(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 546 564 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
30.04.2025 Bulletin 2025/18

(21) Application number: **23206476.6**

(22) Date of filing: **27.10.2023**

(51) International Patent Classification (IPC):
H01Q 1/32 *(2006.01)* ***H01Q 21/28*** *(2006.01)*
H01Q 9/42 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
H01Q 1/3275; H01Q 21/28; H01Q 5/378; H01Q 5/50; H01Q 9/42

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(71) Applicant: **Valeo Comfort and Driving Assistance**
94000 Créteil (FR)

(72) Inventors:
- **JAFARI, Ahmadreza**
94000 Créteil (FR)
- **AKBARPOUR, Alireza**
94000 Créteil (FR)
- **ATMATZAKIS, Georgios**
94000 Créteil (FR)
- **LAHTI, Saku**
94000 Créteil (FR)
- **LUOMANIEMI, Rasmus**
94000 Créteil (FR)
- **KORMILAINEN, Riku**
94000 Créteil (FR)

(74) Representative: **Delplanque, Arnaud**
Valeo Comfort and Driving Assistance
6 rue Daniel Costantini
94000 Créteil (FR)

(54) A FULL BAND CELLULAR ANTENNA

(57) It is provided a vehicle telematic control unit comprising a printed circuit board having an elongated shape with a first extremity and a second extremity. The TCU further comprises a first cellular full band antenna mounted over the first extremity of the PCB, a second cellular full band antenna mounted over the second extremity of the PCB, and a first cellular middle/high band antenna and a second cellular middle/high band antenna mounted between the first cellular full band antenna and the second cellular full band antenna.

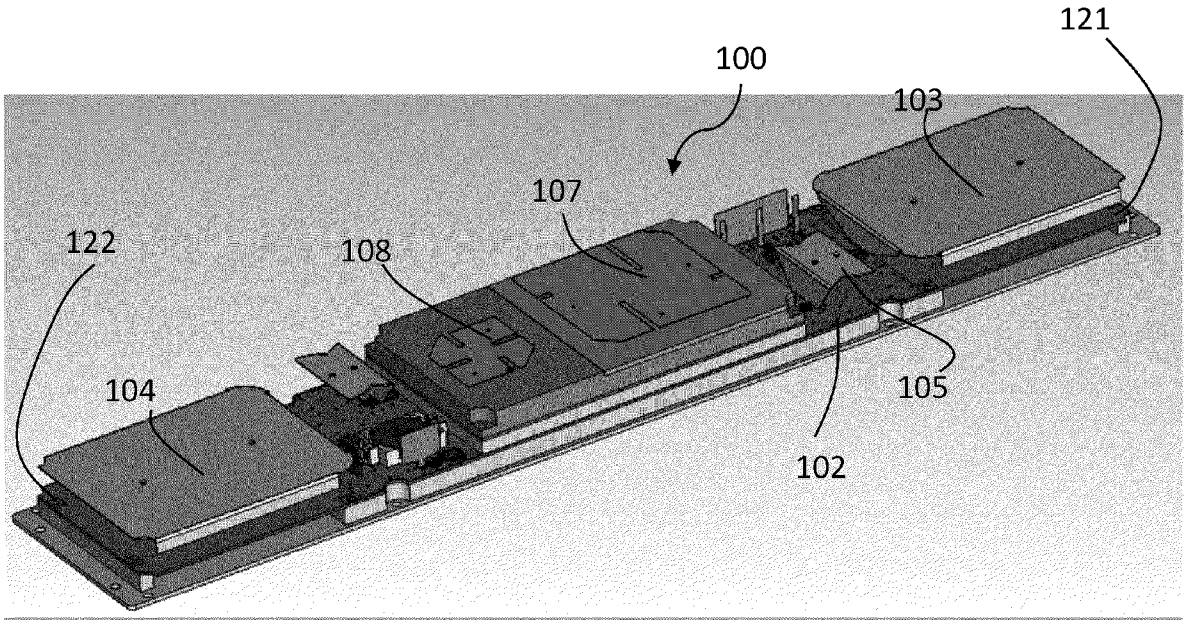

FIG. 2

EP 4 546 564 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to the field of antennas, and more specifically to full band cellular antennas of a vehicle telematic control unit. It is also related to a TCU comprising said antenna, and a vehicle comprising said TCU.

TECHNICAL BACKGROUND

[0002] Various types of antennas are used in the automotive industry to implement various applications (radio, navigation, or telephony). Multiband antenna systems are also commonly used in the automotive industry. Such an antenna system includes a small number of antennas to cover and operate at multiple frequency ranges and/or for redundancy reasons.

[0003] An antenna system can be installed on the roof surface of a vehicle to let the antennas have an unobstructed view overhead. This antenna system is generally connected to one or more electronic devices (e.g., a cellular phone) inside the passenger compartment of the vehicle, such that the antenna system is operable for transmitting and/or receiving signals to/from the electronic device inside the vehicle.

[0004] The role of the Telematics Control Unit (TCU) in a car is to control wireless tracking, diagnostics and communication to and from the vehicle using such an antenna system. Typically a TCU is embedded onboard on a vehicle.

[0005] TCUs are becoming more and more limited in space so as to satisfy vehicle design requirements. Electronic vehicle components for the TCU therefore need to become as small as possible to satisfy the vehicle manufacturing design requirements and fit the necessary amount of components within the TCU.

[0006] Within this context, there is a need for an improved vehicle TCU.

SUMMARY

[0007] It is therefore provided a vehicle telematic control unit (TCU) comprising a printed circuit board (PCB) having an elongated shape with a first extremity and a second extremity. The TCU further comprises a first cellular full band antenna mounted over the first extremity of the PCB, and a second cellular full band antenna mounted over the second extremity of the PCB. The TCU further comprises a first cellular middle/high band antenna and a second cellular middle/high band antenna mounted between the first cellular full band antenna and the second cellular full band antenna.

[0008] The TCU may comprise one or more of the following features:

- having a height less than 30mm, preferably less than 25mm, and more preferably less than 22mm;
- each of the first cellular full band antenna, a second cellular full band antenna, the first cellular middle/-high band antenna, and/or the second cellular middle/high band antenna is a monopole broadband metal stamp antenna;
- each of the first cellular full band antenna, a second cellular full band antenna, the first cellular middle/-high band antenna, and/or the second cellular middle/high band antenna is mounted on a same plane parallel to the PCB;
- each of the first cellular full band antenna and the second cellular full band antenna covers cellular dedicated bands from 0.6GHz to 5GHz;
- each of the first cellular middle/high band antenna and the second cellular middle/high band antenna covers cellular dedicated bands from 1.4GHz to 5GHz;
- the first cellular middle/high band antenna and/or the second cellular middle/high band has an effective height less than 15mm or preferably less than 13mm;
- the first cellular full band antenna and/or the second cellular full band has an effective height less than 20mm or preferably less than 18mm;
- each of the first cellular full band antenna and the second cellular full band antenna comprises a low band element and a high band element, the low band element and the high band element being coupled capacitively to each other;
- further comprising an adapter connected to a feed point of each of the first cellular full band antenna and the second cellular full band antenna; wherein the adapter comprises a first adaptive matching circuit configured to be electrically connected to the first cellular full band antenna, and a second adaptive matching circuit configured to be electrically connected to the second cellular full band antenna; and/or
- further comprising a controller, the controller being configured to tune a matching frequency of the first/-second adaptive matching circuit to a given frequency.

[0009] It is therefore provided a vehicle comprising the TCU.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Non-limiting examples will now be described in reference to the accompanying drawings, where:

FIG.s 1-10 present examples of the TCU; and
FIG.s 11-15 present simulation/test results on examples of the TCU.

