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(54) **Dipole antenna**

(57) A dipole antenna includes a dielectric substrate; a first radiating element formed on the dielectric substrate and having a first bent portion and a second bent portion; a second radiating element formed on the dielectric substrate, having a third bent portion and a fourth bent portion; a feed-in gap located between the first radiating element and the second radiating element; a first feed-in point located between the first bent portion and the second bent portion; and a second feed-in point located between the third bent portion and the fourth bent portion; wherein the first radiating element and the second radiating element are disposed in an opposite direction, and the first feed-in point and the second feed-in point are separated by the feed-in gap.

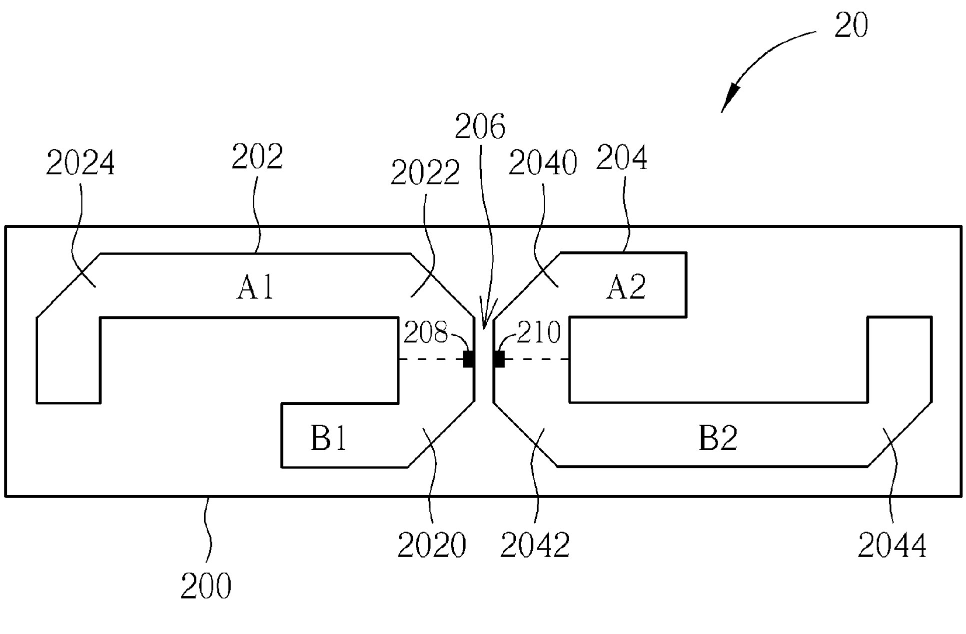

FIG. 2

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Description

Field of the Invention

[0001] The invention relates to a dipole antenna, and more particularly, to a dipole antenna with bent structures for reducing the antenna dimension and supporting multiple frequency bands.

Background of the Invention

[0002] With the evolving technology to the wireless communications, the modern electronic products such as laptop, Personal Digital Assistant (PDA), wireless LAN, mobile phone, smart meter, and USB dongle are able to communicate wirelessly, for example, through the WiFi technology to replace the physical cable for data transmission or receiving. A wireless communication device or system transmits and receives wireless wave via an antenna, as such to deliver or exchange wireless signals, and as further to access wireless networks. The communication system of a wireless local network is in general divided into a plurality of frequency bands, therefore, an antenna complying with operation of multiple frequency bands becomes more demanding. Besides, the trend of the antenna dimension is getting smaller to accommodate with the same interests, i.e., smaller dimension, of electronic products.

[0003] Figure 1 illustrates a schematic diagram of a conventional dipole antenna 10. The conventional dipole antenna 10 comprises radiating elements 100 and 102, and a coaxial transmission line 104. The radiating elements 100 and 102 are connected to the signal source and the ground of the coaxial transmission line 104, respectively. The dipole antenna 10 is not required to connect to a ground plane so that it is insensitive to environmental stimuli. However, the dimension of the dipole antenna 10 is relatively large. The total length of the dipole antenna 10 is about half of the wave length ($\lambda/2$), which means the dipole antenna 10 goes larger when the operating frequency is lowered. Therefore, the conventional dipole antenna 10 is mostly used as an external antenna. However, electronic products with an external antenna do not seem to be stylish, so it lowers the customers' desire to purchase the products. Moreover, the dipole antenna 10 can only operate in a single frequency band so that it cannot meet the demand for the communication system nowadays with multiple frequency bands.

[0004] In the prior art, the dipole antenna is designed to contain two different sized radiating elements, while one is shorter and the other is longer. The sizes of the two radiating elements are adjusted to appropriate values such that the fundamental frequency and the harmonics (i.e. multiplication of the fundamental frequency) of the dipole antenna cover two operating frequency bands. In such antenna design, however, the high frequency band is covered by the multiplication of the fundamental frequency, thereby inducing a dead spot for wireless data transmission due to a null point of the radiation pattern. As a result, the antenna gain and the antenna efficiency are reduced. Moreover, the structure of such antenna is more complicated. Therefore, the manufacturing difficulty, the cost, and the performance of such dipole antenna are unsatisfactory.

[0005] An alternative but known technique is to design the two radiating elements of the dipole antenna in a form of a double-sided trapezoid structure (i.e. the two radiating elements are disposed on the front and backside of the substrate), which therefore generates multiple current paths for achieve high bandwidth. Besides, the overlapping portion where the projection of the radiating elements on the front of the substrate overlaps the radiating elements on the backside of the substrate may be adjusted for impedance matching in an operating frequency band. However, the manufacturing process of this antenna design is very complex. It requires a dual layer board and via, and therefore, the manufacturing cost is high.

[0006] Therefore, it is a common goal in the industry to provide a relative small sized, multi-band supported, efficient, and cost effective antenna.

Summary of the Invention

[0007] An objective of the present invention is to provide an antenna supporting multi-band operation and having simple structure and favorable efficiency, so as to lower the manufacturing cost of an antenna for mass production.

[0008] This is achieved by a dipole antenna according to claim 1. The dependent claims pertain to corresponding further developments and improvements.

