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(71) Applicant: LAIRD TECHNOLOGIES, INC. [US/US];
3481 Rider Trail South, Earth City, Missouri 63045 (US).

(72) Inventor: TEOH, Xin Wen; 3481 Rider Trail South, Earth
City, Missouri 63045 (US).

(74) Agent: FUSSNER, Anthony; Harness, Dickey & Pierce,
PLC, 7700 Bonhomme, Suite 400, St. Louis, Missouri
63105 (US).

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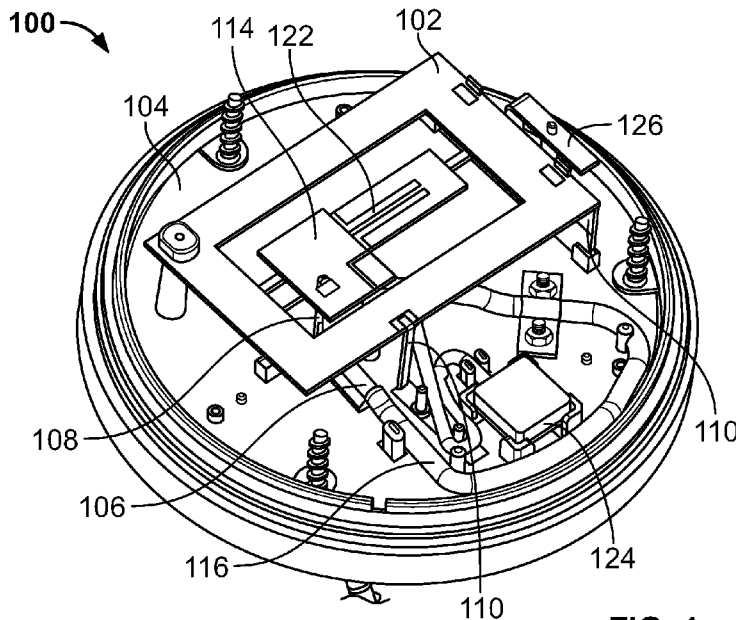


FIG. 1

(57) Abstract: Exemplary embodiments are provided of antennas and antenna systems including the same. In an exemplary embodiment, an antenna generally includes a radiating patch element having an annular rectangular shape. An antenna ground plane is spaced apart from the radiating patch element. A feeding element is electrically coupled to the radiating patch element via proximity coupling. The antenna also includes at least two shorting elements electrically coupling the radiating patch element to the antenna ground plane.

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**ANTENNA SYSTEMS WITH PROXIMITY COUPLED
ANNULAR RECTANGULAR PATCHES**

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a PCT International Application or continuation-in-part of United States Patent Application No. 14/571,580 filed December 16, 2014. The entire disclosure of the above application is incorporated herein by reference.

FIELD

[0002] The present disclosure generally relates to antenna systems with proximity coupled annular rectangular patches.

BACKGROUND

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

[0004] Antenna system design has been growing abruptly with complexity as the new technology vastly advances. The introduction of new frequency bands LTE/4G has led to the need of broader bandwidth for mobile stations, and the market is expecting antennas to be smaller, lower profile with better performance. The challenge in designing a low profile antenna is how to make it vertically polarized with omnidirectional radiation pattern despite the low profile requirement. A conventional planar inverted-F antenna has often been selected due to its small size and low profile application. But the conventional planar inverted-F antenna suffers from narrow bandwidth within the required form factor.

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 of antennas are disclosed. In an exemplary embodiment, an antenna includes a radiating patch element having an annular rectangular shape. An antenna ground plane is spaced apart from the radiating patch element. A feeding element electrically couples to the radiating patch element. The antenna also

includes at least two shorting elements electrically coupling the radiating patch element to the antenna ground plane.

[0007] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0008] 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.

[0009] FIG. 1 is a perspective view of an antenna system or assembly according to an exemplary embodiment;

[0010] FIG. 2 is a top view of the antenna system shown in FIG. 1 rotated about a vertical axis, and illustrating a horizontal feed patch, an annular rectangular radiating patch, L-shaped slots, a relatively close spacing between an active GPS antenna and a cellular antenna;

[0011] FIG. 3 is a perspective view of a portion of the antenna system shown in FIG. 1;

[0012] FIG. 4 is a perspective view of the antenna system shown in FIG. 3 rotated about a vertical axis;

[0013] FIG. 5 is a perspective view of a portion of the antenna assembly shown in FIG. 1;

[0014] FIG. 6 is a perspective view of the antenna system shown in FIG. 1 rotated about a vertical axis;

[0015] FIG. 7 is an exemplary line graph illustrating VSWR versus frequency measured from the exemplary antenna system of FIGS. 1-6;

[0016] FIGS. 8a and 8b are exemplary line graphs illustrating isolation in decibels (dB) versus frequency without the isolator (FIG. 8a) and with the isolator (FIG. 8b) measured for the exemplary antenna system of FIGS. 1-6;

[0017] FIG. 9 illustrates radiation patterns (azimuth plane and ϕ 0° plane) for the antenna system shown in FIGS. 1-6 at frequencies of 698 MHz, 824 MHz, 894 MHz, 960 MHz, 1710 MHz, 1880 MHz, 1990 MHz, and 2170 MHz;

[0018] FIG. 10 is a perspective view of an antenna system or assembly according to another exemplary embodiment;

[0019] FIG. 11 is a top view of the antenna system of FIG. 10 rotated about a vertical axis, and illustrating a horizontal feed patch, an annular radiating patch, and a tapered L-shaped slot;

[0020] FIG. 12 is a perspective view of a portion of the antenna system shown in FIG. 10;

[0021] FIG. 13 is a perspective view of the portion of the antenna system shown in FIG. 12 rotated about a vertical axis, and illustrating two shorting elements and an open-ended slot;

[0022] FIG. 14 is an exemplary line graph illustrating VSWR versus frequency measured from the exemplary antenna system of FIGS. 10-13;

[0023] FIG. 15 illustrates radiation patterns (azimuth plane and ϕ 0° plane) for the antenna system shown in FIGS. 10-13 at frequencies of 698 MHz, 824 MHz, 894 MHz, 960 MHz, 1710 MHz, 1880 MHz, 1990 MHz, and 2170 MHz;

[0024] FIG. 16 is a perspective view of an antenna system or assembly according to another exemplary embodiment and also illustrating examples of the feed element, the patch, the shorting element, and the ground plane or element;

[0025] FIG. 17 is a perspective view of the antenna system shown in FIG. 16 and also illustrating an exemplary base (*e.g.*, plastic base plate, *etc.*) according to an exemplary embodiment;

[0026] FIG. 18 is a top view of the antenna system of FIG. 16;

[0027] FIG. 19 includes front and back perspective views of the feed element shown in FIG. 16;

[0028] FIG. 20 includes front and back views of feed element shown in FIG. 19;

[0029] FIG. 21 is a perspective view of the shorting element shown in FIG. 16;

[0030] FIG. 22 illustrates the shorting element shown in FIG. 21;

[0031] FIG. 23 is a perspective view of the ground plane or element shown in FIG. 16;

[0032] FIG. 24 illustrates the ground plane or element shown in FIG. 23;

[0033] FIG. 25 is an exemplary line graph illustrating VSWR versus frequency measured from the exemplary antenna system of FIGS. 16-18; and

[0034] FIGS. 26 through 35 illustrates radiation patterns (azimuth plane and phi 0° plane) for the antenna system shown in FIGS. 16-18 at frequencies of 698 MHz, 824 MHz, 894 MHz, 960 MHz, 1710 MHz, 1880 MHz, 1990 MHz, 2170 MHz, 2500 MHz, and 2700 MHz, respectively.

DETAILED DESCRIPTION

[0035] Example embodiments will now be described more fully with reference to the accompanying drawings.

[0036] The inventors herein have recognized a need for good and/or improved bandwidth (*e.g.*, from about 698 MHz to about 960 MHz and from about 1710 MHz to about 2170 or 2700 MHz, *etc.*) for a conventional PIFA antenna with a low profile requirement, reduced, and/or eliminated the need for galvanic contact to a larger ground plane, good and/or improved vertical polarization radiation patterns, good and/or improved isolation between an active global positioning satellite (GPS) antenna and a cellular radiator, with both placed in close proximity, *etc.* Accordingly, disclosed herein are exemplary embodiments of antennas and antenna systems including the same (*e.g.*, 100 (FIGS. 1-6), 1300 (FIGS. 10-13), 2200 (FIGS. 16-18), *etc.*) that include one or more of the above mentioned features.

[0037] In some exemplary embodiments, an antenna may be a two port vehicular antenna, and may include a cellular radiator, an active GPS antenna, and an isolator. The antenna may have a broad bandwidth that covers a frequency range of about 698 MHz to about 960 MHz and/or about 1710 MHz to about 2170 MHz. The antenna may be mounted on a ground plane (*e.g.*, a metallic ceiling of a vehicle, machine, *etc.*). The ground plane may be at least 30 centimeters in diameter. Thus, the antenna may be considered as ground dependent (*e.g.*, have a smaller diameter, have a lower profile feature, *etc.*). A radiating element of the antenna (*e.g.*, radiator, *etc.*) may not require galvanic contact to a ground plane of the vehicle or other surface, and may be considered to have proximity coupling with a suitable insulation height between the radiating element and the ground plane.

[0038] In some exemplary embodiments, an antenna may include a cellular radiator, having a broad bandwidth and operable in a frequency range of about 698 MHz to about 960

MHz and/or about 1710 MHz to about 2170 or 2700 MHz. The antenna may have omnidirectional radiation patterns with a dominant vertical polarization at horizon across the operating frequency, with a lower profile and smaller diameter antenna assembly. The antenna may be mounted on a ground plane (*e.g.*, a metallic ceiling of a machine, *etc.*), and may perform well with a ground plane diameter of about 30 centimeters or more. The antenna may be ground dependent with a small diameter and low profile form factor. The antenna may include a radiating element which does not require galvanic contact with the ground plane of the machine, and may be considered to have proximity coupling with a suitable insulation height (*e.g.*, distance, *etc.*) between the radiating element and the ground plane.

[0039] Referring now to the figures, FIGS. 1 and 2 illustrate an exemplary embodiment of an antenna system or assembly embodying one or more aspects of the present disclosure. In particular, the antenna system includes an antenna 100 operable over or with frequencies from about 698 MHz to about 960 MHz and from about 1710 MHz to about 2170 MHz. For example, the antenna 100 may be operable within a first frequency range from about 698 MHz to about 960 MHz and a second frequency range from about 1710 MHz to about 2170 MHz. Or, for example, the antenna 100 may be operable across a single wide frequency range from about 698 MHz to about 2170 MHz.

[0040] The antenna 100 includes a radiating patch element 102, an antenna ground plane 104 spaced apart from the radiating patch element 102, a feeding element 108 electrically coupling (*e.g.*, via proximity coupling or direct galvanic coupling) the radiating patch element 102 to a feed point 106, and two shorting elements 110 electrically coupling (*e.g.*, via direct galvanic coupling, *etc.*) the radiating patch element 102 to the antenna ground plane 104. The antenna system may be referred to as a two port antenna.

[0041] In this example, the radiating patch element 102 (or more broadly, a radiating surface or radiator) is positioned substantially in the center of the antenna ground plane 104. Such configurations may allow the antenna 100 to have desirable radiation patterns for frequencies within one or more bands (*e.g.*, from 698 MHz to 960 MHz and from 1710 MHz to 2170 MHz, *etc.*) and provide omnidirectional characteristics, *etc.* Alternatively, the radiating patch element 102 may be positioned in another suitable location (*e.g.*, off-center, *etc.*) relative to the antenna ground plane 104, if desired.

[0042] The radiating patch element 102 may have an annular rectangular shape, such that the radiating patch element has an outer perimeter that is substantially rectangular, with an open interior portion (*e.g.*, a ring shape, *etc.*). The interior perimeter may also be substantially rectangular. Although FIGS. 1 and 2 illustrate an example shape for the radiating patch element 102, other embodiments may include radiating patch elements 102 having different shapes.

[0043] The radiating patch element 102 is also shorted to the antenna ground plane 104 at two locations (*e.g.*, via shorting elements 110, *etc.*) as shown in FIG. 5. The resonant frequencies ratio in the low frequency band is influenced by the shorting position of the shorting elements 110 and the size of the radiating patch element 102. The position of the shorting elements 110 and the size of the radiating patch element 102 are optimized at about the maximum quarter wavelength of the frequency 698 MHz, which influences the first resonant frequency.

[0044] FIGS. 3 and 4 illustrate a portion of the antenna 100, with the radiating patch element 102 removed, in order to further illustrate details of the feeding element 108. As shown in FIG. 3, the feeding element 108 includes a vertical transmission line 112 and a horizontal feed patch 114 (not shown in FIG. 3). The horizontal feed patch 114 is illustrated in FIG. 2. The feed point 106 includes a coaxial probe 116 coupled to the vertical transmission line 112. This feeding configuration may effectively reduce the inductance of a long probe with a capacitive patch, which is the horizontal feed patch 114.

[0045] The vertical transmission line 112 is coupled to (*e.g.*, defined on, integral with, *etc.*) a printed circuit board 118 (PCB). The resonant frequencies ratio in the low frequency band is also influenced by the position of the vertical transmission line 112. The vertical transmission line 112 may be offset to one end of the horizontal feed patch 114 to have the right separation between the resonant frequencies to attain broad bandwidth characteristic. The vertical transmission line PCB 118 includes an extended ground plane 120 on the back of the vertical transmission line PCB 118. As shown in FIG. 4, the extended ground plane 120 may extend to about half of the height of the vertical transmission line PCB 118. In other embodiments, the extended ground plane 120 may extend to more or less than half the height of the vertical transmission line PCB 118. This configuration may improve (*e.g.*, optimize, *etc.*) the separation between two resonant frequencies in a low frequency band (*e.g.*, 698 MHz to 960

MHz, *etc.*) of the antenna 100 to attain a broader bandwidth characteristic and further improve impedance matching for a high frequency band (*e.g.*, 1710 MHz to 2170 MHz, *etc.*).

[0046] The feeding element 108 may couple electromagnetic waves to the radiating patch element 102 via capacitive means. There may be a gap between the feeding element 108 and the radiating patch element 102, which may be tuned (*e.g.*, optimized, *etc.*) to generate a frequency ratio to substantially match the antenna 100 to the desired operating frequency range (*e.g.*, 698 MHz to 960 MHz, 1710 MHz to 2170 MHz, *etc.*). The gap may be loaded with (*e.g.*, filled with, have dispersed between, *etc.*) a dielectric material, be air loaded, *etc.* In some embodiments, air loading may provide a better frequency match for the antenna 100.

[0047] As shown in FIG. 2, two L-shaped slots 122 defined in the horizontal feed patch 114 may extend the electrical length for the high frequency band. Without the two L-shaped slots 122, the electrical length of the horizontal feed patch 114 may be too short for a frequency of about 1700 MHz. In other embodiments, the slots 122 may have different shapes, be located in different locations on the horizontal feed patch 114, *etc.* The gap between the horizontal feed patch 114 and the radiating patch element 102 may be adjusted accordingly to match the high frequency band.

[0048] As shown in FIG. 3, a shorting element patch 128 is added to the second shorting element 110 to achieve a better impedance matching. The shorting element patch 128 may shorten the electrical path of the signal and change the antenna impedance for the first resonant at the low frequency band.

[0049] As shown in FIG. 2, the antenna 100 may include an active GPS antenna 124, which may be positioned adjacent or closely spaced to the passive radiating patch element 102. The antenna 100 also includes an isolator 126 to improve isolation between the active GPS antenna 124 and the passive radiating patch element 102. For example, the isolator 126 may provide an improvement of about -5 decibels (dB) at a frequency of about 1575 MHz.

[0050] FIGS. 7, 8a, 8b, and 9 provide results measured for the antenna 100 shown in FIGS. 1-6. These results shown in FIGS. 7, 8a, 8b, and 9 are provided only for purposes of illustration and not for purposes of limitation.

[0051] More specifically, FIG. 7 is an exemplary line graph illustrating voltage standing wave ratio (VSWR) versus frequency measured for the antenna 100. Generally, FIG. 7

shows that the antenna 100 is operable with relatively good VSWR for the operating bandwidths (*e.g.*, about 698 MHz to about 960 MHz and about 1710 MHz to about 2170 MHz).

[0052] FIG. 8a illustrates isolation between the active GPS antenna 124 and the passive radiating patch element 102 in decibels (dB) versus frequency measured for the antenna 100 without the isolator 126. For comparison, FIG. 8b illustrates the isolation between the active GPS antenna 124 and the passive radiating patch element 102 in decibels (dB) versus frequency measured for the antenna 100 with the isolator 126. Generally, a comparison of FIGS. 8a and 8b shows the improvement in isolation that may be realized when the isolator 126 is included in the antenna 100. For example, the isolation was about -8 decibels for a frequency of 1.575 GHz with the isolator as compared to about -2.8 decibels without the isolator.

[0053] FIG. 9 illustrates various radiation patterns for the antenna 100. More specifically, FIG. 9 illustrates co-polarization components and cross-polarization components (dotted line) of the radiation patterns for the azimuth plane (on the left) and phi 0° plane (on the right) at frequencies of 698 MHz, 824 MHz, 960 MHz, 1710 MHz, 1880 MHz, 1990 MHz, and 2170 MHz. Generally, FIG. 9 illustrates a radiation pattern in the near horizon that can be identified as a vertically polarized antenna.

[0054] FIGS. 10 and 11 illustrate another exemplary embodiment of an antenna system or assembly 1300 embodying one or more aspects of the present disclosure. In particular, the antenna system includes an antenna 1300 operable over or with frequencies from about 698 MHz to about 960 MHz and from about 1710 MHz to about 2170 MHz. For example, the antenna 1300 may be operable within a first frequency range from about 698 MHz to about 960 MHz and a second frequency range from about 1710 MHz to about 2170 MHz. Or, for example, the antenna 1300 may be operable across a single wide frequency range from about 698 MHz to about 2170 MHz.

[0055] The antenna 1300 includes a radiating patch element 1302, an antenna ground plane 1304 spaced apart from the radiating patch element 1302, a feeding element 1308 electrically coupling (*e.g.*, via proximity coupling or direct galvanic coupling) the radiating patch element 1302 to a feed point 1306, and two shorting elements 1310 electrically coupling (*e.g.*, via direct galvanic coupling, *etc.*) the radiating patch element 1302 to the antenna ground plane 1304.

[0056] In this example, the radiating patch element 1302 (or more broadly, a radiating surface or radiator) is positioned substantially in the center of the antenna ground plane 1304. Such configurations may allow the antenna 1300 to have desirable radiation patterns for frequencies within one or more bands (*e.g.*, from 698 MHz to 960 MHz and from 1710 MHz to 2170 MHz, *etc.*), provide omnidirectional characteristics, *etc.*, as explained above. Alternatively, the radiating patch element 1302 may be positioned in another suitable location (*e.g.*, off-center, *etc.*) relative to the antenna ground plane 1304, if desired.

[0057] The radiating patch element 1302 may have an annular rectangular shape, such that the radiating patch element has an outer perimeter that is substantially rectangular (*e.g.*, one or more edges may have a slightly curved shape as in FIGS. 10 and 11, *etc.*) with an open interior portion (*e.g.*, a ring shape, *etc.*). The interior perimeter may also be substantially rectangular. Although FIGS. 10 and 11 illustrate an example shape for the radiating patch element 1302, other embodiments may include radiating patch elements 1304 having different shapes.

[0058] The radiating patch element 1302 is also shorted to the antenna ground plane 1304 at two locations (*e.g.*, via shorting elements 1310, *etc.*) as shown in FIG. 10. The resonant frequencies ratio in the low frequency band is influenced by the shorting position of the shorting elements 1310 and the size of the radiating patch element 1302. The position of the shorting elements 1310 and the size of the radiating patch element 1302 are optimized at about the maximum quarter wavelength of the frequency 698 MHz, which influences the first resonant frequency.

[0059] FIGS. 12 and 13 illustrate a portion of the antenna 1300, with the radiating patch element 1302 removed, in order to further illustrate details of the feeding element 1308. As shown in FIG. 12, the feeding element 1308 includes a vertical transmission line 1312 and a horizontal feed patch 1314 (not shown in FIG. 12). The horizontal feed patch 1314 is illustrated in FIG. 11. The feed point 1306 includes a coaxial probe 1316 coupled to the vertical transmission line 1312. This feeding configuration may effectively reduce the inductance of a long probe with a capacitive patch, which is the horizontal feed patch 1314.

[0060] The vertical transmission line 1312 is coupled to (*e.g.*, defined on, integral with, *etc.*) a printed circuit board 1318 (PCB). The resonant frequencies ratio in the low frequency band is also influenced by the position of the vertical transmission line 1312. The

vertical transmission line 1312 may be offset to one end of the horizontal feed patch 1314 to have the right separation between the resonant frequencies to attain broad bandwidth characteristic. The vertical transmission line PCB 1318 includes an extended ground plane 1320 on the back of the vertical transmission line PCB 1318. As shown in FIG. 13, the extended ground plane 1320 may extend to about half of the height of the vertical transmission line PCB 1318. In other embodiments, the extended ground plane 1320 may extend to more or less than half the height of the vertical transmission line PCB 1318. This configuration may improve (*e.g.*, optimize, *etc.*) the separation between two resonant frequencies in a low frequency band (*e.g.*, 698 MHz to 960 MHz, *etc.*) of the antenna 1300 to attain a broader bandwidth characteristic and further improve impedance matching for a high frequency band (*e.g.*, 1710 MHz to 2170 MHz, *etc.*).

