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Huang

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(54) **ANTENNA MODULE AND WIRELESS COMMUNICATION DEVICE HAVING SAME**

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(30) **Foreign Application Priority Data**

Feb. 24, 2023 (CN) 202310208944.7

(51) **Int. Cl.**

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H01Q 1/42	(2006.01)
H01Q 21/28	(2006.01)
H01Q 23/00	(2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/3275*** (2013.01); ***H01Q 1/42*** (2013.01); ***H01Q 21/28*** (2013.01); ***H01Q 23/00*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/22; H01Q 1/32; H01Q 1/3275; H01Q 1/36; H01Q 1/362; H01Q 1/42; H01Q 1/50; H01Q 5/35; H01Q 5/371; H01Q 5/40; H01Q 9/40; H01Q 21/28; H01Q 23/00
See application file for complete search history.

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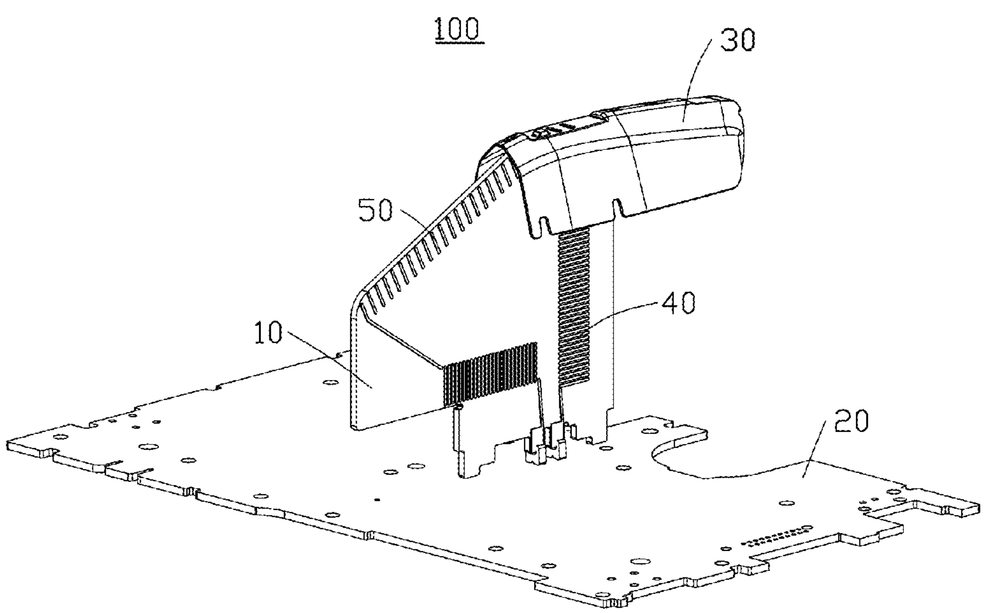
(57) **ABSTRACT**

An antenna module and a wireless communication device are provided, the antenna module includes a first circuit board, a second first circuit board, a radiation cover, a first radiating portion, and a second radiating portion. The radiation cover covers one part of an end of the first circuit board and one part of two opposite surfaces of the first circuit board. The first radiating portion is arranged on the first circuit board and perpendicular to the second circuit board, the first radiating portion receives wireless radiation signals in a first frequency band through the radiation cover. The second radiating portion is arranged on the first circuit board and includes a first radiating section and a second radiating section connected to the first radiating section in a predetermined angle, the second radiating portion receives wireless radiation signals in a second frequency band through the radiation cover.