[0009] As will be seen more clearly from the detailed description as follows, the claimed dipole antenna comprises a dielectric substrate which presents as a horizontal plane; a first radiating element formed on the dielectric substrate, having a first bent portion and a second bent portion; a second radiating element formed on the dielectric substrate and having a third bent portion and a fourth bent portion; a feed-in gap, spaces out the first radiating element and the second radiating element, is located between the first radiating element and the second radiating element; a first feed-in point located between the first bent portion and the second bent portion; and a second feed-in point located between the third bent portion and the fourth bent portion; wherein the first radiating element and the second radiating element are disposed side-by-side horizontally across the dielectric substrate, and wherein the first feed-in point and the second feed-in point are spaced out by the feed-in gap.

Brief Description of the Drawings

[0010]

Figure 1 is a schematic diagram of a conventional dipole antenna

Figure 2 is a schematic diagram of a dipole antenna according to an embodiment of the present invention.

Figure 3 illustrates a resonant path of the low frequency current in the dipole antenna shown in Figure 2.

Figure 4 illustrates a resonant path of the high frequency current in the dipole antenna shown in Figure 2.

Figure 5 illustrates the reflection coefficient of the dipole antenna shown in Figure 2.

Figure 6 illustrates the radiation pattern of the dipole antenna shown in Figure 2 operating in 2.45GHz.

Figure 7 illustrates the radiation pattern of the dipole antenna shown in Figure 2 operating in 5.15GHz.

Figure 8 illustrates the radiation pattern of the dipole antenna shown in Figure 2 operating in 5.55GHz.

Figure 9 illustrates the radiation pattern of the dipole antenna shown in Figure 2 operating in 5.85GHz.

Figure 10 shows the antenna gain and the radiation efficiency of the dipole antenna shown in Figure 2 operating between 2.4GHz and 5.85GHz.

Figure 11 shows a diagram of antenna power loss versus throughput of wireless local area network communication system when the dipole antenna shown in Figure 2 operates between 2.4GHz and 5GHz.

Detailed Description

[0011] Figure 2 is a schematic diagram of a dipole antenna 20 according to an embodiment of the present invention. The dipole antenna 20 includes a dielectric substrate 200 which presents as a plane, radiating elements 202 and 204, a feed-in gap 206, and feed-in points 208 and 210. The radiating elements 202 and 204 formed on the dielectric substrate 200 have bent portions 2020, 2022, and bent portions 2040, 2042. The radiating elements 202 and 204 are side-by-side disposed across the horizontal plane of the dielectric substrate 200, and are spaced out by a feed-in gap 206. The feed-in points 208 and 210 are formed on the radiating elements 202 and 204, respectively, to connect to the central conductor and the outer grounded conductor of a coaxial cable. The feed-in point 208 is substantially located at the middle point between the bent portion 2020 and the bent portion 2022, while the feed-in point 210 is substantially located at the middle point between the bent portion 2040 and the bent portion 2042. The spacing between the feed-in points 208 and 210 is substantially equal to the feed-in gap 206.

[0012] As shown in Figure 2, the top half A1 and the bottom half B1 of the radiating element 202 are not symmetric. Similarly, the top half A2 and bottom half B2 of the radiating element 204 is not symmetric either, wherein the top half portion and the bottom half portion are equally demarcated along a horizontal plane substantially characterized by the vertical middle point of the radiation elements 202, 204. To be specific, the vertical flip of the first radiating element 202 and the second radiating element 204 are symmetric horizontally along substantially the center point of the feed-in gap 206, i.e., the orientation of the first radiating element 202 is a 180 degree transposition from the second radiating element 204. Therefore, there is more than one current resonant path, and each one may have different length. Figures 3 and 4 illustrate the resonant paths of the low frequency current and the high frequency current in the dipole antenna 20, respectively. The dipole antenna 20 has at least two different current resonant paths, in which each current resonant path has different length. One current resonant path flows from the top half segment A1 of the radiating element 202 to the bottom half segment B2 of the radiating element 204 via the feed-in gap 206. With proper positioning to the bent portion 2022 and the bent portion 2042, the dipole antenna 20 may resonate in a relatively low frequency band. For example, if the length of this current resonant path is 64 mm (i.e., approximately 0.51λ), the dipole antenna 20 may resonate in a 2.4GHz frequency band. The other current resonant path flows from the top half segment A2 of the radiating element 204 to the bottom half segment B1 of the radiating element 202 via the feed-in gap 206. With proper positioning to the bent portion 2020 and the bent portion 2040, the dipole antenna 20 may resonate in a relatively high frequency band. For example, if the length of this current resonant path is 26 mm (i.e., approximately 0.46λ), the dipole antenna 20 may resonate in a 5GHz frequency band. In an example, the dipole antenna 20 may be used as an antenna in a built-in wireless local area network (WLAN) device to transmit and receive 2.4GHz and 5GHz radio signals, and support multiple wireless communication protocols (e.g. IEEE 802.11 a/b/g/ac, Bluetooth, HiperLAN). In such case, the dipole antenna 20 may be fully contained in a narrow space as 45 x 13 mm^2.

[0013] The dipole antenna 20 of the present invention uses the bent portions 2020, 2022, 2040 and 2042 to create multiple current resonant paths with different lengths in geometrical structure. Consequently, the dipole antenna 20 may support multiple operating frequency bands in a minimized dimension compared to the conventional dipole antennas. Those skilled in the art can readily make modifications and/or alterations accordingly. For example, the radiating element 202 and the radiating element 204 may be disposed on the dielectric substrate 200 by printing and etching processes. The dielectric substrate 200 may be a fiber glass composite laminate conforming to the FR4 specifications. Other kinds of dielectric substrate may be used depending on the application. In addition, the dimension of the radiating elements 202 and 204 may be properly adjusted according to the operating frequency requirement.