DETAILED DESCRIPTION

[0011] It is provided a vehicle telematic control unit

(TCU) comprising a printed circuit board (PCB), a first cellular full band antenna, and a second cellular full band antenna. The PCB has an elongated shape with a first extremity and a second extremity. The first cellular full band antenna is mounted over the first extremity (121) of the PCB. The second cellular full band antenna is mounted over the second extremity of the PCB. The TCU further comprises a first cellular middle/high band antenna and a second cellular middle/high band antenna. The first cellular middle/high band antenna and the second cellular middle/high band antenna are (each/-both) mounted between the first cellular full band antenna and the second cellular full band antenna.

[0012] Such an arrangement provides an improved solution in TCU design by enabling the integration of two full band antennas in a compact low height profile (i.e., side view). This facilitates the application of such TCUs in modern vehicles, for example a terrestrial vehicle such as an automobile, a motorcycle, or a truck.

[0013] As known, any antenna herein is an interface between radio waves propagating through space and electric currents moving in metal conductors, used with a transmitter or receiver. In transmission, a radio transmitter may supply an electric current to the terminals of the antenna, and the antenna may radiate the energy from the current as electromagnetic waves (radio waves). In reception, the antenna may intercept some of the power of a radio wave in order to produce an electric current at its terminals, that is applied to a receiver to be amplified.

[0014] As known, a TCU in the automobile industry such as the TCU herein is an embedded system on board of a vehicle that wirelessly connects the vehicle to cloud services or other vehicles over a cellular network. The TCU collects telemetry data from the vehicle, such as position, speed, engine data, connectivity quality, etc., from various sub-systems over data and control busses. The TCU has a main printed circuit board (PCB) on which a plurality of elements, antennas, sensors, controllers, or busses may be mounted. A TCU comprising the antenna system is particularly suitable for being installed inside a vehicle, such as a car. For example, the TCU may be installed inside the dashboard of the car or under the roof (e.g., between the cross member and the roof).

[0015] As known, a PCB such as the PCB herein is a medium used to connect electronic components to one another in a controlled manner. The PCB is in the form of a laminated sandwich structure of conductive and insulating layers: each of the conductive layers is designed with a pattern of traces, planes and/or other features, etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate. Electrical components may be fixed to conductive pads on the outer layers in the shape designed to accept the component's terminals, generally by means of soldering, to both electrically connect and mechanically fasten them to the PCB. Additionally or alternatively, connections may be made using vias (plated-through holes that allow interconnections between layers).

[0016] It is also provided a vehicle comprising the TCU.

[0017] Examples of the TCU are now discussed.

[0018] The dimensions of the TCU may be small enough to be installable inside a vehicle, for example inside the dashboard or the body, or under the roof (e.g., between the cross member and the roof). The TCU of claim may have a height less than 30mm, preferably less than 25mm, and more preferably less than 22mm. The height may be referred to as a thickness of said antenna. Such a small height/thickness makes the TCU perfectly employable in modern vehicles.

[0019] In examples, each of the first cellular middle/-high band antenna and the second cellular middle/high band may have an effective height less than 15mm or preferably less than 13mm. Alternatively or additionally, each of the first cellular full band antenna and the second cellular full band may have an effective height less than 20mm or preferably less than 18mm. As known in the field, by an effective height it is meant a distance between the lower part of the antenna to the (main) PCB ground or to the metal structure. Examples of said effective height for a full band antenna and a middle/high band antenna are discussed later in reference to figures.

[0020] In examples, each of the first cellular full band antenna, a second cellular full band antenna, the first cellular middle/high band antenna, and/or the second cellular middle/high band antenna may be a monopole broadband metal stamp antenna.

[0021] Each of the first cellular full band antenna, a second cellular full band antenna, the first cellular middle/high band antenna, and/or the second cellular middle/high band antenna may be mounted on a same plane parallel to the (main) PCB.

[0022] Each antenna in the TCU may be responsible for a specified range of frequencies. In examples, each of the first cellular full band antenna and the second cellular full band antenna covers cellular dedicated bands from 0.6GHz to 5GHz. Alternatively or additionally, each of the first cellular middle/high band antenna and the second cellular middle/high band antenna covers cellular dedicated bands from 1.4GHz to 5GHz.

[0023] According to a first example configuration, each of the first cellular full band antenna and the second cellular full band antenna may comprise a low band element and a high band element. The low band element and the high band element may be coupled capacitively to each other.

[0024] According to a second configuration, which is combinable with the first example configuration, the TCU may further comprise an adapter connected to a feed point of each of the first cellular full band antenna and the second cellular full band antenna. The adapter may be, for example, connected to each of said feed points electrically. The adapter may comprise a first adaptive matching circuit configured to be electrically connected to the first cellular full band antenna, and a second adaptive

matching circuit configured to be electrically connected to the second cellular full band antenna. As known, an adaptive matching circuit comprises digitally tunable capacitors.

[0025] In such second configurations, the TCU may further comprise a controller, the controller being configured to tune a matching frequency of the first and/or second adaptive matching circuit to a given frequency.

[0026] Non-limiting examples of the antenna system are now discussed in reference to FIG.s 1-7.

[0027] FIG. 1 presents a TCU 100 of the first configuration which comprises a first cellular full band antenna 103 and a second cellular full band antenna 104, a first cellular middle/high band antenna 105 and the second cellular middle/high band antenna. TCU 100 further comprises a GNSS dual band antenna 107, an SDARS antenna 108, WIFI 109 and V2X 110. In this configuration, in the full band antennas 103, 104 there is no separation between the low band and high band elements.

[0028] FIG. 2 presents TCU 100 from another view angle and some of the elements of FIG. 1. Each of the full band antennas 103, 104 is located at the extremities 121, 122 of the TCU.

[0029] FIG. 3 presents the connection of the TCU of the first configuration which comprises an adaptive marching network as an adapter 301. Said network is connected to a feed point 302 of each of the first cellular full band antenna and the second cellular full band antenna (FIG. 3 only shows the first cellular full band antenna 303).

[0030] FIG. 4 shows a schematic view of the adaptive matching network of FIG. 3. The antenna feed point is presented as 402 here. The adaptive matching network uses Digitally Tunable Capacitor (DTC) 403.

[0031] FIG. 5 presents a TCU 500 of the second configuration which comprises a first cellular full band antenna 503 and a second cellular full band antenna 504, a first cellular middle/high band antenna 505 and the second cellular middle/high band antenna 506. TCU 500 further comprises a GNSS dual band antenna 507, an SOARS antenna 508, WIFI 509 and V2X 510. In this configuration, each of the full band antennas 103, 104 antennas has a parasitic design with separate low band element 541 and high band elements 542 which are coupled capacitively to each other. TCU 500 further comprises a UWB 511.

[0032] FIG. 6 presents TCU 500 from another view angle and some of the elements of FIG. 5. Each of the full band antennas 503, 504 is located at the extremities 521, 522 of the TCU.

[0033] FIG. 7 shows a 3D view of TCU 500 and a top housing 510. FIGU. 8 presents example dimensions of the top housing 510.

[0034] FIG. 9 shows a zoomed view on a full band antenna 903 (which has the same structure as the antenna 503 of FIG. 5). The antenna 903 has a higher band antenna element 942 with a direct feed from the PCB 902 with the feeding point 932 as a direct feed on the PCB 902. The antenna 903 further has a lower band antenna element 941 which is coupled to the higher band element 942 at the region 950 on one side and grounded to the metal bottom housing on the other side at 931.

