US012388164B2

(12) **United States Patent**
Lee et al.

(10) **Patent No.: US 12,388,164 B2**
(45) **Date of Patent: Aug. 12, 2025**

(54) **ANTENNA MODULE DISPOSED IN VEHICLE**

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(73) Assignee: **LG ELECTRONICS INC.**, Seoul (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **18/874,447**

(22) PCT Filed: **Aug. 9, 2022**

(86) PCT No.: **PCT/KR2022/011875**

§ 371 (c)(1),
(2) Date: **Dec. 12, 2024**

(87) PCT Pub. No.: **WO2024/034702**

PCT Pub. Date: **Feb. 15, 2024**

(65) **Prior Publication Data**

US 2025/0167424 A1 May 22, 2025

(51) **Int. Cl.**
H01Q 1/12 (2006.01)
H01Q 5/30 (2015.01)
H01Q 9/04 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/1271*** (2013.01); ***H01Q 5/30*** (2015.01); ***H01Q 9/0407*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/1271; H01Q 1/32; H01Q 1/38–48; H01Q 1/24; H01Q 5/30–50; H01Q 9/0407
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,061,442 B1 6/2006 Tang et al.
9,270,017 B2 * 2/2016 Villarroel H01Q 1/3275
(Continued)

FOREIGN PATENT DOCUMENTS

JP	2020162120	10/2020
WO	2021201322	10/2021
WO	2022092514	5/2022

OTHER PUBLICATIONS

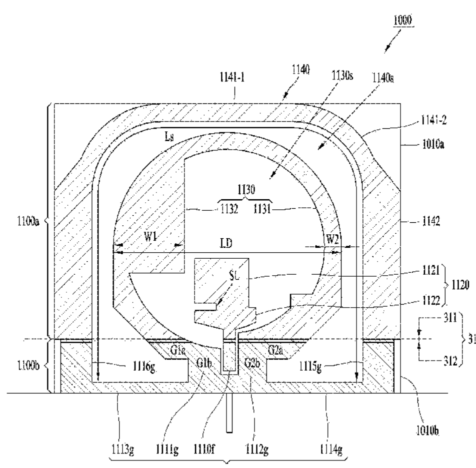
PCT International Application No. PCT/KR2022/011875, International Search Report dated May 3, 2023, 4 pages.

Primary Examiner — Hasan Islam
(74) *Attorney, Agent, or Firm* — LEE, HONG, DEGERMAN, KANG & WAIMEY

(57) **ABSTRACT**

A vehicle comprises: vehicular glass including a transparent region and an opaque region; a transparent dielectric substrate disposed in the transparent region of the vehicular glass; a first area including an antenna on one side surface of the transparent dielectric substrate; and a second area including a power supply pattern and a ground conductive pattern electrically connected to the antenna. The antenna may comprise: a first slot formed between a signal pattern and a first ground pattern and configured to radiate a first signal having a circularly polarized wave in a first frequency band; and a second slot formed between the first ground pattern and a second ground pattern and configured to radiate a second signal having a circularly polarized wave in a second frequency band lower than the first frequency band.

20 Claims, 46 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2017/0324142	A1	11/2017	Talty et al.	
2023/0108271	A1*	4/2023	Park	H01Q 19/005 343/725

* cited by examiner

FIG. 1

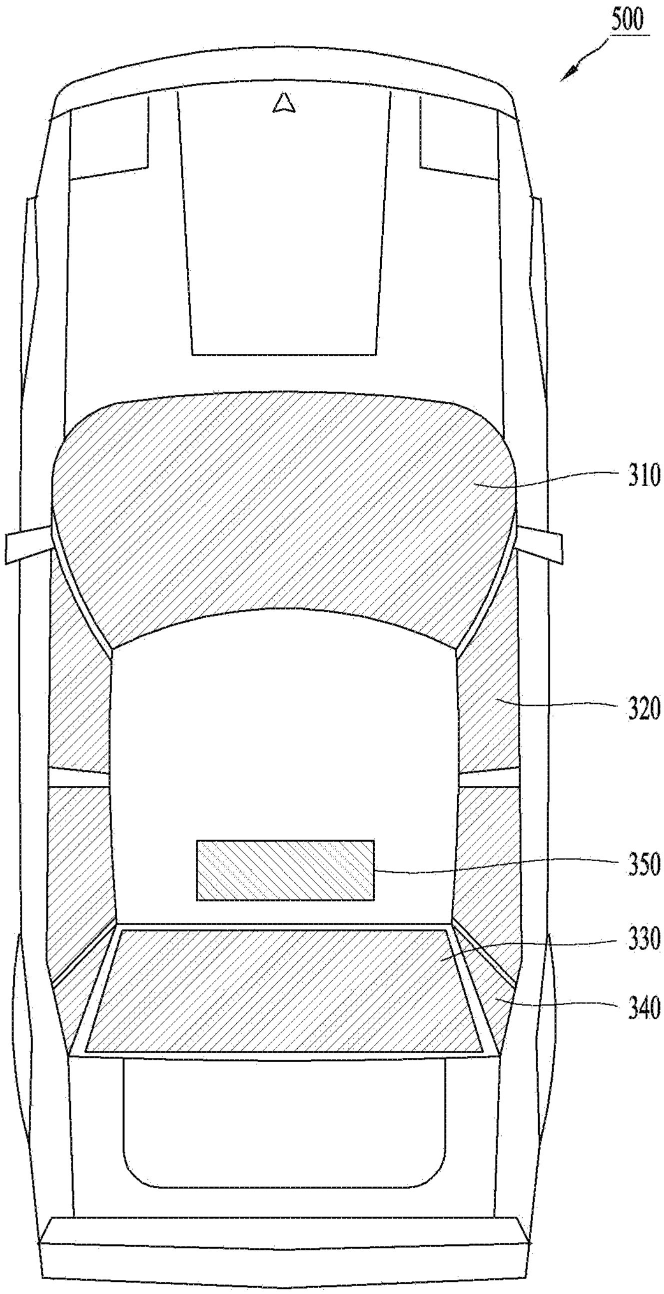


FIG. 2A

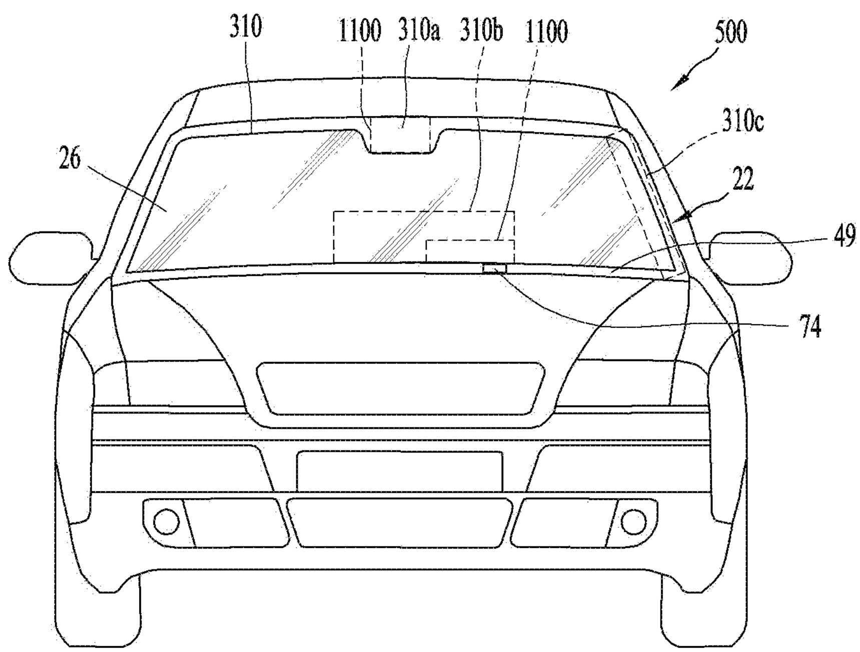


FIG. 2B

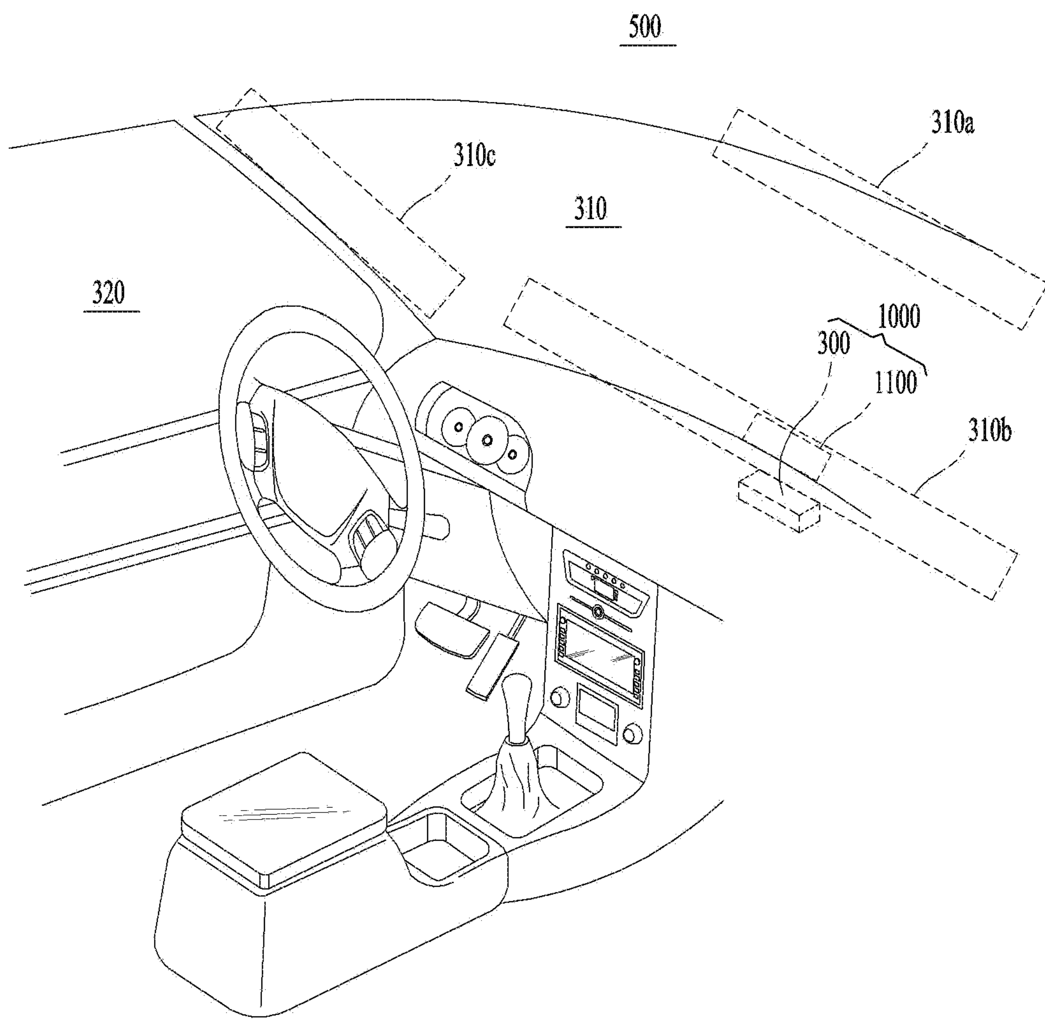


FIG. 2C

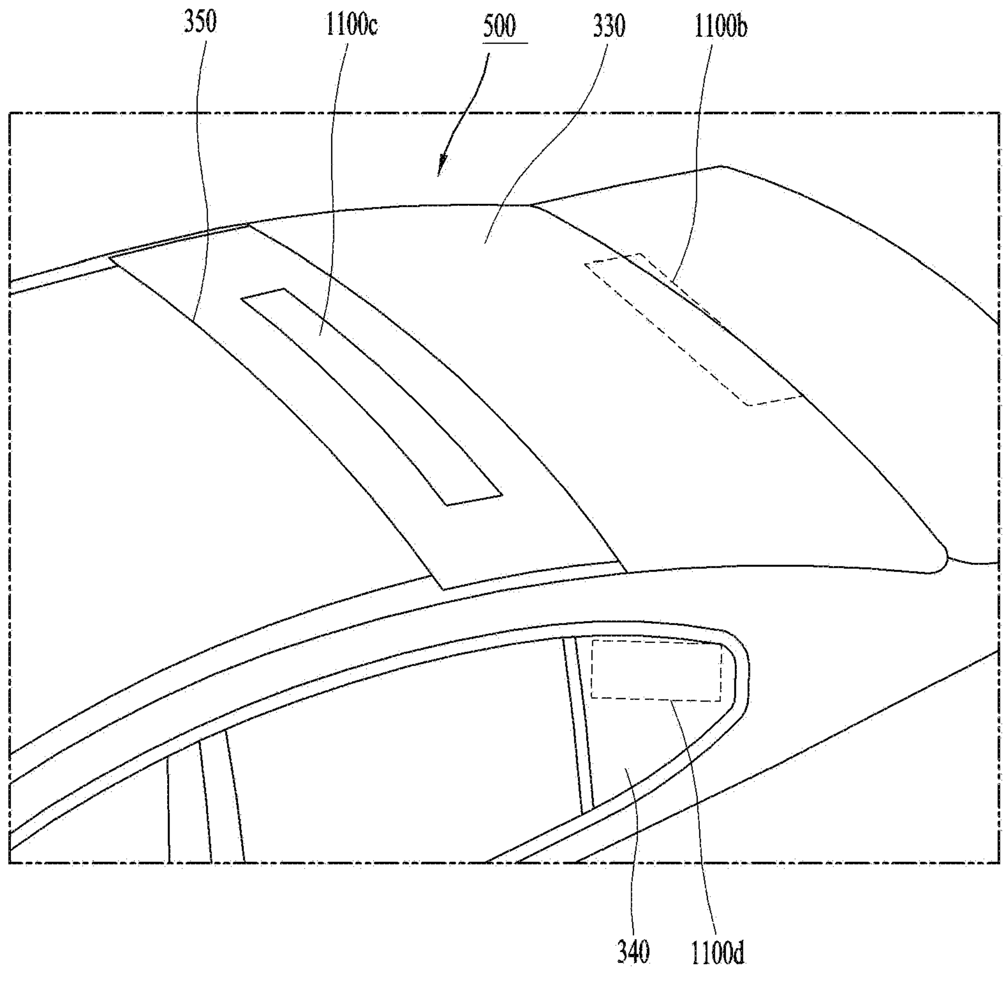


FIG. 3

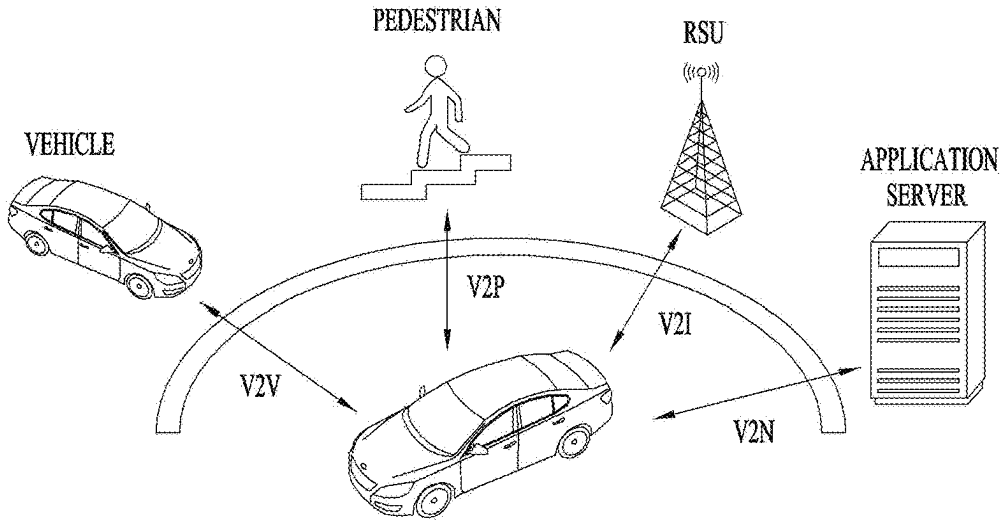

PEDESTRIAN
RSU
VEHICLE
APPLICATION SERVER
V2P
V2I
V2V
V2N

FIG. 4

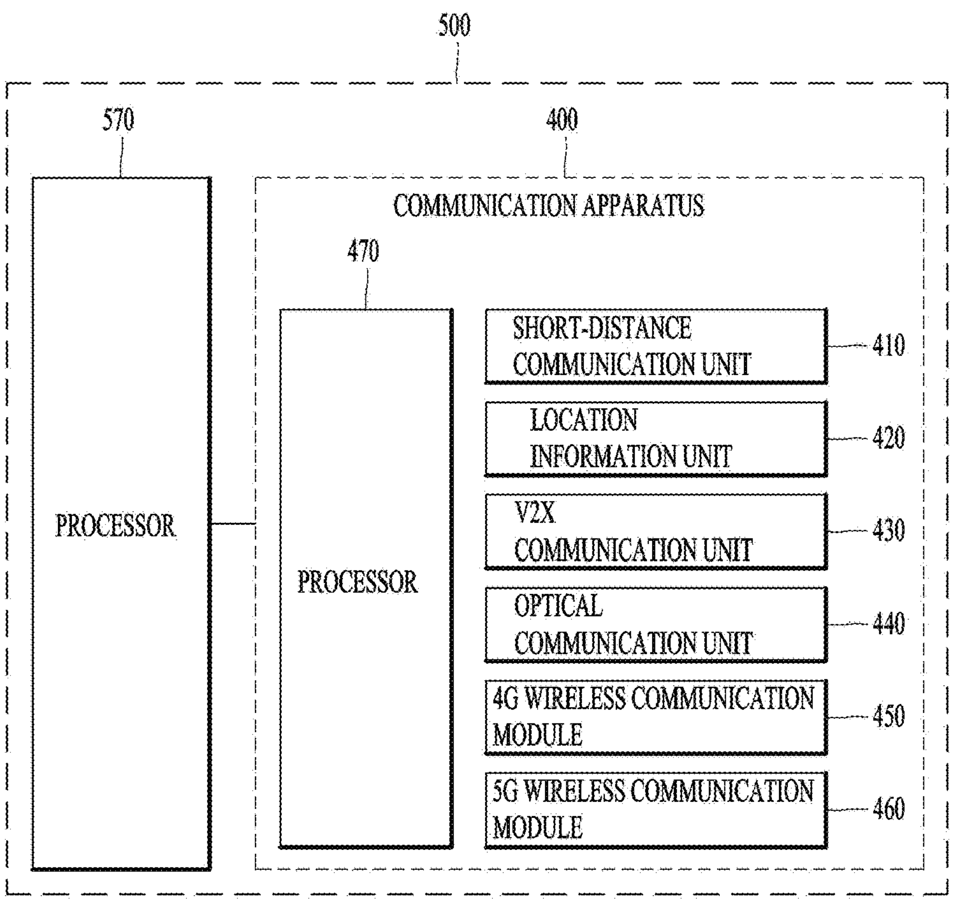

500
570
400
COMMUNICATION APPARATUS
470
PROCESSOR
PROCESSOR
SHORT-DISTANCE COMMUNICATION UNIT
410
LOCATION INFORMATION UNIT
420
V2X COMMUNICATION UNIT
430
OPTICAL COMMUNICATION UNIT
440
4G WIRELESS COMMUNICATION MODULE
450
5G WIRELESS COMMUNICATION MODULE
460

FIG. 5A

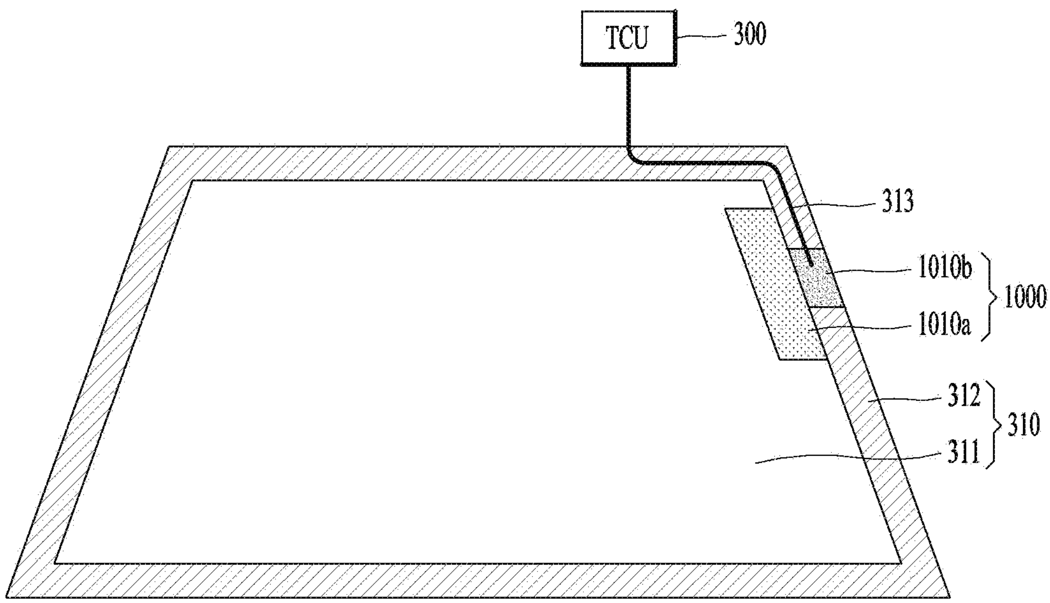

TCU
300
313
1010b
1000
1010a
312
310
311

FIG. 5B

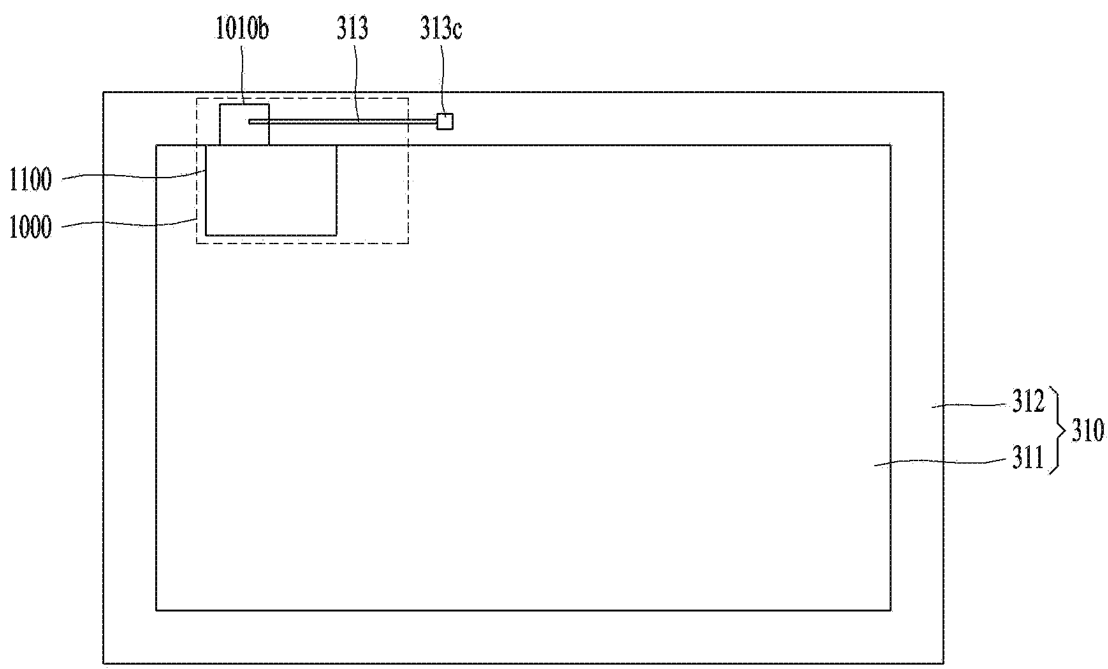

1010b
313
313c
1100
1000
312
310
311

FIG. 5C

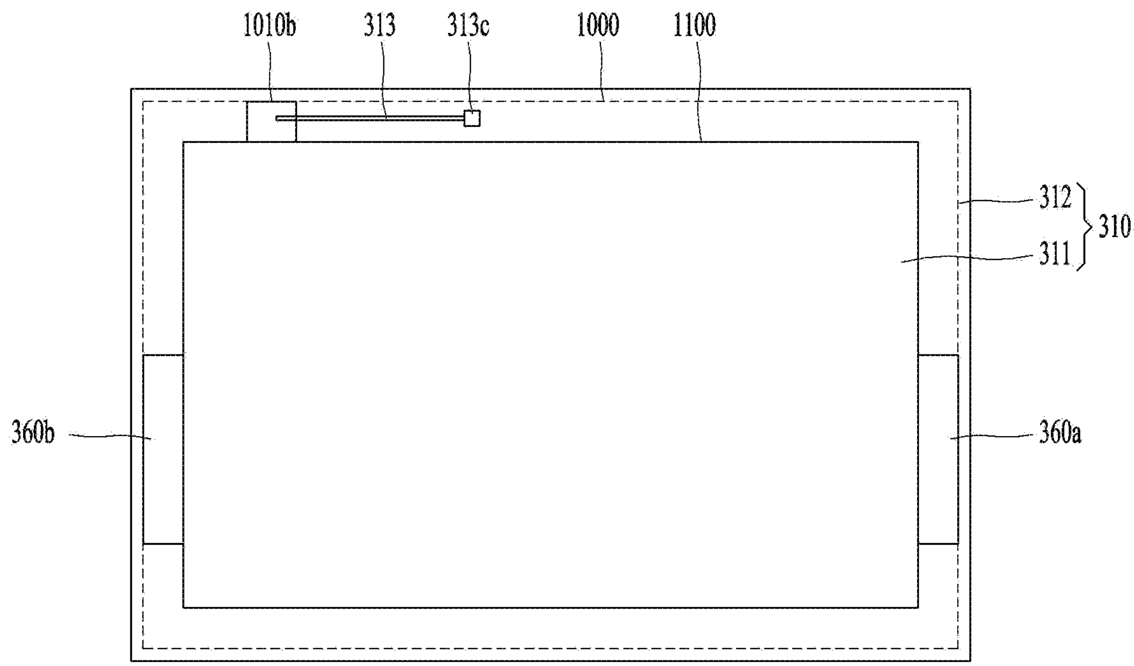
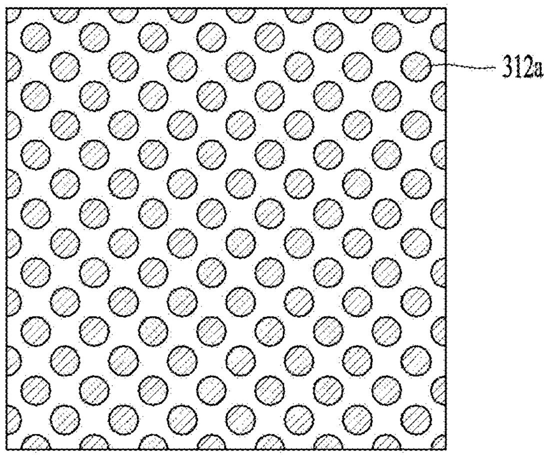
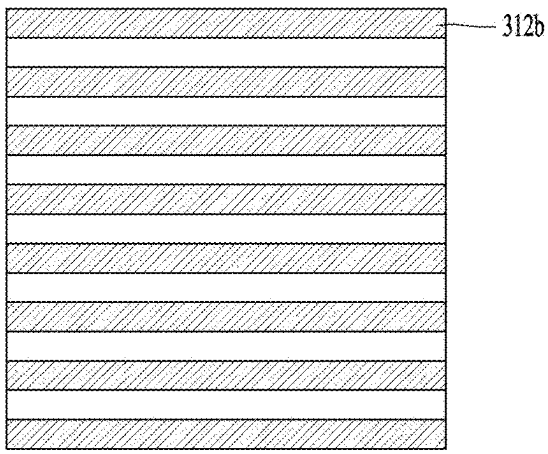


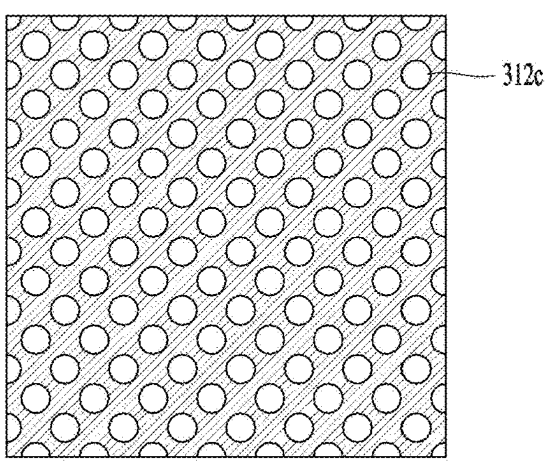
FIG. 6A



(a)

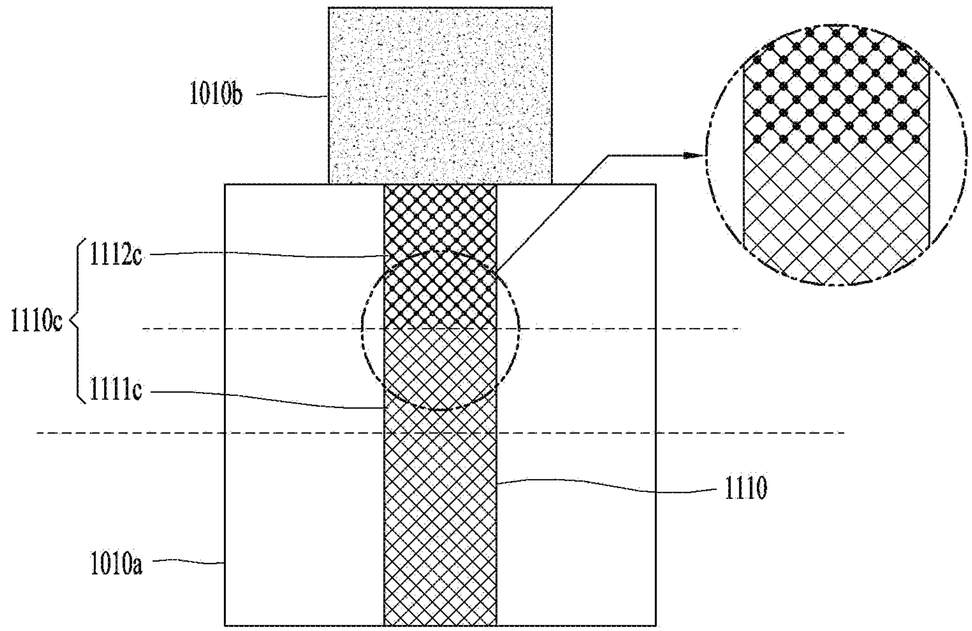


(b)

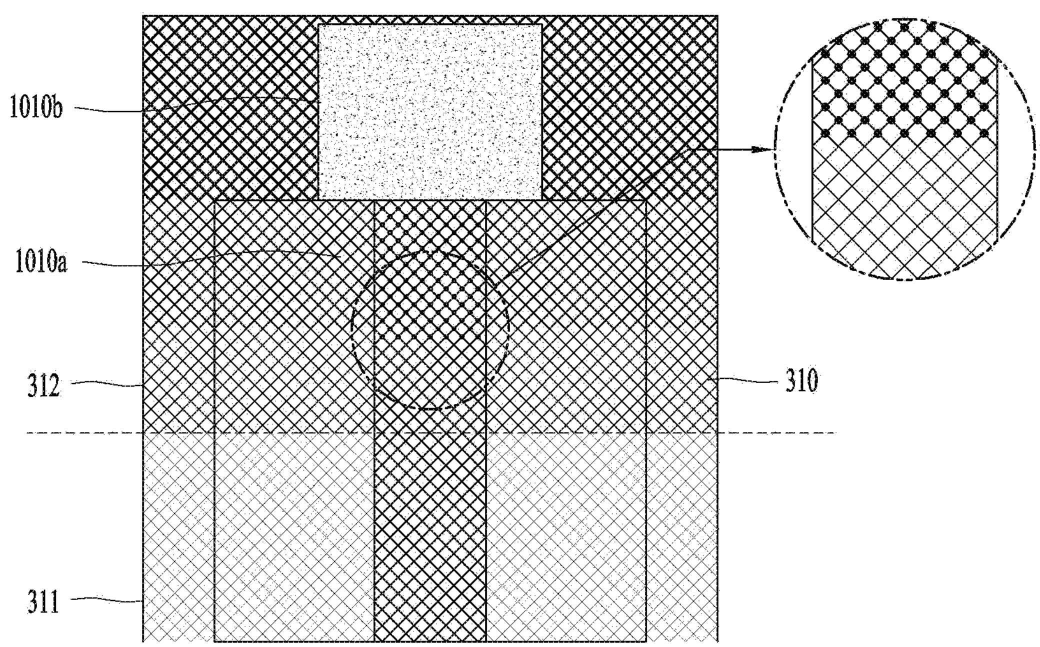


(c)

FIG. 6B

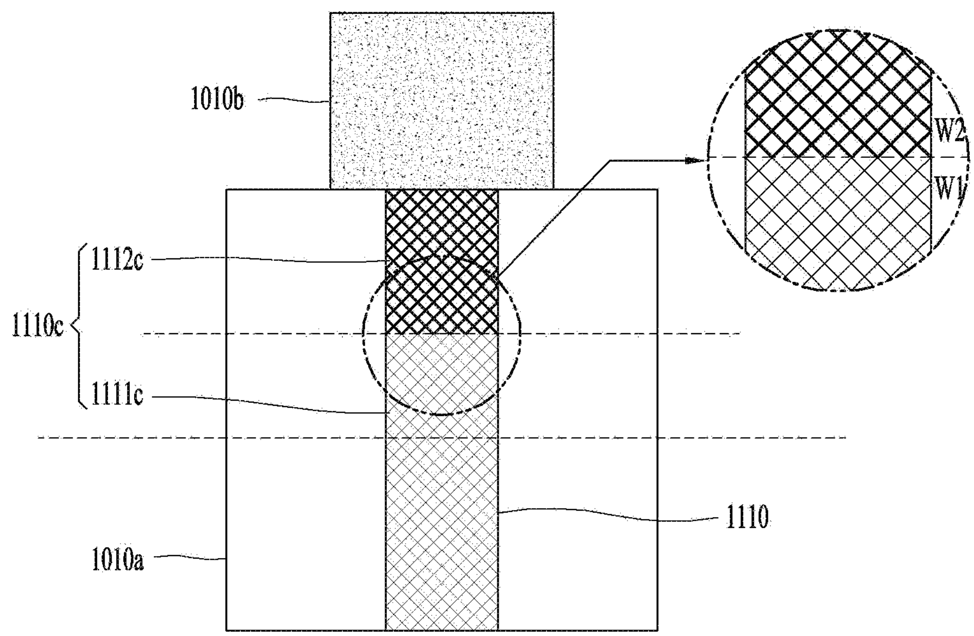


(a)

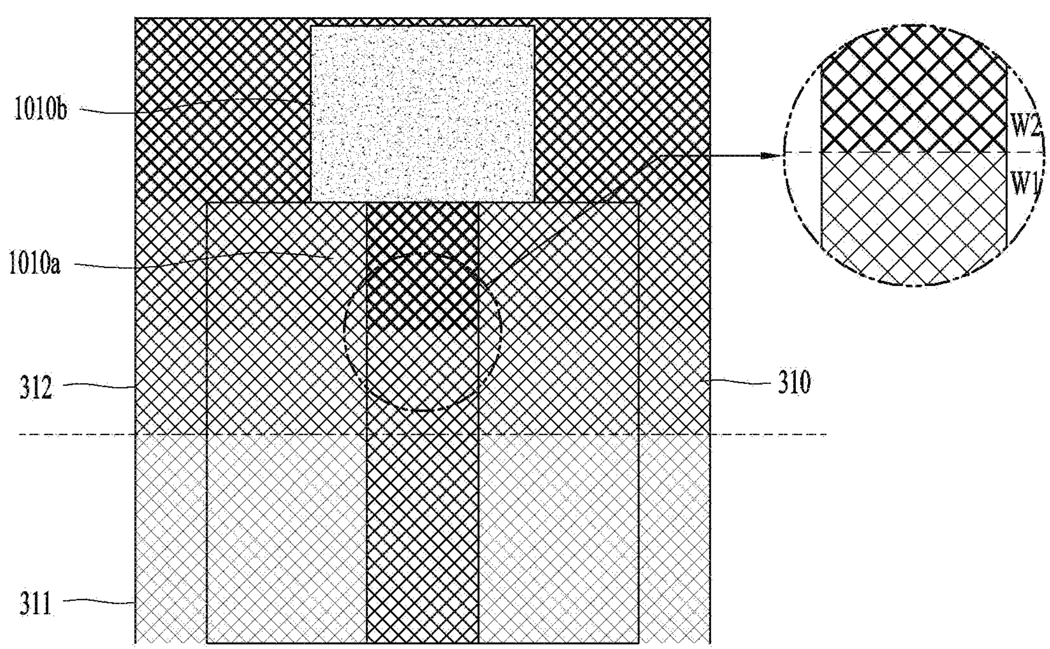


(b)

FIG. 6C

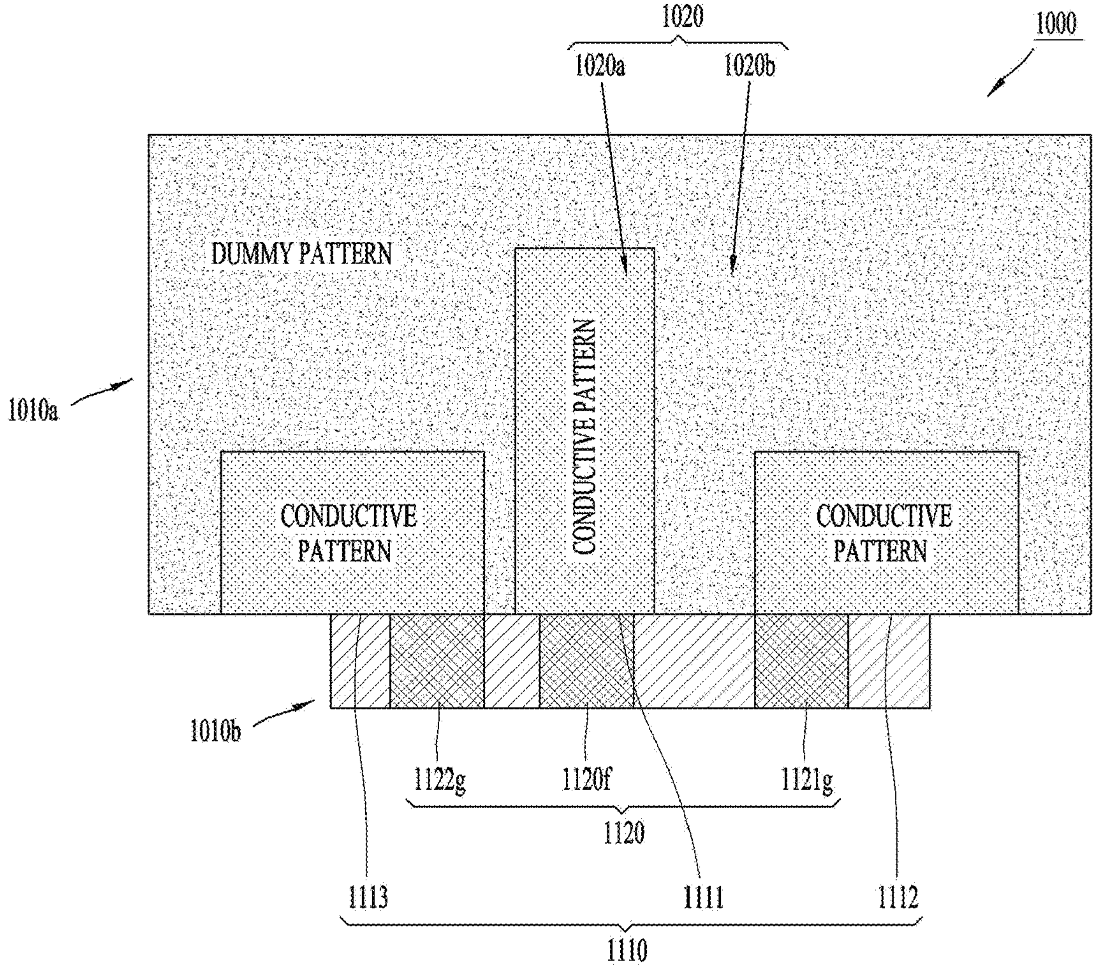

1010b
1112c
1110c
1111c
1110
1010a
W2
W1

(a)