[0014] The outward corner not facing to the gravity center of the radiation elements 202, 204 formed by the bent portions 2020, 2022 and the bent portions 2040, 2042 may be an oblique angle for reducing the parasitic capacitance due to the effect of bended path. Moreover, the amount of the bent portions is not limited. For example, as shown in Figure 2, the radiating elements 202 and 204 may additionally form the bent portions 2024 and 2044 to further reduce the dimension of the dipole antenna 20. Furthermore, the inward corner facing the gravity center of the radiation elements 202, 204 formed by the bent portions 2020, 2022, 2024, 2040, 2042 and 2044 is a right angle, but is not limited herein. Any angles between 90 to 180 degrees may be used as long as the shape of the antenna complies with the formation of multiple current resonant paths. The radiating element 202 and the radiating element 204 may be symmetric in accordance to the center point of the feed-in point 208 and feed-in point 210. Alternatively, the dipole antenna may be asymmetric according to the practical consideration of the antenna design.

[0015] Since the feed-in gap 206 of the dipole antenna 20 is electrically equivalent to a capacitance, the impedance matching of the dipole antenna 20 can be effectively improved by properly adjusting the spacing of the feed-in gap in order to increase the radiation efficiency. Figure 5 shows the reflection coefficient of the dipole antenna 20 shown in Figure 2. The line with triangle markers represents the reflection coefficient of the conventional dipole antenna 10, the line with square markers represents a simulation result of the reflection coefficient for the dipole antenna 20, and the line with circle markers represents a measurement result of the reflection coefficient for the dipole antenna 20. Since the feed-in gap 206 is adjustable, the dipole antenna 20 of the present invention can be designed to have larger reflection coefficient and better radiation efficiency.

[0016] The left portion of the dipole antenna 20 (i.e., the radiating elements 202) is a 180 degree transposition of the right portion (i.e., the radiating elements 204); therefore, the radiation pattern of the dipole antenna 20 is omni-directional in the XZ plane without a null. Figure 6 to Figure 9 illustrate the radiation patterns of the dipole antenna 20 operating in 2.45GHz, 5.15GHz, 5.55GHz, and 5.85GHz, respectively. The geometric structure of the dipole antenna 20 is asymmetric, which affects the uniformity of current distribution. Therefore, the radiation pattern in YZ plane is slightly asymmetric.

[0017] Figure 10 shows the antenna gain and the radiation efficiency of the dipole antenna 20 operating between 2.4GHz and 5.85GHz. When the dipole antenna 20 operates near the 2.4GHz frequency band, the antenna gain is about 1.85 dBi while the radiation efficiency is about 97%. When the dipole antenna 20 operates near the 5GHz frequency band, the antenna gain is about 2.3 dBi while the radiation efficiency is about 96%. Figure 11 shows a diagram of antenna power loss versus throughput of wireless local area network (WLAN) communication system when the dipole antenna 20 operates between 2.4GHz and 5GHz. As can be seen from Figure 11, the WLAN communication system equipped with the dipole antenna 20 has a favorable data throughput.

[0018] In summary, the present invention creates multiple current resonant paths by designing the bent direction and position of the radiating elements and inserting a proper feed-in gap such that the dipole antenna can operate in more than one frequency band. In addition, the space required for disposing the dipole antenna is effectively reduced in the present invention, which benefits implementation of embedded antenna. Moreover, the structure of the dipole antenna in the present invention does not require any via. The dipole antenna of the present invention can be realized on a general printed circuit board (PCB), e.g., an FR4 single layer PCB, for being precisely manufactured and thus achieving good antenna performance. Therefore, the manufacturing cost is reduced.

Claims

1. A dipole antenna (20) **characterized by** comprising:

   a dielectric substrate (200);
   a first radiating element (202) formed on the dielectric substrate (200) having a first bent portion (2020) and a second bent portion (2022);
   a second radiating element (204) formed on the dielectric substrate (200) having a third bent portion (2040) and a fourth bent portion (2042);
   a feed-in gap (206) located between the first radiating element (202) and the second radiating element (204) spaces out the first radiating element (202) and the second radiating element (204);
   a first feed-in point (208) located between the first bent portion (2020) and the second bent portion (2022); and
   a second feed-in point (210) located between the third bent portion (2040) and the fourth bent portion (2042);
   wherein the first radiating element (202) and the second radiating element (204) are disposed side-by-side horizontally across the dielectric substrate (200) and wherein the first feed-in point (208) and the second feed-in point (210) are spaced out by the feed-in gap.

2. The dipole antenna (20) of claim 1, **characterized in that** the first bent portion (2020), the second bent portion (2022), the third bent portion (2040) and/or the fourth bent portion (2042) form a corner facing the gravity center of the radiation elements (202, 204) which is a right angle and form a corner not facing to the gravity center of the radiation elements (202, 204) which is an oblique angle.

3. The dipole antenna (20) of claim 2 wherein the path width of the corners formed by the bent portions (2020, 2022, 2040, 2042) is not uniform.

4. The dipole antenna (20) of any of claims 1 to 3, **characterized in that** a top half portion and a bottom half portion of the first radiating element (202) and the second radiating element (204) are not symmetric, wherein the top half portion and the bottom half portion are equally demarcated along a horizontal plane substantially **characterized by** the vertical middle point of the radiation elements (202, 204).

5. The dipole antenna (20) of any of claims 1 to 3, **characterized in that** the vertical flip of the first radiating element (202) and the second radiating element (204) are symmetric horizontally along substantially the center point of the feed-in gap (206), and the orientation of the first radiating element (202) is a 180 degree transposing to the second radiating element (204).

6. The dipole antenna (20) of any of claims 1-5, **characterized in that** the first radiating element (202) further has a fifth bent portion (2024), and the second radiating element further has a sixth bent portion (2044).

7. The dipole antenna (20) of any of claims 1-6, **characterized in that** the dielectric substrate (200) conforms to FR4 specifications.

8. The dipole antenna (20) of any of claims 1-7, **characterized in that** the dipole antenna (20) does not contain any via.

9. The dipole antenna (20) of claim 1, **characterized in that** the first feed-in point (208) and the second feed-in point (210) are connected to a central conductor and an outer grounded conductor of a coaxial cable, respectively.

