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(54) **TERMINAL DEVICE ANTENNA APPARATUS AND IMPLEMENTATION METHOD**

(57) Provided are a terminal device antenna apparatus and an implementation method therefor, relating to the field of antennas. The method comprises: dividing off, on a metal ground of a terminal device main board, a fully enclosed non-metallic area configured to balance the electric current of the metal ground; disposing an antenna topology unit in the divided off fully enclosed

non-metallic area; and the antenna topology unit generating an operating electric current by using a radio frequency signal provided by the terminal device main board, and coupling the operating electric current to the metal ground, so as to realize wideband impedance matching by means of local resonance multistage echo differential suppression.

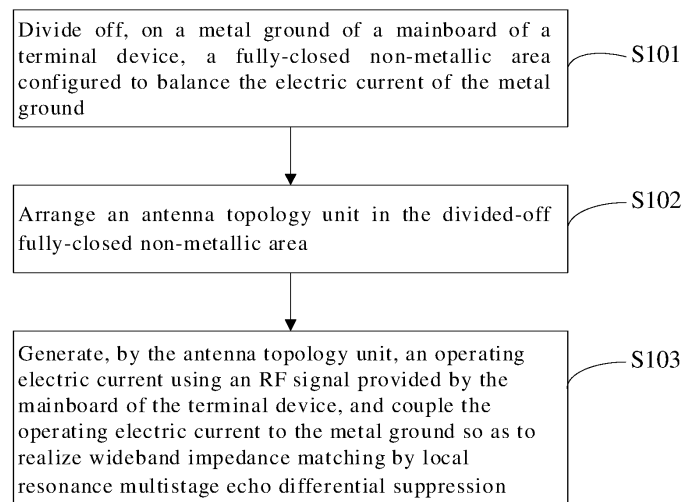


FIG. 1

Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present invention claims priority to Chinese Patent Application No. 201810502731.4, titled "TERMINAL DEVICE ANTENNA APPARATUS AND IMPLEMENTATION METHOD", filed on May 23, 2018, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to the field of antennas, and in particular to an antenna apparatus for a terminal device and an implementation method of the same.

BACKGROUND

[0003] The existing terminal devices mostly adopt antennas such as monopole antennas, planar inverted-F antennas (PIFAs) and loop antennas. These antennas are physically large in order to be compatible with coverages of frequency bands, and the bandwidth of a single type of antenna cannot meet the operation requirement of a terminal device for communication. At present, for an antenna that covers the long term evolution (LTE) frequency band, not only good antenna performances such as return loss, gain and efficiency of the antenna are required, but the size of the antenna is required to be as small as possible. According to the characteristics of an antenna, the conventional antennas can operate resonantly when their size is one-half or one-quarter of the operating wavelength. However, it is very difficult for small terminal devices (e.g., wireless mobile terminals) to have a space suitable for accommodating these antennas, so that the conventional antenna form cannot satisfy the requirements of wireless data transmission. Therefore, how to realize miniaturization and high-performance operation of antennas in small terminal devices is an urgent problem to be solved.

[0004] In the existing technology, an antenna design method for a wireless terminal and a data card single board for a wireless terminal have been proposed. The antenna design method includes steps of: dividing off, on the data card single board of the wireless terminal, a semi-closed area without other metal wirings except for an antenna wiring; and, coupling the antenna wiring to the data card single board. With the existing technology, the operating bandwidth for wideband can be realized while reducing the specific absorption rate (SAR) value of the antenna. However, the existing technology has the following disadvantages. The radiation area is a semi-closed area and is thus greatly affected by the environment, the electric current of the metal ground is unbalanced, the ohmic loss of the electric current path is high, and the electro-static discharge (ESD) resistance is poor.

Moreover, the radiating antenna requires a large clearance, which is about 1/4 of the wavelength of the minimum operating frequency, and the operating frequency band is narrow.

SUMMARY

[0005] Embodiments of the present disclosure provide a method for implementing an antenna apparatus for a terminal device, including steps of: dividing off, on a metal ground of a mainboard of the terminal device, a fully-closed non-metallic area configured to balance the electric current of the metal ground; arranging an antenna topology unit in the divided-off fully-closed non-metallic area; and, generating, by the antenna topology unit, an operating electric current using an RF signal provided by the mainboard of the terminal device, and coupling the operating electric current to the metal ground so as to realize wideband impedance matching by local resonance multistage echo differential suppression.

[0006] Embodiments of the present disclosure further provide an antenna apparatus for a terminal device, including: a metal ground, which is located on a mainboard of the terminal device and has a fully-closed non-metallic area configured to balance the electric current of the metal ground; and, an antenna topology unit, which is arranged in the fully-closed non-metallic area, generates an operating electric current using an RF signal provided by the mainboard of the terminal device, and couples the operating electric current to the metal ground so as to realize wideband impedance matching by local resonance multistage echo differential suppression.

BRIEF DESCRIPTION OF DRAWINGS

[0007]

Fig. 1 is a flowchart of a method for implementing an antenna apparatus for a terminal device according to an embodiment of the present disclosure;

Fig. 2 is a schematic diagram of a connection structure between an antenna apparatus and a terminal device according to an embodiment of the present disclosure;

Fig. 3 is a structural diagram of an antenna apparatus for a terminal device according to an embodiment of the present disclosure;

Fig. 4 is a structural diagram of the antenna apparatus for a terminal device according to an embodiment of the present disclosure;

Fig. 5 is another structural diagram of the antenna apparatus for a terminal device according to an embodiment of the present disclosure;

Fig. 6 is still another structural diagram of the antenna apparatus for a terminal device according to an embodiment of the present disclosure;

Fig. 7 is an equivalent circuit diagram of the antenna apparatus for a terminal device according to an embodiment of the present disclosure;

Fig. 8 is an S11 parameter diagram when the antenna apparatus according to an embodiment of the present disclosure is applied to a terminal device; and

Fig. 9 is a radiation efficiency diagram when the antenna apparatus according to an embodiment of the present disclosure is applied to a terminal device.

DETAILED DESCRIPTION

[0008] The embodiments of the present disclosure will be described in detail below with reference to the accompanying drawings, and it should be understood that the embodiments described below are merely intended to illustrate and explain the technical schemes of the present disclosure and are not intended to limit the scope of protection of the present disclosure.

[0009] Fig. 1 is a flowchart of a method for implementing an antenna apparatus for a terminal device according to an embodiment of the present disclosure. As shown in Fig. 1, the method for implementing an antenna apparatus for a terminal device according to an embodiment of the present disclosure includes steps of S101 to S103.

[0010] At S101, on a metal ground of a mainboard of the terminal device, a fully-closed non-metallic area configured to balance the electric current of the metal ground is divided off.

[0011] Specifically, the mainboard of the terminal device may have at least two layers of printed circuits, and a fully-closed non-metallic area may be divided off on the metal ground of each printed circuit layer of the mainboard of the terminal device. For example, if the mainboard of the terminal device has two circuit layers, i.e., a top layer and a bottom layer, a fully-closed non-metallic area is divided off on the metal ground of the top layer of the mainboard of the terminal device, and a fully-closed non-metallic area is divided off on the metal ground of the bottom layer of the mainboard of the terminal device. If there is an inner layer (at least one inner layer) between the top layer and the bottom layer of the mainboard of the terminal device, a fully-closed non-metallic area is divided off on the metal ground of each inner layer.

[0012] At S102, an antenna topology unit is arranged in the fully-closed non-metallic area.