[0061] The feeding element 1308 may couple electromagnetic waves to the radiating patch element 1302 via capacitive means. There may be a gap between the feeding element 1308 and the radiating patch element 1302, which may be tuned (*e.g.*, optimized, *etc.*) to generate a frequency ratio to substantially match the antenna 1300 to the desired operating frequency range (*e.g.*, 698 MHz to 960 MHz, 1710 MHz to 2170 MHz, *etc.*). The gap may be loaded with (*e.g.*, filled with, have dispersed between, *etc.*) a dielectric material, be air loaded, *etc.* In some embodiments, air loading may provide a better frequency match for the antenna 1300.

[0062] As shown in FIG. 11, two tapered L-shaped slots 1322 defined in the horizontal feed patch 1314 may extend the electrical length for the high frequency band. Without the two tapered L-shaped slots 1322, the electrical length of the horizontal feed patch 1314 may be too short for a frequency of about 1700 MHz. In other embodiments, the slots 1322 may have different shapes, be located in different locations on the horizontal feed patch 1314, *etc.* The gap between the horizontal feed patch 1314 and the radiating patch element 1302 may be adjusted accordingly to match the high frequency band.

[0063] As shown in FIG. 13, a shorting element patch 1328 is added to the second shorting element 1310 to achieve a better impedance matching. The shorting element patch 1328 may shorten the electrical path of the signal and change the antenna impedance for the first resonant at the low frequency band.

[0064] The antenna ground plane 1304 may include a long, open-ended slot 1330 to improve impedance matching to provide an improved margin on the VSWR. There is also a

small slot on the antenna ground plane 1304 to create an additional shorting element, which may bend from the antenna ground plane 1304 without adding extra antenna parts, and may not have any effect on radio frequency (RF) performance of the antenna 1300.

[0065] FIGS. 14 and 15 provide results measured for the antenna 1300 shown in FIGS. 10-13. These results shown in FIGS. 14 and 15 are provided only for purposes of illustration and not for purposes of limitation.

[0066] More specifically, FIG. 14 is an exemplary line graph illustrating voltage standing wave ratio (VSWR) versus frequency measured for the antenna 1300. Generally, FIG. 14 shows that the antenna 1300 is operable with relatively good VSWR for the operating bandwidths (*e.g.*, about 698 MHz to about 960 MHz and about 1710 MHz to about 2170 MHz).

[0067] FIG. 15 illustrates various radiation patterns for the antenna 1300. More specifically, FIG. 15 illustrates co-polarization components and cross-polarization components (dotted line) of the radiation patterns for the azimuth plane (on the left) and phi 0° plane (on the right) at frequencies of 698 MHz, 824 MHz, 894 MHz, 960 MHz, 1710 MHz, 1880 MHz, 1990 MHz, and 2170 MHz. Generally, FIG. 15 illustrates a radiation pattern in the near horizon that can be identified as a vertically polarized antenna.

[0068] FIGS. 16 through 18 illustrate another exemplary embodiment of an antenna system or assembly embodying one or more aspects of the present disclosure. In this exemplary embodiment, the antenna 2200 has a broad bandwidth and is operable within a first frequency range from about 698 MHz to about 960 MHz and a second frequency range from about 1710 MHz to about 2700 MHz.

[0069] As disclosed herein, the antenna 2200 includes a feeding element 2208 that electrically couples (*e.g.*, via proximity coupling or direct galvanic coupling) the radiating patch element 2202 to a feed point 2206. The antenna 2200 also includes an antenna ground plane 2204 spaced apart from the radiating patch element 2202 and two shorting elements 2210, 2211 electrically coupling (*e.g.*, via direct galvanic coupling, *etc.*) the radiating patch element 2202 to the antenna ground plane 2204.

[0070] In this example, the radiating patch element 2202 (or more broadly, a radiating surface or radiator) is positioned substantially in the center of the antenna ground plane 2204 as shown in FIG. 18. Such configurations may allow the antenna 2200 to have desirable radiation patterns for frequencies within one or more bands (*e.g.*, from 698 MHz to 960 MHz

and from 1710 MHz to 2700 MHz, *etc.*), provide omnidirectional characteristics, *etc.* Alternatively, the radiating patch element 2202 may be positioned in another suitable location (*e.g.*, off-center, *etc.*) relative to the antenna ground plane 2204, if desired.

[0071] The radiating patch element 2202 may have an annular rectangular shape, such that the radiating patch element 2202 has an outer perimeter that is substantially rectangular. For example, the radiating patch element 2202 may be substantially rectangular with one or more edges having a slightly curved shape and with open interior portion (*e.g.*, a ring shape, *etc.*). As shown in FIG. 18, the radiating patch element 2202 may be considered to have an outer perimeter that is generally shaped as the letter D. The interior perimeter of the radiating patch element 2202 may be substantially rectangular. Although FIGS. 16 through 18 illustrate an example shape for the radiating patch element 2202, other embodiments may include radiating patch elements 2202 having different shapes.

[0072] The radiating patch element 2202 is also shorted to the antenna ground plane 2204 at two locations (*e.g.*, via shorting elements 2210 and 2211, *etc.*) as shown in FIGS. 16 and 17. The resonant frequencies ratio in the low frequency band is influenced by the shorting position of the shorting elements 2210, 2211 and the size of the radiating patch element 2202. The position of the shorting elements 2210, 2211 and the size of the radiating patch element 2202 are optimized at about the maximum quarter wavelength of the frequency 698 MHz, which influences the first resonant frequency.

[0073] As shown in FIG. 19, the feeding element 2208 includes a vertical transmission line 2212 and a horizontal feed patch 2214. A coaxial cable 2216 is coupled (*e.g.*, soldered, *etc.*) to the feed point 2206 at or towards a bottom of the vertical transmission line 2212. This feeding configuration may effectively reduce the inductance of a long probe with a capacitive patch, which is the horizontal feed patch 2214.

[0074] The vertical transmission line 2212 is coupled to (*e.g.*, defined on, integral with, *etc.*) the printed circuit board 2218 (PCB). The resonant frequencies ratio in the low frequency band is also influenced by the position of the vertical transmission line 2212. The vertical transmission line 2212 may be offset to one end of the horizontal feed patch 2214 to have the right separation between the resonant frequencies to attain broad bandwidth characteristic. The vertical transmission line PCB 2218 includes an extended ground plane 2220 (*e.g.*, an electrically conductive trace, *etc.*) on the back of the vertical transmission line PCB

2218 as shown in FIG. 19. As shown by FIG. 20, the extended ground plane 2220 may extend to about one-half or more of the height of the vertical transmission line PCB 2218. In other embodiments, the extended ground plane 2220 may extend to less than half the height of the vertical transmission line PCB 2218. This configuration may improve (*e.g.*, optimize, *etc.*) the separation between two resonant frequencies in a low frequency band (*e.g.*, 698 MHz to 960 MHz, *etc.*) of the antenna 2200 to attain a broader bandwidth characteristic and further improve impedance matching for a high frequency band (*e.g.*, 1710 MHz to 2700 MHz, *etc.*).

[0075] The feeding element 2208 may couple electromagnetic waves to the radiating patch element 2202 via capacitive means. There may be a gap between the horizontal feed patch 2214 of the feeding element 2208 and the radiating patch element 2202, which may be tuned (*e.g.*, optimized, *etc.*) to generate a frequency ratio to substantially match the antenna 2200 to the desired operating frequency range (*e.g.*, 698 MHz to 960 MHz, 1710 MHz to 2700 MHz, *etc.*). The gap may be loaded with (*e.g.*, filled with, have dispersed between, *etc.*) a dielectric material, be air loaded, *etc.* In some embodiments, air loading may provide a better frequency match for the antenna 2200.

[0076] As shown in FIG. 18, two tapered L-shaped or triangular slots 2222 are defined in or by the horizontal feed patch 2214. The slots 2222 may extend the electrical length for the high frequency band. Without the slots 2222, the electrical length of the horizontal feed patch 2214 may be too short for a frequency of about 1700 MHz. In this exemplary embodiment, the slots 2222 comprise areas along the dielectric substrate 2223 at which the electrically conductive material is not present. As shown in FIG. 18, the dielectric substrate 2223 extends across the open interior portion of the radiating patch element 2202 and is connected to opposing sides of the radiating patch element 2202. In this exemplary manner, the feed patch 2214 and other electrically conductive material 2225 (*e.g.*, trace, *etc.*) on the dielectric substrate 2223 may be supported or suspended within the open interior portion of the radiating patch element 2202 by the dielectric substrate 2223. In other embodiments, the slots 2222 may have different shapes, be located in different locations on the horizontal feed patch 2214, *etc.* The gap between the horizontal feed patch 2214 and the radiating patch element 2202 may be adjusted accordingly to match the high frequency band.

[0077] The antenna 2200 includes an additional high band element 2209 to excite the higher edge of the second frequency range from 2170 MHz to 2700 MHz. The high band

element 2209 is operable as a proximity shorting monopole at about 2700 MHz. As shown in FIGS. 19 and 20, the high band element 2209 is an additional electrically conductive trace provided on the printed circuit board (PCB) 2218 of the feeding element 2208. The high band element 2209 does not galvanically contact the radiating patch element 2202 in this example. In this example, the high band element 2209 includes first and second triangular portions 2213 connected to corresponding ends of first and second horizontal portions 2215, which are along opposite sides of a vertical transmission line 2212 of the feeding element 2208.

[0078] As shown in FIG. 21, a shorting element patch 2228 is added to the second shorting element 2210 to achieve a better impedance matching. The shorting element patch 2228 may shorten the electrical path of the signal and change the antenna impedance for the first resonant at the low frequency band. The shorting element patch 2228 may comprise an electrically conductive trace provided on the printed circuit board (PCB) 2229 of the shorting element 2210.

[0079] The antenna ground plane 2204 may include a long, open-ended slot 2230 to improve impedance matching to provide an improved margin on the VSWR. There is also a small slot on the antenna ground plane 2204 to create the shorting element 2211, which may bend from the antenna ground plane 2204 without adding extra antenna parts, and may not have any effect on radio frequency (RF) performance of the antenna 2200.

[0080] As shown in FIGS. 19 and 20, the feeding element 2208 includes an upwardly protruding portion 2240 that may be soldered via a solder joint to the horizontal feed patch 2214. A lower portion 2242 of the vertical transmission line 2212 may be soldered to a coaxial cable 2216. A lower portion 2244 of the extended ground plane 2220 (*e.g.*, an electrically conductive trace, *etc.*) may be soldered via a solder joint to the antenna ground plane 2204. The high band element 2209 and the extended ground plane 2220 may be defined by etching the PCB 2218. For example, the high band element 2209 and the extended ground plane 2220 may be etched on the PCB 2218 coated in copper or other suitable material (*e.g.*, coated in one ounce of copper per square foot (equivalent to approximately 35um thickness), *etc.*).

[0081] As shown in FIGS. 21 and 22, the shorting element 2210 includes upwardly protruding portions 2246 that may be soldered via solder joints to the radiating patch element 2202. A lower portion 2248 of the shorting element patch 2228 may be soldered via a solder joint to the antenna ground plane 2204. The shorting element patch 2228 may be defined by

etching the PCB 2229. For example, the shorting element patch 2228 may be etched on the PCB 2229 coated in copper or other suitable material (*e.g.*, coated in one ounce of copper per square foot (equivalent to approximately 35um thickness), *etc.*).

[0082] FIG. 24 shows area 2250, 2254, 2258 that may be soldered via solder joints to the PCB 2218 of the feeding element 2208, to the shorting element 2211 of the antenna ground plane 2204, and to the PCB 2229 of the shorting element 2210. More specifically, the feed patch 2214 and PCB 2218 of the feeding element 2208 may be soldered via a solder joint between portions 2240 (FIG. 20) and 2250 (FIG. 24). The shorting element 2211 of the antenna ground plane 2204 and the radiating patch element 2202 may be soldered via a solder joint between the upper portion of shorting element 2211 (FIG. 17) and portion 2254 (FIG. 24). The shorting element 2210 and the radiating patch element 2202 may be soldered via a solder joint between the portions 2246 (FIG. 22) and portion 2258 (FIG. 24).

[0083] As shown in FIG. 16, the coaxial cable 2216 (*e.g.*, a 2 foot long coaxial cable terminated with an SMA-male connector or RTNC-male connector, *etc.*) is electrically connected to the feeding point 2206 of the feeding element 2208. The coaxial cable 2216 may also be grounded adjacent or near the feeding point 2206. For example, an inner conductor of the coaxial cable 2216 may be soldered to the lower portion 2242 of the vertical transmission line 2212, while an outer braid of the coaxial cable 2216 may be soldered to a feature 2262 (*e.g.*, cable holder or grounding point, *etc.*) integrally formed or defined (*e.g.*, stamped, *etc.*) by the ground plane 2204 as shown in FIG. 16. The coaxial cable 2216 is routed from the feeding point 2206 and passes through the slot or opening 2230 in the ground plane 2204. The coaxial cable 2216 then passes through an electrically-conductive (*e.g.*, aluminum, other metal, *etc.*) mounting member 2268.

[0084] FIGS. 25 through 35 provide results measured for the antenna 2200 shown in FIGS. 16-18. These results shown in FIGS. 25 and 35 are provided only for purposes of illustration and not for purposes of limitation.

[0085] More specifically, FIG. 25 is an exemplary line graph illustrating VSWR versus frequency measured from the exemplary antenna 2200 of FIGS. 16-18. Generally, FIG. 25 shows that the antenna 2200 is operable with relatively good VSWR for the operating bandwidths from about 698 MHz to about 960 MHz and from about 1710 MHz to about 2700 MHz.

[0086] FIGS. 26 through 35 illustrate various radiation patterns for the antenna 2200. More specifically, FIGS. 26 through 35 illustrate co-polarization components and cross-polarization components (dotted line) of the radiation patterns for the azimuth plane (on the left) and phi 0° plane (on the right) at frequencies of 698 MHz, 880 MHz, 960 MHz, 1710 MHz, 1950 MHz, 2170 MHz, and 2700 MHz, respectively. Generally, FIGS. 26 through 35 illustrate radiation patterns in the near horizon that can be identified as a vertically polarized antenna.

[0087] The antenna systems disclosed herein including the radiating patch elements, the antenna ground planes, feeding elements, the shorting elements, *etc.*, may be any suitable size (*e.g.*, height, diameter, *etc.*). The size of each component of an antenna system may be determined based on particular specifications, desired results, *etc.* For example, the height of the feeding elements disclosed herein may be determined so that an impedance match in the high band may be substantially achieved.

[0088] Additionally, the shape of each component of the antenna systems may be any suitable shape. For example, the radiating patch elements, feeding elements, shorting elements, *etc.* may be square, oval, pentagonal, *etc.*, depending on manufacturability of a shape, cost effectiveness, particular specifications, desired results, *etc.*

[0089] Further, although the antenna systems disclosed herein are shown to include one antenna, two antennas, or four antennas, any number of antennas may be employed without departing from the present disclosure. For example, an antenna system may include three antennas, five or more antennas, *etc.*

[0090] Exemplary embodiments of the antenna systems disclosed herein may be suitable for a wide range of applications, *e.g.*, that use more than one antenna, such as LTE/4G applications, vehicular antenna systems, and/or infrastructure antenna systems (*e.g.*, customer premises equipment (CPE), terminal stations, central stations, in-building antenna systems, *etc.*). An antenna system disclosed herein may be configured for use as an omnidirectional MIMO (multiple input multiple output) or SISO (single input single output) antenna, although aspects of the present disclosure are not limited solely to omnidirectional antennas and/or MIMO or SISO antennas. An antenna system disclosed herein may be implemented inside an electronic device, such as machine to machine (M2M), vehicular, in-building unit, *etc.* In which case, the internal antenna components would typically be internal to and covered by the electronic device housing. As another example, the antenna system may instead be housed within a radome, which may

have a low profile. In this latter case, the internal antenna components would be housed within and covered by the radome. Accordingly, the antenna systems disclosed herein should not be limited to any one particular end use.

[0091] Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms, and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail. In addition, advantages and improvements that may be achieved with one or more exemplary embodiments of the present disclosure are provided for purpose of illustration only and do not limit the scope of the present disclosure, as exemplary embodiments disclosed herein may provide all or none of the above mentioned advantages and improvements and still fall within the scope of the present disclosure.

[0092] Specific numerical dimensions and values, specific materials, and/or specific shapes disclosed herein are example in nature and do not limit the scope of the present disclosure. The disclosure herein of particular values and particular ranges of values for given parameters are not exclusive of other values and ranges of values that may be useful in one or more of the examples disclosed herein. Moreover, it is envisioned that any two particular values for a specific parameter stated herein may define the endpoints of a range of values that may be suitable for the given parameter (i.e., the disclosure of a first value and a second value for a given parameter can be interpreted as disclosing that any value between the first and second values could also be employed for the given parameter). For example, if Parameter X is exemplified herein to have value A and also exemplified to have value Z, it is envisioned that parameter X may have a range of values from about A to about Z. Similarly, it is envisioned that disclosure of two or more ranges of values for a parameter (whether such ranges are nested, overlapping or distinct) subsume all possible combination of ranges for the value that might be claimed using endpoints of the disclosed ranges. For example, if parameter X is exemplified herein to have values in the range of 1 – 10, or 2 – 9, or 3 – 8, it is also envisioned that Parameter

X may have other ranges of values including 1 – 9, 1 – 8, 1 – 3, 1 - 2, 2 – 10, 2 – 8, 2 – 3, 3 – 10, and 3 – 9.

[0093] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a”, “an” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “comprising,” “including,” and “having,” are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. 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.

[0094] When an element or layer is referred to as being “on”, “engaged to”, “connected to” or “coupled to” another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly engaged to”, “directly connected to” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (*e.g.*, “between” versus “directly between,” “adjacent” versus “directly adjacent,” *etc.*). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0095] The term “about” when applied to values indicates that the calculation or the measurement allows some slight imprecision in the value (with some approach to exactness in the value; approximately or reasonably close to the value; nearly). If, for some reason, the imprecision provided by “about” is not otherwise understood in the art with this ordinary meaning, then “about” as used herein indicates at least variations that may arise from ordinary methods of measuring or using such parameters. For example, the terms “generally”, “about”, and “substantially” may be used herein to mean within manufacturing tolerances.

[0096] Although the terms first, second, third, *etc.* may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components,

regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. 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. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0097] Spatially relative terms, such as “inner,” “outer,” “beneath”, “below”, “lower”, “above”, “upper” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0098] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements, intended or stated uses, 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. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

CLAIMS

WHAT IS CLAIMED IS:

1. An antenna comprising:
a radiating patch element having an annular rectangular shape;
an antenna ground plane spaced apart from the radiating patch element;
a feeding element electrically coupling to the radiating patch element; and
at least two shorting elements electrically coupling the radiating patch element to the antenna ground plane.
2. The antenna of claim 1, wherein the antenna is operable within at least a first frequency range from about 698 megahertz to about 960 megahertz and a second frequency range from about 1710 megahertz to about 2170 megahertz.
3. The antenna of claim 1, wherein the antenna is operable within at least a first frequency range from about 698 megahertz to about 960 megahertz and a second frequency range from about 1710 megahertz to about 2700 megahertz.
4. The antenna of claim 3, wherein the feeding element includes a high band element operable to excite a higher edge of the second frequency range.
5. The antenna of claim 1 or 3, wherein the feeding element includes a high band element operable as a proximity shorting monopole at about 2700 MHz.
6. The antenna of claim 4 or 5, wherein:
the feeding element includes a printed circuit board; and
the high band element comprises an electrically conductive trace on the printed circuit board of the feeding element.
7. The antenna of claim 4, 5, or 6, wherein:
the feeding element includes a vertical transmission line; and
the high band element includes first and second triangular portions connected to corresponding ends of first and second horizontal portions, which are along opposite sides of a vertical transmission line of the feeding element.
8. The antenna of any one of the preceding claims, wherein the feeding element is electrically coupled to the radiating patch element via proximity coupling.

9. The antenna of any one of claims 1 to 5, wherein:
the feeding element includes a vertical transmission line and a horizontal feed patch; and
the feeding element electrically couples the radiating patch element to a feed point.
10. The antenna of claim 9, wherein the location of the vertical transmission line is offset towards one end of the horizontal feed patch of the feeding element.
11. The antenna of claim 9 or 10, wherein the feeding element includes a printed circuit board (PCB) having the vertical transmission line on a first side and an extended ground plane on a second side opposite the first side.
12. The antenna of any one of claims 9 to 11, wherein the horizontal feed patch of the feed element includes at least two L-shaped slots or at least two tapered L-shaped slots configured to extend an electrical length of a high frequency band of the antenna.
13. The antenna of any one of claims 9 to 12, wherein a gap between the horizontal feed patch and the radiating patch element is loaded with a dielectric and/or air-filled substrate.
14. The antenna of any one of the preceding claims, wherein at least one of the shorting elements includes a shorting element patch configured to improve impedance matching.
15. The antenna of any one of the preceding claims, wherein the antenna ground plane includes an open-ended slot configured to improve impedance matching.

