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

(11) **EP 4 220 856 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
02.08.2023 Bulletin 2023/31

(21) Application number: **21899739.3**

(22) Date of filing: **14.10.2021**

(51) International Patent Classification (IPC):
H01Q 1/36 *(2006.01)* ***H01Q 5/307*** *(2015.01)*

(86) International application number:
PCT/CN2021/123915

(87) International publication number:
WO 2022/116705 (09.06.2022 Gazette 2022/23)

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **01.12.2020 CN 202011399314**

(71) Applicant: **REALME MOBILE TELECOMMUNICATIONS (SHENZHEN) CO., LTD.**
Shenzhen, Guangdong 518027 (CN)

(72) Inventor: **YANG, Jiangyan**
Shenzhen, Guangdong 518027 (CN)

(74) Representative: **Taor, Simon Edward William et al**
Venner Shipley LLP
200 Aldersgate
London EC1A 4HD (GB)

(54) ANTENNA APPARATUS AND ELECTRONIC DEVICE

(57) Provided are an antenna apparatus and an electronic device. The antenna apparatus includes a first radiator and a plurality of second radiators. A first gap is defined between each of the second radiators and the first radiator. Each of the second radiators is electrically connected to the first radiator through an electromagnetic coupling by means of the first gap. Each of second radiators is configured to transmit a radio-frequency signal of a first frequency band. The plurality of second radiators and the first radiator are configured to jointly transmit a radio-frequency signal of a second frequency band.

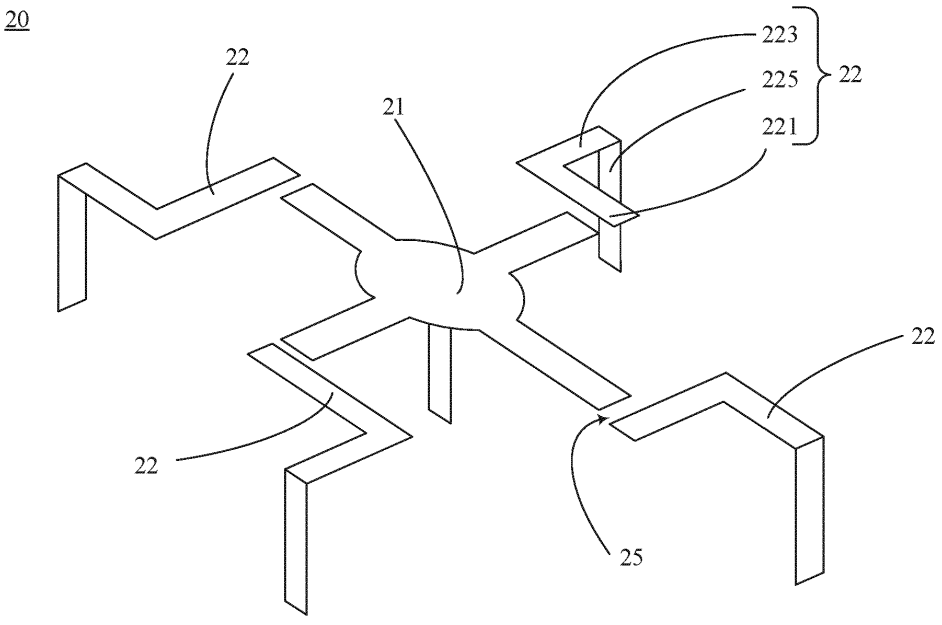

FIG. 2

EP 4 220 856 A1

Description

[0001] The present application claims priority to Chinese Patent Application No. 202011399314.5, titled "ANTENNA APPARATUS AND ELECTRONIC DEVICE" and filed on December 01, 2020, the entire disclosure of which is incorporated herein by reference.

FIELD

[0002] The present disclosure relates to the field of communication technologies, and more particularly, to an antenna apparatus and an electronic device.

BACKGROUND

[0003] With the development of communication technologies, as electronic devices such as smart phones are increasingly more versatile, communication modes of the electronic devices are more diversified. For example, the electronic devices may support a 4th generation mobile communication technology (4G) communication, and may also support a 5th generation mobile communication technology (5G) communication. Furthermore, the 4G communication may include a plurality of frequency bands, and similarly, the 5G communication may also include a plurality of frequency bands.

SUMMARY

[0004] Embodiments of the present disclosure provide an antenna apparatus and an electronic device, which allow radio-frequency signals of different frequency bands to share a second radiator, thereby reducing the number of antennas and reducing layout space occupied by antennas of the electronic device.

[0005] In a first aspect, the embodiments of the present disclosure provide an antenna apparatus. The antenna apparatus includes a first radiator and a plurality of second radiators. The first radiator is grounded. A first gap is defined between each of the plurality of second radiators and the first radiator. Each of the plurality of second radiators is electrically connected to the first radiator through an electromagnetic coupling by means of the first gap. Each of the plurality of second radiators is configured to transmit a radio-frequency signal of a first frequency band. The plurality of second radiators and the first radiator are configured to j ointly transmit a radio-frequency signal of a second frequency band.

[0006] In a second aspect, the embodiments of the present disclosure further provide an electronic device. The electronic device includes a housing and an antenna apparatus disposed inside the housing. The antenna apparatus includes a first radiator and a plurality of second radiators. The first radiator is grounded. A first gap is defined between each of the plurality of second radiators and the first radiator. Each of the plurality of second radiators is electrically connected to the first radiator through an electromagnetic coupling by means of the first gap. Each of the plurality of second radiators is configured to transmit a radio-frequency signal of a first frequency band. The plurality of second radiators and the first radiator are configured to jointly transmit a radio-frequency signal of a second frequency band.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] In order to clearly explain technical solutions of embodiments of the present disclosure, drawings used in description of the embodiments will be briefly described below. The drawings as described below are merely some embodiments of the present disclosure. Based on these drawings, other drawings can be obtained by those skilled in the art without creative effort.

FIG. 1 is a schematic structural diagram of an electronic device according to an embodiment of the present disclosure.

FIG. 2 is a first schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

FIG. 3 is a second schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

FIG. 4 is a third schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

FIG. 5 is a fourth schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

FIG. 6 is a fifth schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

FIG. 7 is a six schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

FIG. 8 is a seventh schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

FIG. 9 is a schematic structural diagram of a circuit board of an electronic device according to an embodiment of the present disclosure.

FIG. 10 is a curve of an S parameter of an antenna apparatus according to an embodiment of the present disclosure.

FIG. 11 is a curve of an isolation degree of an antenna apparatus according to an embodiment of the present disclosure.

FIG. 12 is a curve of efficiency of an antenna apparatus according to an embodiment of this application.

DETAILED DESCRIPTION

[0008] Technical solutions according to embodiments of the present disclosure will be described clearly and completely below in combination with accompanying

drawings of the embodiments of the present disclosure. The embodiments described below are only a part of the embodiments of the present disclosure, rather than all of the embodiments. Based on the embodiments in the present disclosure, all other embodiments obtained by those skilled in the art without creative labor shall fall within the protection scope of the present disclosure.

[0009] The embodiments of the present disclosure provide an electronic device. The electronic device may be a device capable of transmitting a radio-frequency signal such as a smart phone, a tablet computer, a notebook computer, etc.

[0010] As illustrated in FIG. 1, FIG. 1 is a schematic structural diagram of an electronic device according to an embodiment of the present disclosure.

[0011] The electronic device 100 includes a circuit board 10, an antenna apparatus 20, a battery 30, and a housing 40.

[0012] The housing 40 is configured to define an outer contour of the electronic device 100, for accommodating electronic elements and functional components of the electronic device 100 while sealing and protecting the electronic elements and functional components inside the electronic device 100.