[0013] Specifically, the antenna topology unit is arranged in the fully-closed non-metallic area on the metal ground of at least one printed circuit layer. For example, the antenna topology unit is arranged in at least one of the fully-closed non-metallic area on the metal ground of

the top layer, the fully-closed non-metallic area on the metal ground of the bottom layer, or the fully-closed non-metallic area on the metal ground of the inner layer.

[0014] The antenna topology unit may include: a first radiator having a gap with the mainboard of the terminal device; a second radiator, a third radiator and a fourth radiator which are all configured to generate the operating electric current; and, a lumped element.

[0015] At S103, the antenna topology unit generates an operating electric current using an RF signal provided by the mainboard of the terminal device, and couples the operating electric current to the metal ground so as to realize wideband impedance matching by local resonance multistage echo differential suppression.

[0016] Specifically, when the antenna topology unit is in a local resonance state, an echo signal is generated by an equivalent network formed by the second radiator, the first radiator and the fourth radiator, and a reflected signal is generated by an equivalent network formed by the third radiator, the lumped element, the metal ground and the second radiator; and, differential cancellation is performed on the echo signal and the reflected signal to obtain a differential signal, and the differential signal is absorbed by the first radiator, so as to realize wideband impedance matching.

[0017] The method for implementing an antenna apparatus for a terminal according to an embodiment of the present disclosure may further include steps of: arranging, on at least one of the first radiator, the second radiator, the third radiator and the fourth radiator, a first metallic coupling sheet having a gap with the mainboard of the terminal device, and coupling the first metallic coupling sheet to the mainboard of the terminal device through the gap between the first metallic coupling sheet and the mainboard of the terminal device; and/or, arranging, in the non-metallic area without the antenna topology unit arranged therein, a second metallic coupling sheet having a gap with the mainboard of the terminal device, and coupling the second metallic coupling sheet to the mainboard of the terminal device through the gap between the second metallic coupling sheet and the mainboard of the terminal device.

[0018] In the antenna apparatus for a terminal device implemented by an embodiment of the present disclosure, the radiation area is a fully-closed area and is thus less affected by the environment; and the electric current of the metal ground is a balanced electric current, good radiation characteristics can be achieved. Moreover, the antenna apparatus of an "O"-shaped closed loop for a terminal device implemented by an embodiment of the present disclosure, has smaller ohmic impedance, lower loss, higher radiation efficiency and better ESD resistance in comparison to the electric current path of a "C"-shaped loop.

[0019] In addition, in the antenna apparatus for a terminal device implemented by an embodiment of the present disclosure, the clearance of the antenna is small and is about $0.05 \lambda \times 0.025 \lambda$ (the minimum operating

frequency is 698 MHz), which is far less than 1/4 of the wavelength, so that the operating frequency bands of LTE 698-960 MHz and 1710-2690 MHz can be satisfied.

[0020] An embodiment of the present disclosure also provide an antenna apparatus for a terminal device, including: a metal ground, which is located on a mainboard of the terminal device and has a fully-closed non-metallic area configured to balance the electric current of the metal ground; and, an antenna topology unit, which is arranged in the fully-closed non-metallic area, generates an operating electric current using an RF signal provided by the mainboard of the terminal device, and couples the operating electric current to the metal ground so as to realize wideband impedance matching by local resonance multistage echo differential suppression.

[0021] Specifically, the mainboard of the terminal device may have at least two layers of printed circuits, and a fully-closed non-metallic area may be divided off on the metal ground of each printed circuit layer. For example, the metal ground specifically includes a top metal ground of the top printed circuit layer of the mainboard of the terminal device and a bottom metal ground of the bottom printed circuit layer of the mainboard of the terminal device, and both the top metal ground and the bottom metal ground have fully-closed non-metallic areas. If the mainboard of the terminal device has more than two printed circuit layers, that is, if there is an inner layer (at least one printed circuit layer) between the top layer and the bottom layer, the metal ground further includes an inner metal ground of each printed circuit layer of each layer.

[0022] In this case, the antenna topology unit is arranged in the fully-closed non-metallic area on the metal ground of at least one printed circuit layer, for example, being arranged in the fully-closed non-metallic area on the top metal ground, being arranged in the fully-closed non-metallic area on the top metal ground, or in the fully-closed non-metallic area on the inner metal ground, or the like.

[0023] The antenna topology unit may include: a first radiator having a gap with the mainboard of the terminal device; a second radiator, a third radiator and a fourth radiator which are all configured to generate the operating electric current; and, a lumped element.

[0024] When the antenna topology unit is in a local resonance state, an echo signal is generated by an equivalent network formed by the second radiator, the first radiator and the fourth radiator, a reflected signal is generated by an equivalent network formed by the third radiator, the lumped element, the metal ground and the second radiator, differential cancellation is performed on the echo signal and the reflected signal to obtain a differential signal, and the differential signal is absorbed by the first radiator, so as to realize wideband impedance matching.

[0025] The antenna apparatus for a terminal device according to an embodiment of the present disclosure may further include: a first metallic coupling sheet, which is arranged on at least one of the first radiator, the second

radiator, the third radiator and the fourth radiator, has a gap with the mainboard of the terminal device, and realizes coupling with the mainboard of the terminal device through the gap between the first metallic coupling sheet and the mainboard of the terminal device; and/or, a second metallic coupling sheet, which is arranged in the non-metallic area without the antenna topology unit arranged therein, has a gap with the mainboard of the terminal device, and realizes secondary coupling with the mainboard of the terminal device through the gap between the second metallic coupling sheet and the mainboard of the terminal device.

[0026] The application scenarios of the antenna apparatus provided by the embodiments of the present disclosure will be listed below, and the following description will be given by taking the antenna apparatus provided by the embodiments of the present disclosure being applied to a terminal device as an example.

[0027] Fig. 2 is a schematic diagram of a connection structure between an antenna apparatus and a terminal device according to an embodiment of the present disclosure, and Fig. 3 is a structural diagram of the antenna apparatus for a terminal device according to an embodiment of the present disclosure.

[0028] As shown in Figs. 2 and 3, the antenna apparatus for a terminal device according to an embodiment of the present disclosure is applicable to notebook computers, PCs, PADs or other terminal devices. The interface between the antenna apparatus and the terminal device may be a USB interface, PCMCIA interface (PC memory card interface), an Express interface or other interfaces.

[0029] As an example, the antenna apparatus for a terminal device according to an embodiment of the present disclosure may include a mainboard 12 and a USB interface 3, and may be connected to a terminal device such as a notebook computer or a PC through the USB interface 3. The mainboard 12 may be a dielectric board coated with copper on both sides. For example, the mainboard 12 includes a dielectric board made of a non-metallic material and copper layers that are coated on the top and bottom of the dielectric board. However, on the mainboard 12, a top non-metallic area 4 and a bottom non-metallic area 5 are reserved for the arrangement of the antenna topology unit 9. Except for the top non-metallic area 4 and the bottom non-metallic area 5, the remaining area on the mainboard 12 is a metal ground; and, the top metal ground and the bottom metal ground are common-grounded. For example, each non-metallic area may be 11 mm × 21 mm × 2 mm in size.