[0035] FIG. 10 presents the notion of effective height in the full band antenna and middle/high band antenna. As discussed above, an effective height is the distance from the ground to the lower part of the antenna parallel element to the ground. For the Mid/High band antennas, the ground is on the PCB which is beneath the mid/high antenna element. On the other hand, for the full band antennas, the ground is the bottom metal housing since there is no ground on the PCB beneath the full band antenna element.

[0036] The TCU 1000 presented in FIG. 10 is a TCU of the first configuration (e.g., like TCU 100 of FIG. 1) with full band antenna 1030 and middle/high band antenna 1040 (only one side is shown). Following the definition of the effective height above, the distance 1100 is the effective height for the middle/high band antenna and the distance 1200 is the effective height for the full band antenna.

Simulations/tests

[0037] A number of simulations/tests were carried out to examine the performance of the TCU including the antennas as discussed above.

[0038] FIG. 11 shows the antenna total efficiency (on the y-axis) versus frequency for full band antennas according to the first configuration (presented in FIG. 1) with adaptive matching/DTC. Different curves are obtained for different values of capacitors in the adaptive matching/DTC.

[0039] FIG. 12 shows the measured and simulated mean gain of fullband antennas according to the first configuration (presented in FIG. 1) with adaptive matching/DTC. This figure shows "Measured and Simulated mean gain" of full band antennas with adaptive matching/DTC (The first configuration). Different curves are obtained for different values of capacitors in the adaptive matching/DTC.

[0040] FIG. 13 shows a zoomed view of FIG. 12 in the low frequency region (between 0.65-1 GHz).

[0041] FIG. 14 shows the antenna simulated total efficiency (on the y-axis) versus frequency for full band antennas according to the second configuration (presented in FIG. 9). The curve 1410 shows the efficiency for the second full band antenna (at the second extremity, like antenna 504 at the extremity 522 in FIG. 5) and the curve 1420 shows the efficiency for the first full band antenna (at the first extremity, like antenna 503 at the extremity 521 in FIG. 5) .

[0042] FIG. 15 shows the simulated total efficiency of the high band element (on the y-axis) versus frequency for middle/high band antennas according to the first or second configurations.

Claims

1. A vehicle telematic control unit (TCU) (100) comprising:

   - a printed circuit board (PCB) (102) having an elongated shape with a first extremity (121) and a second extremity (122),
   - a first cellular full band antenna (103) mounted over the first extremity (121) of the PCB (102),
   - a second cellular full band antenna (104) mounted over the second extremity (122) of the PCB(102), and
   - a first cellular middle/high band antenna (105) and a second cellular middle/high band antenna (106) mounted between the first cellular full band antenna (103) and the second cellular full band antenna (104)

2. The TCU of claim 1, having a height less than 30mm, preferably less than 25mm, and more preferably less than 22mm.

3. The TCU of any of claims 1 to 2, wherein each of the first cellular full band antenna, a second cellular full band antenna, the first cellular middle/high band antenna, and/or the second cellular middle/high band antenna is a monopole broadband metal stamp antenna.

4. The TCU of any of claims 1 to 3, wherein each of the first cellular full band antenna, a second cellular full band antenna, the first cellular middle/high band antenna, and/or the second cellular middle/high band antenna is mounted on a same plane parallel to the PCB.

5. The TCU of any of claims 1 to 4, wherein each of the first cellular full band antenna and the second cellular full band antenna covers cellular dedicated bands from 0.6GHz to 5GHz.

6. The TCU of any of claims 1 to 5, wherein each of the first cellular middle/high band antenna and the second cellular middle/high band antenna covers cellular dedicated bands from 1.4GHz to 5GHz.

7. The TCU of any of claims 1 to 6, wherein the first cellular middle/high band antenna and/or the second cellular middle/high band has an effective height less than 15mm or preferably less than 13mm.

8. The TCU of any of claims 1 to 7, wherein the first cellular full band antenna and/or the second cellular full band has an effective height less than 20mm or preferably less than 18mm.

9. The TCU of any of claims 1 to 8, wherein each of the first cellular full band antenna and the second cellular full band antenna comprises a low band element and a high band element, the low band element and the high band element being coupled capacitively to each other.

10. The TCU according to any of claims 1 to 9; further comprising

    - an adapter connected to a feed point of each of the first cellular full band antenna and the second cellular full band antenna;

    wherein the adapter comprises a first adaptive matching circuit configured to be electrically connected to the first cellular full band antenna, and a second adaptive matching circuit configured to be electrically connected to the second cellular full band antenna.

11. The TCU of claim 10, further comprising a controller, the controller being configured to tune a matching frequency of the first/second adaptive matching circuit to a given frequency.

