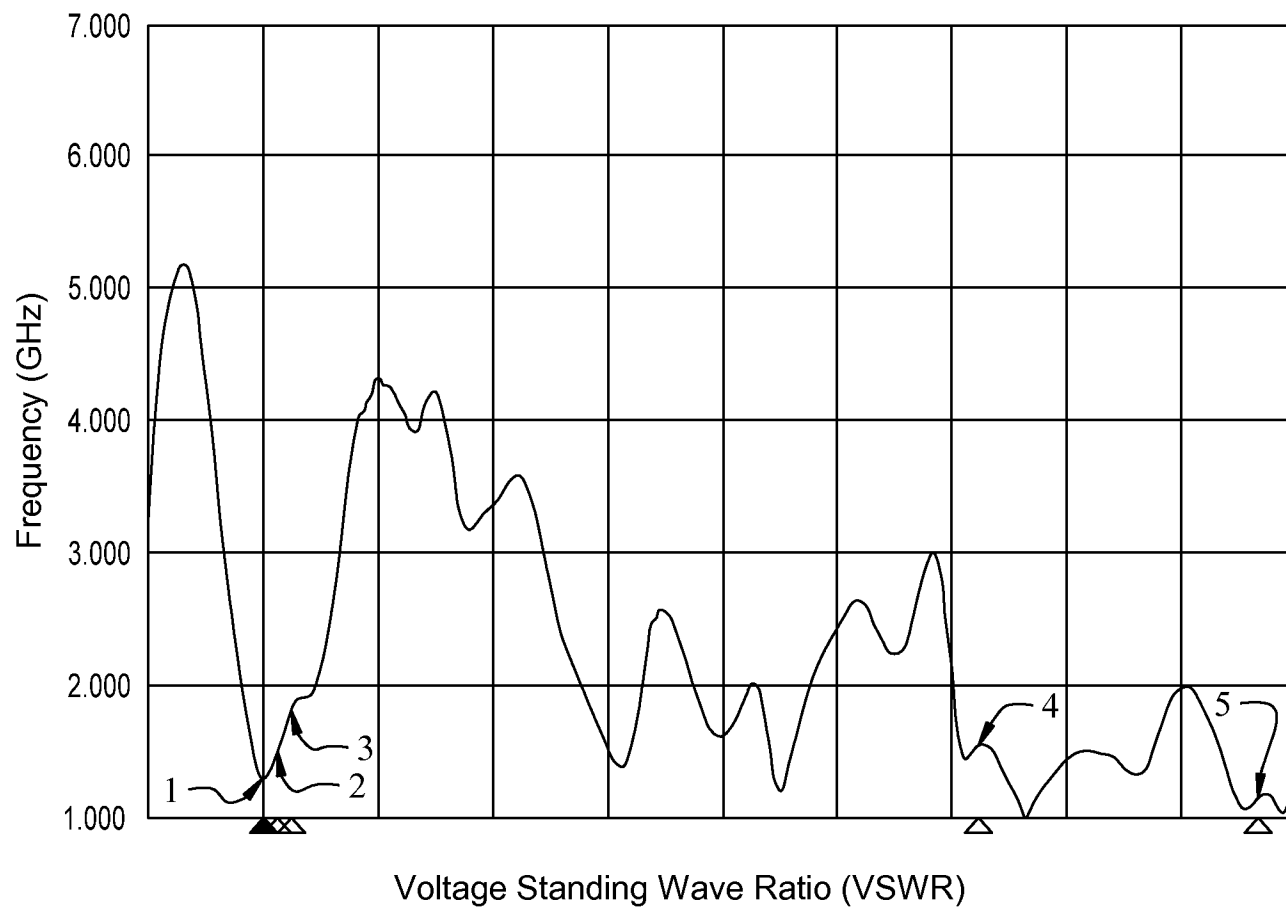


Fig. 2A

Data Point	GHz	VSWR
1	2.4000000	1.2945
2	2.4500000	1.5009
3	2.5000000	1.8121
4	4.9000000	1.5333
5	5.8750000	1.1402