[0030] Fig. 3 is a structural diagram of the antenna apparatus for a terminal device according to an embodiment of the present disclosure. As shown in Fig. 3, the antenna apparatus for a terminal device according to an embodiment of the present disclosure may include a top metal ground 1 and a bottom metal ground 2. The top metal ground 1 may be planar and located on the front surface of the mainboard 12. The bottom metal ground 2 may

also be planar and located on the bottom surface of the mainboard 12. The material of the mainboard 12 may include a non-metallic material, and multiple layers of printed circuits may be included in the area of the metal ground of the mainboard 12. The antenna apparatus for a terminal device according to an embodiment of the present disclosure may be connected to a terminal device through the USB interface 3.

[0031] The antenna topology unit 9 may be arranged in the top non-metallic area 4 on the top metal ground 1 and/or the bottom non-metallic area 5 on the bottom metal ground 2 of the mainboard 12. The top non-metallic area 4 and the bottom non-metallic area 5 may be in any regular or irregular shape such as square, circle, rhombus, trapezoid or triangle, but not limited to rectangle shown in Figs. 2 and 3; and, the top non-metallic area 4 and the bottom non-metallic area 5 are not necessarily identical in shape. A feed port 11 of the antenna topology unit 9 is connected to an RF signal output port provided by the mainboard 12, and the ground of the feed port 11 of the antenna topology unit 9 is connected to the metal ground of the mainboard 12.

[0032] Fig. 4 is a structural diagram of the antenna apparatus for a terminal device according to an embodiment of the present disclosure. As shown in Fig. 4, the antenna topology unit 9 may be arranged in the top non-metallic area 4, and may include a first radiator 91, a second radiator 92, a third radiator 93, a fourth radiator 94, a first lumped element 7, a second lumped element 8, a third lumped element 10 and a first metallic wall 6. The first radiator 91, the second radiator 92, the third radiator 93 and the fourth radiator 94 may be, but not limited to, any regular or irregular shape such as square, circle, rhombus, trapezoid or triangle, and may be arranged in the top non-metallic area 4 by printing or welding. As an example, the first radiator 91, the second radiator 92 and the fourth radiator 94 may be rectangular radiating patches, and the third radiator 93 may be an inductive meander line shown in Fig. 4. The third radiator 93 is coupled to the first radiator 91 through the fourth radiator 94. The third radiator 93 is connected to a short-circuit branch 95 through the third lumped element 10, and connected to the top metal ground 1 through the short-circuit branch 95. The first metallic wall 6 is connected to the top metal ground 1 through the first lumped element 7 and the second lumped element 8. Each of the first lumped element 7, the second lumped element 8 and the third lumped element 10 may be one of or a combination of capacitors, inductors, resistors and other devices, and the resonance characteristics of the antenna can be adjusted by adjusting the parameters and distribution positions of the lumped elements. There is a gap between the fourth radiator 94 and the top metal ground 1. The first radiator 91, the second radiator 92, the third radiator 93, the fourth radiator 94 and the first metallic wall 6 are all made of a metallic material.

[0033] Based on the above-described antenna apparatus for a terminal device according to an embodiment

of the present disclosure, in the transmission process, an RF signal on the mainboard 12 is fed into the antenna topology unit 9 through the feed port 11, so that the antenna topology unit 9 excites an operating electric current. The operating electric current is coupled to the top metal ground 1 and the bottom metal ground 2. The antenna topology unit 9 is equivalent to a resonant circuit, and the operating electric current flows into the top metal ground 1 and the bottom metal ground 2 through the short-circuit branch 95, so as to form a complete radiation resonant circuit. Specifically, in the transmission process, the RF signal on the mainboard 12 is fed into the second radiator 92 through the feed port 11, so that the second radiator 92 excites an electric current. A part of the operating electric current enters the fourth radiator 94 and the third radiator 93 through the first radiator 91 and then enters the metal ground of the mainboard 12 through the third lumped element 10 and the short-circuit branch 95, while the other part of the operating electric current is coupled to the metal ground of the mainboard 12 through the gap between the first radiator 91 and the top metal ground 1, so as to form an electric current loop.

[0034] Fig. 7 is an equivalent circuit diagram of the antenna apparatus for a terminal device according to an embodiment of the present disclosure. As shown in Fig. 7, the second radiator 92 is equivalent to a first distributed inductor L_{se} ; the first radiator 91 is equivalent to a radiation resistor R_{se} ; the first radiator 91 and the fourth radiator 94 generate a first coupling capacitor C_{se} ; the third radiator 93 is equivalent to a second distributed inductor L_{sh} ; a second coupling capacitor C_{sh} and a radiation admittance G_r are generated between the second radiator 92 and the top metal ground 1; and, the third lumped element 10 generates a lumped capacitor C_1 . There is a reverse phase difference between an echo signal generated by the low-frequency RF energy entering, from the feed port 11, into the network formed by the first distributed inductor L_{se} and the first coupling capacitor C_{se} and a reflected signal generated by the low-frequency RF energy entering into the network formed by the second distributed inductor L_{sh} , the second coupling capacitor C_{sh} and the lumped capacitor C_1 . Differential cancellation is performed for multiple times, so that the echo signal is prevented from entering into the feed port 11. Part of the differential signal that cannot be cancelled is absorbed by the radiation resistor R_{se} and the radiation admittance G_r equivalent to the first radiator 91 during multiple reflections, so that the frequency bandwidth is increased.

[0035] The local resonance state of the whole antenna apparatus can be controlled by appropriately adjusting the L_{se} , C_{se} , L_{sh} , C_{sh} and C_1 . By optimizing the shape and size of the first radiator 91, the second radiator 92, the third radiator 93 and the fourth radiator 94 in the antenna apparatus structure, optimizing the size of the gap between radiators and between a radiator and the mainboard 12, and optimizing the parameters and distribution positions of the lumped elements, the resonance and

matching state of the antenna apparatus can be adjusted, and the requirement of fully covering the target bandwidth can be finally satisfied.

[0036] Fig. 5 is another structural diagram of the antenna apparatus for a terminal device according to an embodiment of the present disclosure. The structure of the antenna apparatus shown in Fig. 5 for a terminal device differs from the structure of the antenna apparatus shown in Fig. 4 in that a metallic coupling sheet 13 is arranged on the third radiator 93 and is coupled to the antenna radiator by a non-metallic medium, or by air as a medium. There is a gap between the metallic coupling sheet 13 and the mainboard 12, and the metallic coupling sheet 13 is coupled to the mainboard 12 through the gap, so that secondary coupling of the antenna radiator to the mainboard 12 is realized.

[0037] As shown in Fig. 5, the antenna topology unit 9 may be arranged in the top non-metallic area 4 on the top metal ground 1 of the mainboard 12. The top non-metallic area 4 may be in any regular or irregular shape such as square, circle, rhombus, trapezoid or triangle, but not limited to rectangle shown in Fig. 5. A feed port 11 of the antenna topology unit 9 is connected to a RF signal output port provided by the mainboard 12, and the ground of the feed port 11 of the antenna topology unit 9 is connected to the metal ground of the mainboard 12.