[0013] The circuit board 10 is mounted inside the housing 40. The circuit board 10 can serve as a mainboard of the electronic device 100. The circuit board 10 has a ground point disposed thereon to ground the circuit board 10. The circuit board 10 may be integrated with one, two or more of functional components such as a motor, a microphone, a loudspeaker, a receiver, an earphone interface, a universal serial bus interface (USB interface), a camera, a distance sensor, an ambient light sensor, a gyroscope, and a processor.

[0014] The battery 30 is mounted inside the housing 40 and connected to the circuit board 10 to enable the battery 30 to supply power to the electronic device 100. The circuit board 10 may has a power management circuit disposed thereon. The power management circuit is configured to distribute a voltage provided by the battery 30 to the respective electronic elements in the electronic device 100.

[0015] The antenna apparatus 20 is mounted inside the housing 40 and electrically connected to the circuit board 10. The antenna apparatus 20 can be configured to transmit the radio-frequency signal, for implementing a wireless communication function of the electronic device 100.

[0016] As illustrated in FIG. 2, FIG. 2 is a first schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

[0017] The antenna apparatus 20 includes a first radiator 21 and a second radiator 22.

[0018] The first radiator 21 is grounded. The first radiator 21 is made of a metallic material, such as magnesium alloy or aluminum alloy. The first radiator 21 can be configured to transmit the radio-frequency signal.

[0019] In some embodiments, the first radiator 21 is of a symmetrical structure and includes a plurality of end portions. The plurality of end portions may be arranged at positions symmetrically distributed along a periphery of the first radiator 21. For example, when the first radiator 21 is in a cruciform, the first radiator 21 has four end portions; and when the first radiator 21 is in a herringbone shape, the first radiator 21 has three ends.

[0020] In some embodiments, the first radiator 21 and the circuit board 10 can be disposed in parallel, and a distance between the first radiator 21 and the circuit board 10 can be smaller than or equal to 5 mm. By limiting the distance, performance of the antenna apparatus 20 will not be affected by other conductive elements.

[0021] The second radiator 22 is made of a metallic material, such as magnesium alloy or aluminum alloy. The second radiator 22 can also be configured to transmit the radio-frequency signal. The second radiator 22 is formed by connecting metallic strips, for example, by welding or bending the metallic strips.

[0022] A plurality of second radiators 22 may be provided, and the plurality of second radiators 22 is symmetrically distributed along the periphery of the first radiator 21.

[0023] A first gap 25 is defined between the first radiator 21 and the second radiator 22. A width of the first gap 25 can satisfy that the first radiator 21 is electrically connected to the second radiator 22 through an electromagnetic coupling. For example, the width of the first gap 25 may be 0.5 mm, 1 mm, or 1.5 mm, etc.

[0024] In some embodiments, the number of the second radiators 22 is identical to the number of the end portions of the first radiators 21. For example, the first radiator 21 has four end portions, the antenna apparatus 20 has four second radiators 22, and each second radiator 22 is electrically connected to one end portion of the first radiator 21 through the electromagnetic coupling of the first gap 25.

[0025] It can be understood that, the electromagnetic coupling is generated due to mutual inductance between the first radiator 21 and the second radiator 22. Thus, a current change of one radiator affects another radiator through the mutual inductance, an input and output of the radiator closely cooperate and affect one another, and the electromagnetic coupling is generated between the second radiator 22 and the first radiator 21 through interaction, thereby realizing the electrical connection.

[0026] Each second radiator 22 is configured to transmit a radio-frequency signal of a first frequency band, a mode of which is a quarter wavelength. For example, the radio-frequency signal of the first frequency band may be a 5G radio-frequency signal of a N78 frequency band. The N78 frequency band has a frequency ranging from 3.4 GHz to 3.6 GHz. It can be understood that when the plurality of second radiators 22 is provided, each second radiator 22 can transmit the radio-frequency signal of the first frequency band, and thus the plurality of second radiators 22 can transmit a plurality of radio-frequency signals of the first frequency band, thereby enhancing an

intensity of the radio-frequency signals of the first frequency band. For example, when four second radiators are provided, 4*4 multiple-in multiple-out (MIMO) transmission of the radio-frequency signals of the first frequency band can be formed.

[0027] The plurality of second radiators 22 and the first radiator 21 are configured to jointly transmit a radio-frequency signal of a second frequency band, a mode of which is a five-fourths wavelength. For example, the radio-frequency signal of the second frequency band may be the 5G radio-frequency signal of an N79 frequency band. The N79 frequency band has a frequency ranging from 4.8 GHz to 4.9 GHz.

[0028] In the description of the present disclosure, it should be understood that terms such as "first" and "second" are only used to distinguish similar objects, rather than indicating or implying relative importance or implicitly indicating the number of indicated technical features.

[0029] In the antenna apparatus 20 provided in the embodiments of the present disclosure, the antenna apparatus 20 includes the first radiator 21 and the plurality of second radiators 22; each second radiator 22 is configured to transmit the radio-frequency signal of the first frequency band, and the plurality of second radiators 22 and the first radiator 21 are configured to jointly transmit the radio-frequency signal of the second frequency band. In this way, the plurality of second radiators 22 can be shared, enabling the antenna apparatus 20 to transmit at least two kinds of radio-frequency signals, thereby reducing the number of antennas of the electronic device and reducing the layout space occupied by the antennas of the electronic device.

[0030] In some embodiments, as illustrated in FIG. 3, FIG. 3 is a second schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

[0031] The antenna apparatus 20 further includes a capacitor 23, and the capacitor 23 is grounded.

[0032] The first radiator 21 has a through hole defined thereon, and the capacitor 23 is disposed in the through hole. A second gap 24 is defined between the capacitor 23 and the first radiator 21. The first radiator 21 is electrically connected to the capacitor 23 through an electromagnetic coupling by means of the second gap 24.

[0033] The through hole may be of any shape suitable for an industrial design, such as a circle, a square, or an ellipse. The through hole is disposed at a central position of the first radiator 21.

[0034] A width of the second gap 24 is required to satisfy that the first radiator 21 and the capacitor 23 can electromagnetically couple and thus they can be electrically connected to each other. For example, the width of the second gap 24 may be 0.5 mm, 1 mm, or 1.5 mm, etc.

[0035] Due to a filtering characteristic of the capacitor 23, an isolation degree of each of the second radiators 22 for transmitting the first frequency band can be enhanced. It can be understood that since the plurality of second radiators 22 is at a rather close distance, the plurality of second radiators 22 may affect each other, which may reduce an efficiency of each second radiator 22 in terms of transmitting the radio-frequency signal of first frequency band. However, the capacitor 23 has the filtering effect, and thus the capacitor 23 can enhance the isolation degree between the plurality of second radiators 22, thereby increasing the efficiency of each second radiator 22 in terms of transmitting the radio-frequency signal of the first frequency band.

[0036] In some embodiments, each end portion of the first radiator 21 is equidistant from the through hole defined on the first radiator 21 and electromagnetically coupled to one second radiator 22 by means of the first gap 25. It can be understood that, the through hole is equidistant from each second radiator 22, such that the capacitor 23 can enhance the isolation degree between the plurality of second radiators 22 for transmitting the radio-frequency signals of the first frequency band to the same extent.

[0037] Each second radiator 22 includes a first radiation segment 221, a second radiation segment 225, and a third radiation segment 223, which are sequentially connected. For example, the third radiation segment 223 has a first end connected to the first radiation segment 221 and a second end connected to the second radiation segment 225.