18 Claims, 16 Drawing Sheets



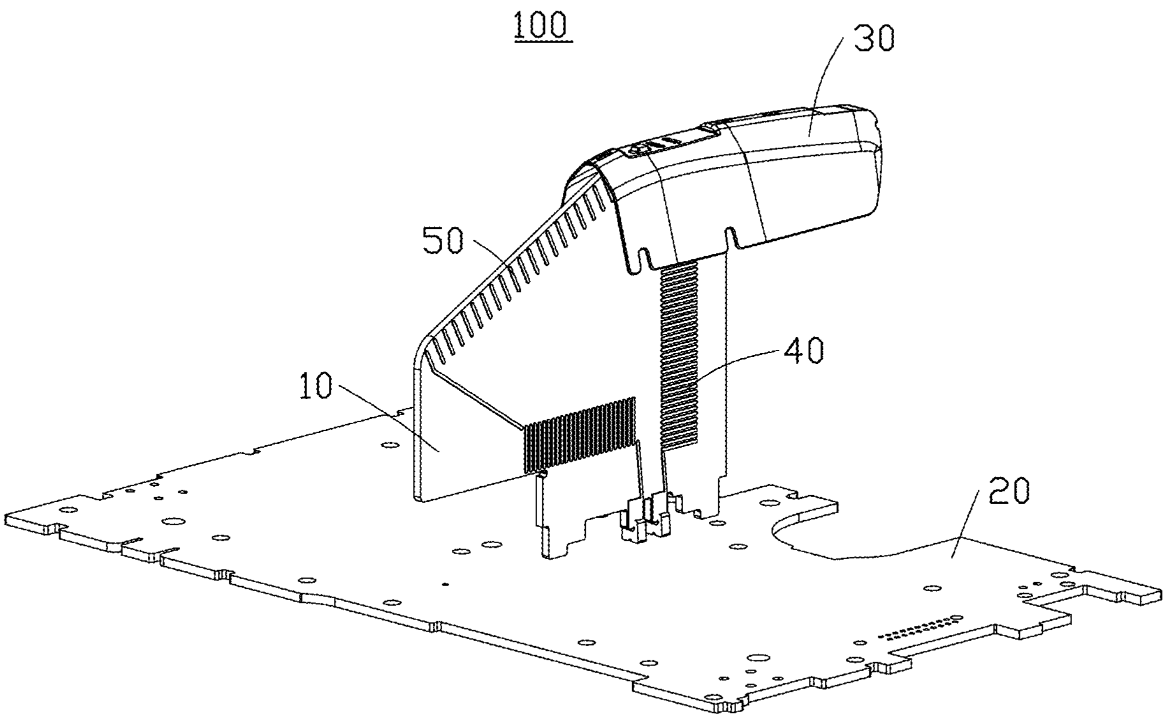


FIG. 1

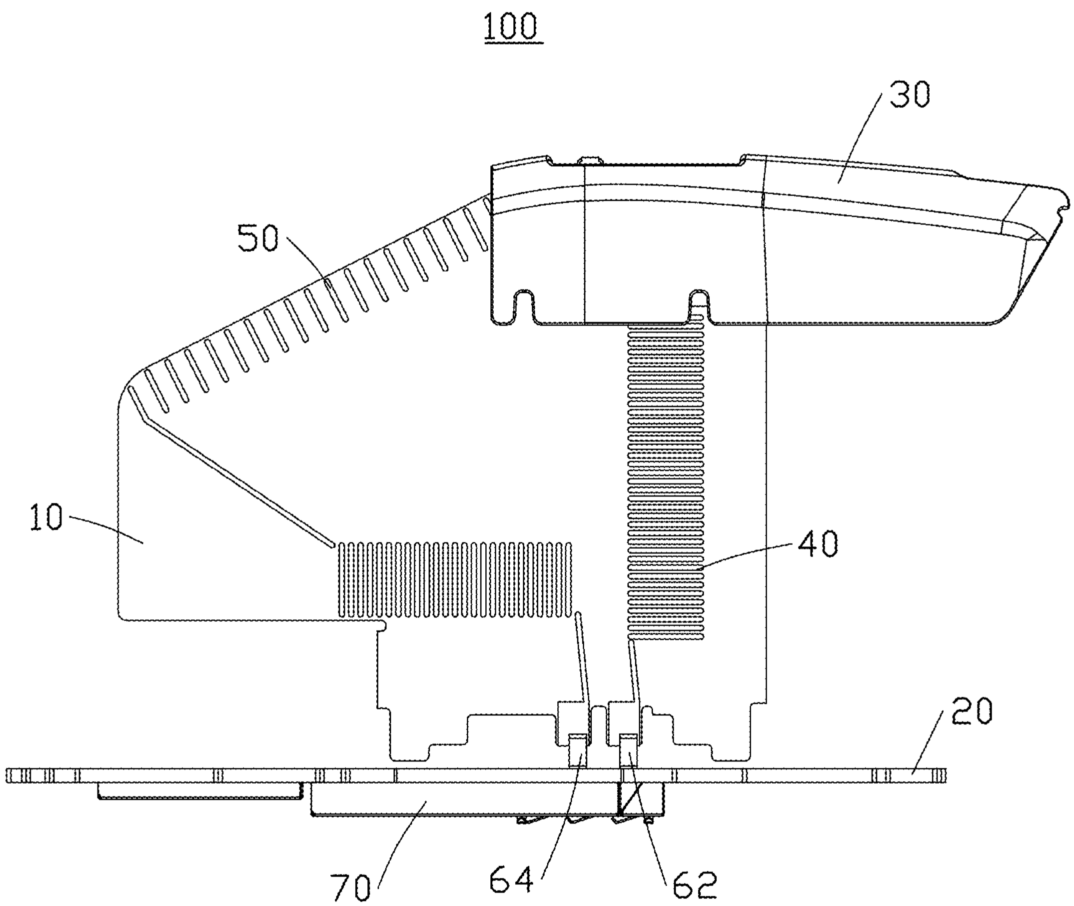


FIG. 2

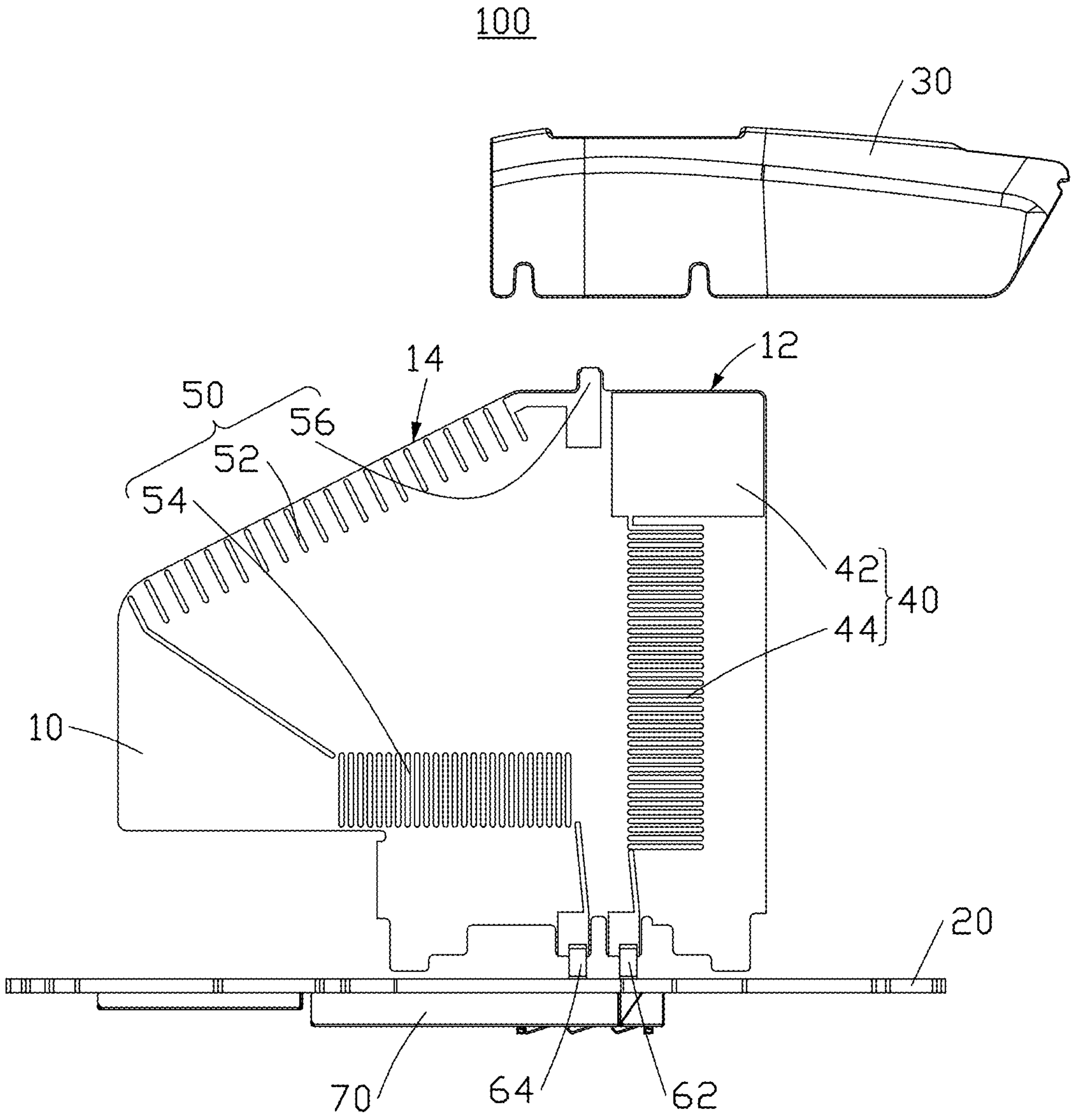


FIG. 3

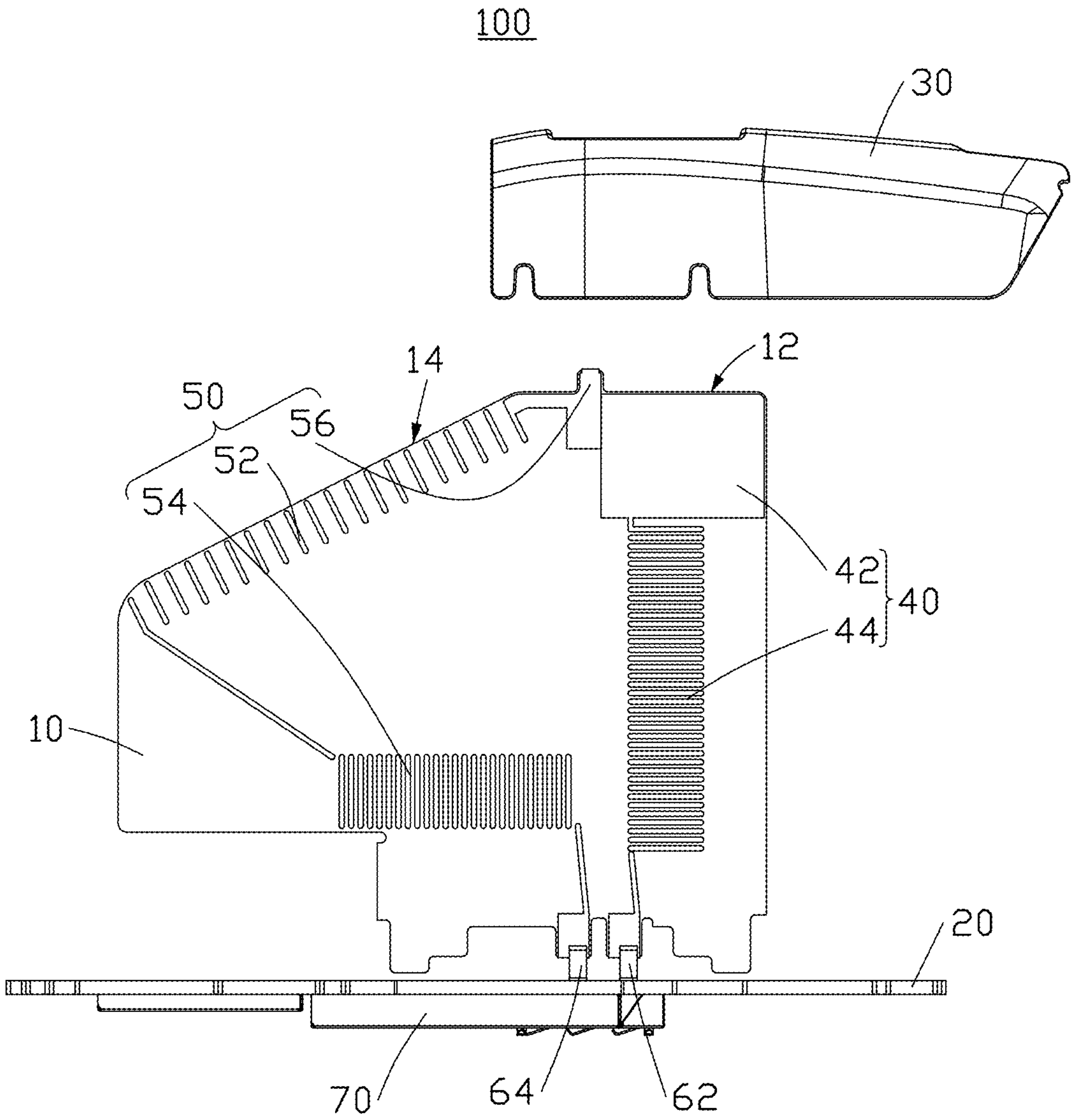


FIG. 4