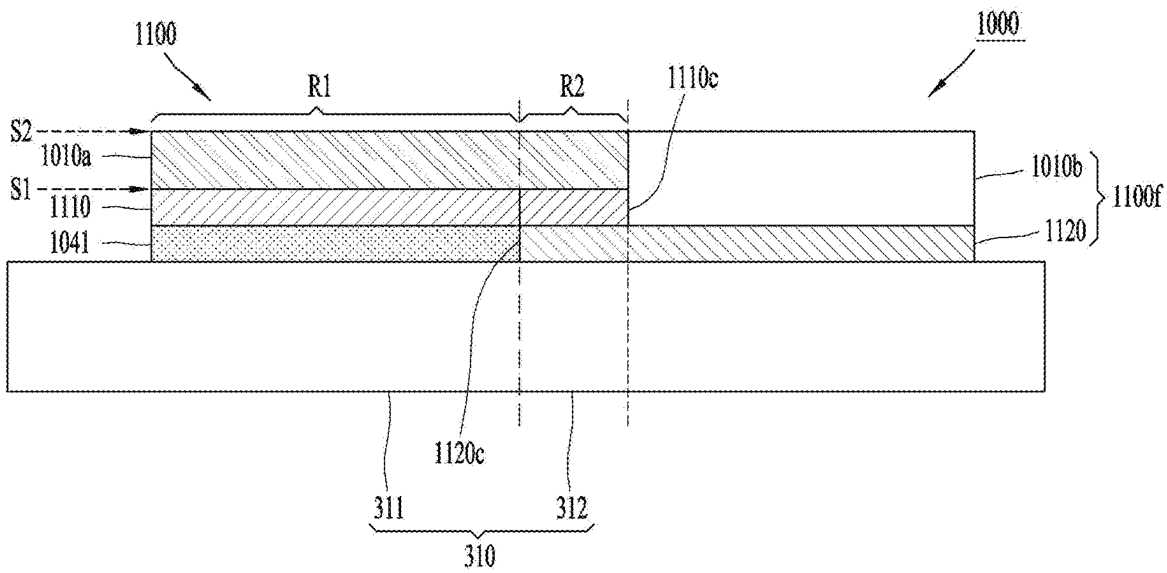

1010b
1010a
312
310
311
W2
W1

(b)

FIG. 7A

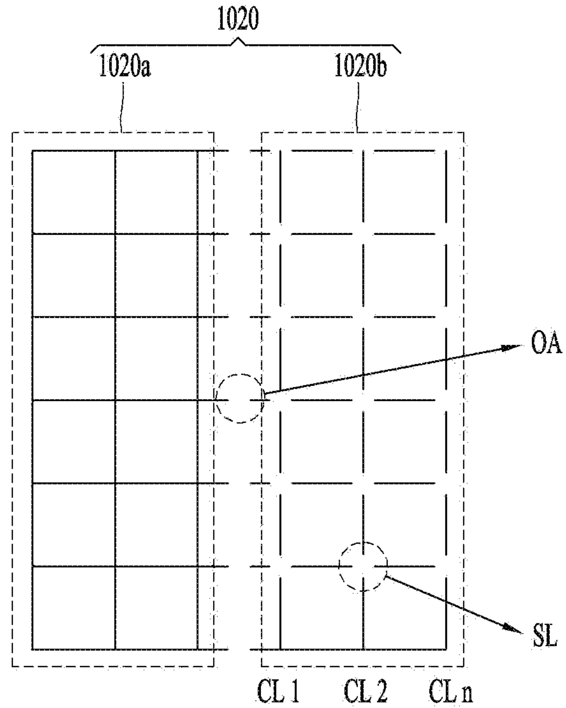

1020
1000
1020a
1020b
DUMMY PATTERN
CONDUCTIVE PATTERN
1010a
CONDUCTIVE PATTERN
CONDUCTIVE PATTERN
1010b
1122g
1120f
1121g
1120
1113
1111
1112
1110

(a)

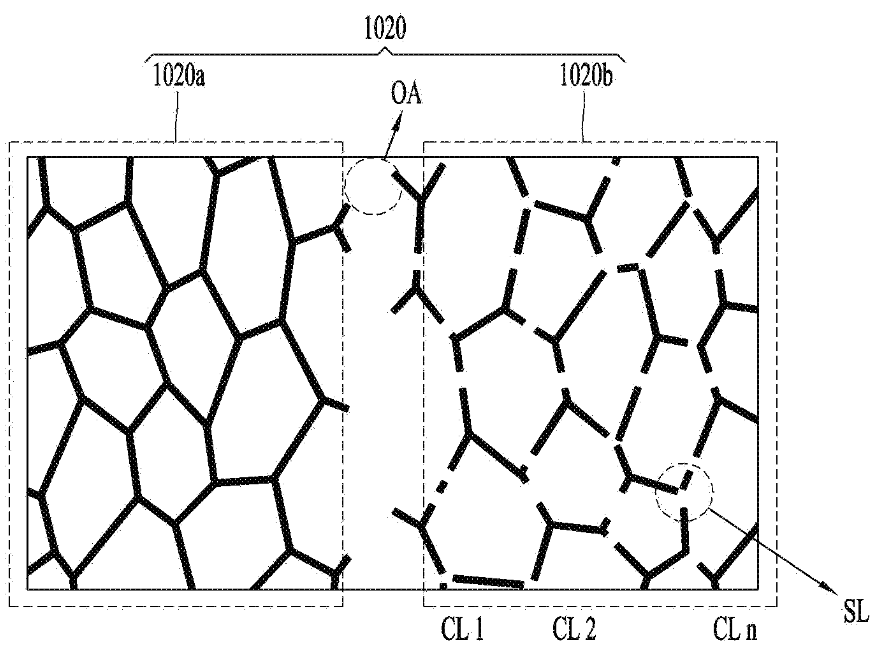

1100
1000
R1
R2
1110c
S2
1010a
S1
1110
1041
1010b
1100f
1120
1120c
311
312
310

(b)

FIG. 7B

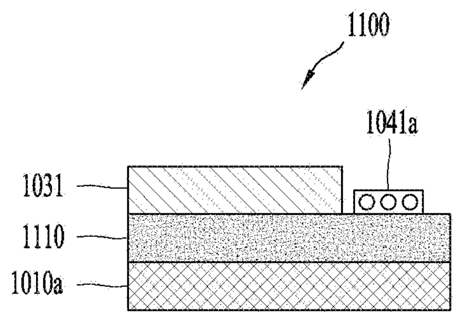

1020
1020a
1020b
OA
SL
CL 1
CL 2
CL n

(a)

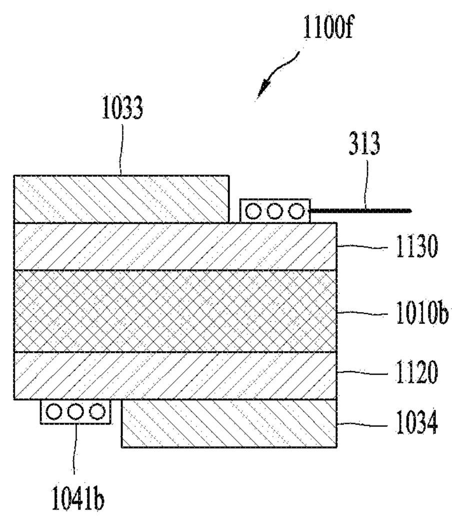

1020
1020a
1020b
OA
SL
CL 1
CL 2
CL n

(b)

FIG. 8A

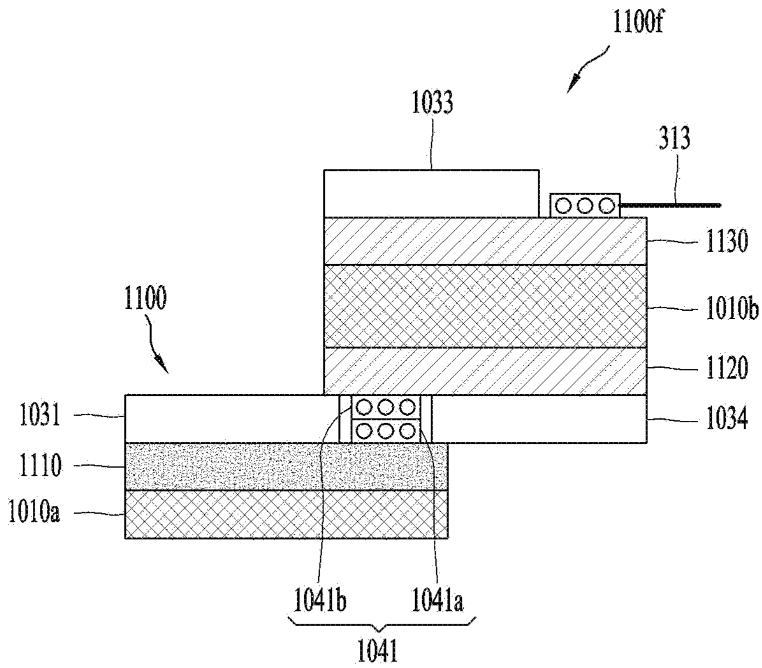

1100
1041a
1031
1110
1010a

(a)

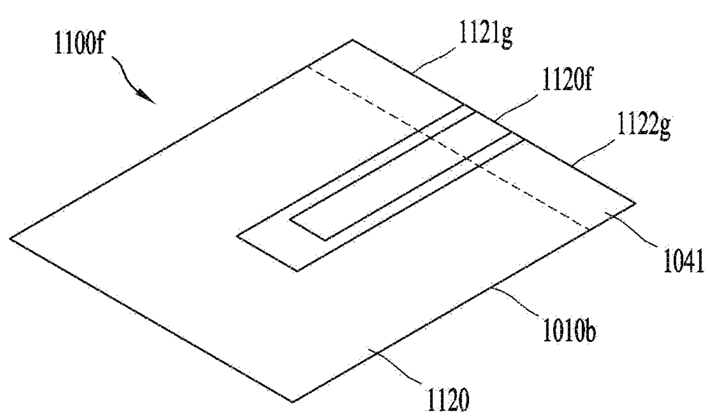

1100f
1033
313
1130
1010b
1120
1034
1041b

(b)

FIG. 8B


1100f
1033
313
1130
1010b
1120
1100
1031
1034
1110
1010a
1041b
1041a
1041

(a)


1100f
1121g
1120f
1122g
1041
1010b
1120

(b)

FIG. 9A

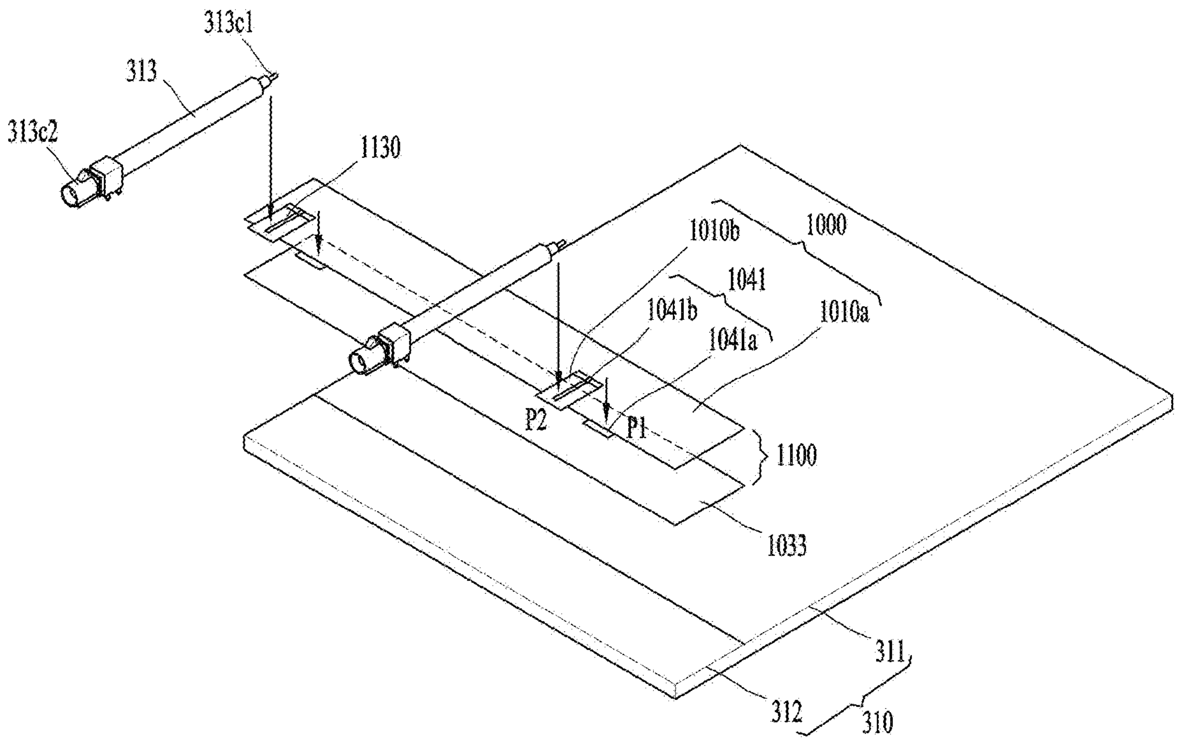

313c1
313
313c2
1130
1000
1010b
1041
1041b
1010a
1041a
P2
P1
1100
1033
311
312
310

FIG. 9B

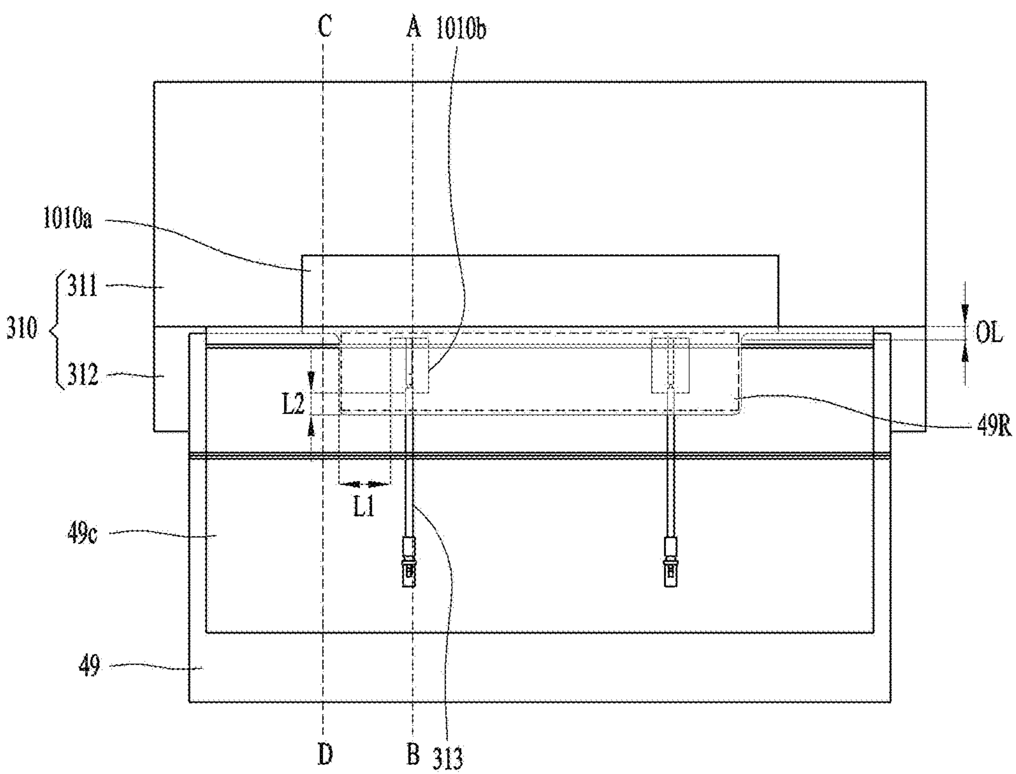
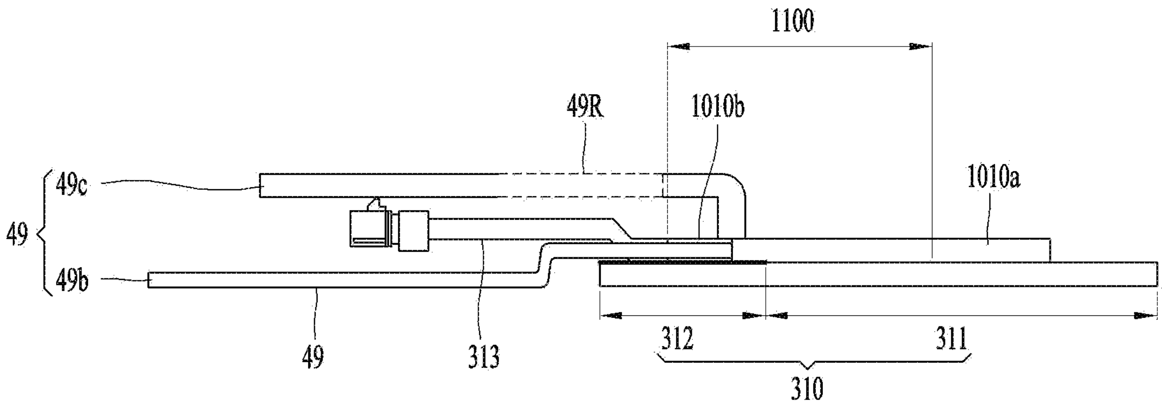
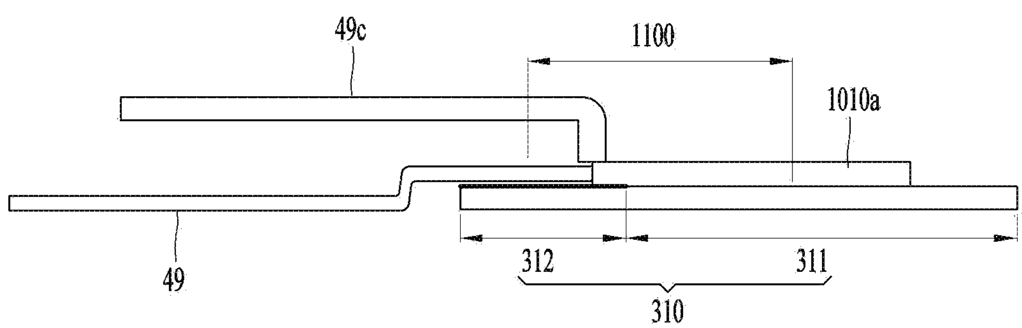

C
A
1010b
1010a
311
310
312
OL
L2
49R
L1
49c
49
D
B
313

FIG. 9C

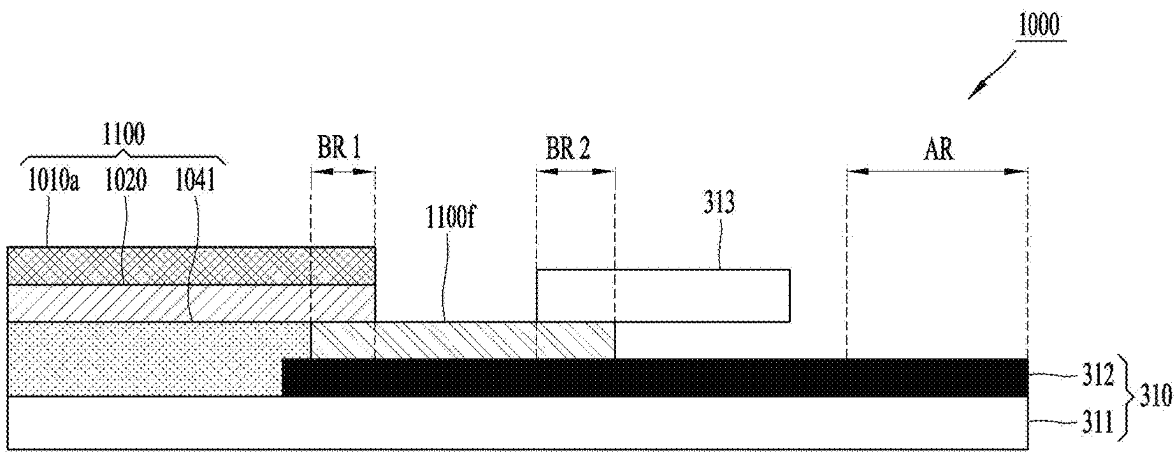

1100
49R
1010b
49c
1010a
49
49b
49
313
312
311
310

(a)

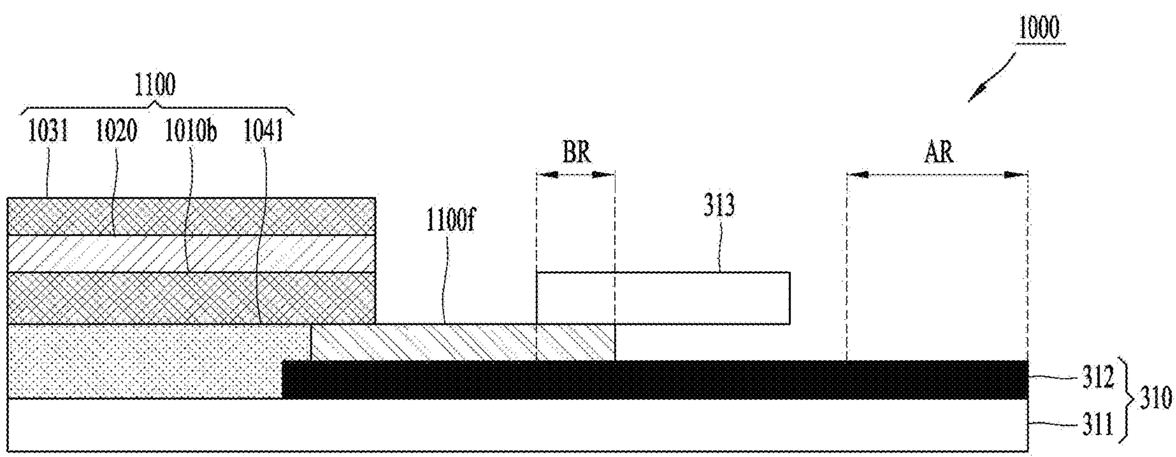

49c
1100
1010a
49
312
311
310

(b)

FIG. 10


1000
1100
1010a
1020
1041
BR 1
BR 2
AR
1100f
313
312
311
310

(a)


1000
1100
1031
1020
1010b
1041
BR
AR
1100f
313
312
311
310

(b)

FIG. 11A

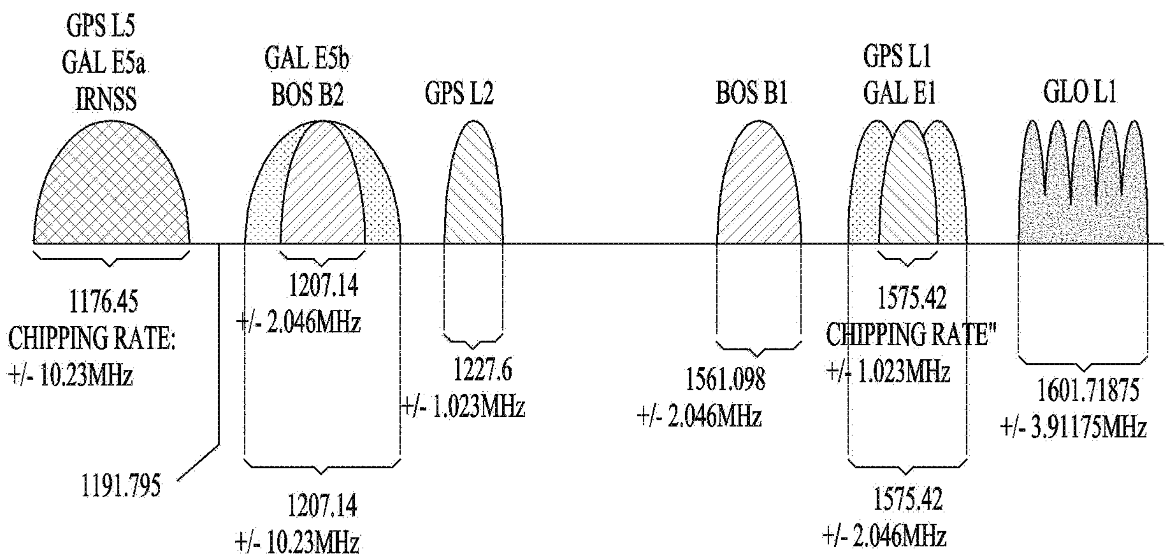
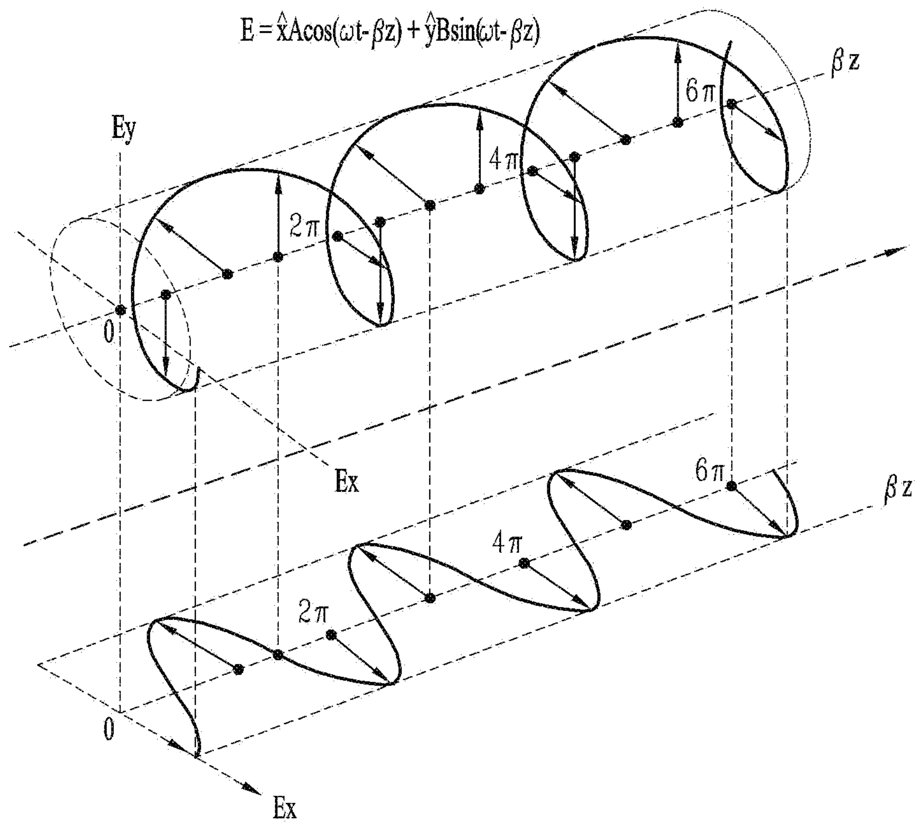
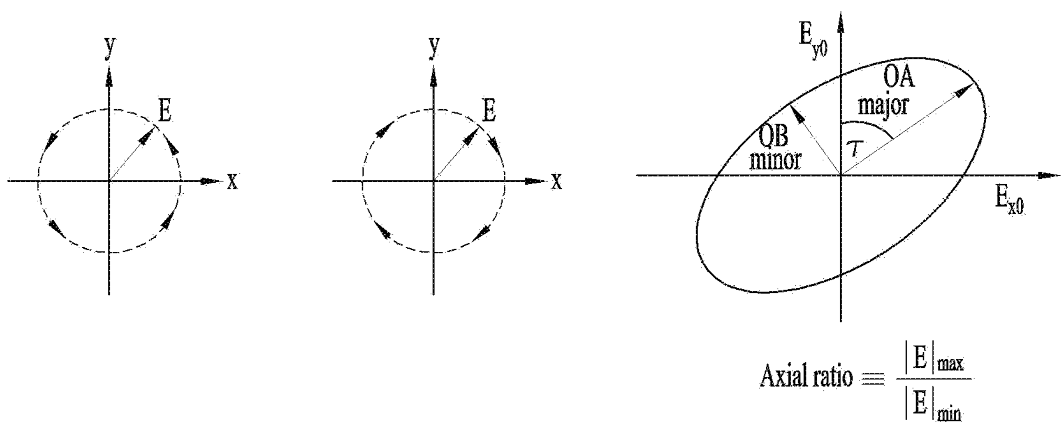

GPS L5
GAL E5a
IRNSS
GAL E5b
BOS B2
GPS L2
BOS B1
GPS L1
GAL E1
GLO L1
1176.45
CHIPPING RATE:
+/- 10.23MHz
1207.14
+/- 2.046MHz
1227.6
+/- 1.023MHz
1561.098
+/- 2.046MHz
1575.42
CHIPPING RATE"
+/- 1.023MHz
1601.71875
+/- 3.91175MHz
1191.795
1207.14
+/- 10.23MHz
1575.42
+/- 2.046MHz

FIG. 11B


E = x̂Acos(ωt-βz) + ŷBsin(ωt-βz)
Ey
Ex
βz
0
2π
4π
6π

(a)


y
x
E
E_{y0}
E_{x0}
OA
major
OB
minor
τ
Axial ratio ≡ |E|max / |E|min

(b) (c) (d)

FIG. 12A

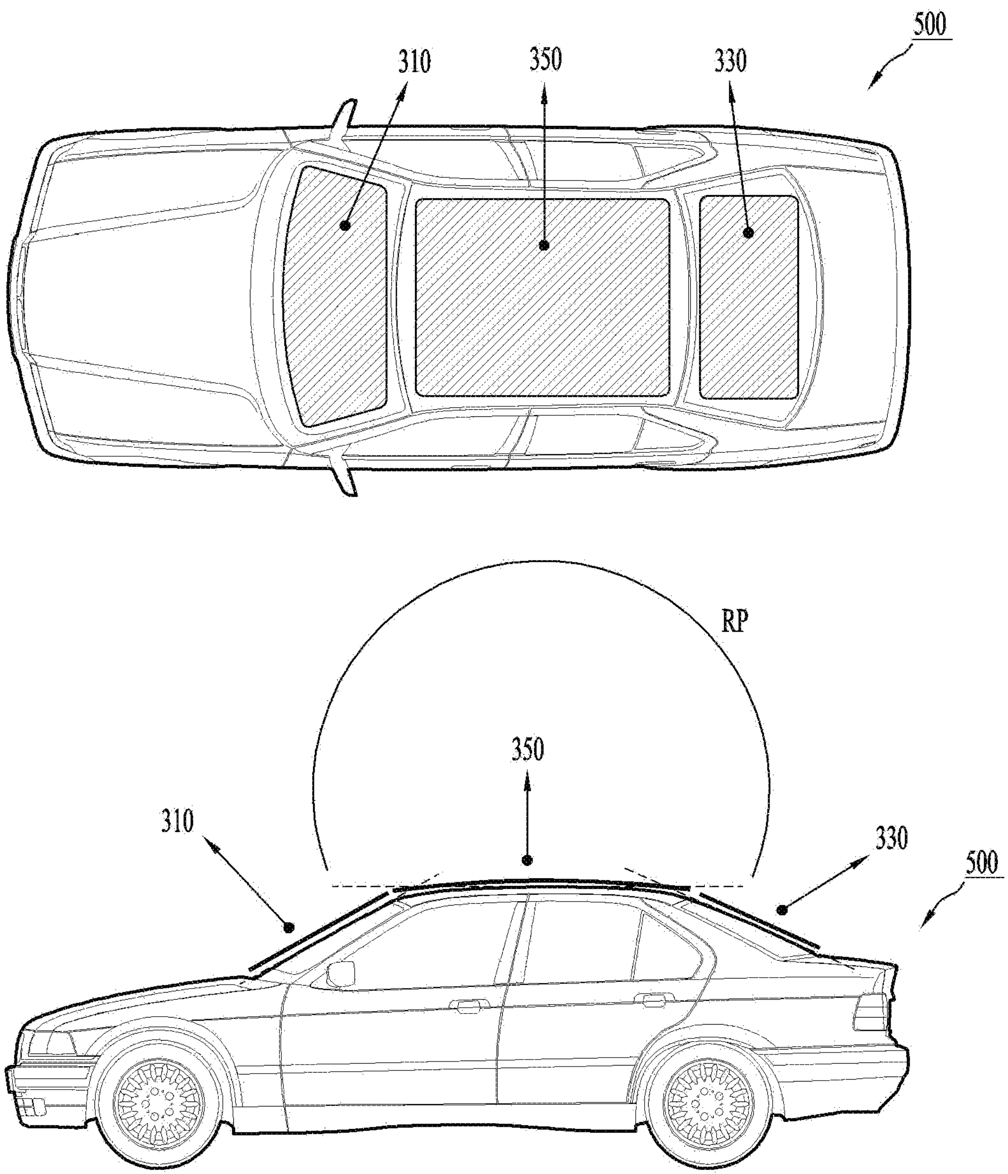


FIG. 12B

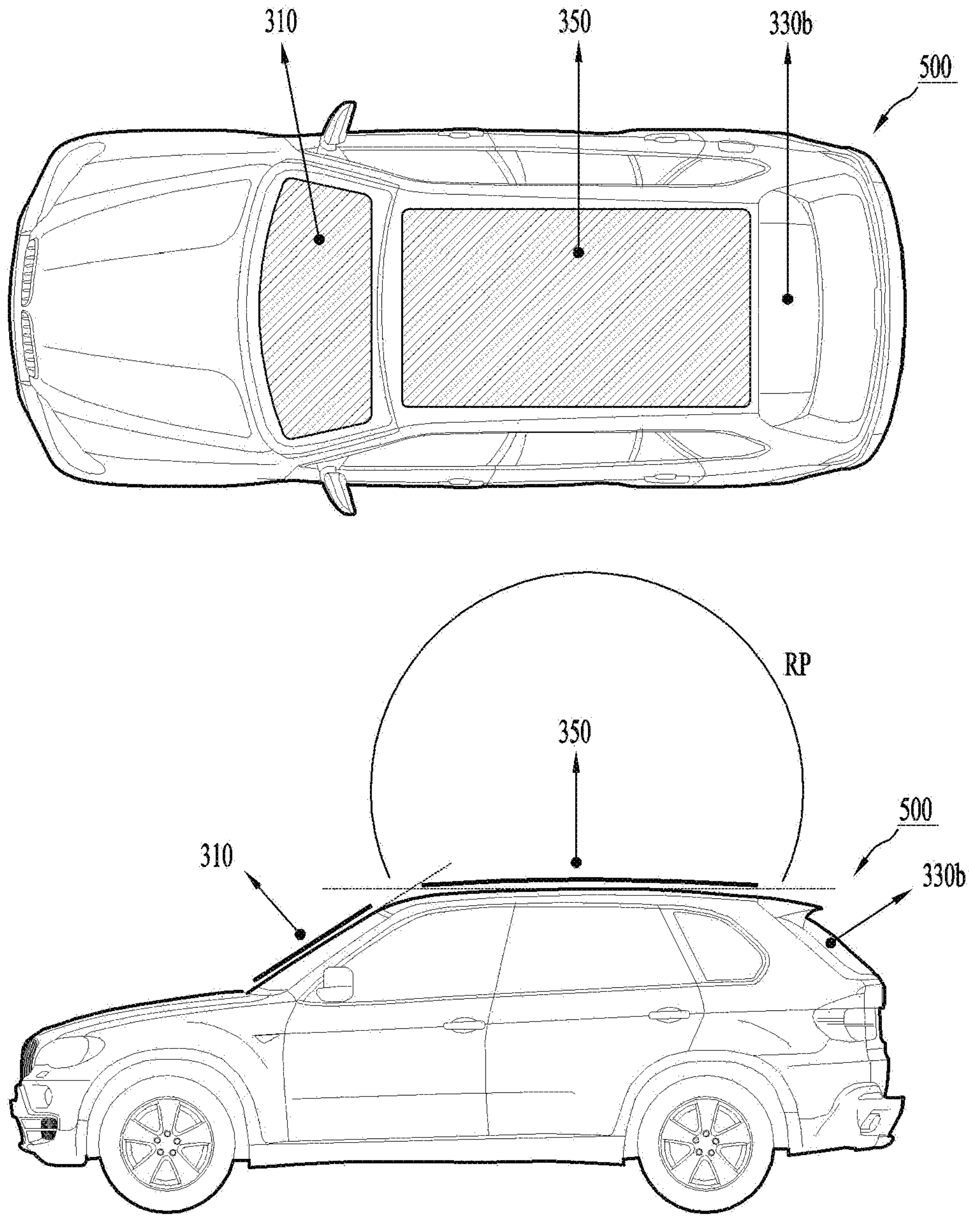


FIG. 13A

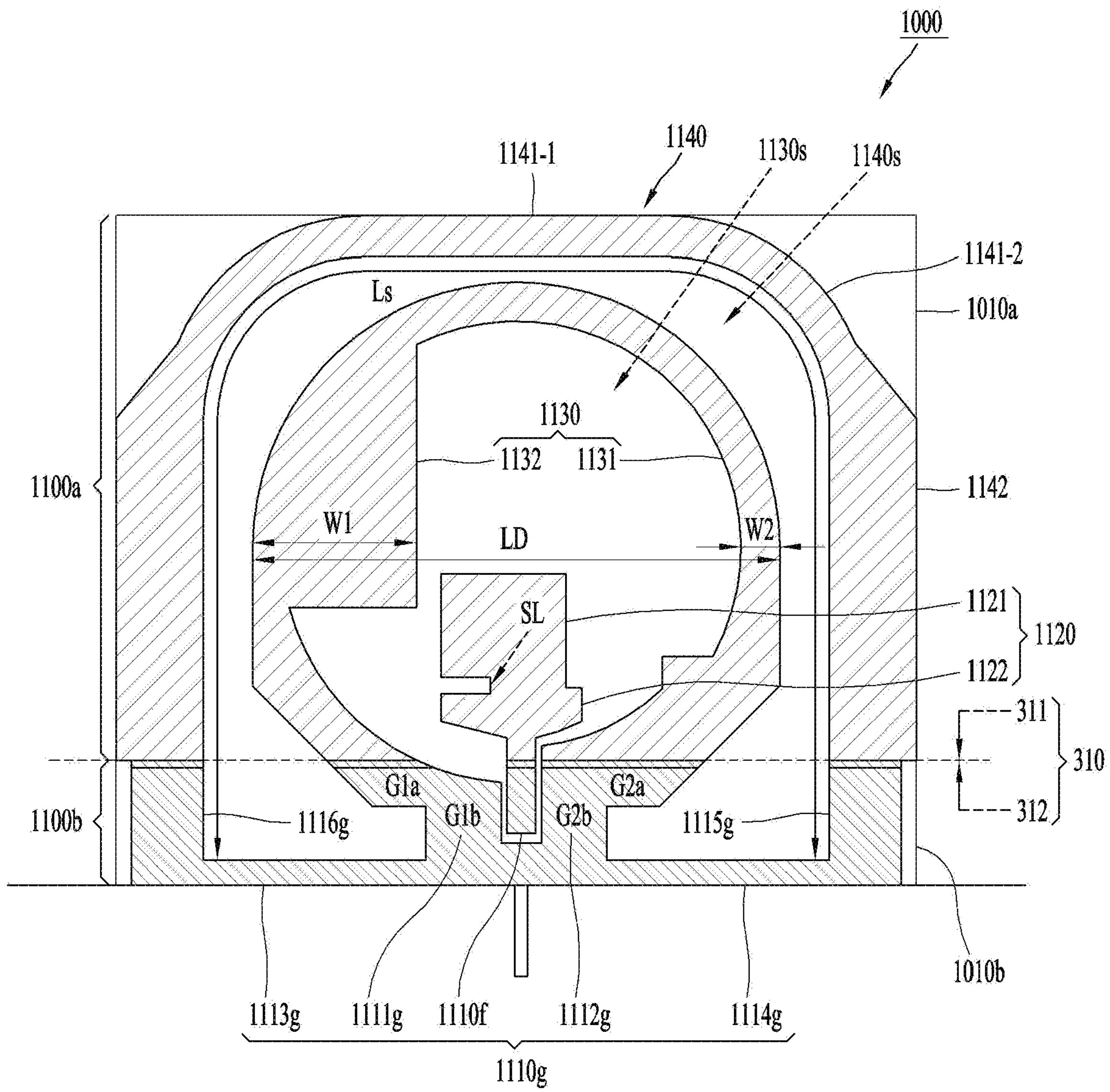

1000
1141-1
1140
1130s
1140s
1141-2
1010a
Ls
1130
1132
1131
1100a
1142
W1
LD
W2
SL
1121
1120
1122
311
310
312
G1a
G2a
1100b
1116g
G1b
G2b
1115g
1010b
1113g
1111g
1110f
1112g
1114g
1110g