[0038] The plurality of first radiation segments 221 is electrically connected to the plurality of end portions of the first radiator 21 through the electromagnetic coupling by means of the first gap 25. For example, four first radiation segments 221 are provided, the first radiation segment 21 has four end portions, and each first radiation segment 221 is electrically connected to one end portion of the first radiator 21 by means of the first gap 25.

[0039] In some embodiments, as illustrated in FIG. 4, FIG. 4 is a third schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

[0040] The second radiator 22 includes a plurality of third radiator segments 223 sequentially connected to form a first end and a second end. For example, the second radiator 22 includes two third radiator segments 223, and the two third radiator segments 223 are sequentially connected to each other and form the first end and the second end. The first end is connected to the first radiator segment 221, and the second end is connected to the second radiator segment 225, thereby jointly forming the second radiator 22.

[0041] A length of the second radiator 22 may increase or decrease with an increase or decrease in the number of the third radiation segments 223. Furthermore, due to different connection manners of the third radiation segments 223, e.g., a bending connection, a shape of the second radiator 22 may change accordingly, and thus an overall shape of the antenna apparatus 20 may also change.

[0042] The length of the antennas of the same structure may increase as an operation frequency decreases

and the wavelength increases. Therefore, the length of the second radiator 22 may be appropriately adjusted based on an applicable resonant frequency.

[0043] In some embodiments, as illustrated in FIG. 5, FIG. 5 is a fourth schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

[0044] The second radiator 22 of the antenna apparatus 20 may only include the first radiation segment 221 and the second radiation segment 225, without including the third radiation segment 223 in the above-mentioned embodiments.

[0045] The first radiation segment 221 and the second radiation segment 225 are connected and perpendicular to each other.

[0046] One end of the first radiation segment 221 is electrically connected to the second radiator 22 through the electromagnetic coupling by means of the first gap 25, and the other end of the first radiation segment 221 is directly connected to one end of the second radiation segment 225.

[0047] As illustrated in FIG. 6, FIG. 6 is a fifth schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

[0048] The antenna apparatus 20 further includes a feed source 23 configured to generate a radio-frequency signal.

[0049] Each second radiator 22 is electrically connected to the feed source 23. Therefore, the feed source 23 can feed the radio-frequency signals to each second radiator 22, and each second radiator 22 can radiate the radio-frequency signals outwards, thereby transmitting the radio-frequency signals of the first frequency band. The he plurality of second radiators 22 and the first radiator 21 can jointly radiate the radio-frequency signals of the second frequency band.

[0050] As illustrated in FIG. 7, FIG. 7 is a sixth schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

[0051] The antenna apparatus 20 further includes a plurality of tuning circuits 26, and each tuning circuit 26 is grounded. The number of the tuning circuits 26 is identical to the number of the second radiators 22. Each second radiator 22 is connected to one of the tuning circuits 26.

[0052] The tuning circuit 26 is composed of one or more tuning circuit elements which enable the tuning circuit 26 to have a characteristic of impedance adjustment, thereby adjusting an electromagnetic wave frequency radiated by the antenna apparatus 20. For example, the elements of the tuning circuit 26 may be a resistor, a capacitor, an inductor, a switch, etc.

[0053] As illustrated in FIG. 8, FIG. 8 is a seventh schematic structural diagram of an antenna apparatus according to an embodiment of the present disclosure.

[0054] The antenna apparatus 20 further includes a plurality of third radiators 26.

[0055] The number of the plurality of third radiators 26 is identical to the number of the plurality of second radiators 22. Each third radiator 26 has one end connected to one second radiator 22, and another end grounded.

[0056] Each of the second radiators 22 and one of the third radiators 26 are configured to jointly transmit a radio-frequency signal of a third frequency band. For example, the radio-frequency signal of the third frequency band may be an N41 frequency band, where the N41 frequency band has a frequency ranging from 2.5 GHz to 2.69 GHz.

[0057] As illustrated in FIG. 9, FIG. 9 is a schematic structural diagram of a circuit board of an electronic device according to embodiments of the present disclosure.

[0058] The antenna apparatus 20 further includes a plurality of first elastic sheets 29 and a plurality of second elastic sheets 27. The plurality of first elastic sheets 29 and the plurality of second elastic sheets 27 are arranged on the circuit board 10.

[0059] The first elastic sheets 29 and the second elastic sheets 27 are made of a metallic material, for example, the magnesium alloy or the aluminum alloy.

[0060] Each first elastic sheet 29 is electrically connected to the ground point on the circuit board 10, and each second elastic sheet 27 is electrically connected to the feed source 23. In addition, each first elastic sheet 29 is connected to the first radiator 21 to ground the first radiator 21. Each second elastic sheet 27 is connected to one of second radiators 22, such that the plurality of second radiators 22 can be electrically connected to the feed source 23.

[0061] In some embodiments, a plurality of third radiators 26 is provided, and each third radiator 26 may also be electrically connected to the ground point on the circuit board 10.

[0062] The first elastic sheet 29 and the second elastic sheet 27 may have any shape suitable for connecting the antenna apparatus 20 and the circuit board 10, for example, a circle, a square, or a triangle.

[0063] Since the first elastic sheet 29 and the second elastic sheet 27 are conductive and elastic, on one hand, the first elastic sheet 29 and the second elastic sheet 27 can have a function of the electrical connection, and on the other hand, the first elastic sheet 29 and the second elastic sheet 27 have a shock absorption function for protecting parts.

[0064] The first elastic sheet 29 and the second elastic sheet 27 can be easily connected to the circuit board 10. For example, the first elastic sheet 29 and the second elastic sheet 27 may be directly welded on the circuit board 10.

[0065] As illustrated in FIG. 10, FIG. 10 is a curve of an S parameter of an antenna apparatus according to embodiments of the present disclosure.

[0066] When the antenna apparatus 20 operates, two resonant frequencies can be generated. For example, one resonant frequency ranges from 3.3 GHz to 3.8 GHz, and the other resonant frequency ranges from 4.4 GHz to 5 GHz.

[0067] As illustrated in FIG. 11, FIG. 11 is a curve of

an isolation degree of an antenna apparatus according to embodiments of the present disclosure.

[0068] L1 represents an isolation degree between the plurality of second radiators 22 when the capacitor 23 is provided in the antenna apparatus 20. L2 is represents isolation degree between the plurality of second radiators 22 when no capacitor 23 is provided in the antenna apparatus 20.

[0069] As revealed by FIG. 11, when the capacitor 23 is provided, the isolation degree between the plurality of second radiators 22 can be improved.

[0070] As illustrated in FIG. 12, FIG. 12 is a curve of an efficiency of an antenna apparatus according to an embodiment of this application.

[0071] L3 represents an efficiency of the plurality of second radiators 22 when the capacitor 23 is provided in the antenna apparatus 20. L4 represents an efficiency of the plurality of second radiators 22 when no capacitor 23 is provided in the antenna device 20.

[0072] As revealed by FIG. 12, when the capacitor 23 is disposed on the antenna apparatus 20, the efficiency of radiating the radio-frequency signal by the second radiator 22 can be improved.

[0073] The antenna apparatus and the electronic device provided in the embodiments of the present disclosure are described in detail above. Specific examples are used herein to describe the principles and embodiments of the present disclosure. The description of the above embodiments is merely used to facilitate the understanding of the present disclosure. Meanwhile, those skilled in the art, based on the concept of the present disclosure, can made modification to the specific embodiments and the application range. The present specification should not be construed as the limitations on the present disclosure.