10. The dipole antenna (20) of claim 1, **characterized in that** the first radiating element (202) and the second radiating element (204) are disposed on the dielectric substrate (200) by printing and etching processes.

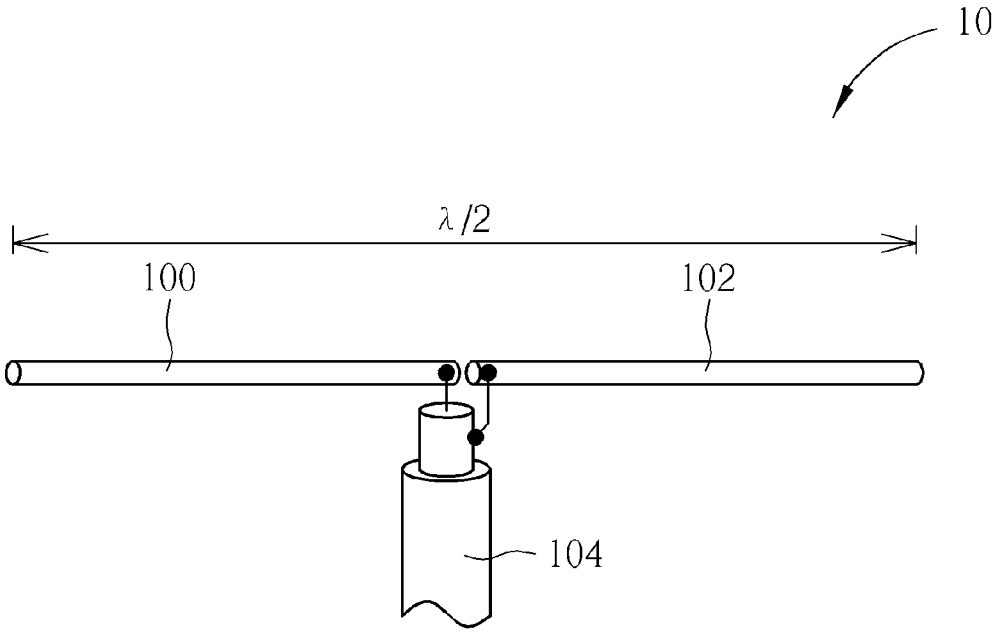

10
λ/2
100
102
104

FIG. 1

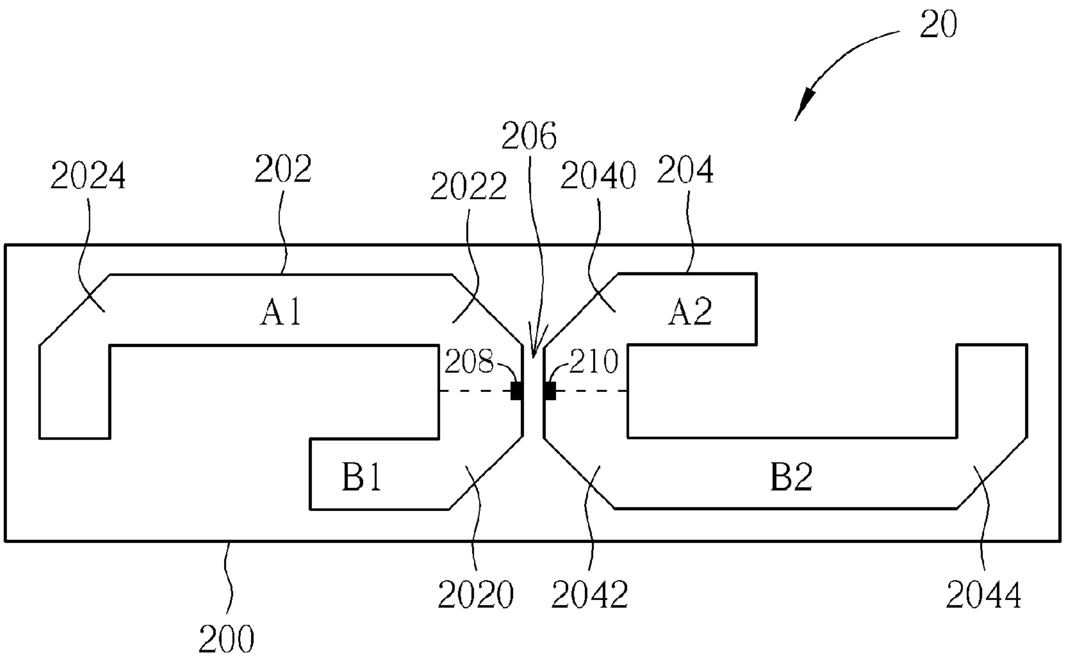