FIG. 13B

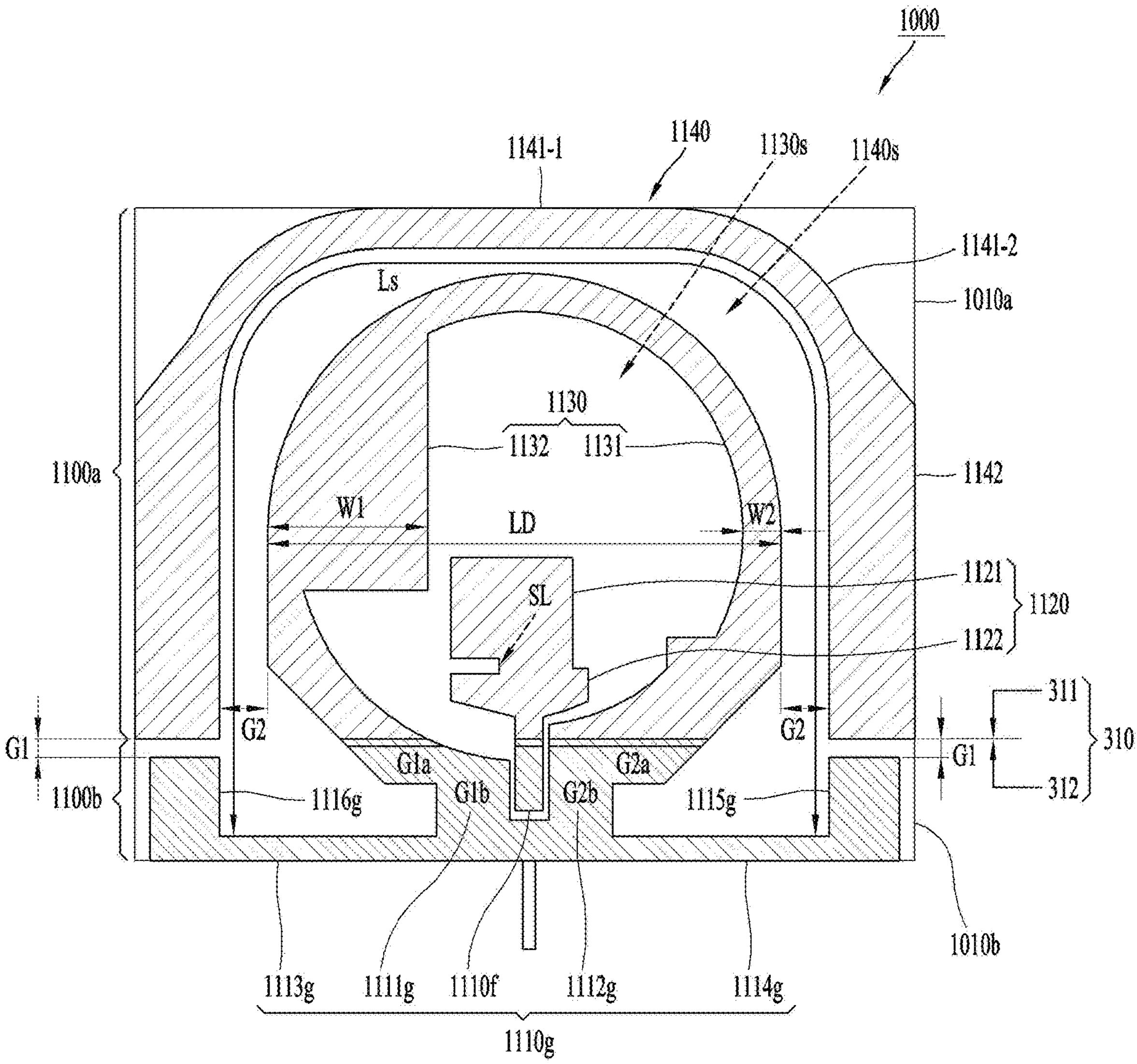

1000
1141-1
1140
1130s
1140s
1141-2
1010a
Ls
1130
1132
1131
1100a
1142
W1
LD
W2
1121
1120
SL
1122
311
310
G2
G2
G1
G1
G1a
G2a
1100b
1116g
G1b
G2b
1115g
312
1010b
1113g
1111g
1110f
1112g
1114g
1110g

FIG. 14A

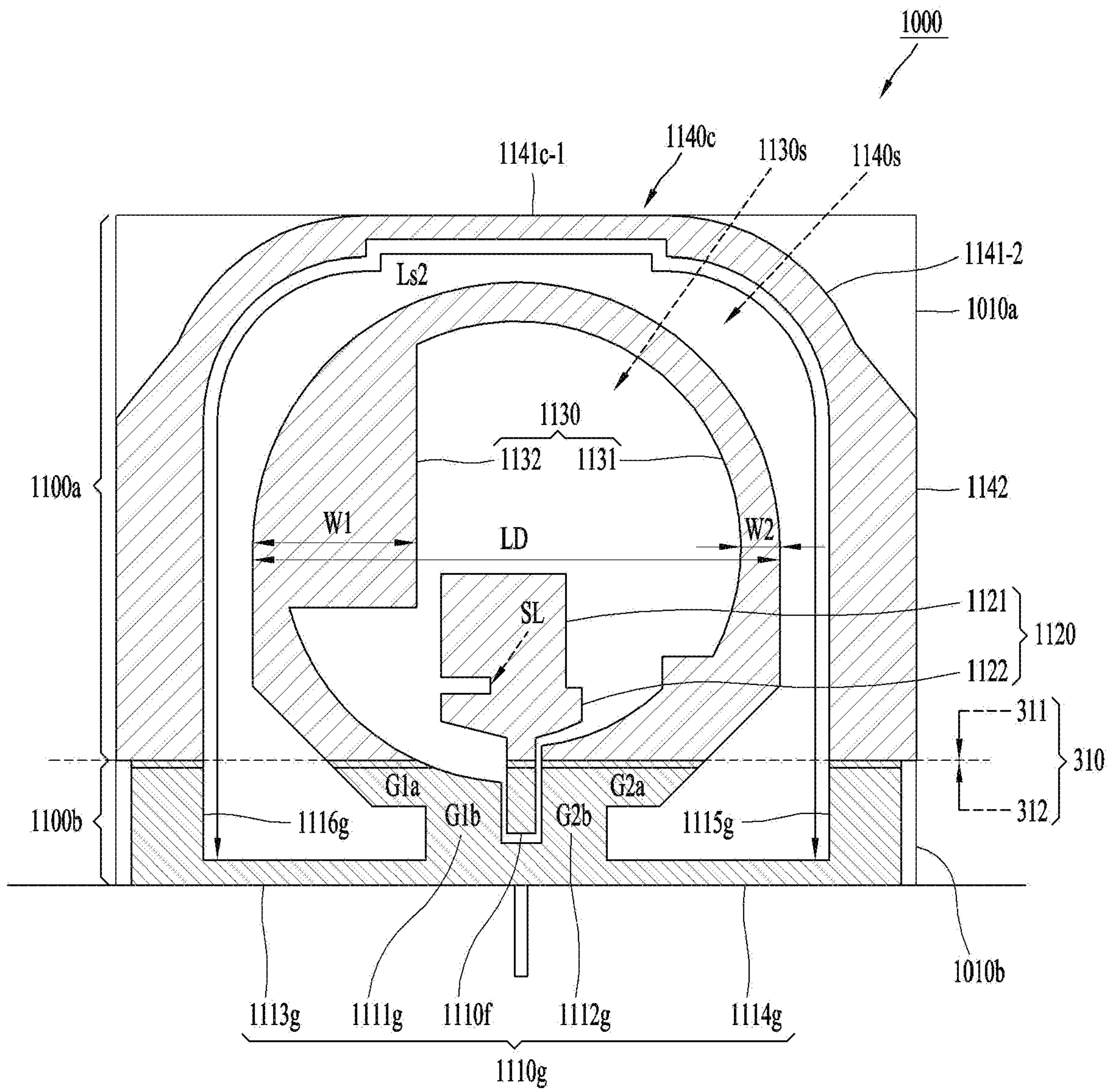
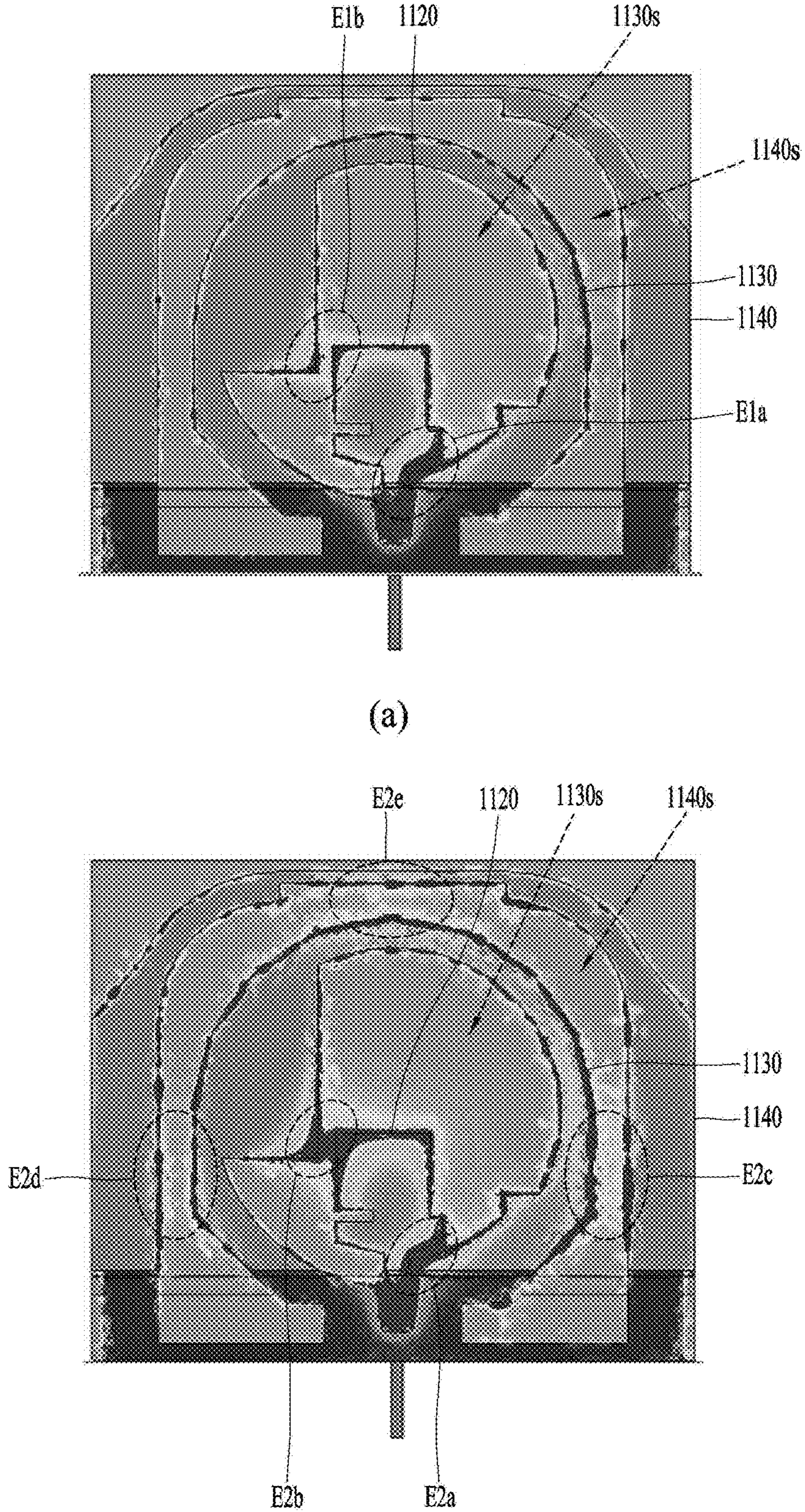

1000
1141c-1
1140c
1130s
1140s
1141-2
1010a
Ls2
1130
1132
1131
1100a
1142
W1
LD
W2
1121
1120
SL
1122
311
310
312
G1a
G2a
1100b
1116g
G1b
G2b
1115g
1010b
1113g
1111g
1110f
1112g
1114g
1110g

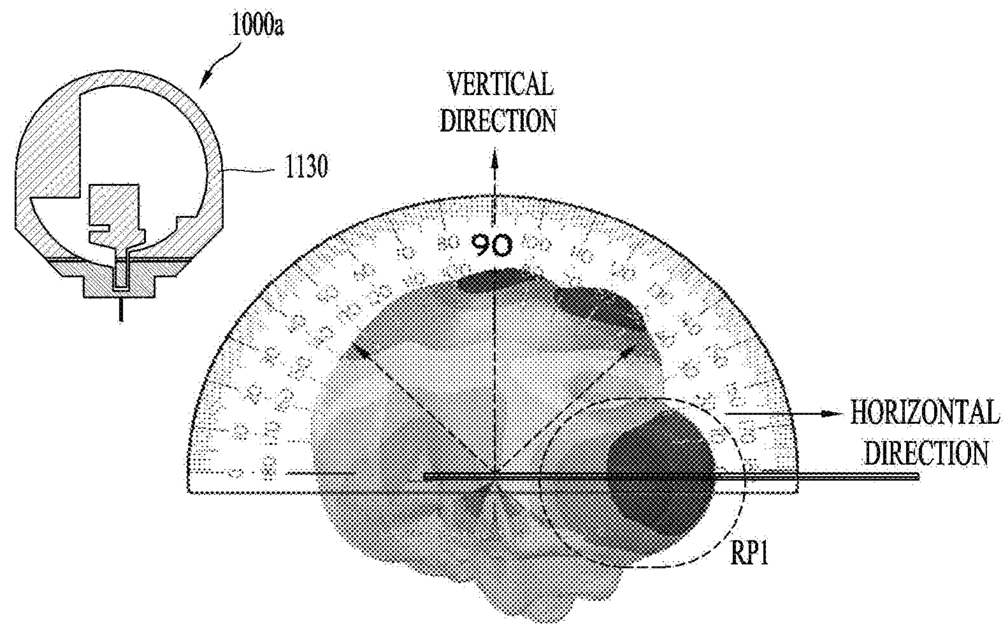
FIG. 14B


E1b
1120
1130s
1140s
1130
1140
E1a
E2e
1120
1130s
1140s
1130
1140
E2d
E2c
E2b
E2a

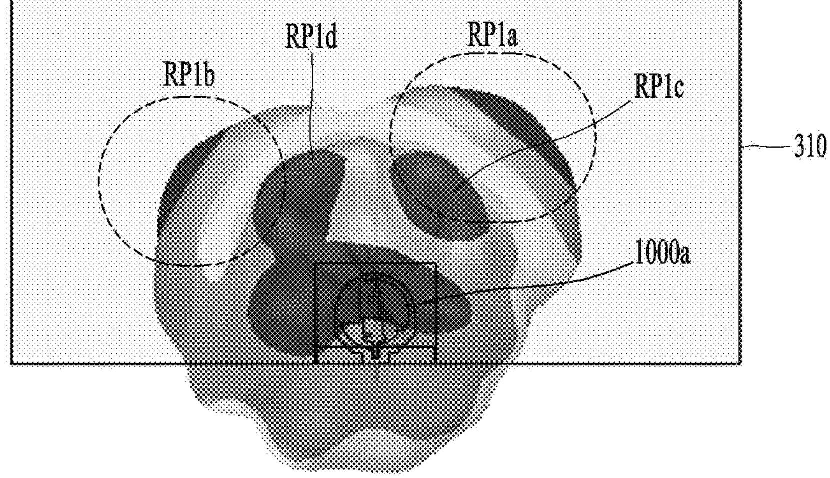
(a)

(b)

FIG. 15A

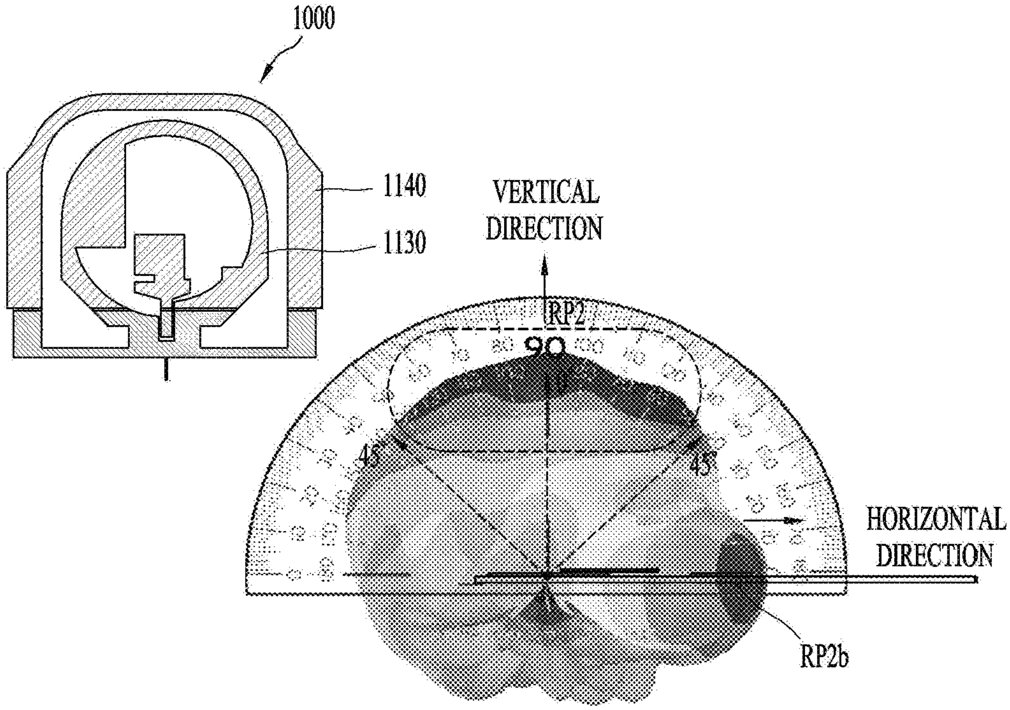

1000a
1130
VERTICAL DIRECTION
90
HORIZONTAL DIRECTION
RP1

(a)

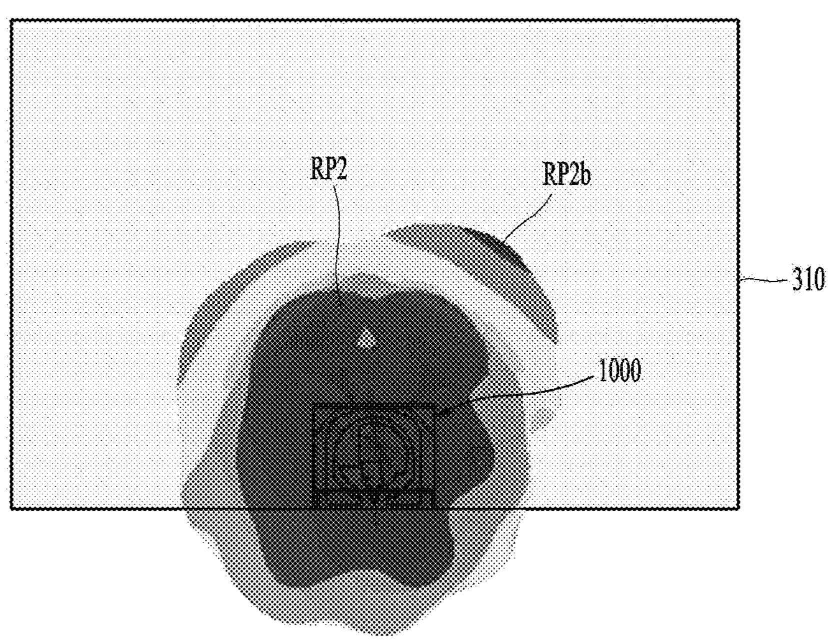

RP1d
RP1a
RP1b
RP1c
310
1000a

(b)

FIG. 15B

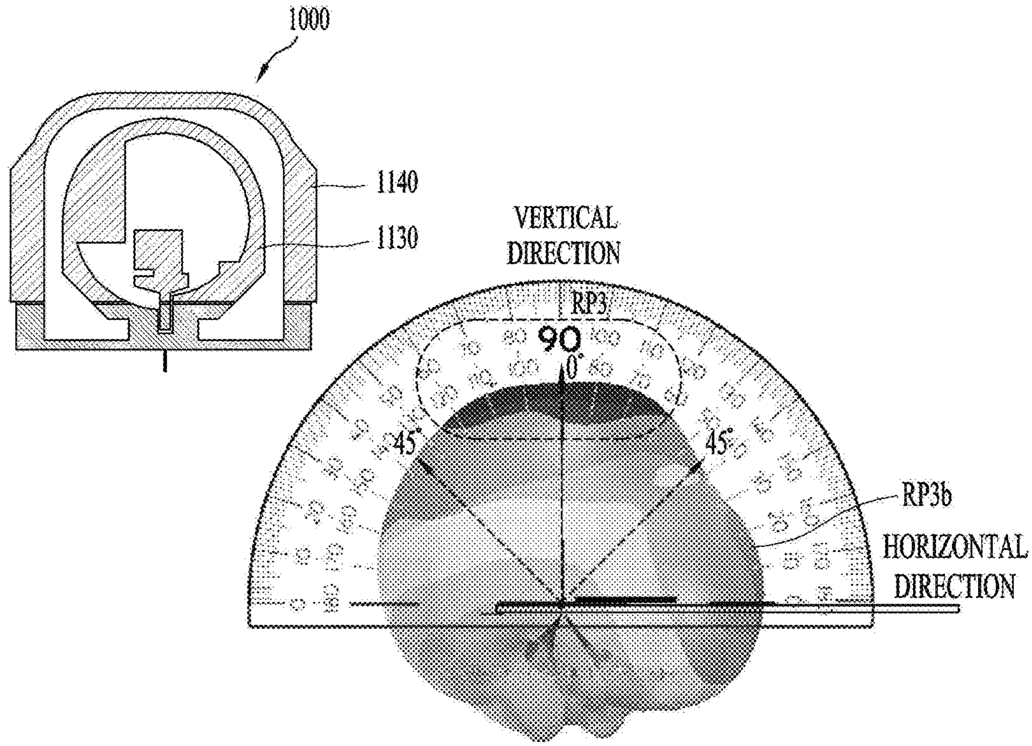

1000
1140
1130
VERTICAL
DIRECTION
RP2
90
45°
45°
HORIZONTAL
DIRECTION
RP2b

(a)

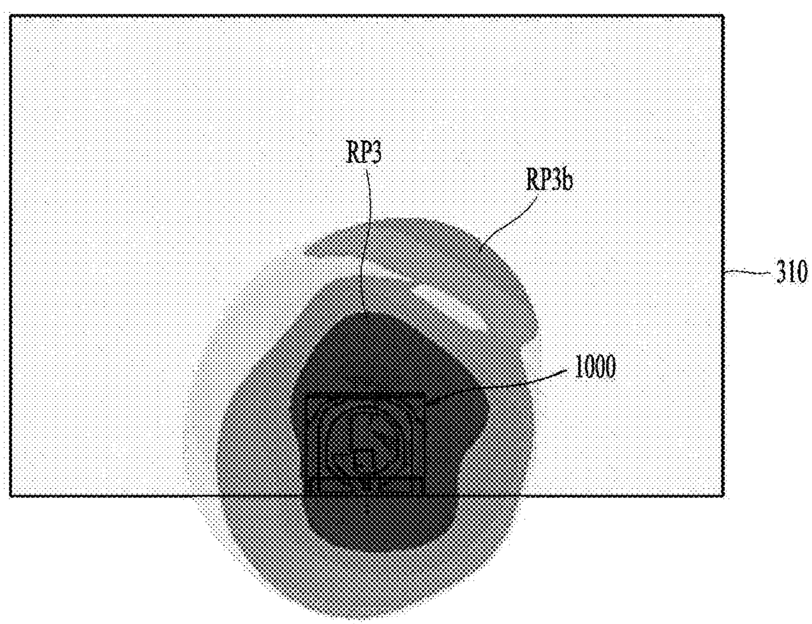

RP2
RP2b
310
1000

(b)

FIG. 15C

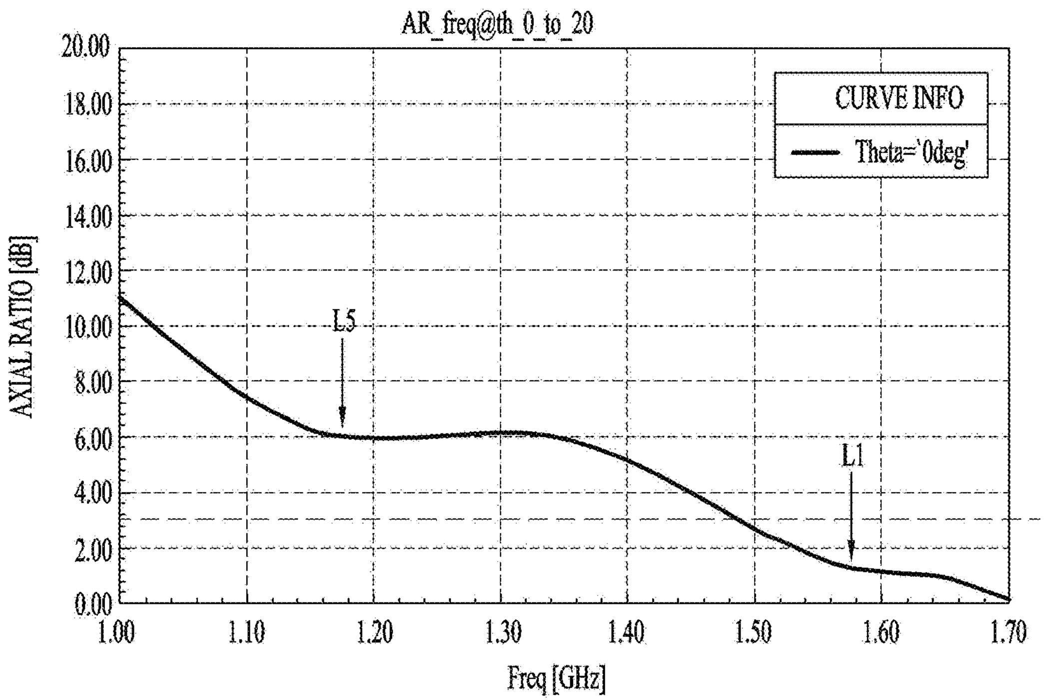

1000
1140
1130
VERTICAL DIRECTION
RP3
90
0°
45°
45°
RP3b
HORIZONTAL DIRECTION

(a)

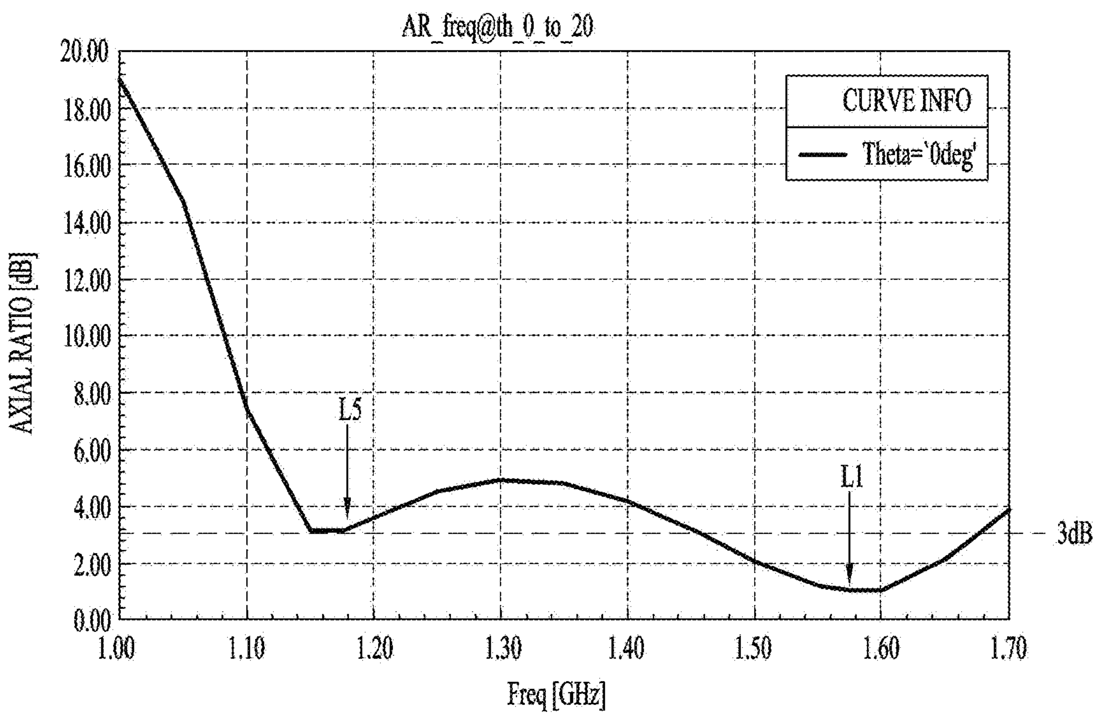

RP3
RP3b
310
1000

(b)

FIG. 16A

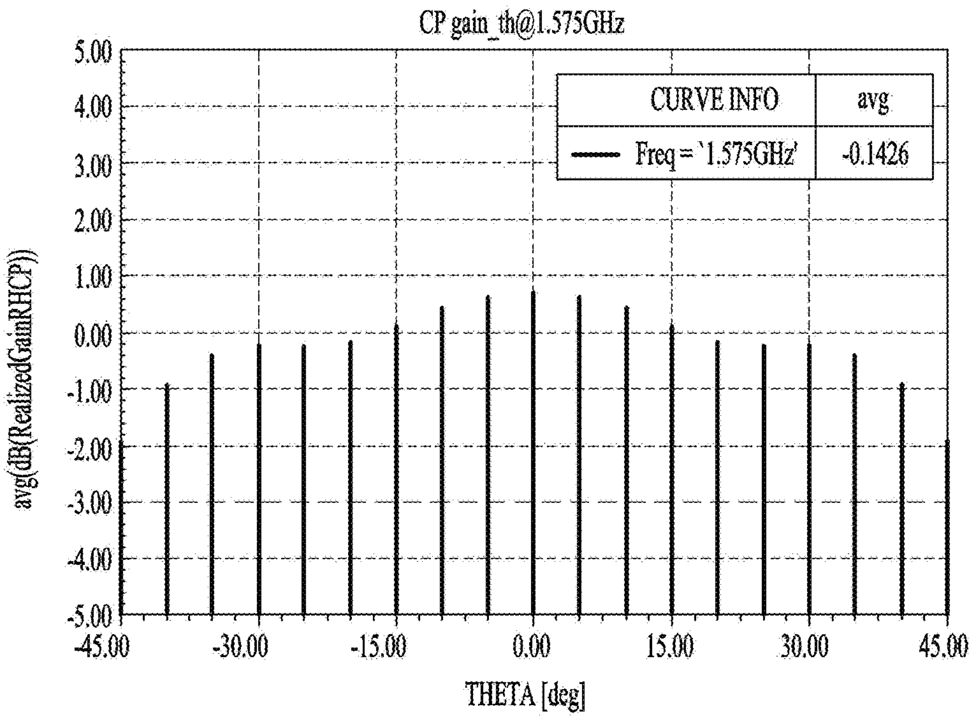

AR_freq@th_0_to_20
CURVE INFO
Theta='0deg'
AXIAL RATIO [dB]
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
L5
L1
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
Freq [GHz]

(a)

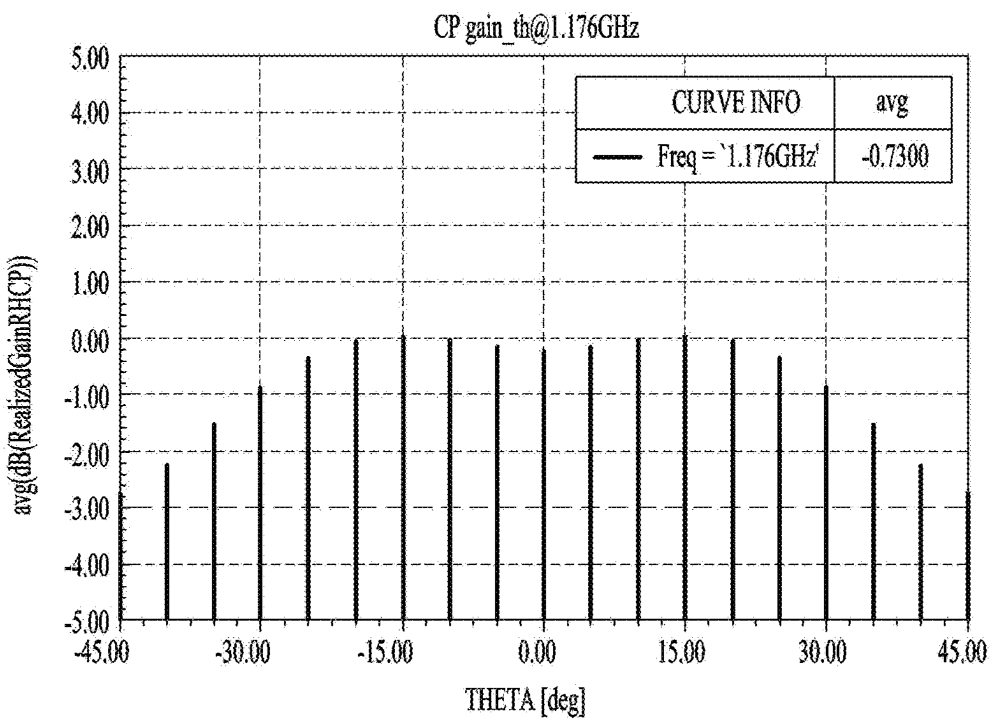

AR_freq@th_0_to_20
CURVE INFO
Theta='0deg'
AXIAL RATIO [dB]
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
L5
L1
3dB
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
Freq [GHz]

(b)

FIG. 16B

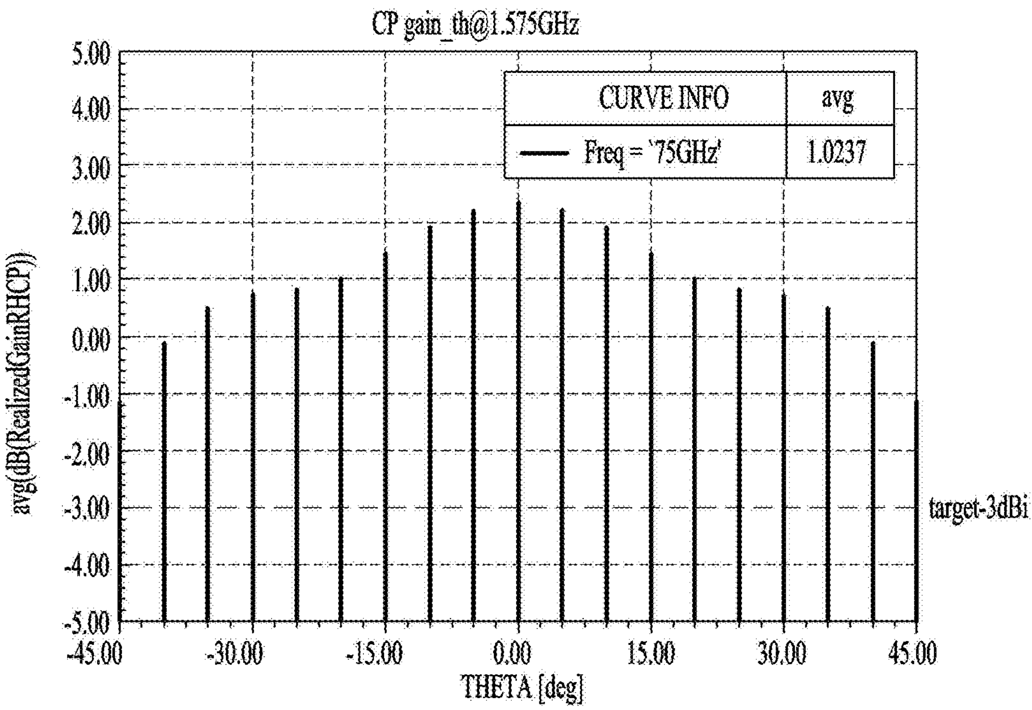

CP gain_th@1.575GHz
CURVE INFO
avg
Freq = '1.575GHz'
-0.1426
avg(dB(RealizedGainRHCP))
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-45.00
-30.00
-15.00
0.00
15.00
30.00
45.00
THETA [deg]

(a)