12. A vehicle comprising the TCU of any of claims 1 to 11.

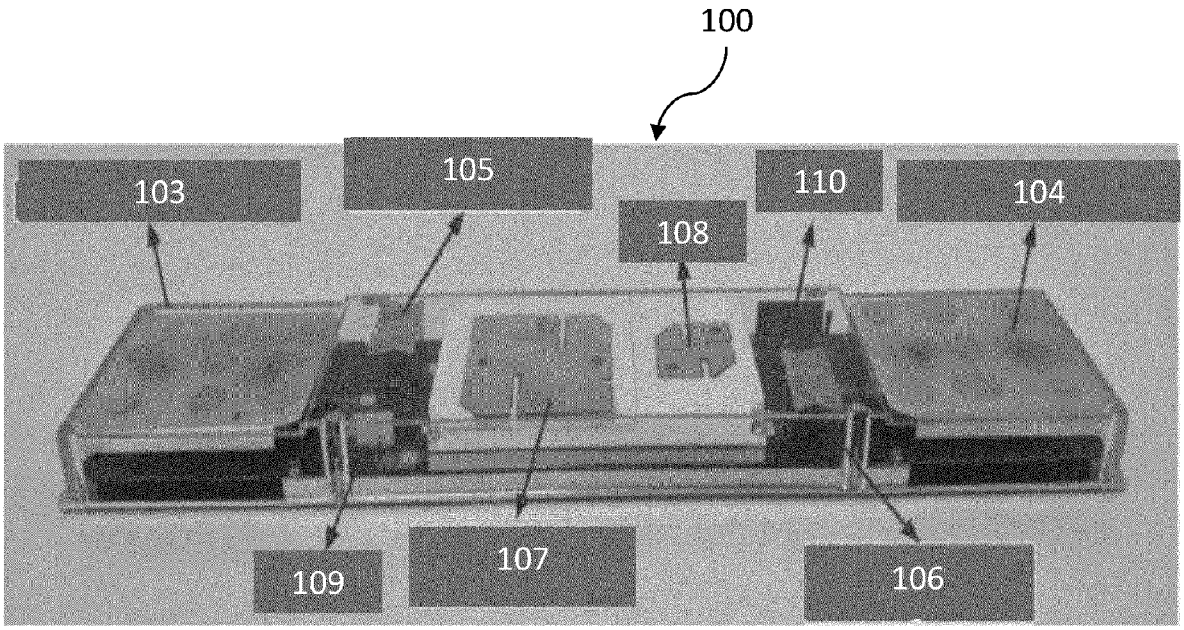
100
103
105
110
104
108
109
107
106

FIG. 1

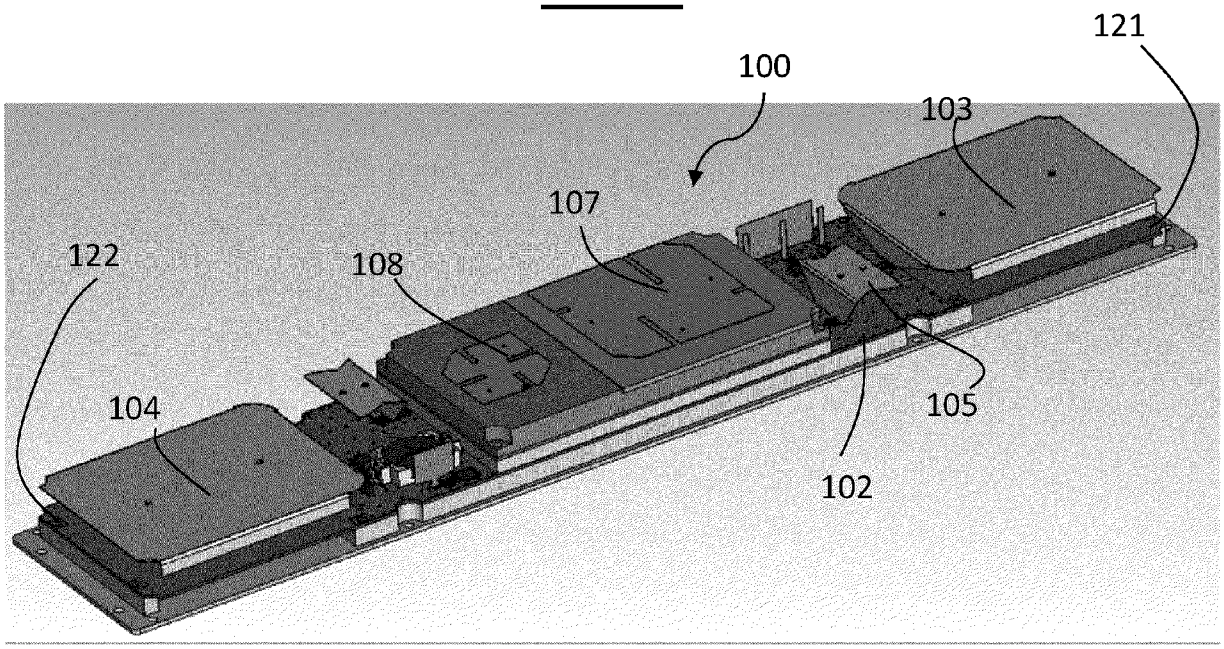
121
100
103
107
122
108
104
105
102

FIG. 2

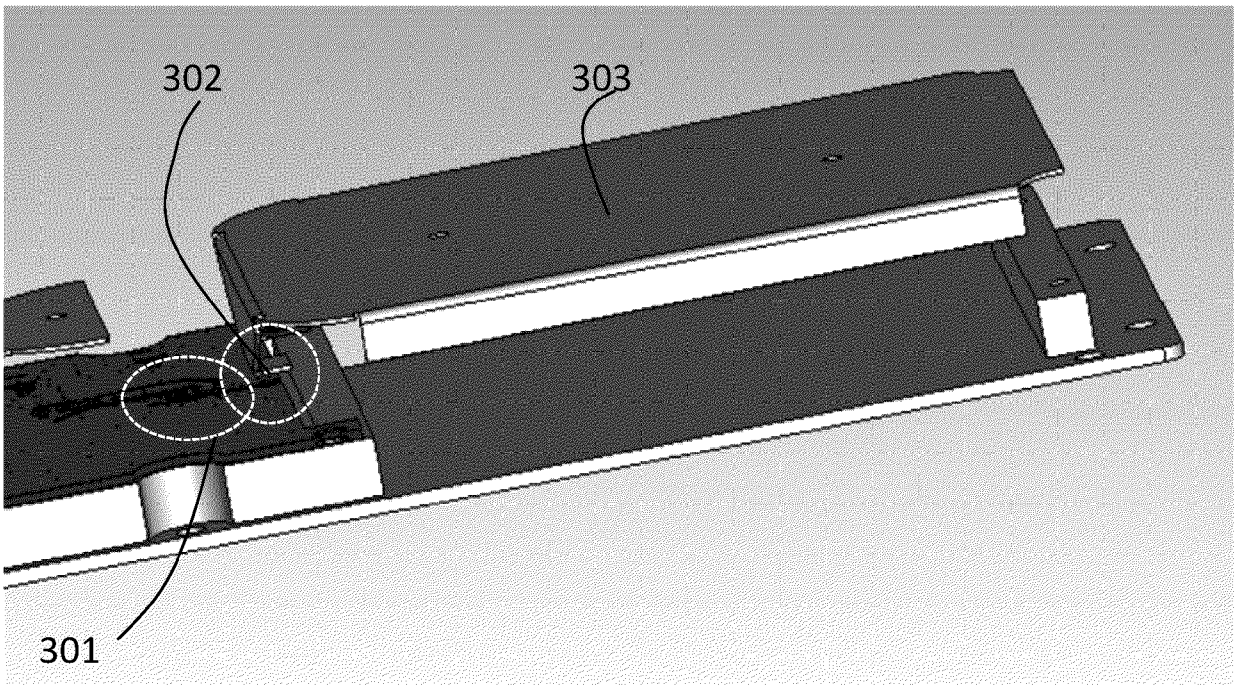
302
303
301

FIG. 3

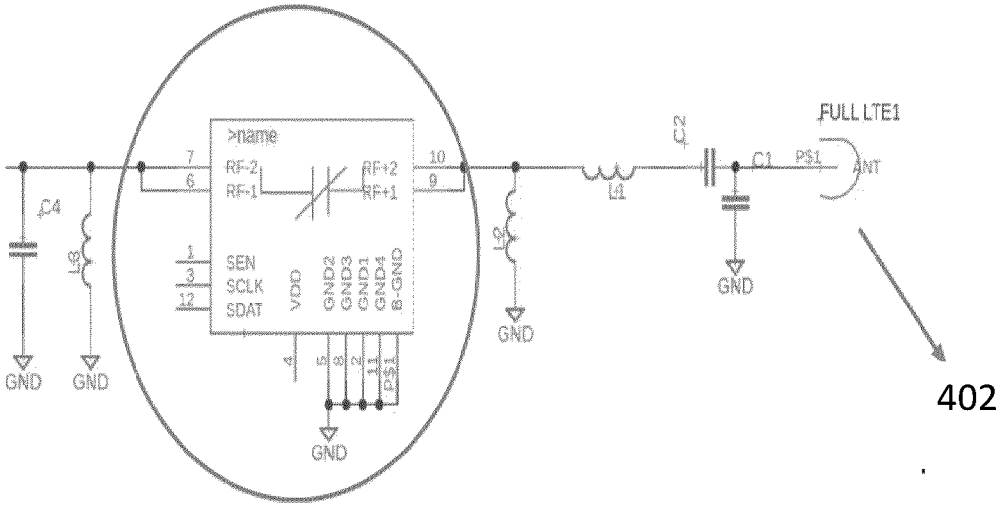
>name
RF-2
RF-1
RF+2
RF+1
SEN
SCLK
SDAT
VDD
GND2
GND3
GND1
GND4
8-GND
GND
FULL LTE1
ANT
402
403

