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(54) **ANTENNA APPARATUS AND ELECTRONIC DEVICE**

(57) The present application relates to an antenna apparatus and an electronic device. The antenna apparatus comprises an antenna body, a feed module, and a frequency band switching module. The antenna body comprises a first conductive branch and a second conductive branch spaced apart, a first feed point is provided on the first conductive branch, and a second feed point is provided on the second conductive branch. The feed module comprises a first feed circuit connected to the first feed point and a second feed circuit connected to the second feed point. The frequency band switching module is connected to the first conductive branch. One end of the frequency switching module is connected to the first conductive branch, and the other end is grounded; the frequency band switching module comprises a switch module and at least two frequency band selection branch circuits, at least two frequency band selection branch circuits being in parallel; the switch module selectively connects at least one among at least two frequency band selection branch circuits into a loop of the first conductive branch, so as to allow the first conductive branch to switchably radiate first radio frequency signals of different frequency bands. The antenna apparatus has a relatively wide covered frequency band range and is relatively low cost.

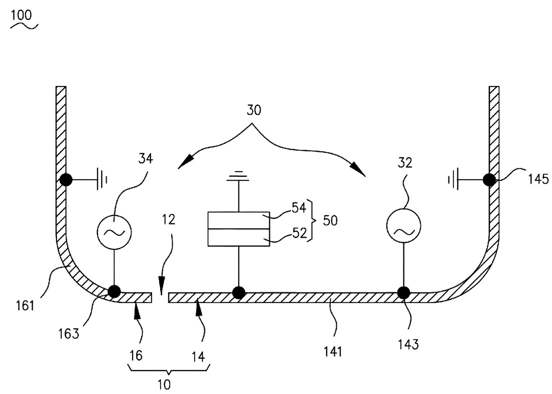


FIG. 1

Description

CROSS-REFERENCING OF RELEVANT APPLICATIONS

[0001] This application claims priority to a Chinese patent application No. CN202011455048.3, entitled "ANTENNA APPARATUS AND ELECTRONIC DEVICE", and filed on December 10, 2020 to China National Intellectual Property Administration. The entire contents of this application are incorporated herein by reference.

TECHNICAL FIELD

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

BACKGROUND

[0003] With the development and progress of science and technology, communication technologies have developed rapidly and got great progress. With the improvement of communication technologies, popularity of intelligent electronic products has reached an unprecedented height, and more and more intelligent terminals or electronic devices, such as smartphones, smart bracelets, smart watches, smart TVs and computers, have become an indispensable part of people's lives. These electronic devices transmit signals through a built-in antenna apparatus, so as to realize voice calls, navigation, wireless Internet access, and other functions. A radiator serves as an important part of the antenna apparatus, and its design form and position layout in the phone directly affect the communication performance of the antenna apparatus.

[0004] In the existing electronic devices, one or more slots are provided on a metal frame, to divide the metal frame into multiple metal branches, which may form multiple metal frame antennas. However, the radiation of signals at multiple frequency bands requires more metal branches, and the cost of the antenna apparatus is high.

SUMMARY

[0005] Embodiments of the present disclosure provide an antenna apparatus and an electronic device.

[0006] In a first aspect, the embodiments of the present disclosure provide an antenna apparatus. The antenna apparatus includes an antenna body, a feeding module, and a band-switching module. The antenna body includes a first conductive branch and a second conductive branch, and a slot is provided between the first conductive branch and the second conductive branch. The first conductive branch is provided thereon with a first feeding point, and the second conductive branch is provided thereon with a second feeding point. The feeding module includes a first feed circuit and a second feed circuit. The first feed circuit is connected to the first feeding point, and is configured to feed a first current signal to the first conductive branch through the first feeding point, to enable the first conductive branch to radiate a first radio frequency signal. The second feed circuit is connected to the second feeding point, and is configured to feed a second current signal to the second conductive branch through the second feeding point, to enable a second radiator of the second conductive branch to radiate a second radio frequency signal. One end of the band-switching module is connected to the first conductive branch, and the other end of the band-switching module is grounded. One end of the band-switching module is connected to the first conductive branch, and the other end of the band-switching module is grounded. A connection node of the band-switching module and the first conductive branch is located between the first feeding point and the slot. The band-switching module includes a switch module and at least two band-selecting branches, where the at least two band-selecting branches are connected in parallel. The band-switching module is configured to selectively connect at least one of the at least two band-selecting branches into a loop of the first conductive branch through the switch module, to enable the first conductive branch to radiate, based on the first current signal, the first frequency radio signal at different frequency bands in a switchable manner.

[0007] In a second aspect, the embodiments of the present disclosure provide an electronic device. The electronic device includes a casing and the antenna apparatus mentioned above, where the antenna apparatus is integrated into the casing.

[0008] In a third aspect, the embodiments of the present disclosure provide an electronic device. The electronic device includes a boundary frame and the apparatus mentioned above. A material of the boundary frame includes metal. The boundary frame is provided with a slot, and the slot of the boundary frame divides the boundary frame into two parts. The antenna apparatus is integrated into the boundary frame. The slot of the boundary frame is the slot between the first conductive branch and the second conductive branch.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In order to illustrate technical schemes in the embodiments of the present disclosure more clearly, the drawings used in the description of the embodiments are briefly introduced below. Apparently, the drawings in the following description are merely some embodiments of the present disclosure. For those skilled in the art, other drawings may be obtained according to these drawings without paying any creative effort.

FIG. 1 illustrates a schematic structural diagram of an antenna apparatus according to the embodiments of the present disclosure.

FIG. 2 illustrates another schematic structural diagram of the antenna apparatus according to the embodiments of the present disclosure.

FIG. 3 illustrates a further schematic structural diagram of the antenna apparatus according to the embodiments of the present disclosure.

FIG. 4 is a schematic diagram illustrating antenna efficiency of the antenna apparatus illustrated in FIG. 3.

FIG. 5 illustrates a schematic structural diagram of an antenna apparatus equipped with a voltage division circuit according to the embodiments of the present disclosure.

FIG. 6 illustrates another schematic structural diagram of the antenna apparatus equipped with a voltage division circuit according to the embodiments of the present disclosure.

FIG. 7 illustrates yet a further schematic structural diagram of the antenna apparatus according to the embodiments of the present disclosure.

FIG. 8 illustrates another schematic structural diagram of the antenna apparatus according to the embodiments of the present disclosure.

FIG. 9 illustrates yet a still further schematic structural diagram of the antenna apparatus according to the embodiments of the present disclosure.

FIG. 10 illustrates yet a still further schematic structural diagram of the antenna apparatus according to the embodiments of the present disclosure.

FIG. 11 is a schematic diagram illustrating a matching circuit module of the antenna apparatus illustrated in FIG. 8.

FIG. 12 illustrates yet a still further schematic structural diagram of the antenna apparatus according to the embodiments of the present disclosure.

FIG. 13 is a schematic diagram of an electronic device according to the embodiments of the present disclosure.

FIG. 14 is a schematic diagram illustrating an internal structure of the electronic device shown in FIG. 13.

DETAILED DESCRIPTION OF EMBODIMENTS

[0010] Embodiments of the present disclosure will be described clearly and comprehensively in combination with the drawings in the embodiments of the present disclosure. Apparently, the described embodiments are merely some of the embodiments of the present disclosure, not all of the embodiments. All other embodiments, obtained by those skilled in the art based on the embodiments in the present disclosure without creative work, fall into the scope of protection of the present disclosure.

[0011] The "electronic device" used in the embodiments of the present disclosure includes, but is not limited to a device that transmits or sends a communication signal via a wire connection (e.g., a connection established via public switched telephone network (PSTN), digital subscriber line (DSL), digital cable, direct cable connection), and/or via a wireless interface (e.g., a wire interface for cellular network, wireless local area network (WLAN), digital TV network such as DVB-H network, satellite network, AM-FM broadcast transmitter, , and/or a wireless interface for another communication terminal). A communication terminal configured to communicate via the wireless interface may be referred to as a "wireless communication terminal", "wireless terminal", "electronic equipment", and/or "electronic device". Examples of the electronic device include, but are not limited to: satellite or cellular telephone; personal communication system (PCS) terminal which can integrate a radio-telephone with functions of data processing, faxing, and data communicating; personal digital assistant (PDA) which may include a radio-telephone, a pager, Internet/Intranet access, a Web browser, a notepad, a calendar, and/or a global positioning system (GPS) receiver; and conventional lap and/or palm receivers, game consoles or other electronic devices including a radio-telephone transceiver.

[0012] In the existing electronic devices, one or more slots are generally provided on a metal frame to divide the metal frame into multiple metal branches, which enables multiple metal frame antennas to be formed. However, the radiation of signals at multiple frequency bands requires more metal branches, and the cost of the antenna apparatus is high.

[0013] In view of the above problem, through a lot of repeated research, the inventors of the present disclosure found that the antenna of the existing electronic device may be improved by adding a band-selecting circuit with a filter between a feeding source and a radiator; specifically, by setting parameters of different components of the filter, for example, by configuring a different capacitor or a different inductor in the filter, a different current signal may be fed from the feeding source to a radiator, and the radiator may radiate a frequency radio signal at a different frequency band. In this way, the working frequency band of the antenna can be expanded, and the addition of additional metal branches to the antenna is avoided. However, for such a tuning scheme, the inventors further found that, in the case where the current signal fed by the feeding source to the radiator is adjusted by means of the filter, if the radiator needs to radiate radio frequency signals at multiple frequency bands, multiple corresponding filters and corresponding circuit switches are required. Although this scheme can reduce the number of the metal branches of the antenna, the number of the filters is increased for more working frequency bands, which is also a great burden on the cost of the antenna.

[0014] Therefore, the inventors of the present disclosure are committed to a study on how to enable the antenna to operate at as many frequency bands as possible while reducing the cost of the antenna as much as possible. Through a lot of repeated research, the inventors proposed an antenna apparatus and an electronic device with the antenna apparatus of the embodiments of the present disclosure. The antenna apparatus includes an antenna body, a feeding module, and a band-switching module. The antenna body includes a first conductive branch and a second conductive branch, and a slot is provided between the first conductive branch and the second conduct branch. A first feeding point is provided on the first conductive branch, and a second feeding point is provided on the second conductive branch. The feeding module includes a first feed circuit and a second feed circuit. The first feed circuit is connected to the first feeding point, and is configured to feed a first current signal to the first conductive branch via the first feeding point, to enable the first conductive branch to radiate a first radio frequency signal. The second feed circuit is connected to the second feeding point, and is configured to feed a second current signal to the second conductive branch via the second feeding point, to enable the second conductive branch to radiate a second radio frequency signal. One end of the band-switching module is connected to the first conductive branch, and the other end of the band-switching module is grounded. A connection node of the band-switching module and the first conductive branch is located between the first feeding point and the slot. The band-switching module includes a switch module and at least two band-selecting branches, and the at least two band-selecting branches are connected in parallel. The band-switching module is configured to selectively connect at least one of the at least two band-selecting branches into a loop of the first conductive branch through the switch module, to enable the first conductive branch to radiate, based on the first current signal, the first frequency radio signal at different frequency bands in a switchable manner.