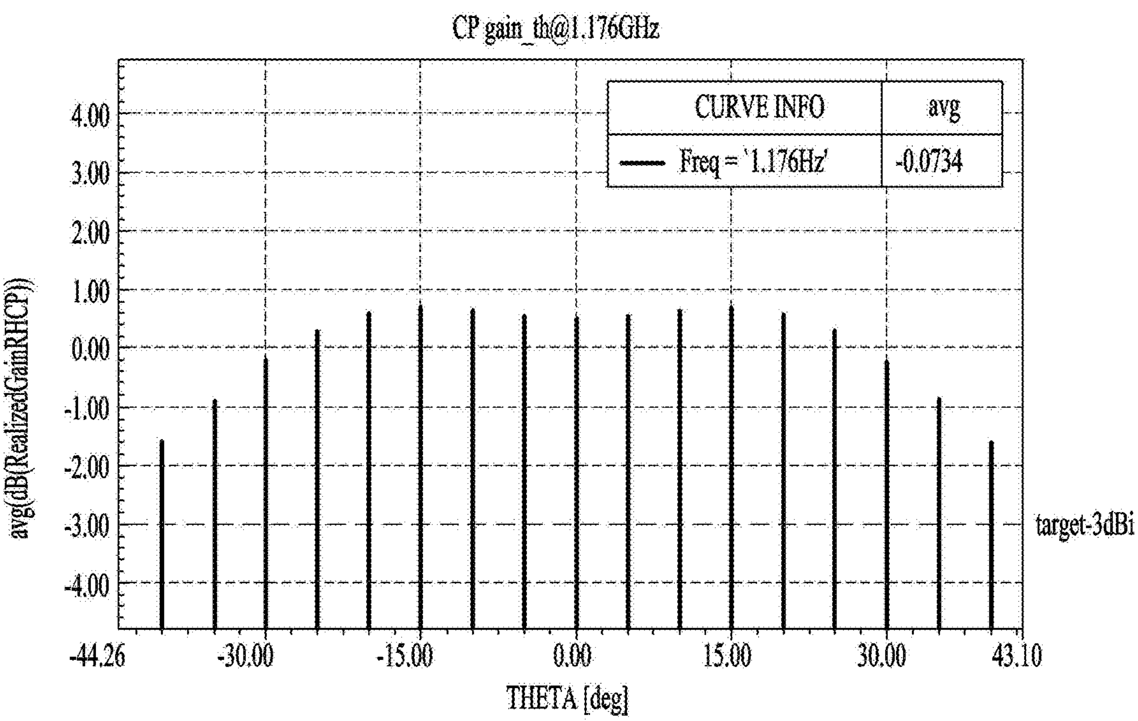

CP gain_th@1.176GHz
CURVE INFO
avg
Freq = '1.176GHz'
-0.7300
avg(dB(RealizedGainRHCP))
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-45.00
-30.00
-15.00
0.00
15.00
30.00
45.00
THETA [deg]

(b)

FIG. 16C

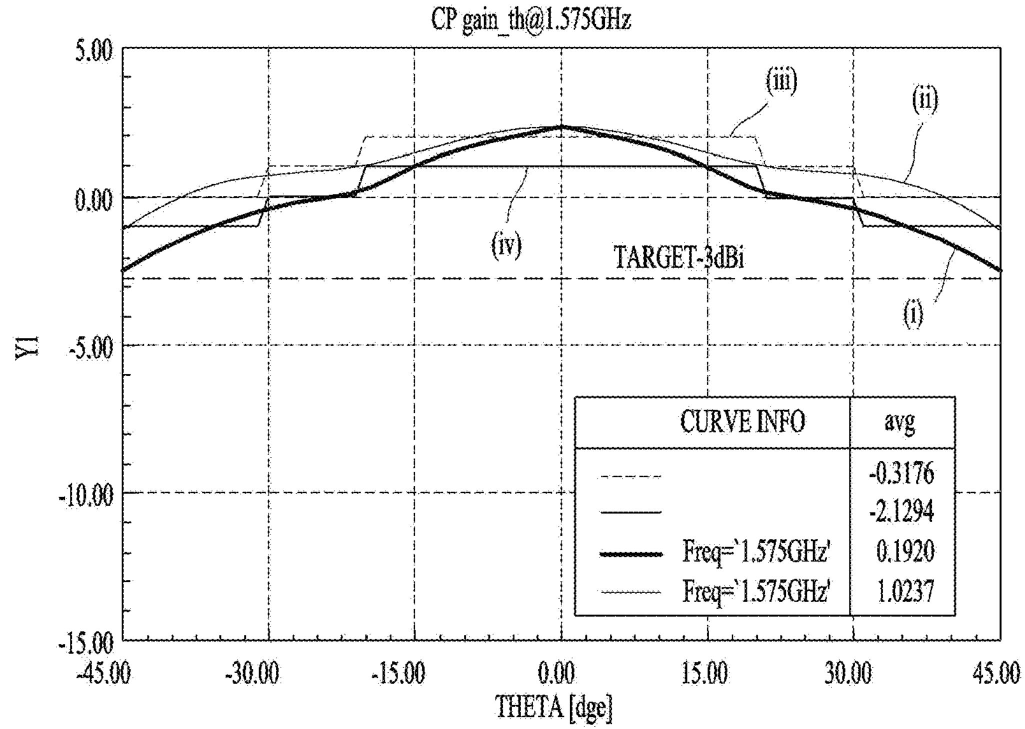

CP gain_th@1.575GHz
CURVE INFO
avg
Freq = '75GHz'
1.0237
avg(dB(RealizedGainRHCP))
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-45.00
-30.00
-15.00
0.00
15.00
30.00
45.00
THETA [deg]
target-3dBi

(a)

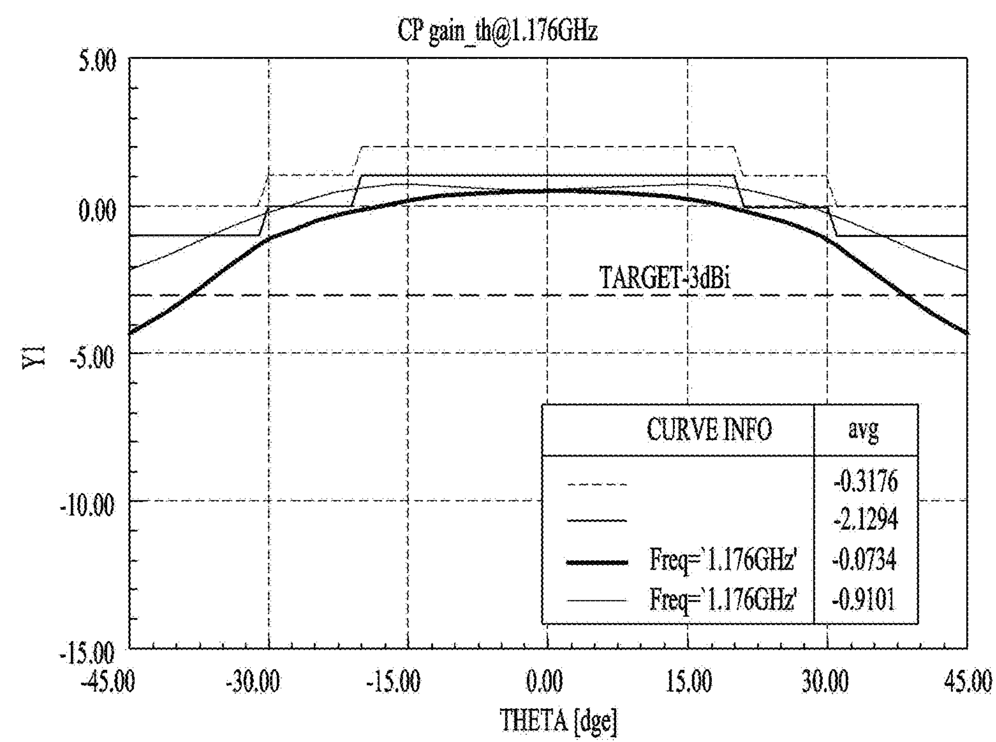

CP gain_th@1.176GHz
CURVE INFO
avg
Freq = '1.176Hz'
-0.0734
avg(dB(RealizedGainRHCP))
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-44.26
-30.00
-15.00
0.00
15.00
30.00
43.10
THETA [deg]
target-3dBi

(b)

FIG. 17A

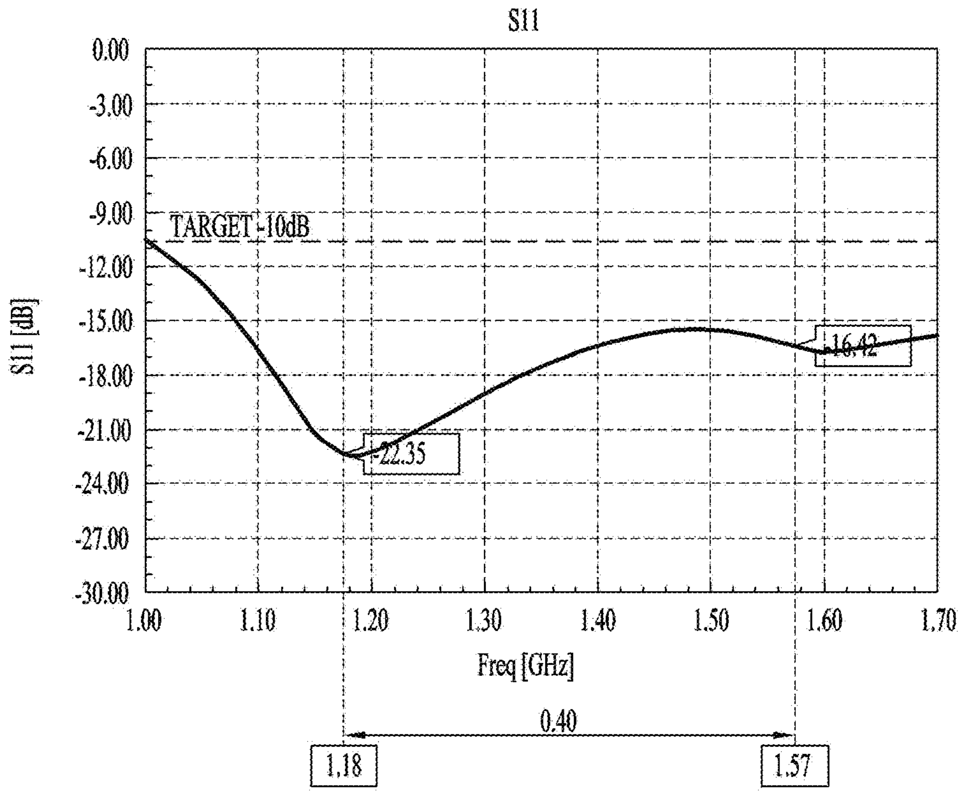

CP gain_th@1.575GHz
5.00
0.00
-5.00
-10.00
-15.00
Y1
-45.00
-30.00
-15.00
0.00
15.00
30.00
45.00
THETA [dge]
(i)
(ii)
(iii)
(iv)
TARGET-3dBi
CURVE INFO
avg
-0.3176
-2.1294
Freq='1.575GHz' 0.1920
Freq='1.575GHz' 1.0237

(a)

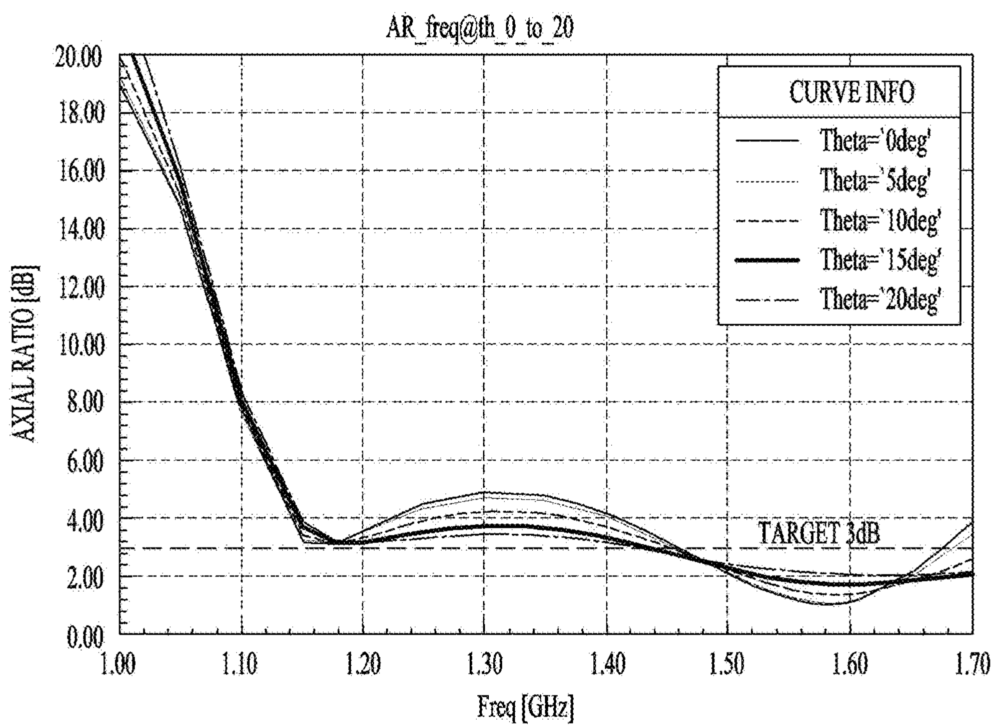

CP gain_th@1.176GHz
5.00
0.00
-5.00
-10.00
-15.00
Y1
-45.00
-30.00
-15.00
0.00
15.00
30.00
45.00
THETA [dge]
TARGET-3dBi
CURVE INFO
avg
-0.3176
-2.1294
Freq='1.176GHz' -0.0734
Freq='1.176GHz' -0.9101

(b)

FIG. 17B


S11
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-27.00
-30.00
S11 [dB]
TARGET -10dB
-22.35
-16.42
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
Freq [GHz]
0.40
1.18
1.57

(a)


AR_freq@th_0_to_20
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
AXIAL RATIO [dB]
CURVE INFO
Theta='0deg'
Theta='5deg'
Theta='10deg'
Theta='15deg'
Theta='20deg'
TARGET 3dB
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
Freq [GHz]

(b)

FIG. 18A

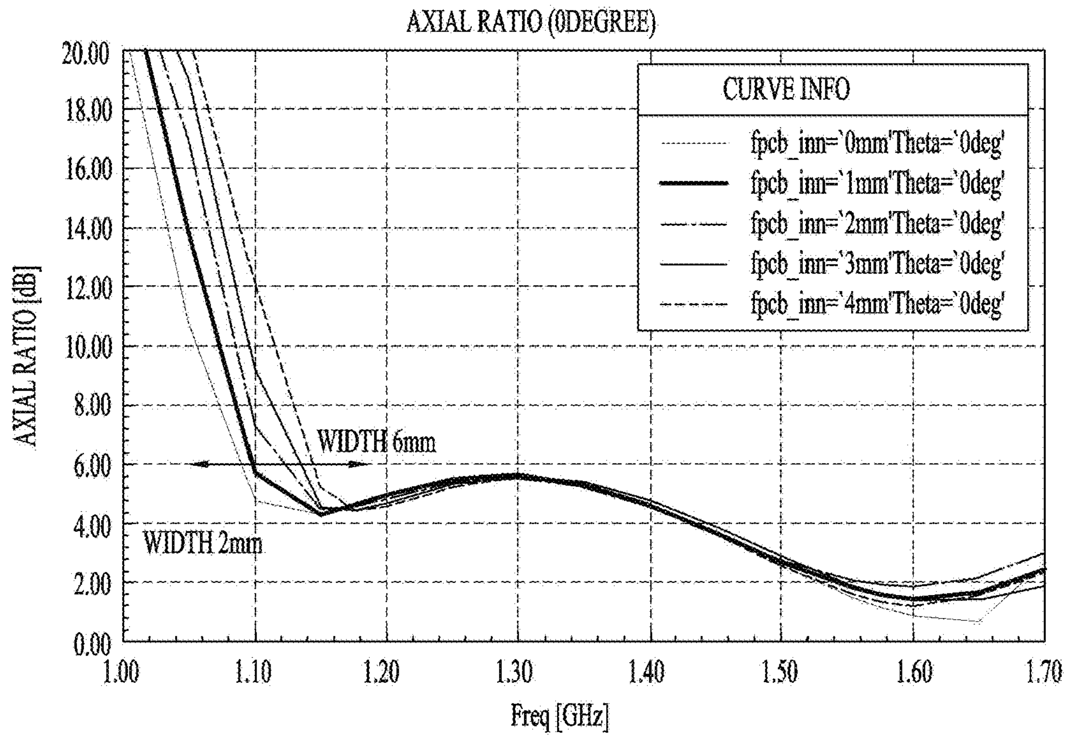


FIG. 18B

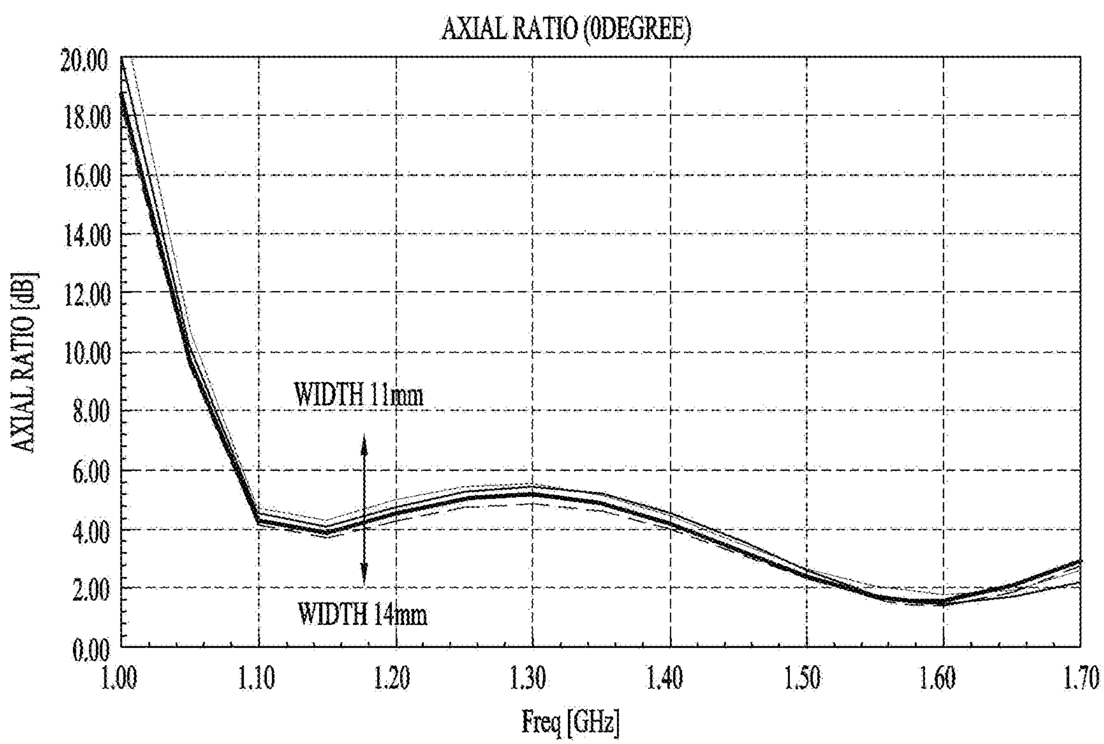


FIG. 18C

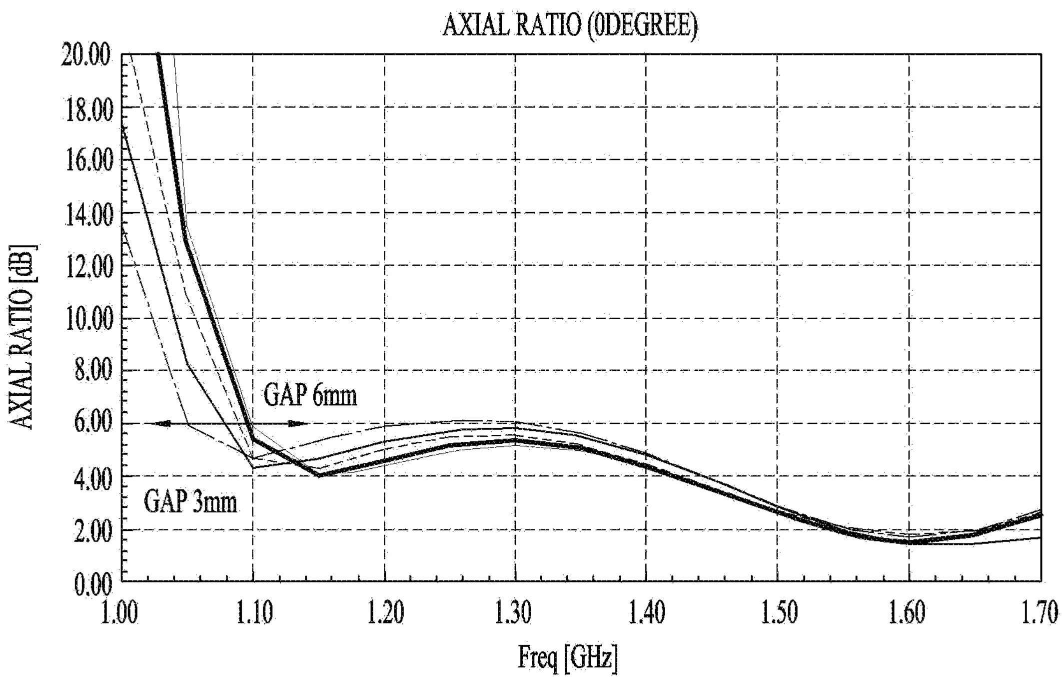

AXIAL RATIO (0DEGREE)
AXIAL RATIO [dB]
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
GAP 6mm
GAP 3mm
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
Freq [GHz]

FIG. 19A

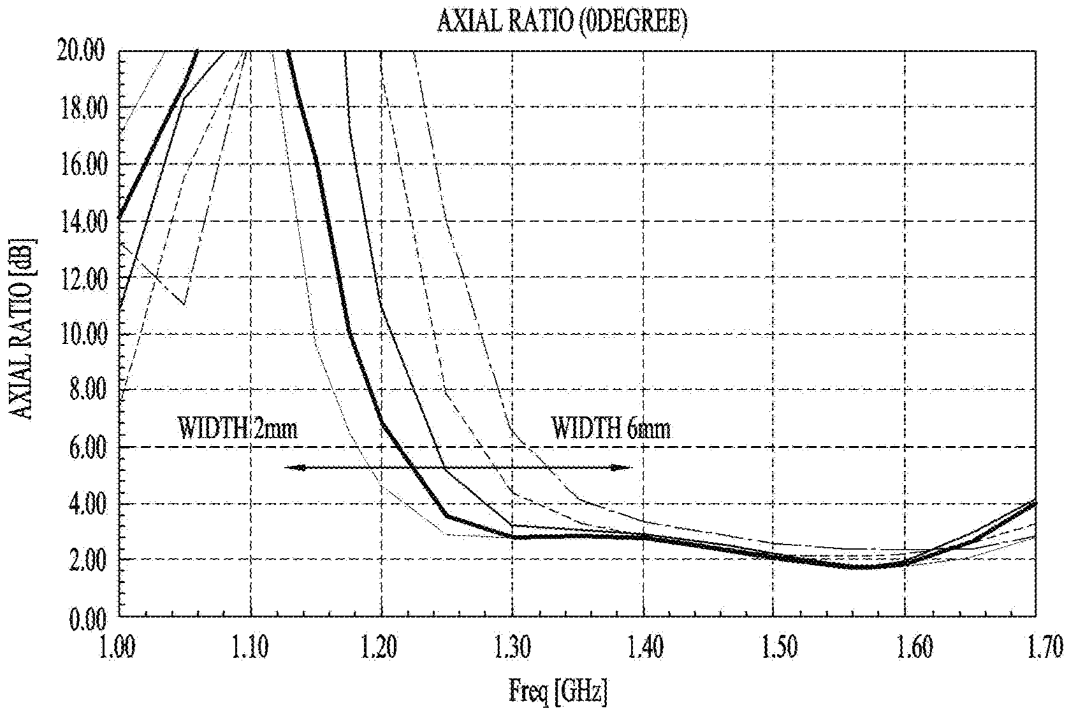


FIG. 19B

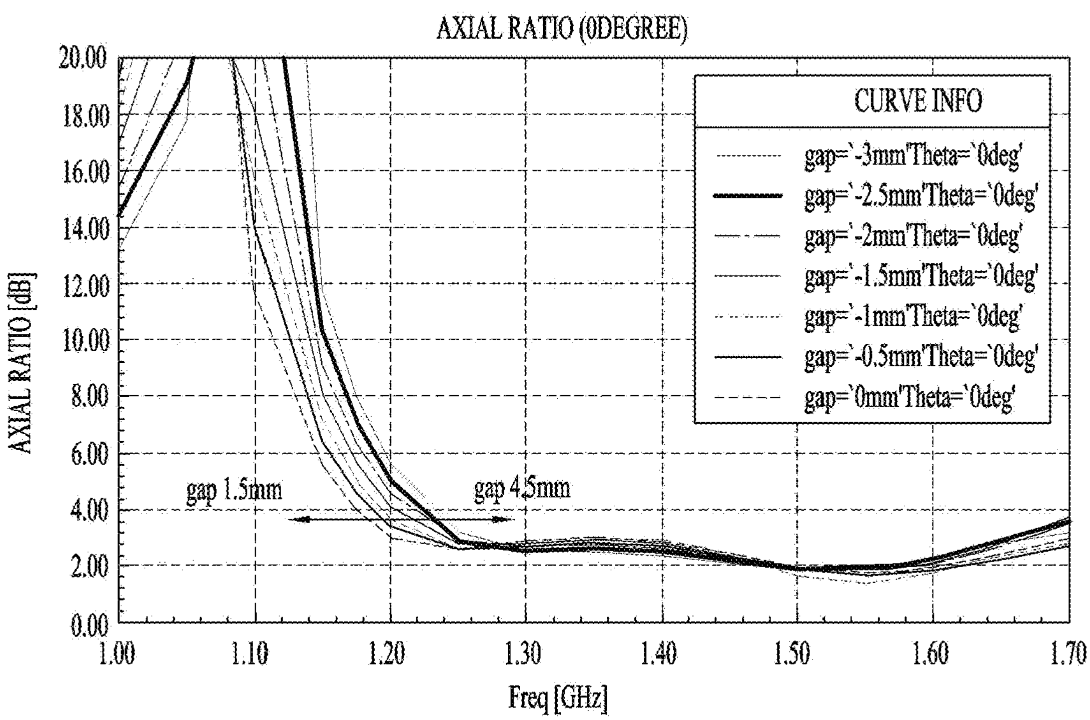


FIG. 19C

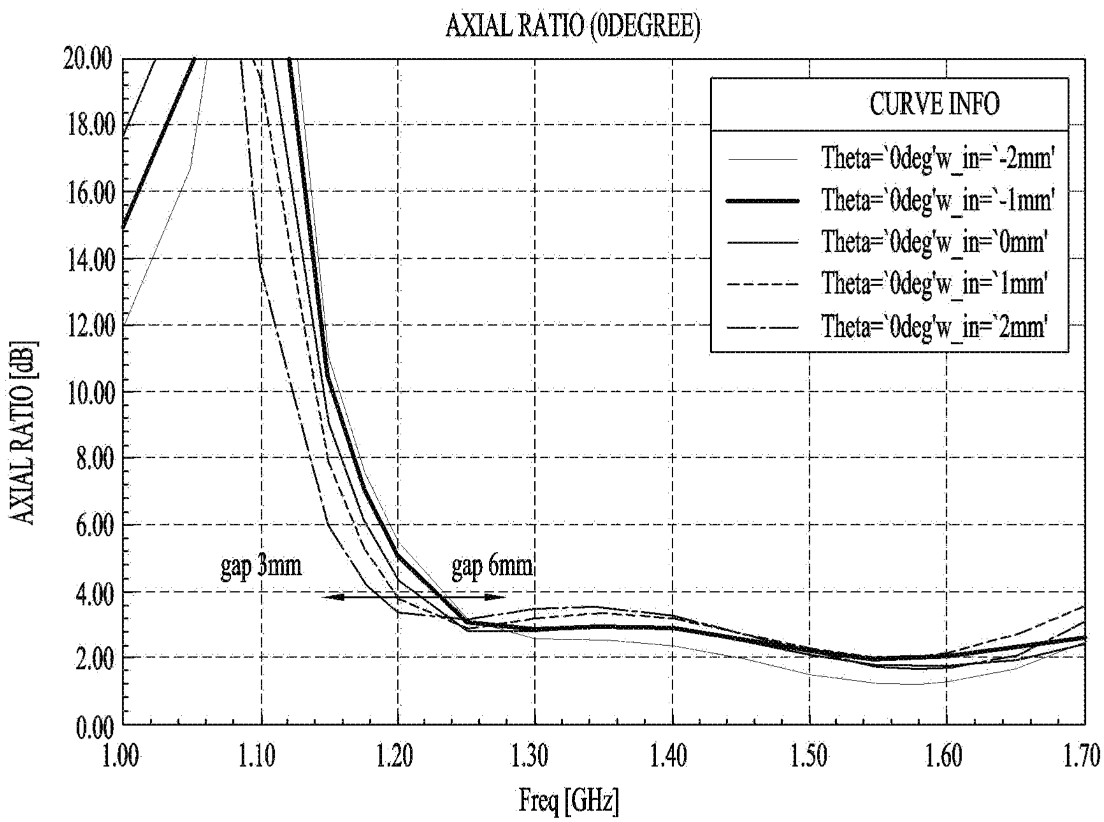
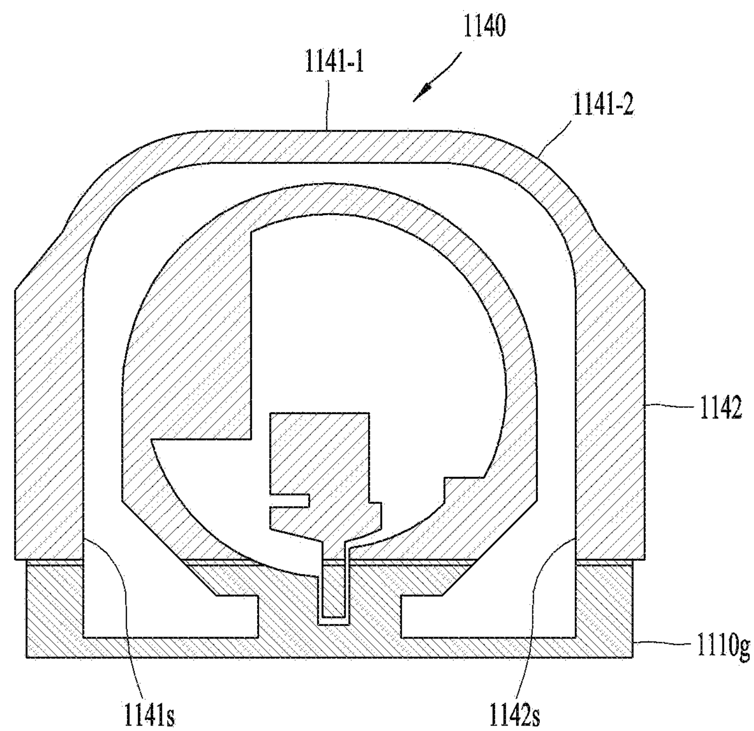

AXIAL RATIO (0DEGREE)
CURVE INFO
Theta='0deg'w_in='-2mm'
Theta='0deg'w_in='-1mm'
Theta='0deg'w_in='0mm'
Theta='0deg'w_in='1mm'
Theta='0deg'w_in='2mm'
AXIAL RATIO [dB]
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
gap 3mm
gap 6mm
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
Freq [GHz]

FIG. 20A

(a)


1140
1141-1
1141-2
1142
1110g
1141s
1142s

(b)

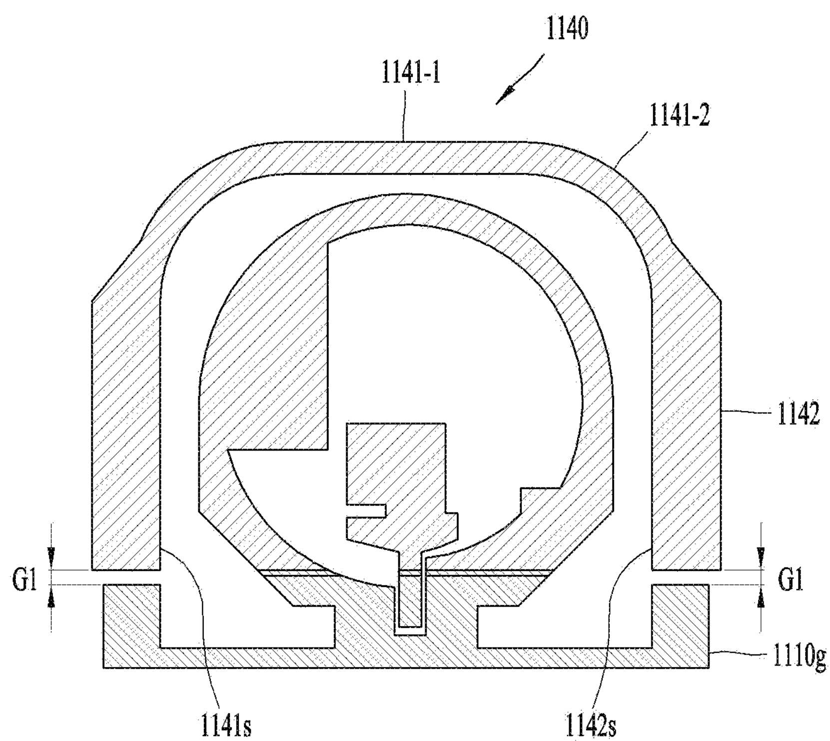
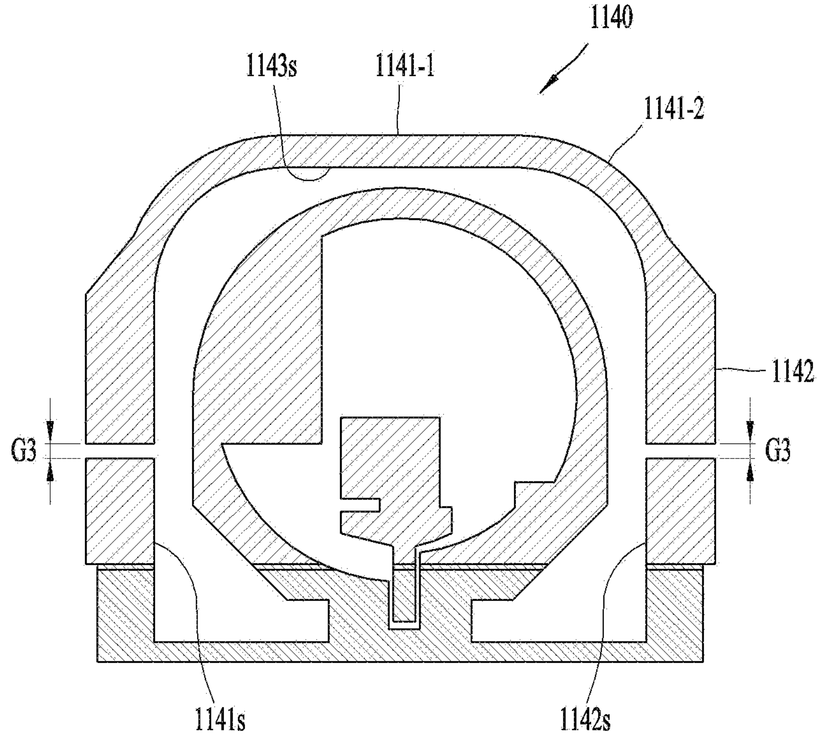

1140
1141-1
1141-2
1142
G1
G1
1110g
1141s
1142s

FIG. 20B

(a)


1140
1143s
1141-1
1141-2
1142
G3
G3
1141s
1142s

(b)

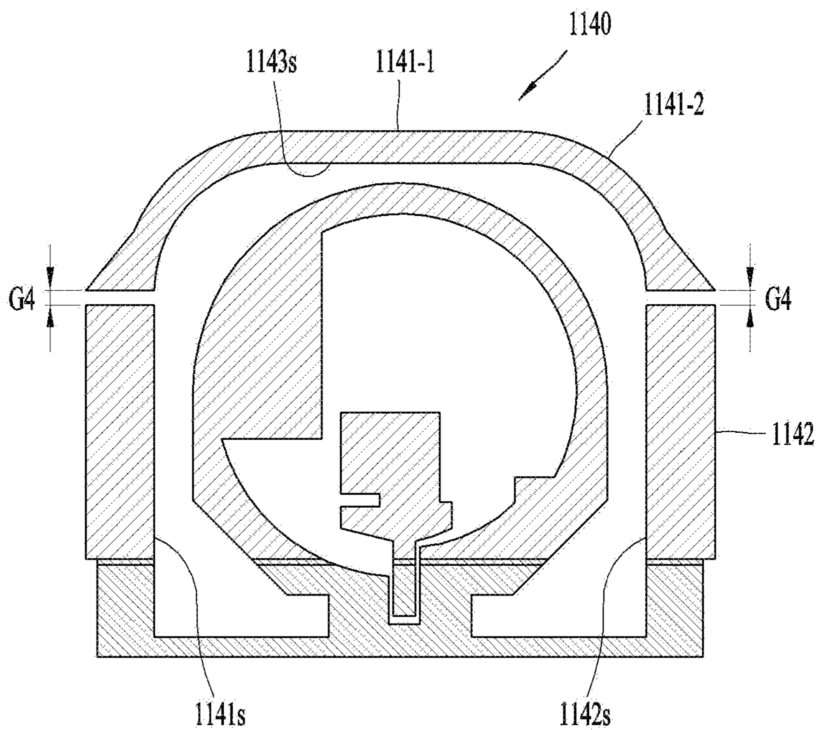
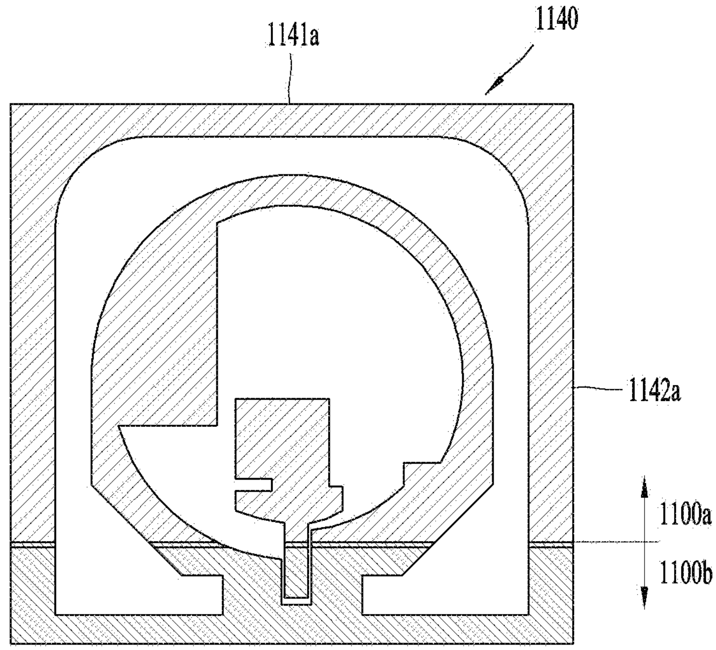

1140
1143s
1141-1
1141-2
G4
G4
1142
1141s
1142s

FIG. 21A

(a)



(b)