Fig. 2B

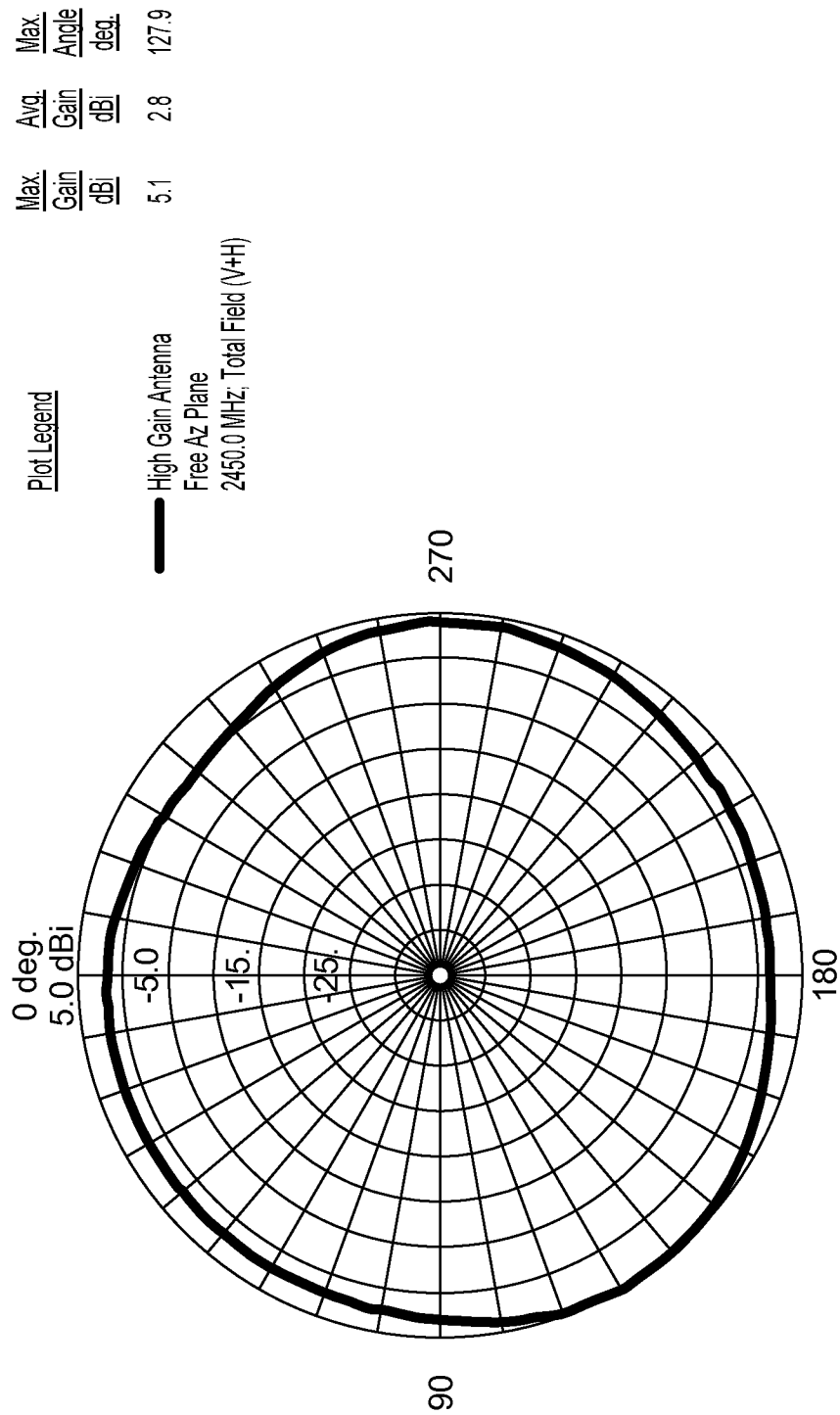


Fig. 3