[0015] In the antenna apparatus mentioned above, the first conductive branch is equipped with the band-switching module, and at least one of the at least two band-selecting branches is connected into the loop of the first conductive branch through the switch module. As such, an impedance matching performance of the first conductive branch may be adjusted by means of different band-selecting branches, and the first conductive branch is enabled to operate at different frequency bands. Thus, the working frequency band of the first conductive branch can be broadened, and the addition of a new conductive branch is avoided for the addition of a different frequency band, which enables a low cost and a small occupation space of the antenna apparatus to a certain extent. Further, in the antenna apparatus mentioned above, one end of the band-switching module is connected to the ground and the other end of the band-switching module is directly connected to the first conductive branch. As such, different band-selecting branches connected in parallel are selectively connected into a loop, and different connected states of the different band-selecting branches can be utilized, which enables more working frequency bands and high stability of frequency modulation.

[0016] The technical schemes in the embodiments of the present disclosure will be described clearly and comprehensively, in combination with the drawings of the embodiments of the present disclosure.

[0017] Referring to FIG. 1, the embodiments of the present disclosure provide an antenna apparatus 100. The antenna apparatus 100 includes an antenna body 10, a feeding module 30 and a band-switching module 50, where the feeding module 30 and the band-switching module 50 each are connected to the antenna body 10. The antenna body 10 is used to receive and radiate a radio frequency signal. The feeding module 30 is used to feed a current signal to the antenna body 10, so that the antenna body 10 can generate a resonance to radiate the radio frequency signal. The feeding module 30 is adapted to be connected to and controlled by a mainboard of the electronic device. One end of the band-switching module 50 is grounded, and the other end of the band-switching module 50 is connected to the antenna body 10. The band-switching module 50 is configured to make different impedance components connect into the loop of the antenna apparatus 100, to enable the antenna body 10 to radiate the frequency radio signal at different frequency bands in a switchable manner.

[0018] The antenna body 10 includes a first conductive branch 14 and a second conductive branch 16. The first conductive branch 14 and the second conductive branch are spaced apart from each other, and a slot 12 is provided between the first conductive branch 14 and the second conductive branch 16. It is understandable that, in some embodiments, the slot 12 may be a gap provided in the antenna body 10. For example, during preparation of the antenna body 10, the slot 12 may be formed on a base material of the antenna body 10 through cutting, stamping or other processing, to divide the antenna body 10 into the first conductive branch 14 and the second conductive branch 16. In other embodiments, the slot 12 may be a gap formed due to assembly of the antenna body 10. For example, the antenna body 10 is formed by assembling together the first conductive branch 14 and the second conductive branch 16; and at the time of assembling the first conductive branch 14 and the second conductive branch 16, a predetermined distance is defined there between, and thus the slot 12 is formed by a space between the first conductive branch 14 and the second conductive branch 16. The embodiments of the present disclosure do not limit the formation of the slot 12, as long as it is ensured that the slot 12 is a gap in the antenna body 10 and at least part of the structure of the first conductive branch 14 is spaced apart from at least part of the structure of the second conductive branch 16.

[0019] In some embodiments, the antenna body 10 is provided with at least one slot 12 (for example, one, two, or more slots 12), and the at least one slot 12 divides the antenna body 10 at least into the first conductive branch 14 and the second conductive branch 16. In some embodiments, as a part of the antenna apparatus, the slot 12 may be considered as a break gap, which may divide the antenna body 10 into at least two conductive branches. When the number of the slots 12 is N, the antenna body 10 may be divided into N+1 conductive branches. In some embodiments, the slot 12 may be filled with air, plastic and/or other dielectric medium. The slot 12 may be in a straight shape, or may be in one or more curved shapes. It is notable that the slot 12 may be provided at any position of the antenna body 10. In the embodiments of the present disclosure, the shape, size, and number of the slot 12 as well as of the position of the slot 12 in the antenna body 10 are not further limited.

[0020] The first conductive branch 14 includes a first radiator 141 and a feeding point 143 provided on the first radiator 141. The first feeding point 143 is used for connection to the feeding module 30, to enable the first radiator 141 to radiate the first radio frequency signal when the feeding module 30 feeds the current signal. In some embodiments, the first conductive branch 14 further includes a first ground terminal 145. The first ground terminal 145 is connected to the first radiator 141, and is adapted to be connected to a reference ground.

[0021] The second conductive branch 16 includes a second radiator 161 and a second feeding point 163 provided on the second radiator 161. The second feeding point 163 is used for connection to the feeding module 30, to enable the second radiator 161 to radiate a second radio frequency signal when the feeding module 30 feeds the current signal. The first radio frequency signal and the second radio frequency signal are at different frequency bands. In some embodiments, the second conductive branch 16 further includes a second ground terminal 165. The second ground terminal 165 is provided on the second radiator 141, and is adapted to be connected to the reference ground. Further, in the embodiments of the present disclosure, the length of the second conductive branch 16 is shorter than the length of the first conductive branch 14, so that the second conductive branch 16 and the first conductive branch 14 are used to radiate the radio frequency signals at different frequency bands, respectively. For example, the second conductive branch 16 is configured to radiate a high band signal. Further, in some embodiments, the first radiator 141 is configured to make, under tuning of the band-selecting module 50, the energy of the first radiator 141 pass through the slot 12 to cause energy coupling with the second radiator 161, so as to achieve tuning of the high band signal. In this case, the width of the slot 12 may be greater than or equal to 0.8mm and less than or equal to 1.5mm. For example, the width of the slot 12 may be 0.8mm, 0.9mm, 1.0mm, 1.1mm, 1.2mm, 1.3mm, 1.4mm, 1.5mm, and so on.

[0022] The feeding module 30 includes a first feed circuit 32 and a second feed circuit 34. The first feed circuit 32 feeds a first current signal to the first conductive branch 14 via the first feeding point 143, to enable the first radiator 141 of the first conductive branch 14 to radiate the first radio frequency signal. The second feed circuit 34 feeds a second current signal to the second conductive branch 16 via the second feeding point 163, to enable the second radiator 161 of the second conductive branch 16 to radiate the second radio frequency signal.

[0023] One end of the band-selecting module 50 is grounded, and the other end of the band-selecting module 50 is connected to the first radiator 143. In the embodiments of the present disclosure, the band-selecting module 50 includes a switch module 52 and at least two band-selecting branches 54. The at least two band-selecting branches 54 are connected in parallel. The switch module 52 is connected to the at least two band-selecting branches 54. The band-switching module 50 is configured to selectively connect at least one of the at least two band-selecting branches 54 into a loop of the first conductive branch 143 through the switch module 52, to enable the first radiator 143 to radiate, based on the first current signal, the first frequency radio signal at different frequency bands in a switchable manner.

[0024] In the embodiments of the present disclosure, the first radio frequency signal is switchable to different working frequency bands. For example, the first radio frequency signal may include a long-term evolution (LTE) signal, and the working frequency band of the first radio frequency signal may include at least two frequency bands of LTE. The LTE signal may include a low band (LB) signal, a middle band (MB) signal, and a high band (HB) signal. In the embodiments of the present disclosure, under the excitation of the first feed circuit 32, the first radiator 141 of the first conductive branch 14 may correspondingly radiate the low band signal of the LTE signal. The frequency of the low band signal ranges from 703MHz to 960MHz. Under the excitation of the second feed circuit 34, the second radiator 161 of the second conductive branch 16 may correspondingly radiate the middle band signal or the high band signal of the LTE signal. That is, the second radio frequency signal may include the high band (HB) signal and the middle band (MB) signal of LTE. The frequency of the middle band signal ranges from 1710MHz to 2170MHz, and the frequency of the high band signal may range from 2300MHz to 2690MHz.

[0025] In the antenna apparatus mentioned above, the first conductive branch is equipped with the band-switching module, and at least one of the at least two band-selecting branches is connected into the loop of the first conductive branch through the switch module. As such, an impedance matching performance of the first conductive branch may be adjusted by means of different band-selecting branches, and the first conductive branch is enabled to operate at different frequency bands. Thus, the working frequency band of the first conductive branch can be broadened, and the addition of a new conductive branch is avoided for the addition of a different frequency band, which enables a low cost and a small occupation space of the antenna apparatus to a certain extent. Further, in the antenna apparatus mentioned above, one end of the band-switching module is connected to the ground and the other end of the band-switching module is directly connected to the first conductive branch. As such, different band-selecting branches connected in parallel are selectively connected into a loop, and different connected states of the different band-selecting branches can be utilized, which enables more working frequency bands and high stability of frequency modulation.

[0026] Referring to FIG. 2, in some embodiments, the at least two band-selecting branches 54 include a first branch 541 and a second branch 543.One end of the first branch 541 is grounded, and the other end of the first branch is connected to the first radiator 141. The second branch 543 is connected in parallel with the first branch 541. The first branch 541 is provided with an impedance component having a different impedance value from that of the second branch 543. In this way, when each of the first and second branches is connected into the loop of the first conductive branch 14, the impedance of the loop is changed, so that the first conductive branch 14 is adjusted to have appropriate impedance matching, to radiate the first radio frequency signal at a required frequency band. In some embodiments, the first branch 541 includes a first capacitor C1, and the second branch 543 includes a first inductor L1. The first capacitor C1 is connected in parallel with the first inductor L1, and both of them are controlled by the switch module 52. The switch module 52 selectively connects the first capacitor C1 or/and the first inductor L1 into the loop of the first conductive branch 14. A capacitance value of the first capacitor C1 and an inductance value of the first inductor L1 may be set according to a specific working frequency band of the first radio frequency signal, which are not limited in the embodiments of the present disclosure.

[0027] Referring to FIG. 3, in some embodiments, the at least two band-selecting branches 54 further include a third branch 545 and a fourth branch 547. One end of the third branch 545 is grounded, and the other end of the third branch 545 is connected to the first radiator 141. The fourth branch 547 is connected in parallel with the third branch 545. Further, the fourth branch 547, the third branch 545, the second branch 543, and the first branch 541 are connected in parallel with each other, and they are all connected to the switch module 52. The fourth branch 547 and the third branch 545 each are provided with a different impedance component of a different impedance value. In this way, when each of the third and fourth branches is connected into the loop of the first conductive branch 14, the impedance of the loop is changed, so that the first conductive branch 14 is adjusted to have appropriate impedance matching, to radiate the first radio frequency signal of a required frequency band. In some embodiments, the third branch 545 includes a second capacitor C2, and the fourth branch 547 includes a second inductor L2. The second capacitor C2, the second inductor L2, the first capacitor C1 and the first inductor L1 are connected in parallel, and they are all controlled by the switch module 52. In the embodiment, the capacitance value of the first capacitor C1 is different from the capacitance value of the second capacitor C2. Further, the capacitance value of the first capacitor C1 may be larger than the capacitance value of the second capacitor C2. The inductance value of the first inductor L1 is different from the inductance value of the second inductor L2. Further, the inductance value of the first inductor L1 may be larger than the inductance value of the second inductor L2. The switch module 52 selectively connects at least one of the first capacitor C1, the first inductor L1, the second capacitor C2, and the second inductor L2 into the loop of the first conductive branch 14, to obtain the first radio frequency signal of the required frequency band. The capacitance value of the second capacitor C2 and the inductance value of the second inductance L2 may be set according to the specific working frequency band of the first radio frequency signal, which are not limited in the embodiments of the present disclosure.