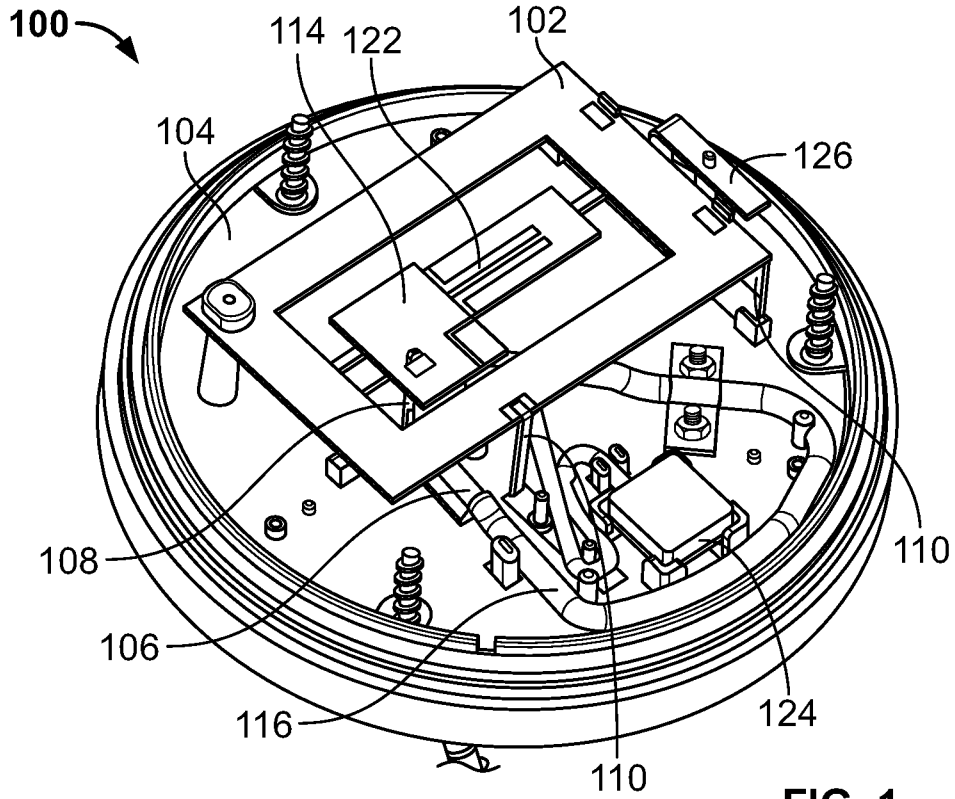


FIG. 1

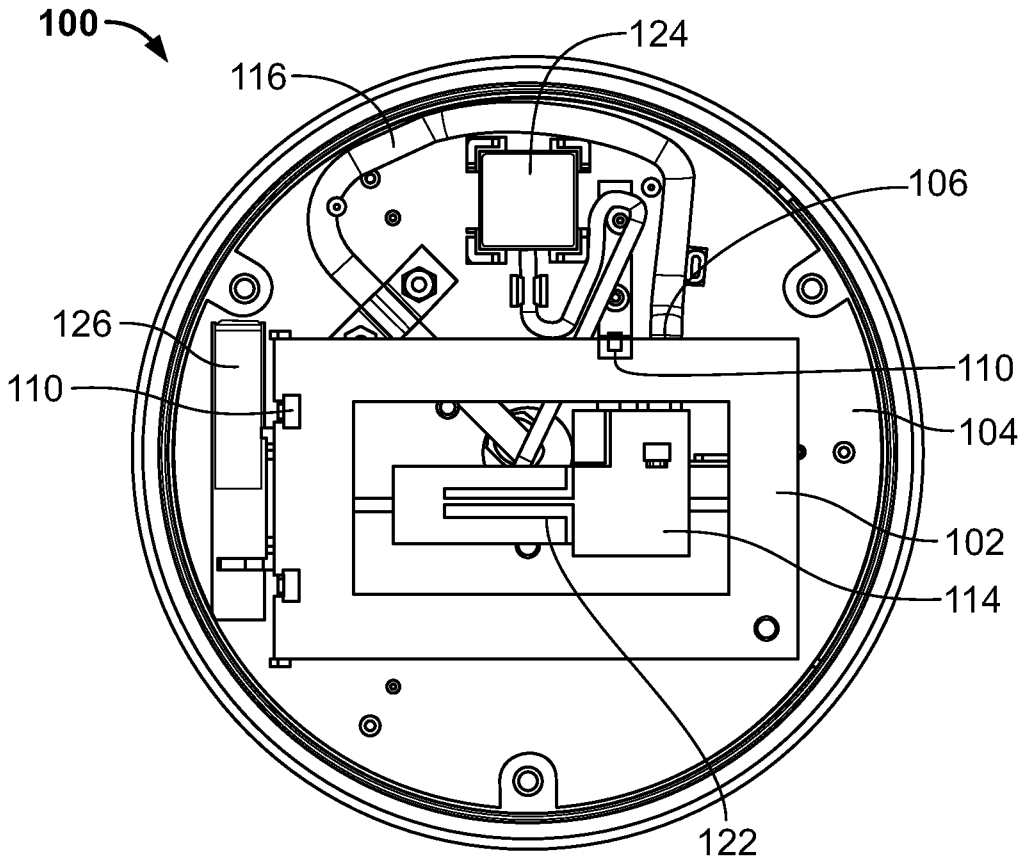


FIG. 2

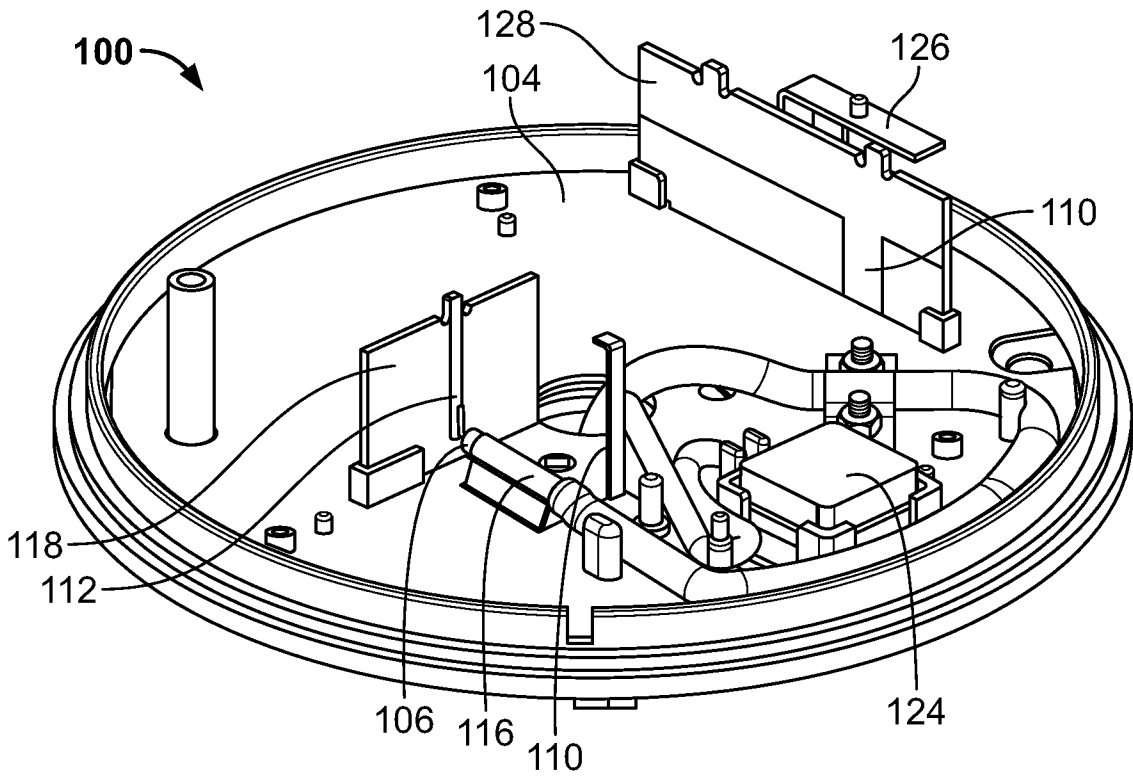


FIG. 3

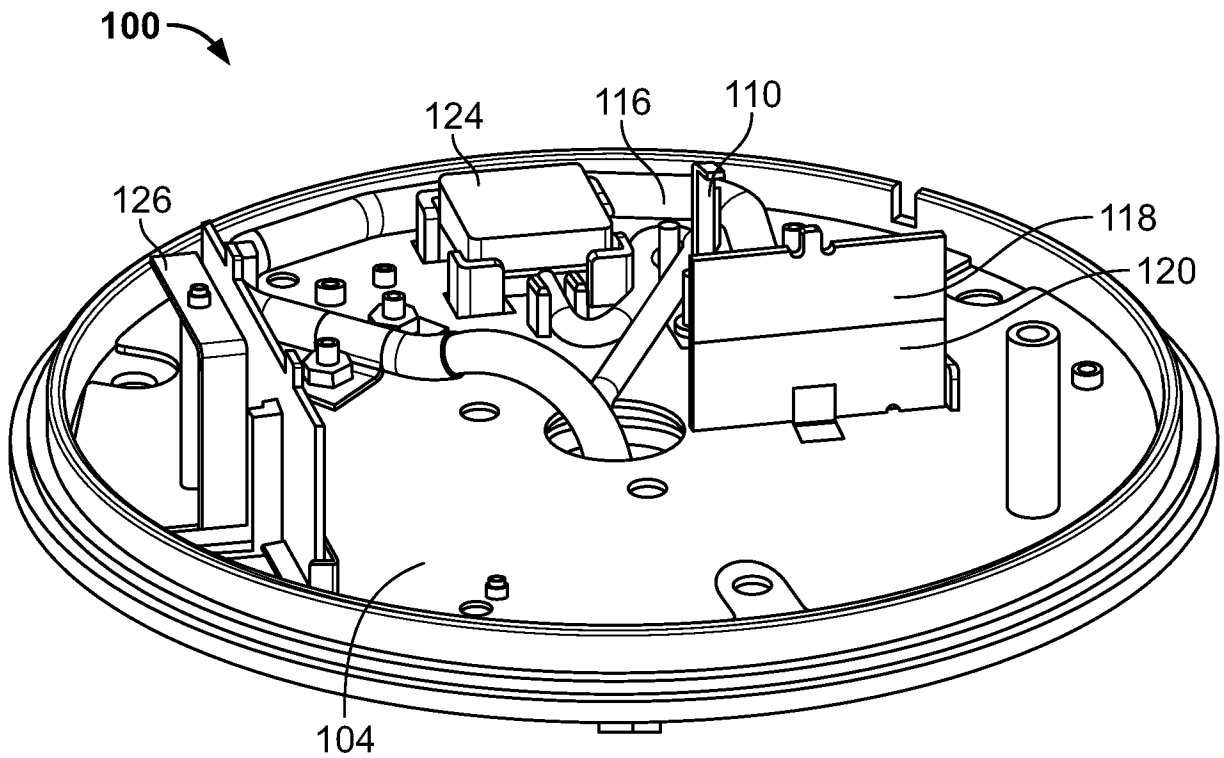


FIG. 4

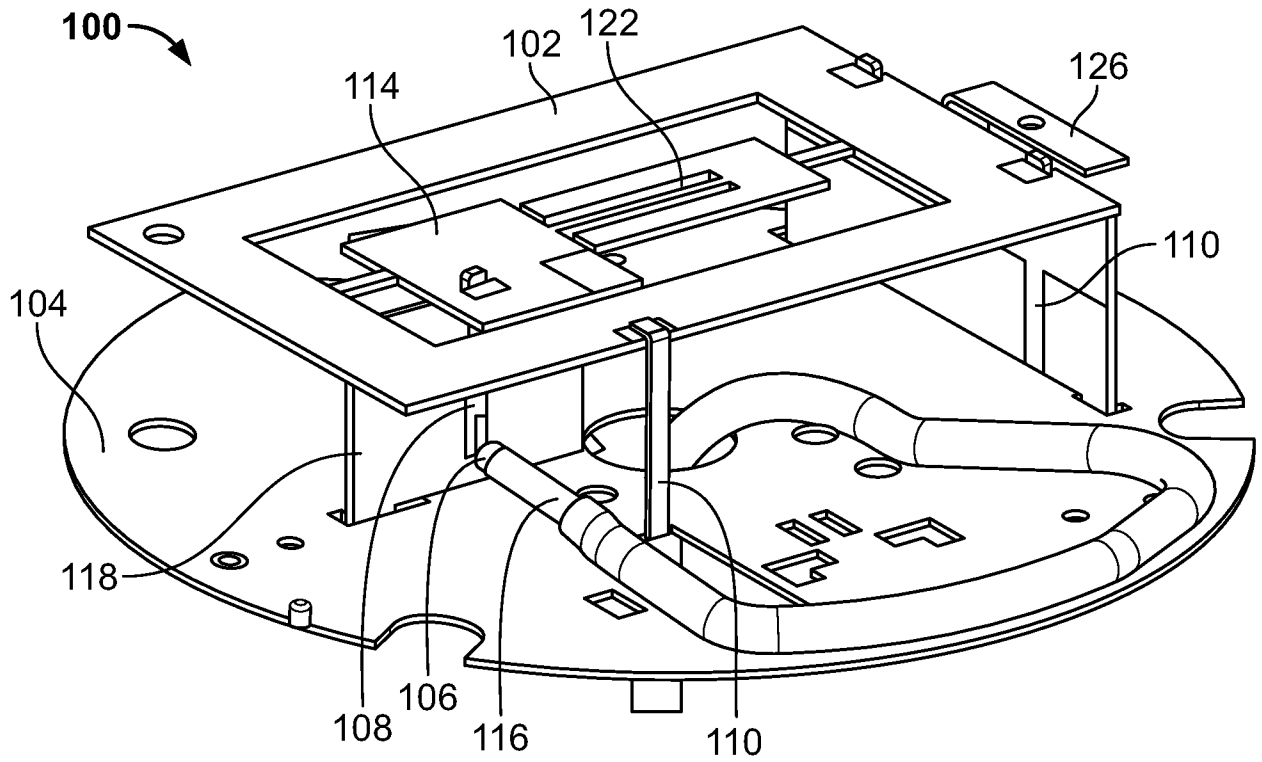


FIG. 5

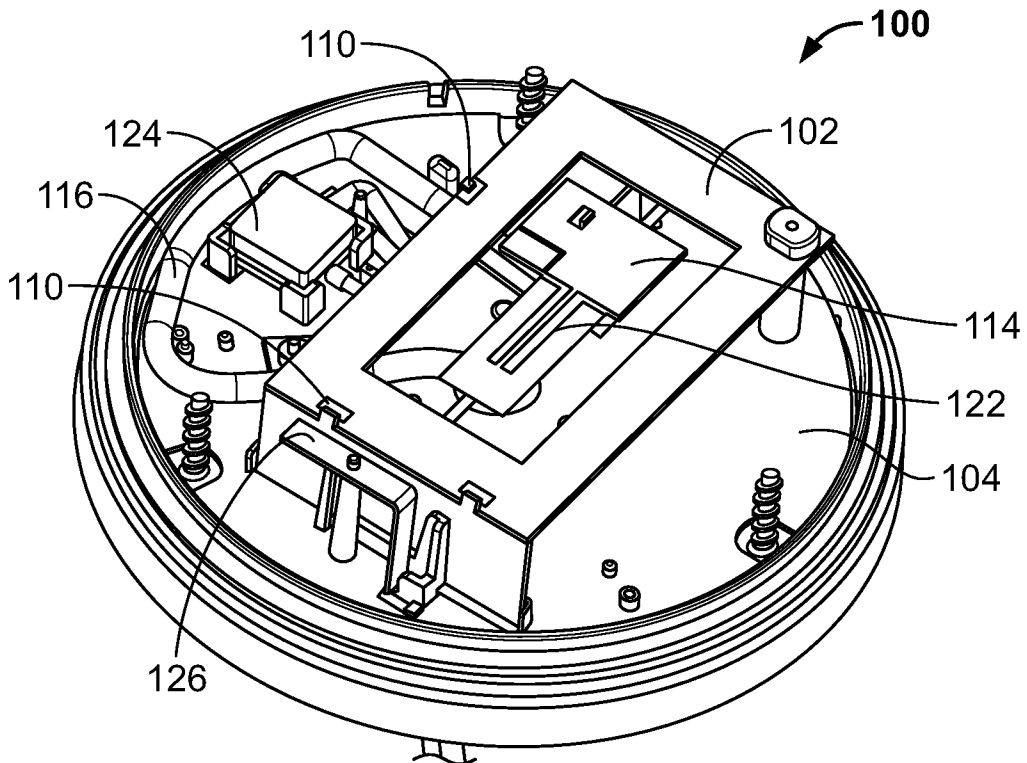
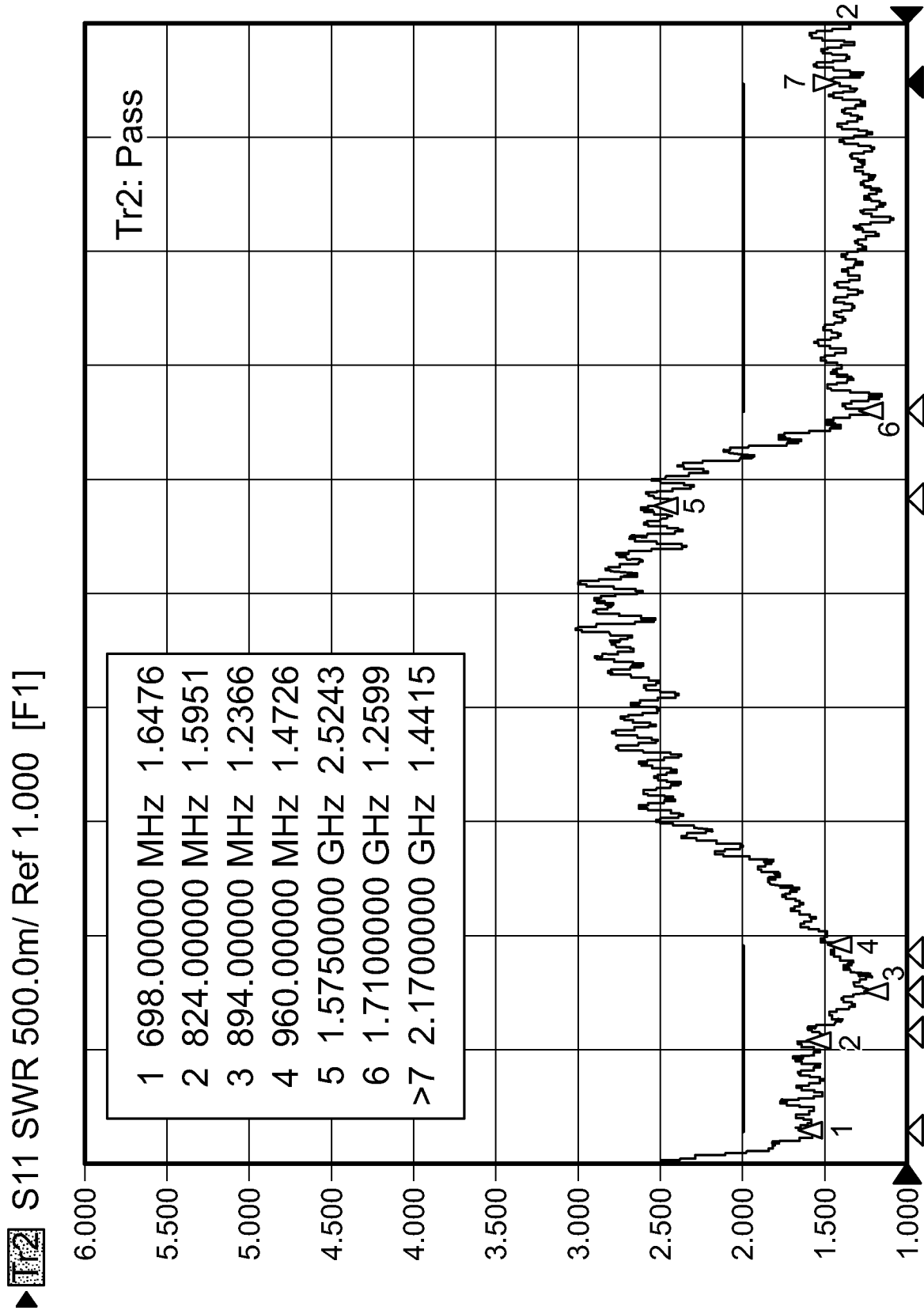