[0038] As shown in Fig. 5, the antenna topology unit 9 may include a first radiator 91, a second radiator 92, a third radiator 93, a fourth radiator 94, a metallic coupling sheet 13, a first lumped element 7, a second lumped element 8, a third lumped element 10 and a first metallic wall 6. The first radiator 91, the second radiator 92, the third radiator 93 and the fourth radiator 94 may be, but not limited to, any regular or irregular shape such as square, circle, rhombus, trapezoid or triangle, and may be arranged in the top non-metallic area 4 by printing or welding. As an example, the first radiator 91, the second radiator 92 and the fourth radiator 94 may be rectangular radiating patches, and the third radiator 93 may be an inductive meander line shown in Fig. 5. The metallic coupling sheet 13 may be, but not limited to, any regular or irregular shape such as square, circle, rhombus, trapezoid or triangle. For example, the metallic coupling sheet 13 may be a rectangular metal sheet. The metallic coupling sheet 13 may be arranged on the whole or part of the top antenna radiator, and is not limited to being arranged on the third radiator 93 as shown in Fig. 5. The third radiator 93 is coupled to the first radiator 91 through the fourth radiator 94, and the third radiator 93 is connected to a short-circuit branch 95 through the third lumped element 10 and connected to the top metal ground 1 through the short-circuit branch 95. The third radiator 93 and the metallic coupling sheet 13 may be completely insulated from each other, or may be conductively connected to each other by additionally providing one or more conductive connection points at appropriate positions. The first metallic wall 6 is connected to the top metal ground 1 through the first lumped element 7 and

the second lumped element 8. The first lumped element 7, the second lumped element 8 and the third lumped element 10 may be one of or a combination of capacitors, inductors, resistors and other devices, and the resonance characteristics of the antenna can be adjusted by adjusting the parameters and distribution positions of the lumped elements. There is a gap between the fourth radiator 94 and the top metal ground 1. The first radiator 91, the second radiator 92, the third radiator 93, the fourth radiator 94, the metallic coupling sheet 13 and the first metallic wall 6 may be all made of a metallic material.

[0039] Based on the above-described antenna apparatus for a terminal device according to an embodiment of the present disclosure, in the transmission process, the RF signal on the mainboard 12 is fed into the second radiator 92 through the feed port 11, so that the second radiator 92 excites an electric current. A part of the operating electric current enters the fourth radiator 94 and the third radiator 93 through the first radiator 91 and then enters the metal ground of the mainboard 12 through the third lumped element 10 and the short-circuit branch 95, while the other part of the operating electric current is coupled to the metal ground of the mainboard 12 through the gap between the first radiator 91 and the top metal ground 1, so as to form an electric current loop. Meanwhile, the third radiator 93 is coupled to the metallic coupling sheet 13 and the mainboard 12 for multiple times through gaps, so that multiple resonance points are generated, and the operating frequency band of the antenna is expanded.

[0040] By optimizing the shape and size of the first radiator 91, the second radiator 92, the third radiator 93, the fourth radiator 94 and the metallic coupling sheet 13 in the antenna apparatus structure, optimizing the size of the gap between radiators, between the radiator and the mainboard 12 and between the metallic coupling sheet 13 and the antenna radiator, and optimizing the parameters and distribution positions of the lumped elements, the resonance and matching state of the antenna apparatus can be adjusted, and the requirement of fully covering the target bandwidth can be finally satisfied.

[0041] Fig. 6 is still another structural diagram of the antenna apparatus for a terminal device according to an embodiment of the present disclosure. As shown in Fig. 6, this structure of the antenna apparatus for a terminal device differs from the structure of the antenna apparatus for a terminal device shown in Fig. 4 in that: a metallic coupling sheet 14 is arranged in the bottom non-metallic area 5, and the metallic coupling sheet 14 may be arranged in the non-metallic area 5 by printing or welding. There is a gap between the metallic coupling sheet 14 and the mainboard 12, and the metallic coupling sheet 14 is coupled to the mainboard 12 through the gap, so that secondary coupling of the antenna radiator to the mainboard 12 is realized.

[0042] As shown in Fig. 6, the antenna topology unit 9 may be arranged in the top non-metallic area 4 on the top metal ground 1 of the mainboard 12, and the metallic

coupling sheet 14 may be arranged in the bottom non-metallic area 5 on the bottom metal ground 2 of the mainboard 12. The top non-metallic area 4 and the bottom non-metallic area 5 may be in any regular or irregular shape such as square, circle, rhombus, trapezoid or triangle, but not limited to rectangle shown in Fig. 6; and, the top non-metallic area 4 and the bottom non-metallic area 5 are not necessarily identical in shape. A feed port 11 of the antenna topology unit 9 is connected to a RF signal output port provided by the mainboard 12, and the ground of the feed port 11 of the antenna topology unit 9 is connected to the metal ground of the mainboard 12.

[0043] As shown in Fig. 6, the antenna topology unit 9 may include a first radiator 91, a second radiator 92, a third radiator 93, a fourth radiator 94, a metallic coupling sheet 14, a first lumped element 7, a second lumped element 8, a third lumped element 10 and a first metallic wall 6. The first radiator 91, the second radiator 92, the third radiator 93 and the fourth radiator 94 may be, but not limited to, any regular or irregular shape such as square, circle, rhombus, trapezoid or triangle, and may be arranged in the top non-metallic area 4 and the bottom non-metallic area 5 by printing or welding. As an example, the first radiator 91, the second radiator 92 and the fourth radiator 94 may be rectangular radiating patches, and the third radiator 93 may be an inductive meander line shown in Fig. 6. The metallic coupling sheet 14 may be, but not limited to, any regular or irregular shape such as square, circle, rhombus, trapezoid or triangle. For example, the metallic coupling sheet 14 may be a rectangular metal sheet which is printed on the bottom non-metallic area 5 and coupled to the top antenna radiator by a non-metallic medium. Moreover, the metallic coupling sheet 14 may be arranged in all or part of a projection area of the top antenna radiator, and is not limited to being arranged in a projection area of the third radiator 93 in the top layer as shown in Fig. 6. The third radiator 93 is coupled to the first radiator 91 through the fourth radiator 94, and the third radiator 93 is connected to a short-circuit branch 95 through the third lumped element 10 and connected to the top metal ground 1 through the short-circuit branch 95. The third radiator 93 and the metallic coupling sheet 14 may be completely insulated from each other, or may be conductively connected to each other by additionally providing one or more conductive connection points at appropriate positions. The first metallic wall 6 is connected to the top metal ground 1 through the first lumped element 7 and the second lumped element 8. The first lumped element 7, the second lumped element 8 and the third lumped element 10 may be one of or a combination of capacitors, inductors, resistors and other devices, and the resonance characteristics of the antenna can be adjusted by adjusting the parameters and distribution positions of the lumped elements. There is a gap between the fourth radiator 94 and the top metal ground 1. The first radiator 91, the second radiator 92, the third radiator 93, the fourth radiator 94, the metallic coupling sheet 14 and the first metallic wall 6 may be all made of

a metallic material.

[0044] Based on the above-described antenna apparatus for a terminal device according to an embodiment of the present disclosure, in the transmission process, the RF signal on the mainboard 12 is fed into the second radiator 92 through the feed port 11, so that the second radiator 92 excites an electric current. A part of the operating electric current enters the fourth radiator 94 and the third radiator 93 through the first radiator 91 and then enters the metal ground of the mainboard 12 through the third lumped element 10 and the short-circuit branch 95, while the other part of the operating electric current is coupled to the metal ground of the mainboard 12 through the gap between the first radiator 91 and the top metal ground 1, so as to form an electric current loop. Meanwhile, the third radiator 93 is coupled to the metallic coupling sheet 14 and the mainboard 12 for multiple times through gaps, so that multiple resonance points are generated, and the operating frequency band of the antenna is expanded.