Claims

1. An antenna apparatus, comprising:

   a first radiator, the first radiator being grounded; and
   a plurality of second radiators, a first gap being defined between each of the plurality of second radiators and the first radiator, and each of the plurality of second radiators being electrically connected to the first radiator through an electromagnetic coupling by means of the first gap, wherein:

      each of the plurality of second radiators is configured to transmit a radio-frequency signal of a first frequency band; and
      the plurality of second radiators and the first radiator are configured to jointly transmit a radio-frequency signal of a second frequency band.

2. The antenna apparatus according to claim 1, wherein:

   the first radiator has a through hole defined thereon; and
   the antenna apparatus further comprises a capacitor disposed in the through hole and grounded, a second gap being defined between the capacitor and the first radiator, and the first radiator being electrically connected to the capacitor through an electromagnetic coupling by means of the second gap.

3. The antenna apparatus according to claim 2, wherein:

   the first radiator comprises a plurality of end portions; and
   each of the plurality of end portions is equidistant from the through hole and electromagnetically coupled to the second radiator through the first gap.

4. The antenna apparatus according to claim 1, wherein each of the plurality of second radiators comprises a first radiation segment and a second radiation segment, the first radiation segment being connected to the second radiation segment and electromagnetically coupled to the first radiator through the first gap, and the second radiation segment being configured to be electrically connected to a feed source.

5. The antenna apparatus according to claim 4, wherein each of the plurality of second radiators further comprises a third radiation segment, the third radiation segment having a first end connected to the first radiation segment and a second end connected to the second radiation segment.

6. The antenna apparatus according to claim 5, wherein a plurality of third radiation segments is provided and sequentially connected to form the first end and the second end.

7. The antenna apparatus according to claim 4, wherein the second radiation segment is perpendicular to the first radiation segment.

8. The antenna apparatus according to claim 1, further comprising a plurality of third radiators, wherein:

   each of the plurality of third radiators is grounded and connected to a corresponding one of the plurality of second radiators; and
   each of the plurality of third radiators is configured to radiate a radio-frequency signal of a third frequency band.

9. The antenna apparatus according to claim 1, wherein the plurality of second radiators is symmetrically distributed along a periphery of the first radiator.

10. An electronic device, comprising a housing and an antenna apparatus disposed inside the housing and comprising:

a first radiator, the first radiator being grounded; and
a plurality of second radiators, a first gap being defined between each of the plurality of second radiators and the first radiator, and each of the plurality of second radiators being electrically connected to the first radiator through an electromagnetic coupling by means of the first gap, wherein:

each of the plurality of second radiators is configured to transmit a radio-frequency signal of a first frequency band; and
the plurality of second radiators and the first radiator are configured to jointly transmit a radio-frequency signal of a second frequency band.

11. The electronic device according to claim 10, wherein:

the first radiator has a through hole defined thereon; and
the antenna apparatus further comprises a capacitor disposed in the through hole and grounded, a second gap being defined between the capacitor and the first radiator, and the first radiator being electrically connected to the capacitor through an electromagnetic coupling by means of the second gap.

12. The electronic device according to claim 11, wherein:

the first radiator comprises a plurality of end portions;
each of the plurality of end portions is equidistant from the through hole and electromagnetically coupled to the second radiator through the first gap.

13. The electronic device according to claim 10, wherein each of the plurality of second radiators comprises a first radiation segment and a second radiation segment, the first radiation segment being connected to the second radiation segment and electromagnetically coupled to the first radiator through the first gap, and the second radiation segment being configured to be electrically connected to a feed source.

14. The electronic device according to claim 13, wherein each of the plurality of second radiators further comprises a third radiation segment, the third radiation segment having a first end connected to the first radiation segment and a second end connected to the second radiation segment.

15. The electronic device according to claim 14, wherein a plurality of third radiation segments is provided and sequentially connected to form the first end and the second end.

16. The electronic device according to claim 13, wherein the second radiation segment is perpendicular to the first radiation segment.

17. The electronic device according to claim 10, further comprising a plurality of third radiators, wherein:

each of the plurality of third radiators is grounded and connected to a corresponding one of the plurality of second radiators; and
each of the plurality of third radiators is configured to radiate a radio-frequency signal of a third frequency band.

18. The electronic device according to claim 10, wherein the plurality of second radiators is symmetrically distributed along a periphery of the first radiator.

19. The electronic device according to claim 10, further comprising a circuit board, the circuit board having a ground point and a feed source that are disposed thereon, wherein:

the first radiator is electrically connected to the ground point; and
each of the plurality of second radiators is electrically connected to the feed source.

20. The electronic device according to claim 19, wherein:

the first radiator and the circuit board are disposed in parallel; and
a distance between the first radiator and the circuit board is smaller than or equal to 5 mm.