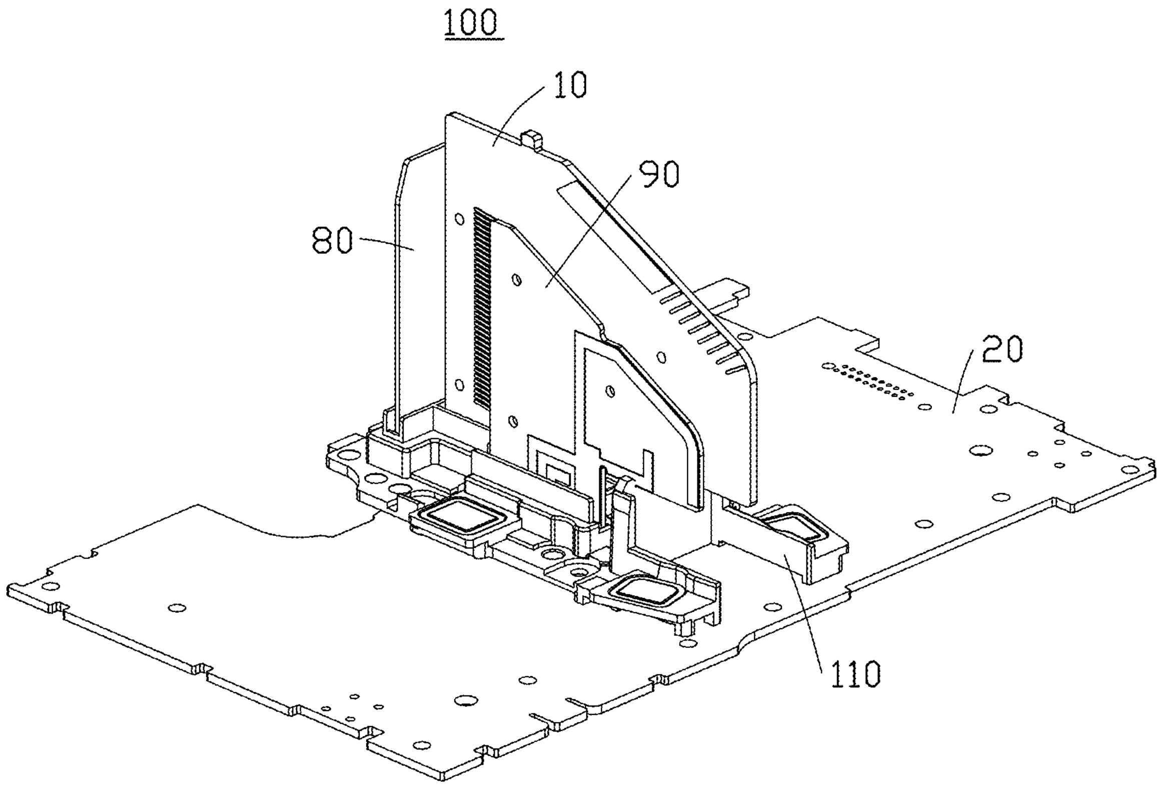


FIG. 5

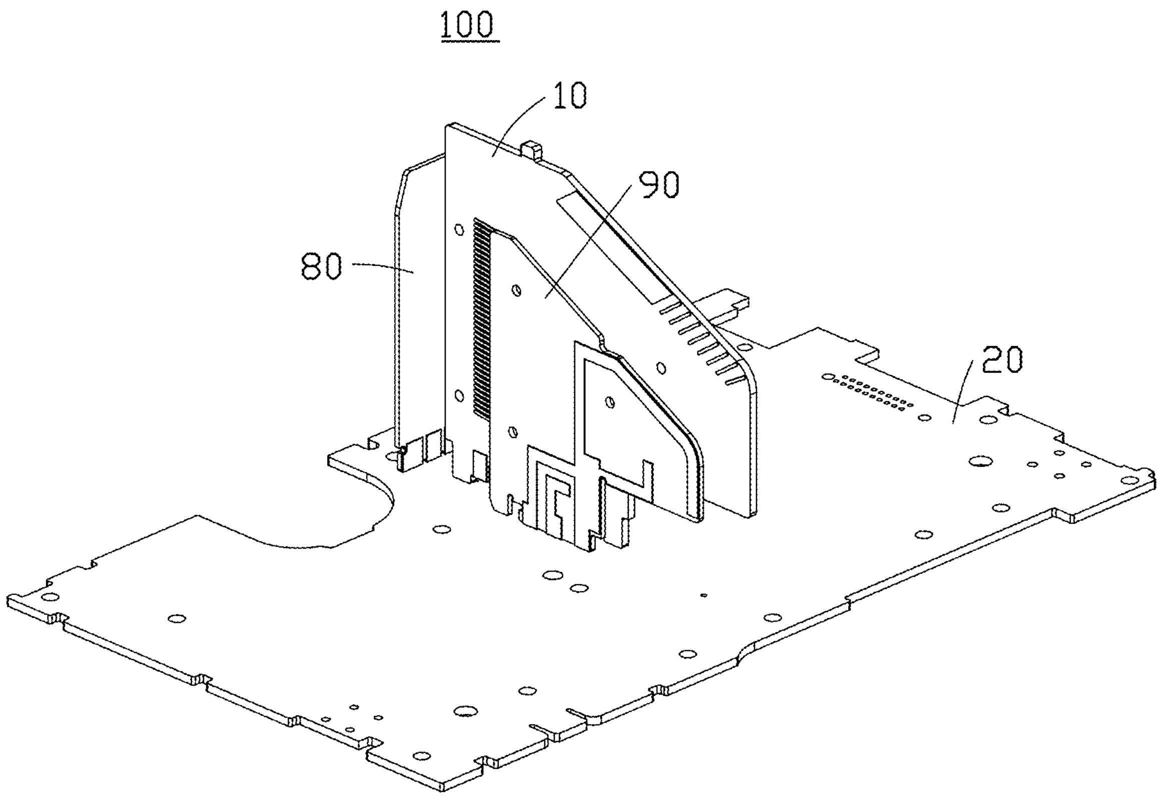


FIG. 6

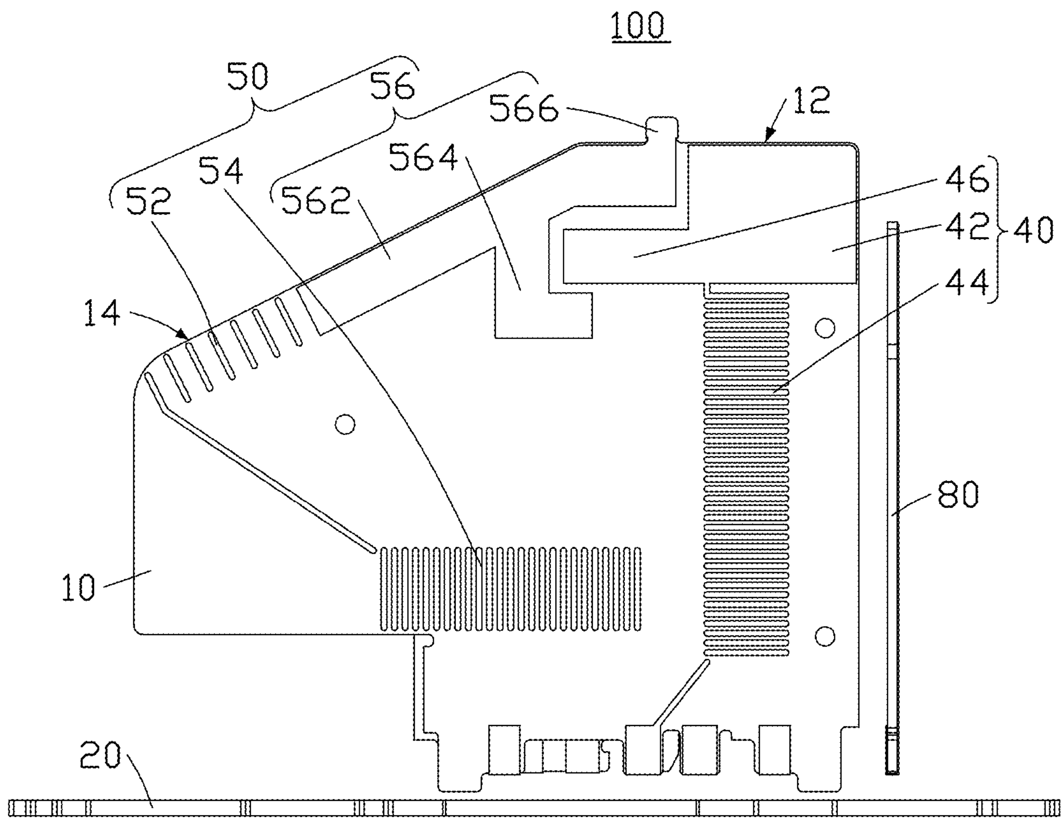


FIG. 7

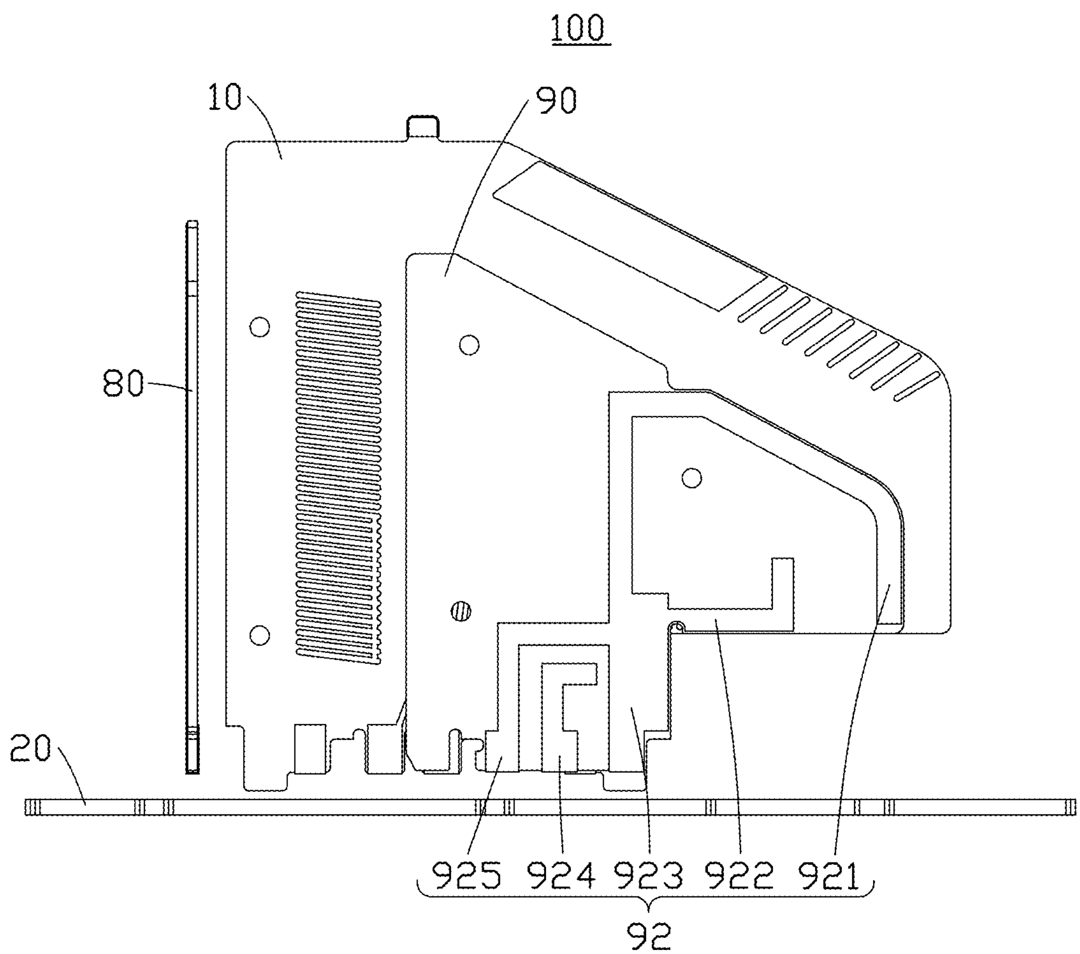


FIG. 8

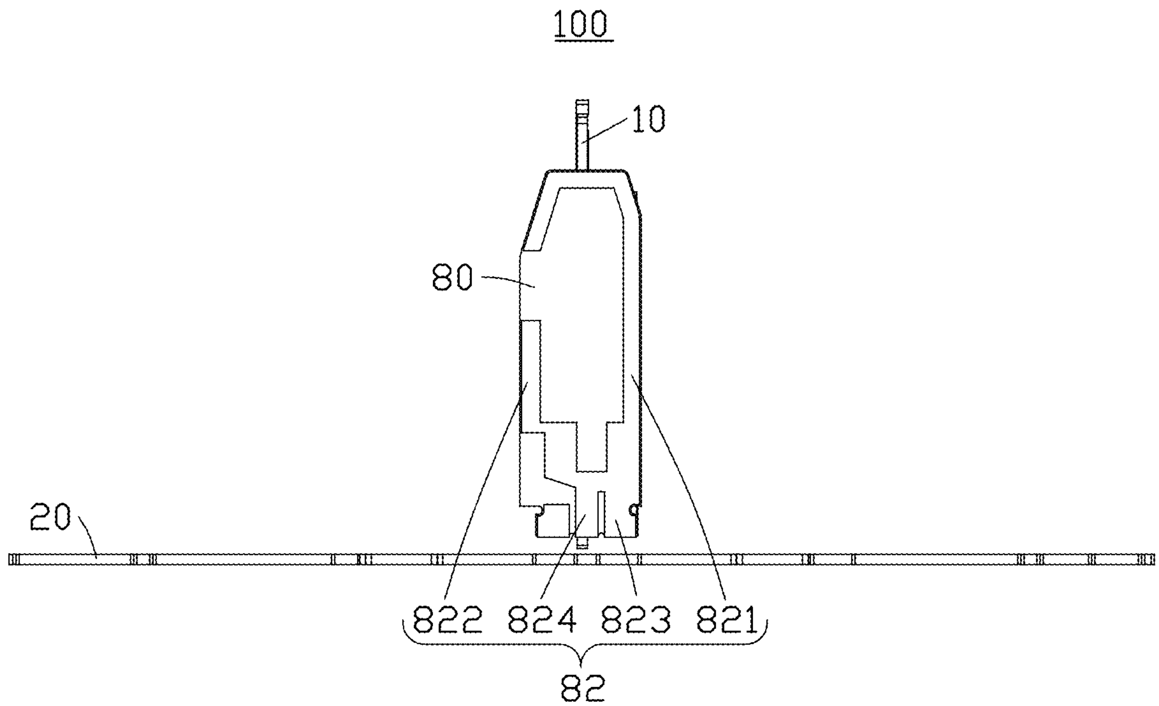