FIG. 4

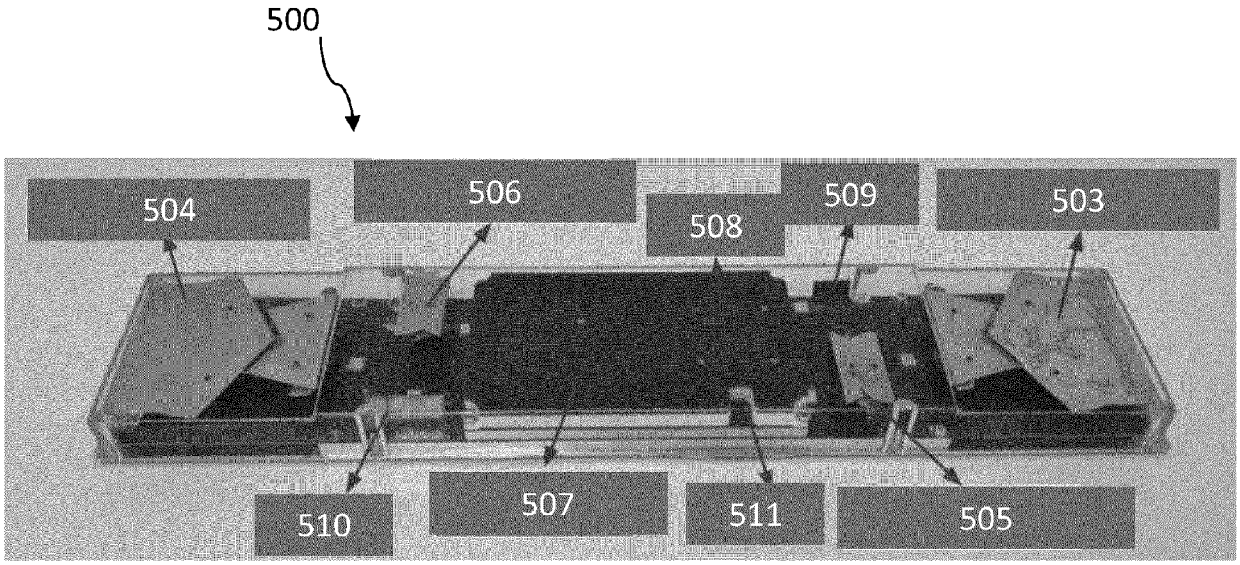

FIG. 5

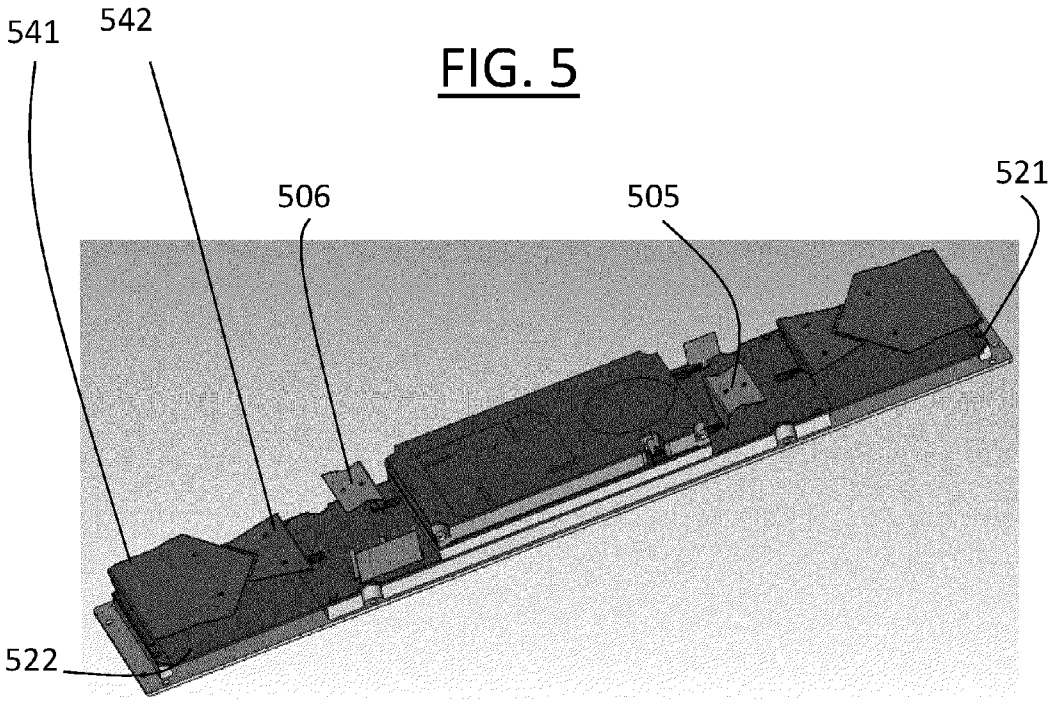

FIG. 6

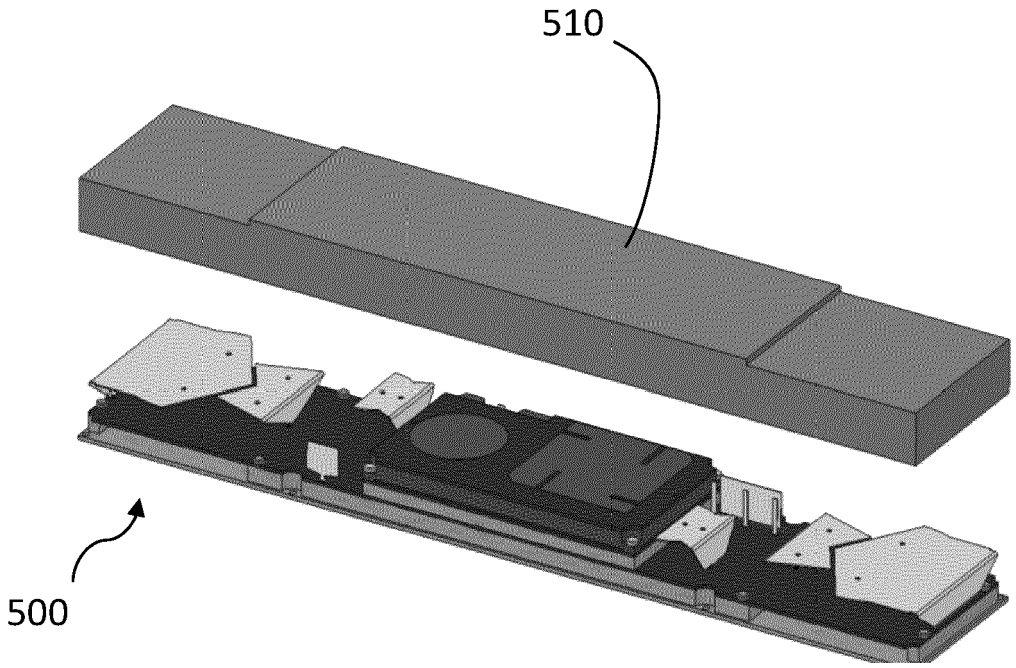

FIG. 7

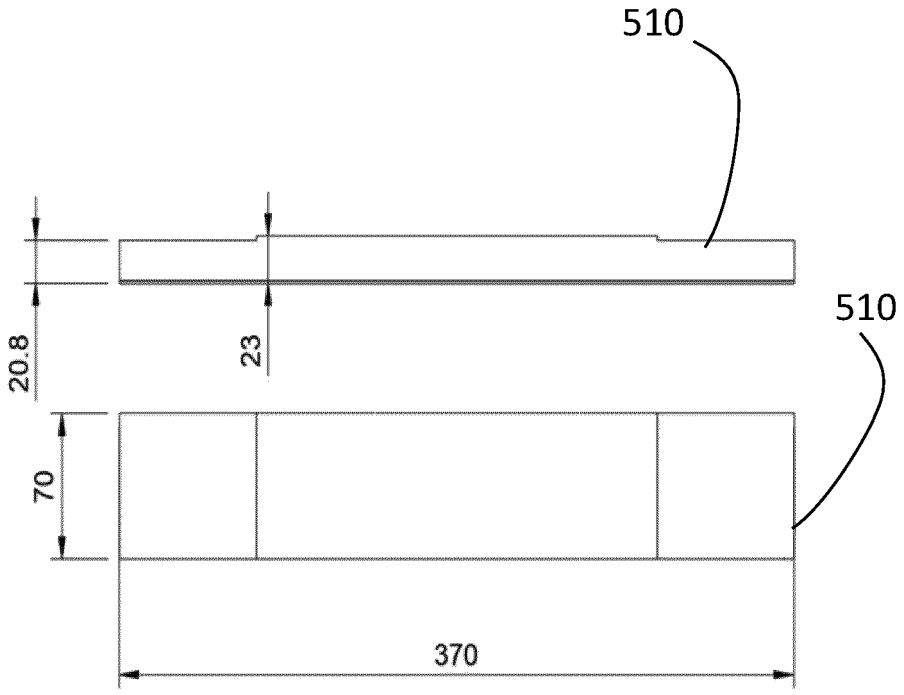

FIG. 8

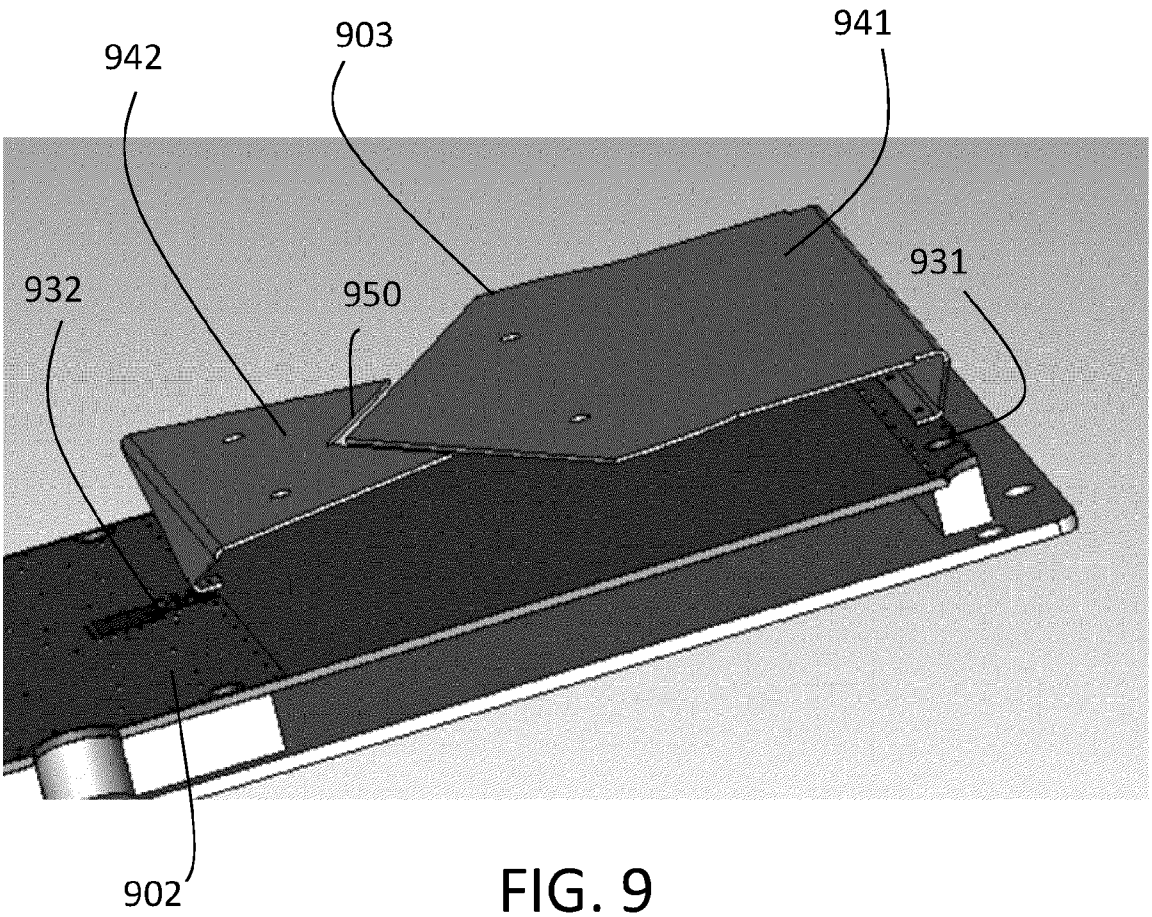

FIG. 9

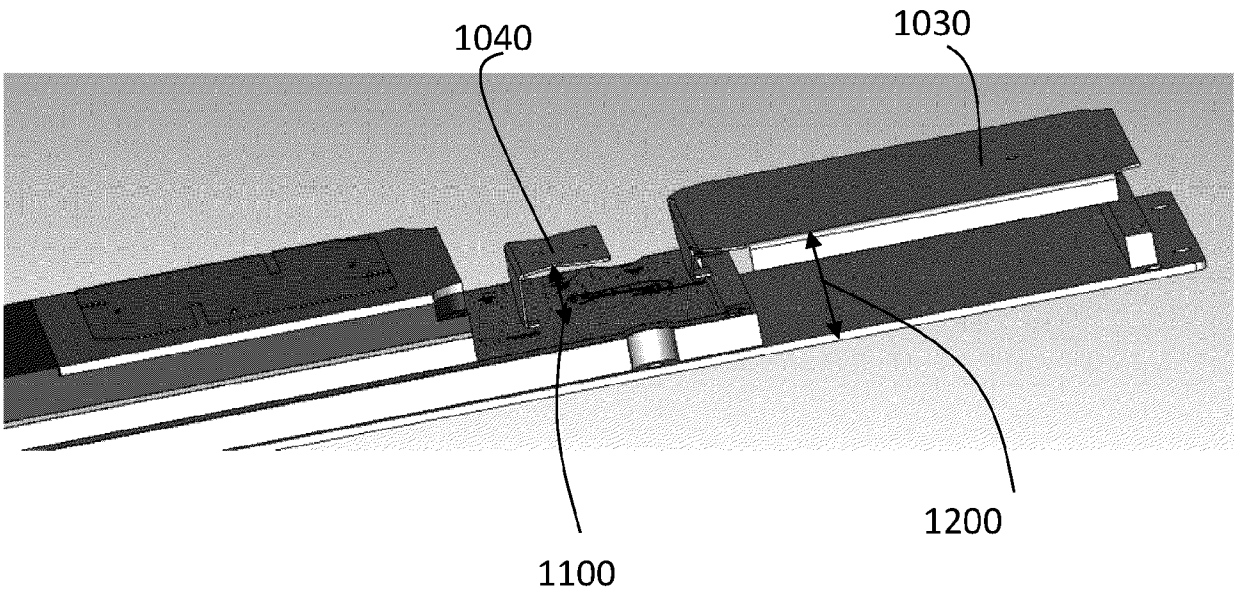

FIG. 10