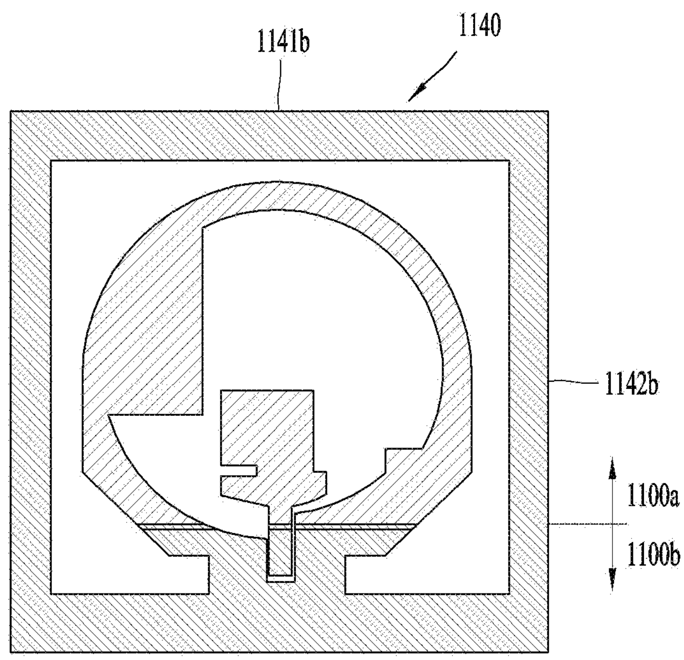


FIG. 21B

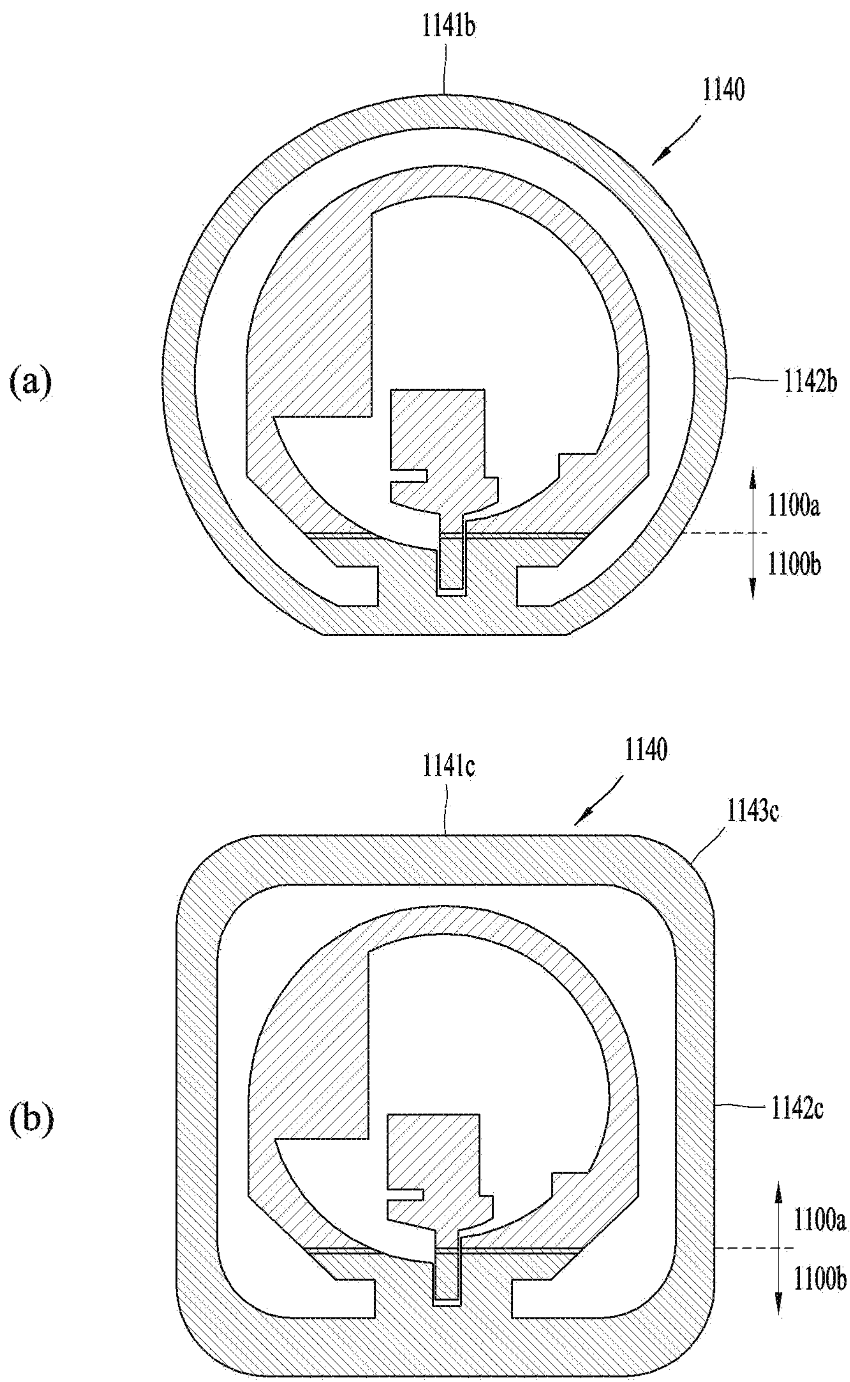
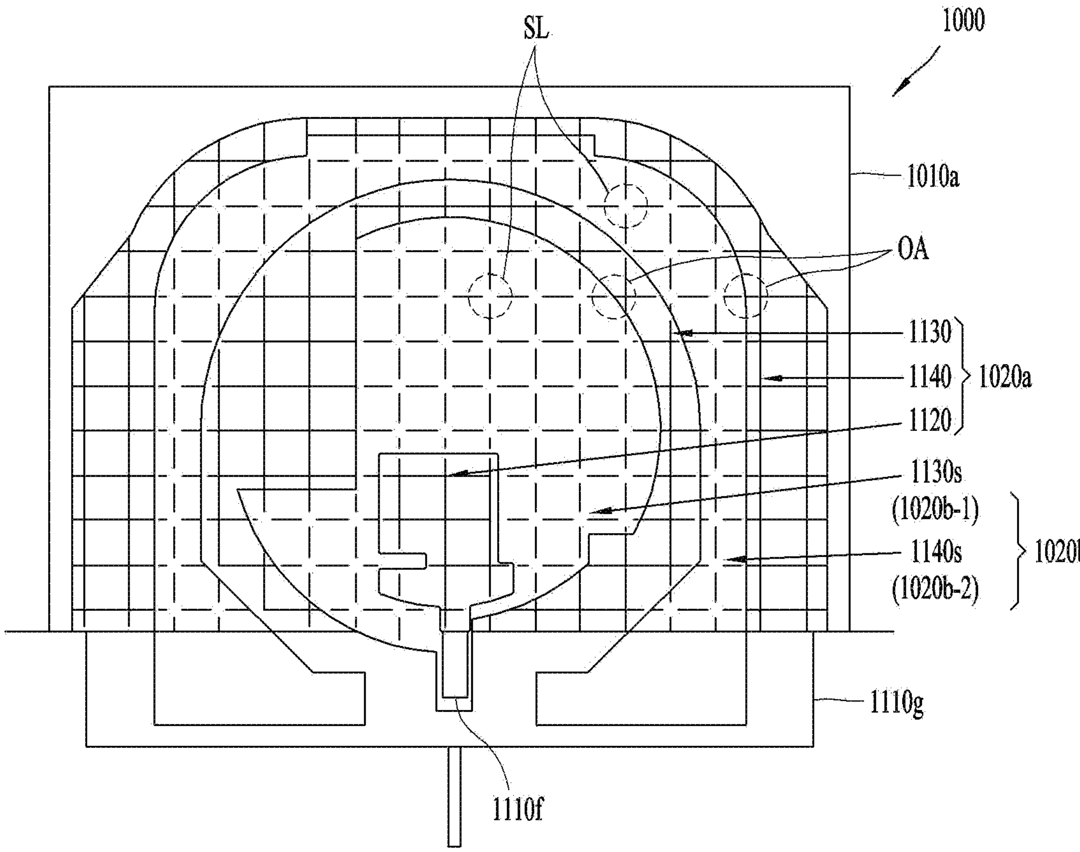

1141b
1140
(a)
1142b
1100a
1100b
1141c
1140
1143c
(b)
1142c
1100a
1100b

FIG. 22



SL
1000
1010a
OA
1130
1140
1020a
1120
1130s
(1020b-1)
1140s
(1020b-2)
1020b
1110g
1110f

FIG. 23A

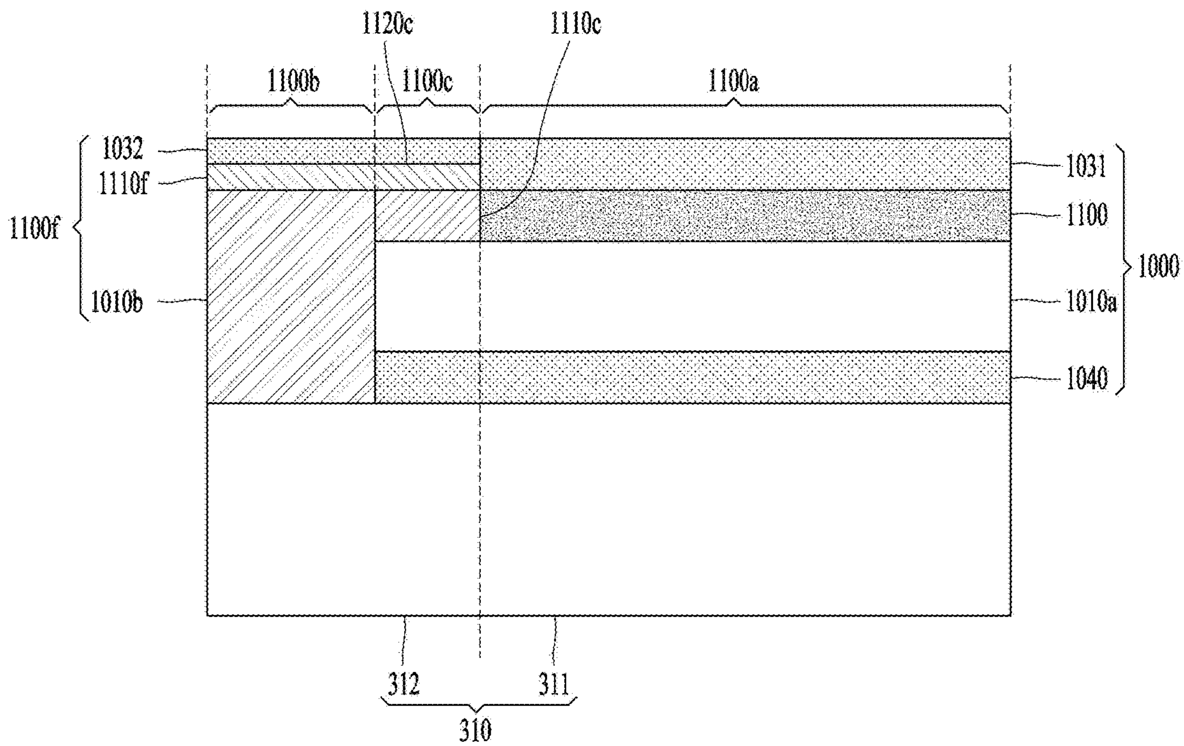
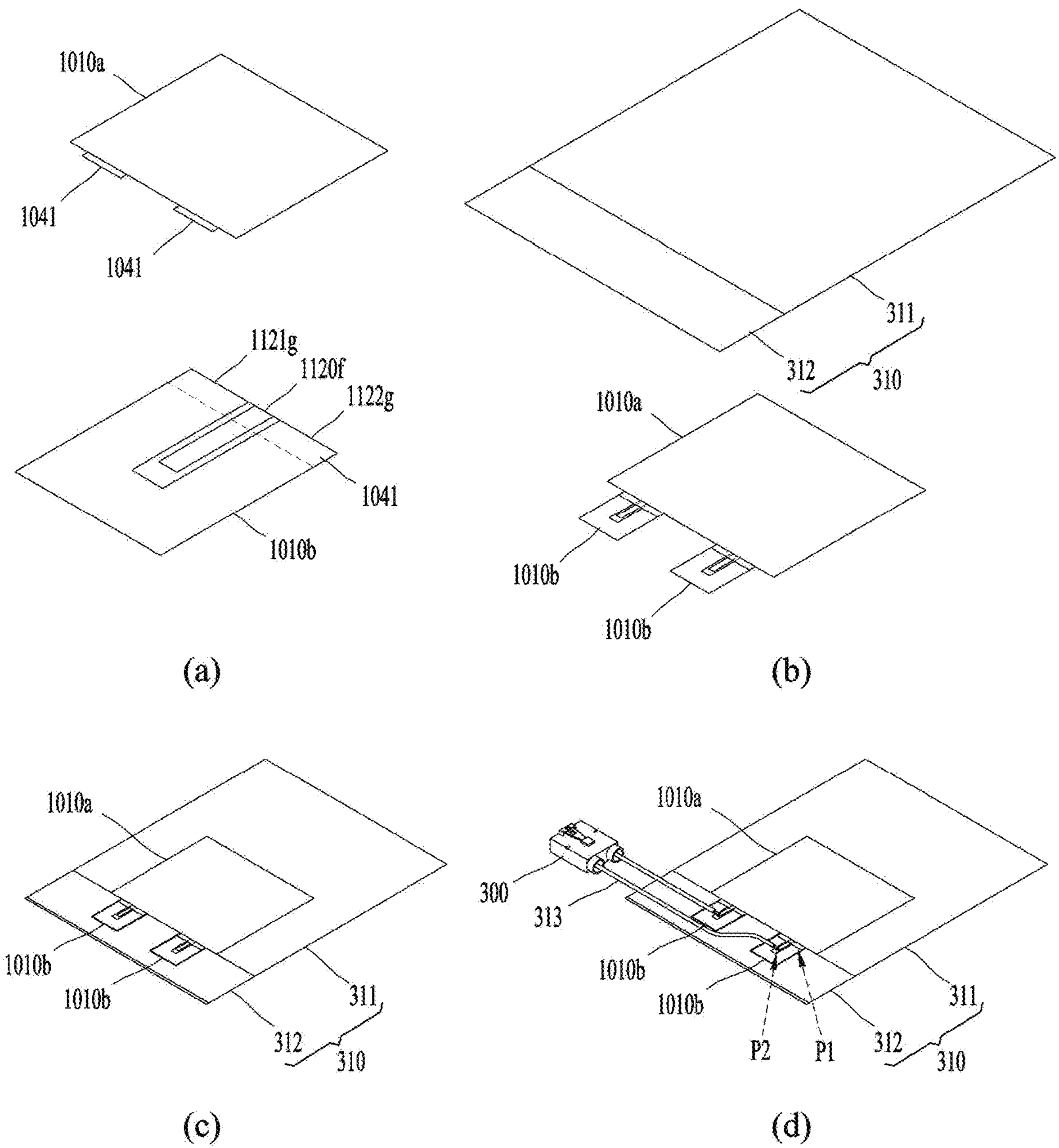

1120c
1110c
1100b
1100c
1100a
1032
1110f
1100f
1010b
1031
1100
1000
1010a
1040
312
311
310

FIG. 23B


1010a
1041
1041
1121g
1120f
1122g
1041
1010b
311
312
310
1010a
1010b
1010b
1010a
1010b
1010b
311
312
310
1010a
300
313
1010b
1010b
P2
P1
312
311
310

(a) (b) (c) (d)

FIG. 23C

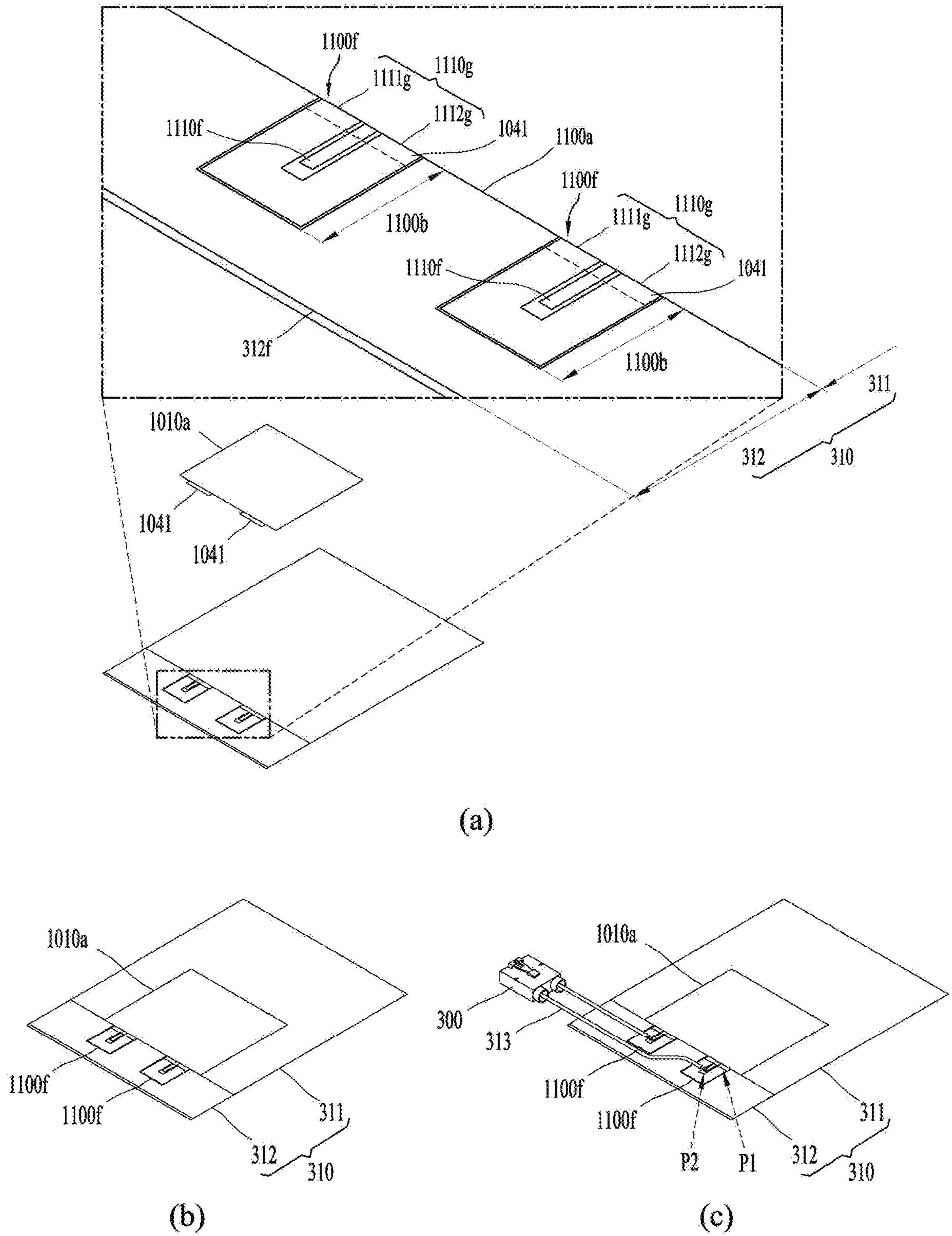
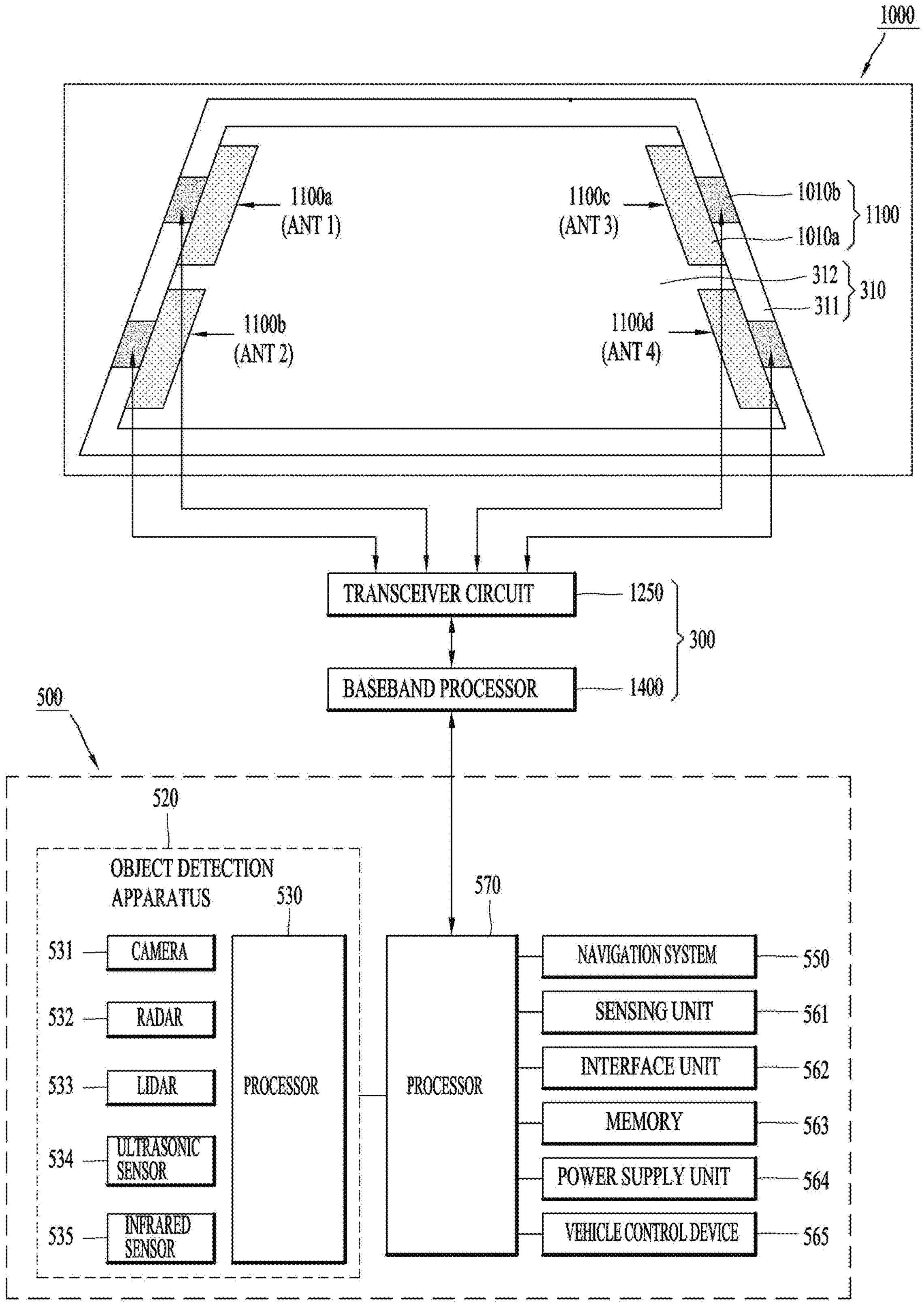

1100f
1110g
1111g
1112g
1110f
1041
1100a
1100b
312f
311
312
310
1010a
1041
1041
(a)
1010a
1100f
1100f
311
312
310
(b)
1010a
300
313
1100f
1100f
P2
P1
311
312
310
(c)

FIG. 24


1000
1100a
(ANT 1)
1100b
(ANT 2)
1100c
(ANT 3)
1100d
(ANT 4)
1010b
1010a
1100
312
311
310
TRANSCEIVER CIRCUIT
1250
BASEBAND PROCESSOR
1400
300
500
520
OBJECT DETECTION APPARATUS
530
531
CAMERA
532
RADAR
533
LIDAR
534
ULTRASONIC SENSOR
535
INFRARED SENSOR
PROCESSOR
570
PROCESSOR
NAVIGATION SYSTEM
550
SENSING UNIT
561
INTERFACE UNIT
562
MEMORY
563
POWER SUPPLY UNIT
564
VEHICLE CONTROL DEVICE
565

ANTENNA MODULE DISPOSED IN VEHICLE

CROSS-REFERENCE TO RELATED APPLICATION

This application is the National Stage filing under 35 U.S.C. 371 of International Application No. PCT/KR2022/011875, filed on Aug. 9, 2022, the contents of which are hereby incorporated by reference herein its entirety.

TECHNICAL FIELD

The present specification relates to a transparent antenna disposed in a vehicle. In particular, certain embodiments pertain to an antenna assembly implemented with a transparent material so that the antenna area is not identifiable on the vehicle glass.

BACKGROUND ART

A vehicle can perform wireless communication services with other vehicles, surrounding objects, infrastructure, or base stations. In this context, various communication services can be provided through wireless communication systems applying LTE or 5G communication technologies. Meanwhile, some of the LTE frequency bands may be allocated to provide 5G communication services. Additionally, a GNSS (Global Navigation Satellite System) antenna configured to perform satellite communication can be installed in the vehicle.

However, the vehicle body and roof are often formed of metal materials, which can block radio waves. Accordingly, a separate antenna structure may be disposed on the upper part of the vehicle body or roof. Alternatively, when the antenna structure is placed beneath the vehicle body or roof, the corresponding parts of the vehicle body or roof where the antenna is located can be made of non-metallic materials.

From a design perspective, it is often necessary for the vehicle body or roof to be integrally formed. In such cases, the exterior of the vehicle body or roof may be made of metal materials, which can significantly reduce antenna efficiency due to interference from the vehicle body or roof.

In this regard, to increase communication capacity without altering the vehicle's exterior design, a transparent antenna can be placed on the glass corresponding to the vehicle's windows. However, due to the electrical loss of transparent material antennas, issues such as degradation of antenna radiation efficiency and impedance bandwidth characteristics may arise. Furthermore, when a transparent antenna is placed on the vehicle's glass panel, antenna radiation efficiency can deteriorate at frequencies above 2 GHz due to losses on the glass panel.

To perform wireless communication in a vehicle, it is necessary to form an antenna radiation pattern in a low elevation area within a predetermined angle range based on the vehicle's horizontal plane. On the other hand, a configured GNSS antenna needs to form a radiation pattern toward the vehicle's ceiling to perform satellite communication. Therefore, unlike antennas configured for wireless communication, the radiation pattern of a GNSS antenna should be formed in the vertical direction.

DISCLOSURE OF INVENTION

Technical Problem

The present specification aims to solve the aforementioned and other problems. Another objective is to provide a vehicle GNSS antenna that can be placed on the vehicle glass.

Another objective of this specification is to form the radiation pattern of a vehicle GNSS antenna toward the vehicle's ceiling.

Another objective of this specification is to enable a GNSS antenna placed in a specific area of the vehicle glass to operate in dual bands.

Another objective of this specification is to improve the circular polarization characteristics of a GNSS antenna operating in dual bands and placed in a specific area of the vehicle glass.

Another objective of this specification is to implement a GNSS antenna that operates in dual-band circular polarization on a single layer.

Another objective of this specification is to minimize changes in antenna characteristics caused by vehicle glass when attaching a GNSS antenna implemented as a transparent antenna to the vehicle glass.

Another objective of this specification is to enhance the invisibility of a GNSS antenna implemented as a transparent antenna when attached to vehicle glass so that the antenna pattern is not distinguishable by the naked eye.

Another objective of this specification is to propose a GNSS antenna technology that operates in dual-band circular polarization with a single-layer structure, reducing the influence of vehicle glass using a transparent material.

Solution to Problem

According to one aspect of the present specification for achieving the above or other objectives, a vehicle includes: vehicle glass including transparent and opaque regions; a transparent dielectric substrate disposed in the transparent region of the vehicle glass; a first region on one surface of the transparent dielectric substrate including an antenna; and a second region including a feed pattern and a ground conductive pattern electrically connected to the antenna. The antenna may include: a first slot formed between a signal pattern and a first ground pattern and configured to radiate a first signal having circular polarization in a first frequency band; and a second slot formed between the first ground pattern and a second ground pattern and configured to radiate a second signal having circular polarization in a second frequency band lower than the first frequency band.

In an embodiment, the antenna may further include: a signal pattern connected to the feed pattern of the second region; a first ground pattern connected to the ground conductive pattern of the second region; and a second ground pattern connected to or spaced apart from the ground conductive pattern of the second region and configured to surround the first ground pattern. The length of the second slot formed inside the second ground pattern may be configured within a range of ¾ to one wavelength corresponding to the operating frequency in the second frequency band. The second ground pattern may be formed to surround the first ground pattern. The second ground pattern may prevent the first signal radiated by the first slot from leaking into the vehicle glass outside the second ground pattern, and the radiation patterns of the first and second signals may be formed toward the vehicle's ceiling.

In an embodiment, at least a portion of the outer boundary of the first ground pattern may be formed in a circular shape. The diameter of the outer boundary of the first ground pattern may be configured within a range of ¼ to ½ wavelength corresponding to the operating frequency in the first frequency band.

In an embodiment, a first portion of the inner boundary of the first ground pattern may be formed in a circular shape.

A second portion of the inner boundary of the first ground pattern may be formed with straight lines in one axial direction and another axial direction. The first ground pattern may have a first width in one axial direction and a second width narrower than the first width.

In an embodiment, the width in one axial direction of the second ground pattern may be formed within a range of 11 mm to 14 mm. Accordingly, the axial ratio of the first and second signals having circular polarization can be maintained below a threshold value.

In an embodiment, the ground conductive pattern may include: a first portion connected to the first ground pattern and having upper and lower regions; a second portion connected to the first ground pattern and having upper and lower regions, with the feed pattern formed between the first and second portions of the ground conductive pattern; a third portion connected to the lower region of the first portion of the ground conductive pattern and configured to be spaced apart from the upper region of the first portion; and a fourth portion connected to the lower region of the second portion of the ground conductive pattern and configured to be spaced apart from the upper region of the second portion.

In an embodiment, the widths of the third and fourth portions of the ground conductive pattern, which are spaced apart from the upper regions of the first and second portions, may be formed within a range of 2 mm to 6 mm. Accordingly, the axial ratio of the first and second signals having circular polarization can be maintained below a threshold value.

In an embodiment, the ground conductive pattern may further include: a fifth portion with one end connected to the third portion of the ground conductive pattern and the other end connected to the second ground pattern; and a sixth portion with one end connected to the fourth portion of the ground conductive pattern and the other end connected to the second ground pattern.

In an embodiment, the ground conductive pattern may further include: a fifth portion with one end connected to the third portion of the ground conductive pattern and the other end spaced apart from the second ground pattern by a first gap; and a sixth portion with one end connected to the fourth portion of the ground conductive pattern and the other end spaced apart from the second ground pattern by a first gap. The first gap may be formed as 1.5 mm or less to maintain the axial ratio of the second signal having circular polarization in the second frequency band below a threshold value.

In an embodiment, a second gap between the inner boundary of the second ground pattern and the outer boundary of the first ground pattern may be formed within a range of 3 mm to 6 mm. The second ground pattern with the second gap can prevent the first signal radiated by the first slot from leaking into the vehicle glass outside the second ground pattern and maintain the axial ratio of the second signal having circular polarization in the second frequency band below a threshold value.

In an embodiment, the outer boundary of the upper region of the first ground pattern may be configured in a circular shape. The inner and outer boundaries of a portion of the upper and side regions of the second ground pattern may be configured as straight lines.

In an embodiment, the outer boundary of the upper region of the first ground pattern may be configured in a circular shape. The outer boundary of the upper and side regions of the second ground pattern may be configured as straight lines or circular shapes in the first region.

In an embodiment, the second ground pattern may include: a first sub-pattern connected to or spaced apart from the first ground conductive pattern; a second sub-pattern connected to or spaced apart from the first ground conductive pattern; and a third sub-pattern configured to form the upper region of the second ground pattern and spaced apart from the ends of the first and second sub-patterns by a predetermined gap.

In an embodiment, the signal pattern, first ground pattern, and second ground pattern may be formed in a metal mesh shape with multiple opening areas at their inner and outer boundaries and interconnected internal regions on the transparent dielectric substrate. The signal pattern, first ground pattern, and second ground pattern may be formed in a Coplanar Waveguide (CPW) structure on the transparent dielectric substrate.

In an embodiment, the antenna assembly formed in the first and second regions may include multiple dummy mesh lattice patterns disposed on the outer portions of the conductive patterns in metal mesh radiating areas on the transparent dielectric substrate. The multiple dummy mesh lattice patterns may be formed without being connected to the feed pattern and ground conductive pattern and may be separated from each other.

In an embodiment, the dummy mesh lattice patterns may include: first dummy mesh lattice patterns disposed in the first slot, which is the outer portion of the signal pattern—the first dummy mesh lattice patterns are mutually separated in one axial and another axial direction and separated from the boundaries of the signal pattern and first ground pattern; and second dummy mesh lattice patterns disposed in the second slot, which is the outer portion of the first ground pattern—the second dummy mesh lattice patterns are mutually separated in one axial and another axial direction and separated from the boundaries of the first and second ground patterns.

According to another aspect of the present specification, a vehicle comprises: a glass panel including transparent and opaque regions; and an antenna assembly disposed on the glass panel. The antenna assembly includes: a first transparent dielectric substrate disposed in the transparent region of the glass panel; an antenna pattern disposed in a first region on one surface of the first transparent dielectric substrate—the first region on one surface of the first transparent dielectric substrate is disposed in the transparent region of the glass panel; a connection pattern connected to the antenna pattern and disposed in a second region on one surface of the first transparent dielectric substrate—the second region on one surface of the first transparent dielectric substrate is disposed in the opaque region of the glass panel; a second dielectric substrate disposed in the opaque region of the glass panel; and a ground conductive pattern and feed pattern disposed in the second region on one surface of the second dielectric substrate.

In an embodiment, the antenna pattern may include: a signal pattern connected to the feed pattern of the second region; a first ground pattern connected to the ground conductive pattern of the second region; a first slot formed between the signal pattern and the first ground pattern and configured to radiate a first signal having circular polarization in a first frequency band; a second ground pattern connected to the ground conductive pattern of the second region and configured to surround the first ground pattern; and a second slot formed between the first and second ground patterns and configured to radiate a second signal having circular polarization in a second frequency band lower than the first frequency band.

In an embodiment, the length of the second slot formed inside the second ground pattern may be configured within a range of ¾ to one wavelength corresponding to the operating frequency in the second frequency band. The second ground pattern may be formed to surround the first ground pattern. The second ground pattern may prevent the first signal radiated by the first slot from leaking into the vehicle glass outside the second ground pattern, and the radiation patterns of the first and second signals may be formed toward the vehicle's ceiling.

In an embodiment, at least a portion of the outer boundary of the first ground pattern may be formed in a circular shape. The diameter of the outer boundary of the first ground pattern may be configured within a range of ¼ to ½ wavelength corresponding to the operating frequency in the first frequency band. A first portion of the inner boundary of the first ground pattern may be formed in a circular shape, and a second portion of the inner boundary may be formed with straight lines in one axial and another axial direction. The first ground pattern may have a first width in one axial direction and a second width narrower than the first width.

In an embodiment, the ground conductive pattern may include: a first portion connected to the first ground pattern and having upper and lower regions; a second portion connected to the second ground pattern and having upper and lower regions, with the feed pattern formed between the first and second portions of the ground conductive pattern; a third portion connected to the lower region of the first portion of the ground conductive pattern and configured to be spaced apart from the upper region of the first portion; and a fourth portion connected to the lower region of the second portion of the ground conductive pattern and configured to be spaced apart from the upper region of the second portion. The widths of the third and fourth portions of the conductive pattern, which are spaced apart from the upper regions of the first and second portions in the second region, may be formed within a range of 2 mm to 6 mm.

In an embodiment, the ground conductive pattern may further include: a fifth portion with one end connected to the third portion of the ground conductive pattern and the other end connected to or spaced apart from the second ground pattern by a first gap; and a sixth portion with one end connected to the fourth portion of the ground conductive pattern and the other end connected to or spaced apart from the second ground pattern by a first gap. The first gap may be formed within a range of 1.5 mm to 4.5 mm.

In an embodiment, the width in one axial direction of the second conductive pattern may be formed within a range of 11 mm to 14 mm. A second gap between the inner boundary of the second ground pattern and the outer boundary of the first ground pattern may be formed within a range of 3 mm to 6 mm.

Advantageous Effects of Invention

The technical effects of the transparent antenna disposed in a vehicle as described above are as follows.

According to the present specification, by forming the GNSS antenna disposed in a specific area of the vehicle glass with a dual-slot structure, the GNSS antenna can operate in dual bands.

According to the present specification, the circular polarization characteristics in dual bands of the GNSS antenna disposed in a specific area of the vehicle glass can be improved through optimization of the dual-slot structure and conductive patterns.

According to the present specification, the conductive patterns and ground conductive patterns acting as radiators for the GNSS antenna operating in dual-band circular polarization can be implemented on a single layer.

According to the present specification, when attaching a GNSS antenna implemented as a transparent antenna to the vehicle glass, antenna characteristic changes due to the vehicle glass can be minimized by placing transparent and opaque substrates in the transparent and opaque regions of the vehicle glass, respectively.

According to the present specification, when attaching a GNSS antenna implemented as a transparent antenna to the vehicle glass, invisibility can be enhanced so that the antenna pattern is not distinguishable by the naked eye through the use of dummy metal mesh lattice structures.

According to the present specification, a GNSS antenna structure that operates in dual-band circular polarization with a single-layer structure can be provided, reducing the influence of vehicle glass using transparent materials and enabling satellite communication.

Additional scope of applicability of the present specification will become apparent from the detailed description provided below. However, it should be understood that various modifications and changes can be made by those skilled in the art within the spirit and scope of the present specification, and thus, specific embodiments such as the detailed description and preferred embodiments of this specification are given by way of example only.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** illustrates vehicle glass on which an antenna structure according to an embodiment of the present specification can be disposed.

FIG. **2**A shows a front view of a vehicle where antenna assemblies are disposed in different regions of the front glass of the vehicle shown in FIG. **1**.

FIG. **2**B illustrates an internal front perspective view of a vehicle where antenna assemblies are disposed in different regions of the front glass of the vehicle shown in FIG. **1**.

FIG. **2**C depicts a side perspective view of a vehicle where an antenna assembly is disposed on the upper glass of the vehicle shown in FIG. **1**.

FIG. **3** represents different types of V2X applications.

FIG. **4** is a block diagram referred to for explaining a vehicle and an antenna system mounted on the vehicle according to embodiments of the present specification.

FIGS. **5**A to **5**C illustrate configurations where an antenna assembly according to the present specification is disposed on vehicle glass.

FIG. **6**A shows various embodiments of frit patterns according to the present specification. FIGS. **6**B and **6**C illustrate transparent antenna patterns and structures where transparent antenna patterns are disposed on vehicle glass according to various embodiments.

FIG. **7**A presents front and cross-sectional views of a transparent antenna assembly according to the present specification. FIG. **7**B illustrates lattice structures of metal mesh radiating areas and dummy metal mesh areas according to various embodiments.

FIG. **8**A depicts the layered structure of an antenna module and a feed module. FIG. **8**B shows an opaque substrate including a layered structure where the antenna module and feed structure are combined and the coupling region.

FIG. **9**A illustrates the coupling structure of a transparent antenna disposed in the transparent and frit regions of vehicle glass.

FIG. **9**B is an enlarged front view of the area where the glass with the transparent antenna formed as in FIG. **9**A is coupled with the vehicle body structure. FIG. **9**C shows cross-sectional views of the coupling structure between the vehicle glass and body structure of FIG. **9**B viewed from different positions.

FIG. **10** illustrates the laminated structure of an antenna assembly according to various embodiments and the attachment area between vehicle glass and the vehicle frame.

FIG. **11**A shows multiple frequency bands related to a vehicle GNSS antenna. FIG. **11**B depicts polarization characteristics related to a vehicle GNSS antenna.

FIGS. **12**A and **12**B illustrate placement structures of vehicle GNSS antennas that can be formed at different locations on vehicle glass according to various embodiments.

FIGS. **13**A and **13**B illustrate the structure of a vehicle GNSS antenna according to the present specification.

FIG. **14**A shows an embodiment in which the inner area of the second ground pattern of the antenna assembly in FIG. **13**A is partially modified.

FIG. **14**B illustrates the electric field distribution in the first and second frequency bands in the antenna assembly of FIG. **14**A.

FIGS. **15**A and **15**B compare the radiation patterns of the antenna in the first frequency band, with and without the second ground pattern.