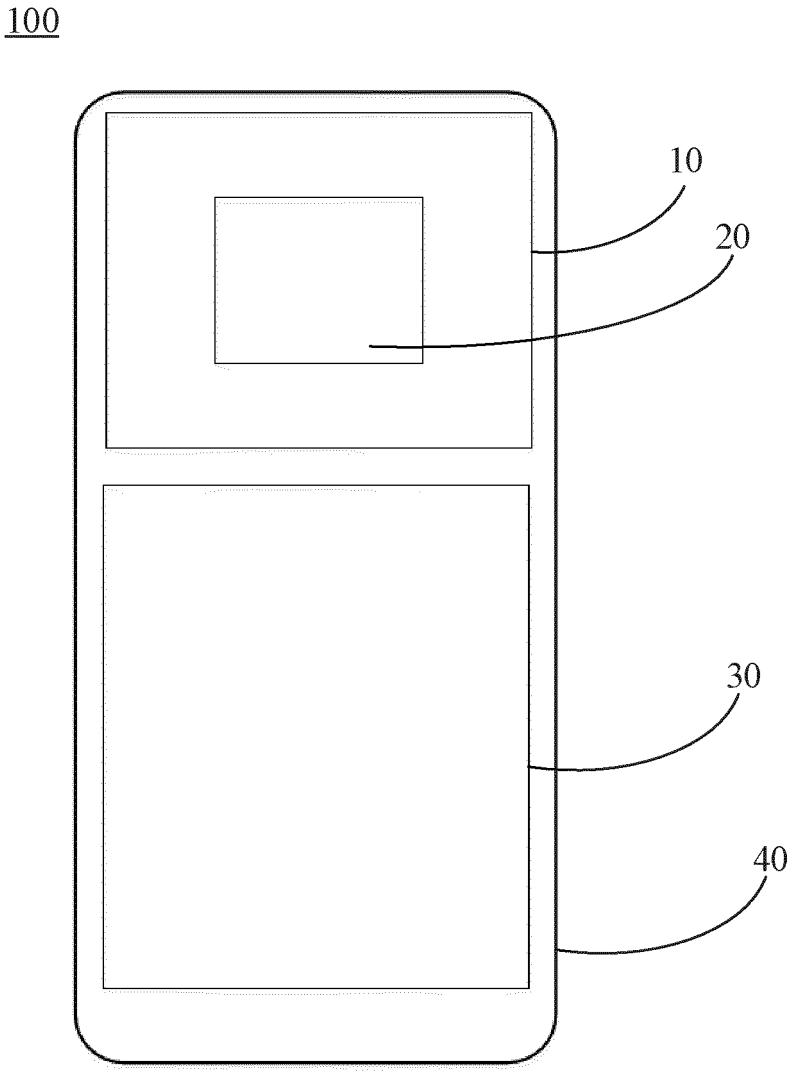

FIG. 1

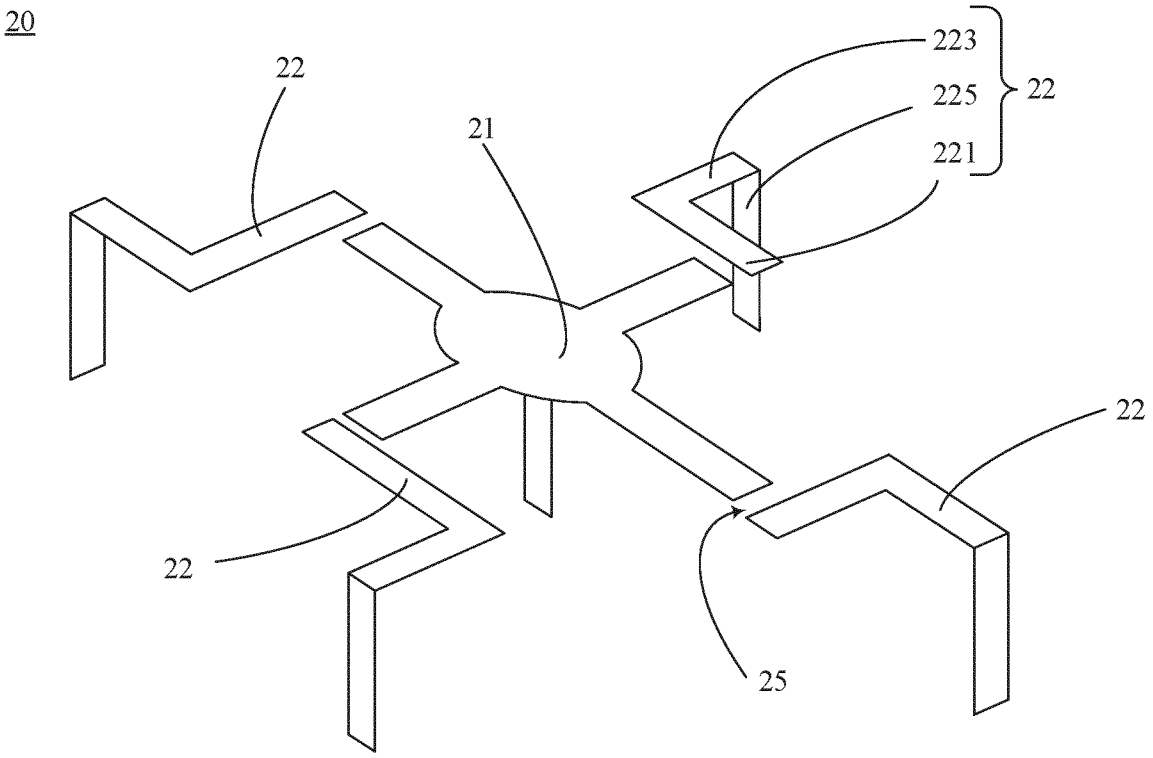
20
22
21
223
225
221
22
22
22
25

FIG. 2

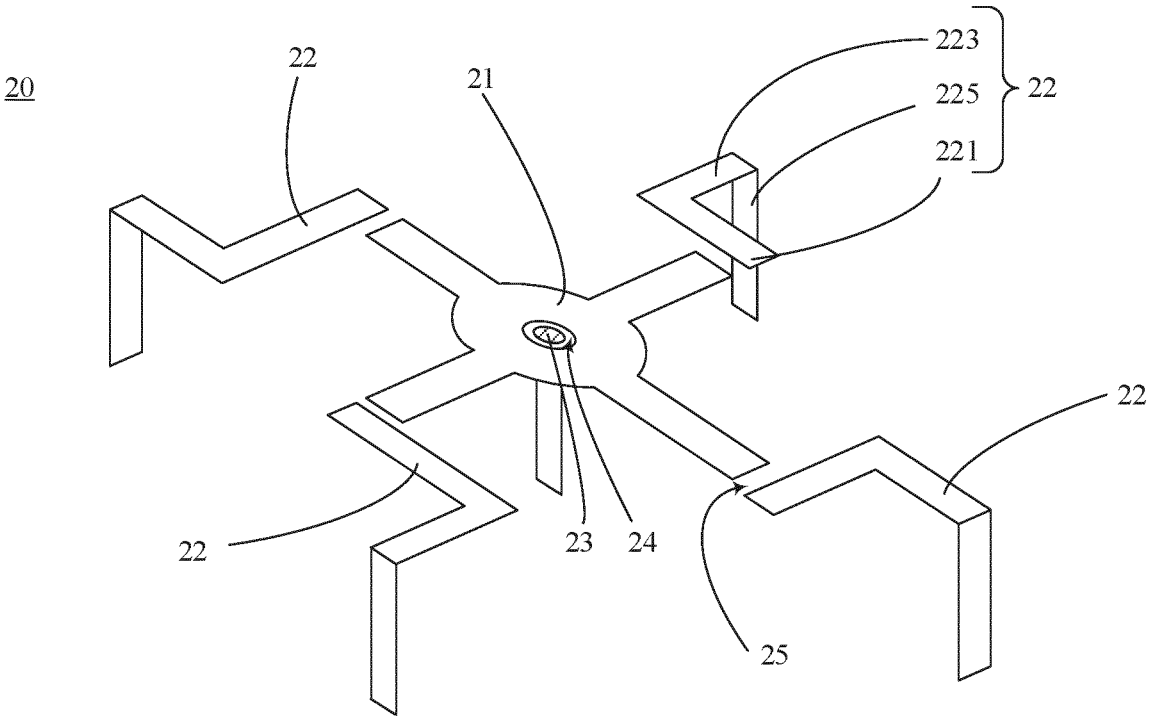
20
22
21
223
225
221
22
22
22
23
24
25

FIG. 3

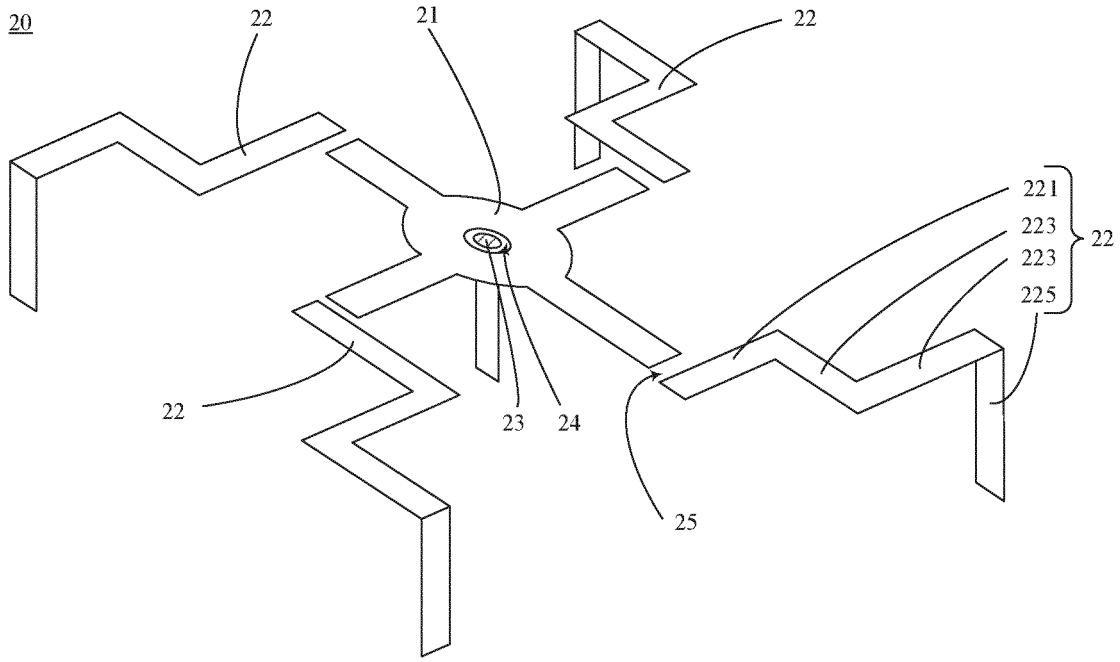
20
22
21
22
221
223
223
225
22
22
23
24
25