FIG. 6

FIG. 7



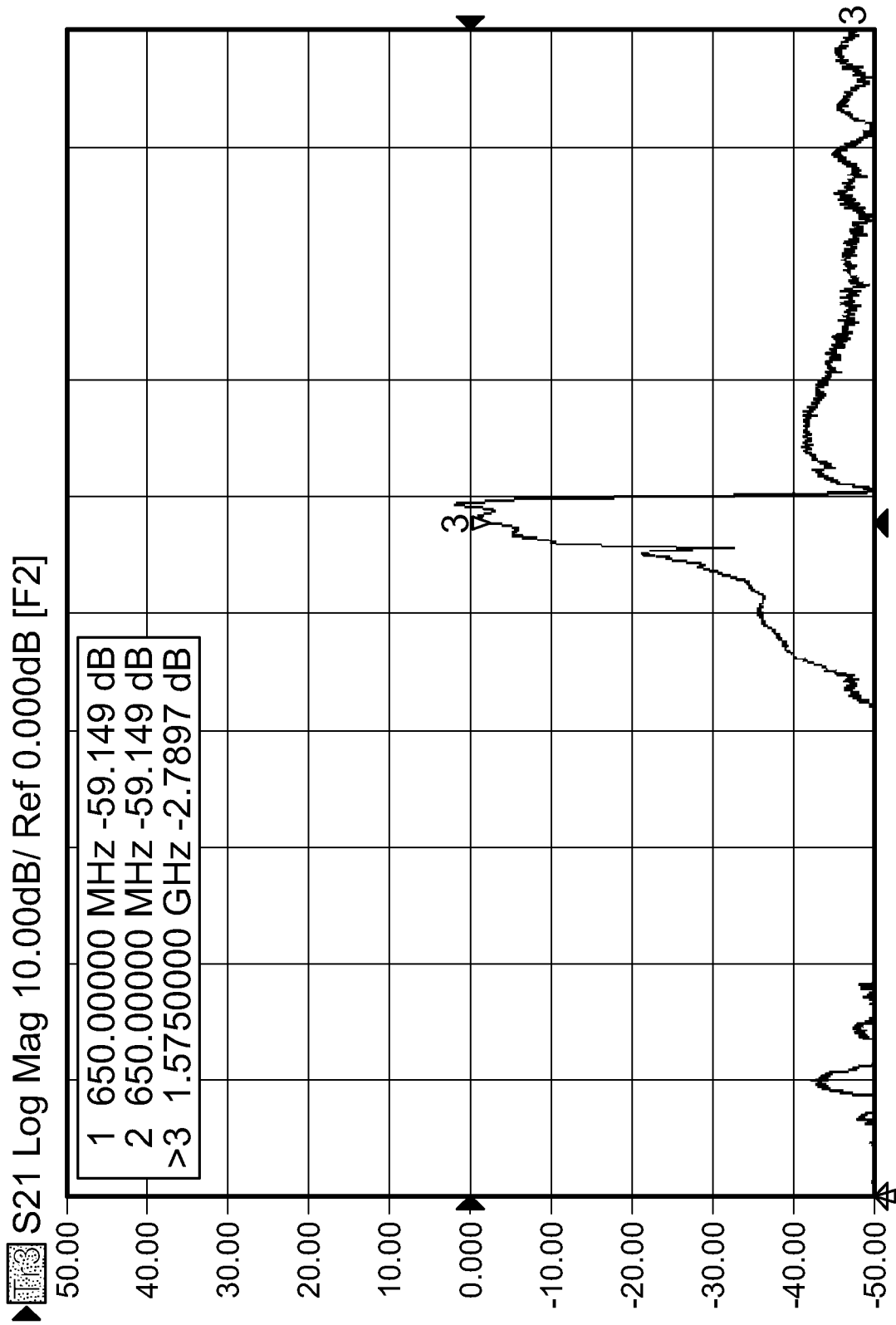


FIG. 8A

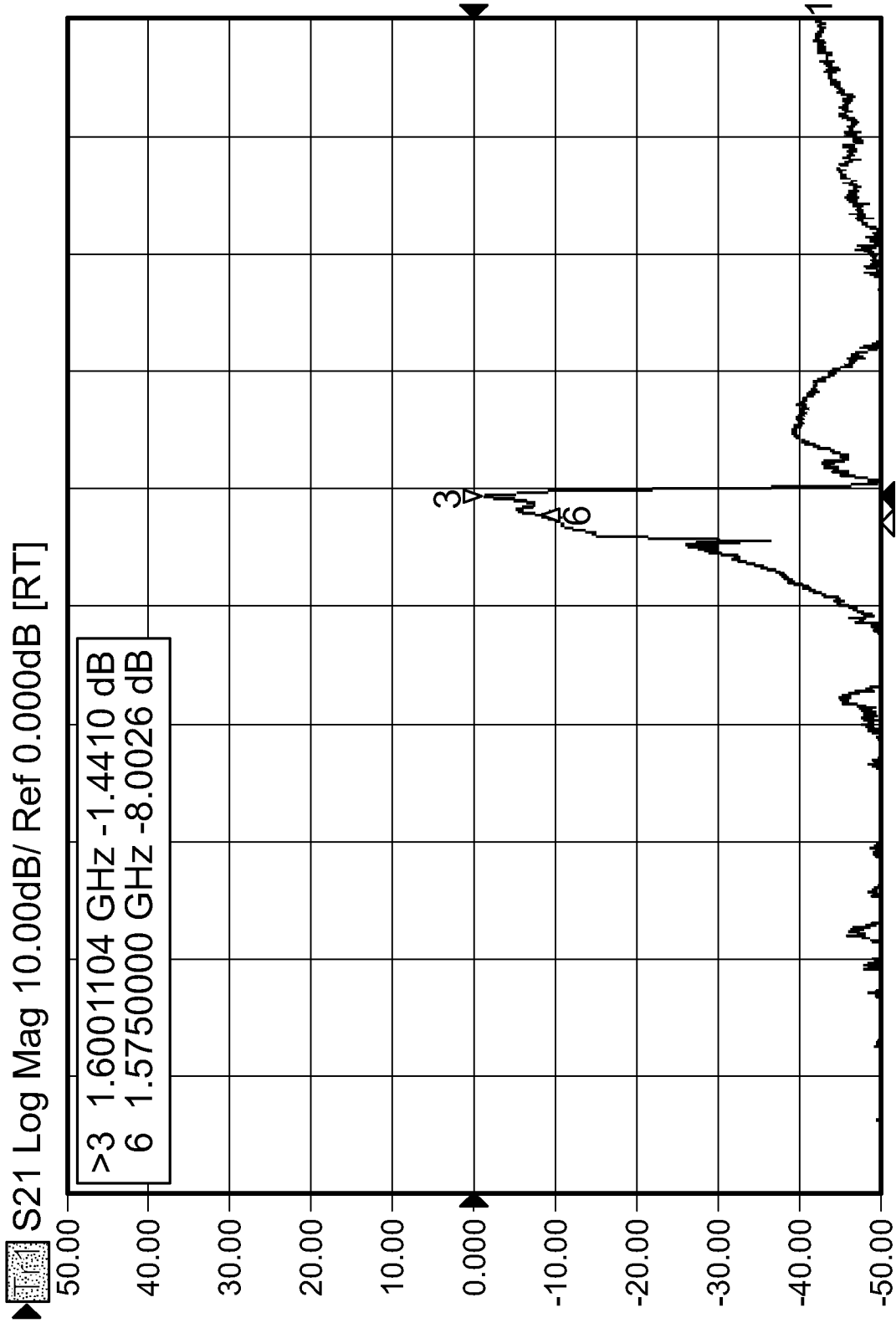
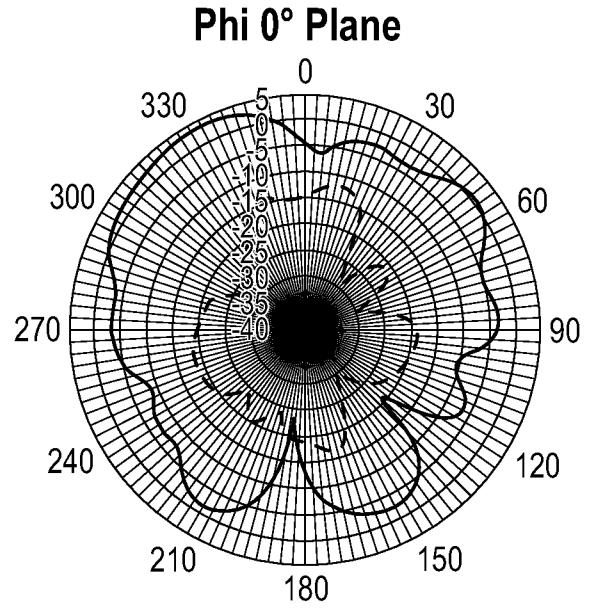
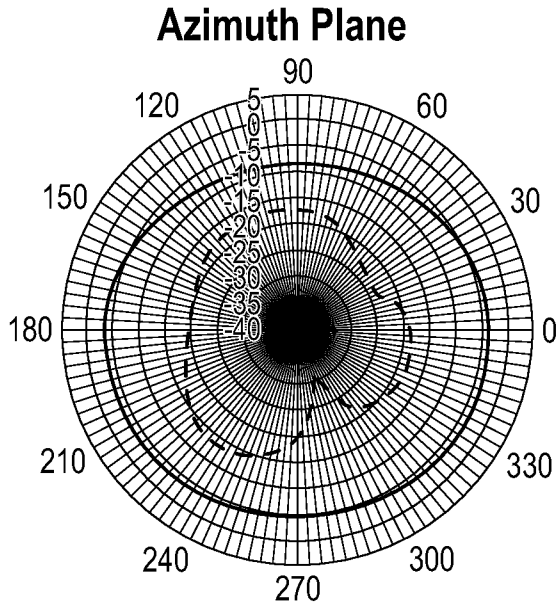


FIG. 8B

7/27

698 MHz



824 MHz

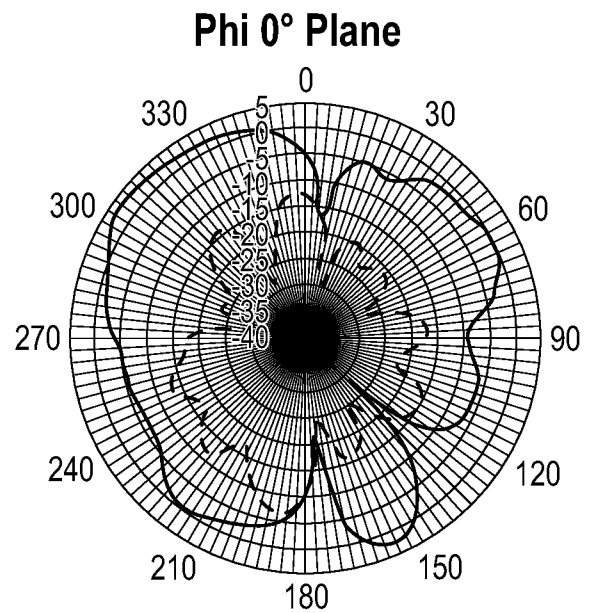
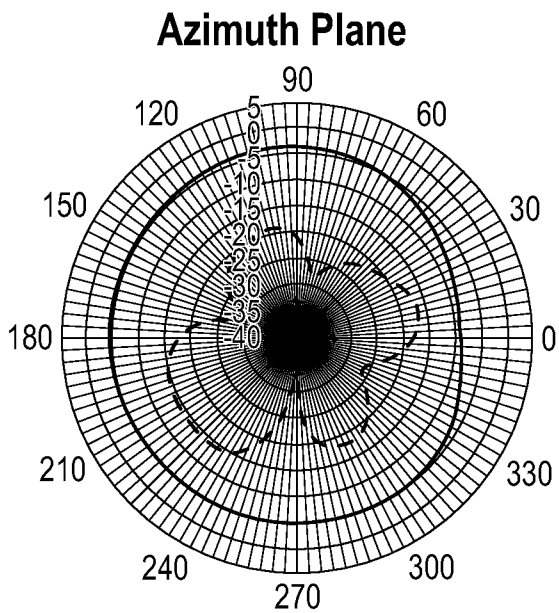
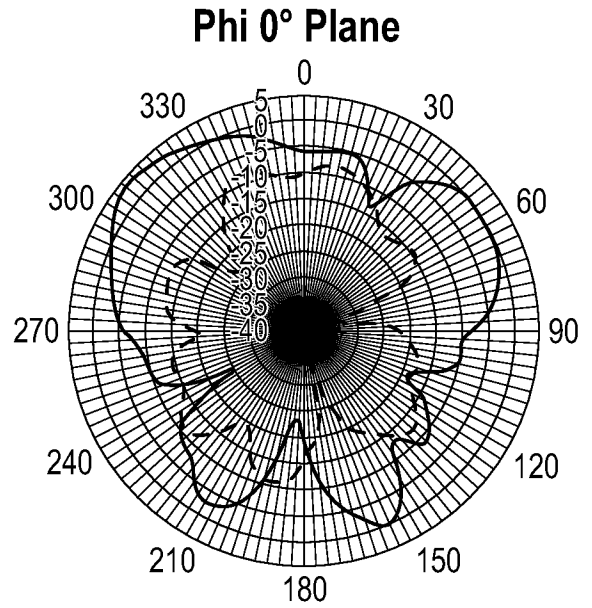
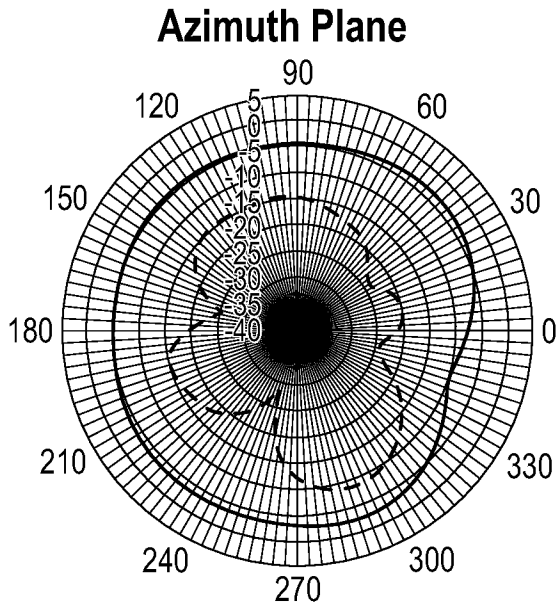


FIG. 9

8/27

894 MHz



960 MHz

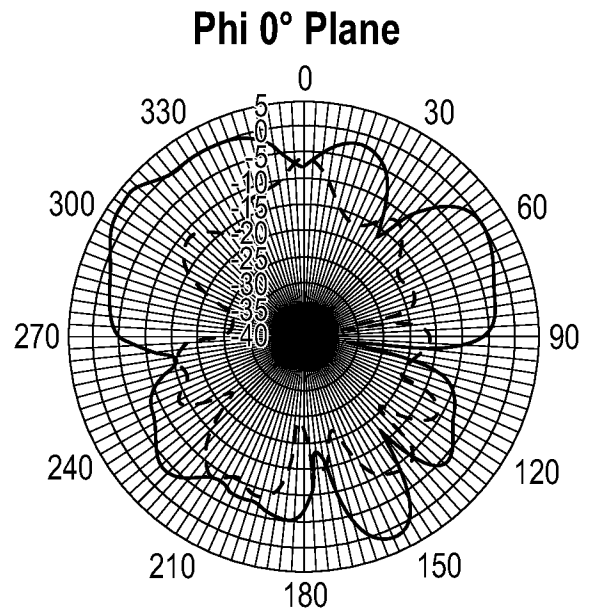
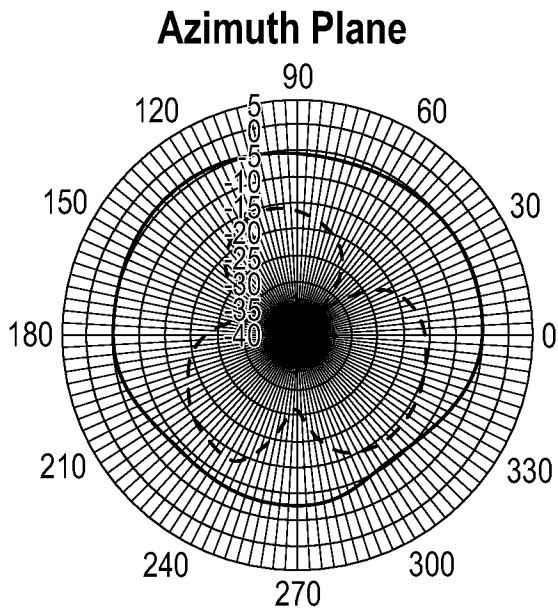
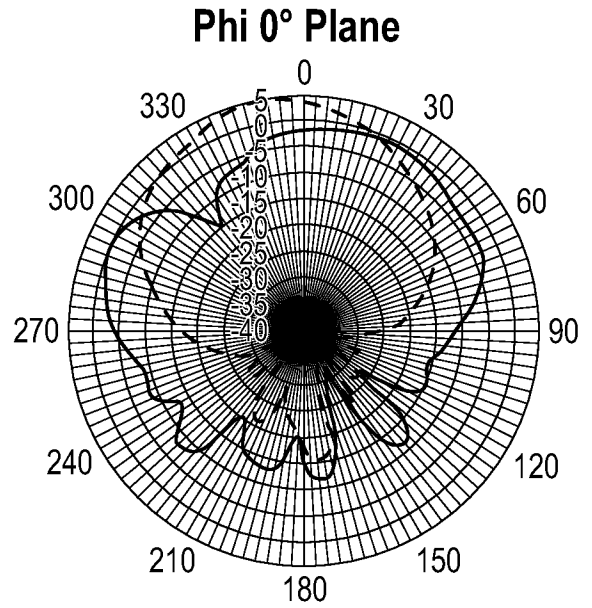
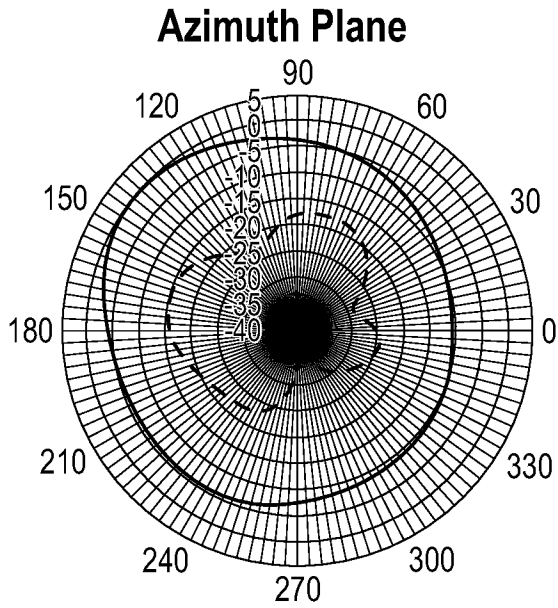


FIG. 9 (Cont.)

9/27

1710 MHz



1880 MHz

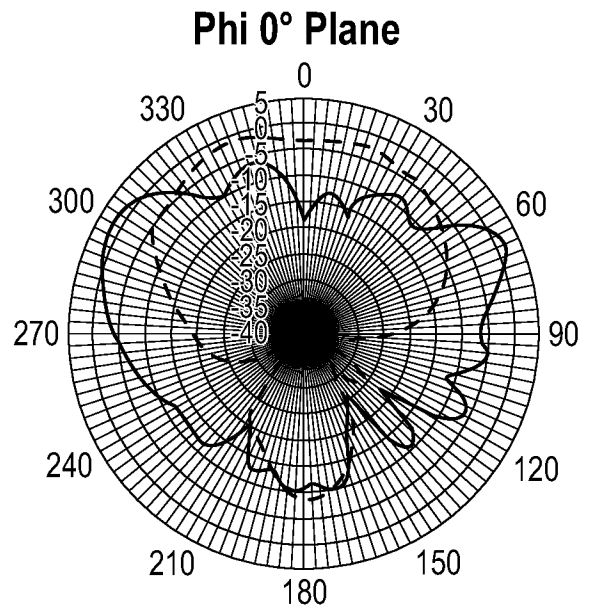
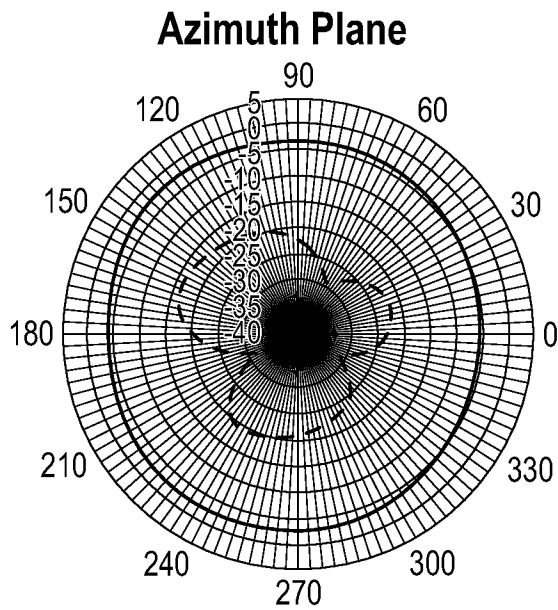
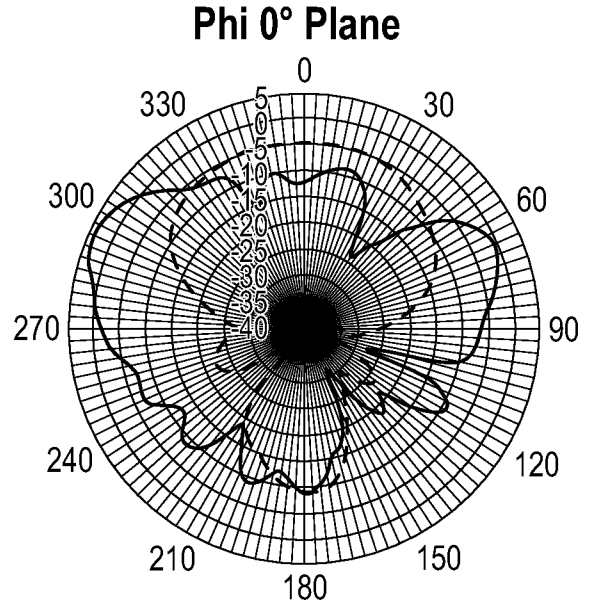
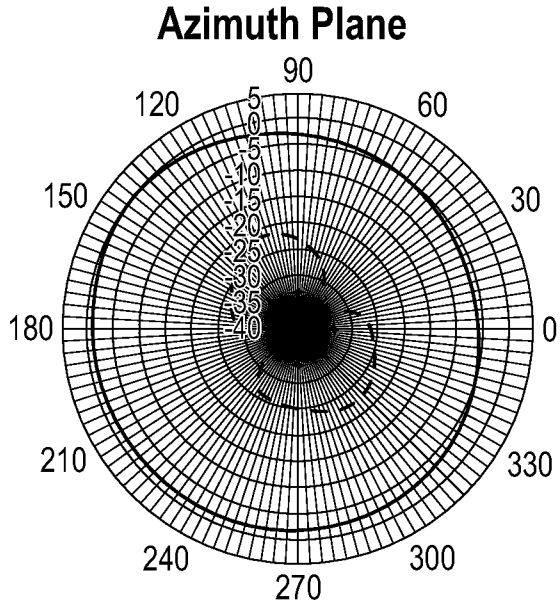


FIG. 9 (Cont.)