20
206
2024
202
2022
2040
204
A1
A2
208
210
B1
B2
2020
2042
2044
200

FIG. 2

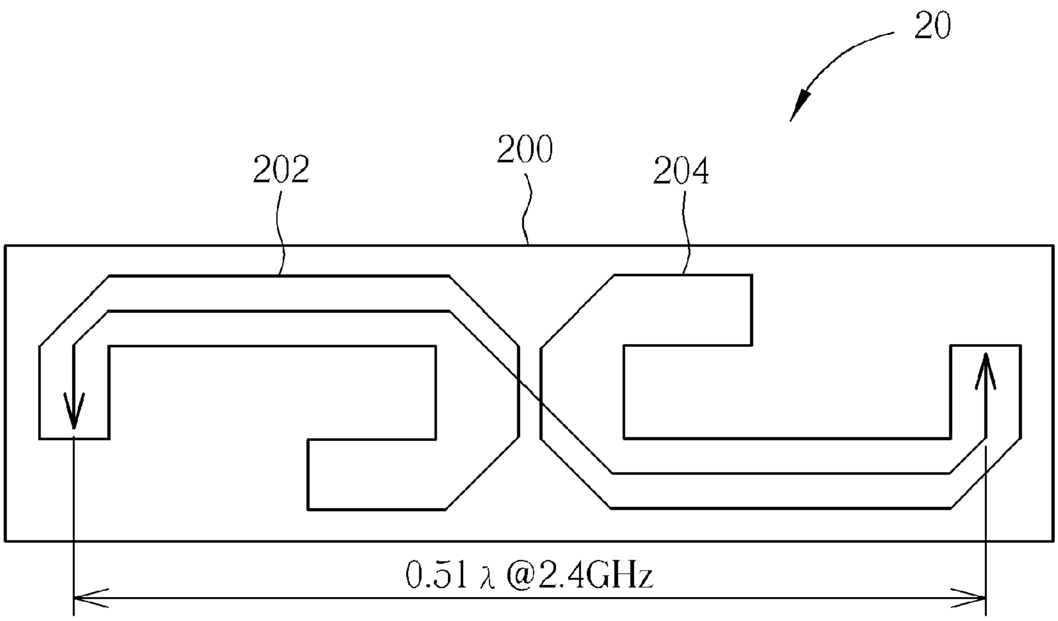


FIG. 3

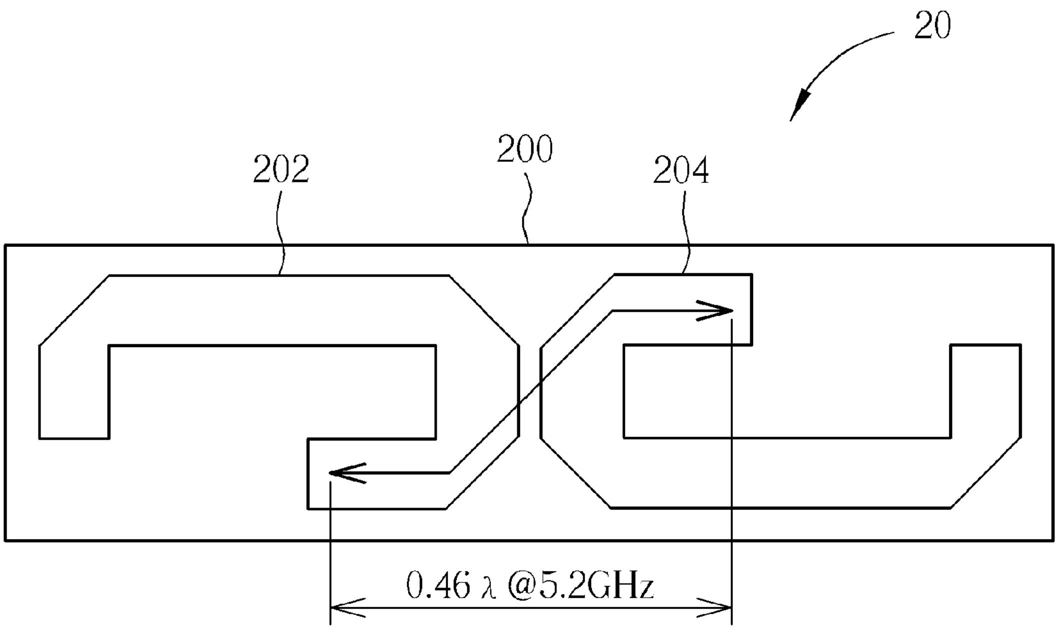


FIG. 4

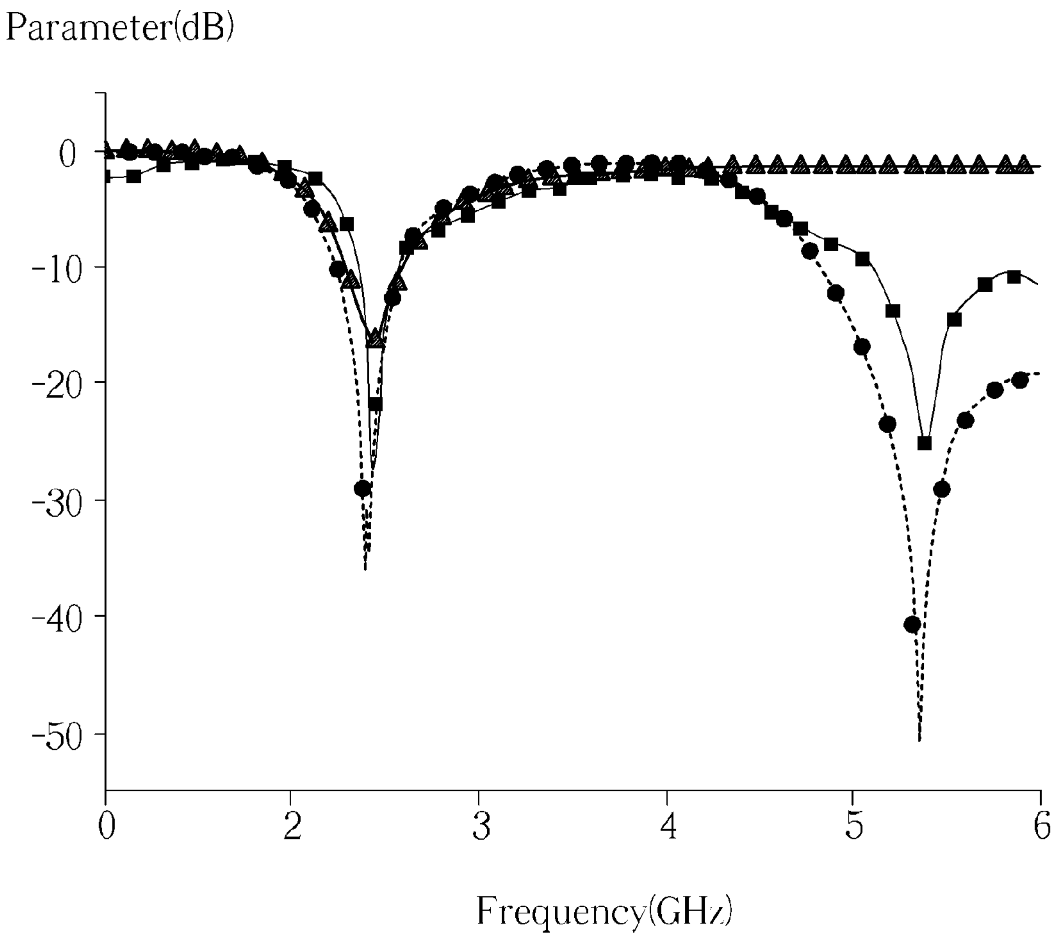
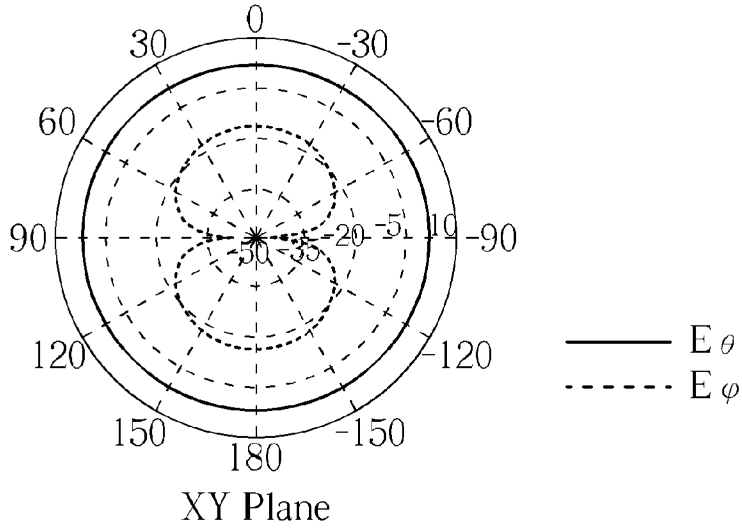
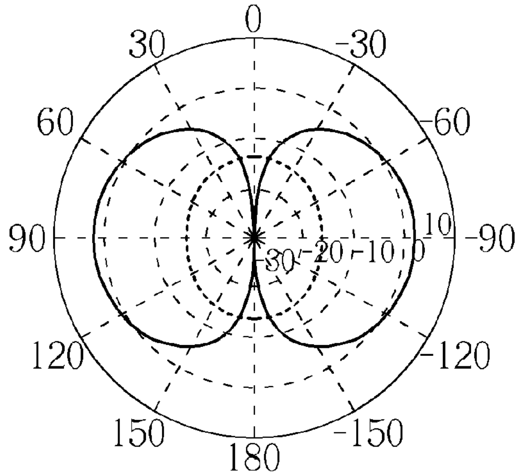