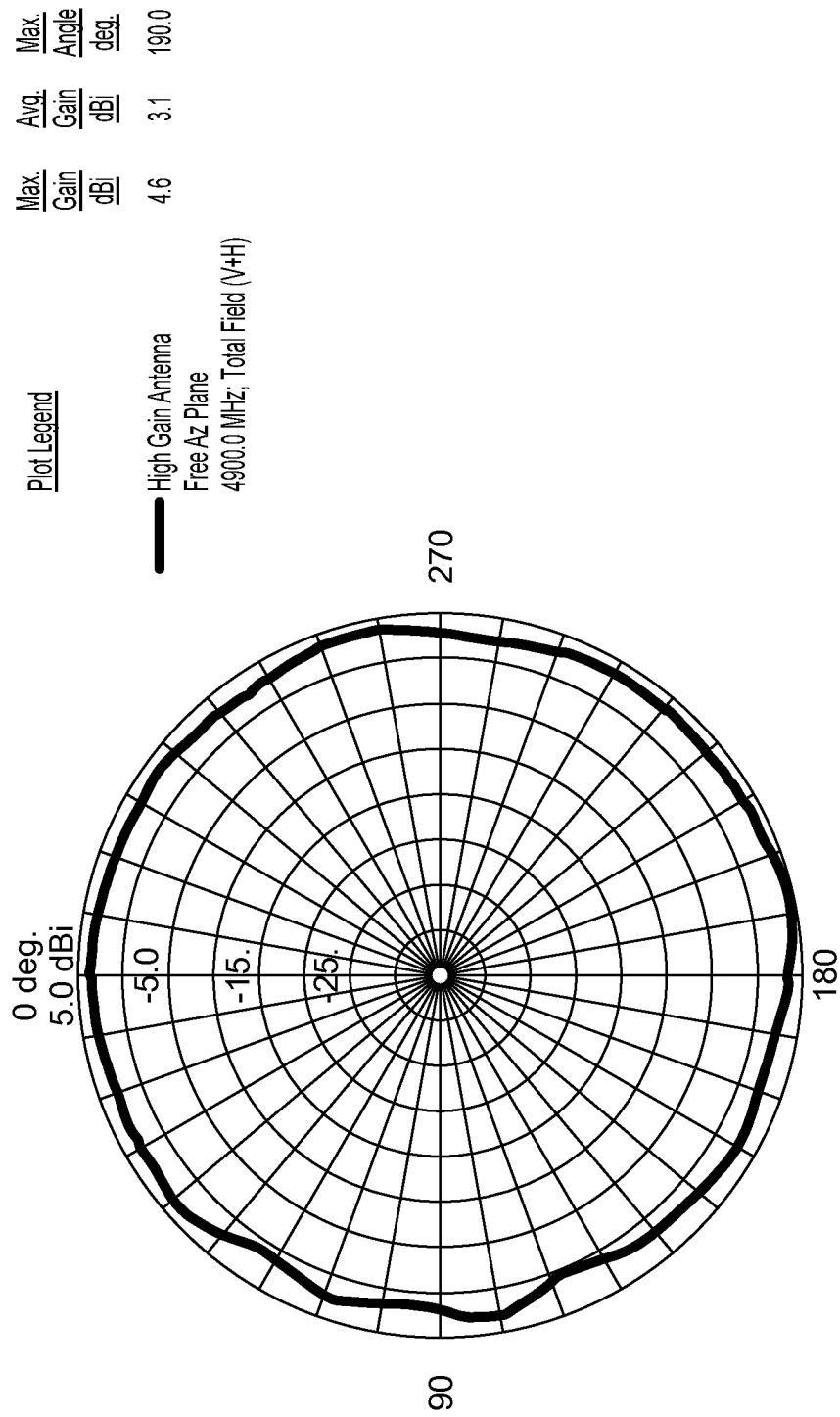


Fig. 4

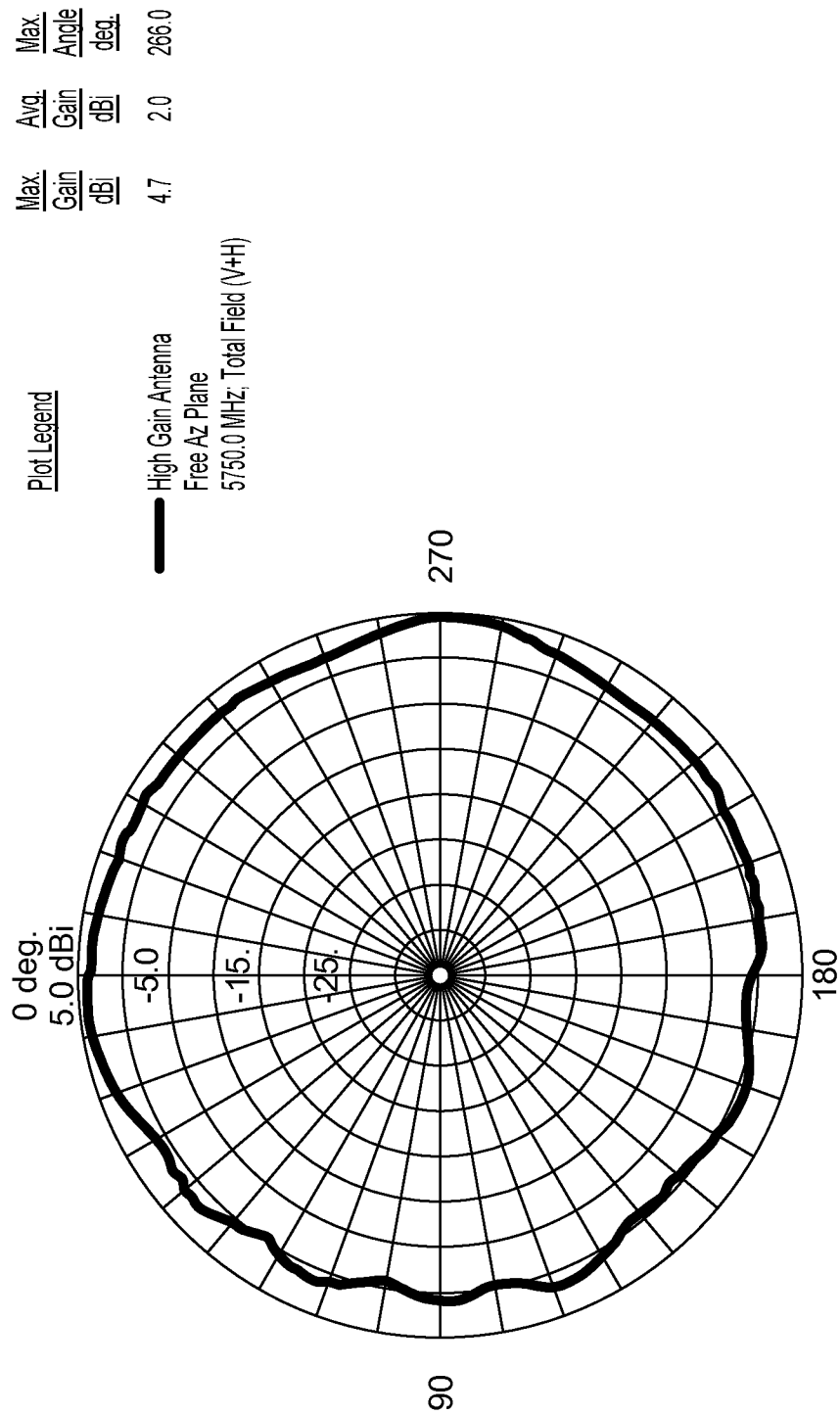