FIG. **15**C shows the radiation pattern of the antenna in the second frequency band with the second ground pattern formed.

FIG. **16**A illustrates the axial ratio depending on the presence or absence of the second ground pattern across different frequencies.

FIGS. **16**B and **16**C depict the gain characteristics at different angles in the first and second frequency bands, depending on whether the second ground pattern is present or not.

FIGS. **17**A and **17**B compare the antenna gain characteristics in the first and second frequency bands depending on the presence or absence of the second ground pattern.

FIGS. **18**A to **18**C show the axial ratio, which represents the circular polarization performance, depending on the gap distance between the vertical/horizontal width of the second ground pattern and the first conductive pattern in the antenna structure of FIG. **13**A.

FIGS. **19**A to **19**C illustrate the axial ratio, representing circular polarization performance, depending on the vertical width of the second ground pattern, the gap distance between the first conductive pattern, and the gap distance between the ground conductive patterns in the antenna structure of FIG. **13**B.

FIGS. **20**A and **20**B show embodiments where at least part of the second ground pattern is segmented.

FIGS. **21**A and **21**B illustrate configurations where the second ground pattern is transformed into various shapes, such as rectangular, circular, or curved, according to the embodiments.

FIG. **22** shows the structure of the antenna assembly in FIGS. **13**A and **13**B, implemented with a metal mesh shape and dummy mesh lattice patterns.

FIG. **23**A shows the laminated structure of the antenna assembly in FIGS. **13**A and **13**B.

FIG. **23**B depicts the process flow for manufacturing the antenna assembly in FIG. **13**A or **13**B, where it is bonded to a glass panel.

FIG. **23**C illustrates the process flow of the feed structure of the antenna assembly in FIG. **13**A or **13**B, placed in the opaque region of the glass panel.

FIG. **24** shows multiple antenna modules placed in different locations of a vehicle and combined with other vehicle components according to the present specification.

MODE FOR THE INVENTION

The following describes the embodiments disclosed in this specification in detail with reference to the accompanying drawings. In the following description, regardless of the reference numbers used, identical or similar components will be assigned the same reference numbers, and redundant descriptions will be omitted. The suffixes "module" and "part" used for components in the description are given only for ease of writing the specification and may be used interchangeably without indicating distinct meanings or functions. Additionally, specific explanations of related well-known technologies may be omitted if they obscure the essence of the embodiments disclosed in this specification. Moreover, the attached drawings are provided only to aid in the understanding of the embodiments disclosed in this specification and should not be construed as limiting the technical ideas disclosed herein. All modifications, equivalents, and substitutions within the spirit and scope of the present invention should be considered as included.

Terms including ordinal numbers such as first and second may be used to describe various components, but these components are not limited by these terms. These terms are used solely to distinguish one component from another.

When a component is referred to as being "connected" or "coupled" to another component, it can be directly connected or coupled to the other component, or there may be intervening components. In contrast, when a component is referred to as being "directly connected" or "directly coupled" to another component, there are no intervening components.

Unless otherwise specified, the singular expressions used herein include plural meanings.

In the present application, terms such as "comprises" or "has" are intended to specify the existence of features, numbers, steps, operations, components, parts, or combinations thereof, but do not preclude the possibility of the existence or addition of one or more other features, numbers, steps, operations, components, parts, or combinations thereof.

The antenna system described in this specification can be mounted on a vehicle. The configuration and operation according to the embodiments disclosed in this specification may also apply to a communication system mounted on a vehicle, that is, the antenna system. In this regard, the antenna system mounted on the vehicle may include multiple antennas and transceiver circuits and processors controlling these antennas.

The following describes an antenna assembly (antenna module) that can be placed on the windows of a vehicle according to the present specification, as well as a vehicle antenna system including the antenna assembly. In this regard, the antenna assembly refers to a structure in which conductive patterns are combined on a dielectric substrate, and it may also be referred to as an antenna module.

FIG. **1** illustrates the glass of a vehicle where the antenna structure according to the embodiment of the present specification can be disposed. Referring to FIG. **1**, the vehicle **500** can include a front glass **310**, door glass **320**, rear glass **330**, and quarter glass **340**. In addition, the vehicle **500** may also be configured to include upper glass **350** formed on the roof area of the vehicle.

Accordingly, the glass constituting the windows of the vehicle **500** may include front glass **310** located at the front of the vehicle, door glass **320** located in the door area of the vehicle, and rear glass **330** located in the rear area of the vehicle. In addition, the glass constituting the windows of the vehicle **500** may also include quarter glass **340** located in some areas of the vehicle's door. Furthermore, the glass constituting the windows of the vehicle **500** may also include upper glass **350** located in the upper area of the vehicle, separated from the rear glass **330**. Accordingly, the glass constituting each window of the vehicle **500** may be referred to as a window.

The front glass **310** prevents wind from entering the vehicle from the front direction, so it may be referred to as a front windshield. The front glass **310** may be formed with a two-layer laminated structure with a thickness of about 5.0 to 5.5 mm. The front glass **310** may be formed with a laminated structure of glass/anti-scattering film/glass.

The door glass **320** may be formed with a two-layer laminated structure or a single-layer tempered glass. The rear glass **330** may be formed with a two-layer laminated structure or a single-layer tempered glass with a thickness of about 3.5 to 5.5 mm. There needs to be a separation distance between the defogger and the AM/FM antenna and the transparent antenna on the rear glass **330**. The quarter glass **340** may be formed with single-layer tempered glass with a thickness of about 3.5 to 4.0 mm, though it is not limited to this.

The size of the quarter glass **340** may vary depending on the type of vehicle, and the size of the quarter glass **340** may be smaller than that of the front glass **310** and rear glass **330**.

The following describes the structure where the antenna assembly according to the present specification is placed in different regions of the front glass of the vehicle. The antenna assembly attached to vehicle glass may be implemented as a transparent antenna. In this regard, FIG. **2**A shows the front view of a vehicle where the antenna assembly is placed in different regions of the front glass of the vehicle shown in FIG. **1**. FIG. **2**B shows the internal front perspective view of a vehicle where the antenna assembly is placed in different regions of the front glass of the vehicle shown in FIG. **1**. FIG. **2***c* shows the side perspective view of a vehicle where the antenna assembly is placed on the upper glass of the vehicle shown in FIG. **1**.

Referring to FIG. **2**A, the front view of vehicle **500** shows the configuration where the vehicle transparent antenna according to the present specification may be placed. The pane assembly **22** may include an antenna in the upper region **310***a*. The pane assembly **22** may include an antenna in the upper region **310***a*, lower region **310***b*, and/or side region **310***c*. Additionally, the pane assembly **22** may include a translucent pane glass **26** formed from a dielectric substrate. The antennas in the upper region **310***a*, lower region **310***b*, and/or side region **310***c* are configured to support one or more communication systems.

The antenna module **1100** may be implemented in the upper region **310***a*, lower region **310***b*, or side region **310***c* of the front glass **310**. When the antenna module **1100** is placed in the lower region **310***b* of the front glass **310**, the antenna module **1100** may extend to the body **49** of the lower region of the translucent pane glass **26**. The body **49** of the lower region of the translucent pane glass **26** may be implemented with lower transparency than other parts. Part of the feed section or other interface lines may be implemented in the body **49** of the lower region of the translucent pane glass **26**. The connector assembly **74** may be implemented in the body **49** of the lower region of the translucent pane glass **26**. The body **49** of the lower region may form part of the metal body of the vehicle.

Referring to FIG. **2**B, the antenna assembly **1000** may be configured to include a telematics control unit (TCU) **300** and the antenna module **1100**. The antenna module **1100** may be placed in different regions of the vehicle glass.

Referring to FIGS. **2**A and **2**B, the antenna assembly may be placed in the upper region **310***a*, lower region **310***b*, and/or side region **310***c* of the vehicle glass. Referring to FIGS. **2**A through **2**C, the antenna assembly may be placed in the front glass **310**, rear glass **330**, quarter glass **340**, and upper glass **350** of the vehicle.

Referring to FIGS. **2**A through **2**C, the antenna in the upper region **310***a* of the front glass **310** of the vehicle may be configured to operate in the low band LB, mid band MB, and high band HB of the 4G/5G communication system, as well as the 5G Sub6 band. The antennas in the lower region **310***b* and/or side region **310***c* may also be configured to operate in the LB, MB, HB, and 5G Sub6 bands of the 4G/5G communication system. The antenna structure **1100***b* on the rear glass **330** of the vehicle may also be configured to operate in the LB, MB, HB, and 5G Sub6 bands of the 4G/5G communication system. The antenna structure **1100***c* on the upper glass **350** of the vehicle may also be configured to operate in the LB, MB, HB, and 5G Sub6 bands of the 4G/5G communication system. The antenna structure **1100***d* on the quarter glass **350** of the vehicle may also be configured to operate in the LB, MB, HB, and 5G Sub6 bands of the 4G/5G communication system.

At least part of the outer area of the front glass **310** of the vehicle may be formed with translucent pane glass **26**. The translucent pane glass **26** may include a first part where part of the feed section and the antenna are formed, and a second part where part of the feed section and a dummy structure are formed. Additionally, the translucent pane glass **26** may further include a dummy area where no conductive patterns are formed. For example, the transparent area of the pane assembly **22** may be formed transparently to secure light transmission and a field of view.

Although it is illustrated that conductive patterns can be formed in some areas of the front glass **310**, they can be extended to the side glass **320**, rear glass **330**, or any glass structure in FIG. **1**. In the vehicle **500**, passengers or the driver can see the road and surrounding environment through the pane assembly **22**. Furthermore, passengers or the driver can view the road and surrounding environment without interference from the antenna in the upper region **310***a*, lower region **310***b*, and/or side region **310***c*.

The vehicle **500** can be configured to communicate not only with nearby vehicles but also with pedestrians, surrounding infrastructure, and/or servers. In this regard, FIG. **3** shows different types of V2X applications. Referring to FIG. **3**, V2X (Vehicle-to-Everything) communication includes V2V (Vehicle-to-Vehicle), which refers to communication between vehicles; V2I (Vehicle-to-Infrastructure), which refers to communication between a vehicle and eNB or RSU (Road Side Unit); V2P (Vehicle-to-Pedestrian), which refers to communication between a vehicle and terminals carried by individuals such as pedestrians, cyclists, vehicle drivers, or passengers; and V2N (Vehicle-to-Network), which refers to communication between a vehicle and networks or other entities.

Meanwhile, FIG. **4** is a block diagram used to explain the vehicle and the antenna system mounted on the vehicle according to the embodiments of the present specification.

The vehicle **500** can be configured to include a communication device **400** and a processor **570**. The communication device **400** may correspond to the telematics control unit of the vehicle **500**.

The communication device **400** is a device for performing communication with external devices. Here, external devices may be other vehicles, mobile terminals, or servers. The communication device **400** may include one or more of a transmission antenna, a reception antenna, an RF (Radio Frequency) circuit, and RF components capable of implementing various communication protocols to perform communication. The communication device **400** may include a short-range communication section **410**, a location information section **420**, a V2X communication section **430**, an optical communication section **440**, a 4G wireless communication module **450**, and a 5G wireless communication module **460**. The communication device **400** may include a processor **470**. Depending on the embodiment, the communication device **400** may include other components in addition to the components described or exclude some of the components described.

The 4G wireless communication module **450** and the 5G wireless communication module **460** perform wireless communication with one or more communication systems through one or more antenna modules. The 4G wireless communication module **450** can transmit and/or receive signals to devices in the first communication system through the first antenna module. In addition, the 5G wireless communication module **460** can transmit and/or receive signals to devices in the second communication system through the second antenna module. The 4G wireless communication module **450** and the 5G wireless communication module **460** may also be implemented as a single integrated communication module. Here, the first and second communication systems may each be the LTE communication system and the 5G communication system. However, the first and second communication systems are not limited to this and can be extended to any other communication systems.

The processor of the device in the vehicle **500** may be implemented as an MCU (Micro Control Unit) or a modem. The processor **470** of the communication device **400** corresponds to the modem, and the processor **470** may be implemented as an integrated modem. The processor **470** can obtain surrounding information from other nearby vehicles, objects, or infrastructure through wireless communication. The processor **470** can perform vehicle control using the obtained surrounding information.

The processor **570** of the vehicle **500** may correspond to the processor of a CAN (Car Area Network) or ADAS (Advanced Driving Assistance System), but it is not limited to this. In the case of distributed control in the vehicle **500**, the processor **570** of the vehicle **500** may be replaced with the processor of each device.

Meanwhile, the antenna module placed inside the vehicle **500** may be configured to include a wireless communication section. The 4G wireless communication module **450** can transmit and receive 4G signals to and from a 4G base station through a 4G mobile communication network. At this time, the 4G wireless communication module **450** can transmit one or more 4G transmission signals to the 4G base station. In addition, the 4G wireless communication module **450** can receive one or more 4G reception signals from the 4G base station. In this regard, MIMO (Multi-Input Multi-Output) may be performed by multiple 4G transmission signals transmitted to the 4G base station for the uplink (UL). In addition, MIMO (Multi-Input Multi-Output) may be performed by multiple 4G reception signals received from the 4G base station for the downlink (DL).

The 5G wireless communication module **460** can transmit and receive 5G signals to and from a 5G base station through a 5G mobile communication network. Here, the 4G and 5G base stations may have a non-standalone (NSA) structure. For example, the 4G and 5G base stations may be deployed in a non-standalone (NSA) structure. Alternatively, the 5G base station may be deployed in a standalone (SA) structure, separate from the 4G base station. The 5G wireless communication module **460** can transmit one or more 5G transmission signals to the 5G base station through the 5G mobile communication network. In addition, the 5G wireless communication module **460** can receive one or more 5G reception signals from the 5G base station. At this time, the 5G frequency band may use the same band as the 4G frequency band, which is referred to as LTE re-farming. Meanwhile, the Sub6 band, a frequency band below 6 GHz, may be used as the 5G frequency band. On the other hand, the millimeter-wave (mmWave) band may be used as the 5G frequency band to perform high-speed broadband communication. When the millimeter-wave (mmWave) band is used, the electronic device may perform beamforming to extend communication coverage with the base station.

Regardless of the 5G frequency band, more MIMO (Multi-Input Multi-Output) can be supported in the 5G communication system to improve transmission speed. In this regard, MIMO can be performed for the uplink (UL) by multiple 5G transmission signals transmitted to the 5G base station. In addition, MIMO can be performed for the downlink (DL) by multiple 5G reception signals received from the 5G base station.

Meanwhile, dual connectivity (DC) may be established between the 4G base station and the 5G base station through the 4G wireless communication module **450** and the 5G wireless communication module **460**. This dual connectivity may be referred to as EN-DC (EUTRAN NR DC). If the 4G and 5G base stations are co-located, throughput improvement can be achieved through inter-carrier aggregation (CA). Accordingly, if the 4G base station and the 5G base station are in an EN-DC state, the 4G wireless communication module **450** and the 5G wireless communication module **460** can simultaneously receive 4G reception signals and 5G reception signals. Meanwhile, short-range communication between electronic devices (such as vehicles) can be performed using the 4G wireless communication module **450** and the 5G wireless communication module **460**. In one embodiment, wireless communication can be performed between vehicles in a V2V mode without going through a base station after resources are allocated.

Meanwhile, for improving transmission speed and communication system convergence, carrier aggregation (CA) can be performed using at least one of the 4G wireless communication module **450** and the 5G wireless communication module **460** along with the Wi-Fi communication module **113**. In this regard, 4G+WiFi carrier aggregation (CA) can be performed using the 4G wireless communication module **450** and the Wi-Fi communication module **113**. Alternatively, 5G+WiFi carrier aggregation (CA) can be performed using the 5G wireless communication module **460** and the Wi-Fi communication module.

Meanwhile, the communication device **400** can implement a vehicle display device along with the user interface device. In this case, the vehicle display device may be referred to as a telematics device or an AVN (Audio Video Navigation) device.

Meanwhile, the broadband transparent antenna structure that can be placed on the glass of the vehicle according to the present specification can be implemented on a single dielectric substrate on the same plane as the CPW feed section. Additionally, the broadband transparent antenna structure placed on the vehicle glass according to the present specification can be implemented with a broadband structure where the ground is formed on both sides of the radiator.

The following describes the antenna assembly associated with the broadband transparent antenna structure according to the present specification. In this regard, FIGS. **5**A through **5**C illustrate configurations where the antenna assembly according to the present specification is placed on vehicle glass. Referring to FIG. **5**A, the antenna assembly **1000** may include a first dielectric substrate **1010***a* and a second dielectric substrate **1010***b*. The first dielectric substrate **1010***a* may be implemented as a transparent substrate and referred to as a transparent substrate **1010***a*. The second dielectric substrate **1010***b* may be implemented as an opaque substrate.

The glass panel **310** may be configured to include a transparent region **311** and an opaque region **312**. The opaque region **312** of the glass panel **310** may be a frit layer formed with a frit layer region. The opaque region **312** may be formed to surround the transparent region **311**. The opaque region **312** may be formed in the outer area of the transparent region **311**. The opaque region **312** may form the boundary area of the glass panel **310**.

The signal pattern formed on the dielectric substrate (**1010**) can be connected to the telematics control unit (TCU) **300** through a connector component **313** such as a coaxial cable. The telematics control unit (TCU) **300** may be placed inside the vehicle, but it is not limited to this. The telematics control unit (TCU) **300** may be placed on the vehicle's dashboard or in the ceiling area inside the vehicle, but it is not limited to this.

FIG. **5**B shows a configuration where the antenna assembly **1000** is placed in a part of the glass panel **310**. FIG. **5**C shows a configuration where the antenna assembly **1000** is placed over the entire area of the glass panel **310**.

Referring to FIGS. **5**B and **5**C, the glass panel **310** may include a transparent region **311** and an opaque region **312**. The opaque region **312** may be a non-visible area with a transparency level below a certain threshold and may be referred to as a frit region, BP (Black Printing) region, or BM (Black Matrix) region. The opaque region **312** may be formed to surround the transparent region **311**. The opaque region **312** may be formed in the outer area of the transparent region **311**. The opaque region **312** may form the boundary area of the glass panel **310**. The second dielectric substrate **1010***b*, corresponding to the feed substrate, or defogger pads (**360***a*, **360***b*), may be placed in the opaque region **312**. The second dielectric substrate **1010***b* placed in the opaque region **312** may be referred to as the opaque substrate. Even when the antenna assembly **1000** is placed over the entire area of the glass panel **310** as shown in FIG. **5**C, defogger pads **360***a*, **360***b* may still be placed in the opaque region **312**.

Referring to FIG. **5**B, the antenna assembly **1000** may include a first transparent dielectric substrate **1010***a* and a second dielectric substrate **1010***b*. Referring to FIGS. **5**B and **5**C, the antenna assembly **1000** may include an antenna module **1100** formed with conductive patterns and a second dielectric substrate **1010***b*. The antenna module **1100** may be formed with a transparent electrode and implemented as a transparent antenna module. The antenna module **1100** may be implemented with one or more antenna elements. The antenna module **1100** may include MIMO antennas and/or other antenna elements for wireless communication. Other antenna elements may include at least one of GNSS/radio/broadcast/WiFi/satellite communication/UWB, or Remote Keyless Entry (RKE) antennas for vehicle applications.

Referring to FIGS. **5**A through **5**C, the antenna assembly **1000** can interface with the telematics control unit (TCU) **300** through the connector component **313**. The connector component **313** may include a connector (**313***c*) formed at the end of a cable and electrically connected to the TCU **300**. The signal pattern formed on the second dielectric substrate **1010***b* of the antenna assembly **1000** can be connected to the TCU **300** through connector components such as a coaxial cable. The antenna module **1100** may be electrically connected to the TCU **300** through the connector component **313**. Although the TCU **300** may be placed inside the vehicle, it is not limited to this. The TCU **300** may be placed on the vehicle's dashboard or in the ceiling area inside the vehicle, but it is not limited to this.

Meanwhile, when the transparent antenna assembly according to the present specification is attached to the inside or surface of the glass panel **310**, the transparent electrode, including the antenna pattern and dummy pattern, can be placed in the transparent region **311**. In contrast, the opaque substrate can be placed in the opaque region **312**.

The antenna assembly formed on the vehicle glass according to the present specification may be placed in the transparent region and opaque region. In this regard, FIG. **6**A shows various embodiments of frit patterns according to the present specification. FIGS. **6**B and **6**C illustrate transparent antenna patterns and the structure where transparent antenna patterns are placed on vehicle glass according to the embodiments.

Referring to (a) of FIG. **6**A, the frit pattern **312***a* may be formed in a metal pattern with a circular (or polygonal, elliptical) shape with a predetermined diameter. The frit pattern **312***a* may be arranged in a two-dimensional structure along both axes. The frit pattern **312***a* may be formed in an offset structure where the center points of the patterns forming adjacent rows are spaced apart by a predetermined distance.

Referring to (b) of FIG. **6**A, the frit pattern **312***b* may be formed as a rectangular pattern in one axial direction. The frit pattern **312***c* may be arranged in a one-dimensional structure in one axial direction or in a two-dimensional structure along both axes.

Referring to (c) of FIG. **6**A, the frit pattern **312***c* may be formed as a slot pattern where metal patterns are removed in a circular (or polygonal, elliptical) shape with a predetermined diameter. The frit pattern **312***b* may be arranged in a two-dimensional structure along both axes. The frit pattern **312***c* may be formed in an offset structure where the center points of the patterns forming adjacent rows are spaced apart by a predetermined distance.

Referring to FIGS. **5**A through **6**C, the opaque substrate **1010***b* and the transparent substrate **1010***a* may be configured to be electrically connected in the opaque region **312**. In this regard, a very small dummy pattern may be placed around the antenna pattern to improve invisibility and avoid visually distinguishing the antenna pattern without degrading antenna performance. Accordingly, the surrounding area of the transparent electrode in the antenna pattern can be designed to have a similar light transmittance as the antenna pattern.

The transparent antenna assembly, including the opaque substrate **1010***b* bonded to the transparent electrode, can be mounted on the glass panel **310**. In this regard, to ensure invisibility, the opaque substrate **1010***b*, which is connected to the RF connector or coaxial cable, is placed in the opaque region **312** of the vehicle glass. Meanwhile, the transparent electrode is placed in the transparent region **311** of the vehicle glass to ensure invisibility of the antenna from the exterior of the vehicle glass.

Some parts of the transparent electrode may be attached to the opaque region **312** depending on the case. The frit pattern in the opaque region **312** can be formed with a gradient transitioning from the opaque region **312** to the transparent region **311**. If the transmittance of the frit pattern and the transparent electrode is matched within a predetermined range, antenna invisibility can be improved while enhancing the transmission efficiency of the transmission line. Meanwhile, the sheet resistance can be reduced while ensuring invisibility with a metal mesh shape similar to the frit pattern. Furthermore, the risk of disconnection in the transparent electrode layer during production and assembly can be reduced by increasing the line width of the metal mesh lattice in the area connected to the opaque substrate **1010***b*.

Referring to (a) of FIG. **6**A and FIG. **6**B, the conductive pattern **1110** of the antenna module can be composed of metal mesh lattices with the same line width in the opaque region **312**. The conductive pattern **1110** may include a connection pattern **1110***c* that connects the transparent substrate **1010***a* and the opaque substrate **1010***b*. The frit patterns with a specific shape may be arranged at regular intervals on both sides of the connection pattern **1110***c* in the opaque region **312**. The connection pattern **1110***c* may include a first transmittance section **1111***c* formed with a first transmittance and a second transmittance section **1112***c* formed with a second transmittance.

The frit patterns **312***a* formed in the opaque region **312** may be arranged with metal lattices with a predetermined diameter in one axial and another axial direction. The metal lattices of the frit patterns **312***a* may be placed at the intersections of the metal mesh lattices in the second transmittance section **1112***c* of the connection pattern **1110***c*.

Referring to (b) of FIG. **6**A and FIG. **6**B, the frit patterns **312***b* formed in the opaque region **312** may be arranged with slot lattices with a predetermined diameter where metal regions are removed, in one axial and another axial direction. The slot lattices of the frit patterns **312***b* may be placed between the metal mesh lattices in the connection pattern **1110***c*. Accordingly, the metal regions of the frit patterns **312***b* without slot lattices may be placed at the intersections of the metal mesh lattices.

Referring to FIGS. **6**A and **6**C, the connection pattern **1110***c* may be composed of metal mesh lattices with a first line width **W1** in the first transmittance section **1111***c* adjacent to the transparent region **311**. The connection pattern **1110***c* may be formed with a second line width **W2**, which is thicker than the first line width **W1**, in the second transmittance section **1112***c* adjacent to the opaque substrate **1010***b*. In this regard, the first transparency of the first transmittance section **1111***c* may be set higher than the second transparency of the second transmittance section **1112***c*.

When the transparent antenna assembly is attached inside the vehicle glass as shown in FIGS. **5**A through **5**C, the transparent electrode section can be placed in the transparent region **311**, and the opaque substrate **1010***b* can be placed in the opaque region **312**. In some cases, the transparent electrode section may also be placed in the opaque region **312**.

Part of the metal pattern of the low-transmittance electrode section and high-transmittance electrode section located in the opaque region **312** can be arranged in the gradient region of the opaque area **312**. If the transmission lines of the antenna pattern and the low-transmittance electrode section are made of transparent electrodes, antenna gain loss may occur due to reduced transmission efficiency caused by increased sheet resistance. To address this issue, the transmittance of the frit pattern **312** and the transparent electrode can be matched within a certain range to minimize the gain reduction.

By increasing the line width of the transparent electrodes in areas with low transmittance or adding shapes identical to the frit pattern **312***a*, **312***b*, **312***c*, a lower sheet resistance can be achieved. This solution helps maintain transmission efficiency while also ensuring the invisibility of the antenna. The transmittance and patterns of the opaque region **312** are not limited to the structure shown in FIG. **6**A and may vary depending on the glass or vehicle manufacturer. Accordingly, the shape and transparency (line width and spacing) of the transparent electrode on the transmission line may be modified in various ways.

FIG. **7**A shows a front and cross-sectional view of the transparent antenna assembly according to this specification. FIG. **7**B illustrates the grid structure of the metal mesh radiator and dummy metal mesh areas according to various embodiments.

(a) of FIG. **7**A shows a front view of the transparent antenna assembly **1000**, and (b) of FIG. **7**A shows a cross-sectional view, illustrating the layered structure of the transparent antenna assembly **1000**. Referring to FIG. **7**A, the antenna assembly **1000** may be configured to include the first transparent dielectric substrate **1010***a* and the second dielectric substrate **1010***b*. On one surface of the first transparent dielectric substrate **1010***a*, conductive patterns **1110** functioning as radiators may be arranged. On one surface of the second dielectric substrate **1010***b*, feed patterns **1120***f* and ground patterns **1121***g*, **1122***g* may be formed. The conductive patterns **1110** functioning as radiators may include one or more conductive patterns. The conductive patterns **1110** may include the first pattern **1111** connected to the feed pattern **1120***f* and the second pattern **1112** connected to the ground pattern **1121***g*. The conductive patterns **1110** may also include a third pattern **1113** connected to the ground pattern (**1122***g*).

The conductive patterns **1110** forming the antenna module may be implemented as a transparent antenna. Referring to FIG. **7**B, the conductive patterns **1110** may be formed with metal mesh patterns **1020***a* of specific line widths, creating a metal mesh radiator region. Dummy metal mesh patterns **1020***b* may be formed in the inner or outer areas between the first, second, and third patterns **1111**, **1112**, **1113** to maintain a certain level of transparency. The metal mesh patterns **1020***a* and dummy metal mesh patterns **1020***b* can form a metal mesh layer **1020**.

(a) of FIG. **7**B illustrates the structure of typical metal mesh patterns **1020***a* and dummy metal mesh patterns **1020***b*. (b) of FIG. **7**B shows the structure of atypical metal mesh patterns **1020***a* and dummy metal mesh patterns **1020***b*. As shown in (a) of FIG. **7**B, the metal mesh layer **1020** can be formed with a transparent antenna structure composed of multiple metal mesh grids. The metal mesh layer **1020** can be formed in regular shapes such as rectangles, diamonds, or polygons. Multiple metal mesh grids may be configured as conductive patterns that function as feed lines or radiators. The metal mesh layer **1020** forms the transparent antenna area. For example, the metal mesh layer **1020** may have a thickness of approximately 2 mm, but it is not limited to this.

The metal mesh layer **1020** may be configured to include metal mesh patterns **1020**a and dummy metal mesh patterns **1020**b. The metal mesh patterns **1020**a and dummy metal mesh patterns **1020**b may be designed with opening areas OA where the ends are disconnected to prevent electrical connection. Dummy metal mesh patterns **1020**b may include slits SL to ensure that the ends of the mesh grids CL**1**, CL**2**, . . . , CLn are not connected.

Referring to (b) of FIG. **7**B, the metal mesh layer **1020** may be formed with multiple atypical metal mesh grids. The metal mesh layer **1020** may be configured to include metal mesh patterns **1020**a and dummy metal mesh patterns **1020**b. The metal mesh patterns **1020**a and dummy metal mesh patterns **1020**b may be designed with opening areas OA where the ends are disconnected to prevent electrical connection. Dummy metal mesh patterns **1020**b may include slits SL to ensure that the ends of the mesh grids CL**1**, CL**2**, . . . , CLn are not connected.

Meanwhile, the transparent substrate with the transparent antenna formed according to this specification may be placed on the glass of the vehicle. In this regard, FIG. **8**a shows the layered structure of the antenna module and the feed module. FIG. **8**B shows the layered structure of the antenna module and feed structure, including the bonding parts, with the opaque substrate.

Referring to (a) of FIG. **8**A, the antenna module **1100** may be configured to include the first transparent dielectric substrate **1010**a, formed in the first layer, and the first conductive pattern **1110**, placed in the second layer. The first conductive pattern **1110** may be implemented as a metal mesh layer **1020** that includes metal mesh patterns **1020**a and dummy metal mesh patterns **1020**b, as shown in FIG. **7**B. The antenna module **1100** may further include a protective layer **1031** and an adhesive layer **1041**a placed in the second layer.

Referring to (b) of FIG. **8**A, the feed structure **1100**f may include the second dielectric substrate **1010**b, the second conductive pattern **1120**, and the third conductive pattern **1130**. The feed structure **1100**f may further include the first and second protective layers **1033**, **1034**, stacked on the second and third conductive patterns **1120**, **1130**, respectively. The feed structure **1100**f may also include an adhesive layer **1041**b formed in part of the second conductive pattern **1120**.

The second conductive pattern **1120** may be placed on one surface of the second dielectric substrate **1010**b, and the third conductive pattern **1130** may be placed on the other surface. A first protective layer **1033** may be formed on the upper side of the third conductive pattern **1130**. A second protective layer **1034** may be formed on the lower side of the second conductive pattern **1120**. The first and second protective layers **1033**, **1034** may be configured with low permittivity values below a certain threshold, allowing for low-loss feeding in the transparent antenna area.

Referring to (a) of FIG. **8**B, the antenna module **1100** may be combined with the feed structure **1100**f, implemented as an opaque substrate in the second dielectric substrate **1010**b. The first conductive pattern **1110**, implemented as a transparent electrode layer in a metal mesh layer, may be formed on top of the first transparent dielectric substrate **1010**a. A protective layer **1031** may be formed on top of the first conductive pattern **1110**. An adhesive layer **1041**a may be formed on top of the protective layer **1031** and the first conductive pattern **1110**. An adhesive layer **1041**a may be formed adjacent to the protective layer **1031**.

The first adhesive layer **1041**a, formed on top of the first conductive pattern **1110**, may be bonded to the second adhesive layer **1041**b, formed below the second conductive pattern **1120**. The first transparent dielectric substrate **1010**a and the second dielectric substrate **1010**b may be adhered together by bonding the first and second adhesive layers **1041**a, **1041**b. Consequently, the metal mesh grid formed on the first transparent dielectric substrate **1010**a may be electrically connected to the feed pattern formed on the second dielectric substrate **1010**b.

The second dielectric substrate **1010**b may form the feed structure **1100**f, where the second conductive pattern **1120** and the third conductive pattern **1130** are placed on both sides. The feed structure **1100**f may be implemented as an FPCB (Flexible Printed Circuit Board), but it is not limited to this. The first protective layer **1033** may be placed on the top of the third conductive pattern **1130**, and the second protective layer **1034** may be placed on the bottom of the second conductive pattern **1120**. The adhesive layer **1041**b below the third conductive pattern **1130** may be bonded to the adhesive layer **1041**a of the antenna module **1100**. Thus, the feed structure **1100**f may be combined with the antenna module **1100**, and the first and second conductive patterns **1110**, **1120** may be electrically connected.

The thickness of the antenna module **1100**, implemented with the first transparent dielectric substrate **1010**a, may be formed to a first thickness. The thickness of the feed structure **1100**f, implemented with the second dielectric substrate **1010**b, may be formed to a second thickness. For example, the thickness of the dielectric substrate **1010**a, the first conductive pattern **1110**, and the protective layer **1031** of the antenna module **1100** may be 75 μm, 9 μm, and 25 μm, respectively. The first thickness of the antenna module **1100** may be 109 m. The thickness of the dielectric substrate **1010**b, the second conductive pattern **1120**, and the third conductive pattern **1130** of the feed structure **1100**f may be 50 μm, 18 μm, and 18 μm, respectively, with the first and second protective layers **1033**, **1034** having a thickness of 28 km. Accordingly, the second thickness of the feed structure **1100**f may be 142 m. Since the adhesive layers **1041**a, **1041**b are formed above the first conductive pattern **1110** and below the second conductive pattern **1120**, the total thickness of the antenna assembly may be smaller than the sum of the first and second thicknesses. For example, the thickness of the antenna assembly **1000**, including the antenna module **1100** and the feed structure **1100**f, may be formed to 198 km.

Referring to (b) of FIG. **8**B, the conductive pattern **1120** may be formed on one surface of the second dielectric substrate **1010**b, forming the feed structure **1100**f. The conductive pattern **1120** may be implemented as a CPW structure feed with the ground patterns **1121**g, **1122**g formed on both sides of the feed pattern **1120**f. The feed structure **1100**f may be combined with the antenna module **1100** through the adhesive layer **1041** formed in the region, as shown in (a) of FIG. **8**B.

The antenna module and feed structure forming the antenna assembly according to this specification may be placed on the vehicle glass and combined through a specific bonding structure. In this regard, FIG. **9**A shows the bonding structure of the transparent antenna placed in the transparent and frit regions of the vehicle glass.

Referring to FIG. **9**A, the first transparent dielectric substrate **1010**a may be bonded to the glass panel **310** through the adhesive layer **1041**. The conductive pattern on the first transparent dielectric substrate **1010***a* may be bonded to the conductive pattern **1130** of the second dielectric substrate **1010***b* through ACF bonding. ACF bonding involves bonding the contact surface with a tape containing metal balls at high temperatures and pressure (e.g., 120 to 150° C., 2 to 5 Mpa) for a few seconds, establishing electrical contact between the electrodes using metal balls. ACF bonding electrically connects the conductive patterns and, at the same time, provides adhesion through heat curing of the adhesive layer **1041**.

The first transparent dielectric substrate **1010***a* and the second dielectric substrate **1010***b*, implemented as an FPCB, may be bonded using local soldering techniques. The connection pattern of the FPCB and the transparent antenna electrode may be connected through local soldering using coils in a magnetic induction method. During local soldering, the temperature of the soldered area may be raised without deforming the FPCB, maintaining a flat surface. This allows for highly reliable electrical connections between the conductive patterns of the first transparent dielectric substrate **1010***a* and the second dielectric substrate **1010***b* through local soldering.

The metal mesh layer **1020**, protective layer **1033**, and adhesive layer **1041** of the first transparent dielectric substrate **1010***a*, as shown in FIG. **7**A, can form a transparent electrode. The second dielectric substrate **1010***b*, implemented as an opaque substrate, may be an FPCB, but it is not limited to this. The second dielectric substrate **1010***b*, implemented as an FPCB with a feed pattern, may be configured to connect to the connector component **313** and the transparent electrode.

The second dielectric substrate **1010***b*, implemented as an opaque substrate, may be attached to part of the first transparent dielectric substrate **1010***a*. The first transparent dielectric substrate **1010***a* may be formed in the transparent region **311** of the glass panel **310**. The second dielectric substrate **1010***b* may be formed in the opaque region **312** of the glass panel **310**. Part of the first transparent dielectric substrate **1010***a* may extend into the opaque region **312**, where it is bonded to the feed pattern formed on the second dielectric substrate **1010***b* and electrically connected to the metal mesh layer of the transparent antenna.

The first transparent dielectric substrate **1010***a* and the second dielectric substrate **1010***b* may be bonded together through the adhesion of the adhesive layers **1041***a*, **1041***b*. The position where the second dielectric substrate **1010***b* is bonded to the adhesive layer **1041** may be set as the first position P**1**. The location where the connector component **313** is soldered to the opaque substrate **1010***b* may be set as the second position P**2**.

Meanwhile, the vehicle glass with the antenna assembly formed according to this specification can be combined with the vehicle body structure. In this regard, FIG. **9**B is an enlarged front view of the area where the glass with the transparent antenna formed in FIG. **9**A is combined with the vehicle body structure. FIG. **9**C shows cross-sectional views of the bonding structure between the vehicle glass and the body structure of FIG. **9**B viewed from different positions.

Referring to FIG. **9**B, the first transparent dielectric substrate **1010***a*, with the transparent antenna formed in the transparent region **311** of the glass panel **310**, may be placed in the transparent region **311**. The second dielectric substrate **1010***b* may be placed in the opaque region **312** of the glass panel **310**. The transmittance of the opaque region **312** may be lower than that of the transparent region **311**, and the opaque region **312** may be referred to as a BM (Black Matrix) region. Part of the first transparent dielectric substrate **1010***a*, where the transparent antenna is formed, may extend into the BM region of the opaque region **312**. The first transparent dielectric substrate **1010***a* and the opaque region **312** may be formed to overlap by an overlap length OL in one axial direction.

(a) of FIG. **9**C shows a cross-sectional view of the antenna assembly cut along line AB in FIG. **9**B. (b) of FIG. **9**C shows a cross-sectional view of the antenna assembly cut along line CD in FIG. **9**B.

Referring to FIG. **9**B and (a) of FIG. **9**C, the first transparent dielectric substrate **1010***a* with the transparent antenna formed in the transparent region **311** of the glass panel **310** may be placed in the transparent region **311**. The second dielectric substrate **1010***b* may be placed in the opaque region **312** of the glass panel **310**. Part of the first transparent dielectric substrate **1010***a* may extend into the opaque region **312**, where it is bonded and connected to the feed pattern formed on the second dielectric substrate **1010***b* and the metal mesh layer of the transparent antenna.

An interior cover **49***c* may be configured to house the connector component **313** connected to the second dielectric substrate **1010***b*. The connector component **313** may be placed in the space between the metal body **49***b* and the interior cover **49***c*, and the connector component **313** may be combined with the in-vehicle cable. The interior cover **49***c* may be placed in the upper area of the metal body **49***b*. The interior cover **49***c* may be formed with a bent section at one end to combine with the metal body **49***b*.

The interior cover **49***c* may be formed of metal or dielectric material. When the interior cover **49***c* is formed of metal, the interior cover **49***c* and the metal body **49***b* may form a metal frame **49**. In this regard, the vehicle may include a metal frame **49**. The opaque region **312** of the glass panel **310** may be supported by part of the metal frame **49**. For this purpose, part of the body **49***b* of the metal frame **49** may be bent to combine with the opaque region **312** of the glass panel **310**.