FIG. 9

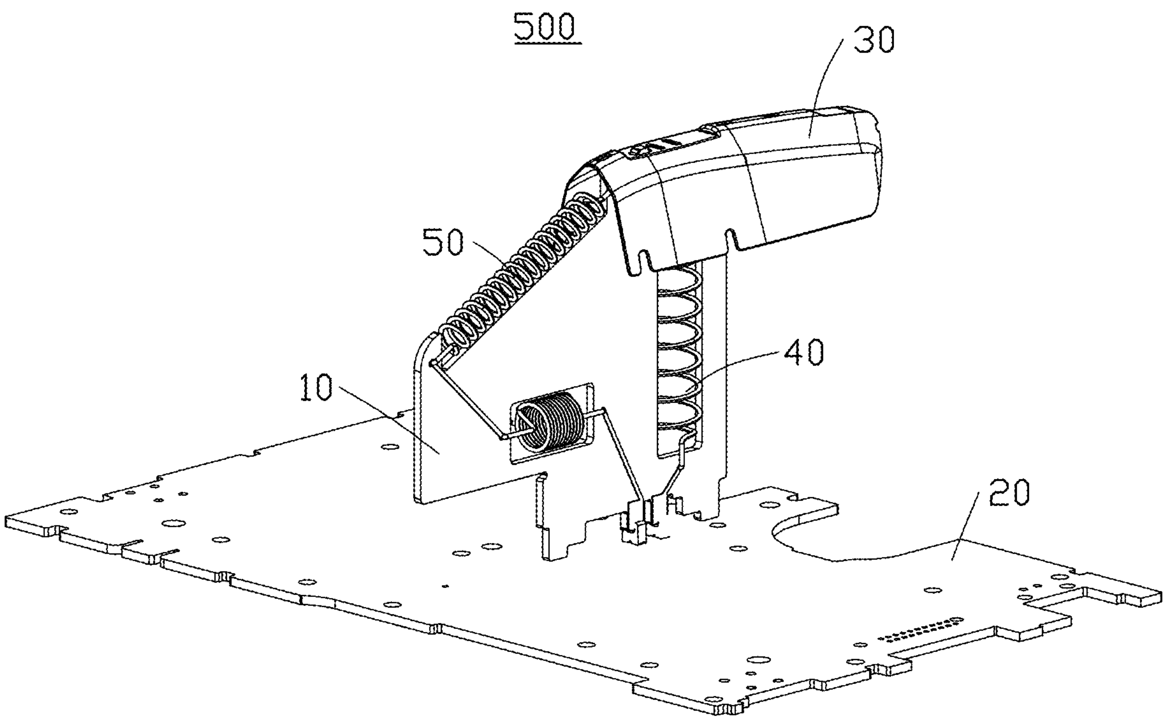


FIG. 10

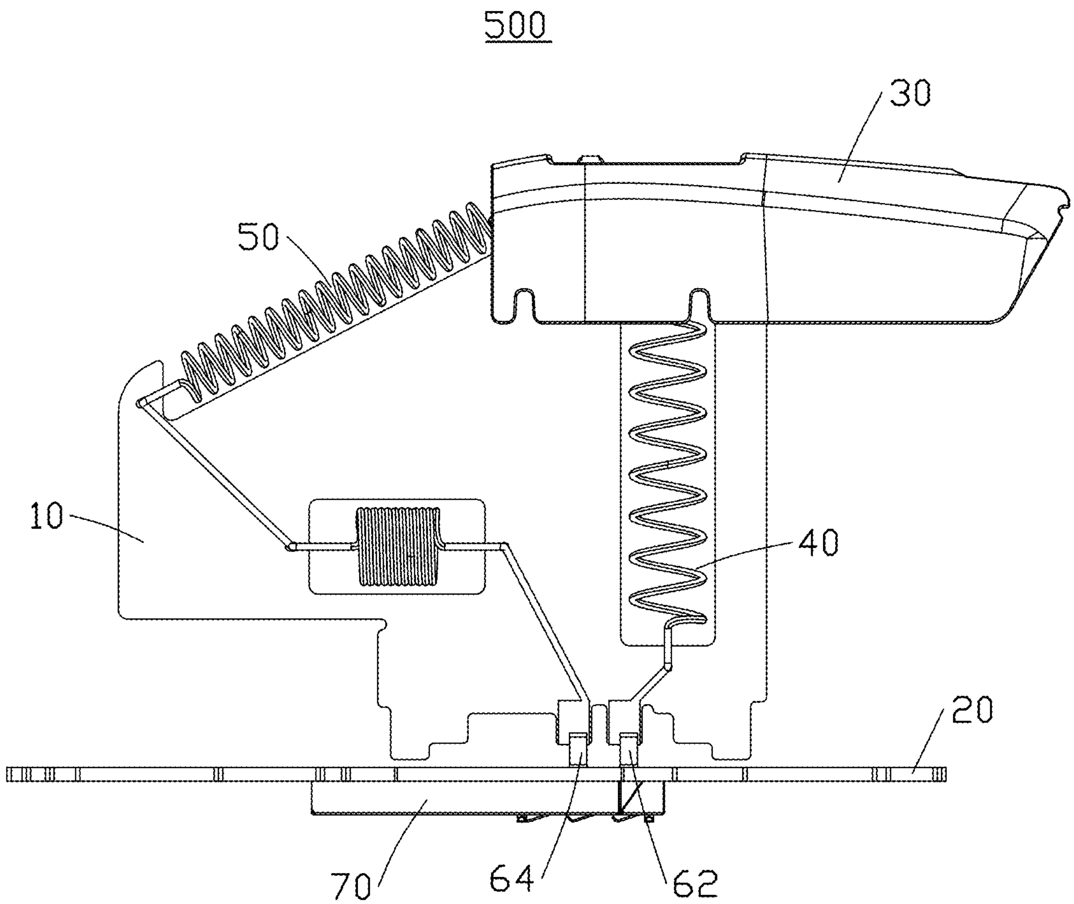


FIG. 11

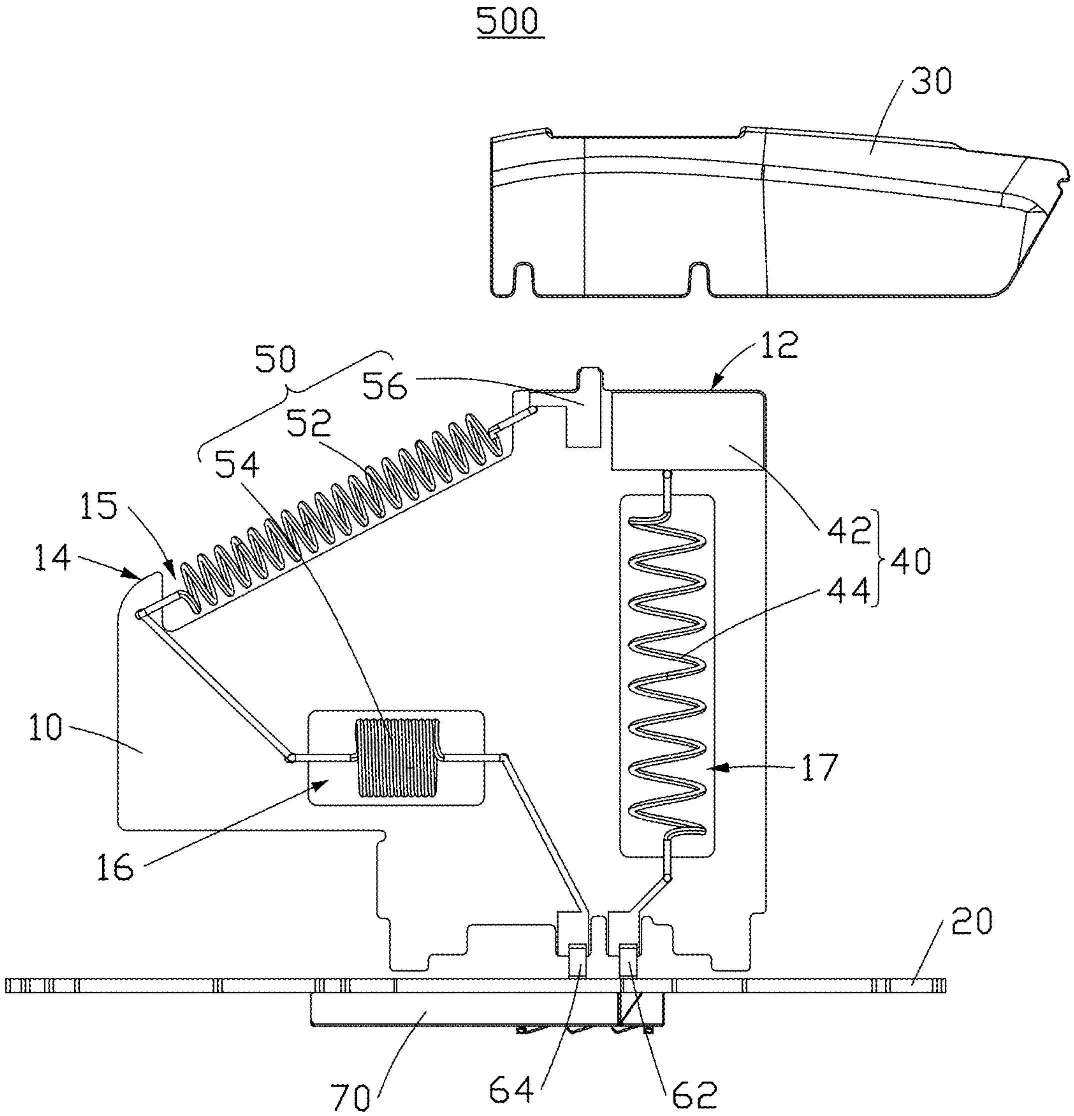


FIG. 12

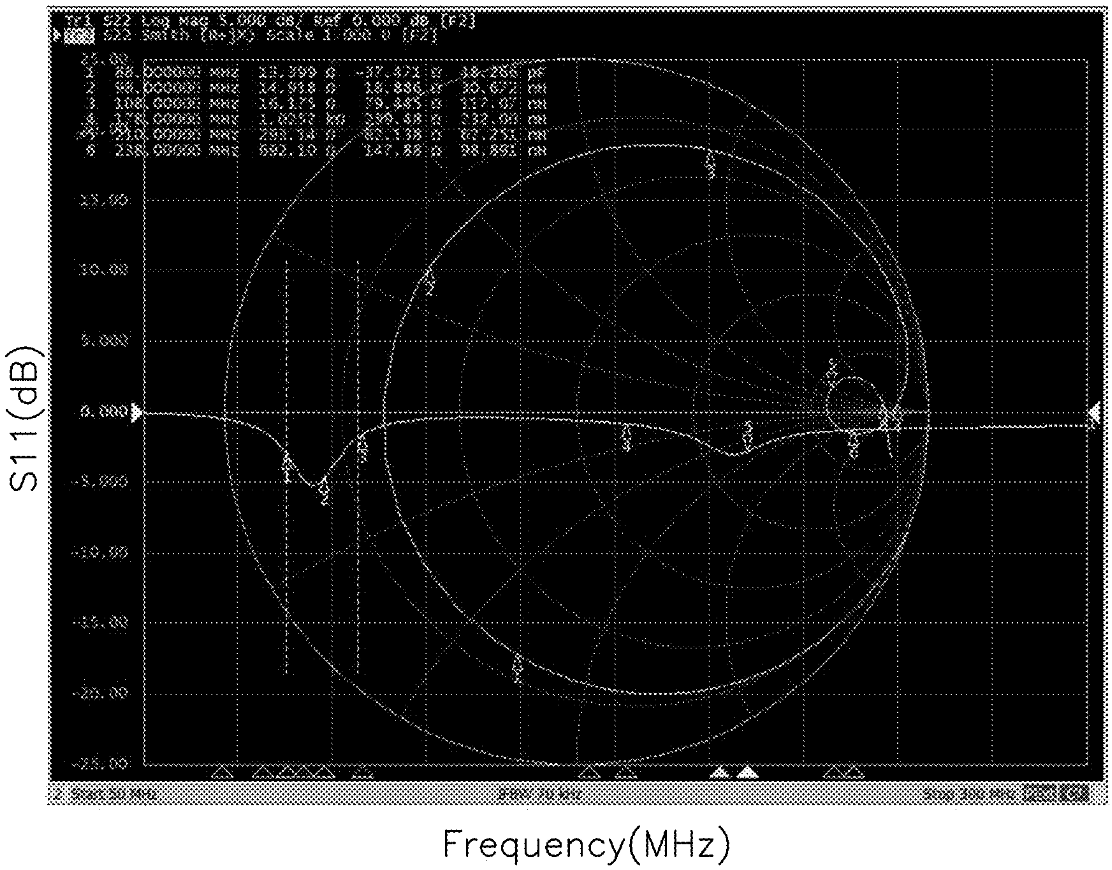


FIG. 13