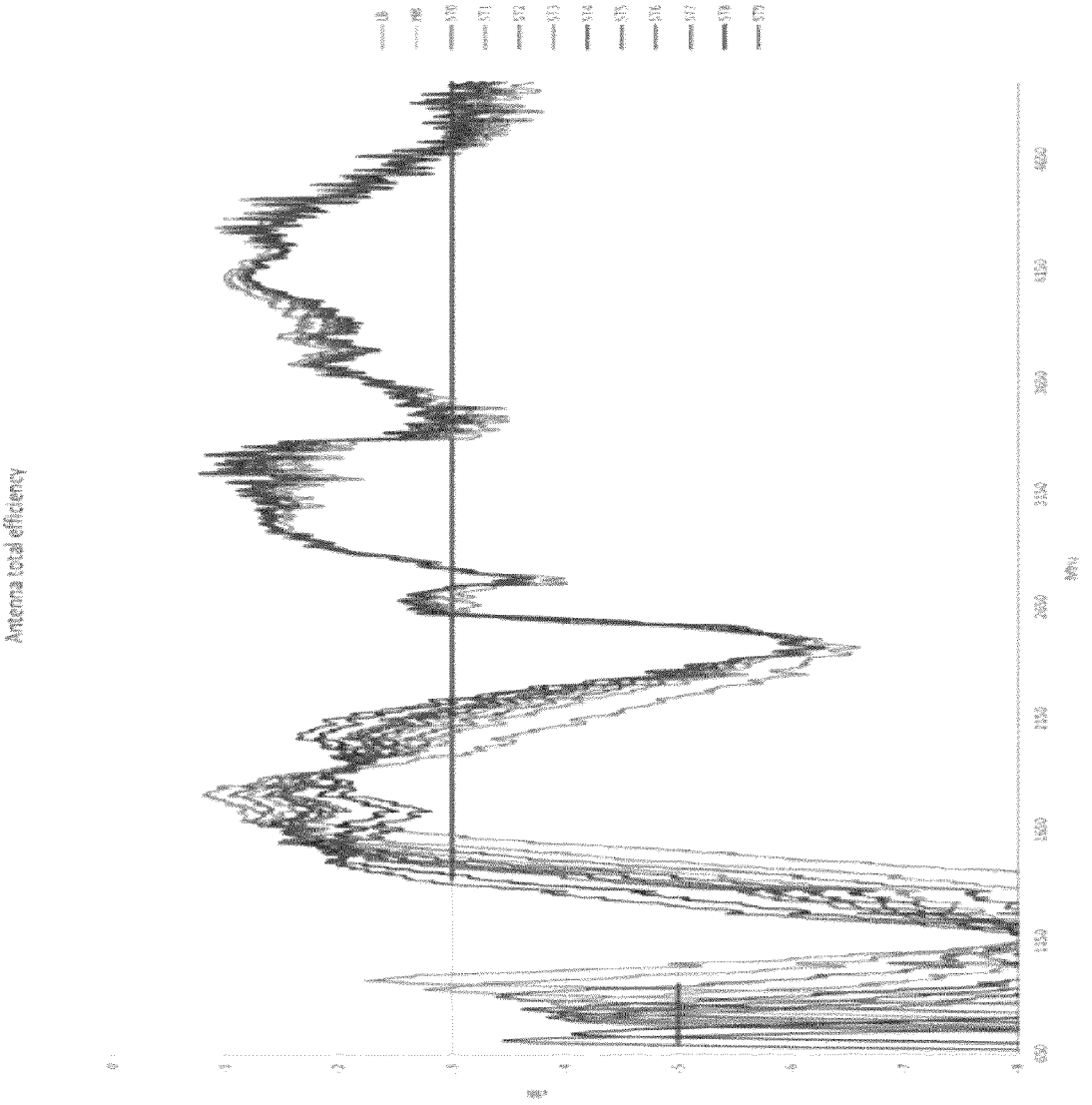

FIG. 11

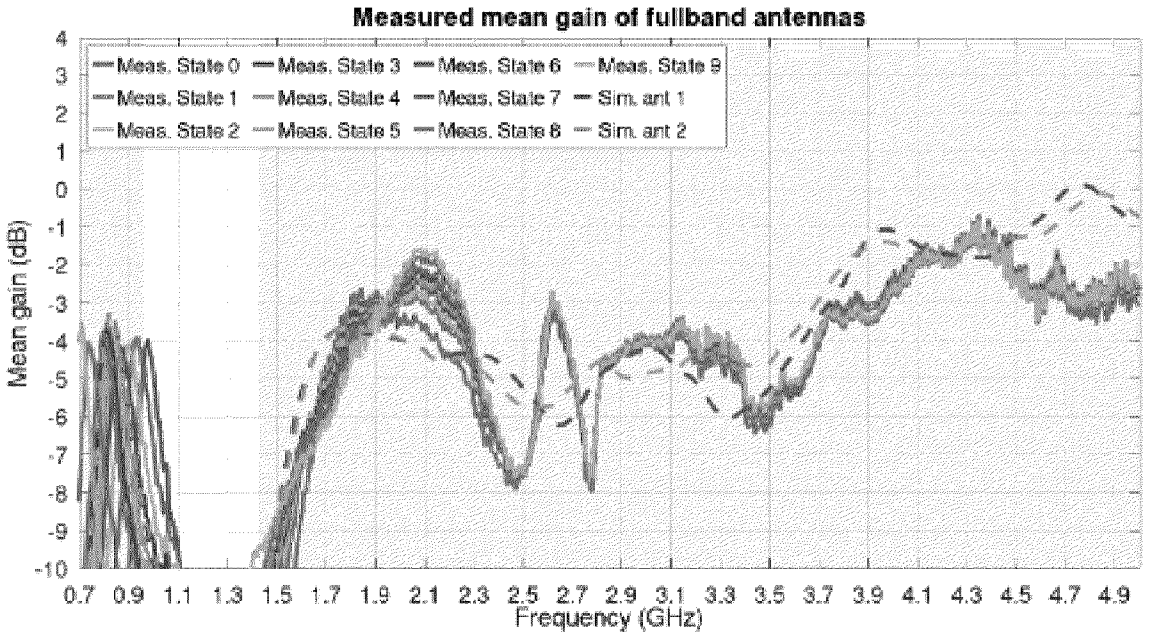
Measured mean gain of fullband antennas
Meas. State 0
Meas. State 1
Meas. State 2
Meas. State 3
Meas. State 4
Meas. State 5
Meas. State 6
Meas. State 7
Meas. State 8
Meas. State 9
Sim. ant 1
Sim. ant 2
Mean gain (dB)