[0028] In the embodiment, the switch module 52 is connected to the band-selecting branches 54, and is used to control each of the band-selecting branches to be on or off. The switch module 52 may be connected between the band-selecting branches 54 and the first radiator 141, or may also be connected between the band-selecting branches 54 and the reference ground. In the embodiment, the switch module 54 includes at least two switches, and a one-to-one correspondence is provided between the at least two switches and the at least two band-selecting branches 54. Each of the switches is connected to one corresponding band-selecting branch 54, to control the corresponding band-selecting branch 54 to be on or off. Specifically, in the embodiment illustrated in FIG. 3, the switch module may include a first switch K1, a second switch K2, a third switch K3, and a fourth switch K4. The first switch K1 is connected between the first band-selecting branch 541 and the first radiator 141. The second switch K2 is connected between the second band-selecting branch 543 and the first radiator 141. The third switch K3 is connected between the third band-selecting branch 545 and the first radiator 141. The fourth switch K4 is connected between the fourth band-selecting branch 547 and the first radiator 141. In the embodiment, each of the switches may be a single-pole single-throw switch or an electronic switching tube, etc. Among them, the electronic switching tube may be a MOS transistor, a transistor, etc. Specific components of the switch module 54 are not further limited in the embodiments, as long as the requirements of controlling the on or off of the multiple band-selecting branches 54 can be met.

[0029] Based on the above band-switching module 50, a situation where the band-switching module 50 switches the working frequency band of the first conductive branch 14 is illustrated below by examples. In the embodiment, the inductance of the first inductor L1 may range from 25nH to 45nH, the inductance of the second inductor L2 may range from 10nH to 25nH, the capacitance of the first capacitor C1 may range from 0.5pF to 1.5pF, and the capacitance of the second capacitor C2 may range from 0.2pF to 0.7pF. When the first conductive branch

14 is required to operate at a primary receive (PRX) band of B5 (824-849MHz for uplink, and 869-894MHz for downlink), all the band-selecting branches 54 are controlled, through the switch module 52, to be off, or the second capacitor C2 is controlled, through the third switch K3, to be connected into the loop; and under the excitation of the first current signal of the first feed circuit 32, the first radio frequency signal at the PRX band of B5 may be obtained. When the first conductive branch 14 is required to operate at a diversity receive (DRX) band of B5, the first inductor L1 is controlled, through the second switch K2, to be connected into the loop; and under the excitation of the first current signal of the first feed circuit 32, the first radio frequency signal at the DRX band of B5 may be obtained. When the first conductive branch 14 is required to operate at a PRX band of B8 (880-915MHz for uplink, and 952-960MHz for downlink), the second inductor L2 is controlled, through the fourth switch K4, to be connected into the loop; and under the excitation of the first current signal of the first feed circuit 32, the first radio frequency signal at the PRX band of B8 may be obtained. When the first conductive branch 14 is required to operate at a DRX band of B8, the first inductor L1 and the second inductor L2 are controlled, through the second switch K2 and the fourth switch K4, to be connected in parallel into the loop, and a total inductance of 7.5nH-16nH is obtained; and under the excitation of the first current signal of the first feed circuit 32, the first radio frequency signal at the DRX band of B8 may be obtained. When the first conductive branch 14 is required to operate at a DRX band of B28, the second capacitor C2 is controlled, through the third switch K3, to be connected into the loop, and under the excitation of the first current signal of the first feed circuit 32, the first radio frequency signal at the DRX band of B28 may be obtained. When the first conductive branch 14 is required to operate at a PRX band of B28, the first capacitor C1 and the second capacitor C2 are controlled, through the first switch K1 and the third switch K3, to be connected in parallel into the loop, and a total capacitance of about 0.7pF-2.0pF is obtained; and under the excitation of the first current signal of the first feed circuit 32, the first radio frequency signal at the PRX band of B28 may be obtained.

[0030] It can be seen that, with the band-switching module 50 provided in the embodiment, the first radio frequency signal at LB may be obtained by means of the different band-selecting branches 54, where each band, such as B5, B8, and B28, of LB is subdivided into the PRX band and the DRX band for tuning. Thus, by connecting, into the loop, at least one of the different band-selecting branches 54 connected in parallel, sideband performance of the antenna apparatus 100 can be improved, and the LB bandwidth can be avoided from being too narrow.

[0031] Further, in the embodiment, the band-switching module 50 may also assist excitation of the coupling between the first conductive branch 14 and the second conductive branch 16. For example, the first radiator 141 is configured to make, under the tuning of the band-selecting module 50, the energy of the first radiator pass through the slot 12 to cause energy coupling with the second radiator 161, so as to meet the resonance requirements of the middle and high frequency bands. For example, in a case where the antenna apparatus 100 is adjusted to being in a 1/2λ mode, the working frequency band of the antenna apparatus 100 is further adjusted to a band near a resonant point of a 1/4λ mode of the second conductive branch 16, or to a band near a resonant point of a 3/4λ mode of the first conductive branch 14, so as to obtain a mixed mode. This enables the bandwidth of the second conductive branch 16 in the 1/4λ mode and the bandwidth of the first conductive branch 14 in the 3/4λ mode to be widened, and the efficiency of the antenna to be improved. Specifically, when the antenna apparatus 100 is in the 1/2λ mode, the first capacitor C1 and the second capacitor C2 are controlled, through the first switch K1 and the third switch K3, to be connected in parallel into the loop, to obtain the second radio frequency signal of a B3 band (1710-1785MHz for uplink, and 1805-1880MHz for downlink).

[0032] Referring to FIG. 4, FIG. 4 illustrating antenna efficiency obtained when the mixed mode tuning is adopted to obtain the B3 band according to the embodiment, and antenna efficiency obtained when a traditional single mode is adopted to obtain the B3 band. It can be seen that, when the B3 band is obtained in the mixed mode by adopting the band-switching module 50 according to the embodiment, the bandwidth is relatively wider, and the efficiency is higher. As can be seen, the state of the band-switching module 50 where the first capacitor C1 and the second capacitor C2 are connected in parallel into the loop in this case, is the same as the state of the band-switching module 50 for the PRX band of B28 mentioned above. That is, the state of the band-switching module 50 may be multiplexed. Under the same state of the band-switching module 50, resonances of two modes can be obtained, which ensures that fewer components are required for the antenna apparatus 100 in the embodiments, and that the cost of the antenna apparatus 100 is relatively low.

[0033] Accordingly, when the antenna apparatus 100 is in the 1/2λ mode, the first inductor L1 and the second inductor L2 are controlled, through the second switch K2 and the fourth switch K4, to be connected in parallel into the loop, so that mixing with the 3/4λ mode of the first conductive branch is available, and the second radio frequency signal of a B41 band (2496Hz-2690MHz) is obtained, which has a relatively wide bandwidth and high efficiency. As can be seen, the state of the band-switching module 50 where the first inductor L1 and the second inductor L2 are connected in parallel into the loop in this case, is the same as the state of the band-switching module 50 of the DRX band of B8 mentioned above; this enables the switch state of the band-switching module 50 to be multiplexed, and more carrier aggregation (CA) states are available. This is because that: the CA state requires the antenna to support two or more bands at the same time, and the antenna apparatus 100 provided in embodiments of the present disclosure enables some middle and high frequency bands to exist simultaneously (for example, B3 and B1 exist simultaneously, B3 and B41 exist simultaneously), and the multiplexing of the switch state(s) enables a band of LB and a band of MHB to exist simultaneously, thus more CA states are supported without increasing the cost. Other working frequency bands may be obtained by adjusting different capacitors and inductors for connection into the circuits, which will not be enumerated in the description.

[0034] In the antenna apparatus mentioned above, the first conductive branch is equipped with the band-switching module, and at least one of the at least two band-selecting branches is connected into the loop of the first conductive branch through the switch module. As such, by means of different band-selecting branches, the first conductive branch is enabled to work at different frequency bands. Thus, the working frequency band of the first conductive branch can be broadened, and the addition of a new conductive branch is avoided for the addition of a different frequency band, which enables a low cost and a small occupation space of the antenna apparatus to a certain extent. Moreover, the state(s) of the band-switching module may be multiplexed. Under the same state of the band-switching module, resonances of two modes can be obtained, which further ensures that fewer components are required for the antenna apparatus in the embodiments, and that the cost of the antenna apparatus is relatively low.

[0035] Referring to FIG. 6, in some embodiments, the antenna apparatus 100 further includes a voltage division circuit 60. The voltage division circuit 60 is connected to the band-switching module 50, and is used to perform voltage division on the circuit of the band-switching module 50, to improve the voltage withstand ability of the circuit, and to avoid adverse effect on the circuit caused by low withstand voltage of the switch module 52. Further, a first end of the voltage division circuit 60 is grounded, and a second end of the voltage division circuit 60 is connected to the circuit of the band-switching module 50. For example, in some embodiments, the second end of the voltage division circuit 60 may be connected to a common connection node of the switch module 52 and the first radiator 141, and the first end of the voltage division circuit may be directly grounded. In other embodiments, the second end of the voltage division circuit 60 may be connected to the common connection node of the switch module 52 and the first radiator 141, and the first end of the voltage division circuit 60 may be connected to a common connection node of the multiple band-selecting branches 54 and the reference ground. In this case, it may be considered that the voltage division circuit 60 is connected in parallel with the band-switching module 50 (as illustrated in FIG. 6). It is understandable that "the common connection node" in the embodiments of the present disclosure should be considered as a common connection node of circuits, and it is not limited to one physical node, but should be considered as points on the circuits where the electronic potential thereof is appropriately the same.

[0036] In other embodiments (as illustrated in FIG. 7), the second end of the voltage division circuit 60 may be connected to the common connection node of the switch module 52 and the first radiator 141, and the first end of the voltage division circuit 60 is grounded through the first inductor L1. That is, when the second switch K2 is off, the voltage division circuit 60 is connected in series with the first inductor L1, and then is the grounding. In this way, the voltage division circuit 60 may occupy a small footprint of a circuit board, which facilitates the wiring of the circuit board. Of course, in some embodiments, it is also possible that the second end of the voltage division circuit 60 may be connected to the common connection node of the switch module 52 and the first radiator 141, and the first end of the voltage division circuit is grounded through the second inductor L2. That is, when the second switch K4 is off, the voltage division circuit 60 is connected in series with the second inductor L2, and then is the grounding.

[0037] In the embodiments of the present disclosure, the voltage division circuit 60 may include a component such as a resistor or/and an inductor. In the embodiment, the voltage division circuit 60 includes a voltage division inductor L0. A first end of the voltage division inductor L0 is grounded, and a second end of the voltage division inductor L0 is connected to the circuit of the band-switching module 50. The inductance value of the voltage division inductor is greater than or equal to 30nH, so as to improve the voltage withstand ability of the band-switching module 50. Of course, in other embodiments, the specific inductance value of the voltage division inductor L0 may be adapted according to the inductance value of the first inductor L1 or the second inductor L2 connected in series with the voltage division inductor L0, which will not be enumerated in the description.