10/27

1990 MHz



2170 MHz

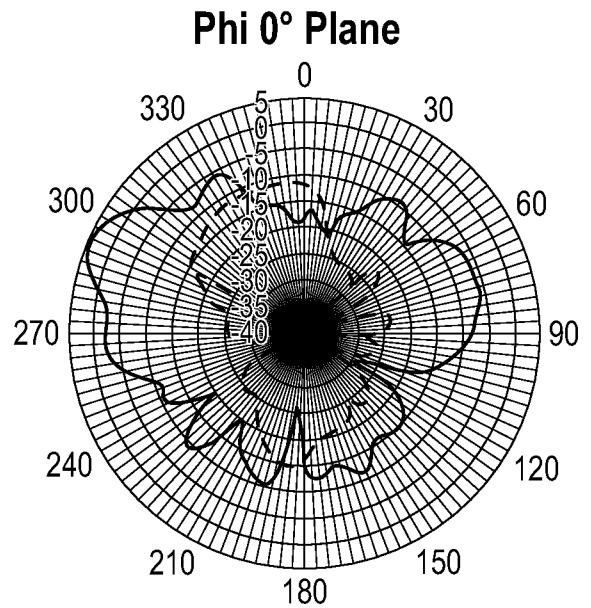
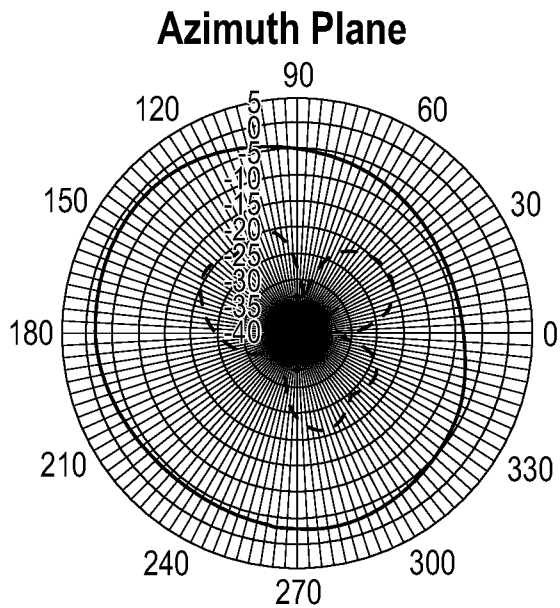
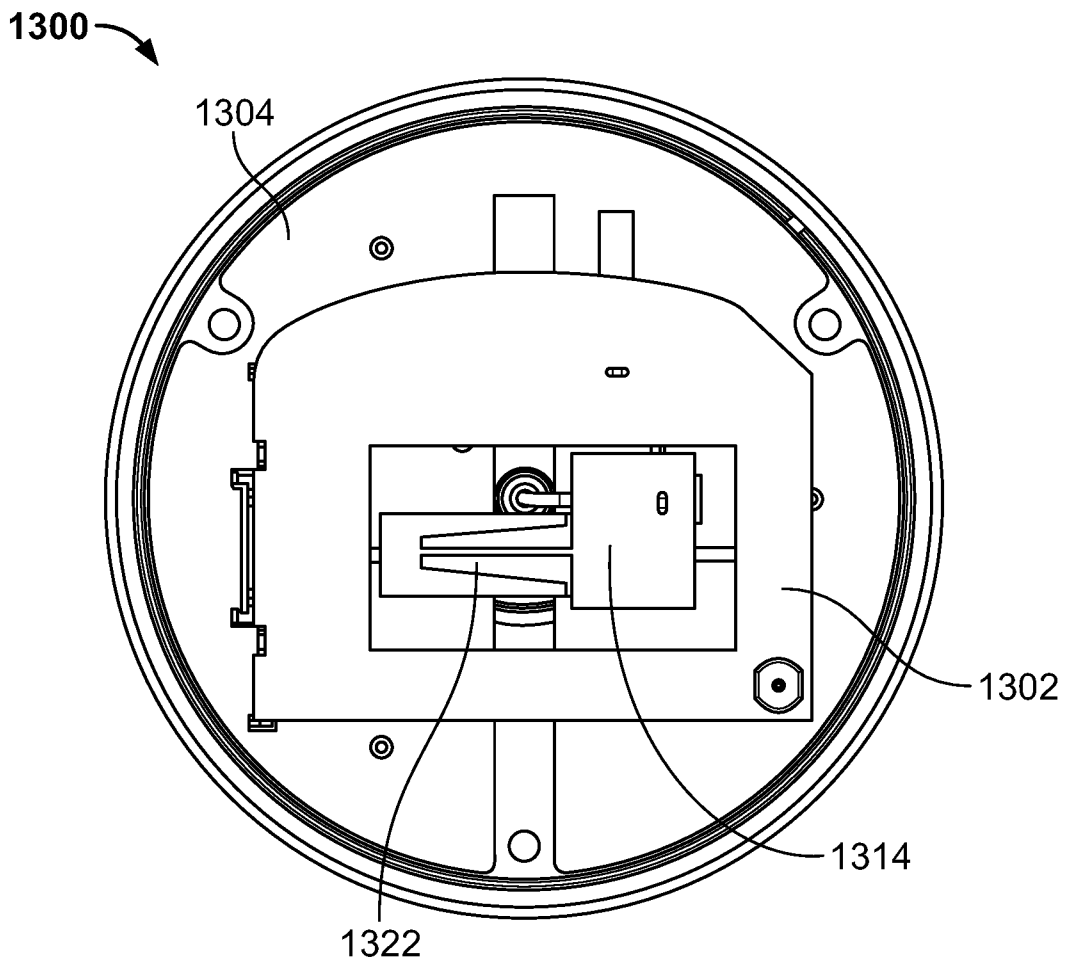
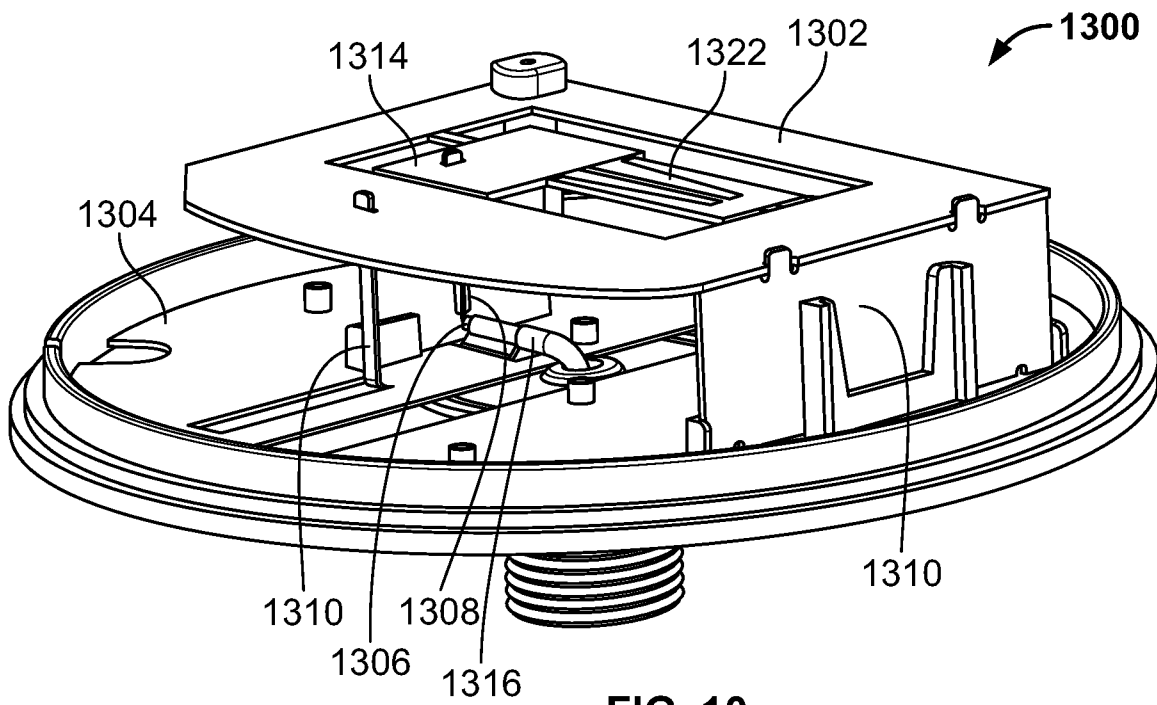


FIG. 9 (Cont.)

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12/27

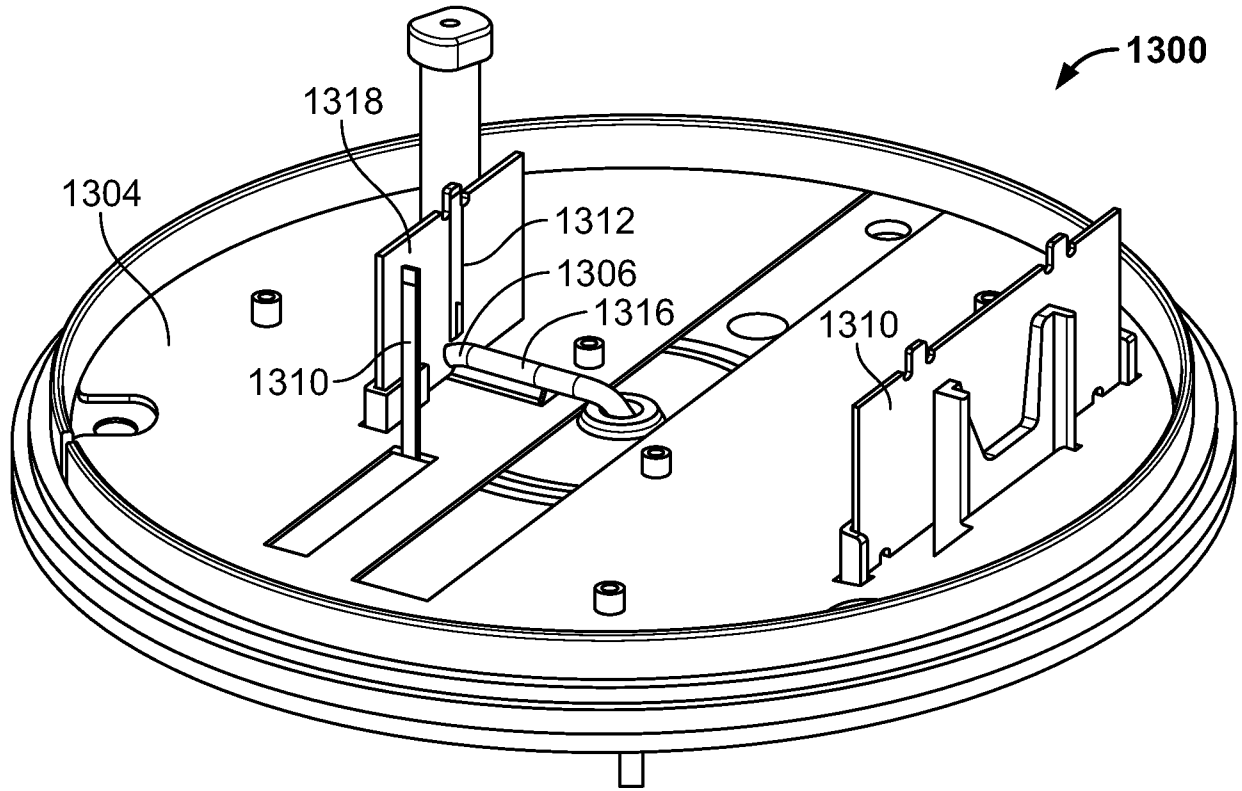


FIG. 12

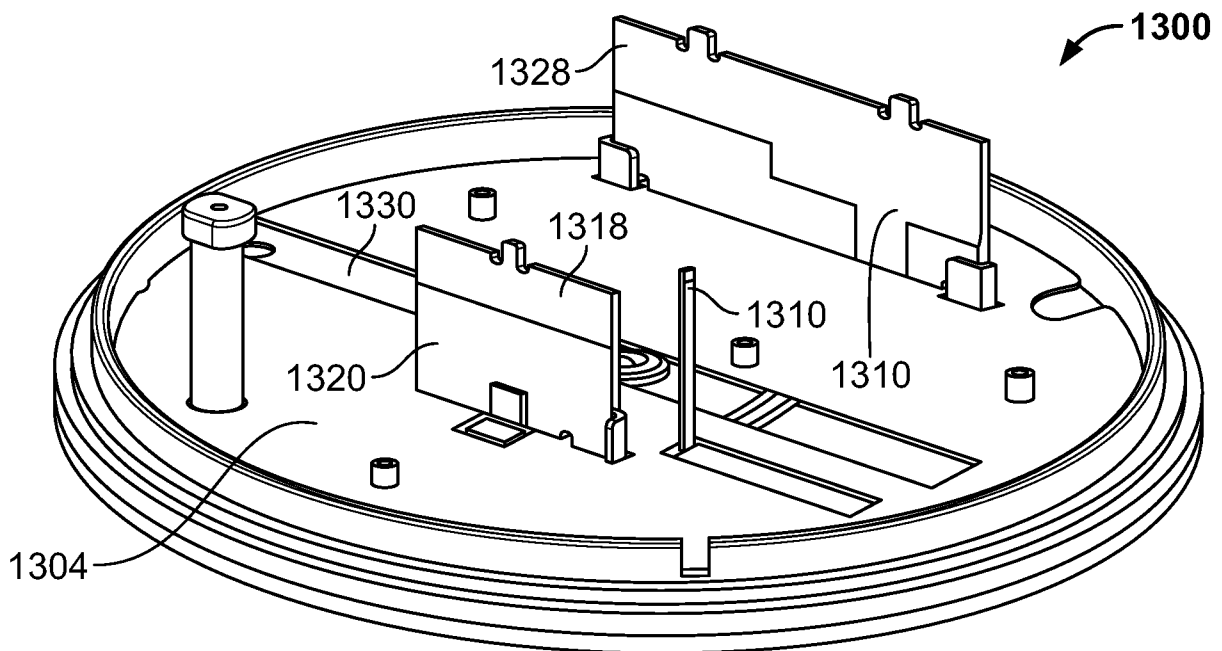


FIG. 13

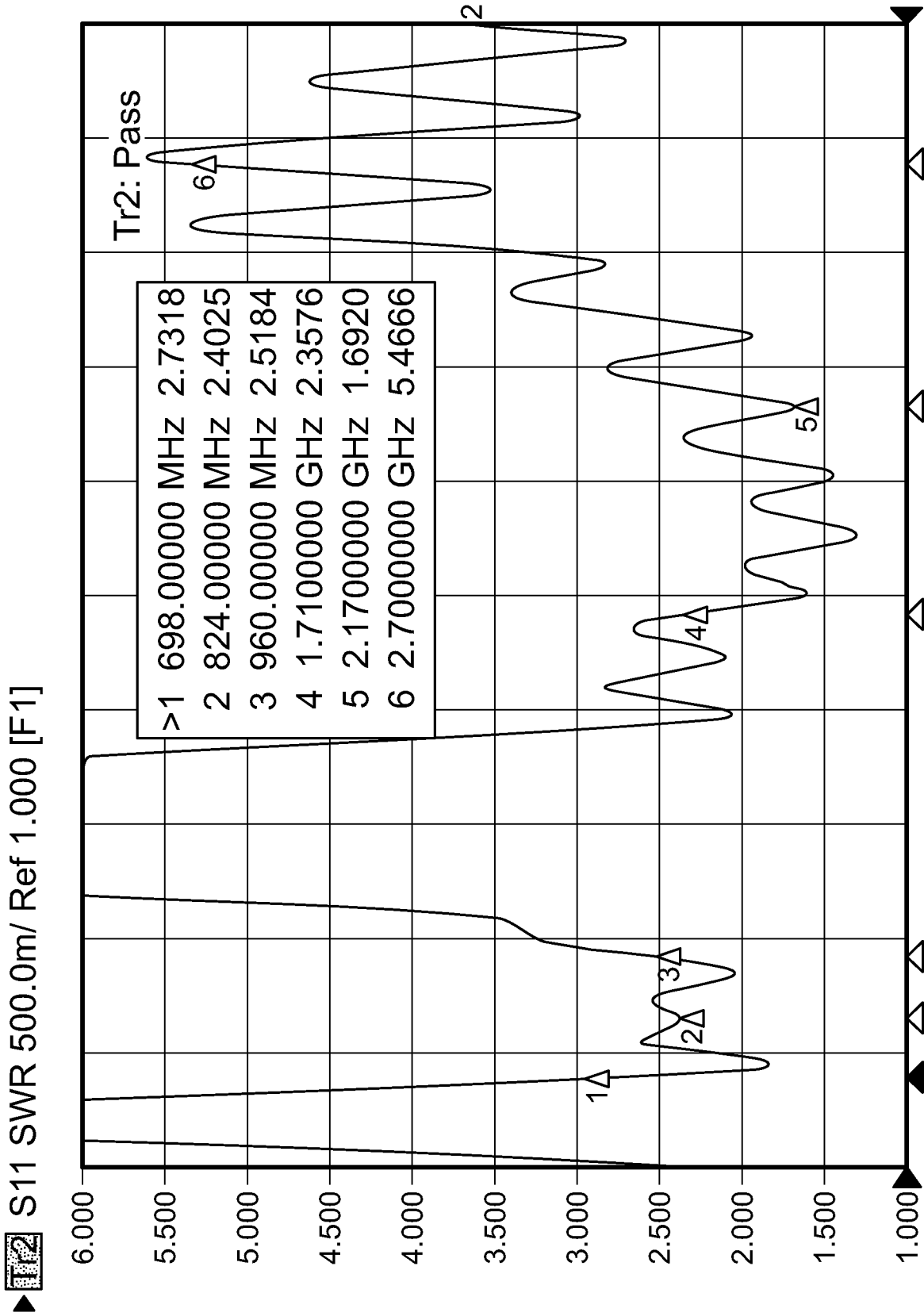
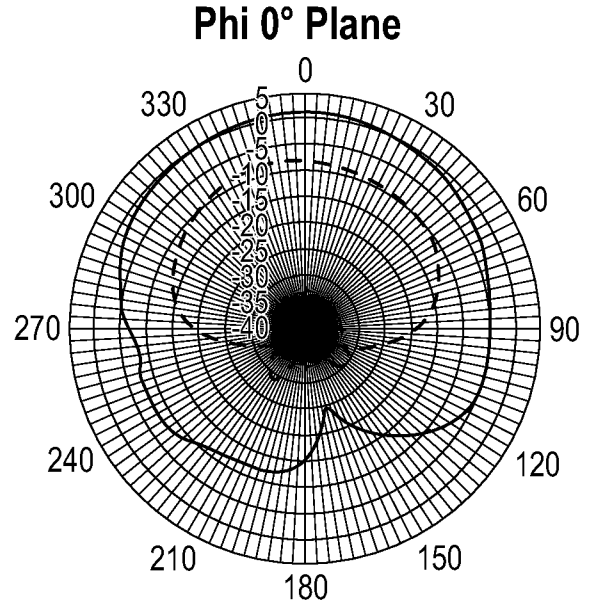
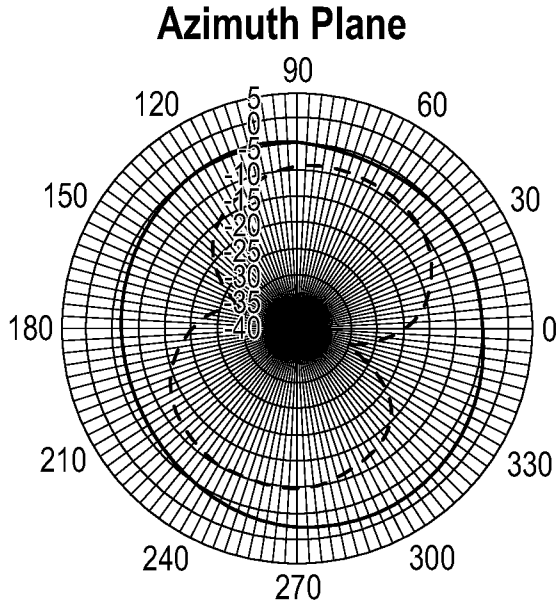