Frequency (GHz)

FIG. 12

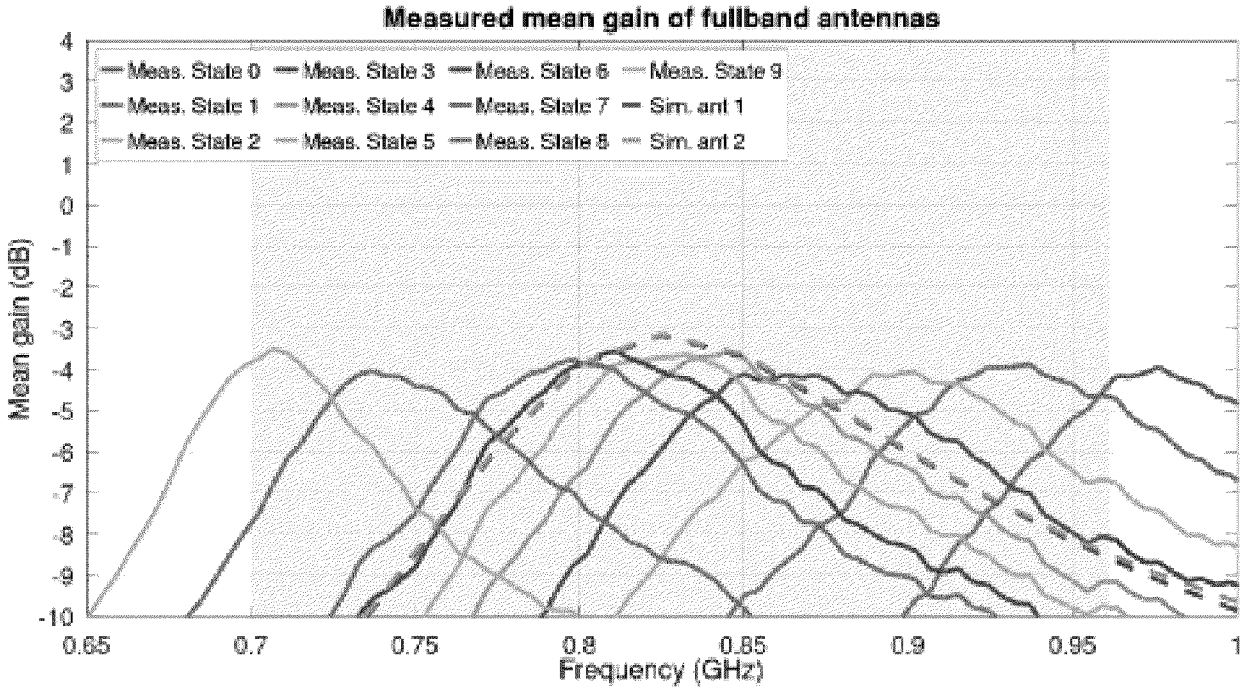
Measured mean gain of fullband antennas
Meas. State 0
Meas. State 1
Meas. State 2
Meas. State 3
Meas. State 4
Meas. State 5
Meas. State 6
Meas. State 7
Meas. State 8
Meas. State 9
Sim. ant 1
Sim. ant 2
Mean gain (dB)
Frequency (GHz)