When the interior cover **49***c* is made of metal, a metal region may be partially removed from the upper area of the second dielectric substrate **1010***b* inside the interior cover **49***c*. A recess portion **49**R, where the metal region is removed, may be formed in the interior cover **49***c*. Accordingly, the metal frame **49** may include the recess portion **49**R. The second dielectric substrate **1010***b* may be placed inside the recess portion **49**R of the metal frame **49**.

The recess portion **49**R may also be referred to as the metal cut region. One side of the recess portion **49**R may be spaced by a first length L1 from one side of the opaque substrate **1010***b*, exceeding a critical value. The lower boundary side of the recess portion **49**R may be spaced by a second length L2 from the lower boundary side of the opaque substrate **1010***b*, exceeding a critical value. By removing part of the metal from the interior cover **49***c*, signal loss and antenna performance changes caused by the surrounding metal structure can be prevented.

Referring to FIG. **9**B and (b) of FIG. **9**C, no recess portion is formed in the area of the interior cover **49***c* where no connector components or opaque substrates are placed. In this regard, the interior cover **49***c* may protect the internal components of the antenna module **1100** while allowing heat generated inside to be discharged to the outside through the recess portion **49**R of FIG. **9**B and (a) of FIG. **9**C. Furthermore, the recess portion **49**R of the interior cover **49***c* allows for quick identification of whether a repair or replacement of the connection part is needed. Meanwhile, the absence of the recess portion in areas without connector components and second dielectric substrates prevents damage to the internal components of the antenna module **1100**.

Meanwhile, the antenna assembly **1000** according to this specification may be formed in various shapes on the glass panel **310**, and the glass panel **310** may be attached to the vehicle frame. In this regard, FIG. **10** shows the laminated structure of the antenna assembly and the attachment area between the vehicle glass and the vehicle frame according to various embodiments.

Referring to (a) of FIG. **10**, the glass panel **310** may include a transparent region **311** and an opaque region **312**. The antenna assembly **1000** may be configured to include the antenna module **1100** and the feed structure **1100***f*. The antenna module **1100** may include the first transparent dielectric substrate **1010***a*, a transparent electrode layer **1020**, and an adhesive layer **1041**. The transparent electrode layer **1020**, implemented as a transparent substrate, may be electrically connected to the feed structure **1100***f*, implemented as an opaque substrate. The feed structure **1100***f* and the transparent electrode layer **1020** may be directly connected through the first bonding area **BR1**. The feed structure **1100***f* and the connector component **313** may be directly connected through the second bonding area **BR2**. Heat may be applied for bonding in the first and second bonding areas **BR1**, **BR2**. Accordingly, the bonding areas **BR1**, **BR2** may be referred to as heating sections. An attachment area AR, corresponding to the sealant region for attaching the glass panel **310** to the vehicle frame, may be formed in the side end area of the opaque region **312** of the glass panel **310**.

Referring to (b) of FIG. **10**, the glass panel **310** may include the transparent region **311** and the opaque region **312**. The antenna assembly **1000** may be configured to include the antenna module **1100** and the feed structure **1100***f*. The antenna module **1100** may include the protective layer **1031**, the transparent electrode layer **1020**, the first transparent dielectric substrate **1010***a*, and the adhesive layer **1041**. Part of the feed structure **1100***f*, implemented as an opaque substrate, and part of the antenna module **1100**, implemented as a transparent substrate, may overlap. The transparent electrode layer **1020** of the antenna module **1100** and the feed structure **1100***f* may be coupled for feeding. The feed structure **1100***f* and the connector component **313** may be directly connected through the bonding area BR. Heat may be applied for bonding in the bonding area **BR1**. Accordingly, the bonding area BR may be referred to as the heating section. An attachment area AR, corresponding to the sealant region for attaching the glass panel **310** to the vehicle frame, may be formed in the side end area of the opaque region **312** of the glass panel **310**.

Referring to (a) and (b) of FIG. **10**, a (hard) coating layer may be included on the transparent substrate **1010***a* to protect the transparent electrode layer **1020** from the external environment. Meanwhile, the adhesive layer **1041** may include UV-blocking components to prevent yellowing from sunlight.

Meanwhile, the broadband transparent antenna structure placed on the vehicle glass according to this specification can be implemented as a single dielectric substrate on the same plane as the CPW feed section. The broadband transparent antenna structure can also be implemented with a ground formed on both sides of the radiator, forming a broadband structure. The broadband transparent antenna for vehicles may include an antenna module configured to perform 4G and 5G wireless communications. Furthermore, the broadband transparent antenna for vehicles may include a GNSS (Global Navigation Satellite System) antenna configured to provide location services.

Below is a description of the antenna assembly associated with the broadband transparent antenna structure according to this specification. In this regard, FIG. **11**A shows multiple frequency bands related to the GNSS antenna for vehicles, and FIG. **11**B shows the polarization characteristics related to the GNSS antenna for vehicles.

Referring to FIG. **11**A, the frequency bands in which the GNSS antenna for vehicles operates may include the first frequency band corresponding to the L1 band and the second frequency band corresponding to the L5 band. The first frequency band corresponding to the L1 band may be set to 1559.0 to 1605.9 MHz. The first frequency band may include the L1 band associated with GPS. The first frequency band may also include the L1 band associated with GLONASS. The second frequency band corresponding to the L5 band may be set to 1166.2 to 1186.7 MHz. The second frequency band may include the L5 band associated with GPS.

The antenna assembly implemented as a GNSS antenna for vehicles may be configured for dual-band resonance, operating in both the first and second frequency bands. The antenna assembly implemented as a GNSS antenna for vehicles may operate having circular polarization. The antenna assembly may be configured to operate with right-hand circular polarization (RHCP).

Referring to (a) of FIG. **11**B, the signal formed in the GNSS antenna for vehicles may propagate in the z-axis direction. Referring to (a) to (c) of FIG. **11**B, the signal formed in the GNSS antenna for vehicles may be configured to have circular polarization, where the electric field rotates along the x-axis and y-axis. Referring to (a) and (c) of FIG. **11**B, the signal formed in the GNSS antenna for vehicles may propagate in the z-axis direction with right-hand circular polarization (RHCP) while maintaining circular polarization along the x-axis and y-axis. The signal formed in the GNSS antenna for vehicles may be expressed mathematically as Equation 1.

$$E = \vec{x}A\cos(\omega t - \beta z) + \vec{y}B\cos(\omega t - \beta z) \quad \text{[Equation 1]}$$

A signal with a superior circular polarization (RHCP) is A=B in the Equation 1 and can be formed with a phase difference of 90 degrees. A signal with a left-hand circular polarization (LHCP) is A=B in the Equation 1 and can be formed with a phase difference of −90 degrees. The ratio of the maximum value ($|E|_{max}$) and the minimum value ($|E|_{min}$) of $|E|$ in the Equation 1 can be defined as the axial ratio AR as shown in Equation 2.

$$\text{Axial ratio} = \frac{|E|_{min}}{|E|_{max}} \quad \text{[Equation 2]}$$

According to Equations 1 and 2, as well as (d) of FIG. **11**B, when the values of A and B differ, the signal generated by the vehicle GNSS antenna can be configured to exhibit elliptical polarization. Circularly polarized signals must be maintained below a certain level, such as 3 dB or 6d B, towards the ceiling direction from the plane where the antenna is installed. The antenna gain should also be kept below a certain level, for instance, −3 dB, within a 45-degree range from the 0-degree ceiling direction.

As mentioned earlier, a GNSS antenna generating circularly polarized signals can be placed in different positions on the vehicle glass. FIGS. **12**A and **12**B illustrate the arrangement of GNSS antennas in various positions on the vehicle glass based on the examples provided.

Referring to FIGS. **1** and **12**A, a GNSS antenna can be placed on either the front glass **310**, rear glass **330**, or upper glass **350** of a sedan-type vehicle **500**. The front glass **310** can be constructed with a two-layer laminated structure, about 5 to 5.5 mm thick, consisting of glass/anti-scattering film/glass layers. The rear glass **330** may also have a two-layer laminated structure, with a thickness ranging between 3.5 to 5.5 mm, or be made of single-layer tempered glass. The rear glass **330** may contain defroster wires and an AM/FM antenna, and the transparent GNSS antenna should be placed at a specified distance from these components.

The GNSS antenna should have a radiation pattern directed towards the ceiling. Therefore, it can be installed on the upper glass **350** of the vehicle **500**. The upper glass **350** also has a two-layer laminated structure, 5 to 5.5 mm thick, formed from layers of glass and anti-scattering film.

In the case of an SUV-type vehicle **500**, as shown in FIGS. **1** and **12**B, the GNSS antenna can be placed on the front glass **310** or upper glass **350**. The front glass **310** of the SUV can have a two-layer laminated structure similar to that of the sedan, with a thickness of 5 to 5.5 mm. Since the GNSS antenna needs to radiate towards the ceiling, it can be installed on the upper glass **350**, which has the same laminated structure. The rear glass (**330***b*) of the SUV may have a steeper angle compared to the rear glass **330** of the sedan in FIG. **12**A, making it unsuitable for placing the GNSS antenna. The upper glass **350** in the SUV retains the same structure with layers of glass and film.

Referring to FIGS. **1**, **12**A, and **12**B, a GNSS antenna placed on the front glass **310**, rear glass **330**, or upper glass **350** can be implemented as a transparent antenna. The sheet resistance of the transparent antenna can range between 0.5 and 1.0 Ω/sq, although this can vary depending on the transparency or type of metal mesh used. The vehicle GNSS antenna described in this specification is designed to minimize the impact of the vehicle glass on its performance. To achieve this, the design takes into account factors such as the type, size, thickness, and film attachment of the vehicle glass, which could affect the antenna's performance. The GNSS antenna is optimized accordingly to mitigate any negative impact caused by these variables.

Referring to FIGS. **12**A and **12**B, the radiation pattern of the vehicle GNSS antenna can be implemented in an upper hemisphere shape. In this context, the radiation pattern of the GNSS antenna is formed within the range of −45 degrees to +45 degrees, with respect to 0 degree, directed toward the ceiling of the vehicle. The radiation pattern RP is oriented toward the ceiling direction. The GNSS antenna can be installed on the front glass **310**, rear glass **330**, or upper glass **350** of the vehicle **500**. The upper glass **350**, located in the roof area, may also be referred to as the moonroof glass. The GNSS antenna, placed on any of these glass sections, can be designed using a monopole element or slot element to minimize the impact caused by the vehicle glass.

The physical properties and size of the vehicle glass may affect the performance of the antenna. The larger and thicker the glass, the greater the potential for performance degradation. Additionally, dielectric losses within the glass can lead to reduced antenna gain and altered radiation patterns. To minimize these effects, the vehicle GNSS antenna is designed to be compact and implemented as a single-layer structure. For optimal satellite communication radiation patterns, it is most advantageous to position the GNSS antenna on the upper glass **350**, which is typically placed at a horizontal angle.

FIGS. **13**A and **13**B illustrate the vehicle GNSS antenna structures according to this specification. In FIG. **13**A, the antenna assembly **1000** has an outer conductive pattern **1140** of the transparent antenna connected to the ground conductive pattern **1110***g* in the opaque area. In FIG. **13**B, the outer conductive pattern **1140** of the transparent antenna is spaced apart by a gap G1 from the ground conductive pattern **1110***g* in the opaque area.

Referring to FIGS. **1** through **13**B, the vehicle **500** includes a vehicle glass **310** and an antenna assembly **1000**. The antenna assembly **1000** can be composed of a transparent dielectric substrate **1010***a*, a first region **1100***a*, and a second region **1100***b*.

The first region **1100***a* includes the antenna **1100** on one side of the transparent dielectric substrate **1010***a*. The second region **1100***b* comprises the grounded conductive pattern **1110***g* and a feeding pattern **1110***f*. The first and second regions may be referred to as the radiating area and the ground area (or feeding area), respectively. Since the antenna **1100** consists of multiple conductive patterns, it is also referred to as the antenna module **1100**.

The antenna assembly **1000**, designed as a transparent antenna, can adopt a single-layer CPW (coplanar waveguide) antenna structure. Referring to FIGS. **13**A and **13**B, the antenna **1100** includes a signal pattern **1120**, a first ground pattern **1130**, and a first slot **1130***s*. The antenna **1100** also includes a second ground pattern **1140** and a second slot **1140***s*.

The signal pattern **1120** connects to the feeding pattern **1110***f* in the second region **1100***b*. The first ground pattern **1130** connects to the first portion **1111***g* of the grounded conductive pattern **1110***g* in the second region **1100***b*. The first slot **1130***s* is formed between the signal pattern **1120** and the first ground pattern **1130**. This first slot **1130***s* radiates a first signal having circular polarization in the first frequency band, which could be the L1 frequency band from 1559.0 to 1605.9 MHz. The first slot **1130***s* may also radiate a second signal having circular polarization in a lower frequency band, such as the L5 band from 1166.2 to 1186.7 MHz.

To optimize antenna characteristics in the first frequency band, the shape of the signal pattern **1120** and the first ground pattern **1130** can be fine-tuned. The signal pattern **1120** may consist of an upper first signal pattern **1121** and a lower second signal pattern **1122**. A slit region SL without conductive material may be formed between the first and second signal patterns **1121** and **1122**. The inner boundary of the first ground pattern **1130** can be circular in some areas, with protrusions in other areas for optimal configuration.

The first part **1131** of the inner boundary of the first ground pattern **1130** may have a circular shape. Protrusions **1132** can be formed on this boundary to match the contours of the signal patterns **1121** and **1122**.

The second ground pattern **1140** is connected to the second portion **1112***g* of the grounded conductive pattern **1110***g* in the second region **1100***b*. The second ground pattern **1140** surrounds the first ground pattern **1130** and is designed to prevent radiation leakage into the vehicle glass at the L1 frequency band. Therefore, the second ground pattern **1140** helps form a radiation pattern directed towards the ceiling. The second slot **1140***s* is formed between the first and second ground patterns **1130**, **1140** and radiates the second signal in the L5 frequency band.

Thus, the first slot **1130***s* radiates signals in both the L1 and L5 frequency bands. The second slot **1140***s*, located outside the first slot **1130***s*, radiates the second signal in the L5 band. The length Ls of the second slot **1140***s* is configured between ¾ of the wavelength and one full wavelength (3λ/4 to λ) of the operating frequency in the L5 band.

Meanwhile, the vehicle GNSS antenna according to the specification may optimize the shapes of the first and second ground patterns **1130**, **1140** to enhance antenna performance in the first and second frequency bands. Referring to FIGS. **13**A and **13**B, the outer boundary of the first ground pattern **1120***g* may be at least partially circular in shape. The diameter L of the outer boundary of the first ground pattern **1130** may be configured within a range of 3λ/4 to λ, corresponding to the operating wavelength in the first frequency band.

The first portion **1131** of the inner boundary of the first ground pattern **1130** may be formed in a circular shape. The second portion **1132** of the inner boundary of the first ground pattern **1130** may be formed in a straight line along one axis and another straight line along a different axis. The first ground pattern **1130** may have a first width W**1** along one axis and a second, narrower width W**2** along the same axis.

Meanwhile, the second ground pattern **1140** may be formed to surround the first ground pattern **1130**. Thus, the second ground pattern **1140** may prevent signals radiated by the first slot **1130***s* from leaking to the vehicle glass outside the second ground pattern **1140**. The radiation patterns of the first signal in the first frequency band and the second signal in the second frequency band can be directed toward the vehicle's roof by the second ground pattern **1140** surrounding the first ground pattern **1130**. In this context, the radiation pattern of the antenna **1100** may be formed in a direction perpendicular to the vehicle glass, i.e., toward the vehicle's roof.

Meanwhile, the inner region of the second ground pattern in the antenna assembly of the present specification may be optimized to tune antenna performance. In this regard, FIG. **14**A shows an embodiment in which the inner region of the second ground pattern in the antenna assembly of FIG. **13**A is partially modified. FIG. **14**B shows the electric field distribution in the first and second frequency bands in the antenna assembly of FIG. **14**A.

As shown in FIG. **14**A, the inner region of the second ground pattern **1140** may be recessed. The recessed shape of the inner region of the second ground pattern **1140** is not limited to the antenna assembly of FIG. **13**A. For example, the inner region of the second ground pattern **1140** in the antenna assembly of FIG. **13**B may also be recessed.

Referring to FIG. **14**A, the antenna assembly **1000** may have a recessed shape in the inner region of the upper part **1141***c***-1** of the ground pattern **1140***c*. The first width of the inner region of the upper part **1141***c***-1** of the ground pattern **1140***c* may be narrower than the second width of the second part **1141-2** of the upper region **1141**. Meanwhile, the recessed structure of the inner boundary of the upper part **1141***c***-1** of the ground pattern **1140***c* may maintain a certain distance from the outer boundary of the first ground pattern **1130**. The recessed structure of the inner boundary of the upper part **1141***c***-1** of the ground pattern **1140***c* may maintain a certain distance from the outer boundary of the first ground pattern **1130** at a predetermined level or greater.

The length Ls**2** of the second slot **1140***s* formed inside the second ground pattern **1140***c* may be configured between ¾ wavelength and one wavelength of the operating frequency in the second frequency band. As a result, the wavelength length of the second slot **1140***s* may be increased without increasing the overall size of the antenna assembly. This allows the resonance frequency of the antenna in the second frequency band (L5 band) to shift to a lower frequency band.

(a) of FIG. **14** shows the electric field distribution at 1.575 GHz in the first frequency band for the antenna assembly. (b) of FIG. **14** shows the electric field distribution at 1.176 GHz in the second frequency band for the antenna assembly.

Referring to (a) FIG. **14**, the first signal in the first frequency band may be radiated through the first slot **1130***s* formed between the signal pattern **1120** and the first ground pattern **1130**. Peak electric field areas may be formed in the first region E**1***a* and the second region E**1***b* of the first slot **1130***s*. The first region E**1***a* and second region E**1***b* of the first slot **1130***s* may be formed on one side of the upper part and the other side of the lower part of the signal pattern **1120**. Accordingly, a current may be formed along the first slot **1130** corresponding to the inner region of the first ground pattern **1130**.

Referring to (b) of FIG. **14**, the first signal in the first frequency band may be radiated through the first slot **1130***s* formed between the signal pattern **1120** and the first ground pattern **1130**. Peak electric field areas may be formed in the first region E**2***a* and the second region E**2***b* of the first slot **1130***s*. The first region E**2***a* and the second region E**2***b* of the first slot **1130***s* may be formed on one side of the upper part and the other side of the lower part of the signal pattern **1120**. Accordingly, the first current in the first frequency band may be formed along the first slot **1130***s*, corresponding to the inner region of the first ground pattern **1130**.

The second signal in the second frequency band may be radiated through the second slot **1140***s* formed between the first ground pattern **1130** and the second ground pattern **1140**. Peak electric field areas may be formed in the third region E**2***c*, the fourth region E**2***d*, and the fifth region E**2***e* of the second slot **1140***s*. The third region E**2***c*, the fourth region E**2***d*, and the fifth region E**2***e* of the second slot **1140***s* may be formed along the inner region of the second ground pattern **1140**. Accordingly, the second current in the second frequency band may be formed along the second slot **1140***s* corresponding to the inner region of the second ground pattern **1140**.

FIGS. **15**A and **15**B compare the radiation patterns of the antenna in the first frequency band depending on the presence of the second ground pattern. FIG. **15**C shows the radiation pattern of the antenna in the second frequency band when the second ground pattern is present.

FIG. **15**A shows the radiation pattern of the antenna assembly **1000***a* at 1.575 GHz in the first frequency band (L1 band). FIG. **15**B shows the radiation pattern of the antenna assembly **1000** at 1.575 GHz in the first frequency band (L1 band). FIG. **15**C shows the radiation pattern of the antenna assembly **1000** at 1.176 GHz in the second frequency band (L5 band).

Referring to (a) of FIG. **15**A, the antenna assembly **1000***a*, having only the first ground pattern **1130**, does not have a second ground pattern. The antenna assembly **1000***a*, which has only the first ground pattern **1130**, may be referred to as a single-slot antenna. The radiation pattern peak RP**1** of the antenna assembly **1000***a* may be formed at an angle greater than 45 degrees relative to the vertical direction of the vehicle roof, which is the 0-degree reference. The radiation pattern peak RP**1** of the antenna assembly **1000***a*, which lacks the second ground pattern surrounding the first ground pattern **1130**, may be formed in the horizontal direction toward the vehicle glass. As a result, the GNSS signal reception characteristics of the antenna assembly **1000***a*, which lacks the second ground pattern surrounding the first ground pattern **1130**, may fall below the threshold.

(b) of FIG. **15**A shows the radiation pattern of the antenna assembly **1000***a* of (a) of FIG. **15**A as seen from the vehicle roof direction. The antenna assembly **1000** may be disposed on the glass panel **310**. The radiation pattern peaks RP**1***a*, RP**1***b* of the antenna assembly **1000***a* toward the vehicle glass may have higher values than the radiation pattern peaks RP**1***c*, RP**1***d* toward the vehicle roof. The first region of the radiation pattern peaks RP**1***a*, RP**1***b* of the antenna assembly **1000***a* toward the vehicle glass may cover a larger area than the second and third regions of the radiation pattern peaks RP**1***c*, RP**1***d* toward the vehicle roof.

Referring to (a) of FIG. **15**B, the antenna assembly **1000** includes the second ground pattern **1140** surrounding the first ground pattern **1130**. The antenna assembly **1000**, which includes the first and second ground patterns **1130**, **1140**, may be referred to as a dual-slot antenna because it includes both the first and second slots. The radiation pattern peak RP**2** of the antenna assembly **1000** may be formed in a range of −45 degrees to +45 degrees relative to the vertical direction of the vehicle roof, which is the 0-degree reference. The radiation pattern peak RP**2** of the antenna assembly **1000**, where the second ground pattern **1140** is formed surrounding the first ground pattern **1130**, is formed toward the vehicle roof. Accordingly, the GNSS signal reception characteristics of the antenna assembly **1000**, where the second ground pattern **1140** surrounds the first ground pattern **1130**, may meet or exceed the threshold.

(b) of FIG. **15**B shows the radiation pattern of the antenna assembly **1000** of (a) of FIG. **15**B as seen from the vehicle roof direction. The antenna assembly **1000** may be disposed on the glass panel **310**. The radiation pattern peak RP**2** of the antenna assembly **1000** toward the vehicle roof may have higher values than the radiation pattern peak RP**2***b* toward the vehicle glass. The first region of the radiation pattern peak RP**2***b* of the antenna assembly **1000** toward the vehicle glass may cover a smaller area than the second region of the radiation pattern peak RP**2** toward the vehicle roof. As a result, the radiation pattern area toward the vehicle glass is reduced due to the second ground pattern **1140** surrounding the first ground pattern **1130**, and the radiation pattern is formed primarily toward the vehicle roof.

Referring to (a) of FIG. **15**C, even in the second frequency band (L5 band), the radiation pattern peak RP**3** of the antenna assembly **1000** may be formed in a range of −45 degrees to +45 degrees relative to the vertical direction of the vehicle roof, which is the 0-degree reference. The radiation pattern peak RP**3** of the antenna assembly **1000**, where the second ground pattern **1140** surrounds the first ground pattern **1130**, is formed toward the vehicle roof. Accordingly, the GNSS signal reception characteristics of the antenna assembly **1000**, where the second ground pattern **1140** surrounds the first ground pattern **1130**, may meet or exceed the threshold.

(b) of FIG. **15**C illustrates the radiation pattern of the antenna assembly **1000** from (a) of FIG. **15**C as viewed from the roof direction of the vehicle. The antenna assembly **1000** may be placed on the glass panel **310**. The radiation pattern peak RP**3** of the antenna assembly **1000** in the roof direction has a higher value than the radiation pattern peak RP**3***b* in the glass direction. The first region of the radiation pattern peak RP**3***b* in the glass direction is narrower than the second region of the radiation pattern peak RP**3** in the roof direction. Accordingly, the second ground pattern **1140** surrounding the first ground pattern **1130** reduces the radiation pattern area in the glass direction and shifts the focus of the radiation pattern toward the roof.

Meanwhile, the vehicle GNSS antenna with the second ground pattern according to this specification may have a radiation pattern directed toward the vehicle's roof and may maintain an axial ratio below a specific threshold in both the first and second frequency bands. In this regard, FIG. **16**A illustrates the axial ratio for different frequencies depending on the presence or absence of the second ground pattern. FIGS. **16**B and **16**C show the gain characteristics for different angles in the first and second frequency bands depending on the presence or absence of the second ground pattern.

Referring to (a) of FIG. **15**A and (a) of FIG. **16**A, the axial ratio of the antenna assembly **1000***a*, which has only the first ground pattern **1130** and no second ground pattern, may be below the threshold, for example, 3 dB, only in the first frequency band (L1 band). In the second frequency band (L5 band), the axial ratio of the antenna assembly **1000***a* may exceed the threshold, for example, 3 dB, resulting in degraded circular polarization performance.

Referring to (a) of FIG. **15**B, (a) of FIG. **15**C, and (b) of FIG. **16**A, the axial ratio of the antenna assembly **1000**, with the second ground pattern **1140** surrounding the first ground pattern **1130**, may be below the threshold, for example, 3 dB, in both the first frequency band (L1 band) and the second frequency band (L5 band). Therefore, the axial ratio of the antenna assembly **1000** may be improved in the second frequency band (L5 band) compared to the antenna assembly **1000***a* without the second ground pattern, resulting in enhanced circular polarization performance.

Referring to (a) of FIG. **15**A and (a) of FIG. **16**B, in the first frequency band (L1 band), the antenna gain of the antenna assembly **1000***a* may range from about −1 dB to 0.7 dB between −45 degrees and 45 degrees. The average antenna gain of the antenna assembly **1000***a* in the range of −45 degrees to 45 degrees in the first frequency band (L1 band) is approximately −0.14 dB. Referring to (a) of FIG. **14**A and (b) of FIG. **15**B, in the second frequency band (L5 band), the antenna gain of the antenna assembly **1000***a* may range from about −2.2 dB to 0 dB between −45 degrees and 45 degrees. The average antenna gain of the antenna assembly **1000***a* in the range of −45 degrees to 45 degrees in the second frequency band (L5 band) is approximately −0.73 dB.

Referring to (a) of FIG. **15**B, (a) of FIG. **15**C, and (a) of FIG. **16**C, in the first frequency band (L1 band), the antenna gain of the antenna assembly **1000** may range from about −0.1 dB to 2.4 dB between −45 degrees and 45 degrees. The average antenna gain of the antenna assembly **1000** in the range of −45 degrees to 45 degrees in the first frequency band (L1 band) is approximately 1.02 dB. Therefore, the average antenna gain of the antenna assembly **1000** is improved by about 1.15 dB compared to the antenna assembly **1000***a* without the second ground pattern. Referring to (a) of FIG. **15**B, (a) of FIG. **15**C, and (b) of FIG. **16**B, in the second frequency band (L5 band), the antenna gain of the antenna assembly **1000** may range from about −1.6 dB to 0.7 dB between −45 degrees and 45 degrees. The average antenna gain of the antenna assembly **1000** in the range of −45 degrees to 45 degrees in the second frequency band (L5 band) is approximately −0.07 dB. Therefore, the average antenna gain of the antenna assembly **1000** is improved by about 0.7 dB compared to the antenna assembly **1000***a* without the second ground pattern.

As described above, the second ground pattern formed in the vehicle GNSS antenna can improve the antenna gain characteristics. Accordingly, FIGS. **17**A and **17**B compare the antenna gain characteristics in the first and second frequency bands depending on the presence or absence of the second ground pattern. FIG. **17**A illustrates the antenna gain characteristics at 1.575 GHz in the first frequency band depending on the presence or absence of the second ground pattern. FIG. **17**B illustrates the antenna gain characteristics at 1.176 GHz in the second frequency band depending on the presence or absence of the second ground pattern. Referring to FIGS. **17**A and **17**B, the target antenna gain may be set to be −3 dBi or higher between −45 degrees and +45 degrees.

Referring to FIG. **15**A, (a) of FIG. **16**B, and (a) of FIG. **17**A, (i) shows the normalized antenna gain value of the antenna assembly **1000***a* without the second ground pattern. Referring to FIG. **15**A, (a) of FIG. **16**C, and FIG. **17**A, (ii) shows the normalized antenna gain value of the antenna assembly **1000** with the second ground pattern **1140**. (iii) shows the angle-dependent antenna gain values of the antenna assembly **1000***a* without the second ground pattern. (iv) shows the angle-dependent antenna gain values of the antenna assembly **1000** with the second ground pattern **1140**. Referring to (i) in (a) of FIG. **17**A, the average gain of the antenna assembly **1000***a* without the second ground pattern is approximately 0.19 dB. Referring to (ii) in (a) of FIG. **17**A, the average gain of the antenna assembly **1000** with the second ground pattern **1140** is approximately 1.02 dB. Therefore, the formation of the second ground pattern **1140** in the antenna assembly **1000** can improve the average gain by about 0.8 dB or more.

Referring to FIG. **15**B, (b) of FIG. **16**B, and (b) of FIG. **17**A, (i) shows the normalized antenna gain value of the antenna assembly **1000***a* without the second ground pattern. Referring to FIG. **15**A, (b) of FIG. **16**C, and (b) of FIG. **17**A, (ii) shows the normalized antenna gain value of the antenna assembly **1000** with the second ground pattern **1140**. (iii) shows the angle-dependent antenna gain values of the antenna assembly **1000***a* without the second ground pattern. (iv) shows the angle-dependent antenna gain values of the antenna assembly **1000** with the second ground pattern **1140**.

Referring to (i) in (b) of FIG. **17**A, the average gain of the antenna assembly **1000***a* without the second ground pattern is approximately −0.91 dB. The antenna gain of the antenna assembly **1000***a* without the second ground pattern is below the target antenna gain of −3 dBi in the regions below −40 degrees and above +40 degrees. Therefore, the second ground pattern **1140** needs to be further formed to meet the target antenna gain of −3 dBi or higher. Referring to (ii) in (b) of FIG. **17**A, the average gain of the antenna assembly **1000** with the second ground pattern **1140** is approximately −0.07 dB. Thus, forming the second ground pattern **1140** in the antenna assembly **1000** improves the average gain by about 0.8 dB or more.

FIG. **17**B illustrates the reflection coefficient and axial ratio characteristics of the vehicle GNSS antenna in FIG. **13**A.(a) of FIG. **17**B shows the reflection coefficient characteristics of the vehicle GNSS antenna. (b) of FIG. **17**B shows the axial ratio characteristics of the vehicle GNSS antenna at different vertical angles relative to the vehicle roof.

Referring to (a) of FIG. **17**B, the antenna assembly exhibits dual resonance at the first frequency in the first frequency band and the second frequency in the second frequency band. The antenna assembly can exhibit dual resonance at 1.57 GHz in the first frequency band and 1.18 GHz in the second frequency band. The antenna assembly has a reflection coefficient below the target value of −10 dB in frequency bands above 1 GHz.

Referring to (b) of FIG. **17**B, the axial ratio is shown at 0, 5, 10, 15, and 20 degrees relative to the vertical direction at 0 degrees toward the vehicle roof. The antenna assembly exhibits first and second minimum values of the axial ratio at the first frequency in the first frequency band and the second frequency in the second frequency band. The axial ratio of the antenna assembly is below 3 dB in the first frequency band and approximately 3 dB in the second frequency band. The antenna assembly can receive circularly polarized signals with a reception level above a certain threshold within a range of −20 degrees to 20 degrees relative to the vehicle roof. Accordingly, the antenna assembly can perform satellite communication within a specified angle range relative to the vehicle roof.

Meanwhile, the dimensions of the conductive patterns in the vehicle GNSS antenna according to this specification are optimized to enhance antenna performance, such as circular polarization performance. In this regard, FIGS. **18**A to **18**C illustrate the axial ratio AR characteristics of circular polarization based on the vertical/horizontal width of the second ground pattern and the gap distance between the first conductive pattern and the ground pattern in the antenna structure of FIG. **13**A. FIGS. **19**A to **19**C illustrate the axial ratio AR characteristics of circular polarization based on the vertical width of the second ground pattern, the gap distance between the first conductive pattern and the ground conductive pattern in the antenna structure of FIG. **13**B.

Meanwhile, the ground conductive pattern **1110***g* in the vehicle GNSS antenna according to this specification may be composed of multiple conductive parts. In this regard, referring to FIGS. **13**A and **13**B, the ground conductive pattern **1110***g* may include a first part **1111***g*, a second part **1112***g*, a third part **1113***g*, and a fourth part **1114***g*.

The first part **1111***g* may be configured to connect to the first ground pattern **1130**. The first part **1111***g* may be configured to connect to one end of the first ground pattern **1130** formed on one side of the signal pattern **1120**. The first part **1111***g* may include an upper region G**1***a* and a lower region G**1***b*.

The second part **1112***g* may be configured to connect to the second ground pattern **1140**. The second part **1112***g* may be configured to connect to the other end of the first ground pattern **1130** formed on the other side of the signal pattern **1120**. The second part **1112***g* may include an upper region G**2***a* and a lower region G**2***b*. A feeding pattern **1110***f* may be formed between the first part **1111***g* and the second part **1112***g* of the ground conductive pattern **1110***g*.

The third part **1113***g* may be configured to connect to the lower region G**1***b* of the first part **1111***g* of the ground conductive pattern **1110***g*. The third part **1113***g* may be configured to be spaced apart from the upper region G**1***a* of the first part **1111***g* of the ground conductive pattern **1110***g* by a predetermined distance.

The fourth part **1114***g* may be configured to connect to the lower region G**2***b* of the second part **1112***g* of the ground conductive pattern **1110***g*. The fourth part **1114***g* may be configured to be spaced apart from the upper region G**2***a* of the second part **1112***g* of the ground conductive pattern **1110***g* by a predetermined distance.

Meanwhile, the width of the third part **1113***g* and the fourth part **1114***g* of the ground conductive pattern **1110***g* may be formed within a predetermined range to maintain a specific gap distance from the adjacent conductive parts. Referring to FIGS. **13**A and **18**A, the width of the third part **1113***g* and the fourth part **1114***g*, which are spaced apart from the upper regions Gla, G2*a* of the first part **1111***g* and the second part **1112***g* of the conductive pattern, may range from 2 mm to 6 mm. In this regard, as the thickness of the lower region of the ground conductive pattern **1110***g*, implemented as FPCB, increases, the overall slot length becomes shorter, causing the lower operating frequency of the axial ratio band to increase. Therefore, in the antenna assembly structure where the ground conductive pattern **1110***g* is connected to the second ground pattern **1130**, the axial ratio in the second frequency band of 1166.2 to 1186.7 MHz can be below the threshold. Accordingly, the axial ratio of the first signal in the first frequency band and the second signal in the second frequency band, both having circular polarization, can be maintained below the threshold, for example, below 6 dB.

Referring to FIG. **13**B and FIG. **19**A, the width of the third part **1113***g* and the fourth part **1114***g*, which are spaced apart from the upper regions G1*a*, G2*a* of the first part **1111***g* and the second part **1112***g*, may be formed to be less than 2 mm. In this context, as the thickness of the lower region of the ground conductive pattern **1110***g* implemented as FPCB increases, the total slot length shortens, which increases the lower frequency of the operating band based on the axial ratio. As a result, in the antenna assembly structure where the ground conductive pattern **1110***g* is separated from the second ground pattern **1130**, the axial ratio in the second frequency band of 1166.2 to 1186.7 MHz can be maintained below the threshold. Therefore, the axial ratio of the first signal in the first frequency band and the second signal in the second frequency band, both having circular polarization, can be maintained below the threshold, for example, below 6 dB.

Meanwhile, the ground conductive pattern **1110***g* may be configured to extend from the lower region to the upper regions on one side and the other side and either connect to the second ground pattern **1140** or be spaced by a certain gap. Referring to FIGS. **13**A and **13**B, the ground conductive pattern **1110***g* may further include a fifth part **1115***g* and a sixth part **1116***g*.

Referring to FIG. **13**A, the fifth part **1115***g* may be configured such that one end connects to the third part **1130***g* of the ground conductive pattern **1110***g*. The other end of the fifth part **1115***g* may connect to the second ground pattern **1140**. The other end of the fifth part **1115***g* may be configured to connect to one end of the second ground pattern **1140** formed on one side of the signal pattern **1120**. The sixth part **1116***g* may be configured to connect one end to the fourth part **1114***g* of the ground conductive pattern **1110***g*. The other end of the sixth part **1116***g* may connect to the second ground pattern **1140**. The sixth part **1116***g* may be configured such that its other end connects to the other end of the second ground pattern **1140** formed on the other side of the signal pattern **1120**.

Referring to FIG. **13**B the fifth part **1115***g* may be configured such that one end connects to the third part **1130***g* of the ground conductive pattern **1110***g*. The other end of the fifth part **1115***g* may be spaced by a first gap G**1** in the vertical direction from the second ground pattern **1140** in the other axial direction. The other end of the fifth part **1115***g* may be spaced by a first gap G**1** from one end of the second ground pattern **1140** formed on one side of the signal pattern **1120**. The sixth part **1116***g* may be configured such that one end connects to the fourth part **1114***g* of the ground conductive pattern **1110***g*. The other end of the sixth part **1116***g* may be spaced by a first gap G**1** from the second ground pattern **1140** in the vertical direction in the other axial direction. The other end of the sixth part **1116***g* may be spaced by a first gap G**1** from the other end of the second ground pattern **1140** formed on the other side of the signal pattern **1120**.

Referring to FIGS. **13**A, **13**B, and **18**B, the width of the second ground pattern **1140** in one axial direction may be formed in the range of 11 mm to 14 mm. This allows the axial ratio of the first signal in the first frequency band and the second signal in the second frequency band, both having circular polarization, to be maintained below the threshold, for example, below 6 dB. Referring to FIG. **13**B and FIG. **19**B, the first gap G**1** may be formed in the range of 1.5 mm to 4.5 mm. In another example, the first gap G**1** may be formed to be less than 1.5 mm. In this context, when the first gap G**1** is 1.5 mm in the antenna structure of FIG. **13**B, the axial ratio can be below 5 dB, and the lower frequency can include 1166.2 MHz. As a result, the axial ratio of the second signal having circular polarization in the second frequency band can be maintained below the threshold, for example, below 6 dB.

Meanwhile, the inner boundary of the second ground pattern **1140** and the outer boundary of the first ground pattern **1130** may be spaced by a second gap G**2** in a horizontal axial direction. Referring to FIG. **13**A and FIG. **18**C, the second gap G**2** may be formed in the range of 3 mm to 6 mm. Meanwhile, referring to FIG. **13**B and FIG. **19**C, the second gap G**2** may be formed to be less than 3 mm. In this regard, as the width of the second ground pattern **1140** increases inward and the second gap G**2** narrows, the lower frequency of the operating band in the second frequency band, based on the axial ratio, decreases.

In the antenna structure of FIG. **13**A, where the ground conductive pattern **1110***g* is connected to the second ground pattern **1130**, if the second gap G**2** is less than 3 mm, the lower frequency decreases, but the axial ratio at the upper frequency increases slightly, up to about 6 dB. Accordingly, referring to FIGS. **13**A and **16**C, the second gap G**2** may be formed in the range of 3 mm to 6 mm. Meanwhile, in the antenna structure of FIG. **13**B, where the ground conductive pattern **1110***g* is separated from the second ground pattern **1130**, if the second gap G**2** is 3 mm, the axial ratio can be below 4 dB, and the lower frequency can include 1166.2 MHz. As a result, referring to FIGS. **13**B and **17**C, the second gap G**2** may be formed to be less than 3 mm.