FIG. 5


0
30
-30
60
-60
90
-90
120
-120
150
-150
180
-50
-35
-20
-5
10
E θ
E φ
XY Plane


0
30
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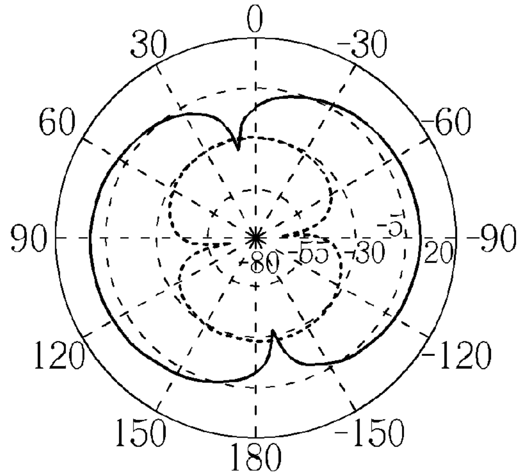
90
-90
120
-120
150
-150
180
-30
-20
-10
0
10
XZ Plane


0
30
-30
60
-60
90
-90
120
-120
150
-150
180
-80
-55
-30
-5
20
YZ Plane

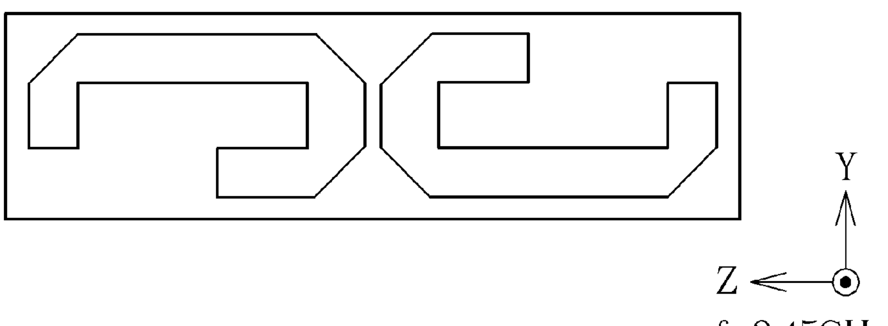

Y
Z