FIG. 4

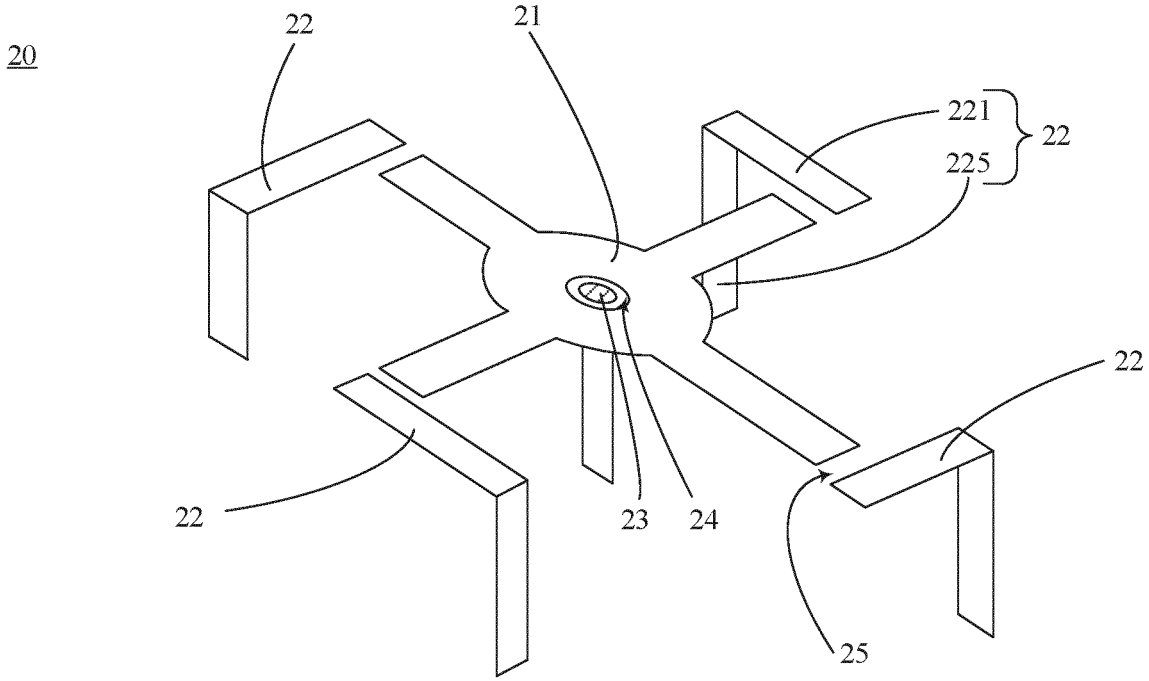
20
22
21
221
225
22
22
22
23
24
25

FIG. 5

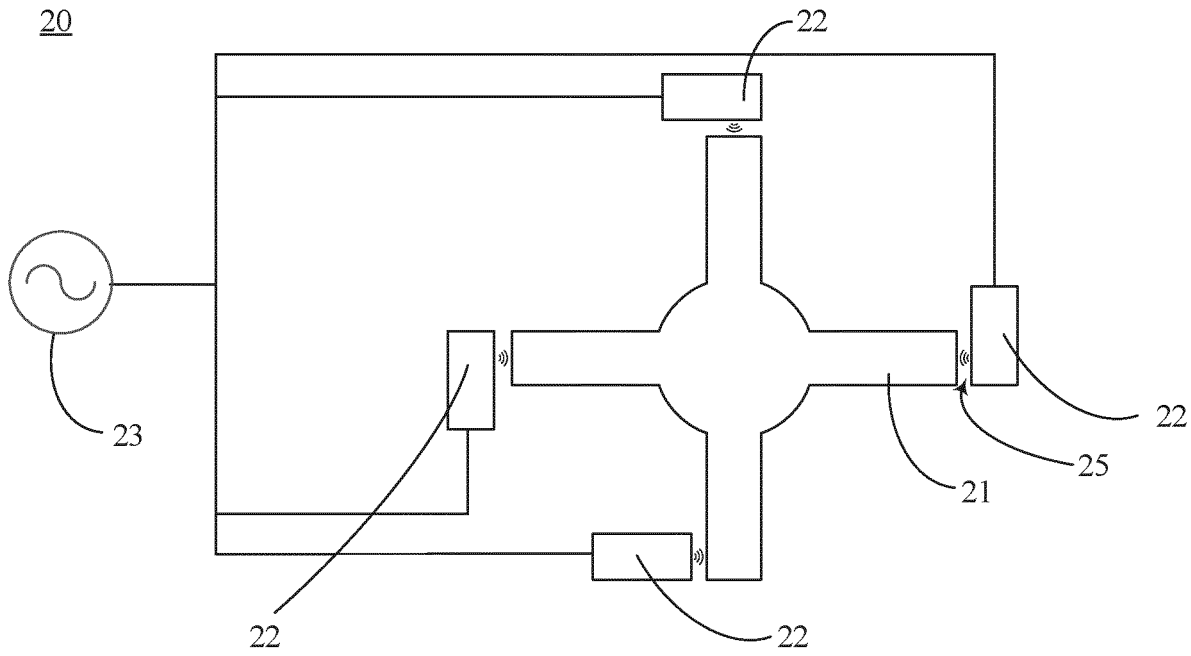
20
22
23
22
25
21
22
22

FIG. 6

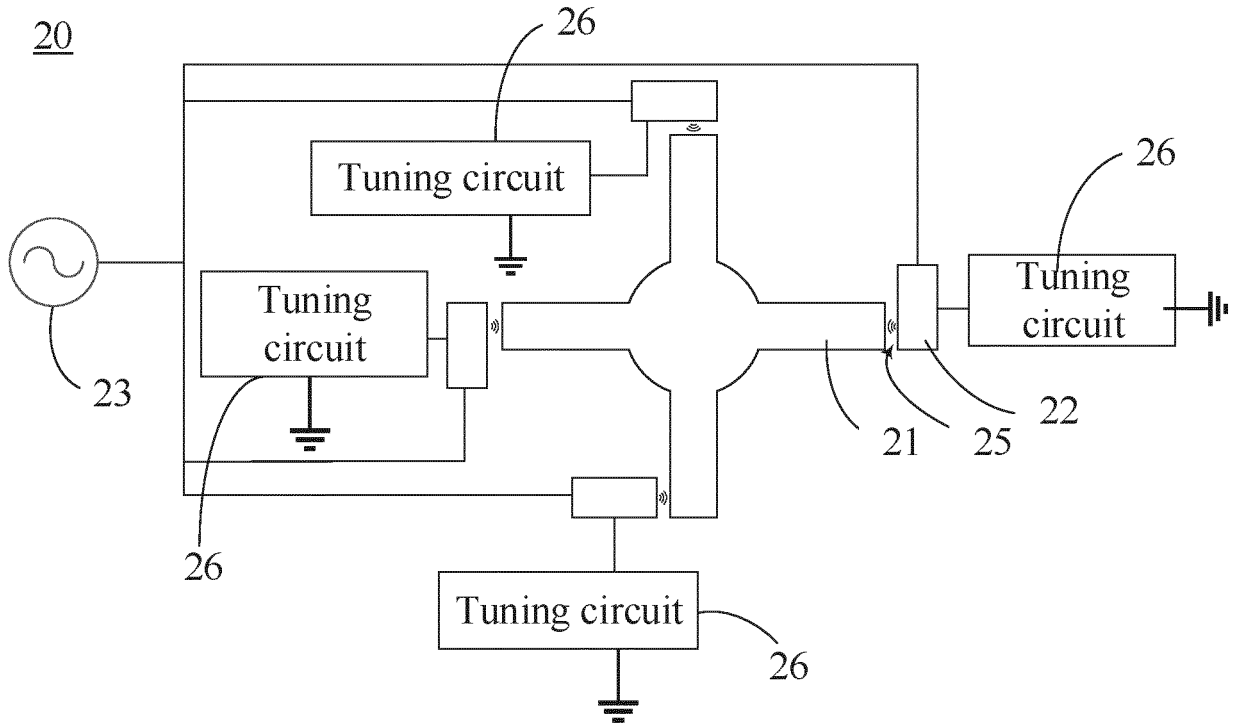
20
26
Tuning circuit
26
Tuning circuit
Tuning circuit
23
22
21
25
26
Tuning circuit
26