FIG. 14

14/27

698 MHz



824 MHz

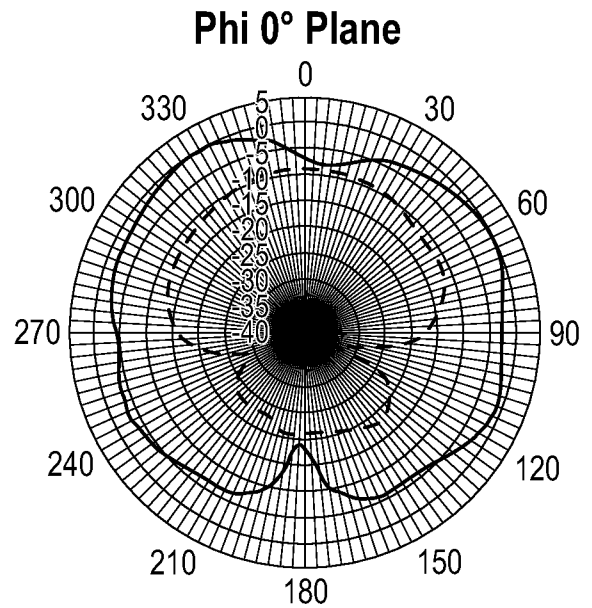
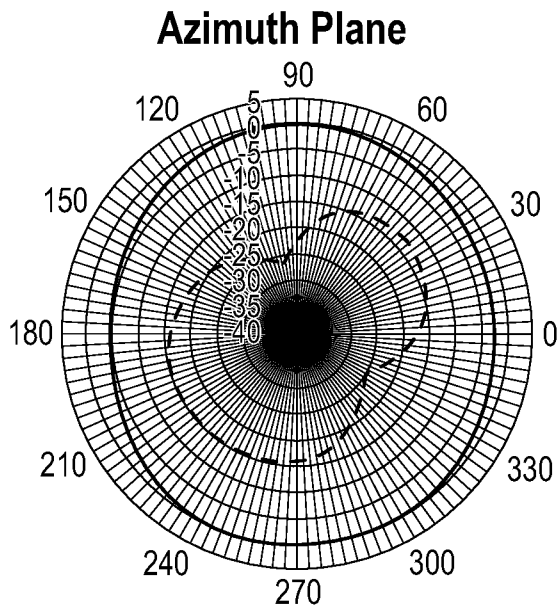
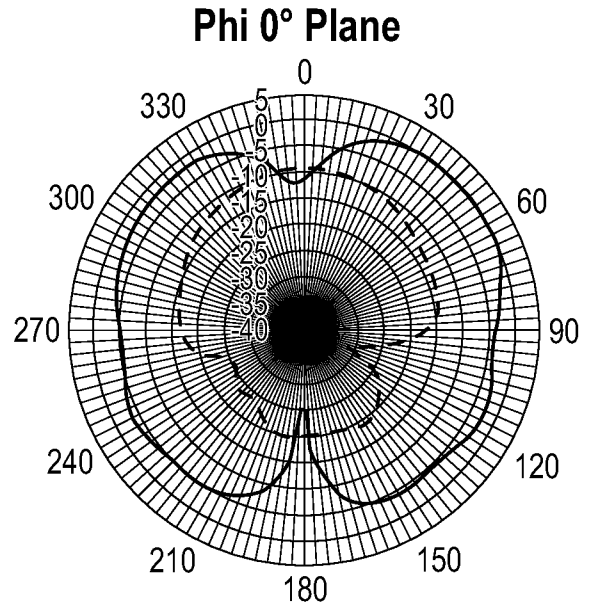
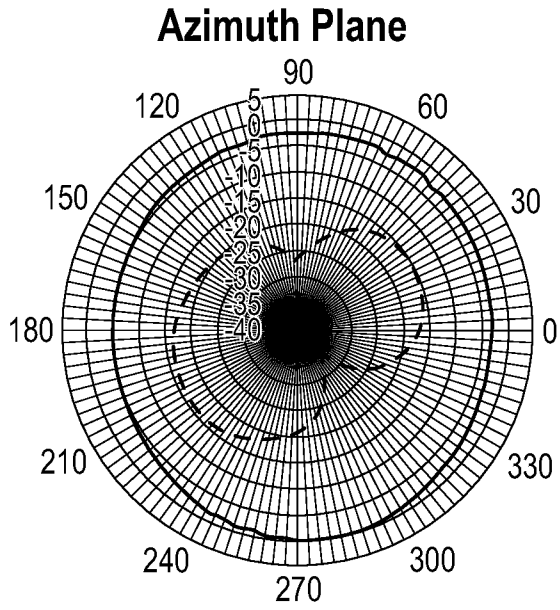


FIG. 15

15/27

894 MHz



960 MHz

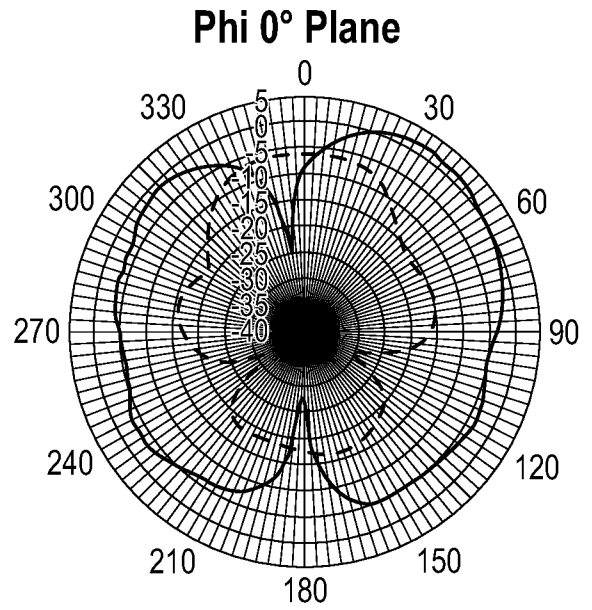
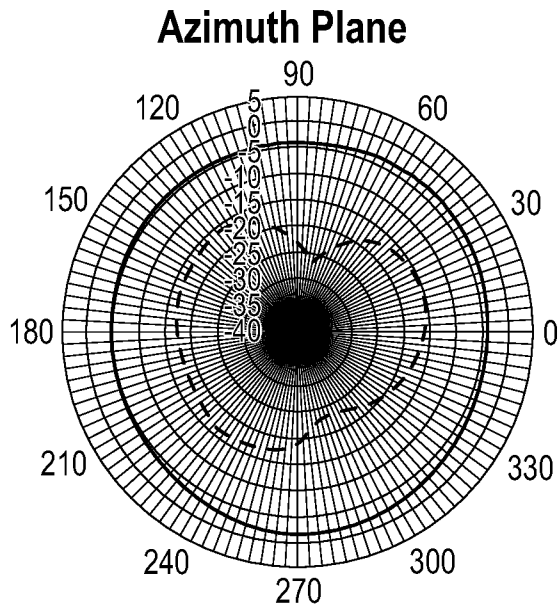
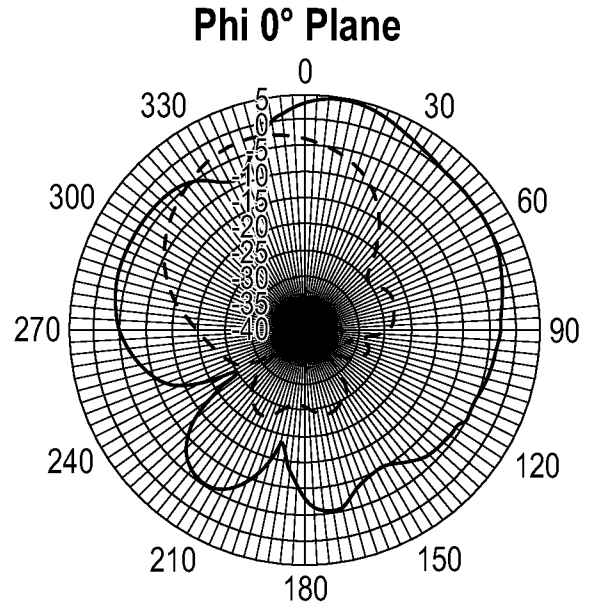
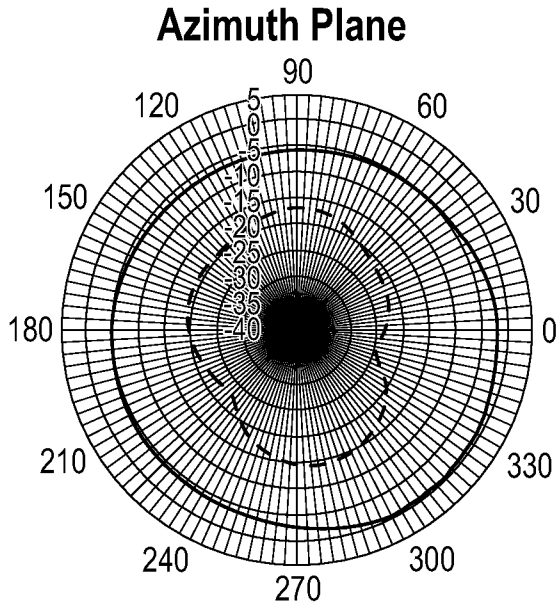


FIG. 15 (Cont.)

16/27

1710 MHz



1880 MHz

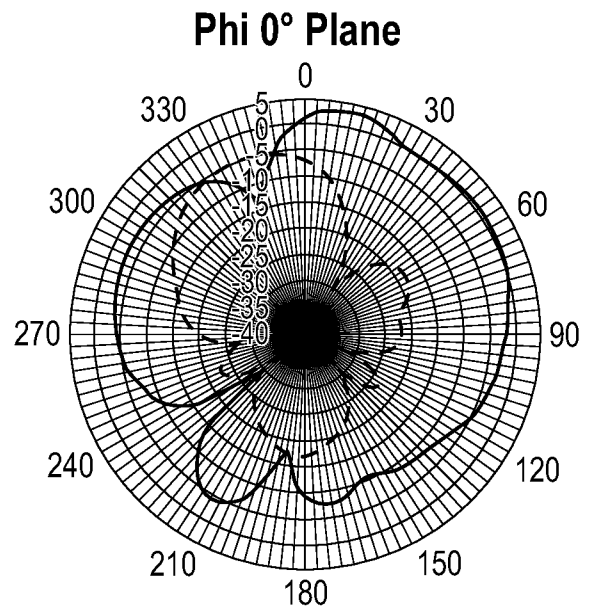
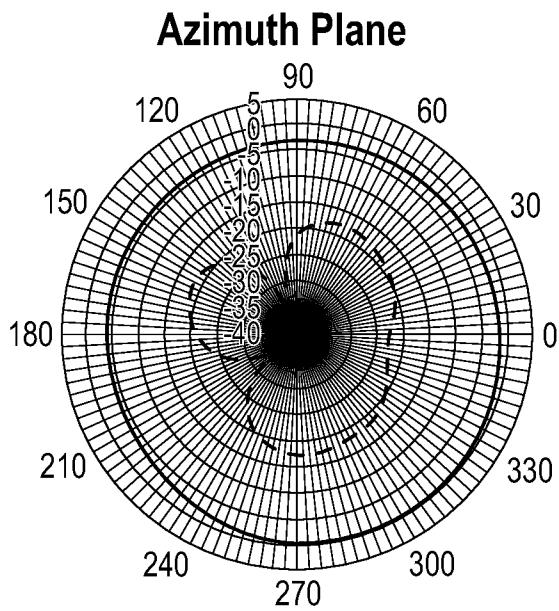
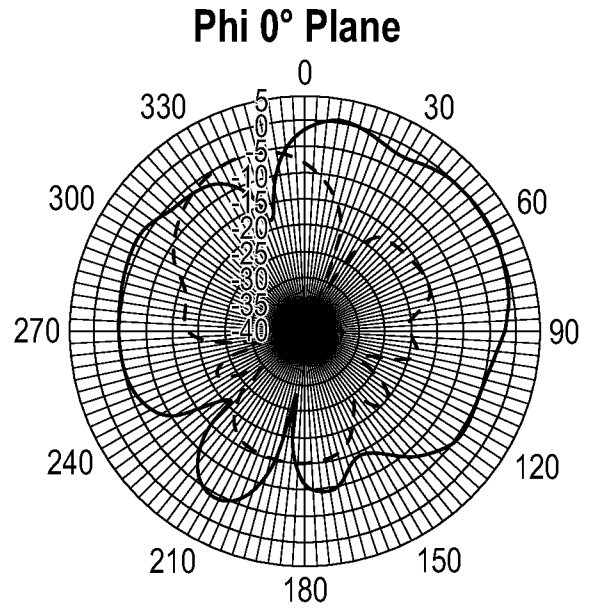
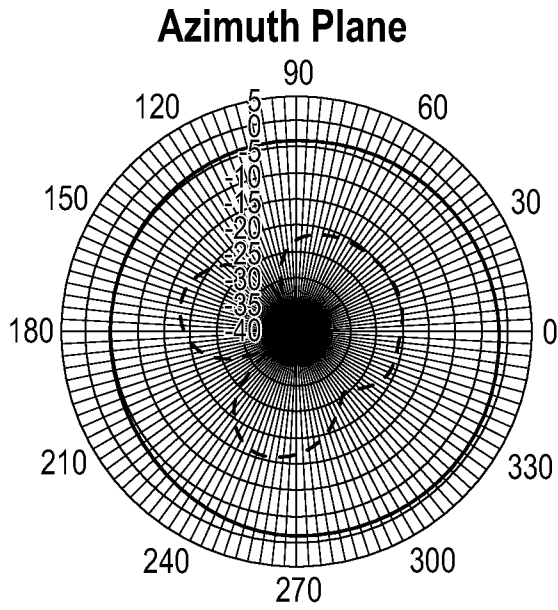


FIG. 15 (Cont.)

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1990 MHz



2170 MHz

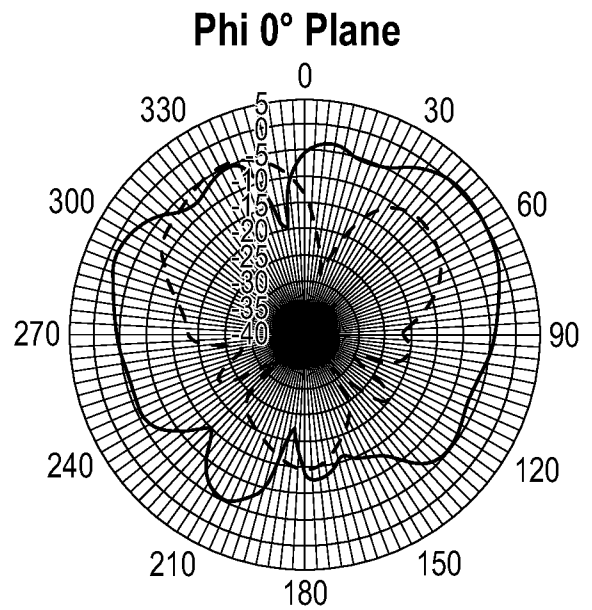
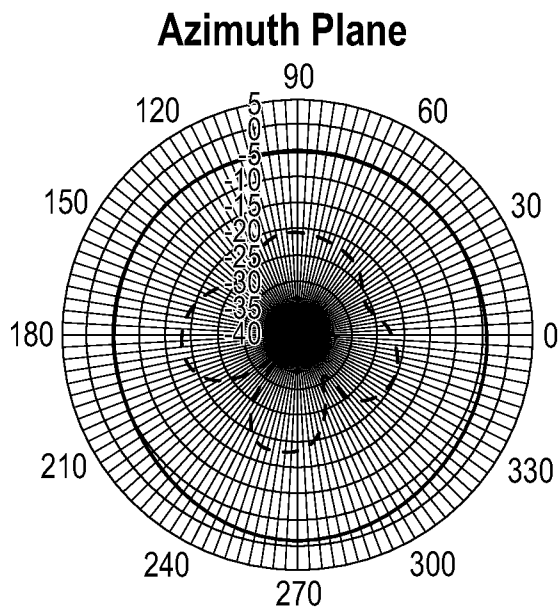


FIG. 15 (Cont.)

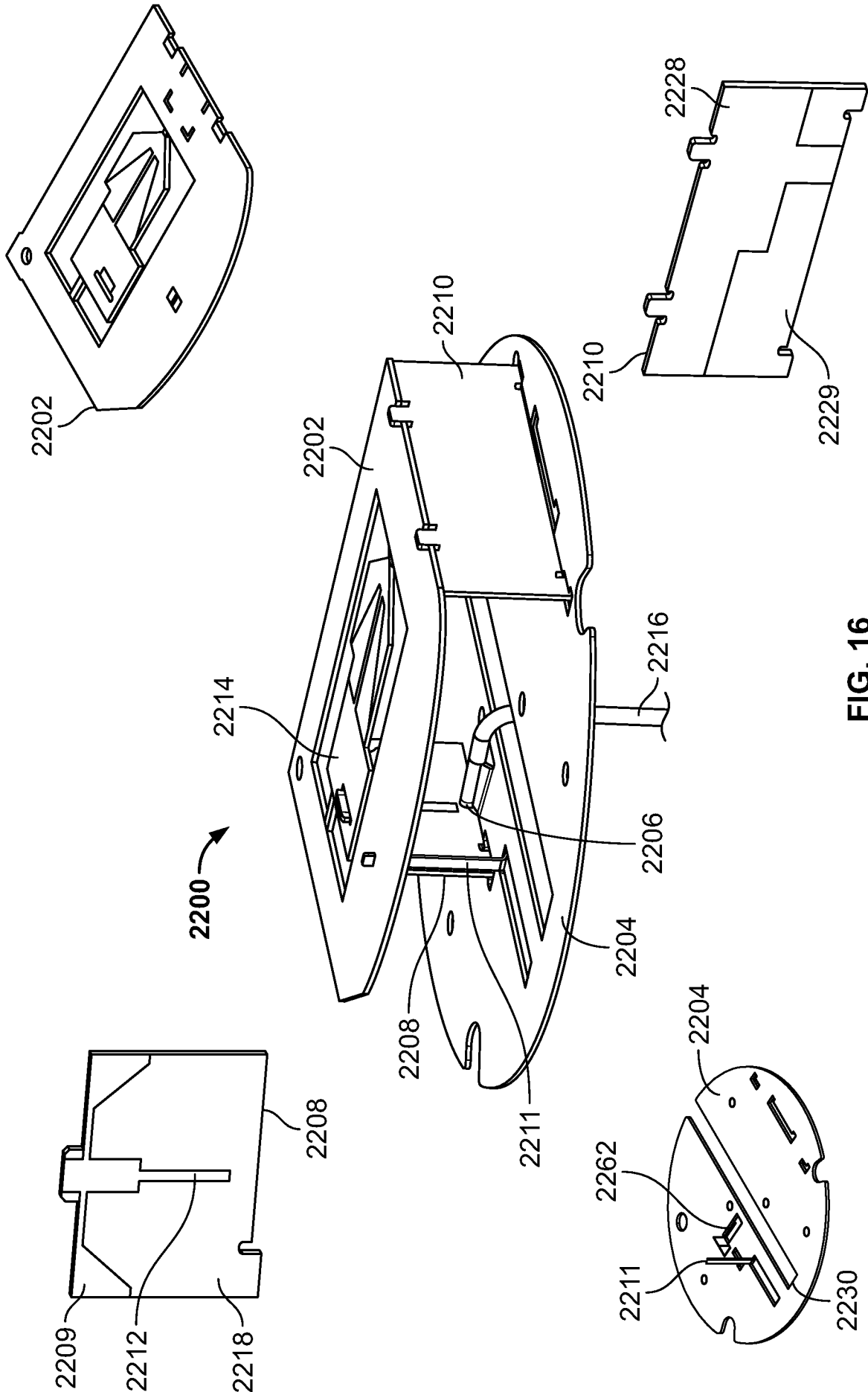


FIG. 16

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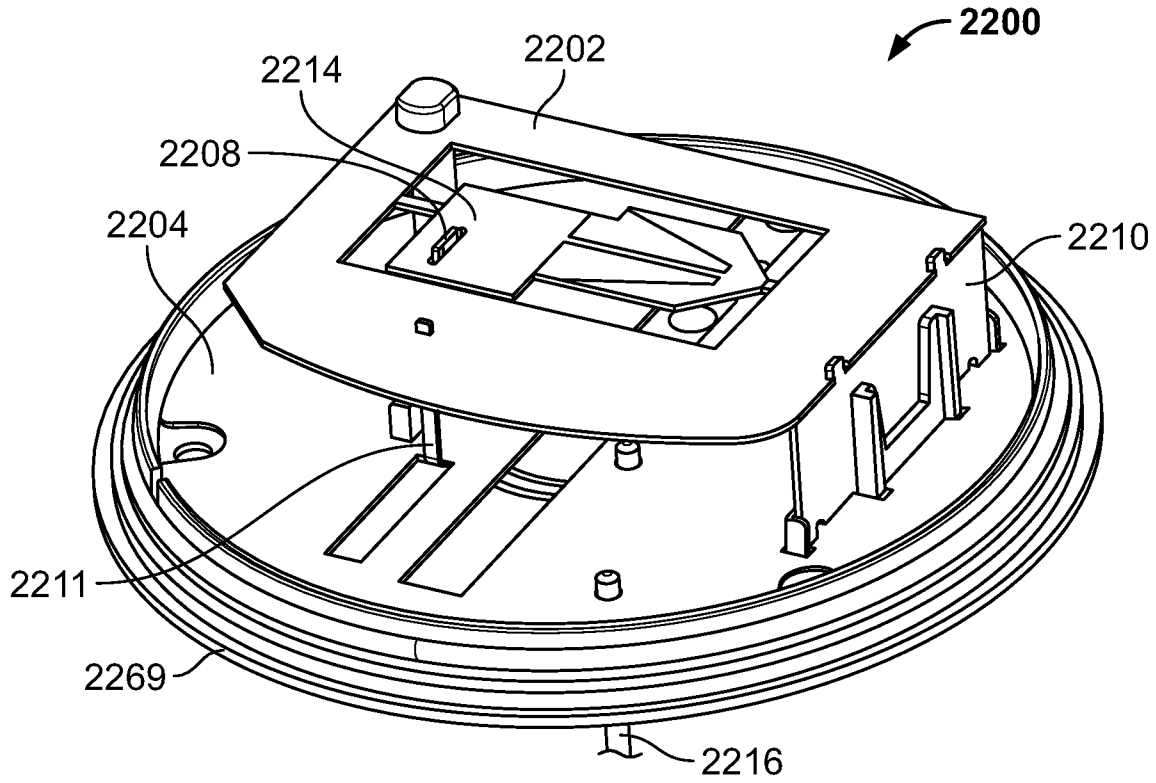