The second ground pattern **1140** with the second gap G**2** may prevent the first signal radiated by the first slot **1130***s* from leaking to the vehicle glass **310** outside the second ground pattern **1140**. Furthermore, the second ground pattern **1140** with the second gap G**2** may maintain the axial ratio of the second signal having circular polarization in the second frequency band below the threshold, for example, below 6 dB.

Meanwhile, the shapes of the first and second ground patterns **1130**, **1140** of the vehicle GNSS antenna according to this specification may be configured in various ways. In this regard, FIGS. **20**A and **20**B illustrate configurations in which at least a portion of the second ground pattern is segmented. FIGS. **21**A and **21**B show configurations where the second ground pattern is modified into various shapes, such as rectangular, circular, or curved forms.

Referring to FIGS. **13**A, **13**B, **20**A, and **20**B, the upper region of the outer boundary of the first ground pattern **1130** may be configured in a circular shape. Meanwhile, a portion **1141-1** of the upper region and the side region **1142** of the second ground pattern **1140** may be configured as straight lines. In this regard, the inner and outer boundaries of the first portion **1141-1** of the upper region **1141** and the side region **1142** of the second ground pattern **1140** may be configured as straight lines. The inner and outer boundaries of the second portion **1141-2**, the remaining part of the upper region **1141** of the second ground pattern **1140**, may be configured in a curved shape. The second portion **1141-2** of the upper region of the second ground pattern **1140** may be formed to connect the first portion **1141-1** of the upper region and the side region **1142**.

Referring to FIG. **13**A and (a) of FIG. **20**A, the end of the second ground pattern **1140** may be configured to connect to the end of the ground conductive pattern **1110***g*. Meanwhile, referring to FIG. **13**B and (b) of FIG. **20**A, the end of the second ground pattern **1140** may be configured to be spaced from the end of the ground conductive pattern **1110***g*. The end of the second ground pattern **1140** may be configured to be spaced by a first gap G**1** from the end of the ground conductive pattern **1110***g*. Referring to (a) of FIG. **18**B, the side region **1142** of the second ground pattern **1140** may be configured to be spaced by a third gap G**3**. Referring to (b) of FIG. **18**B, the second portion **1141-2** of the upper region of the second ground pattern **1140** may be configured to be spaced by a fourth gap G**4** from the side region **1142**.

Referring to FIGS. **21**A and **21**B, the outer boundary of the upper region **1131** of the first ground pattern **1130** may be configured in a circular shape, as shown in FIGS. **13**A, **13**B, **20**A, and **20**B. Referring to (a) and (b) of FIG. **21**A, the outer boundaries of the upper region **1141***a* and the side region **1142***a* of the second ground pattern **1140** may be configured as straight lines in the first region **1100***a*.

Referring to (a) of FIG. **21**A, a portion of the inner boundary of the upper region **1141***a* of the second ground pattern **1140** may be formed in a circular shape corresponding to the outer boundary of the first ground pattern **1130**. Referring to (b) of FIG. **21**A, the inner boundaries of the upper region **1141***a* and the side region **1141***a* of the second ground pattern **1140** may be formed as straight lines in the first region **1100***a*. Referring to (a) of FIG. **21**B, the outer boundaries of the upper region **1141***b* and the side region **1142***b* of the second ground pattern **1140** may be configured in a circular shape in the first region **1100***a*. Referring to (a) of FIG. **21**B, the outer boundaries of the upper region **1141***c* and the side region **1142***c* of the second ground pattern **1140** may be configured as straight lines in the first region **1100***a*. The middle region **1143***c* of the upper region **1141***c* and the side region **1142***c* may be configured as curves.

Referring to FIGS. **13**B, **20**A, and **20**B, the second ground pattern **1130** of the vehicle GNSS antenna according to this specification may be configured to include multiple sub-patterns with at least a portion separated. The second ground pattern **1140** may be configured to include a first sub-pattern **1141***s*, a second sub-pattern **1142***s*, and a third sub-pattern **1143***s*.

Referring to FIGS. **13**A, **13**B, and **20**A, the first sub-pattern **1141***s* may be configured to either connect to the first ground conductive pattern **1110***g* or be spaced by a first gap G**1**. The second sub-pattern **1142***s* may be configured to either connect to the first ground conductive pattern **1110***g* or be spaced by a first gap G**1**.

Referring to FIG. **20**B, the third sub-pattern **1143***s* of the second ground pattern **1140** may be configured to be spaced by a predetermined gap G**3** from the end of the first sub-pattern **1141***s* and the end of the second sub-pattern **1142***s*. The third sub-pattern **1143***s* of the second ground pattern **1140** may form the upper region of the second ground pattern **1140**. The first sub-pattern **1141***s* and the second sub-pattern **1142***s* may form the side regions of the second ground pattern **1140** and may be configured as straight lines.

Meanwhile, the vehicle GNSS antenna according to this specification may be implemented as a transparent antenna. Additionally, the vehicle GNSS antenna according to this specification may be implemented as a CPW (Coplanar Waveguide) antenna structure with a single-layer configuration. In this regard, FIG. **22** illustrates a structure in which the antenna assembly of FIGS. **13**A and **13**B is implemented with a metal mesh pattern and dummy mesh grid patterns.

Referring to FIGS. **7**A, **13**A, **13**B, and **22**, the signal pattern **1120**, the first ground pattern **1130**, and the second ground pattern **1140** may be formed as a metal mesh pattern **1020***a* on the transparent dielectric substrate **1010***a*, with the inner regions of the mesh interconnected. The metal mesh pattern **1020***a* may be configured to have multiple open areas OA at the inner and outer boundaries. Additionally, the signal pattern **1120**, the first ground pattern **1130**, and the second ground pattern **1140** may be formed as a coplanar waveguide (CPW) structure implemented with a single metal layer on the transparent dielectric substrate **1010***a*.

The antenna assembly **1000** may further include multiple dummy mesh grid patterns **1020***b* in addition to the metal mesh pattern **1020***a*, which forms the radiating element region. The antenna assembly **1000** formed in the first region **1100***a* and the second region **1100***b* may include multiple dummy mesh grid patterns **1020***b*. The dummy mesh grid patterns **1020***b* may be placed on the outer portion of the metal mesh pattern **1020***a* on the transparent dielectric substrate **1010***a*. The multiple dummy mesh grid patterns **1020***b* may be configured not to connect to the feeding pattern **1110***f* or the ground conductive pattern **1110***g*. The multiple dummy mesh grid patterns **1020***b* may be configured to be separated from each other by slits SL.

The multiple dummy mesh grid patterns **1020***b* may be configured to include the first and second dummy grid patterns **1020***b*-**1**, **1020***b*-**2** placed in the regions where the first and second slots **1130***s*, **1140***s* are formed. The first dummy grid patterns **1020***b*-**1** may be placed in the first slot **1130***s*, which is the outer portion of the signal pattern **1120**. The first dummy grid patterns **1020***b*-**1** may be configured to be separated from each other in the horizontal axial direction and the vertical axial direction. The first dummy grid patterns **1020***b*-**1** may be configured to be separated from the boundaries of the signal pattern **1110***f* formed inside and the first ground pattern **1130** formed outside.

The second dummy grid patterns **1020***b*-**2** may be placed in the second slot **1140***s*, which is the outer portion of the first ground pattern **1130**. The second dummy grid patterns **1020***b*-**2** may be configured to be separated from each other in both the horizontal axial direction and the vertical axial direction. The second dummy grid patterns **1020***b*-**2** may be configured to be separated from the boundaries of the first ground conductive pattern **1130** formed inside and the second ground conductive pattern **1140** formed outside.

The above describes an antenna assembly of a transparent antenna structure according to one aspect of this specification. The following will describe a vehicle equipped with a GNSS antenna for vehicles according to another aspect of this specification.

In this context, the conductive patterns of the antenna region forming the antenna assembly in a vehicle equipped with the GNSS antenna according to this specification may be connected in the overlapping areas with the conductive patterns of the feeding structure. In this regard, FIG. **23**A shows the stacked structure of the antenna assembly in FIG. **13**A and FIG. **13**B.

Referring to FIG. **23**A, the antenna assembly of FIG. **13**A and FIG. **13**B may be placed on the vehicle's glass panel

310. For ease of explanation, the stacked structure of FIG. 21C is described based on the antenna assembly of FIG. 13A, but it is not limited to this and can also apply to the antenna assembly of FIG. 13B.

The glass panel **310** may include a transparent area **311** and an opaque area **312**. The first area **1100***a*, corresponding to the antenna region of the antenna assembly **1000**, may be formed in the transparent area **311**. The second area **1100***b*, corresponding to the feeding region of the antenna assembly **1000**, may be formed in the opaque area **312**. The portion of the first area **1100***a* that connects to the feeding pattern **1110***f* of the second area **1100***b* may be placed in the opaque area **312**.

The antenna assembly **1000** may have conductive patterns **1100** formed as a metal mesh layer on a transparent dielectric substrate **1010***a*. The transparent antenna element may be implemented by the conductive patterns **1100** formed in the metal mesh layer. Dummy metal mesh grids, separated from the transparent antenna element, may be placed on the metal mesh layer **1020**. A first protective layer **1031** may be formed over the metal mesh layer **1020**. An adhesive layer (**1040**) may be formed below the transparent dielectric substrate **1010***a*.

The conductive pattern, including the feeding pattern **1110***f* and the ground pattern, may be formed on the second dielectric substrate **1010***b*. The second dielectric substrate **1010***b* may be implemented as FPCB but is not limited to this. A second protective layer **1032** may be formed over the feeding pattern **1110***f*. The second dielectric substrate **1010***b*, the conductive pattern including the feeding pattern **1110***f* and the ground pattern, and the second protective layer (**1032**) may form the feeding structure **1100***f*. The feeding pattern **1110***f* may be connected to the conductive patterns **1100** formed in the metal mesh layer in the bonding area, corresponding to the third area **1100***c*. In the third area **1100***c*, the first connection pattern **1110***c* among the conductive patterns **1100** may be connected to the second connection pattern **1120***c*, which is the end of the feeding pattern **1110***f*.

Meanwhile, the antenna assembly according to this specification may include a first transparent dielectric substrate with a transparent electrode layer and a second dielectric substrate. In this regard, FIG. **23**B shows the process flow for producing an antenna assembly in FIG. **13**A or FIG. **13**B, which is bonded to a glass panel.

Referring to (a) of FIG. **23**B, a first transparent dielectric substrate **1000***a* with a transparent electrode layer may be produced. Also, a second dielectric substrate **1000***b* with a feeding pattern **1120***f* and ground patterns **1121***g*, **1122***g* formed on both sides of the feeding pattern **1120***f* may be produced. The second dielectric substrate **1000***b* may be implemented as FPCB but is not limited to this. Adhesive areas corresponding to the adhesive layer **1041** may be formed on both the first transparent dielectric substrate **1000***a* and the second dielectric substrate **1000***b*. The antenna pattern **1100** of the antenna region **1100***a* in the antenna assembly **1000** of FIG. **13**A or FIG. **13**B may be formed on the first transparent dielectric substrate **1000***a*. The feeding pattern **1100***f* and the ground conductive pattern **1100***g* of the feeding region **1100***b* in the antenna assembly **1000** of FIG. **13**A or FIG. **13**B may be formed on the second dielectric substrate **1000***b*.

Referring to (b) of FIG. **23**B, a glass panel **310** with a transparent area **311** and an opaque area **312** may be produced. Also, the antenna assembly **1000** may be produced by bonding at least one second dielectric substrate **1000***b* to the lower region of the first transparent dielectric substrate **1000***a*. The first transparent dielectric substrate **1000***a* and the second dielectric substrate **1000***b* may be bonded through ACF bonding or low-temperature soldering to form a transparent antenna assembly. This electrically connects the conductive pattern formed on the first transparent dielectric substrate **1000***a* to the conductive pattern formed on the second dielectric substrate **1000***b*. When multiple antenna elements are implemented on the glass panel **310**, the feeding structure **1100***f*, produced with the second dielectric substrate **1000***b*, can also be implemented with multiple feeding structures.

Referring to (c) of FIG. **23**B, the transparent antenna assembly **1000** may be attached to the glass panel **310**. In this regard, the first transparent dielectric substrate **1000***a* with the transparent electrode layer may be placed in the transparent area **311** of the glass panel **310**. Meanwhile, the second dielectric substrate **1000***b*, which is opaque, may be placed in the opaque area **312** of the glass panel **310**.

Referring to (d) of FIG. **23**B, the first transparent dielectric substrate **1000***a* and the second dielectric substrate **1000***b* may be bonded at the first position **P1**. Connector components **313**, such as Fakra cables, may be bonded to the second dielectric substrate **1000***b* at the second position **P2**. The transparent antenna assembly **1000** may be connected to the telematics control unit (TCU) **300** through the connector components **313**. For this purpose, the second conductive pattern formed on the second dielectric substrate **1010***b* may be electrically connected to one connector end of the connector component **313**. The other connector end of the connector component **313** may be electrically connected to the telematics control unit (TCU) **300**.

Meanwhile, the feeding structure **1110***f* of the antenna assembly according to this specification may be placed in an area where the frit pattern **312** of the glass panel **310** is removed. In this regard, FIG. **23**C shows the process flow of the feeding structure of the antenna assembly in FIG. **13**A or FIG. **13**B, which is placed in the opaque area of the glass panel.

The antenna assembly in FIG. **23**C differs structurally from the antenna assembly in FIG. **23**B because the opaque substrate is not produced separately but is integrated into the glass panel **310**. In FIG. **23**C, the feeding structure, implemented as an opaque substrate, is not separately produced as an FPCB but is implemented directly by printing on the glass panel **310**.

Referring to (a) of FIG. **23**C, a first transparent dielectric substrate **1000***a* with a transparent electrode layer may be produced. Also, a glass panel **310** with a transparent area **311** and an opaque area **312** may be produced. During the vehicle glass panel manufacturing process, metal wires/pads may be implemented (fired) for connector connections. A transparent antenna mounting part may be implemented in metal form on the glass panel **310**, similar to the defroster implemented on the vehicle glass. In this regard, a second conductive pattern may be implemented in the area where the adhesive layer **1041** is formed to electrically connect the first conductive pattern of the first transparent dielectric substrate **1000***a*. The antenna pattern **1100** of the antenna region **1100***a* in the antenna assembly **1000** of FIG. **13**A or FIG. **13**B may be formed on the first transparent dielectric substrate **1000***a*. The feeding pattern **1100***f* and the ground conductive pattern **1100***g* of the feeding region **1100***b* in the antenna assembly **1000** of FIG. **13**A or FIG. **13**B may be formed on the second dielectric substrate **1000***b*.

In this regard, the second dielectric substrate **1000***b*, on which the second conductive pattern is formed, may be integrally produced with the glass panel **310**. The second dielectric substrate **1000***b* may be integrally formed with the glass panel **310** in the opaque area **312** of the glass panel **310**. The frit pattern **312** may be removed from the opaque area **312** where the second dielectric substrate **1000***b* is formed. The second conductive pattern may be implemented by forming the feeding pattern **1120***f* and the ground patterns **1121***g*, **1122***g* on both sides of the feeding pattern **1120***f* on the second dielectric substrate **1000***b*.

Referring to (b) of FIG. **23**C, the transparent antenna assembly **1000** may be attached to the glass panel **310**. In this regard, the first transparent dielectric substrate **1000***a* with the transparent electrode layer may be placed in the transparent area **311** of the glass panel **310**. At least one second dielectric substrate **1000***b* may be bonded to the lower region of the first transparent dielectric substrate **1000***a*, forming the antenna assembly **1000**. The first transparent dielectric substrate **1000***a* and the second dielectric substrate **1000***b* may be bonded through ACF bonding or low-temperature soldering to form the transparent antenna assembly. This electrically connects the first conductive pattern formed on the first transparent dielectric substrate **1000***a* to the second conductive pattern formed on the second dielectric substrate **1000***b*. When multiple antenna elements are implemented on the glass panel **310**, the feeding structure **1100***f* produced from the second dielectric substrate **1000***b* can also be implemented with multiple feeding structures.

Referring to (c) of FIG. **23**C, the first transparent dielectric substrate **1000***a* and the second dielectric substrate **1000***b* may be bonded at the first position P**1**. Connector components **313**, such as Fakra cables, may be bonded to the second dielectric substrate **1000***b* at the second position P**2**. The transparent antenna assembly **1000** may be connected to the telematics control unit (TCU) **300** through the connector components **313**. For this purpose, the second conductive pattern formed on the second dielectric substrate **1010***b* may be electrically connected to one connector end of the connector component **313**. The other connector end of the connector component **313** may be electrically connected to the telematics control unit (TCU) **300**.

Referring to FIGS. **1** to **23**C, a vehicle equipped with an antenna assembly of a transparent antenna structure according to this specification is described. The antenna assembly **1000** may be a vehicle GNSS antenna. The vehicle may include a glass panel **310** and the antenna assembly **1000**. The glass panel **310** may include a transparent area **311** and an opaque area **312**. The antenna assembly **1000** may be placed on the glass panel **310**.

The antenna assembly **1000** may include a first transparent dielectric substrate **1010***a*, an antenna pattern **1100**, a connection pattern **1100***c*, and a second dielectric substrate **1010***b*. The antenna assembly **1000** may further include the ground conductive pattern **1110***g* and feeding pattern **1110***f* formed on the second dielectric substrate **1010***b*.

The first transparent dielectric substrate **1010***a* may be placed in the transparent area **311** of the glass panel **310**. The antenna pattern **1100** may be placed in the first area on one side of the first transparent dielectric substrate **1010***a* and may be configured to radiate a wireless signal in the GNSS or GPS band. The first area **1100***a* on one side of the first transparent dielectric substrate **1010***a* may be placed in the transparent area **311** of the glass panel **310**.

The connection pattern **1100***c* may be configured to connect the antenna pattern **1100** to the feeding pattern **1110***f*. The connection pattern **1100***c* may include the first connection pattern **1110***c*, which is the end of the antenna pattern **1100**, and the second connection pattern (**1120***c*), which is the end of the feeding pattern **1110***f*. The connection pattern **1100***c* may be placed in the second area **1100***b* on one side of the first transparent dielectric substrate **1010***a* or the second dielectric substrate **1010***b*. The second area **1100***b* on one side of the first transparent dielectric substrate **1010***a* may be placed in the opaque area **312** of the glass panel **310**.

The second dielectric substrate **1010***b* may be placed in the opaque area **312** of the glass panel **310**. The ground conductive pattern **1110***g* and the feeding pattern **1110***f* may be placed in the second area **1100***b* on one side of the second dielectric substrate **1010***b*.

The antenna pattern **1100** may include the signal pattern **1120**, the first ground pattern **1130**, the first slot **1130***s*, the second ground pattern **1140**, and the second slot **1140***s*. The signal pattern **1120** may be connected to the feeding pattern **1110***f* in the second area **1100***b*. The first ground pattern **1130** may be connected to the ground conductive pattern **1110***g* in the second area **1100***b*. The first slot **1130***s* may be formed between the signal pattern **1120** and the first ground pattern **1130**. The first slot **1130***s* may be configured to radiate a first signal having circular polarization in the first frequency band.

The second ground pattern **1140** may be connected to the ground conductive pattern **1110***g* in the second area **1100***a* and may be configured to surround the first ground pattern **1130**. The second slot **1140***s* may be formed between the first ground pattern **1130** and the second ground pattern **1140**. The second slot **1140***s* may be configured to radiate a second signal having circular polarization in a second frequency band lower than the first frequency band. The length of the second slot **1140***s*, formed inside the second ground pattern **1140**, may be configured to be between ¾ and one wavelength corresponding to the operating frequency within the second frequency band. The second ground pattern **1140** may be formed to surround the first ground pattern **1130**, preventing the first signal radiated by the first slot **1130***s* from leaking through the vehicle's glass **310** outside the second ground pattern **1140**. Additionally, the second ground pattern **1140**, formed to surround the first ground pattern **1130**, may allow the radiation patterns of the first signal in the first frequency band and the second signal in the second frequency band to be directed toward the vehicle's roof.

The first ground pattern **1130** may have at least part of its outer boundary formed in a circular shape. The diameter of the outer boundary of the first ground pattern **1130** may be configured between ¼ and ½ of the wavelength corresponding to the operating frequency in the first frequency band. The first portion **1131** of the inner boundary of the first ground pattern **1130** may be formed in a circular shape. The second portion **1132** of the inner boundary of the first ground pattern **1130** may be formed with straight lines in both axial directions. The first ground pattern **1130** may be formed with a first width Wi in one axial direction and a second width W**2** narrower than the first width W**1**.

The ground conductive pattern **1110***f* may be configured to include the first portion **1111***g*, the second portion **1112***g*, the third portion **1113***g*, and the fourth portion **1114***g*.

The first portion **1111***g* may be configured to connect to the first ground pattern **1130**. The first portion **1111***g* may be configured to connect to one end of the first ground pattern **1130** formed on one side of the signal pattern **1120**. The first portion **1111***g* may be configured to have an upper region G**1***a* and a lower region G**1***b*.

The second portion **1112***g* may be configured to connect to the second ground pattern **110**. The second portion **1112***g* may be configured to connect to the other end of the first ground pattern **1130** formed on the other side of the signal pattern **1120**. The second portion **1112***g* may be configured to have an upper region G2*a* and a lower region G2*b*. The feeding pattern **1110***f* may be formed between the first portion **1111***g* and the second portion **1112***g* of the ground conductive pattern **1110***g*.

The third portion **1113***g* may be configured to connect to the lower region G1*b* of the first portion **1111***g* of the ground conductive pattern **1110***g*. The third portion **1113***g* may be configured to be spaced from the upper region G1*a* of the first portion **1111***g* of the ground conductive pattern **1110***g* by a predetermined distance.

The fourth portion **1114***g* may be configured to connect to the lower region G2*b* of the second portion **1112***g* of the ground conductive pattern **1110***g*. The fourth portion **1114***g* may be configured to be spaced from the upper region G2*a* of the second portion **1112***g* of the ground conductive pattern **1110***g* by a predetermined distance. The width of the third portion **1113***g* and the fourth portion **1114***g*, spaced from the upper regions G1*a*, G2*a* of the first portion **1111***g* and the second portion **1112***g*, respectively, may be configured to be in the range of 2 mm to 6 mm. Accordingly, the axial ratio of the first signal in the first frequency band having circular polarization and the second signal in the second frequency band may be maintained below a threshold, for example, 6 dB.

The ground conductive pattern **1110***g* may be configured to further include the fifth portion **1115***g* and the sixth portion **1116***g*. The fifth portion **1115***g* may be configured to connect one end to the third portion **1130***g* of the ground conductive pattern **1110***g*. The fifth portion **1115***g* may be configured to connect the other end to the second ground pattern **1140** or to be spaced apart by the first gap G**1**. The fifth portion **1115***g* may be configured to connect the other end to one end of the second ground pattern **1140** formed on one side of the signal pattern **1120** or to be spaced apart by the first gap G**1**. The sixth portion **1116***g* may be configured to connect one end to the fourth portion **1114***g* of the ground conductive pattern **1110***g*. The sixth portion **1116***g* may be configured to connect the other end to the second ground pattern **1140** or to be spaced apart by the first gap G**1**. The sixth portion **1116***g* may be configured to connect the other end to the other end of the second ground pattern **1140** formed on the other side of the signal pattern **1120** or to be spaced apart by the first gap G**1**. The first gap may be configured to be in the range of 1.5 mm to 4.5 mm. Accordingly, the axial ratio of the second signal in the second frequency band having circular polarization may be maintained below a threshold, for example, 6 dB.

Meanwhile, the width of the second ground pattern **1140** in one axial direction may be configured to be in the range of 11 mm to 14 mm. Accordingly, the axial ratio of the first signal in the first frequency band having circular polarization and the second signal in the second frequency band may be maintained below a threshold, for example, 6 dB. The inner boundary of the second ground pattern **1140** and the outer boundary of the first ground pattern **1130** may be configured to be spaced apart by the second gap G**2** in the horizontal axial direction. The second gap G**2** may be configured to be in the range of 3 mm to 6 mm. The second ground pattern **1140**, with the second gap G**2**, may prevent the first signal radiated by the first slot **1130***s* from leaking outside the second ground pattern **1140** through the vehicle's glass **310**. Additionally, the second ground pattern **1140**, with the second gap G**2**, may maintain the axial ratio of the second signal having circular polarization in the second frequency band below a threshold, for example, 6 dB.

The following describes a vehicle equipped with an antenna module according to one aspect of this specification. In this regard, FIG. **24** shows a configuration in which multiple antenna modules are placed in different positions of the vehicle and combined with other components of the vehicle.

Referring to FIGS. **1** to **24**, the vehicle **500** may be equipped with a conductive vehicle body that operates as an electrical ground. The vehicle **500** may be equipped with multiple antennas **1100***a* to **1100***d*, which may be placed in different locations on the glass panel **310**. The antenna assembly **1000** may be configured to include a communication module **300** along with the multiple antennas **1100***a* to **1100***d*. The communication module **300** may include a transceiver circuit **1250** and a processor **1400**. The communication module **300** may correspond to the TCU of the vehicle or form at least part of the TCU.

The vehicle **500** may include an object detection device **520** and a navigation system **550**. The vehicle **500** may also include a separate processor **570** in addition to the processor **1400** included in the communication module **300**. The processor **1400** and the separate processor **570** may be physically or functionally separated and implemented on a single substrate. The processor **1400** may be implemented as a TCU, and the processor **570** may be implemented as an ECU (Electronic Control Unit).

If the vehicle **500** is an autonomous vehicle, the processor **570** may be an Autonomous Driving Control Unit (ADCU), which integrates the ECU. Based on information detected by the camera **531**, radar **532**, and/or lidar **533**, the processor **570** may navigate the route and control the acceleration or deceleration of the vehicle **500**. For this purpose, the processor **570** may interact with the processor **530**, corresponding to the MCU in the object detection device **520**, and/or the communication module **300**, corresponding to the TCU.

The vehicle **500** may include the first transparent dielectric substrate **1010***a* and the second dielectric substrate **1010***b* placed on the glass panel **310**. The first transparent dielectric substrate **1010***a* may be formed inside the vehicle's glass panel **310** or attached to the surface of the glass panel **310**. The first transparent dielectric substrate **1010***a* may be configured to form conductive patterns in the shape of a metal mesh grid. The vehicle **500** may include an antenna module **1100** with conductive patterns formed in the shape of a metal mesh to radiate wireless signals on one side of the dielectric substrate **1010**.

The antenna assembly **1000** may include the first antenna module **1100***a* to the fourth antenna module **1100***d* to perform multiple-input and multiple-output (MIMO). The first antenna module **1100***a*, the second antenna module **1100***b*, the third antenna module **1100***c*, and the fourth antenna module **1100***d* may be placed at the upper left, lower left, upper right, and lower right of the glass panel **310**, respectively. The first antenna module **1100***a* to the fourth antenna module **1100***d* may be referred to as the first antenna ANT**1** to the fourth antenna ANT**4**, respectively. The first antenna ANT**1** to the fourth antenna ANT**4** may be configured to radiate signals in the 4G and 5G frequency bands to perform 4G wireless communication and 5G wireless communication. At least one of the first antenna ANT**1** to the fourth antenna ANT**4** may be configured as a GNSS antenna for vehicles to radiate signals in the first frequency band (L1 band) and the second frequency band (L5 band).

As described above, the vehicle **500** may include a telematics control unit (TCU) **300** as the communication module. The TCU **300** may control the reception and transmission of signals through at least one of the first to fourth antenna modules **1100***a* to **1100***d*. The TCU **300** may be configured to include a transceiver circuit **1250** and a baseband processor **1400**.

Accordingly, the vehicle may be configured to include a transceiver circuit **1250** and a processor **1400**. Part of the transceiver circuit **1250** may be placed in the antenna module or a combination of these units. The transceiver circuit **1250** may control the wireless signals in at least one of the first frequency band to the third frequency band to be radiated through the antenna modules ANT**1** to ANT**4**. The first to third frequency bands may be the low band (LB), mid band (MB), and high band (HB) for 4G/5G wireless communication, but they are not limited to this.

The processor **1400** may be operably coupled to the transceiver circuit **1250** and configured as a modem operating in the baseband. The processor **1400** may be configured to receive or transmit signals through at least one of the first antenna module ANT**1** and the second antenna module ANT**2**. The processor **1400** may perform diversity operation or MIMO operation using the first antenna module ANT**1** and the second antenna module ANT**2** to deliver signals inside the vehicle.

The antenna modules may be placed in different areas on one side and the other side of the glass panel **310**. The antenna modules may simultaneously receive signals from the vehicle's front direction to perform multiple-input and multiple-output (MIMO). In this regard, the antenna modules may include the third antenna module ANT**3** and the fourth antenna module ANT**4** in addition to the first antenna module ANT**1** and the second antenna module ANT**2** to perform 4×4 MIMO.

The processor **1400** may be configured to select the antenna module to communicate with the corresponding entity based on the driving route of the vehicle and the communication route with the entity communicating with the vehicle. The processor **1400** may perform MIMO operation using the first antenna module ANT**1** and the second antenna module ANT**2** based on the driving direction of the vehicle. Alternatively, the processor **1400** may perform MIMO operation using the third antenna module ANT**3** and the second antenna module ANT**4** based on the driving direction of the vehicle.

The processor **1400** may perform multiple-input and multiple-output (MIMO) in the first band through at least two antennas among the first antenna ANT**1** to the fourth antenna ANT**4**. The processor **1400** may perform MIMO in the second and third bands through at least two antennas among the first antenna ANT**1** to the fourth antenna ANT**4**.

Accordingly, if signal transmission/reception performance in the vehicle is degraded in one band, signal transmission/reception in the vehicle may be enabled through another band. For example, the vehicle may preferentially perform communication connections in the low band, the first band, for wide communication coverage and connection reliability, and then perform communication connections in the second and third bands.

The processor **1400** may control the transceiver circuit **1250** to perform carrier aggregation (CA) or dual connectivity (DC) through at least one of the first antenna ANT**1** to the fourth antenna ANT**4**. In this regard, communication capacity may be expanded through the aggregation of the second and third bands, which are wider than the first band. Additionally, communication reliability may be improved through dual connectivity with surrounding vehicles or entities using multiple antenna elements placed in different areas of the vehicle.

The above describes a broadband transparent antenna assembly that can be placed on vehicle glass and a vehicle equipped with it. The technical effects of such a broadband transparent antenna assembly that can be placed on vehicle glass and the vehicle are as follows.

According to this specification, the GNSS antenna, placed in a specific area of the vehicle glass, can operate in dual bands by forming a dual-slot structure.

According to this specification, the circular polarization characteristics in dual bands can be improved through the dual-slot structure and optimization of the conductive patterns of the GNSS antenna placed in a specific area of the vehicle glass.

According to this specification, the conductive pattern functioning as a radiator of the GNSS antenna operating in circular polarization in dual bands and the ground conductive pattern can be implemented on a single layer.

According to this specification, when a GNSS antenna implemented as a transparent antenna is attached to the vehicle glass, the transparent substrate and the opaque substrate can be placed in the transparent and opaque areas of the vehicle glass, respectively, to minimize changes in the antenna characteristics caused by the vehicle glass.

According to this specification, when a GNSS antenna implemented as a transparent antenna is attached to the vehicle glass, the dummy metal mesh lattice structure can enhance invisibility, making the antenna pattern indistinguishable to the naked eye.

According to this specification, a GNSS antenna structure can be provided that reduces the influence of vehicle glass through a transparent material while also operating in circular polarization in dual bands with a single-layer structure to perform satellite communication.

The additional scope of applicability of this specification will become apparent from the detailed description provided below. However, various modifications and changes within the spirit and scope of this specification will be readily apparent to those skilled in the art, and thus, specific embodiments such as the detailed description and preferred embodiments of this specification should be understood as illustrative rather than limiting.

With respect to this specification, the design and operation of a vehicle equipped with an antenna assembly that includes a transparent antenna, as well as its control, can be implemented as computer-readable code on a recorded medium. The computer-readable medium includes any type of storage device in which data readable by a computer system is stored. Examples of computer-readable media include HDD (Hard Disk Drive), SSD (Solid State Disk), SDD (Silicon Disk Drive), ROM, RAM, CD-ROM, magnetic tape, floppy disk, optical data storage devices, and also forms implemented as carrier waves (such as transmissions over the internet). Additionally, the computer may include a control unit of the terminal. Therefore, the above detailed description should be considered illustrative rather than restrictive in all respects. The scope of this specification should be determined by reasonable interpretation of the appended claims, and all modifications within the equivalent scope of this specification are included in its scope.

The invention claimed is:

1. A glass assembly comprising:

a transparent area;

an opaque area formed outer to the transparent area; and

an antenna assembly disposed at the glass assembly,

wherein the antenna assembly comprises:

a first transparent dielectric substrate;

an antenna pattern disposed in a first area of the first transparent dielectric substrate that is disposed in the transparent area of the glass assembly;

a connection pattern connected to the antenna pattern and disposed in a second area of the first transparent dielectric substrate that is disposed in the opaque area of the glass assembly; and

a second dielectric substrate disposed in the opaque area of the glass assembly,

wherein the second dielectric substrate comprises a ground conductive pattern and a feed pattern,

wherein the antenna pattern comprises:

a signal pattern connected to the feed pattern of the second dielectric substrate and a first ground pattern connected to the ground conductive pattern of the second dielectric substrate, to form a first slot between the signal pattern and the first ground pattern, the first slot configured to radiate a first signal having circular polarization in a first frequency band; and

a second ground pattern connected to the ground conductive pattern of the second dielectric substrate to form a second slot between the first ground pattern and the second ground pattern, the second slot configured to radiate a second signal having circular polarization in a second frequency band lower than the first frequency band,

wherein the second ground pattern is configured to surround the first ground pattern.

2. The glass assembly of claim **1**, wherein at least a portion of an outer boundary of the first ground pattern is formed in a circular shape, and

wherein a diameter of the outer boundary of the first ground pattern is in a range between ¼ and ½ of a wavelength corresponding to the first frequency band.

3. The glass assembly of claim **1**, wherein a first portion of an inner boundary of the first ground pattern is formed in a circular shape,

wherein a second portion of the inner boundary of the first ground pattern is formed with straight lines in a first direction and a second direction, and

wherein the first ground pattern is formed with a first width in the first direction and a second width in the first direction narrower than the first width.

4. The glass assembly of claim **1**, wherein a width of the second ground pattern in one direction is in a range of 11 mm to 14 mm.

5. The glass assembly of claim **1**, wherein a second gap between an inner boundary of the second ground pattern and an outer boundary of the first ground pattern is in a range of 3 mm to 6 mm.

6. The glass assembly of claim **1**, wherein a portion of an outer boundary of the first ground pattern is formed in a circular shape, and

wherein a portion of an inner boundary of the second ground pattern is formed with straight lines.

7. The glass assembly of claim **6**, wherein a portion of an outer boundary of the second ground pattern is formed with straight lines.

8. The glass assembly of claim **1**, wherein the ground conductive pattern comprises:

a first portion connected to a first end of the first ground pattern; and

a second portion connected to a second end of the first ground pattern,

wherein the feed pattern is formed between the first portion and the second portion of the ground conductive pattern.

9. The glass assembly of claim **8**, wherein the ground conductive pattern further comprises:

a third portion connected to the first portion of the ground conductive pattern; and

a fourth portion connected to the second portion of the ground conductive pattern,

wherein the third portion and the fourth portion of the ground conductive pattern form an outer boundary of the antenna assembly.

10. The glass assembly of claim **9**, wherein the ground conductive pattern further comprises:

a fifth portion connected to the fourth portion of the ground conductive pattern and a first end of the second ground pattern; and

a sixth portion connected to the third portion of the ground conductive pattern and a second end of the second ground pattern,

wherein the fifth portion and the sixth portion of the ground conductive pattern further form the outer boundary of the antenna assembly.

11. The glass assembly of claim **1**, wherein the antenna pattern is formed as a metal mesh structure,

wherein the antenna assembly further comprises dummy mesh grid patterns,

wherein the dummy mesh grid patterns are disposed in the first area of the first transparent dielectric substrate, and

wherein the dummy mesh grid patterns include:

first dummy mesh grid patterns disposed in the first slot; and

second dummy mesh grid patterns disposed in the second slot.

12. A glass assembly comprising:

a transparent area;

an opaque area formed outer to the transparent area; and

an antenna assembly disposed at the glass assembly,

wherein the antenna assembly comprises:

a first transparent dielectric substrate disposed at the transparent area of the glass assembly;

an antenna pattern disposed in a first area of the first transparent dielectric substrate that is disposed in the transparent area of the glass assembly;

a connection pattern connected to the antenna pattern and disposed in a second area of the first transparent dielectric substrate that is disposed in the opaque area of the glass assembly; and

a second dielectric substrate disposed in the opaque area of the glass assembly,

wherein the second dielectric substrate comprises a ground conductive pattern and a feed pattern,

wherein the antenna pattern comprises:

a signal pattern connected to the feed pattern of the second dielectric substrate and a first ground pattern connected to the ground conductive pattern of the second dielectric substrate to form a first slot between the signal pattern and the first ground pattern, the first slot configured to radiate a first signal having circular polarization in a first frequency band;

a second ground pattern electrically connected to the ground conductive pattern and spaced apart from the ground conductive pattern of the second dielectric substrate to form a second slot between the first ground pattern and second ground pattern, the second slot configured to radiate a second signal having circular polarization in a second frequency band lower than the first frequency band,

wherein the second ground pattern is configured to surround the first ground pattern.

13. The glass assembly of claim **12**, wherein the ground conductive pattern comprises:

a first portion connected to a first end of the first ground pattern; and

a second portion connected to a second end of the first ground pattern,

wherein feed pattern is formed between the first portion and the second portion of the ground conductive pattern.

14. The glass assembly of claim **13**, wherein the ground conductive pattern comprises:

a third portion connected to the first portion of the ground conductive pattern; and

a fourth portion connected to the second portion of the ground conductive pattern,

wherein the third portion and the fourth portion of the ground conductive pattern form an outer boundary of the antenna assembly.

15. The glass assembly of claim **14**, wherein the ground conductive pattern further comprises:

a fifth portion connected to the fourth portion of the ground conductive pattern and spaced apart from a first end of the second ground pattern by a first gap; and

a sixth portion connected to the third portion of the ground conductive pattern and spaced apart from a second end of the second ground pattern by another first gap,

wherein the first gap is formed within a range of 1.5 mm or less.

16. The glass assembly of claim **15**, wherein both sides of the second ground pattern each comprises a third gap.

17. The glass assembly of claim **12**, wherein at least a portion of an outer boundary of the first ground pattern is formed in a circular shape, and

wherein a diameter of the outer boundary of the first ground pattern is in a range between ¼ and ½ of a wavelength corresponding to the first frequency band.

18. The glass assembly of claim **12**, wherein a first portion of an inner boundary of the first ground pattern is formed in a circular shape,

wherein a second portion of the inner boundary of the first ground pattern is formed with straight lines, and

wherein the first ground pattern is formed with a first width and a second width that is narrower than the first width.

19. The glass assembly of claim **12**, wherein a width of the second ground pattern is formed within a range of 11 mm to 14 mm.

20. The glass assembly of claim **12**, wherein the antenna pattern is formed as a metal mesh structure,

wherein the antenna assembly further comprises dummy mesh grid patterns,

wherein the dummy mesh grid patterns are disposed in the first area of the first transparent dielectric substrate, and

wherein the dummy mesh grid patterns include:

first dummy mesh grid patterns disposed in the first slot and

second dummy mesh grid patterns disposed in the second slot.

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