f=2.45GHz

FIG. 6

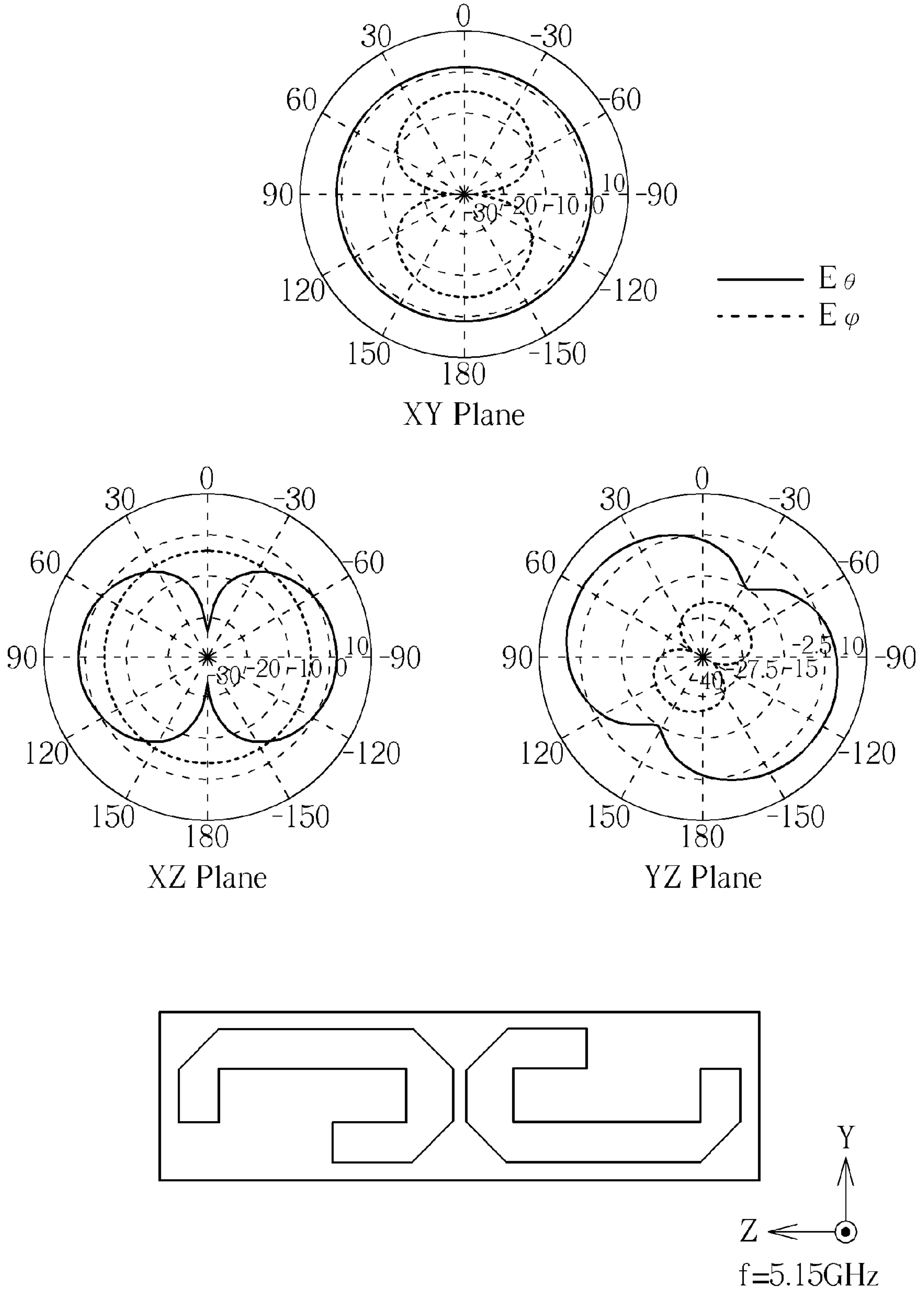

0
30
-30
60
-60
90
-90
120
-120
150
-150
180
-30
-20
-10
0
10
XY Plane
E θ
E φ
XZ Plane
-2.5
-15
-27.5
-40
YZ Plane
Y
Z
f=5.15GHz

FIG. 7

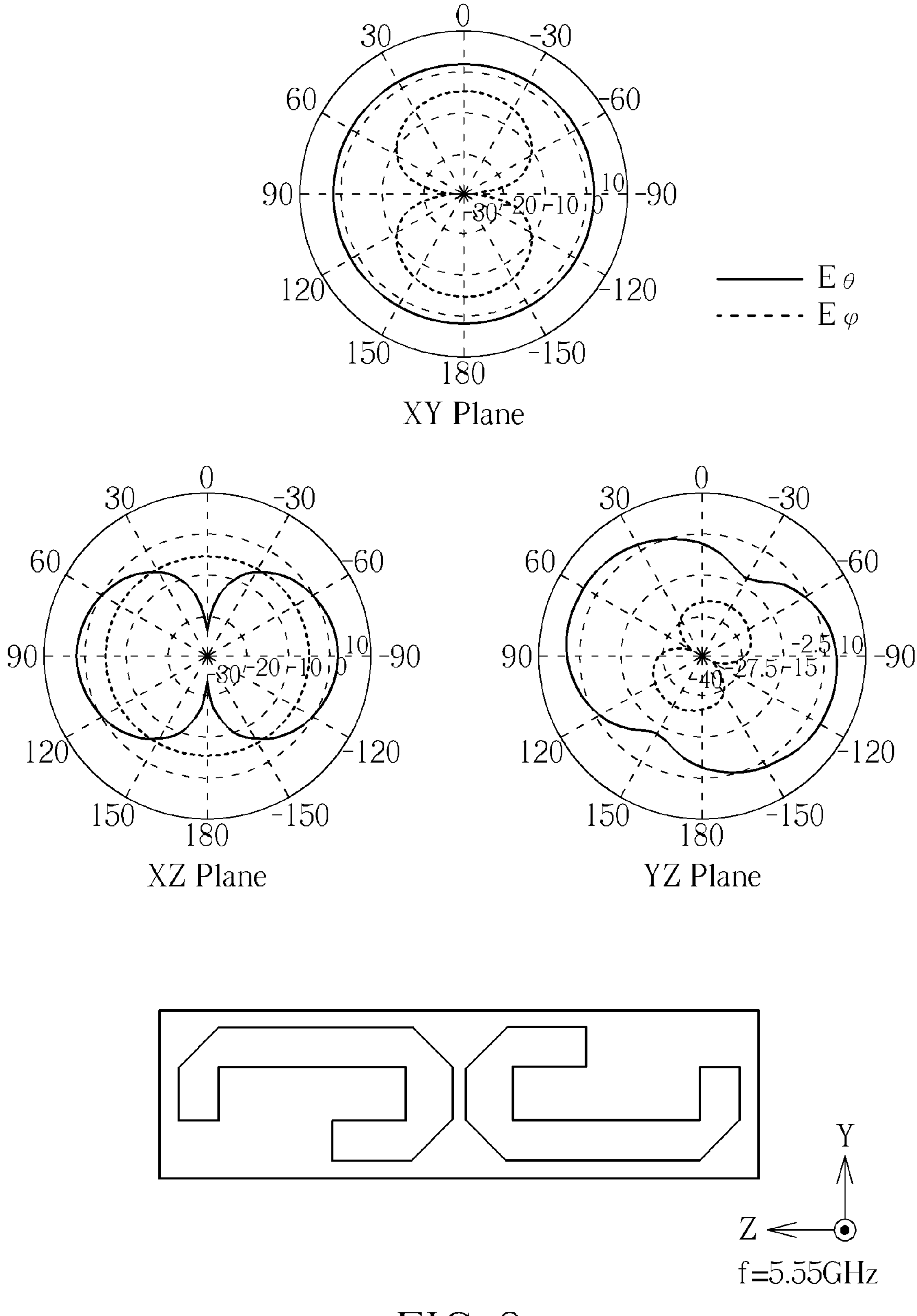

0
30
-30
60
-60
90
-90
120
-120
150
-150
180
10
-30
-20
-10
0
Eθ
Eφ
XY Plane
XZ Plane
-2.5
-27.5
-15
-40
YZ Plane
Y
Z
f=5.55GHz