[0038] It is understandable that the number of the band-switching module 50 of the antenna apparatus 100 is not limited in the embodiments of the present disclosure. For example, in the above embodiments, there is one band-switching module 50, and the one band-switching module 50 is connected to the first conductive branch 14, to broaden the working frequency band of the first conductive branch 14. Referring to FIG. 5, in some other embodiments, there may be two band-switching modules 50; one of the two band-switching modules 50 may be connected to the first conductive branch 14 to broaden the working frequency band of the first conductive branch 14, and the other of the two band-switching modules 50 may be connected to the second conductive branch 16 to broaden the working frequency band of the second conductive branch 16. Any of the two band-switching modules 50 may have features provided by the above embodiments, which will not to be repeated in the embodiment. For example, one of the two band-switching modules 50 is connected to the first conductive branch 14, and the other one is connected to the second conductive branch 16; the band-switching module 50 connected to the second conductive branch 16 is configured to connect at least one of the at least two band-selecting branches 54 into the loop of the second conductive branch 16 through the switch module 52, so as to enable the second conductive branch 16 to operate at different frequency bands. Further, a connection node between the band-switching module 50 and the second conductive branch 16 is located between the second feeding point 163 and the slot 12, to ensure the high reliability of the band-switching module 50 in tuning.

[0039] In some other embodiments, when N slots 12 are provided in the antenna body 10, the N slots 12 divide the antenna body 10 into N+1 conductive branches. For each of the conductive branches, one corresponding band-switching module 50 may be equipped, and the band-switching module 50 is configured to connect at least one of at least two band-selecting branches 54 into a loop of the corresponding conductive branch through the switch module 52, to enable the corresponding conductive branch to operate at different frequency bands.

[0040] Referring to FIG. 8, in some embodiments, the first feed circuit 32 includes a first feeding source 321. The first feeding source 321 is connected to the first feeding point 143, so as to feed the first current signal into the first conductive branch 14. Further, the first feed circuit 32 may further include a first matching sub-circuit 323 used to adjust the first radio frequency signal. The first matching sub-circuit 323 is connected between the first feeding source 321 and the first feeding point 143. The first matching sub-circuit 323 may be used to adjust an input impedance of the first radiator 141, so as to improve the transmission performance of the first radiator 141. The first matching sub-circuit 323 may include a combination of a capacitor and/or an inductor etc. In the embodiments of the present disclosure, the specific components of the first matching sub-circuit 323 is not further limited. In the embodiment, the first feeding point 143 is provided at the end of the first conductive branch 14 away from the slot 12. It is understandable that, in other embodiments, the parameter of the first matching sub-circuit 323 may affect the position where the first feeding point 143 is provided. For example, the first feeding point 143 may be provided at the end of the first conductive branch 14 close to the slot 12. The specific position of the first feeding point 143 is related to a first matching circuit 241. That is, the specific position of the first feeding point 143 may be set according to the first matching circuit 241.

[0041] In the embodiment, the second feed circuit 34 includes a second feeding source 341. The second feeding source 341 is connected to the second feeding point 163, to feed the second current signal into the second conductive branch 16. Further, the second feed circuit 34 may further include a second matching sub-circuit 343 used to adjust the second radio frequency signal. The second matching sub-circuit 343 is connected between the second feeding source 341 and the second feeding point 163. The second matching sub-circuit 343 may be used to adjust an input impedance of the second radiator 161, so as to improve the transmission performance of the second radiator 161. The second matching sub-circuit 343 may include a combination of a capacitor and/or an inductor etc. In the embodiment, the specific components of the second matching sub-circuit 343 is not further limited. In the embodiment, the second feeding point 163 is provided at the end of the second conductive branch 16 away from the slot 12. It is understandable that, in other embodiments, the parameter of the second matching sub-circuit 343 may affect the position where the second feeding point 163 is provided. For example, the second feeding point 163 may be provided at the end of the second conductive branch 16 close to the slot 12. The specific position of the second feeding point 163 is related to a second matching circuit 241. That is, the specific position of the second feeding point 163 may be set according to the second matching circuit 241.

[0042] Referring to FIG. 9, in some embodiments, the first feed circuit 32 may further include a first filter sub-circuit 325. The first filter sub-circuit 325 is connected between the first matching sub-circuit 323 and the first feeding point 143. The first filter sub-circuit 325 is used to filter out radio signals at frequencies different from the frequency of the first radio frequency signal, and it is in an on state when the first radio frequency signal flows through the first filter sub-circuit 325. In some embodiments, the first filter sub-circuit 325 is a low-pass filter sub-circuit. The low-pass filter sub-circuit may be considered as a circuit that is in an on state when the first radio frequency signal passes through the first filter sub-circuit 325, and it blocks a non-first radio frequency signal, whose frequency is higher than the frequency of the first radio frequency signal, from passing through the first filter sub-circuit 325. Specifically, the first filter sub-circuit 325 may include a third capacitor C3 and a third inductor L3. A first end of the third capacitor C3 is connected with each of a first end of the third inductor L3 and the first feeding point 143, and the other end of the third capacitor C3 is connected with the first matching sub-circuit 323. A second end of the third inductor L3 is grounded.

[0043] In some embodiments, the second feed circuit 34 may further include a second filter sub-circuit 345. The second filter sub-circuit 345 is connected between the second matching sub-circuit 343 and the second feeding point 163. The second filter sub-circuit 345 is used to filter out radio signals at frequencies different from the frequency of the second radio frequency signal, and it is in an on state when the second radio frequency signal flows through the second filter sub-circuit 345. In some embodiments, the second filter sub-circuit 345 is a high-pass filter sub-circuit. The high-pass filter sub-circuit may be considered as a circuit that is in an on state when the second radio frequency signal passes through the second filter sub-circuit 345, and it blocks a non-second radio frequency signal, whose frequency is lower than the frequency of the second radio frequency signal, from passing through the second filter sub-circuit 345. Specifically, the second filter sub-circuit 345 may include a fourth capacitor C4 and a fourth inductor L4. A first end of the fourth capacitor C4 is connected with each of a first end of the fourth inductor L4 and the second feeding point 163, and the other end of the fourth capacitor C4 is connected with the second matching sub-circuit 343. A second end of the fourth inductor L4 is grounded.

[0044] Referring to FIG. 10, in some embodiments, the antenna apparatus 100 may further include a matching circuit module 70. One end of the matching circuit module 70 is grounded, and the other end of the matching circuit module 70 is connected to the first conductive branch 14. Further, the matching circuit module 70 is connected to the first radiator 141. A connection node of the matching circuit module 70 and the first radiator 141 is located between the first feeding point 143 and the connection node of the band-switching module 50 and the first radiator 141. As such, the matching circuit module 70 can not only perform fine-tuning and correction on the frequency band of the first radio frequency signal, but also adjust a loop impedance of the first conductive branch 14, so as to improve the transmission performance of the first radiator 141, while enabling the working frequency band thereof to be wide and the adjustment to be more reliable. In the embodiment, the matching circuit module 70 may include a combination of a capacitor and/or an inductor, etc., and after the adjustment of the antenna apparatus 100, parameters of the capacitor and/or the inductor are not changed with the working frequency band of the antenna apparatus 100, so as to ensure that the matching circuit module 70 can reliably improve the impedance matching performance of the first radiator 141, thus enabling excellent signal transmission performance of the antenna apparatus 100.

[0045] Referring to FIG. 11, in some embodiments, the matching circuit module 70 may include a matching capacitor C5, a first matching inductor L5 and a second matching inductor L6. A first end of the second matching inductor L6 is connected to the first radiator 141, and a second end of the second matching inductor L6 is grounded. The matching capacitor C5 is connected in series with the first matching inductor L5 and then they as a whole are connected in parallel at both ends of the second matching inductor L6. That is, a first end of the first matching inductor L5 is connected to the first end of the second matching inductor L6, and a second end of the first matching inductor L5 is connected to a first end of the matching capacitor C5; and a second end of the matching capacitor C5 is connected to the second end of the second matching inductor L6. Among them, the capacitance value of the matching capacitor C5 may range from 0.5 pF to 2.7pF, the inductance value of the first matching inductance L5 may range from 1nH to 5.1nH, and the inductance value of the second matching inductance L6 may range from 5.6nH to 20nH. By providing the matching circuit module 70 on the first radiator 141, and making the connection node of the matching circuit module 70 and the first radiator 141 located between the first feeding point 143 and the second feeding point 163, the isolation between the two feeding points can be improved, and better signal transmission performance of the antenna apparatus 100 is enabled.

[0046] Referring to FIG. 12, in some embodiments, the first conductive branch 14 may include a first feeding part 147. The first feeding part 147 is connected between the first radiator 141 and the first feed circuit 32. The first feeding point 143 may be provided at the first feeding part 147; for example, it is provided at an end of the first feeding part 147 away from the first radiator 141, or provided at a coupling point of the first feeding part 147 and the first radiator 141. The first feeding part 147 may be a conductive clip or screw. Specifically, the first feeding point 143 may be connected to the first feed circuit 32 through the conductive clip or screw. The first feed circuit 32 may feed, through the clip or screw, the first current signal into the first conductive branch 14 via the first feeding point 143, for generation of the radiation; accordingly, the first radio frequency signal may be radiated at multiple different working frequency bands. The first conductive branch 14 may further include a first grounding part 149 connected to the first radiator 141. The first ground terminal 145 is provided at the first grounding part 149. The first ground terminal 145 may be connected with the reference ground through the first grounding part 149, for connection to the ground. The first grounding part 149 may be a clip, a screw or other electrical conductors, or may be a flexible circuit board. The first grounding part 149 may further be a connection arm made of the same material as the first conductive branch 14. Exemplary, the first grounding part 149 and the first conductive branch 14 may be integrated to simplify the structure of the antenna apparatus 100.

[0047] In the embodiment, the second conductive branch 16 may include a second feeding part 167. The second feeding part 167 is connected between the second radiator 161 and the second feed circuit 34. The second feeding point 163 may be provided at the second feeding part 167; for example, it is be provided at an end of the second feeding part 167 away from the second radiator 161, or be provided at a coupling point of the second feeding part 167 and the second radiator 161. The second feeding part 167 may be a conductive clip or screw. Specifically, the second feeding point 163 may be connected to the second feed circuit 32 through the conductive clip or screw. The second feed circuit 32 may feed, through the clip or screw, the second current signal into the second conductive branch 16 via the second feeding point 163, for generation of the radiation; accordingly, the second radio frequency signal may be radiated at multiple different working frequency bands. The second conductive branch 16 may further include a second grounding part 169 connected to the second radiator 161. The second ground terminal 165 is provided at the second grounding part 169. The second ground terminal 165 may be connected with the reference ground through the second grounding part 169, for connection to the ground. The second grounding part 169 may be a clip, a screw and other electrical conductors, or may be a flexible circuit board. The second grounding part 169 may further be a connection arm made of the same material as the second conductive branch 16. Exemplary, the second grounding part 169 and the second conductive branch 16 may be integrated to simplify the structure of the antenna apparatus 100.

[0048] In the above antenna apparatus, the first conductive branch is equipped with the band-switching module, and at least one of the at least two band-selecting branches is connected into the loop of the first conductive branch through the switch module. As such, by means of different band-selecting branches, the first conductive branch is enabled to work at different frequency bands. Thus, the working frequency band of the first conductive branch can be broadened, and the addition of a new conductive branch is avoided for the addition of a different frequency band, which enables a low cost and a small occupation space of the antenna apparatus to a certain extent.

[0049] Referring to FIG. 13, an electronic device 400 is further provided in the embodiments of the present disclosure. The electronic device 400 may be, but is not limited to, a mobile phone, a tablet, a laptop, a palmtop, a mobile Internet device (MID), a wearable device (such as a smart watch, a smart bracelet, a pedometer) or other communication devices that may be equipped with an antennae apparatus. It is illustrated in the embodiment by taking, as an example, a case where the electronic device 400 is a mobile phone.