Fig. 5

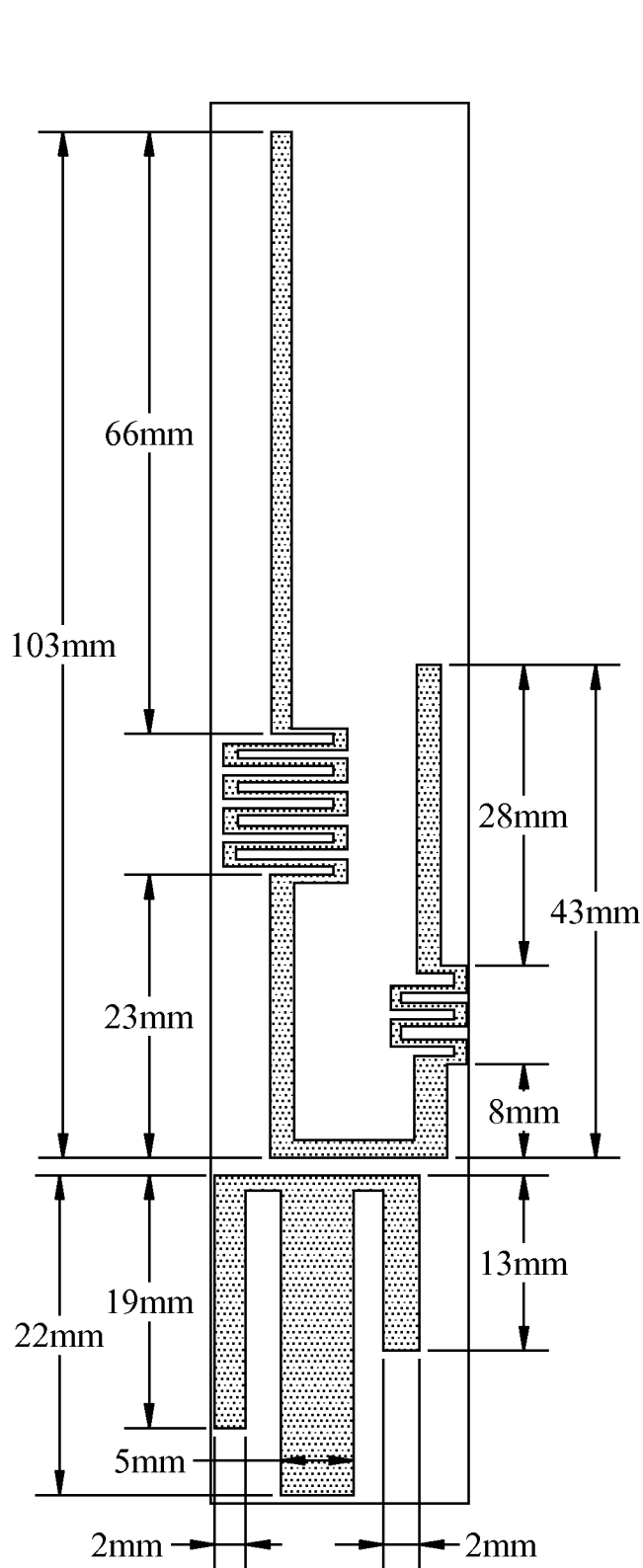


Fig. 6