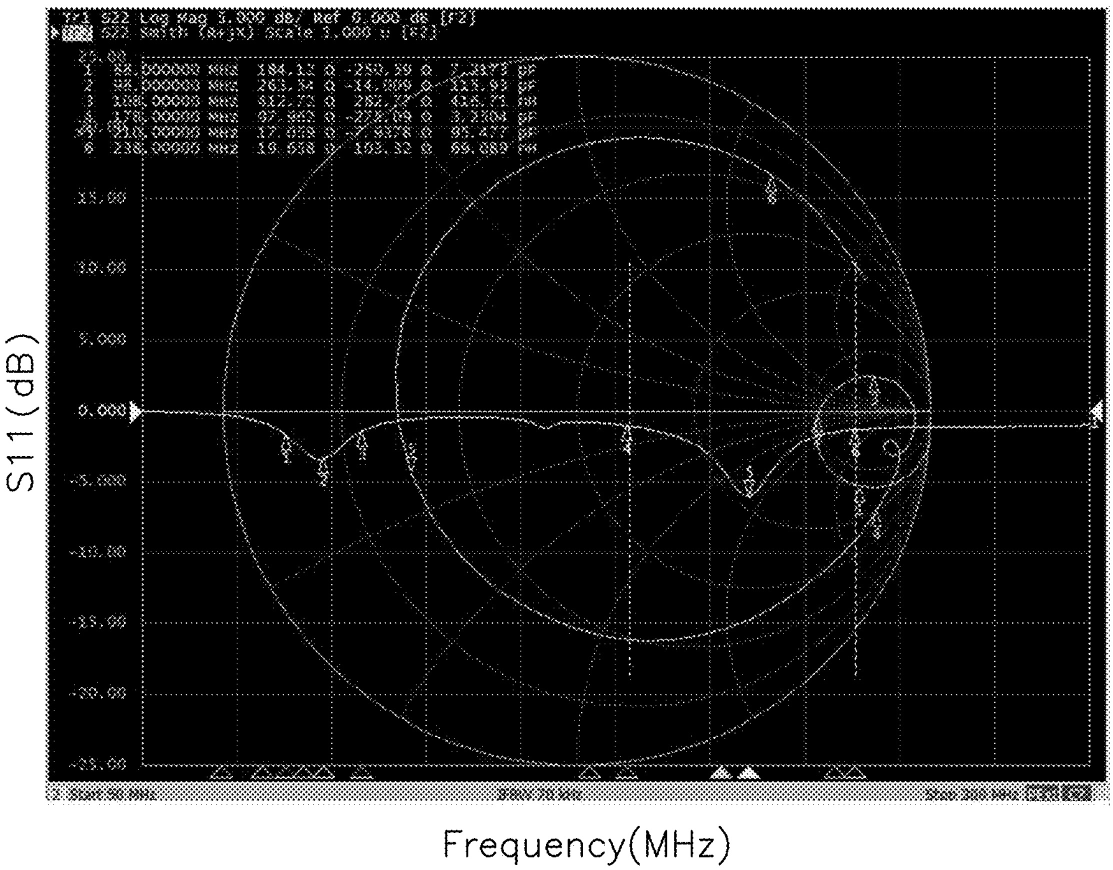

S11(dB)
Frequency(MHz)
15.00
10.00
5.000
0.000
-5.000
-10.00
-15.00
-20.00
-25.00

FIG. 14

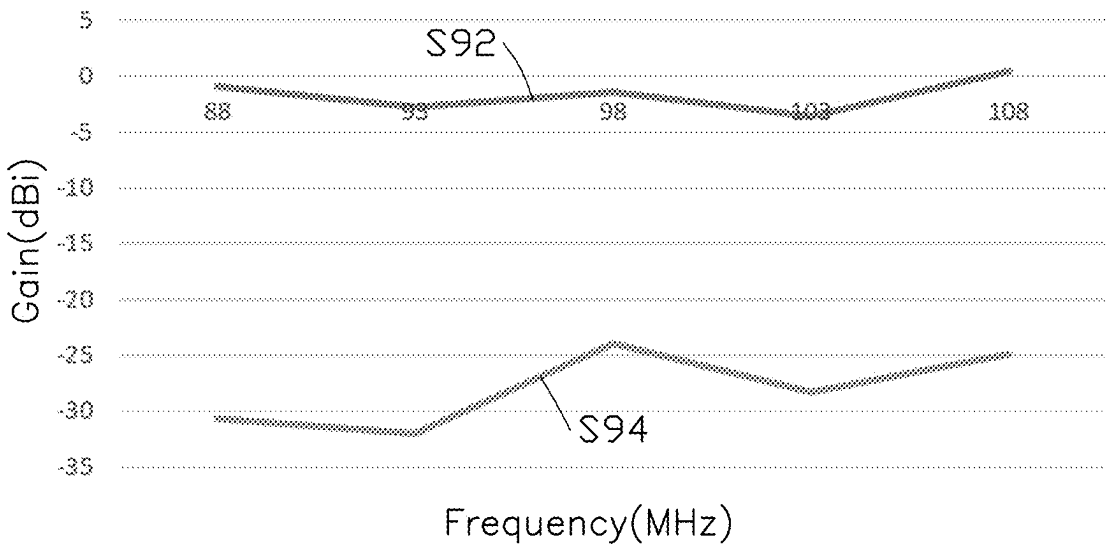

5
0
-5
-10
-15
-20
-25
-30
-35
Gain(dBi)
S92
S94
88
93
98
103
108
Frequency(MHz)