[0050] The electronic device 400 includes a casing 1001, a display 1003, and an antenna apparatus 1004, where the display 1003 and the antenna apparatus 1004 are provided on the casing 1001. It is understandable that, in the description of the present disclosure, an orientational or positional relationship indicated by the term, such as "up", "down", "front", "back", "left", "right", and "in", is the orientational or positional relationship shown based on the drawings; this is merely simplified for facilitating the description of the present disclosure, and it does not indicate or imply that a device or component referred to must be in a specific orientation, or constructed and operated in a specific orientation; thus, this should not be considered as limitation of the present disclosure.

[0051] In the embodiment, the display 1003 generally includes a display panel, and may also include a circuit responsive to a touch operation performed on the display panel. The display panel may be a liquid crystal display (LCD). In some embodiments, the display panel may also serve as a touch display. In the description of the present disclosure, the description given with reference to terms "an embodiment", "some embodiments", "other embodiments" or the like, means that specific features, structures, materials or characteristics described in combination with the embodiment(s) or example(s) are included in at least one embodiment or example of the present disclosure. In the specification, a schematic representation of a term is not necessarily for same embodiments or examples. Furthermore, specific features, structures, materials, or characteristics described may be combined in an appropriate manner in any or more embodiments or examples. In addition, those skilled in the art may combine different embodiments or examples described in the specification and may combine features of the different embodiments or examples, without contradiction.

[0052] Specifically, in the embodiments of the present disclosure, the casing 1001 includes a rear casing 1010 and a middle frame 1011. The rear casing 1010 and the display 1003 are respectively provided on opposite sides of the middle frame 1011.

[0053] Referring to FIG. 14, the middle frame 1011 may be of an integrally formed structure. The middle frame may be divided, in terms of structure, into a bearing part 1012 and a boundary frame 1013 surrounding the bearing part 1012. It is understandable that, the terms "bearing part" and "boundary frame" are only named for convenience of description. The structures filled with slashes as illustrated in the drawings is merely for the purpose of distinction, and they do not represent the actual structures of the bearing part and the boundary frame. There may not be a clear dividing line between the bearing part and the boundary frame, or each of them may be assembled together from two or more components. The naming of the "bearing part" and the "boundary frame" should not limit the structure of the middle frame 1011. The bearing part 1012 is used to bear a part of the structure of the display 1003, and to bear or install electronic components of the electronic device 200, such as a mainboard 1005, a battery 1006, and a sensor module 1007. The boundary frame 1013 is connected to a periphery of the bearing part 1012. Further, the boundary frame 1013 is provided around the outer periphery of the bearing part 1012, and protrudes relative to a surface of the bearing part 1012, so that a space for accommodating electronic components is formed between the boundary frame 1013 and the bearing part 1012. In the embodiments, the display 1013 is covered on the boundary frame 1013, and an exterior surface of the electronic device 400 is formed by the boundary frame 1013, the rear casing 1010, and the display 1003 jointly.

[0054] In the embodiment, the antenna apparatus 1004 may be any of the antenna apparatus 100 provided in the above embodiments, or may have any of the features mentioned in the above embodiments or any combination of the features; reference may be made to the above embodiments for the relevant features, which are not repeated in the embodiment. The antenna apparatus 1004 is integrated in the casing 1001. For example, the antenna apparatus 1004 may be provided in the middle frame 1011, or may also be provided in the rear casing 1010, which is not limited in the description. Similar to the above antenna apparatus 100, the antenna apparatus 1004 in the embodiment may include the antenna body 10 as well as the feeding module 30 and the band-switching module 50 which are connected to the antenna body 10. The antenna body 10 may include the first conductive branch 14 and the second conductive branch. The antenna body 10 is provided in the middle frame 1011. The feeding module 30 may be connected to the mainboard 1005. The first ground terminal 145 and the second ground terminal 165 may be connected to at least one of the mainboard 1005, the bearing part 1012 and the rear casing 1010.

[0055] Further, in the embodiments illustrated in FIG. 14, the boundary frame 1013 is made of metal (the material of the boundary frame 1013 includes metal). For example, the material of the boundary frame 1013 may include aluminum alloy, magnesium alloy, etc. The antenna apparatus 1004 is integrated into the boundary frame 1013. In the embodiment, a slot 1014 is provided in the boundary frame 1013. The slot 1014 is communicated with the outside, and divides the boundary frame 1013 into two parts. The antenna apparatus 1004 is integrated into a part of the boundary frame 1013. The slot 1014 is the slot 12 in the above embodiments. Thus, the boundary frame 1013 made of metal is used as a part of the radiator of the antenna apparatus 1004, which is beneficial to reduce the space within the electronic device 400, and also provide a larger clear space for the antenna apparatus 1004, thereby being helpful to ensure a high radiation efficiency.

[0056] In the embodiment, a gap is provided between the bearing part 1013 and a part of the boundary frame 1013 serving as the antenna body 10. The gap is communicated with the slot 1014, so that the bearing part 1012 and a ground terminal of the radiator 12 (such as the radiator of the second conductive branch 16 or the radiator of the first conductive branch 14) are spaced apart from each other, to avoid the bearing part 1012 from affecting the resonant frequency of the radiator. Further, a non-shielding body 1015 may be provided in the slot 1014. The non-shielding body 1015 is made of nonmetal (such as resin), which has a characteristic of allowing an electromagnetic wave signal to pass therethrough, to enable signal transmission of the antenna apparatus 1004. An outer surface of the non-shielding body 1015 is flush with the outer surface of the boundary frame 1013, to ensure the integrity of the appearance of the electronic device 400.

[0057] In some other embodiments, the boundary frame 1013 may be made of nonmetal, and the antenna apparatus 100 may be integrated into the boundary frame 1013. For example, the boundary frame 1013 may be made of plastic, resin or other materials. The antenna body 10 of the antenna apparatus 100 may be integrated into the boundary frame 1013 by means of over molding (for example, the overall antenna body 10 is embedded inside the boundary frame 1013), and may also be integrated into the boundary frame 1013 by means of attaching (for example, the antenna body 10 is attached to a surface of the boundary frame 1013).

[0058] In some embodiments, the boundary frame 1013 may be a rounded rectangular frame. The boundary frame 1013 may include a first boundary frame and a third boundary frame arranged opposite to each other, and a second boundary frame and a fourth boundary frame arranged opposite to each other, where the second boundary frame is connected with each of the first boundary frame and the third boundary frame. The first boundary frame may be considered as a top boundary frame of the electronic device 400, the third boundary frame may be considered as a bottom boundary frame of the electronic device 400, and the second boundary frame and the fourth boundary frame may be considered as side boundary frames of the electronic device 400. A part or all of the antenna apparatus 1004 may be formed by a part of the boundary frame 1013. Exemplarily, the antenna body 10 of the antenna apparatus 1013 may be partially or completely integrated in at least one of the top boundary frame, the bottom boundary frame and the side boundary frames of the electronic device 400.

[0059] In the antenna apparatus and the electronic device provided by the embodiments of the disclosure mentioned above, the first conductive branch is equipped with the band-switching module, and at least one of the at least two band-selecting branches is connected into the loop of the first conductive branch through the switch module. As such, an impedance matching performance of the first conductive branch may be adjusted by means of different band-selecting branches, and the first conductive branch is enabled to operate at different frequency bands. Thus, the working frequency band of the first conductive branch can be broadened, and the addition of a new conductive branch is avoided for the addition of a different frequency band, which enables a low cost and a small occupation space of the antenna apparatus to a certain extent. Further, the at least two band-selecting branches are connected in parallel, and at least one of the at least two band-selecting branches may be selected so as to be connected into the loop of the first conductive branch. For example, multiple band-selecting branches are connected into the loop of the first conductive branch at the same time, or a single band-selecting branch is separately connected into the loop of the first conductive branch. These band-selecting branches may be connected into the loop in different combinations, so as to make full use of the combinations of the band-selecting branches. This enables the first conductive branch to operate at more different frequency bands, while ensuring a small number of the band-selecting branches, and further reduces the cost of the antenna apparatus.

[0060] It is notable that, in the description of the present disclosure, when one component is considered to be "provided" on another component, it may be connected to or directly provided on the another component, or a middle component may exist at the same time (i.e. the two are connected indirectly). When one component is considered to be "connected" to another component, it may be directly connected to the another component, or a middle component may exist at the same time, i.e., the two components may be connected indirectly.

[0061] In the description, the described specific features or characteristics may be combined in any one or more embodiments or examples in an appropriate manner. In addition, those skilled in the art may combine the different embodiments or examples described in the specification and combine the features of the different embodiments or examples, without contradiction. Finally, it is notable that, the above embodiments are merely intended to illustrate the technical schemes of the present disclosure, rather than limiting the present disclosure. Although the disclosure has been described in detail with reference to the foregoing embodiments, those skilled in the art should understand that they may still modify the technical schemes described in the foregoing embodiments, or make an equivalent substitution to part of the technical features thereof. These modifications and substitutions do not render the essence of the corresponding technical scheme to depart from the spirit and scope of the embodiments of the present disclosure.

Claims

1. An antenna apparatus, comprising:

an antenna body, comprising a first conductive branch and a second conductive branch, wherein a slot is provided between the first conductive branch and the second conductive branch; wherein a first feeding point is provided on the first conductive branch, and a second feeding point is provided on the second conductive branch;

a feeding module, comprising a first feed circuit and a second feed circuit; wherein the first feed circuit is connected to the first feeding point, and is configured to feed a first current signal to the first conductive branch via the first feeding point, to enable the first conductive branch to radiate a first radio frequency signal; the second feed circuit is connected to the second feeding point, and is configured to feed a second current signal to the second conductive branch via the second feeding point, to enable the second conductive branch to radiate a second radio frequency signal; and

a band-switching module, wherein one end of the band-switching module is connected to the first conductive branch, and the other end of the band-switching module is grounded; a connection node of the band-switching module and the first conductive branch is located between the first feeding point and the slot; the band-switching module comprises a switch module and at least two band-selecting branches, and the at least two band-selecting branches are connected in parallel; the band-switching module is configured to selectively connect at least one of the at least two band-selecting branches into a loop of the first conductive branch through the switch module, to enable the first conductive branch to radiate, based on the first current signal, the first frequency radio signal at different frequency bands in a switchable manner.

2. The antenna apparatus of claim 1, wherein the at least two band-selecting branches comprise a first branch and a second branch; the first branch comprises a first capacitor, the second branch comprises a first inductor, and the first capacitor and the first inductor are connected in parallel.

3. The antenna apparatus of claim 2, wherein the at least two band-selecting branches further comprise a third branch and a fourth branch; the third branch comprises a second capacitor, the fourth branch comprises a second inductor, and the first capacitor, the first inductor, the second capacitor and the second inductor are connected in parallel.

4. The antenna apparatus of claim 3, wherein a capacitance value of the first capacitor is different from a capacitance value of the second capacitor; and an inductance value of the first inductor is different from an inductance value of the second inductor.

5. The antenna apparatus of any one of claims 1 to 4, wherein the switch module comprises at least two switches, and a one-to-one correspondence is provided between the at least two switches and the at least two band-selecting branches; each of the switches is connected to one corresponding band-selecting branch, to control the corresponding band-selecting branch to be on or off.