FIG. 7

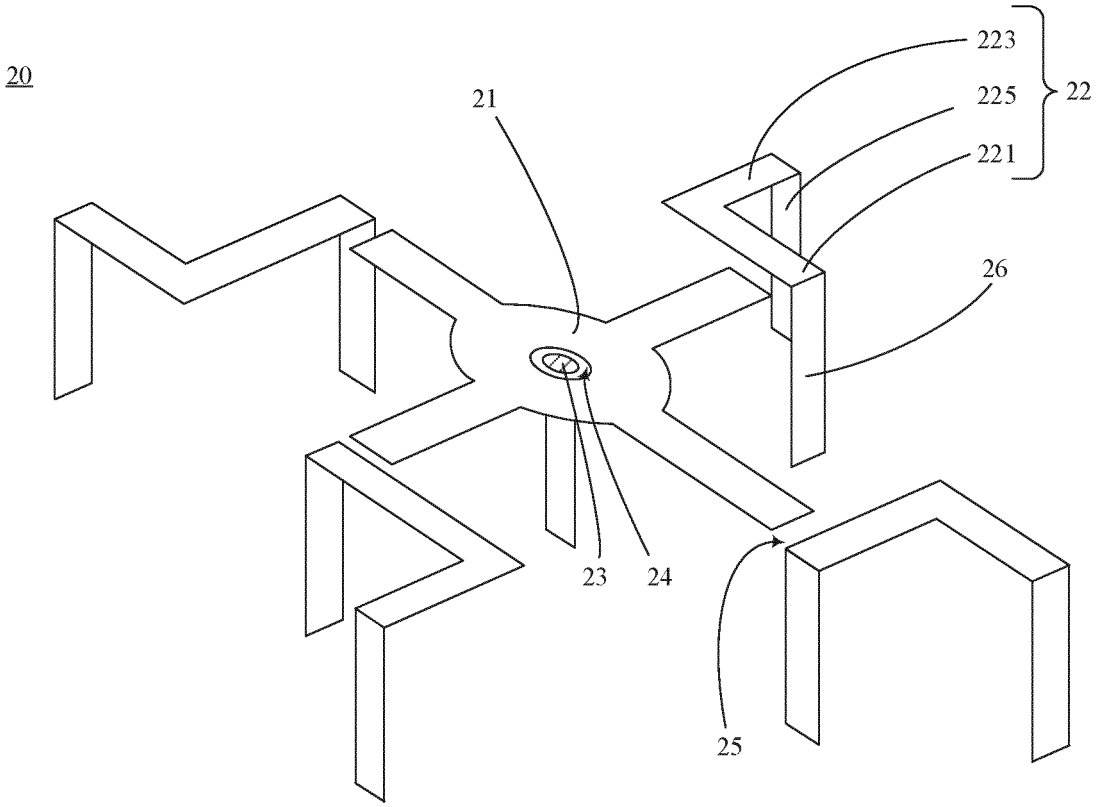

FIG. 8

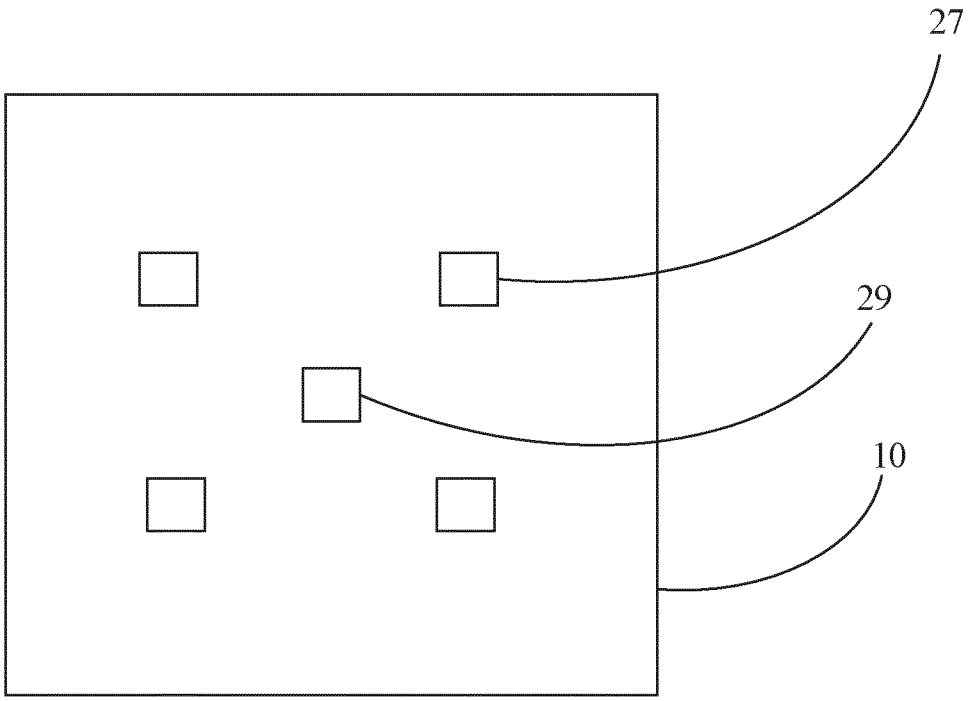

FIG. 9

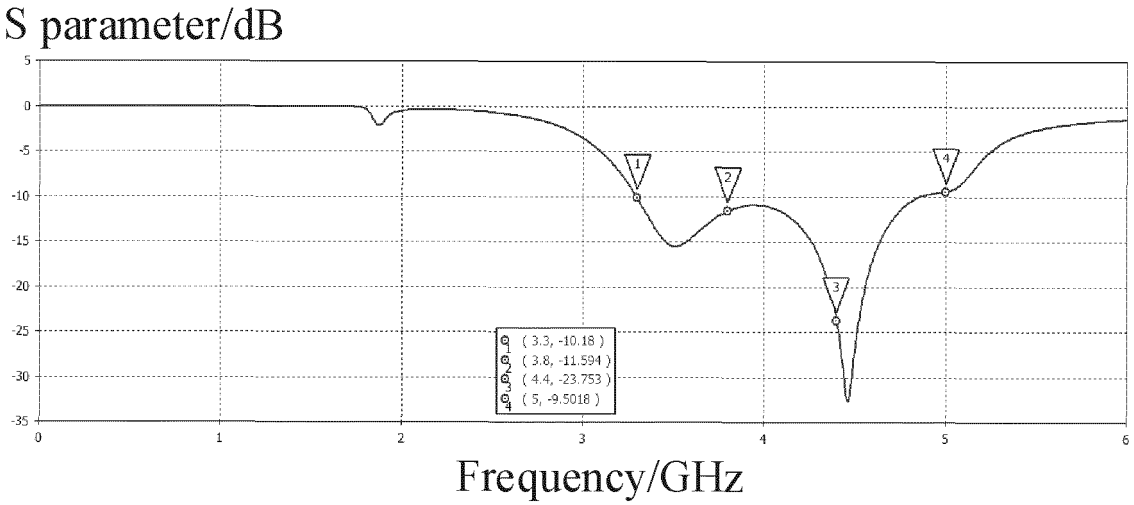
S parameter/dB
5
0
-5
-10
-15
-20
-25
-30
-35
0
1
2
3
4
5
6
1
2
3
4
(3.3, -10.18)
(3.8, -11.594)
(4.4, -23.753)
(5, -9.5018)
Frequency/GHz