FIG. 15

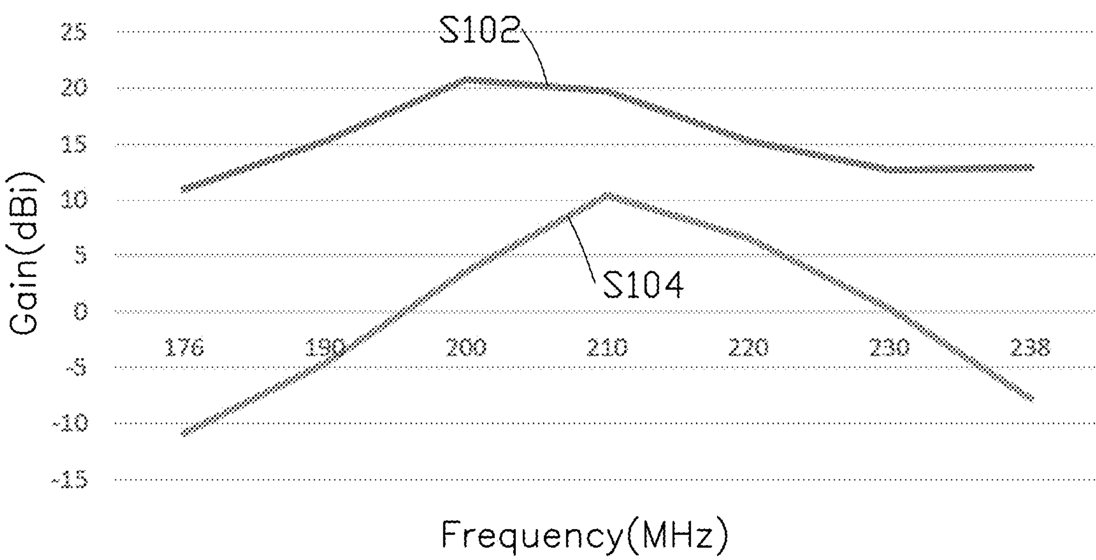

S102
S104
Gain(dBi)
25
20
15
10
5
0
-5
-10
-15
176
190
200
210
220
230
238
Frequency(MHz)

FIG. 16

ANTENNA MODULE AND WIRELESS COMMUNICATION DEVICE HAVING SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to Chinese Patent Application No. 202310208944.7 filed on Feb. 24, 2023, in China National Intellectual Property Administration, the contents of which are incorporated by reference herein.

FIELD

The subject matter herein generally relates to wireless communication, and more particularly to an antenna module of a wireless communication device having the antenna module.

BACKGROUND

Antennas, such as shark fin antennas, are mounted to vehicles, such as automobiles, and severed as car antennas, which may operate wireless communication signals of a high frequency band, such as above 500 MHz. However, when the shark fin antennas operate wireless communication signals of low frequency bands, such as FM frequency band of 88-108 MHz and DAB frequency band of 178-238 MHz, due to a long wave length, vehicle mounted antennas are usually pull-rod antennas. Additionally, the shark fin antennas need to be adapted to an entire vehicle design and meet structural strength requirements, adapting to the vehicle design and ensuring adequate antenna performances are challenging.

BRIEF DESCRIPTION OF THE DRAWINGS

Implementations of the present disclosure will now be described, by way of embodiments, with reference to the attached figures.

FIG. **1** is a schematic diagram of an antenna module according to a first embodiment of the present application.

FIG. **2** is a cross-sectional diagram of the antenna module of FIG. **1**.

FIG. **3** is an explored cross-sectional diagram of the antenna module of FIG. **1**.

FIG. **4** is an explored cross-sectional diagram of the antenna module according to another embodiment of the present application.

FIG. **5** is a schematic diagram of the antenna module according to another embodiment of the present application.

FIG. **6** is another schematic diagram of the antenna module of FIG. **5**.

FIG. **7** is a plane diagram of a first circuit board of the antenna module of FIG. **5**.

FIG. **8** is a plane diagram of a second circuit board of the antenna module of FIG. **5**.

FIG. **9** is a plane diagram of a third circuit board of the antenna module of FIG. **5**.

FIG. **10** is a schematic diagram of an antenna module according to a second embodiment of the present application.

FIG. **11** is a cross-sectional diagram of the antenna module of FIG. **10**.

FIG. **12** is an explored cross-sectional diagram of the antenna module of FIG. **11**.

FIG. **13** is a curve graph of S11 parameters when the antenna module operates in a first frequency band.

FIG. **14** is a curve graph of S11 parameters when the antenna module operates in a second frequency band.

FIG. **15** is a gain diagram when the antenna module operates in the first frequency band.

FIG. **16** is a gain diagram when the antenna module operates in the second frequency band.

DETAILED DESCRIPTION

It will be appreciated that for simplicity and clarity of illustration, where appropriate, reference numerals have been repeated among the different figures to indicate corresponding or analogous elements. Additionally, numerous specific details are set forth in order to provide a thorough understanding of the embodiments described herein. However, it will be understood by those of ordinary skill in the art that the embodiments described herein can be practiced without these specific details. In other instances, methods, procedures and components have not been described in detail so as not to obscure the related relevant feature being described. The drawings are not necessarily to scale and the proportions of certain parts may be exaggerated to better illustrate details and features. The description is not to be considered as limiting the scope of the embodiments described herein.

Several definitions that apply throughout this disclosure will now be presented.

The term "coupled" is defined as connected, whether directly or indirectly through intervening components, and is not necessarily limited to physical connections. The connection can be such that the objects are permanently connected or releasably connected. The term "substantially" is defined to be essentially conforming to the particular dimension, shape, or another word that "substantially" modifies, such that the component need not be exact. For example, "substantially cylindrical" means that the object resembles a cylinder, but can have one or more deviations from a true cylinder. The term "comprising" means "including, but not necessarily limited to"; it specifically indicates open-ended inclusion or membership in a so-described combination, group, series, and the like.

FIG. **1** shows at least one embodiment of an antenna module **100** that can be applied to a wireless communication device, such as a vehicle with wireless communication function, for transmitting and receiving radio waves for transmitting and exchanging wireless signals. The vehicle may be an automobile. The antenna module **100** may be a shark fin antenna.

Referring to FIGS. **1-3**, the antenna module **100** includes a first circuit board **10**, a second circuit board **20**, a radiation cover **30**, a first radiating portion **40**, a second radiating portion **50**, a first feed point **62**, a second feed point **64**, and a low noise amplifier (LNA) circuit **70**.

A surface of the first circuit board **10** is perpendicular to a surface of the second circuit board **20**. In at least one embodiment, the second circuit board **20** may be arranged inside the vehicle, such as a plane of a ceiling of the vehicle; the first circuit board **10** may be arranged on the top of the vehicle for broadly receiving wireless signals.

The first circuit board **10** may be a carrier of the radiation cover **30**, the first radiating portion **40**, and the second radiating portion **50**. The first circuit board **10** at least includes a top side **12** and a bevel side **14**. The top side **12** is a side of the first circuit board **10** that away from the second circuit board **20**. The top side **12** is parallel with the second circuit board **20**. The bevel side **14** and the top side

12 are connected with a predetermined angle. Thus, the bevel side 14 and the second circuit board 20 are also in the predetermined angle.

The first radiating portion 40 is arranged on the first circuit board 10 and perpendicular to the second circuit board 20. In one embodiment, the first radiating portion 40 can be arranged on at least one surface of the first circuit board 10. In another embodiment, the first radiating portion 40 can be arranged throughout the first circuit board 10 and arranged on two opposite surfaces of the first circuit board 10. In another embodiment, the first radiating portion 40 can be respectively arranged on two opposite surfaces of the first circuit board 10.

The second radiating portion 50 is arranged on the first circuit board 10. The second radiating portion 50 includes a first radiating section 52, a second radiating section 54, and a connecting portion 56. The first radiating section 52 and the second radiating section 54 are connected to the connected in a predetermined angle. In one embodiment, the first radiating section 52, the second radiating section 54, and the connecting portion 56 can be arranged on at least one surface of the first circuit board 10. In another embodiment, the first radiating section 52, the second radiating section 54, and the connecting portion 56 can be arranged on two opposite surfaces of the first circuit board 10.

In at least one embodiment, the first radiating section 52 and the second radiating section 54 are in coil shaped. Two opposite ends of the first radiating section 52 are connected to the second radiating section 54 and the connecting portion 56, respectively. The first radiating section 52 is arranged along the bevel side 14 of the first circuit board 10, so the first radiating section 52 and the second circuit board 20 are in a predetermined angle. The second radiating section 54 is parallel with the second circuit board 20, opposite ends of the second radiating section 54 are connected to the first radiating section 52 and the second feed point 64, respectively. The connecting portion 56 is arranged along the top side 12 of the first circuit board 10, the connecting portion 56 extends through and out of the top side 12, for securing the radiation cover 30 to the first circuit board 10.

The first radiating portion 40 includes a third radiating section 42 and a fourth radiating section 44 connected to each other. In at least one embodiment, the third radiating section 42 is substantially rectangular, the fourth radiating section 44 is in coil shaped. The third radiating section 42 is arranged along the top side 12 of the first circuit board 10, and spaced apart from the connecting portion 56, so the third radiating section 42 and the connecting portion 56 can form signal or electric current coupling effect. The fourth radiating section 44 is substantially perpendicular to the second circuit board 20, opposite ends of the fourth radiating section 44 are connected to the third radiating section 42 and the first feed point 62, the fourth radiating section 44 is spaced apart from the second radiating section 54. The fourth radiating section 44 is mainly configured to adjust a resonance frequency of the first radiating portion 40. In one embodiment, the third radiating section 42 and the fourth radiating section 44 can be arranged on at least one surface of the first circuit board 10. In another embodiment, the third radiating section 42 and the fourth radiating section 44 can be arranged on two opposite surfaces of the first circuit board 10.