6. The antenna apparatus of any one of claims 1 to 5, wherein the antenna apparatus further comprises a voltage division circuit, a first end of the voltage division circuit is grounded, and a second end of the voltage division circuit is connected to the band-switching module.

7. The antenna apparatus of claim 6, wherein the voltage division circuit comprises a voltage division inductor, a first end of the voltage division inductor is grounded, and a second end of the voltage division inductor is connected to the band-switching module.

8. The antenna apparatus of any one of claims 1 to 7, wherein the antenna apparatus further comprises a matching circuit module configured to adjust the first radio frequency signal, one end of the matching circuit module is grounded, and the other end of the matching circuit module is connected to the first conductive branch.

9. The antenna apparatus of claim 8, wherein a connection node of the matching circuit module and the first conductive branch is located between the first feeding point and the connection node of the band-switching module and the first conductive branch.

10. The antenna apparatus of claims 8 or 9, wherein the matching circuit module comprises a matching capacitor, a first matching inductor, and a second matching inductor; a first end of the sixth capacitor is connected to the first conductive branch, and a second end of the sixth capacitor is grounded; the fifth capacitor and the fifth inductor are connected in series and then they are connected in parallel at both ends of the sixth capacitor.

11. The antenna apparatus of any one of claims 1 to 10, wherein the band-switching module comprises two band-switching modules, one of the two band-switching modules is connected to the first conductive branch, and the other one of the two band-switching modules is connected to the second conductive branch; the band-switching module connected to the second conductive branch is configured to connect at least one of the at least two band-selecting branches into a loop of the second conductive branch, to enable the second conductive branch to operate at different frequency bands.

12. The antenna apparatus of claim 11, wherein a connection node of the band-switching module and the second conductive branch is located between the second feeding point and the slot.

13. The antenna apparatus of any one of claims 1 to 12, wherein the first conductive branch comprises a first radiator and a first ground terminal; the first feeding point is provided at the first radiator, one end of the first ground terminal is grounded, and the other end of the first ground terminal is connected to the first radiator; and
the second conductive branch comprises a second radiator and a second ground terminal; the second feeding point is provided at the second radiator, one end of the second ground terminal is grounded, and the other end of the second ground terminal is connected to the second radiator.

14. The antenna apparatus of claim 13, wherein the first conductive branch further comprises a first feeding part, the first feeding part is connected between the first radiator and the first feed circuit, and the first feeding point is provided at the first feeding part;
the second conductive branch further comprises a second feeding part, the second feeding part is connected between the second radiator and the second feed circuit, and the second feeding point is provided at the second feeding part.

15. The antenna apparatus of any one of claims 1 to 14, wherein the first feed circuit comprises a first feeding source, the first feeding source is connected to the first feeding point and is configured to feed the first current signal to the first conductive branch; and
the second feed circuit comprises a second feeding source, the second feeding source is connected to the second feeding point and is configured to feed the second current signal to the second conductive branch.

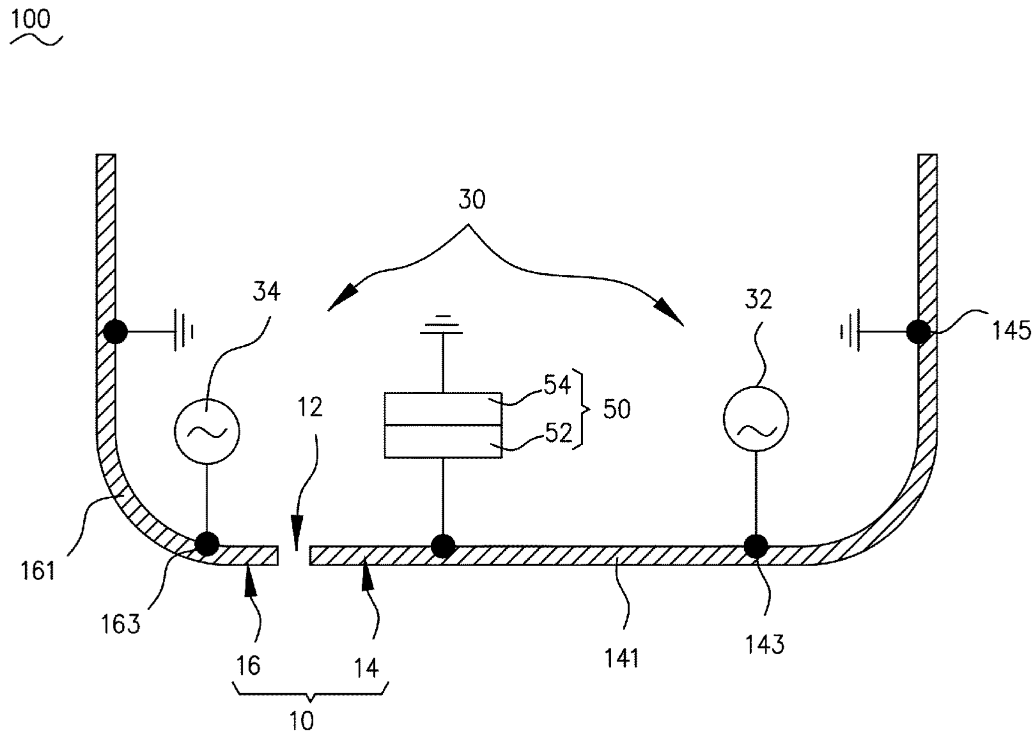
16. The antenna apparatus of claim 15, wherein the first feed circuit further comprises a first matching sub-circuit and a first filter sub-circuit; the first matching sub-circuit is connected between the first feeding source and the first feeding point, and is configured to adjust an input impedance of the first conductive branch; and the first filter sub-circuit is connected between the first matching sub-circuit and the first feeding point; and
the second feed circuit further comprises a second matching sub-circuit and a second filter sub-circuit; the second matching sub-circuit is connected between the second feeding source and the second feeding point, and is configured to adjust an input impedance of the second conductive branch; and the second filter sub-circuit is connected between the second matching sub-circuit and the second feeding point.

17. An electronic device, comprising a casing and the antenna apparatus of any one of claims 1 to 16, the antenna apparatus being integrated into the casing.

18. The electronic device of claim 17, wherein the casing comprises a bearing part and a boundary frame connected to a periphery of the bearing part, the slot is provided in the boundary frame, and the antenna apparatus is integrated into the boundary frame.

19. An electronic device, comprising a boundary frame and the antenna apparatus of any one of claims 1 to 16, wherein a material of the boundary frame comprises metal, the boundary frame is provided with a slot, the slot of the boundary frame divides the boundary frame into two parts, the antenna apparatus is integrated into the boundary frame, the slot of the boundary frame is the slot between the first conductive branch and the second conductive branch.

20. The electronic device of claim 19, wherein a non-shielding body is provided in the slot, and the non-shielding body is configured for transmission of an electromagnetic wave signal.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143
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FIG. 1

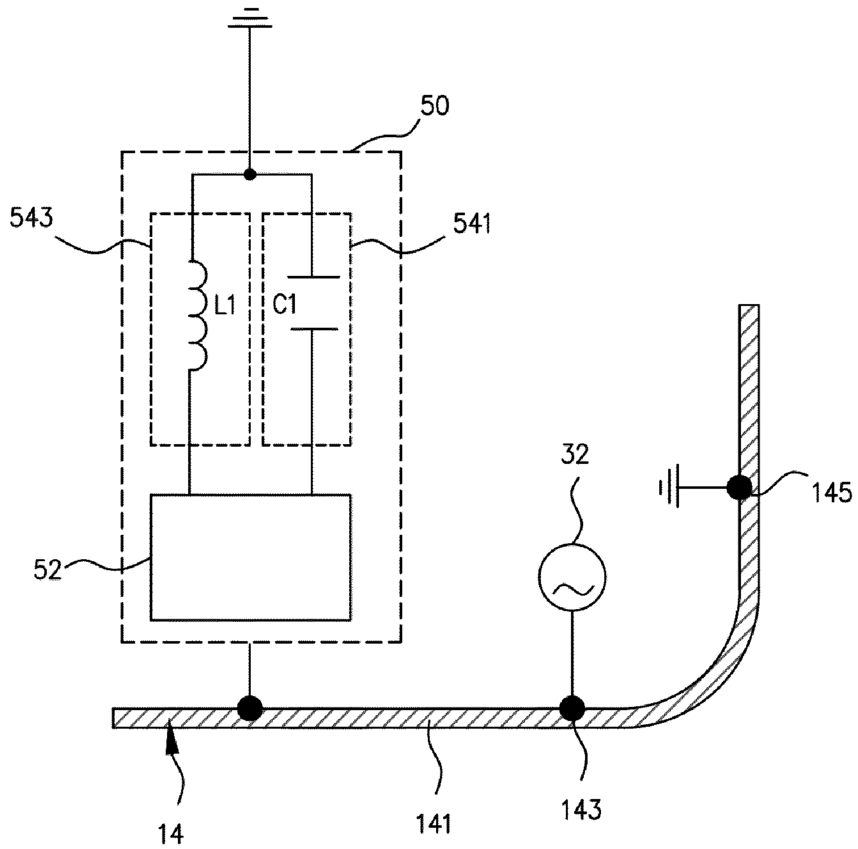
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FIG. 2