[0045] By optimizing the shape and size of the first radiator 91, the second radiator 92, the third radiator 93, the fourth radiator 94 and the metallic coupling sheet 14 in the antenna apparatus structure, optimizing the size of the gap between radiators, between the radiator and the mainboard 12 and between the metallic coupling sheet 14 and the antenna radiator, and optimizing the parameters and distribution positions of the lumped elements, the resonance and matching state of the antenna apparatus can be adjusted, and the requirement of fully covering the target bandwidth is finally satisfied.

[0046] In conclusion, in the antenna apparatus provided by the embodiments of the present disclosure, by arranging a non-metallic area only containing elements such as antenna radiators, metallic coupling sheets and gaps on the mainboard and by optimizing the shape of the non-metallic area and the elements in the non-metallic area, the requirement of fully covering the target frequency band can be finally satisfied.

[0047] In the embodiments of the present disclosure, the shape of each antenna radiator is not limited to the shape shown in the drawings, and the size of each radiator and the size of the gap between radiators are not limited to the size shown in the drawings.

[0048] In the embodiments of the present disclosure, the shape of the non-metallic area may be any regular or irregular shape and be not limited to the shape shown in the drawings, and the shape of the non-metallic area in the top layer of the mainboard is not necessarily identical to that of the non-metallic area in the bottom layer of the mainboard.

[0049] In the embodiments of the present disclosure, the network for resonance may be composed of inductors or capacitors, or may be a combination of inductors and capacitors.

[0050] In the embodiments of the present disclosure, the antenna apparatus is not limited to operating in the frequency band range described in the embodiments of

the present disclosure, and the size of the antenna may be adjusted as required to satisfy the requirements of the operating frequency band.

[0051] Fig. 8 is a diagram illustrating the S11 parameter when the antenna apparatus according to an embodiment of the present disclosure is applied to a terminal device. The antenna apparatus covers the required LTE frequency bands 698 MHz-960 MHz and 1710 MHz-2690 MHz, and satisfies the requirements for high performance of the antenna.

[0052] Fig. 9 is a diagram illustrating the radiation efficiency when the antenna apparatus according to an embodiment of the present disclosure is applied to a terminal device. The antenna apparatus has a radiation efficiency of more than 60% in a low frequency band and a radiation efficiency of more than 60% in a high frequency band. It can be known that, the antenna apparatus covers the required LTE frequency bands 698 MHz-960 MHz and 1710 MHz-2690 MHz, so the antenna apparatus has high efficiency and satisfies the requirements for high performance of the antenna.

[0053] In conclusion, the antenna apparatus provided in the embodiments of the present disclosure has the following technical effects. With a metal-border enclosing structure, it is realized that the radiation area is a fully-closed area and the electric current of the metal ground is balanced. With the metal-border enclosing structure, an "0"-shaped closed loop is realized, which has smaller ohmic impedance, lower loss, higher radiation efficiency and better ESD resistance in comparison to the electric current path of the "C"-shaped loop. By local resonance multistage echo differential suppression, the wideband impedance matching under miniaturized high reactance is realized, and the antenna clearance is reduced. The clearance is about $0.05 \lambda \times 0.025 \lambda$ (the minimum operating frequency is 689 MHz), which is far less than 1/4 of the wavelength. Meanwhile, wide LTE frequency bands 698 MHz-960 MHz and 1710 MHz-2690 MHz are covered.

[0054] Although some embodiments of the present disclosure have been described in detail above, the present disclosure is not limited thereto, and various modifications may be made by those skilled in the art in accordance with the principles of the present disclosure. Accordingly, any modifications made in accordance with the principles of the present disclosure should be understood to fall into the scope of the present disclosure.

Claims

1. A method for implementing an antenna apparatus for a terminal device, comprising steps of:

dividing off, on a metal ground of a mainboard of the terminal device, a fully-closed non-metallic area configured to balance an electric current of the metal ground;

arranging an antenna topology unit in the divided-off fully-closed non-metallic area; and generating, by the antenna topology unit, an operating electric current using an RF signal provided by the mainboard of the terminal device, and coupling the operating electric current to the metal ground so as to realize wideband impedance matching by local resonance multistage echo differential suppression.

2. The method of claim 1, wherein the mainboard of the terminal device has at least two printed circuit layers, and the step of dividing off, on a metal ground of a mainboard of the terminal device, a fully-closed non-metallic area configured to balance the electric current of the metal ground comprises: dividing off a fully-closed non-metallic area on a metal ground of each printed circuit layer of the mainboard of the terminal device.
3. The method of claim 2, wherein the step of arranging an antenna topology unit in the divided-off fully-closed non-metallic area comprises: arranging the antenna topology unit in the fully-closed non-metallic area of at least one printed circuit layer.
4. The method of claim 2, wherein the metal ground of each printed circuit layer of the mainboard of the terminal device is common-grounded.
5. The method of any one of claims 1 to 4, wherein the antenna topology unit comprises: a first radiator having a gap with the mainboard of the terminal device; a second radiator configured to generate the operating electric current, a third radiator and a fourth radiator; and, a lumped element; the step of generating, by the antenna topology unit, an operating electric current using an RF signal provided by the mainboard of the terminal device, and coupling the operating electric current to the metal ground so as to realize wideband impedance matching by local resonance multistage echo differential suppression comprises:

during a local resonance state of the antenna topology unit, generating an echo signal by an equivalent network formed by the second radiator, the first radiator and the fourth radiator, and generating a reflected signal by an equivalent network formed by the third radiator, the lumped element, the metal ground and the second radiator; and performing differential cancellation on the echo signal and the reflected signal to obtain a differential signal, and absorbing the differential signal by the first radiator so as to realize wideband impedance matching.

6. The method of claim 5, further comprising steps of:

arranging, on at least one of the first radiator, the second radiator, the third radiator and the fourth radiator, a first metallic coupling sheet having a gap with the mainboard of the terminal device, and coupling the first metallic coupling sheet to the mainboard of the terminal device through the gap between the first metallic coupling sheet and the mainboard of the terminal device; and/or

arranging, in the non-metallic area without the antenna topology unit arranged therein, a second metallic coupling sheet having a gap with the mainboard of the terminal device, and coupling the second metallic coupling sheet to the mainboard of the terminal device through the gap between the second metallic coupling sheet and the mainboard of the terminal device.

7. An antenna apparatus for a terminal device, comprising:

a metal ground, which is located on a mainboard of the terminal device and has a fully-closed non-metallic area configured to balance an electric current of the metal ground; and
an antenna topology unit, which is arranged in the fully-closed non-metallic area, generates an operating electric current using an RF signal provided by the mainboard of the terminal device, and couples the operating electric current to the metal ground so as to realize wideband impedance matching by local resonance multistage echo differential suppression.

8. The apparatus of claim 7, wherein the mainboard of the terminal device has at least two printed circuit layers, and the metal ground of each printed circuit layer has a fully-closed non-metallic area.

9. The apparatus of claim 8, wherein the antenna topology unit is arranged in the fully-closed non-metallic area on the metal ground of at least one printed circuit layer.

10. The apparatus of claim 8, wherein the metal ground of each printed circuit layer of the mainboard of the terminal device is common-grounded.

11. The apparatus of claim 7, wherein the antenna topology unit comprises: a first radiator having a gap with the mainboard of the terminal device; a second radiator configured to generate the operating electric current, a third radiator and a fourth radiator; and, a lumped element; wherein, during a local resonance state of the antenna topology unit, an echo signal is generated by an equivalent

network formed by the second radiator, the first radiator and the fourth radiator, a reflected signal is generated by an equivalent network formed by the third radiator, the lumped element, the metal ground and the second radiator, differential cancellation is performed on the echo signal and the reflected signal to obtain a differential signal, and the differential signal is absorbed by the first radiator to realize wideband impedance matching.