Referring to FIG. 4, in another embodiment, the third radiating section 42 and the connecting portion 56 are connected, so the third radiating section 42 and the connecting portion 56 can form signal or electric current conduct effect.

Referring to FIG. 7, in another embodiment, the third radiating section 42 further includes an extending arm 46. The extending arm 46 is extended from a side of the third radiating section 42 away from the top side 12 along a direction parallel with the top side 12, and extended towards the connecting portion 56. The connecting portion 56 includes a first arm 562, a second arm 564, and a protruding portion 566. The first arm 562 is arranged along the top side 12 and the bevel side 14, the first arm 562 is connected to the first radiating section 52. Comparing to the embodiment shown in FIG. 3, the part of the first arm 562 arranged along the bevel side 14 is replaced by the first radiating section 52 to decrease the length of the first radiating section 52. The second arm 564 is substantially L-shaped, the second arm 564 is extended from a substantially middle portion of the first arm 562 towards the second circuit board 20 and bent, and then extended towards the fourth radiating section 44. The protruding portion 566 is protruded from the top side 12. The third radiating section 42 and the extending arm 46 are largely spaced apart from the first arm 562 and the second arm 564, which forming a greater coupling area to increase the coupling effect and an impedance matching.

In at least one embodiment, the first radiating section 52, the second radiating section 54, the third radiating section 42, and the fourth radiating section 44 may be formed on a surface of the first circuit board 10 by printing. The printing may include a Laser-Direct-structuring (LDS) technology, etc.

The radiation cover 30 at least covers one part of an end of the first circuit board 10. In detail, the radiation cover 30 at least covers the top side 12 of the first circuit board 10, and at least partially protrudes from a side of the first circuit board 10 away from the bevel side 14. As shown in FIG. 2, one part of the radiation cover 30 covers the end of the first circuit board 10 and two surfaces of the first circuit board 10. In addition, another part of the radiation cover 30 does not cover the first circuit board 10 (right part of the radiation cover 30 as shown in FIG. 2). The connecting portion 56 has a protrusion structure protruding from the top side 12 and secured through the radiation cover 30, so the radiation cover 30 is secured to the first circuit board 10, the second radiating portion 50 and the radiation cover 30 can conduct signal or electric current through the connecting portion 56. The radiation cover 30 covers the third radiating section 42, but spaced apart from the third radiating section 42, so the third radiating section 42 and the radiation cover 30 can conduct signal or electric current.

In another embodiment, the connecting portion 56 and the top side 12 may be both connected to the radiation cover 30, so the radiation cover 30 is secured to the first circuit board 10, the second radiating portion 50 and the radiation cover 30 can conduct signal or electric current through the connecting portion 56, the first radiating portion 40 and the radiation cover 30 can conduct signal or electric current through the third radiating section 42.

The first feed point 62 and the second feed point 64 are arranged on a side of the first circuit board 10 away from the top side 12 at interval. The first feed point 62 and the second feed point 64 are configured to feed electric current into the first radiating portion 40 and the second radiating portion 50.

The second circuit board 20 arranges with an electric current feed source, a ground plane, and system circuits. The electric current feed source is configured to provide electric current for the antenna module 100. The ground plane is configured to provide grounding for the antenna module 100. The system circuits are configured to execute system functions of the antenna module **100**, such as receiving and processing wireless communication signals.

The LNA circuit **70** is arranged on a surface of the second circuit board **20** that away from the first circuit board **10**. The LNA circuit **70** is electrically connected between the electric current feed source and each of the first feed point **62** and the second feed point **64**. The LNA circuit **70** may be configured to decrease noise of the wireless signals received by the antenna module **100**, to improve a signal to noise ratio (SNR) and provide a good signal quality.

Referring to FIGS. **5** and **6**, in at least one embodiment, the antenna module **100** may further include a third circuit board **80** and a fourth circuit board **90**. A surface of the third circuit board **80**, the surface of the second circuit board **20**, and the surface of the first circuit board **10** are perpendicular to each other. A surface of the fourth circuit board **90** is parallel with the surface of the first circuit board **10**, the surface of the fourth circuit board **90**, the surface of the third circuit board **80**, and the surface of the second circuit board **20** are perpendicular to each other.

Referring to FIG. **8**, the fourth circuit board **90** arranges with a vice radiator **92** of a 4G antenna. The vice radiator **92** includes a first radiating arm **921**, a second radiating arm **922**, a feed arm **923**, a first ground arm **924**, and a second ground arm **925**. The feed arm **923**, the first ground arm **924**, and the second ground arm **925** are arranged at intervals.

One end of the feed arm **923** is electrically connected to the electric current feed source of the second circuit board **20** for feeding electric current. The first ground arm **924** is substantially L-shaped and arranged between the feed arm **923** and the second ground arm **925** at intervals. One end of the first ground arm **924** is grounded, another end of the first ground arm **924** is a free end. The second ground arm **925** is substantially L-shaped, one end of the second ground arm **925** is grounded, another end of the second ground arm **925** is connected to the feed arm **923**. The first radiating arm **921** is extended along the feed arm **923** and then bent, the first radiating arm **921** is substantially U-shaped. The second radiating arm **922** is substantially L-shaped, one end of the second radiating arm **922** is substantially perpendicular to the feed arm **923**, another end of the second radiating arm **922** is spaced apart from the first radiating arm **921**.

The feed arm **923** supplies electric current, the electric current flows through the first radiating arm **921**, the second radiating arm **922**, and the second ground arm **925**, the electric current is further coupled to the first ground arm **924**, thereby exciting a 4G mode to generate a radiation signal in a 4G frequency band.

Referring to FIG. **9**, the third circuit board **80** arranges with a main radiator **82** of the 4G antenna. The main radiator **82** includes a third radiating arm **821**, a fourth radiating arm **822**, a feed arm **823**, and a third ground arm **824**. One end of the feed arm **823** is electrically connected to the electric current feed source of the second circuit board **20** for feeding electric current. The third ground arm **824** is spaced apart from the feed arm **823**, one end of the third ground arm **824** is grounded. The third radiating arm **821** is extended along the feed arm **823** and then bent, the third radiating arm **821** is substantially U-shaped. The fourth radiating arm **822** is substantially stepped-shaped, one end of the fourth radiating arm **822** is substantially perpendicular to the feed arm **823**, another end of the fourth radiating arm **822** is spaced apart from the third radiating arm **821**. Another end of the third radiating arm **821** is further connected to the fourth radiating arm **822**.

The feed arm **823** supplies electric current, the electric current flows through the third radiating arm **821**, the fourth radiating arm **822**, and the third ground arm **824**, thereby exciting the 4G mode to generate a radiation signal in the 4G frequency band.

In at least one embodiment, the vice radiator **92** of the 4G antenna arranged on the fourth circuit board **90** may be severed as a diversity antenna of the 4G antenna, the main radiator **82** of the 4G antenna arranged on the third circuit board **80** may be severed as a main antenna of the 4G antenna.

In another embodiment, the vice radiator **92** of the 4G antenna arranged on the fourth circuit board **90** may be severed as a main antenna of the 4G antenna, the main radiator **82** of the 4G antenna arranged on the third circuit board **80** may be severed as a diversity antenna of the 4G antenna.

Referring to FIG. **5**, the antenna module **100** further includes a carrier **110**. The carrier **110** is arranged on the second circuit board **20**. The first circuit board **10**, the third circuit board **80**, and the fourth circuit board **90** may be secured to the second circuit board **20** through the carrier **110**. In at least one embodiment, the carrier **110** may define a plurality of slots for securing the first circuit board **10**, the third circuit board **80**, and the fourth circuit board **90**. The carrier **110** may be made of non-conductive materials.

The fourth radiating section **44** supplies electric current from the electric current feed source of the second circuit board **20** through the first feed point **62**, the fourth radiating section **44** and the third radiating section **42** conduct the electric current, the electric current is further coupled to the radiation cover **30**, thereby forming a first electric current conducting path. When the antenna module **100** is powered on, the radiation cover **30** may receive and conduct wireless radiation signals, the third radiating section **42** obtains the wireless radiation signals from the radiation cover **30** by coupling, the third radiating section **42** and the fourth radiating section **44** conduct the wireless radiation signals, and further conduct to the second circuit board **20** through the first feed point **62** and the LNA circuit **70**, thereby exciting a first working mode to receive the wireless radiation signals in a first frequency band. In at least one embodiment, the first mode may include a Digital Audio Broadcasting (DAB) mode, the first radiation frequency band may include 178-238 MHz frequencies.

The second radiating section **54** supplies electric current from the electric current feed source of the second circuit board **20** through the second feed point **64**, the second radiating section **54**, the first radiating section **52**, and the connecting portion **56** conduct the electric current, the connecting portion **56** further conducts the electric current to the radiation cover **30**, thereby forming a second electric current conducting path. When the antenna module **100** is powered on, the radiation cover **30** may receive and conduct wireless radiation signals, the connecting portion **56** obtains the wireless radiation signals from the radiation cover **30** by conducting, the connecting portion **56**, the first radiating section **52**, and the second radiating section **54** conduct the wireless radiation signals, and further conduct to the second circuit board **20** through the second feed point **64** and the LNA circuit **70**, thereby exciting a second working mode to receive the wireless radiation signals in a second frequency band. In at least one embodiment, the second working mode may include a Frequency Modulation (FM) mode, the second radiation frequency band may include 88-108 MHz frequencies.

The frequencies of the first radiation frequency band (that is the DAB frequency band, 178-238 MHz) is greater than the frequencies of the second radiation frequency band (that is the FM frequency band, 88-108 MHZ).

Referring to FIGS. **10**, **11**, and **12**, a second embodiment of the present disclosure provides an antenna module **500**. The antenna module **500** of the second embodiment and the antenna module **100** of the first embodiment are substantially the same, merely the first radiating portion and the second radiating portion arranged on the first circuit board are different.