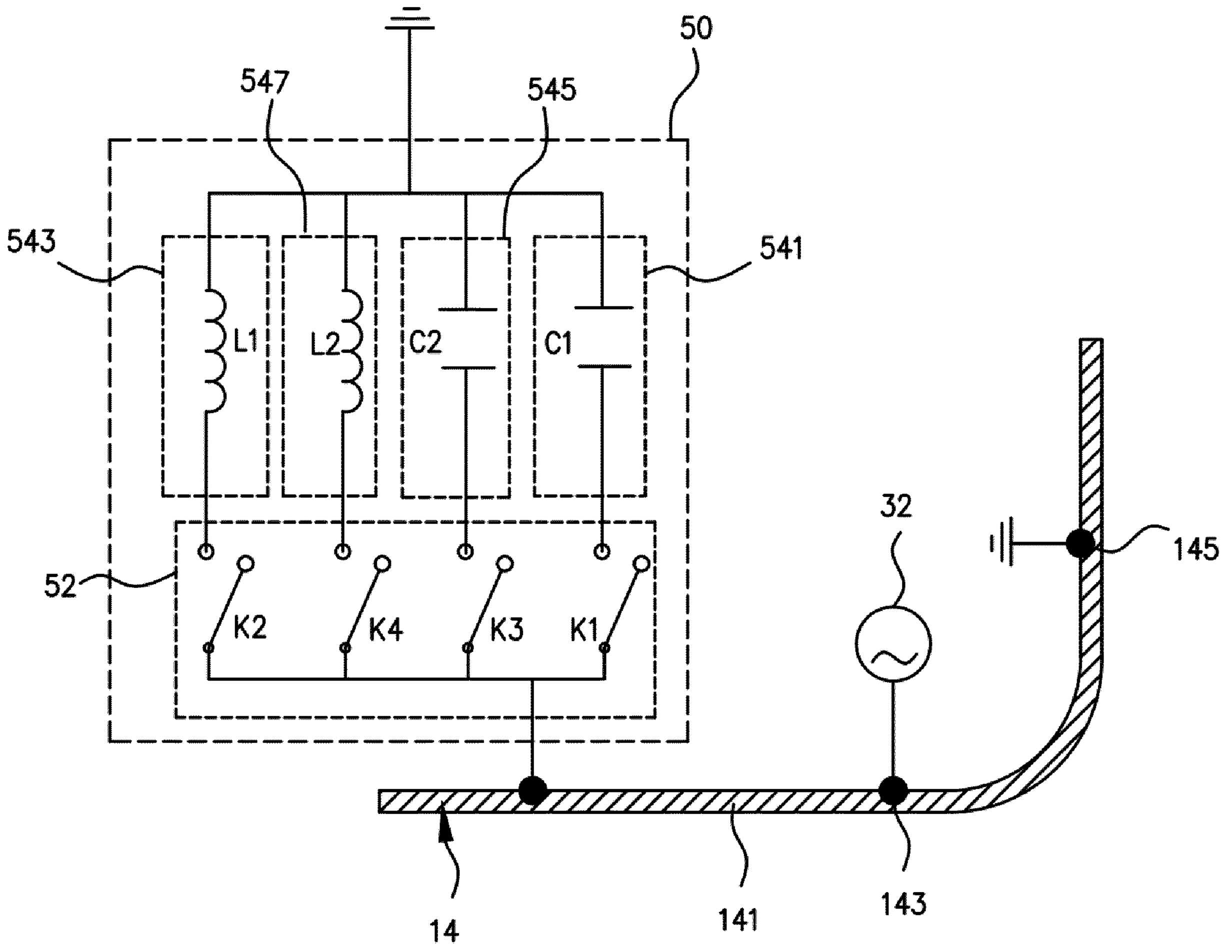
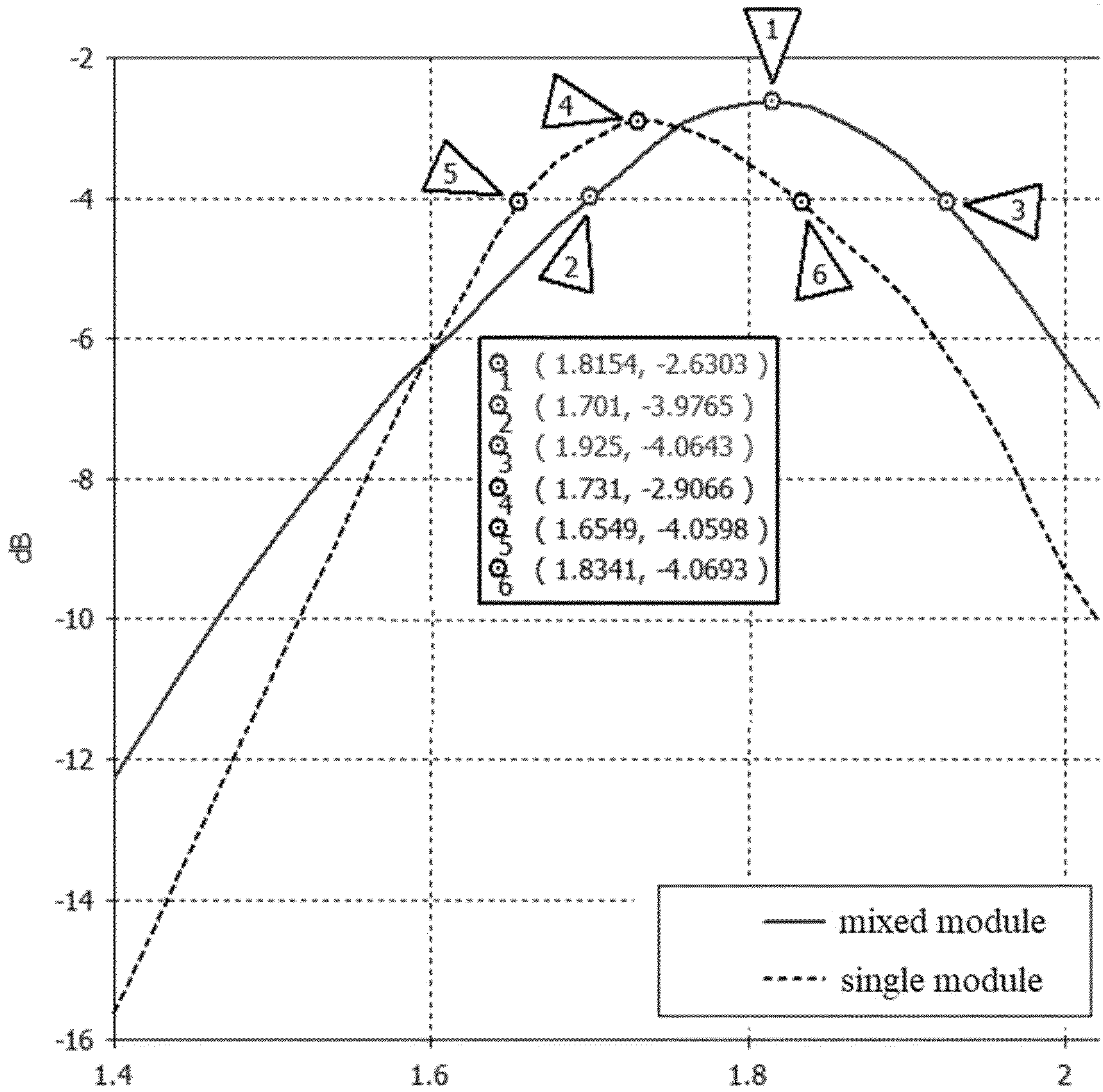


FIG. 3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-4
-6
-8
-10
-12
-14
-16
dB
1.4
1.6
1.8
2
1
2
3
4
5
6
1 (1.8154, -2.6303)
2 (1.701, -3.9765)
3 (1.925, -4.0643)
4 (1.731, -2.9066)
5 (1.6549, -4.0598)
6 (1.8341, -4.0693)
mixed module
single module

FIG. 4

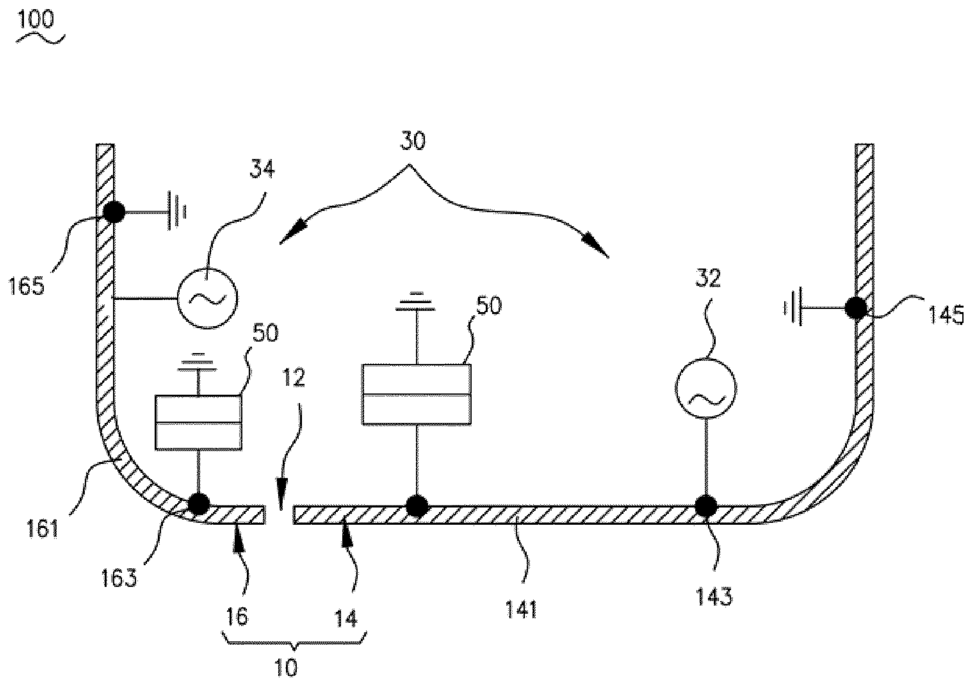
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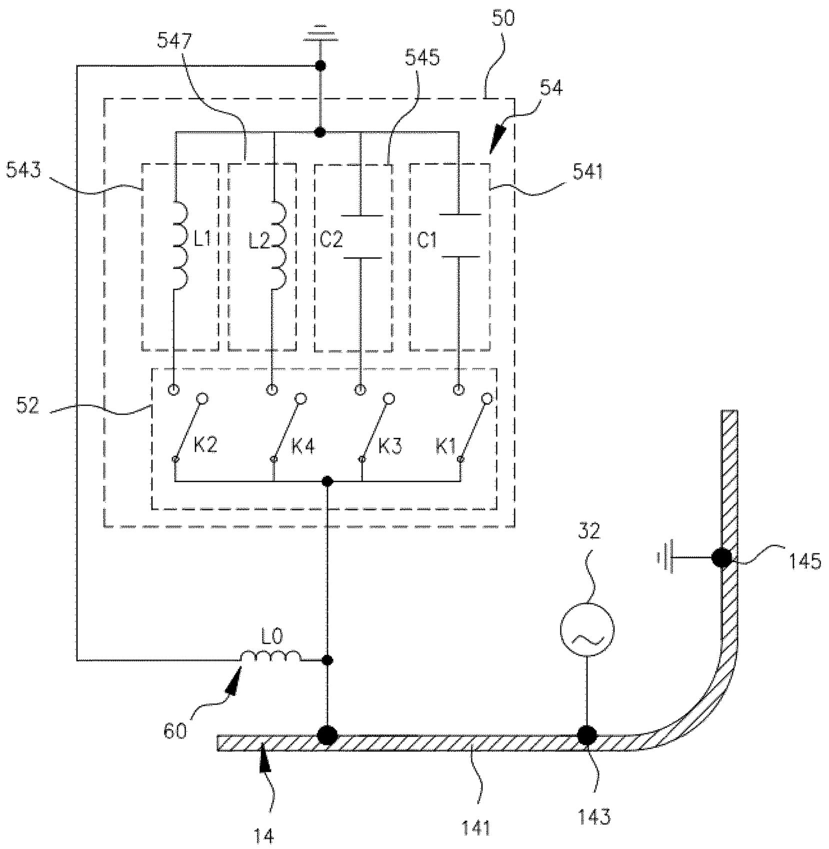
FIG. 5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L1
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K3
K1
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14
141
143