12. The apparatus of claim 11, further comprising:

a first metallic coupling sheet, which is arranged on at least one of the first radiator, the second radiator, the third radiator and the fourth radiator, has a gap with the mainboard of the terminal device, and realizes coupling with the mainboard of the terminal device through the gap between the first metallic coupling sheet and the mainboard of the terminal device; and/or
a second metallic coupling sheet, which is arranged in the non-metallic area without the antenna topology unit arranged therein, has a gap with the mainboard of the terminal device, and realizes secondary coupling with the mainboard of the terminal device through the gap between the second metallic coupling sheet and the mainboard of the terminal device.

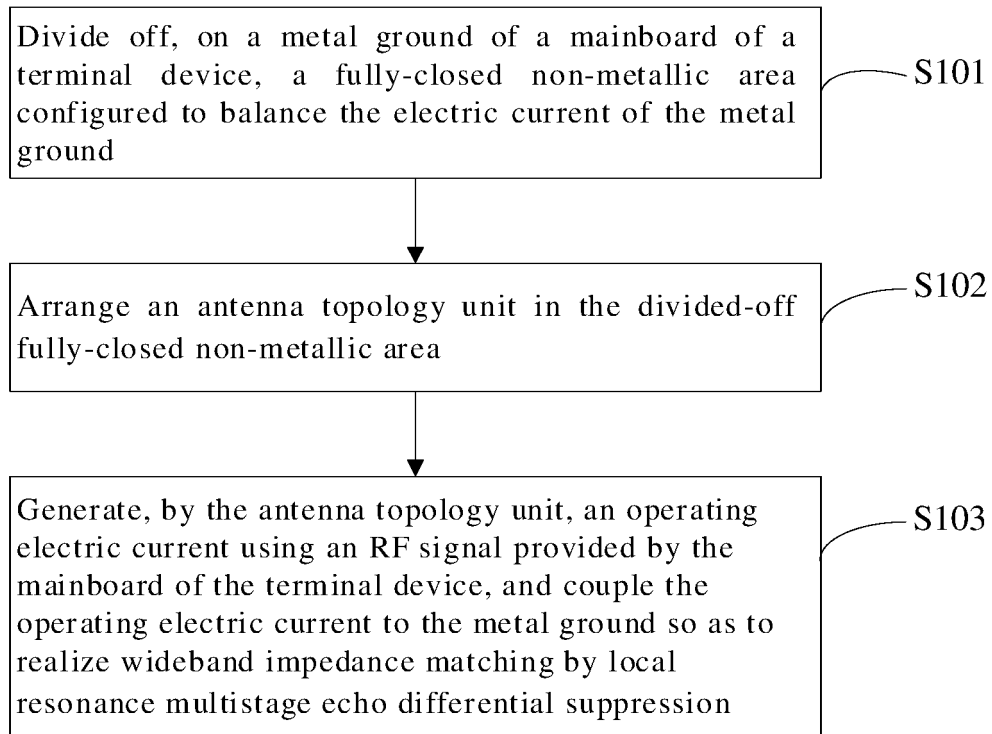


FIG. 1

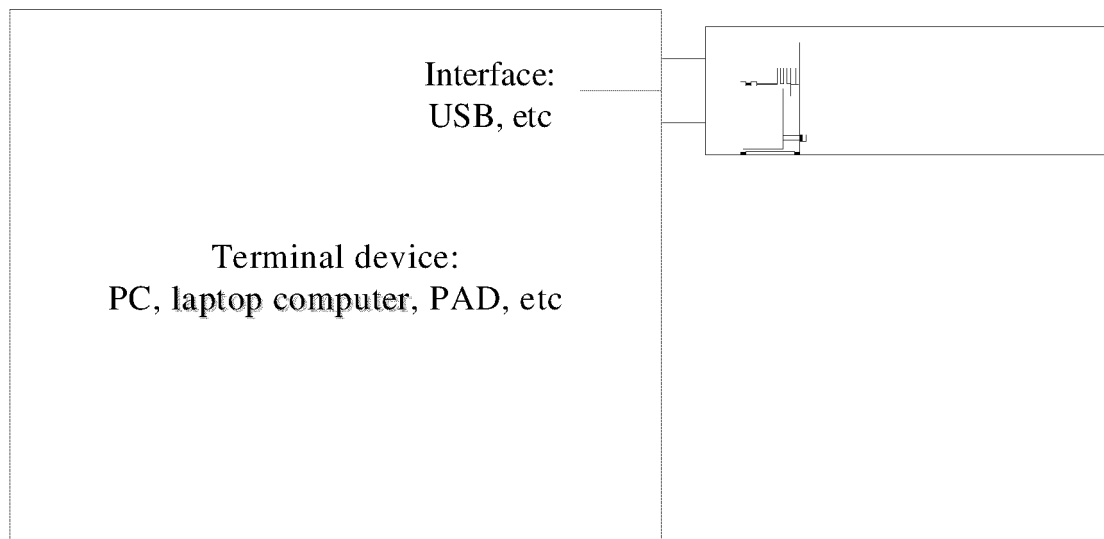


FIG. 2

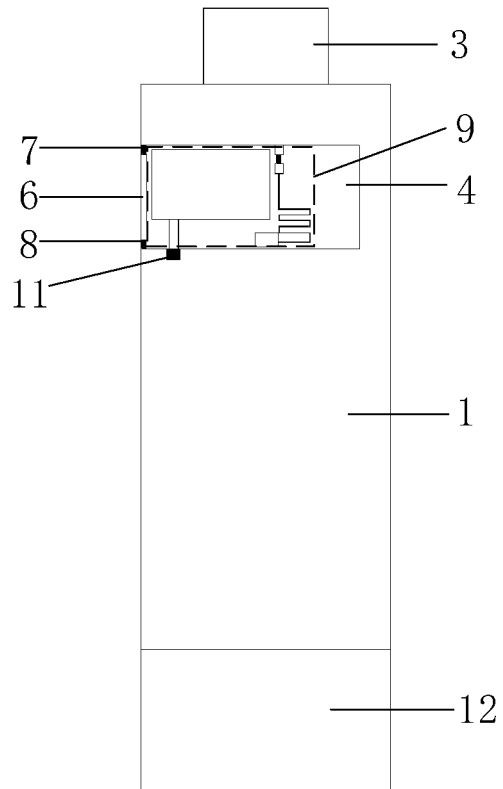


FIG. 3a

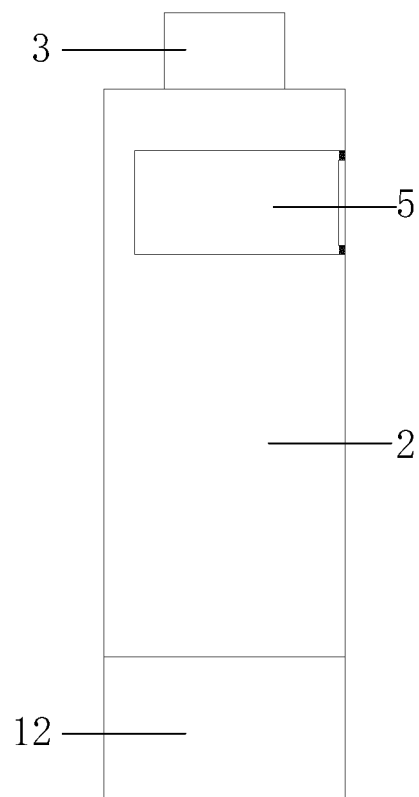


FIG. 3b

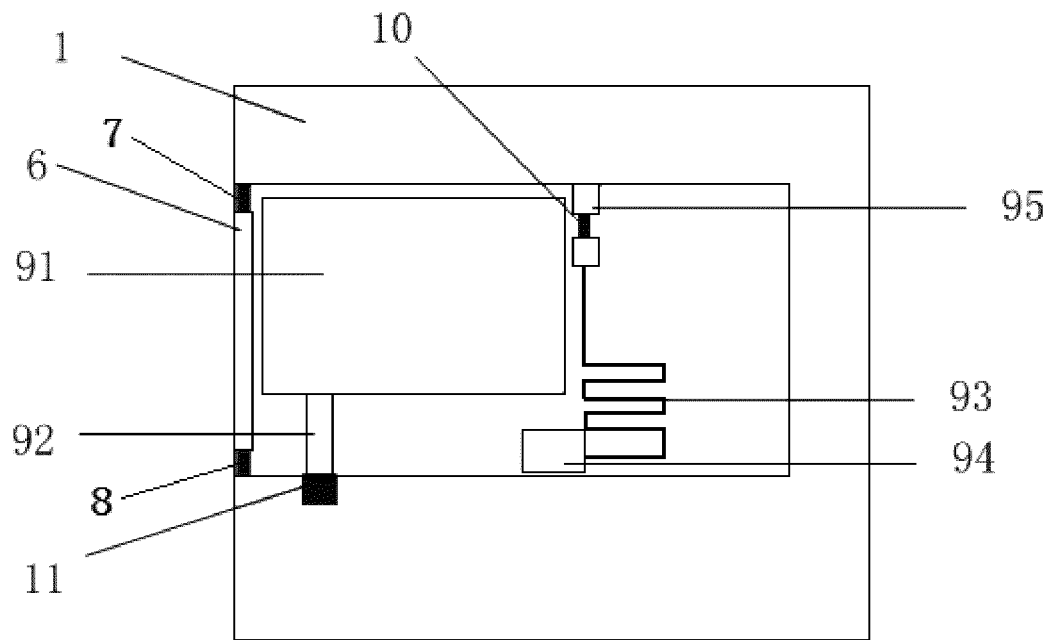


FIG. 4

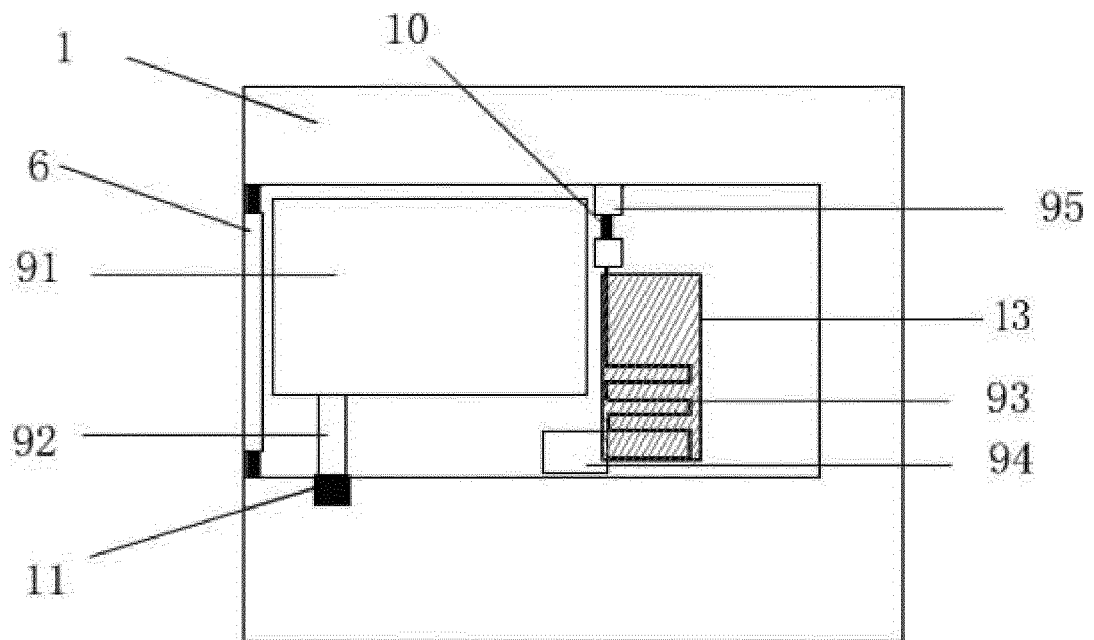