In detail, the first circuit board **10** defines a plurality of slots, such as a first slot **15**, a second slot **16**, and a third slot **17**. The first slot **15** is defined along the bevel side of the first circuit board **10**, the first radiating section **52** is arranged in the first slot **15**. The second slot **16** is substantially parallel with the second circuit board **20**, the second radiating section **54** is arranged in the second slot **16**. The third slot **17** is substantially perpendicular to second circuit board **20**, the fourth radiating section **44** is arranged in the third slot **17**. The first radiating section **52**, the second radiating section **54**, and the fourth radiating section **44** are substantially coil shaped, which are stereochemical structures and arranged in the plurality of slots **15**, **16**, **17** defined in the first circuit board **10**.

In at least one embodiment, the first radiating section **52**, the second radiating section **54**, and the fourth radiating section **44** can be other forms, such as circuit forms, besides the circuit board printed coils or stereochemical coil shaped. Selectively, the first radiating section **52**, the second radiating section **54**, and the fourth radiating section **44** may be all circuit board printed coils, all in stereochemical coil shaped, all in circuit forms, or any combination forms selective from the circuit board printed coils, the stereochemical coil shaped, and the circuit forms. In some other embodiment, the first radiating portion **40** and the second radiating portion **50** are printed on at least one surface of the first circuit board **10**. In some other embodiment, the first radiating portion **40** and the second radiating portion **50** may be printed on one surface or two surfaces of the first circuit board **10**.

FIG. **13** is a graph of scattering parameters (S11 parameters) when the antenna modules **100**, **500** operates in the first frequency band. Wherein, the curve shown in FIG. **13** shows the antenna modules **100**, **500** may achieve great S11 values when operate in the first frequency band (DAB frequency band, 178-238 MHz).

FIG. **14** is a graph of scattering parameters (S11 parameters) when the antenna modules **100**, **500** operates in the second frequency band. Wherein, the curve shown in FIG. **14** shows the antenna modules **100**, **500** may achieve great S11 values when operate in the second frequency band (FM frequency band, 88-108 MHZ).

FIG. **15** is a gain curve graph when the antenna modules **100**, **500** operates in the first frequency band. Wherein, a curve S**92** is an active antenna gain curve graph when the antenna modules **100**, **500** operates in the first frequency band (DAB frequency band, 178-238 MHz), that is, a gain curve graph when the antenna modules **100**, **500** including the LNA circuit **70**. A curve S**94** is a passive antenna gain curve graph when the antenna modules **100**, **500** operates in the first frequency band (DAB frequency band, 178-238 MHz), that is, a gain curve graph when the antenna modules **100**, **500** excluding the LNA circuit **70**.

FIG. **16** is a gain curve graph when the antenna modules **100**, **500** operates in the second frequency band. Wherein, a curve S**102** is an active antenna gain curve graph when the antenna modules **100**, **500** operates in the second frequency band (FM frequency band, 88-108 MHz), that is, a gain curve graph when the antenna modules **100**, **500** including the LNA circuit **70**. A curve S**104** is a passive antenna gain curve graph when the antenna modules **100**, **500** operates in the second frequency band (FM frequency band, 88-108 MHZ), that is, a gain curve graph when the antenna modules **100**, **500** excluding the LNA circuit **70**.

The antenna modules **100**, **500** may be applied in the vehicle and sever as car shark fin antennas, through printing or defining slots for arranging the first radiating portion **40** and the second radiating portion **50** on the first circuit board **10**, the radiation cover **30** receives wireless radiation signals, and further conducts or couples the wireless radiation signals to the first radiating portion **40** and the second radiating portion **50**, and the LNA circuit **70** of the second circuit board **20** provides matching and amplifying for the received wireless radiation signals, so the antenna modules **100**, **500** may receive wireless radiation signals of the predetermined frequency bands (such as the DAB frequency band and the FM frequency band), and have a great antenna performance and gain.

The embodiments shown and described above are only examples. Even though numerous characteristics and advantages of the present technology have been set forth in the foregoing description, together with details of the structure and function of the present disclosure, the disclosure is illustrative only, and changes may be made in the detail, including in matters of shape, size and arrangement of the parts within the principles of the present disclosure, up to and including the full extent established by the broad general meaning of the terms used in the claims.

What is claimed is:

1. An antenna module applied in a vehicle, the antenna module comprising:

- a first circuit board and a second circuit board, a surface of the first circuit board being perpendicular to a surface of the second circuit board;
- a radiation cover, the radiation cover covering one part of an end of the first circuit board and one part of two opposite surfaces of the first circuit board;
- a first radiating portion, the first radiating portion arranged on the first circuit board and perpendicular to the second circuit board, the first radiating portion configured to receive wireless radiation signals in a first frequency band through the radiation cover;
- a second radiating portion, the second radiating portion arranged on the first circuit board, the second radiating portion comprising a first radiating section and a second radiating section connected to the first radiating section in a predetermined angle, the second radiating section being parallel with the second circuit board, the second radiating portion configured to receive wireless radiation signals in a second frequency band through the radiation cover; and
- a third circuit board and a fourth circuit board, wherein a surface of the third circuit board, the surface of the second circuit board, and the surface of the first circuit board are perpendicular to each other; a surface of the fourth circuit board is parallel with the surface of the first circuit board.

2. The antenna module of claim **1**, wherein the first radiating portion comprises a third radiating section and a fourth radiating section connected to each other, the radiation cover covers at least one part of the third radiating section and is spaced apart from the third radiating section, the third radiating section obtains the wireless radiation signals from the radiation cover by coupling, the fourth radiating section is perpendicular to the second circuit board.

3. The antenna module of claim 2, wherein the first radiating portion and the second radiating portion are printed on at least one surface of the first circuit board.

4. The antenna module of claim 2, wherein the first circuit board defines a plurality of slots, the first radiating section, the second radiating section, and the fourth radiating section are arranged in the plurality of slots.

5. The antenna module of claim 2, wherein the first radiating section, the second radiating section, and the fourth radiating section are coil shaped, the third radiating section is rectangular shaped.

6. The antenna module of claim 1, wherein the second radiating portion further comprises a connecting portion, one end of the connecting portion is connected to the radiation cover, another end of the connecting portion is connected to the first radiating section, the connecting portion obtains the wireless radiation signals from the radiation cover and conducts the wireless radiation signals to the first radiating section and the second radiating section.

7. The antenna module of claim 1, wherein the third circuit board comprises a main radiator of a 4G antenna, the fourth circuit board comprises a second radiator of the 4G antenna, the main radiator of the 4G antenna and the second radiator of the 4G antenna are configured to generate radiation signals in a 4G frequency band.

8. The antenna module of claim 1, further comprising a first feed point and a second feed point, wherein the first feed point and the second feed point are arranged on the first circuit board, the first feed point and the second feed point are configured to feed electric currents into the first radiating portion and the second radiating portion.

9. The antenna module of claim 8, further comprising a low noise amplifier (LNA) circuit, wherein the LNA circuit is arranged on a surface of the second circuit board which is away from the first circuit board, the LNA circuit is electrically connected between an electric current feed source of the second circuit board and each of the first feed point and the second feed point.

10. A wireless communication device comprising an antenna module, the antenna module comprising:
- a first circuit board and a second circuit board, a surface of the first circuit board being perpendicular to a surface of the second circuit board;
- a radiation cover, the radiation cover covering one part of an end of the first circuit board and one part of two opposite surfaces of the first circuit board;
- a first radiating portion, the first radiating portion arranged on the first circuit board and perpendicular to the second circuit board, the first radiating portion configured to receive wireless radiation signals in a first frequency band through the radiation cover;
- a second radiating portion, the second radiating portion arranged on the first circuit board, the second radiating portion comprising a first radiating section and a second radiating section connected to the first radiating section in a predetermined angle, the second radiating section being parallel with the second circuit board, the second radiating portion configured to receive wireless radiation signals in a second frequency band through the radiation cover; and
- a third circuit board and a fourth circuit board, wherein a surface of the third circuit board, the surface of the second circuit board, and the surface of the first circuit board are perpendicular to each other; a surface of the fourth circuit board is parallel with the surface of the first circuit board.

11. The wireless communication device of claim 10, wherein the first radiating portion comprises a third radiating section and a fourth radiating section connected to each other, the radiation cover covers at least one part of the third radiating section and is spaced apart from the third radiating section, the third radiating section obtains the wireless radiation signals from the radiation cover by coupling, the fourth radiating section is perpendicular to the second circuit board.

12. The wireless communication device of claim 11, wherein the first radiating portion and the second radiating portion are printed on at least one surface of the first circuit board.

13. The wireless communication device of claim 11, wherein the first circuit board defines a plurality of slots, the first radiating section, the second radiating section, and the fourth radiating section are arranged in the plurality of slots.

14. The wireless communication device of claim 11, wherein the first radiating section, the second radiating section, and the fourth radiating section are coil shaped, the third radiating section is rectangular shaped.

15. The wireless communication device of claim 10, wherein the second radiating portion further comprises a connecting portion, one end of the connecting portion is connected to the radiation cover, another end of the connecting portion is connected to the first radiating section, the connecting portion obtains the wireless radiation signals from the radiation cover and conducts the wireless radiation signals to the first radiating section and the second radiating section.

16. The wireless communication device of claim 10, wherein the third circuit board comprises a main radiator of a 4G antenna, the fourth circuit board comprises a second radiator of the 4G antenna, the main radiator of the 4G antenna and the second radiator of the 4G antenna are configured to generate radiation signals in a 4G frequency band.

17. The wireless communication device of claim 10, wherein the antenna module further comprises a first feed point and a second feed point, wherein the first feed point and the second feed point are arranged on the first circuit board, the first feed point and the second feed point are configured to feed electric currents into the first radiating portion and the second radiating portion.

18. The wireless communication device of claim 17, the antenna module further comprises a low noise amplifier (LNA) circuit, wherein the LNA circuit is arranged on a surface of the second circuit board which is away from the first circuit board, the LNA circuit is electrically connected between an electric current feed source of the second circuit board and each of the first feed point and the second feed point.

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