FIG. 13

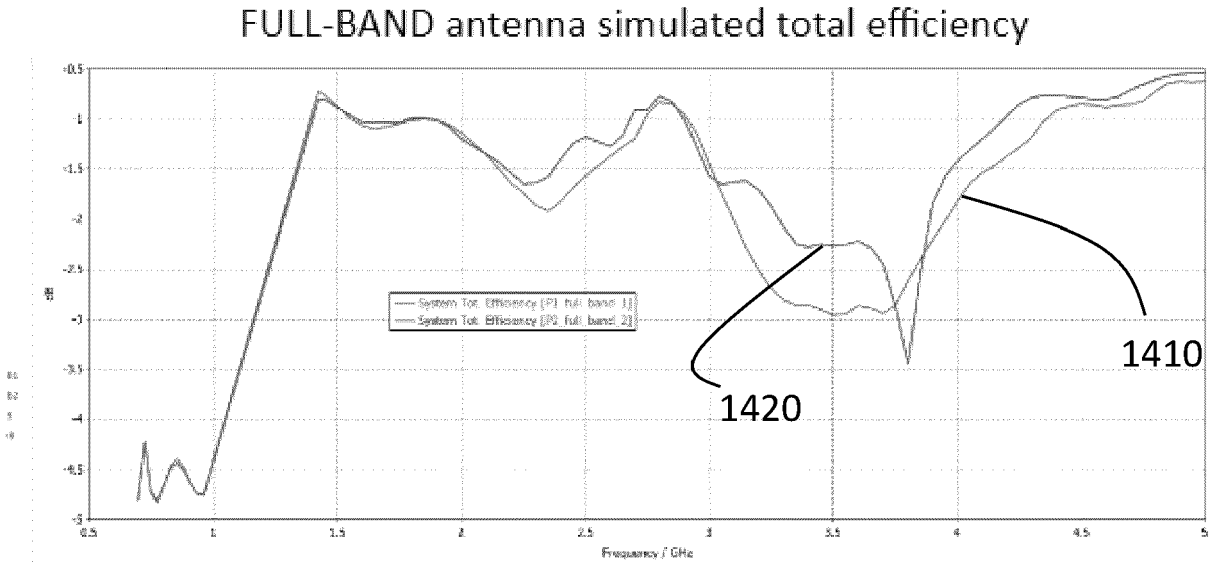
FULL-BAND antenna simulated total efficiency
1410
1420
Frequency / GHz

FIG. 14

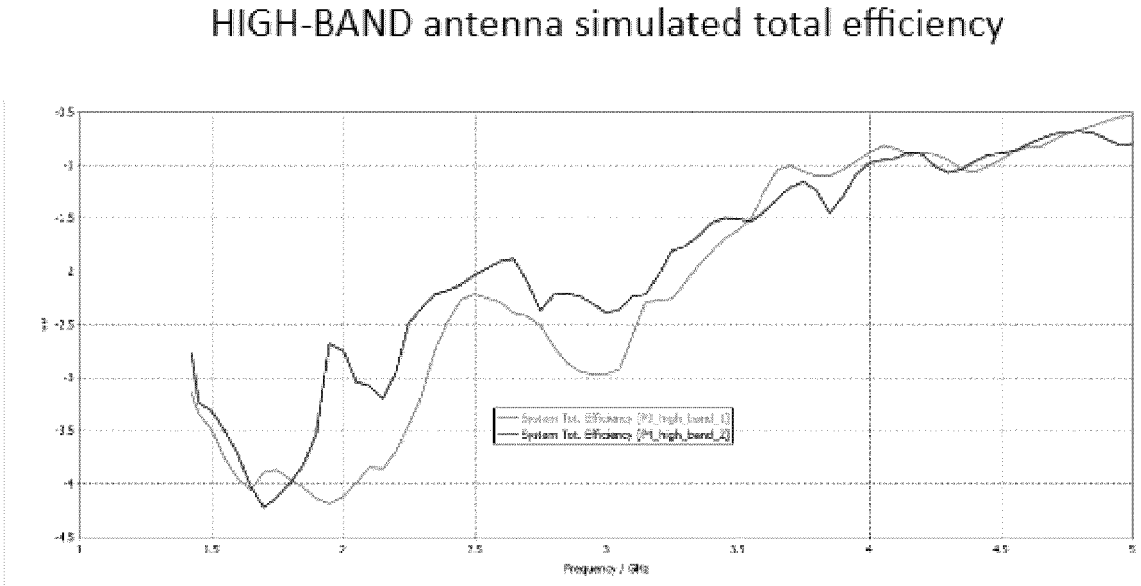
HIGH-BAND antenna simulated total efficiency
Frequency / GHz

FIG. 15

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 23 20 6476

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2023/066184 A1 (KIM YONGKON [KR]) 2 March 2023 (2023-03-02) * paragraph [0116]; figure 3C * * paragraph [0159] - paragraph [0208]; figures 5B, 7A-8B *	1-9,12 10,11	INV. H01Q1/32 H01Q21/28 ADD. H01Q9/42
Y	CN 219 040 740 U (BEIJING XIAOMI MOBILE SOFTWARE CO LTD) 16 May 2023 (2023-05-16) * paragraph [0046] - paragraphs [0051], [0086]; figure 1 *	10,11	
A	CN 110 247 199 A (CHANGZHOU CTW ELECTRONICS CO LTD) 17 September 2019 (2019-09-17) * paragraphs [0011], [0075] - paragraph [0080]; figures 1, 2 *	1	
A	US 2022/376384 A1 (HWANG CHUL [KR]) 24 November 2022 (2022-11-24) * paragraphs [0025], [0030], [0047]; figure 3 *	1	

TECHNICAL FIELDS SEARCHED (IPC)

H01Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	5 April 2024	Hueso González, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 20 6476

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

05-04-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2023066184 A1	02-03-2023	KR 20220084396 A	21-06-2022
		US 2023066184 A1	02-03-2023
		WO 2021145463 A1	22-07-2021
CN 219040740 U	16-05-2023	NONE	
CN 110247199 A	17-09-2019	NONE	
US 2022376384 A1	24-11-2022	CN 114586237 A	03-06-2022
		KR 20210041366 A	15-04-2021
		US 2022376384 A1	24-11-2022
		WO 2021071143 A1	15-04-2021

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82