FIG. 5

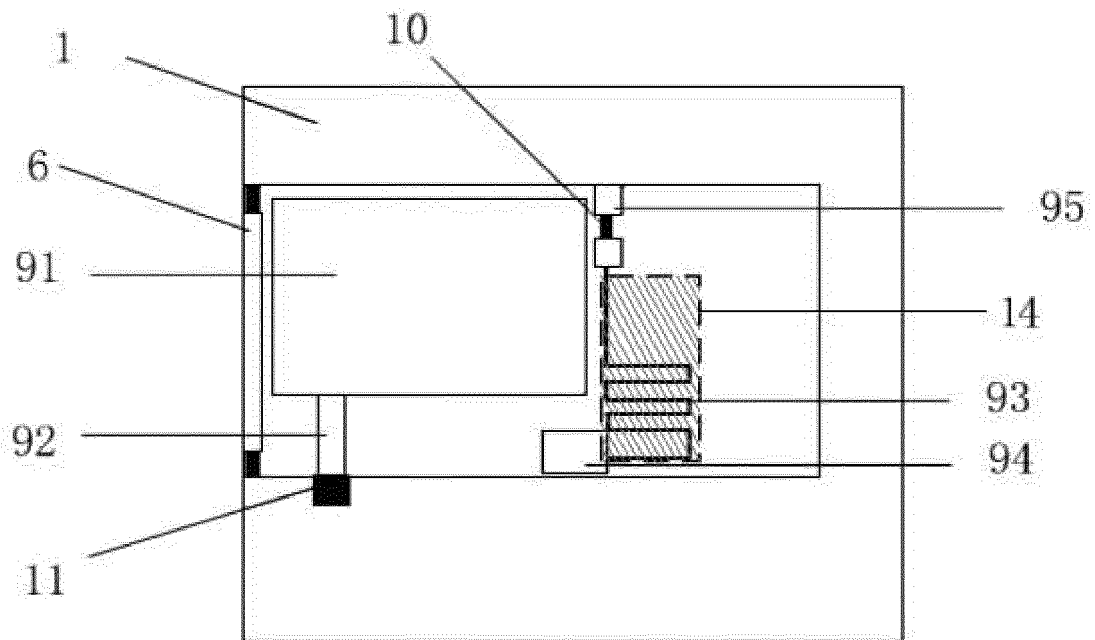


FIG. 6

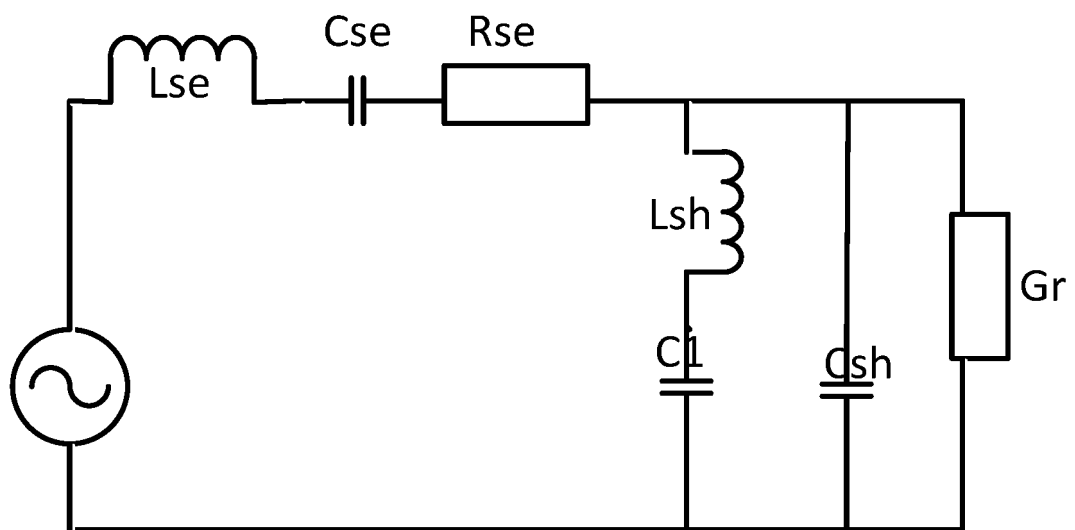


FIG. 7

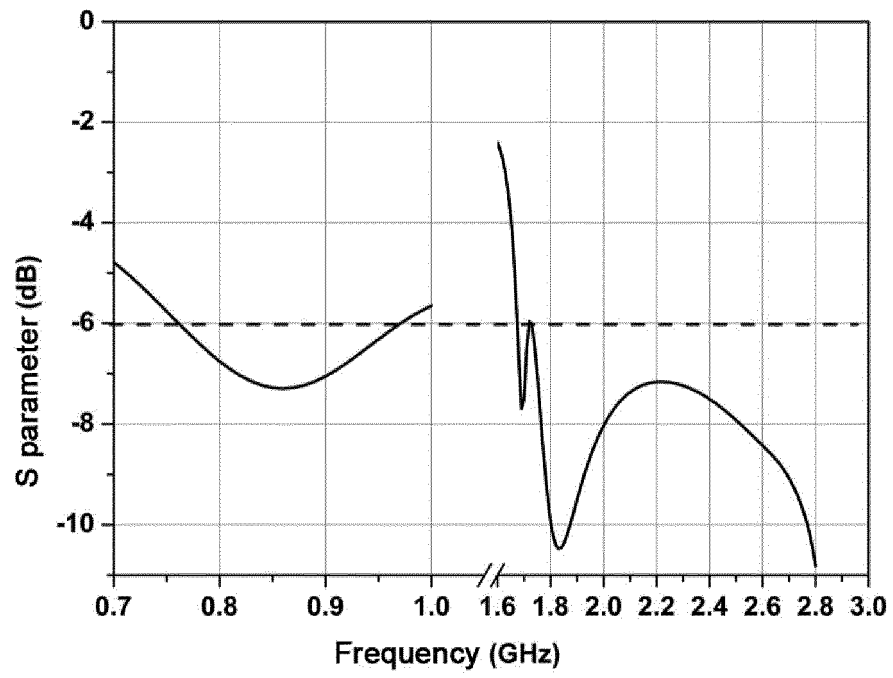


FIG. 8

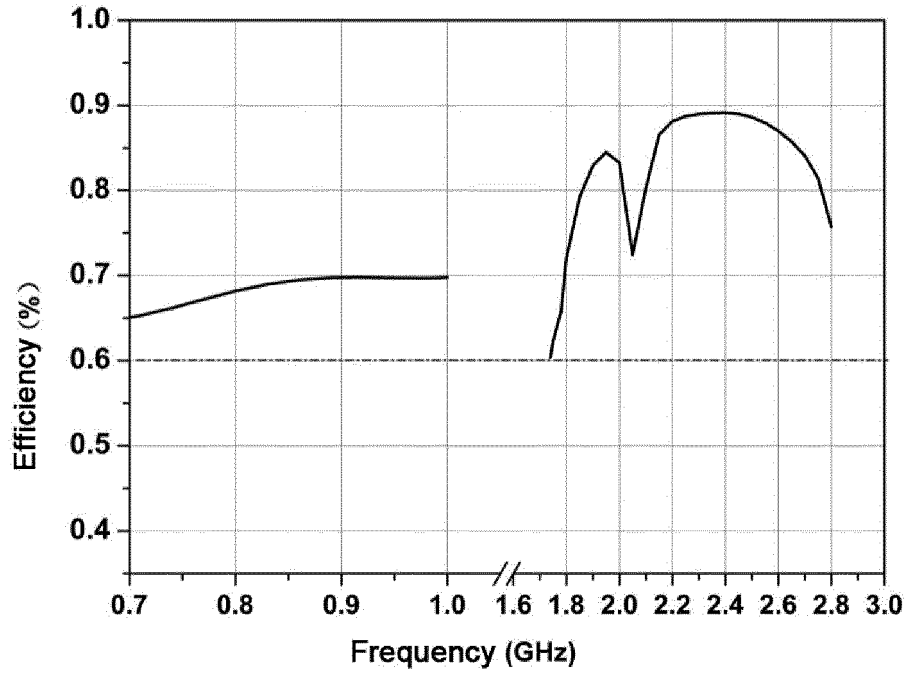


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2019/087992

5	A. CLASSIFICATION OF SUBJECT MATTER H01Q 1/36(2006.01)i	
	According to International Patent Classification (IPC) or to both national classification and IPC	
	B. FIELDS SEARCHED	
10	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	
15	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, 无线, 移动, 便携, USB, 数据库, 无线网卡, 无线上网卡, 净空区, 地, 封闭, 闭合, 环绕, 围绕, 包围, 回路, 连续, 缺陷, 空, 非金属, 无金属, 介质, 除, 挖, antenna, aerial, terminal, wireless, mobile, dongle, PCMCIA, card, ground	
	C. DOCUMENTS CONSIDERED TO BE RELEVANT	
20	Category*	Citation of document, with indication, where appropriate, of the relevant passages
	X	CN 105870625 A (ZTE CORPORATION) 17 August 2016 (2016-08-17) description, paragraphs 0029-0048, and figure 3
25	A	CN 102790267 A (UNIVERSITY OF ELECTRONIC SCIENCE AND TECHNOLOGY OF CHINA) 21 November 2012 (2012-11-21) entire document
	A	CN 101847214 A (HUAWEI DEVICE CO., LTD.) 29 September 2010 (2010-09-29) entire document
	A	CN 204375961 U (ZTE CORPORATION) 03 June 2015 (2015-06-03) entire document
30	A	CN 102354807 A (UNIVERSITY OF ELECTRONIC SCIENCE AND TECHNOLOGY OF CHINA) 15 February 2012 (2012-02-15) entire document
35	A	US 2015255864 A1 (ZTE CORP) 10 September 2015 (2015-09-10) entire document
	☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.	
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	Date of the actual completion of the international search 02 August 2019	Date of mailing of the international search report 08 August 2019
50	Name and mailing address of the ISA/CN State Intellectual Property Office of the P. R. China (ISA/CN) No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088 China	Authorized officer
55	Facsimile No. (86-10)62019451	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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REFERENCES CITED IN THE DESCRIPTION

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