FIG. 17

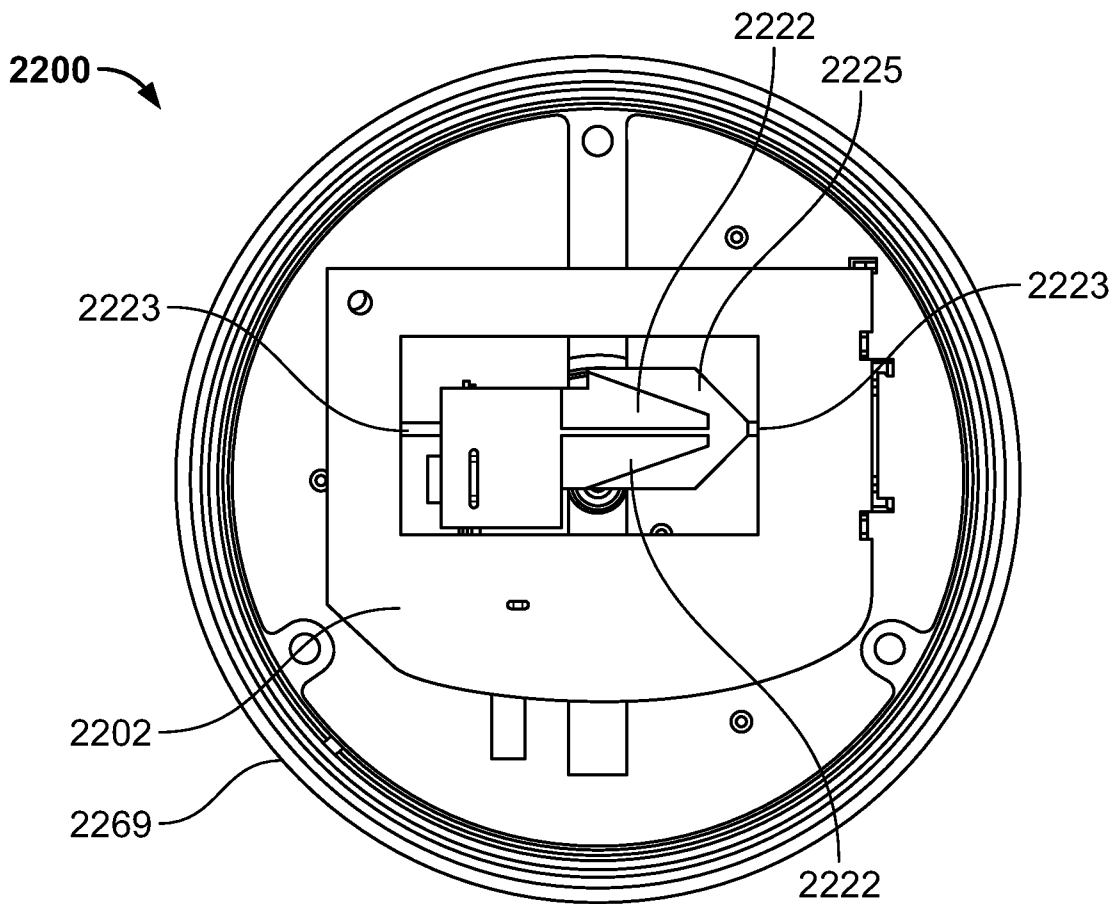


FIG. 18

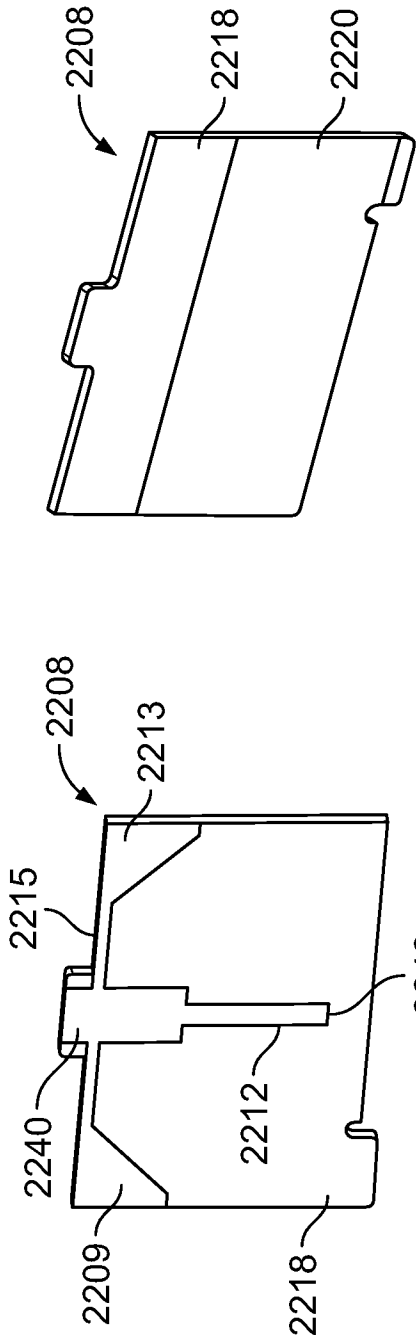


FIG. 19

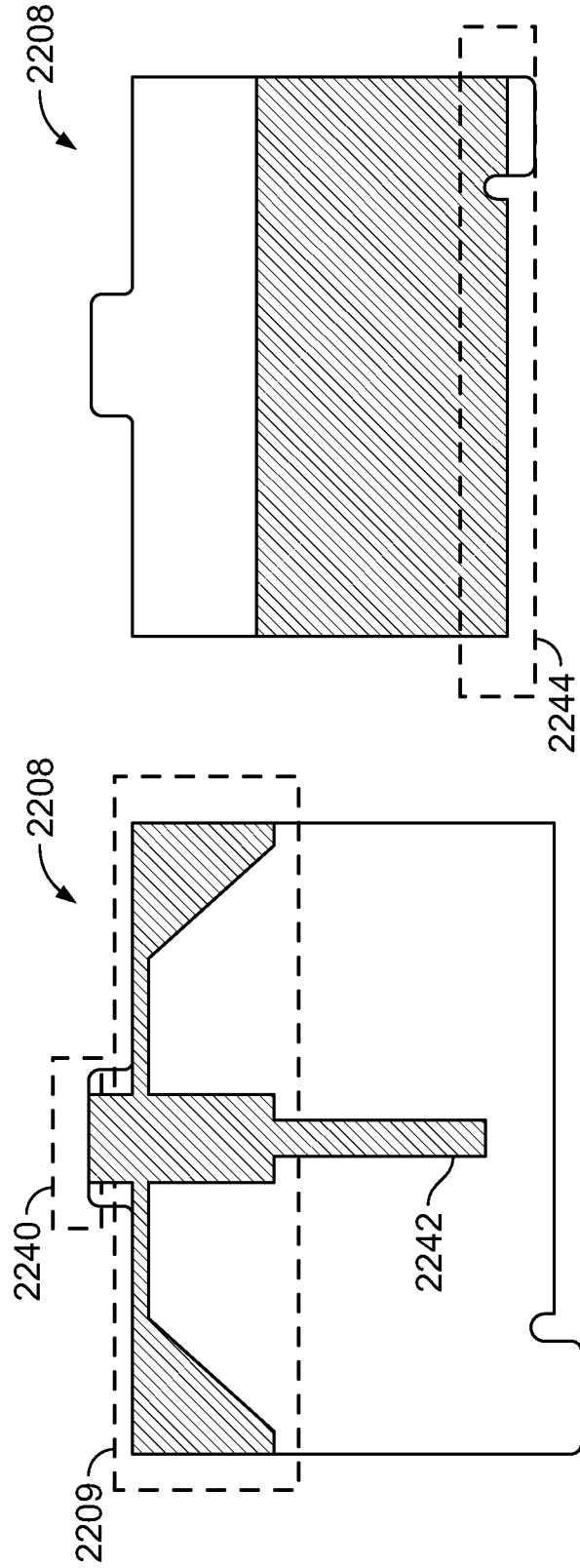


FIG. 20

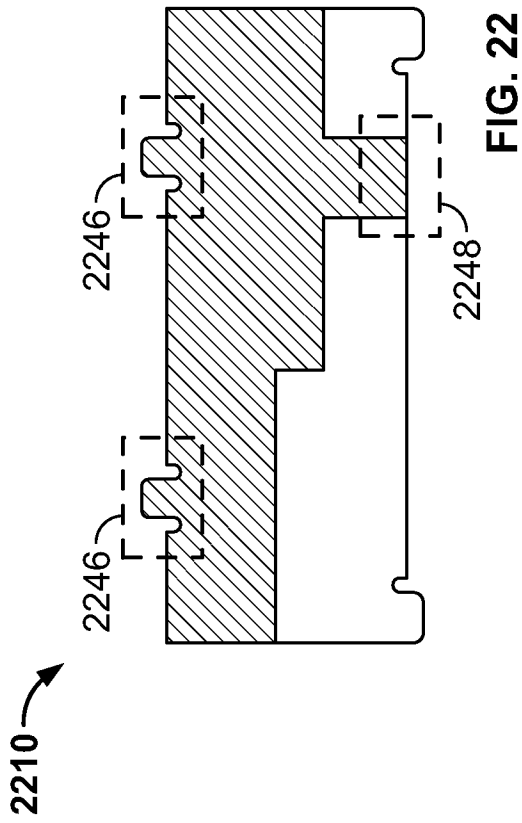


FIG. 21

FIG. 22

2210

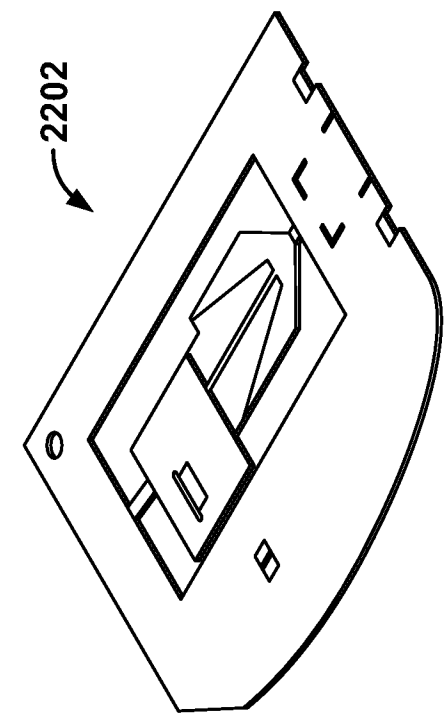


FIG. 23

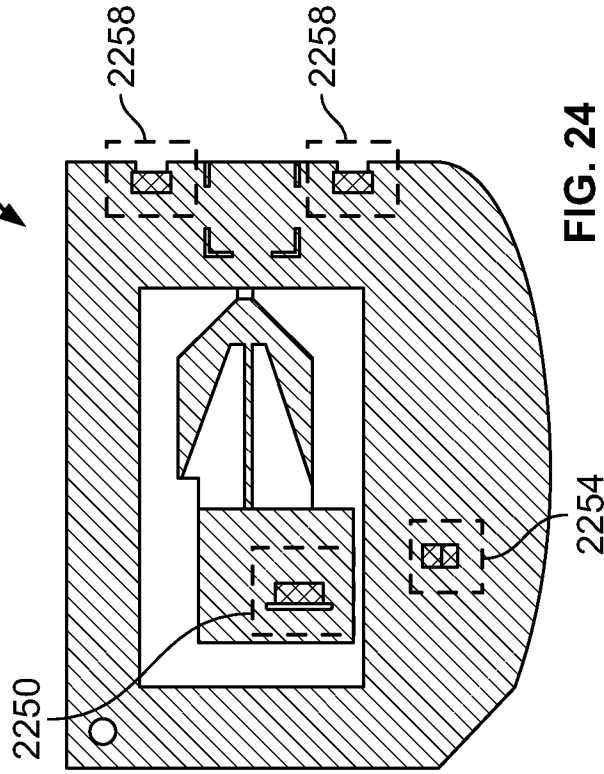


FIG. 24

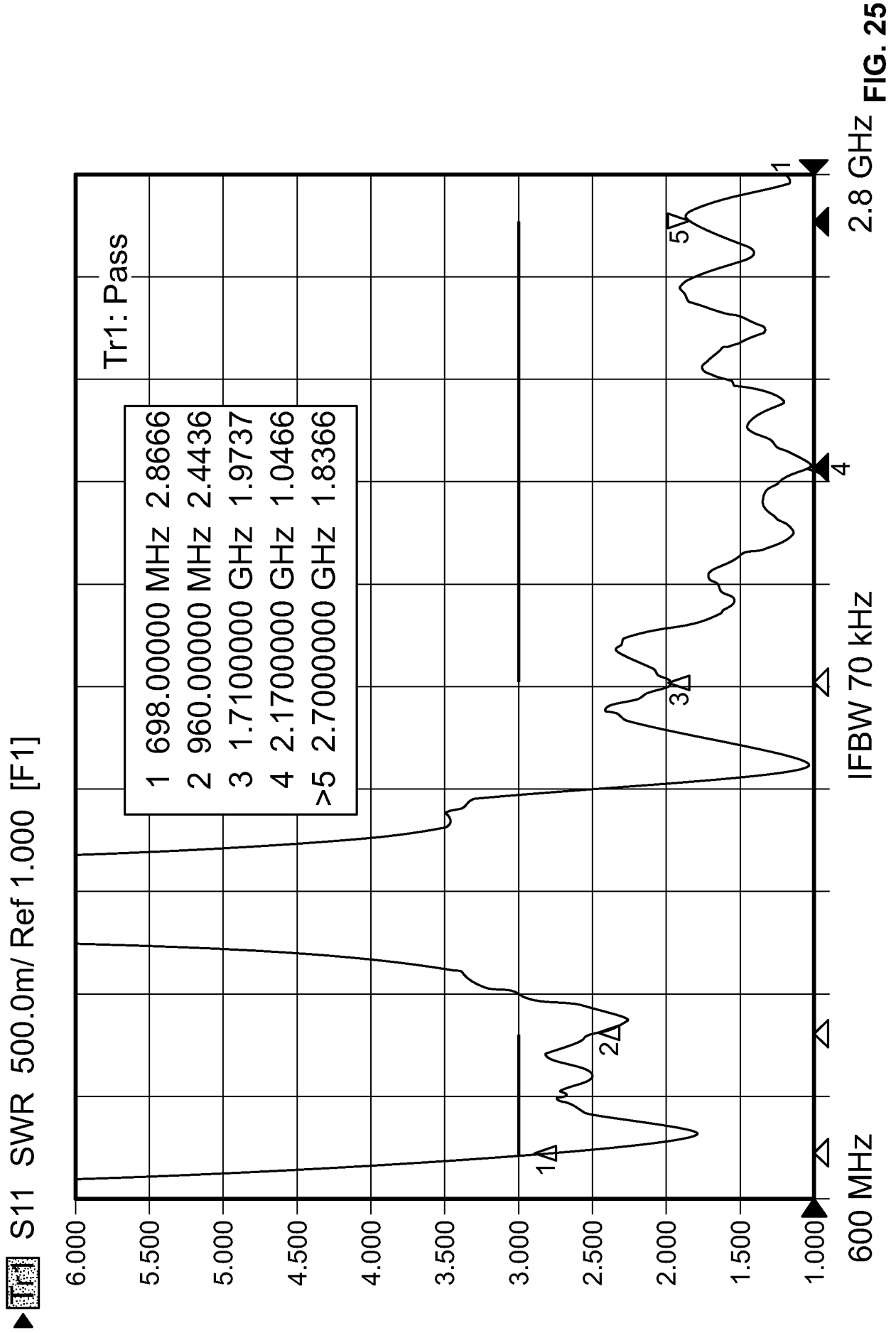


FIG. 25

698 MHz

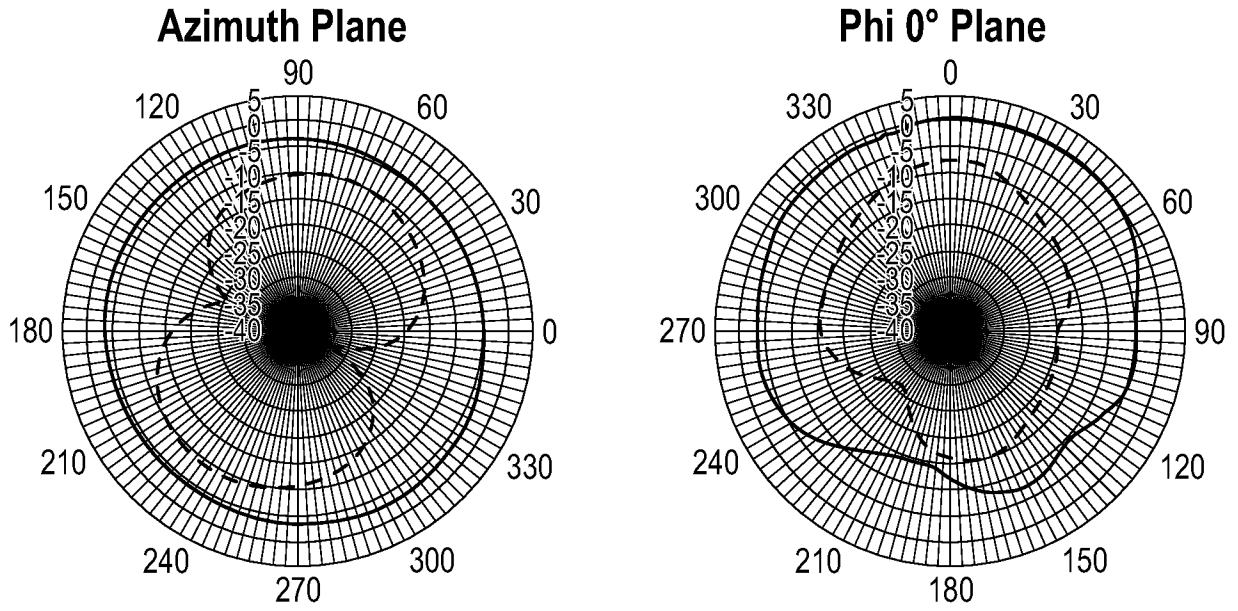


FIG. 26

824 MHz

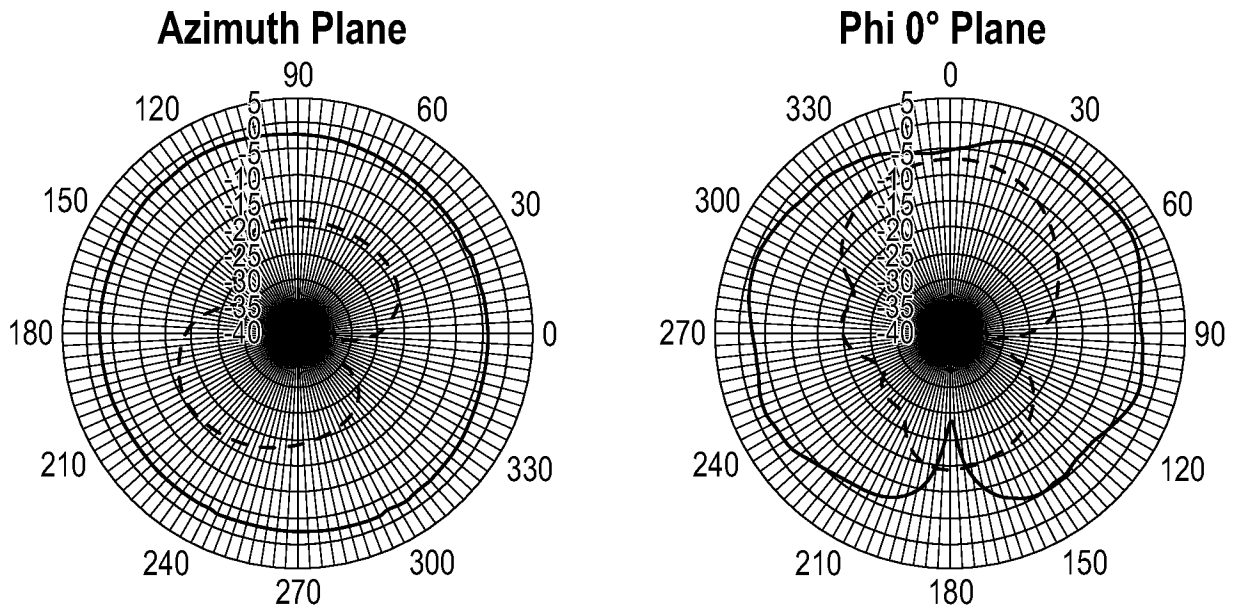


FIG. 27

894 MHz

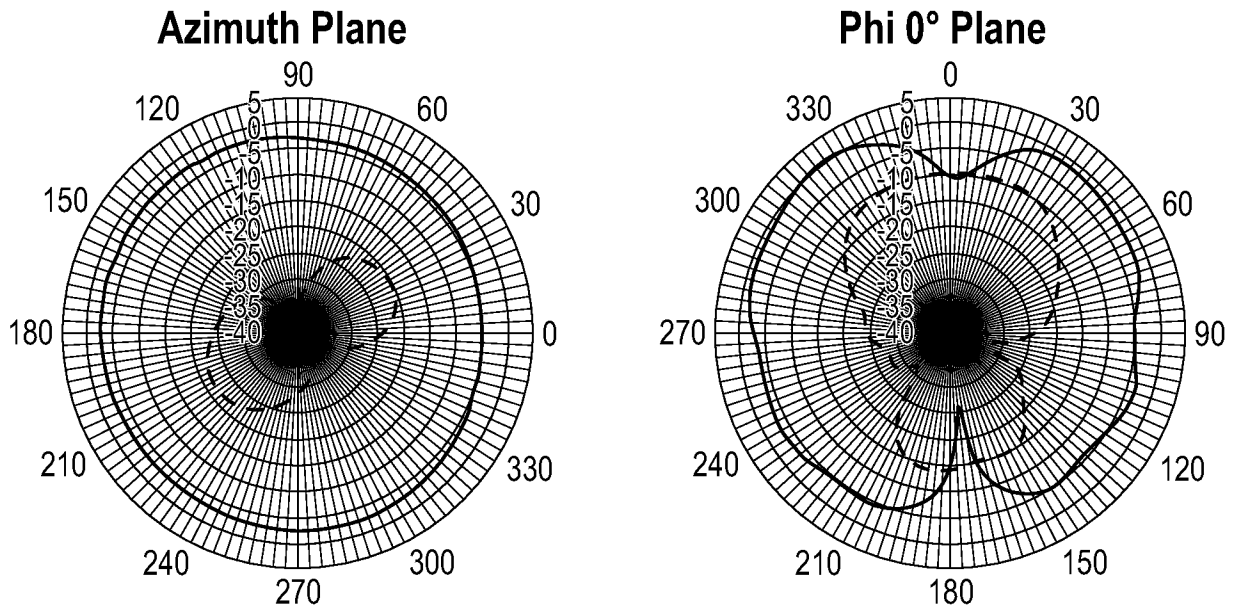


FIG. 28

960 MHz

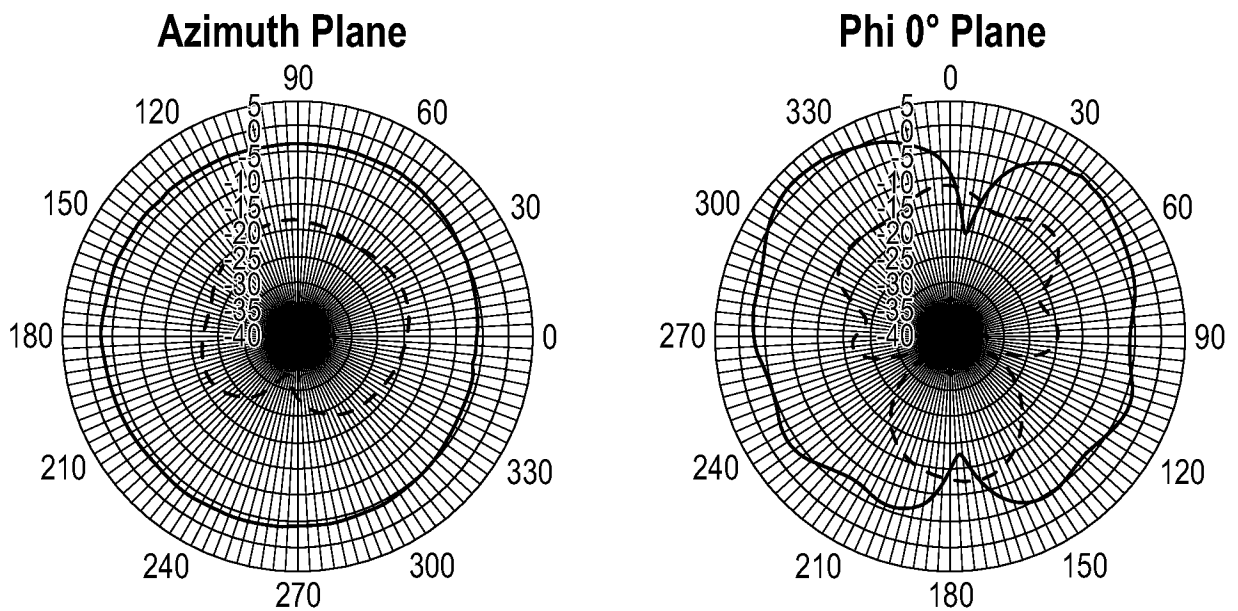


FIG. 29

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1710 MHz

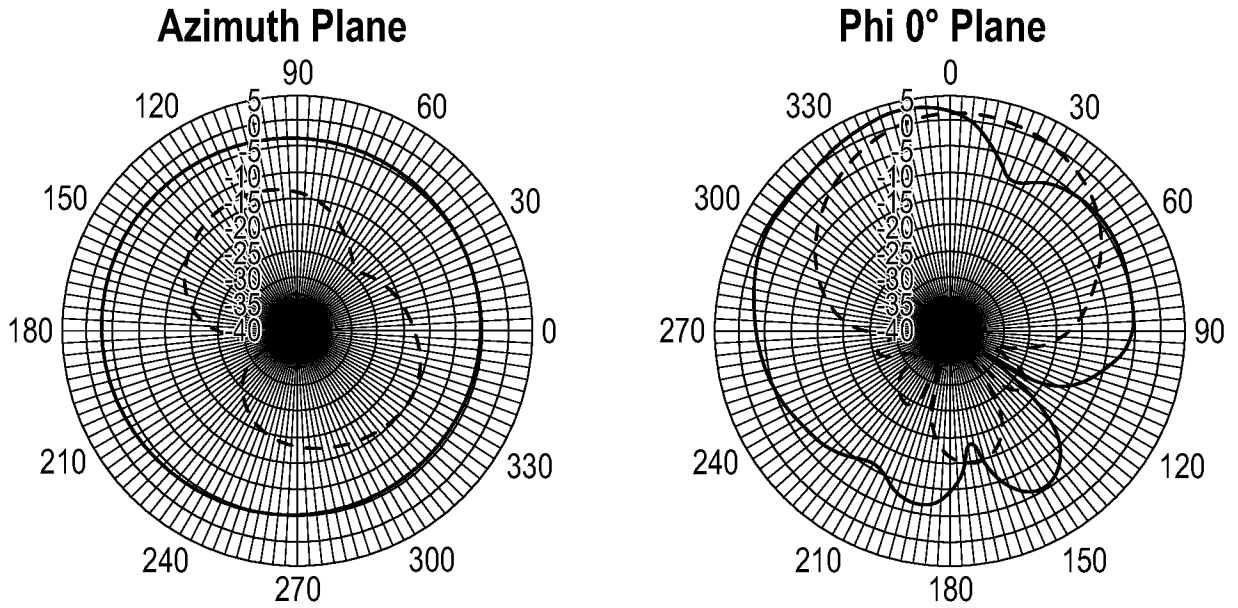


FIG. 30

1880 MHz

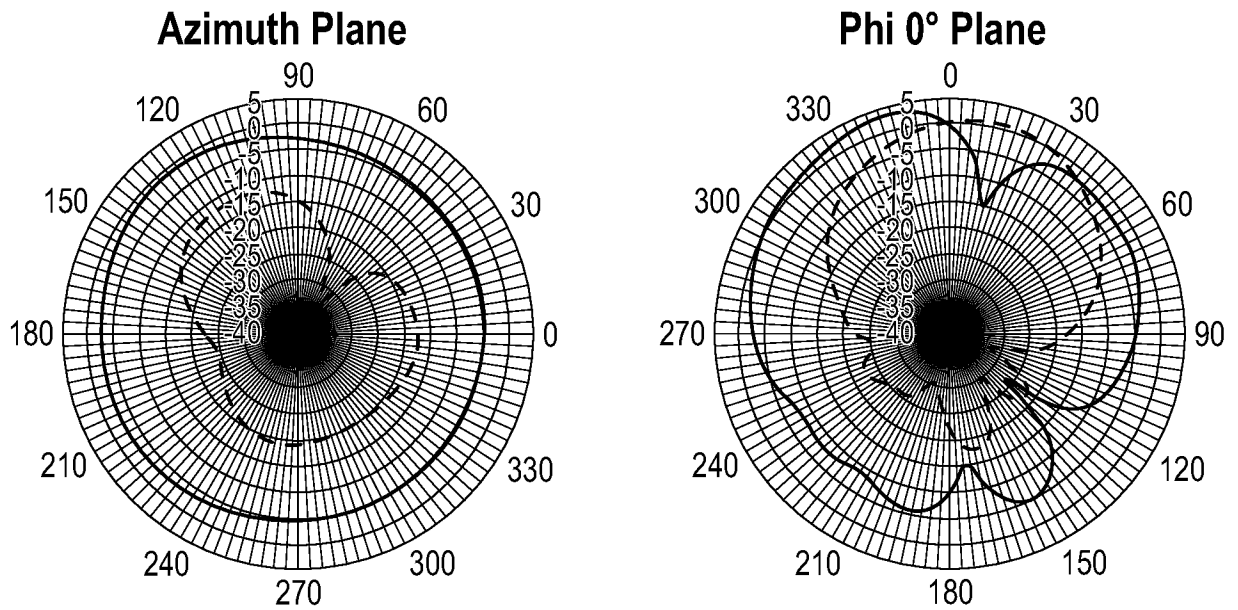


FIG. 31

1990 MHz

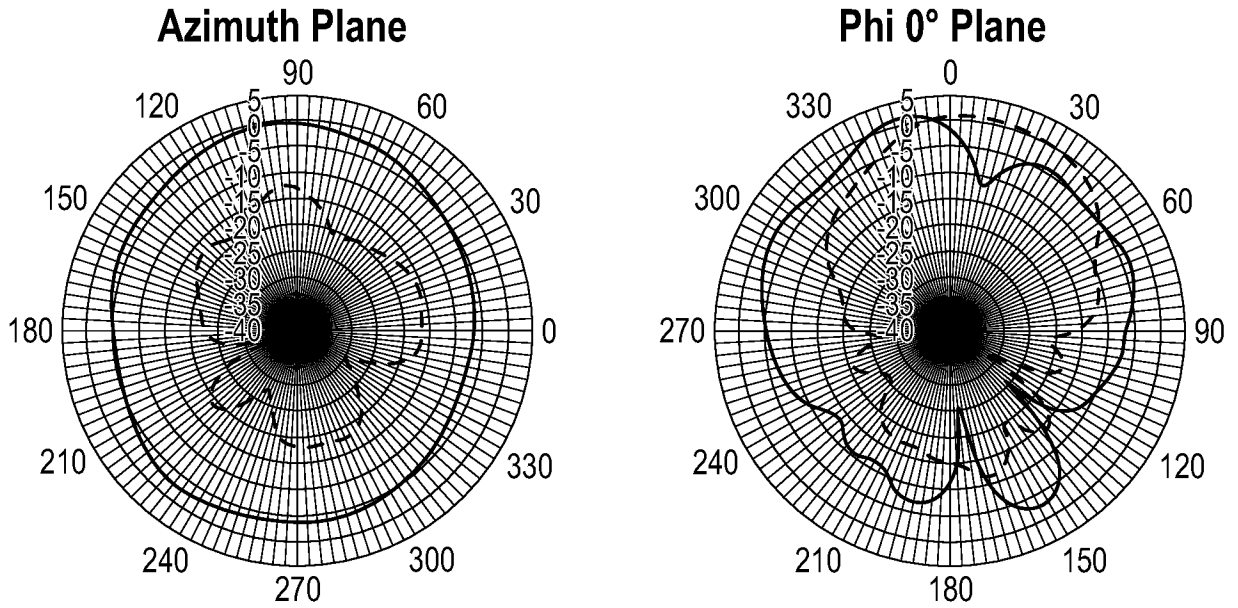


FIG. 32

2170 MHz

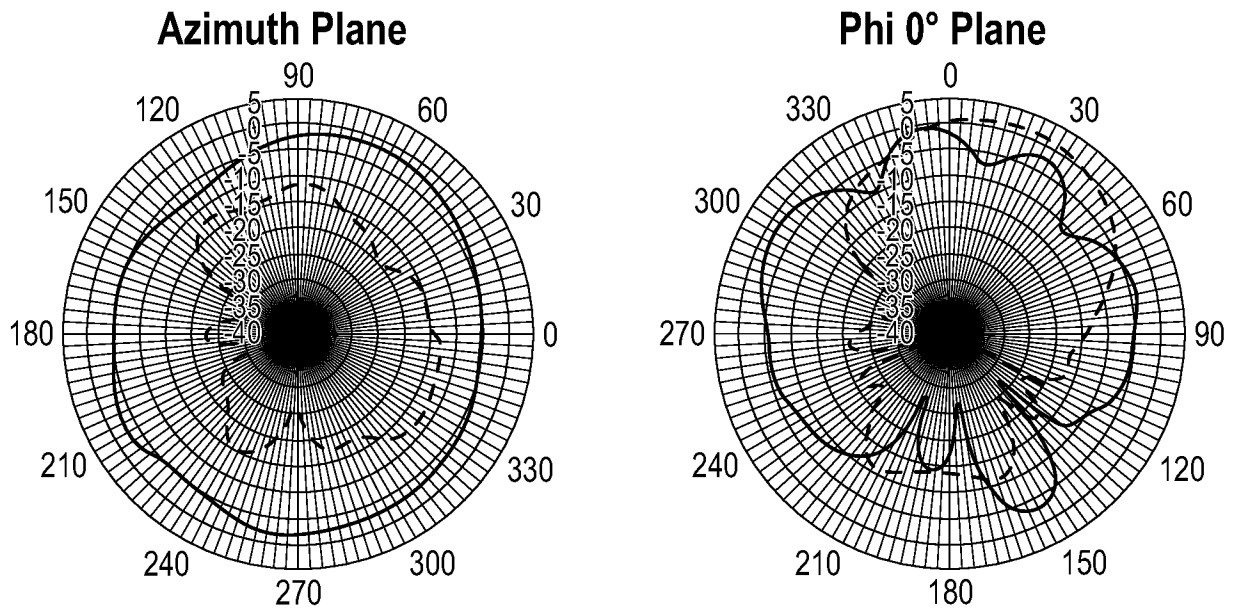


FIG. 33

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2500 MHz

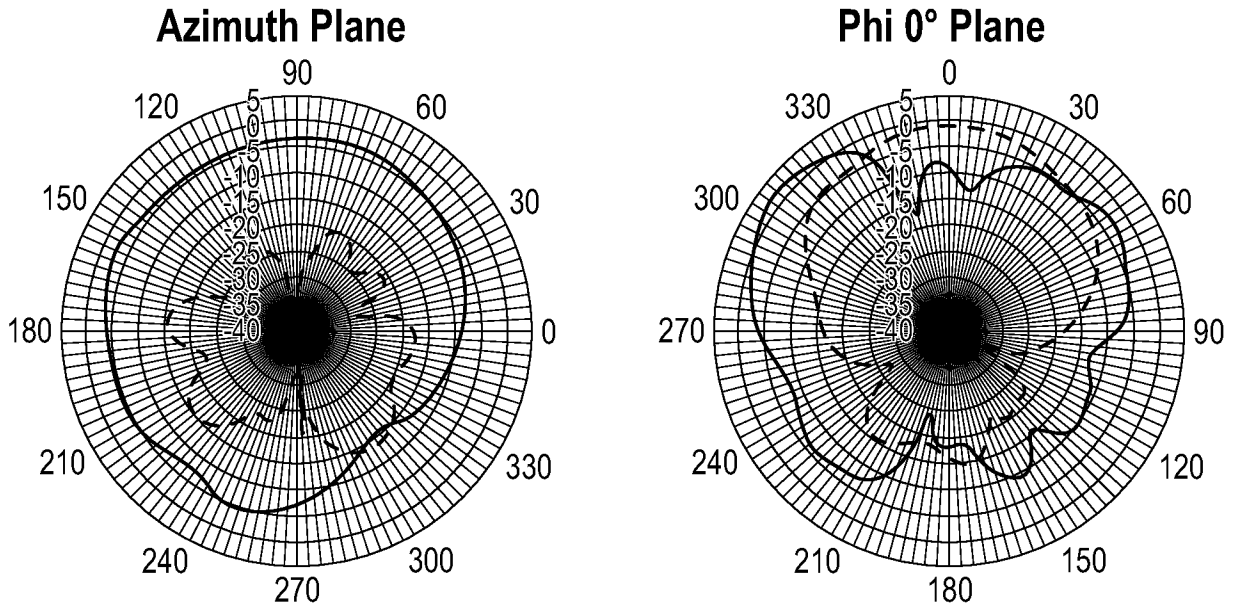


FIG. 34

2700 MHz

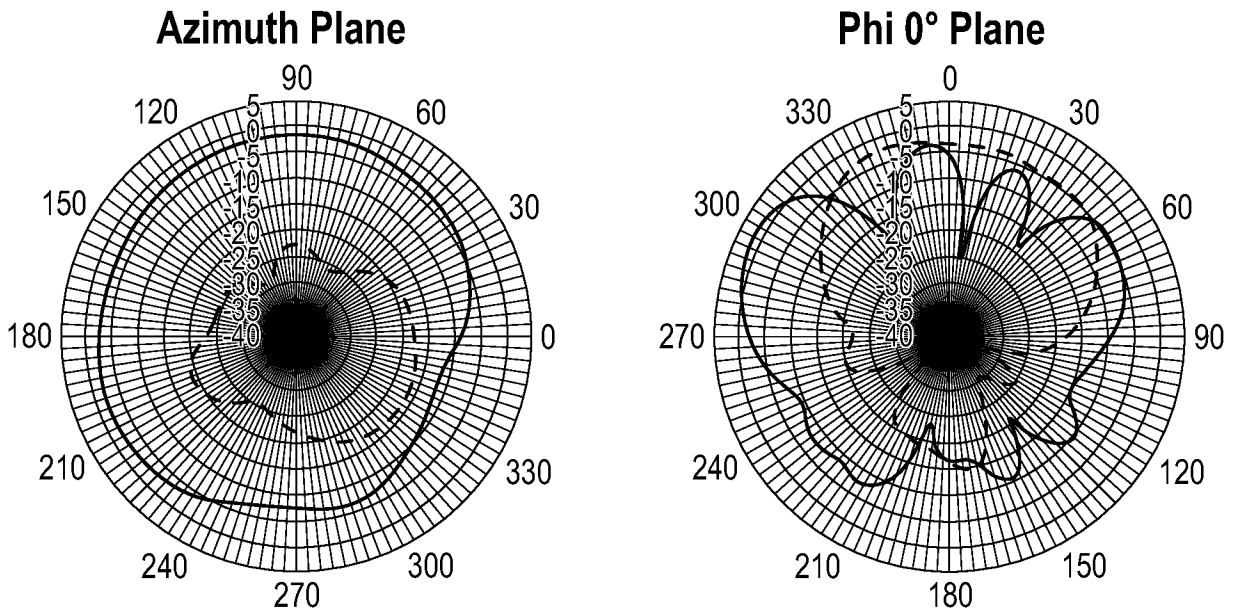


FIG. 35

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.: 10
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claim 10 is unclear, because it refers to multiple dependent claim 9 which does not comply with PCT Rule 6.4(a).

3. Claims Nos.: 6-9, 11-15
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.