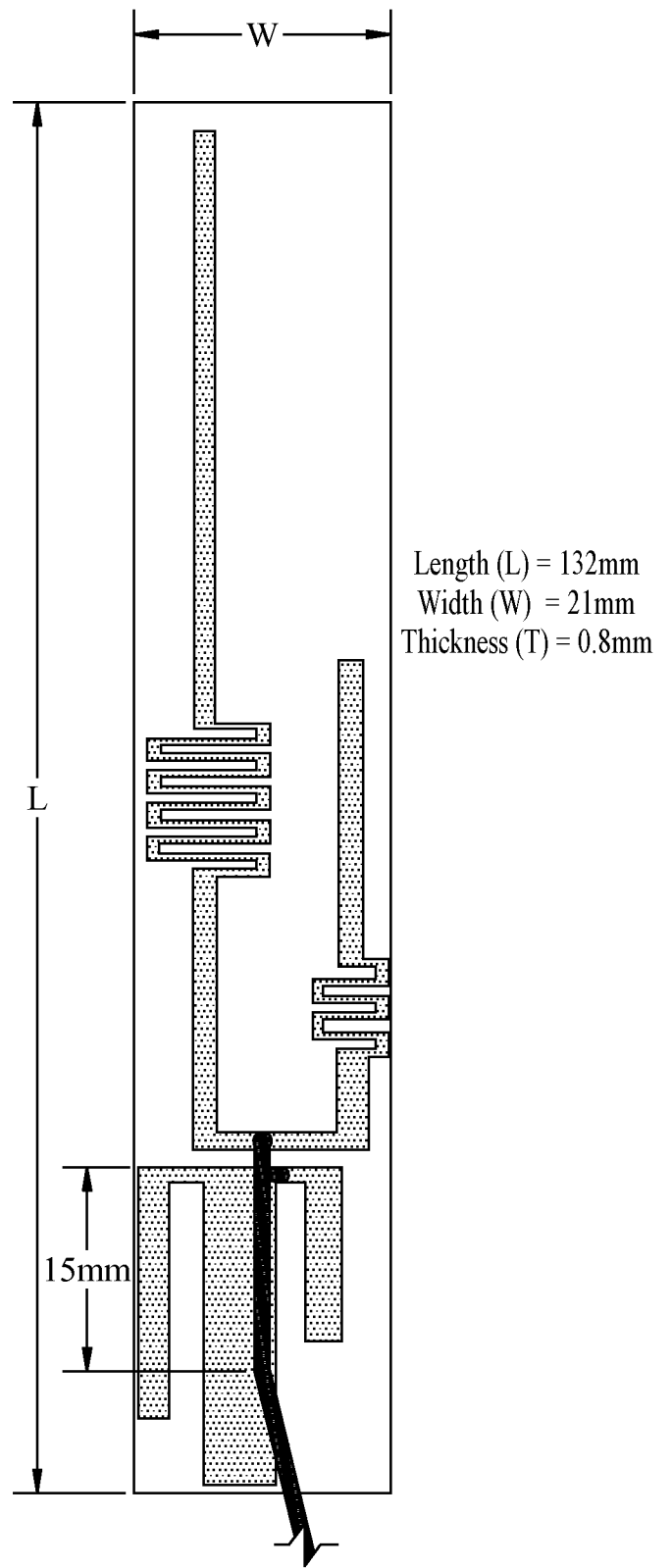


Fig. 7

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