FIG. 8

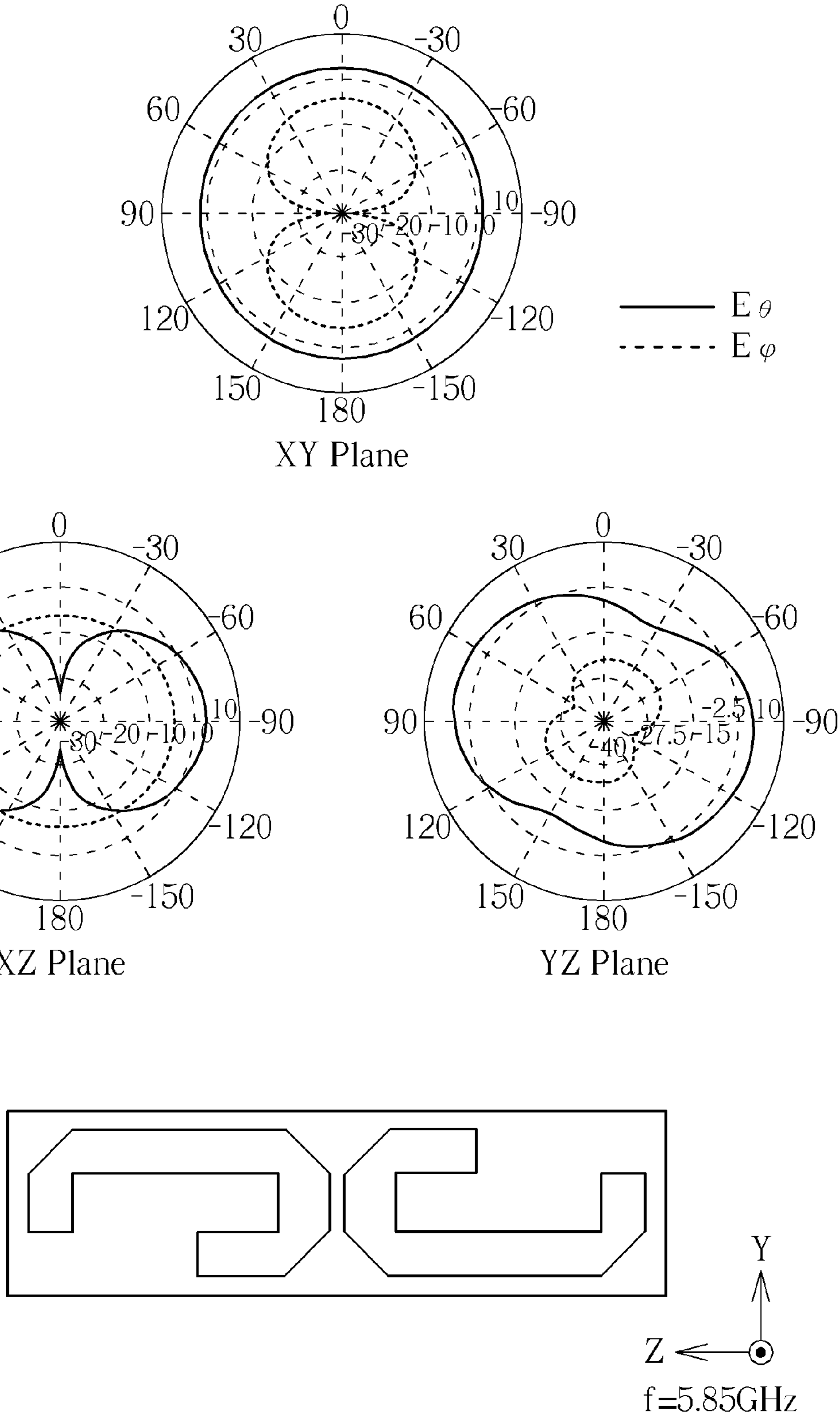


FIG. 9

Frequency (GHz)	Antenna gain(dBi)	Radiation efficiency(%)
2.4	1.82	97.34
2.42	1.84	97.55
2.44	1.86	97.48
2.46	1.88	97.15
2.48	1.90	96.57
2.5	1.92	95.75
5.15	1.98	94.18
5.25	2.12	95.02
5.35	2.24	95.41
5.45	2.37	95.48
5.55	2.50	95.32
5.65	2.64	95.00
5.75	2.78	94.65
5.85	2.89	94.35

FIG. 10

Power loss(dB)	2.4 GHz (M bit/s)	5 GHz (M bit/s)
10	167	169
40	165	112
45	137	78
50	94	37
55	63	***
60	30	***

FIG. 11

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EUROPEAN SEARCH REPORT

Application Number
EP 14 16 7338

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2008/174505 A1 (WONG KIN-LU [TW] ET AL) 24 July 2008 (2008-07-24) * figure 1 * * paragraph [0003] * * paragraph [0006] * * paragraph [0009] * * paragraph [0010] * * paragraph [0020] * * paragraph [0032] * * claim 5 * -----	1,3,5-10 2-4	INV. H01Q1/38 H01Q9/26
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TECHNICAL FIELDS SEARCHED (IPC)
H01Q

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	13 November 2014	Yvonnet, Yannick

EPO FORM 1503 03.82 (P04C01)

CATEGORY OF CITED DOCUMENTS

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13-11-2014

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