3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

A. CLASSIFICATION OF SUBJECT MATTER**H01Q 9/04(2006.01)i, H01Q 9/42(2006.01)i, H01Q 1/38(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01Q 9/04; H01Q 1/50; H01Q 1/38; H01Q 11/14; B23P 17/00; H01Q 1/48; H01Q 1/24; H01Q 9/42

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: antenna, feeding element, shorting elements, high band

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012-0013521 A1 (STEPHEN V. SALIGA et al.) 19 January 2012 See paragraphs [0017]-[0023] and figures 1-3.	1-3
Y		4-5
Y	US 2002-0145569 A1 (KENGO ONAKA et al.) 10 October 2002 See paragraphs [0034]-[0035] and figures 1-3.	4-5
A	US 2012-0007781 A1 (JOO YONG KIM et al.) 12 January 2012 See claims 1-5 and figures 1-6.	1-5
A	US 2011-0215978 A1 (STEFAN LINDENMEIER et al.) 08 September 2011 See claims 1-2 and figures 1A-6.	1-5
A	US 2008-0158066 A1 (MING-JU YU et al.) 03 July 2008 See claims 1-4 and figures 3-5.	1-5

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

31 March 2016 (31.03.2016)

Date of mailing of the international search report

31 March 2016 (31.03.2016)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsu-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

Jang, Gijeong

Telephone No. +82-42-481-8364



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/065733

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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