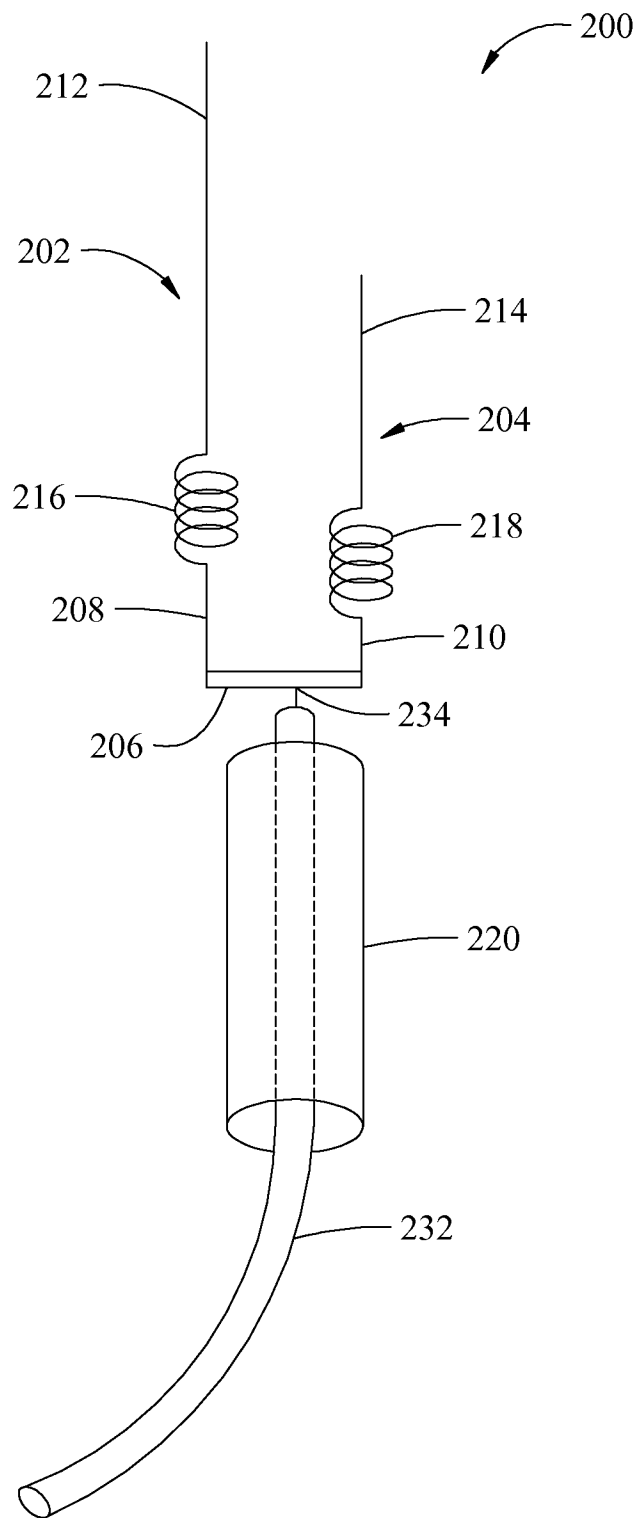


Fig. 9