FIG. 10

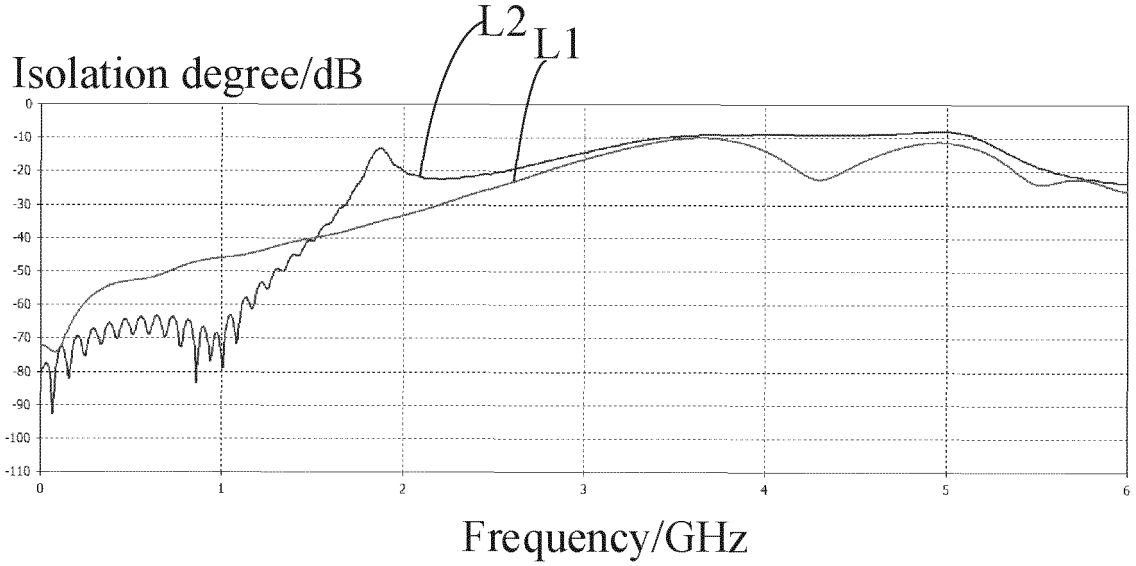
L2
L1
Isolation degree/dB
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
0
1
2
3
4
5
6
Frequency/GHz

FIG. 11

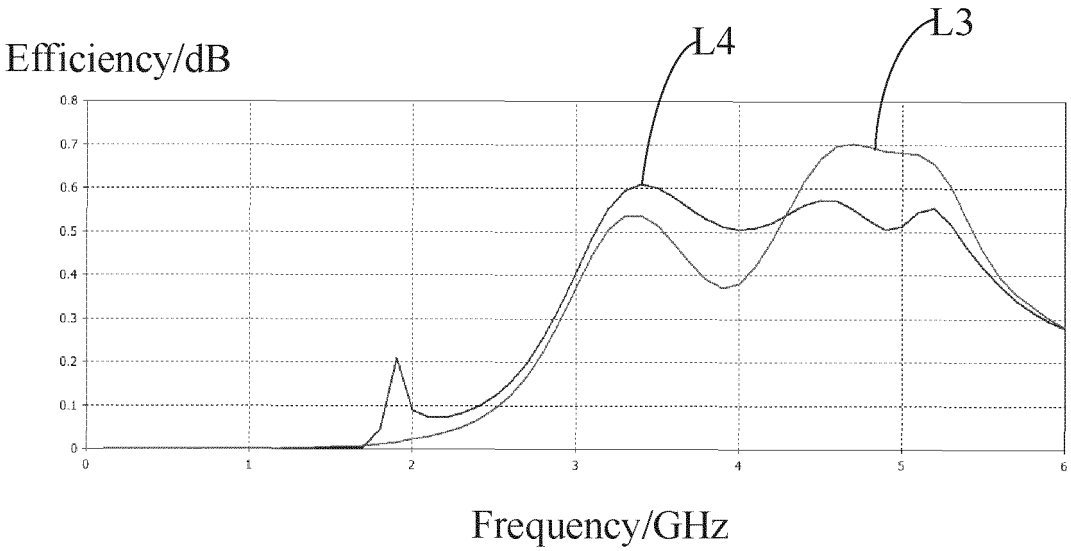
Efficiency/dB
L4
L3
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
Frequency/GHz

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/123915

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 1/36(2006.01)i; H01Q 5/307(2015.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01Q

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

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

VEN; CNABS; CNTXT; USTXT; EPTXT; WOTXT; CNKI; IEEE: 天线, 终端, 移动, 便携, 手机, 第一频段, 第二频段, 多个, 耦合, antenna, aerial, terminal, portable, cellphone, mobile, first, second, multiple, band, couple

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 109378586 A (INVENTEC TECHNOLOGY CO., LTD. et al.) 22 February 2019 (2019-02-22) description, paragraphs 0041-0055, figure 1	1, 4-7, 9, 10, 13-16, 18-20
X	CN 109980364 A (HUAWEI TECHNOLOGIES CO., LTD.) 05 July 2019 (2019-07-05) description, paragraphs 0045-0091, figure 1	1, 4-7, 9, 10, 13-16, 18-20
PX	CN 112436272 A (REALME INC.) 02 March 2021 (2021-03-02) entire document	1-20
A	CN 111244616 A (VIVO COMMUNICATION TECHNOLOGY CO., LTD.) 05 June 2020 (2020-06-05) entire document	1-20
A	CN 110768006 A (OPPO GUANGDONG MOBILE COMMUNICATIONS CO., LTD.) 07 February 2020 (2020-02-07) entire document	1-20
A	CN 102315513 A (INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE) 11 January 2012 (2012-01-11) entire document	1-20

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 December 2021	**30 December 2021**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China** Facsimile No. **(86-10)62019451**	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/123915

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2015263418 A1 (FUJITSU LTD.) 17 September 2015 (2015-09-17) entire document	1-20

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2021/123915

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 109378586 A	22 February 2019	CN 109378586 B	29 January 2021
		US 2020168988 A1	28 May 2020
		US 10700425 B2	30 June 2020
CN 109980364 A	05 July 2019	WO 2020173298 A1	03 September 2020
CN 112436272 A	02 March 2021	None	
CN 111244616 A	05 June 2020	None	
CN 110768006 A	07 February 2020	WO 2021082988 A1	06 May 2021
CN 102315513 A	11 January 2012	CN 102315513 B	17 June 2015
US 2015263418 A1	17 September 2015	JP 6183249 B2	23 August 2017
		JP 2015177241 A	05 October 2015
		US 9627750 B2	18 April 2017

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- CN 202011399314 **[0001]**