FIG. 6

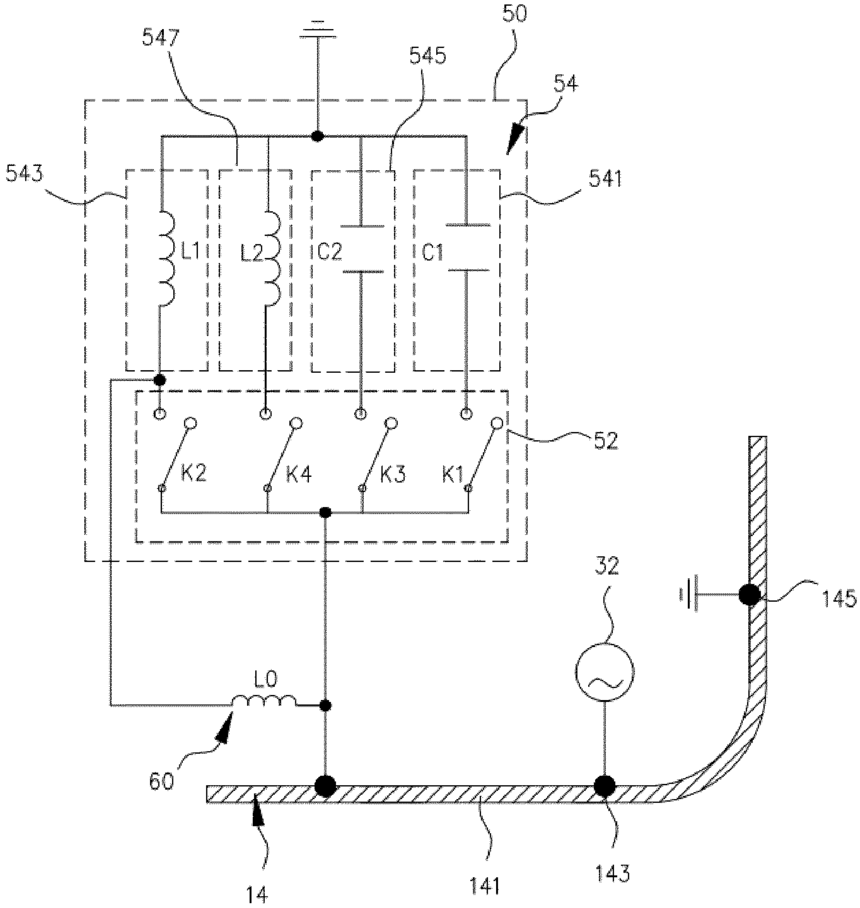
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FIG. 7

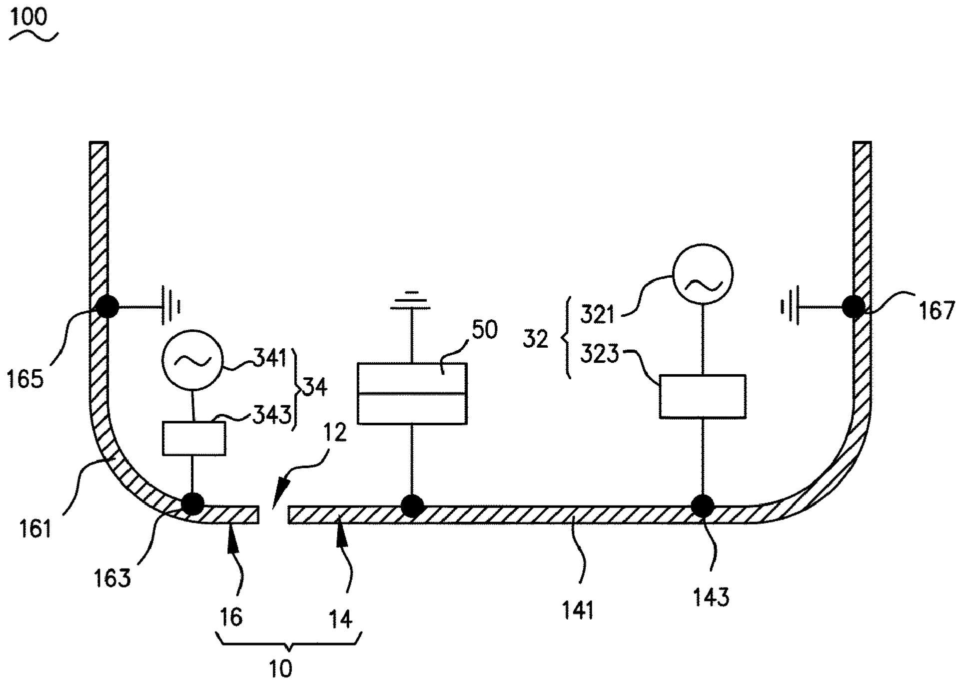
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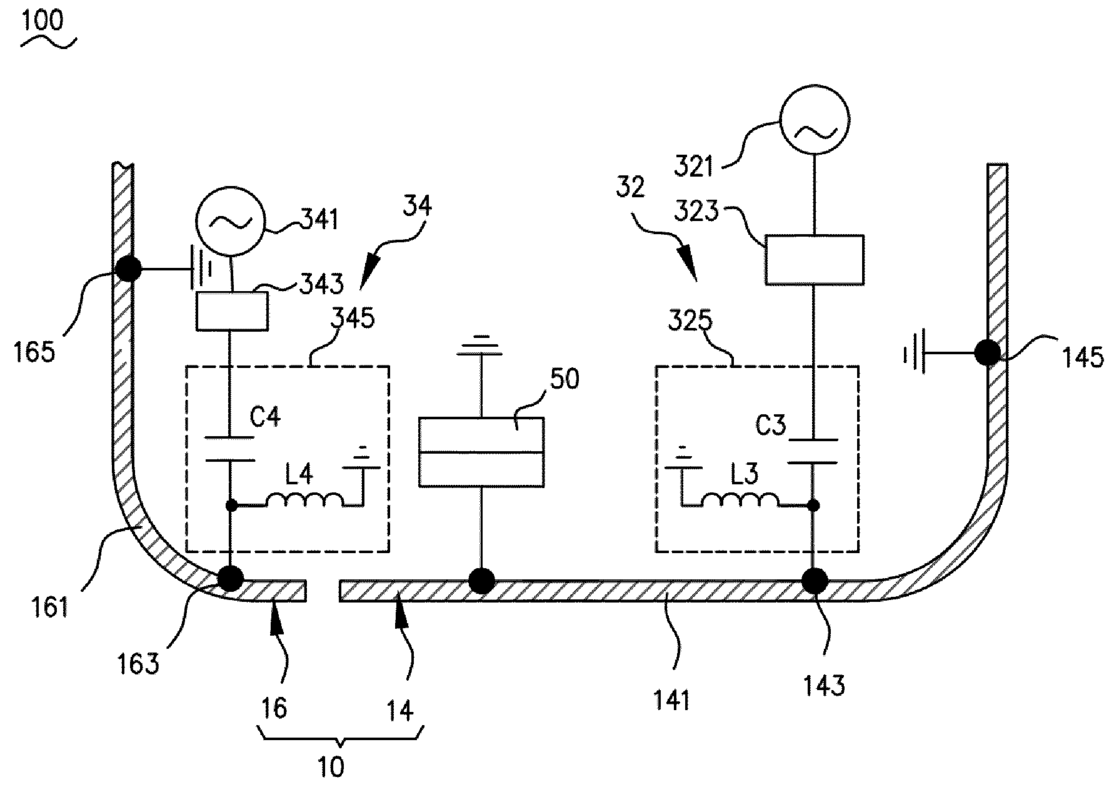
FIG. 8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C4
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L4
L3
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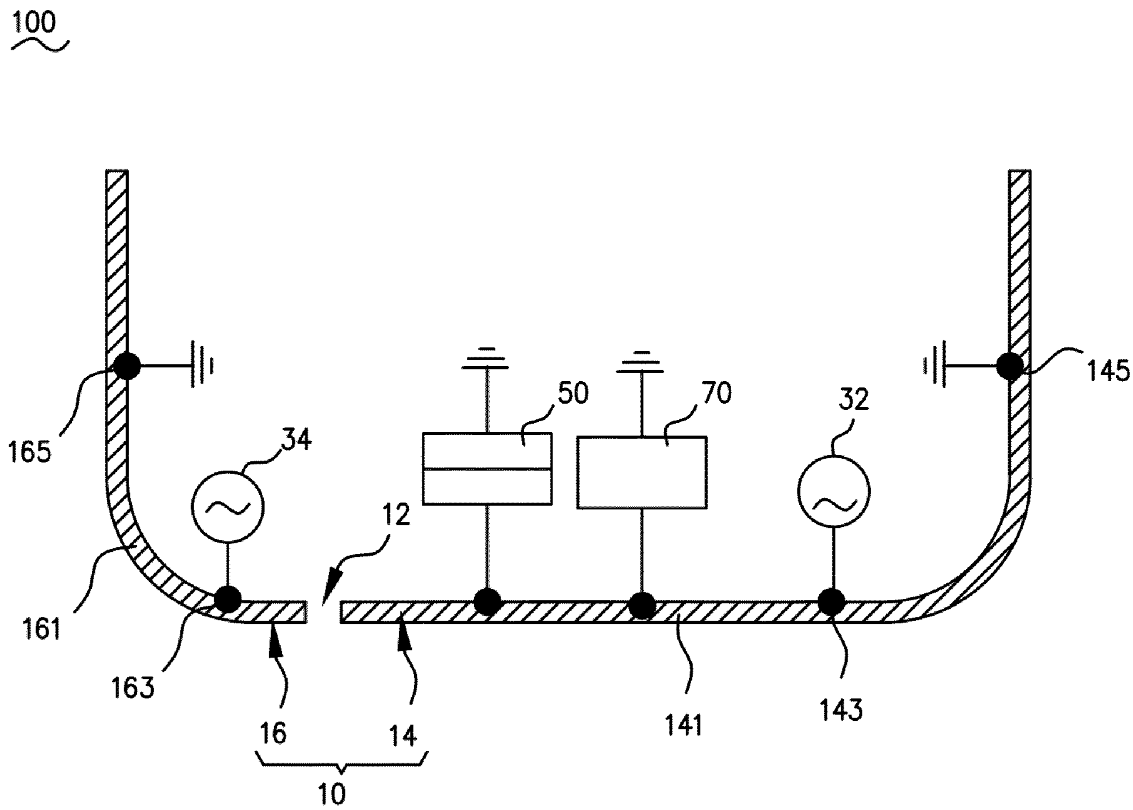
141
10

FIG. 9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10

FIG. 10

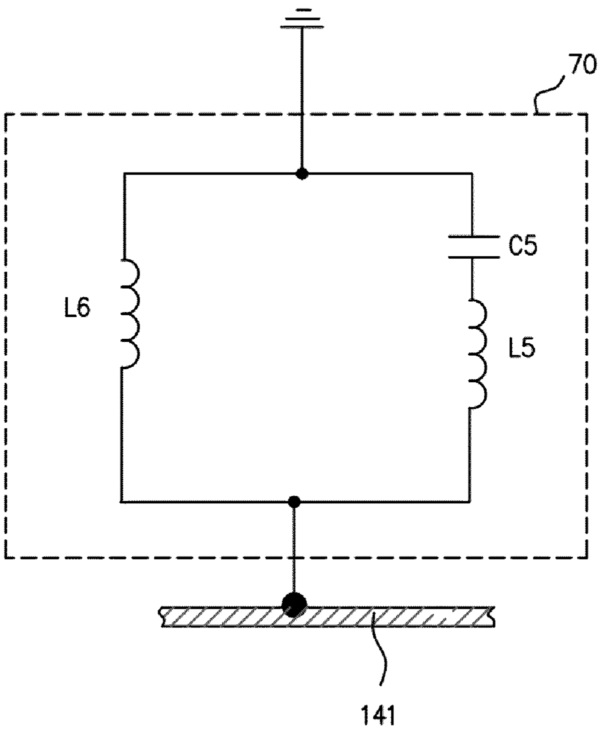
70
C5
L6
L5
141

FIG. 11

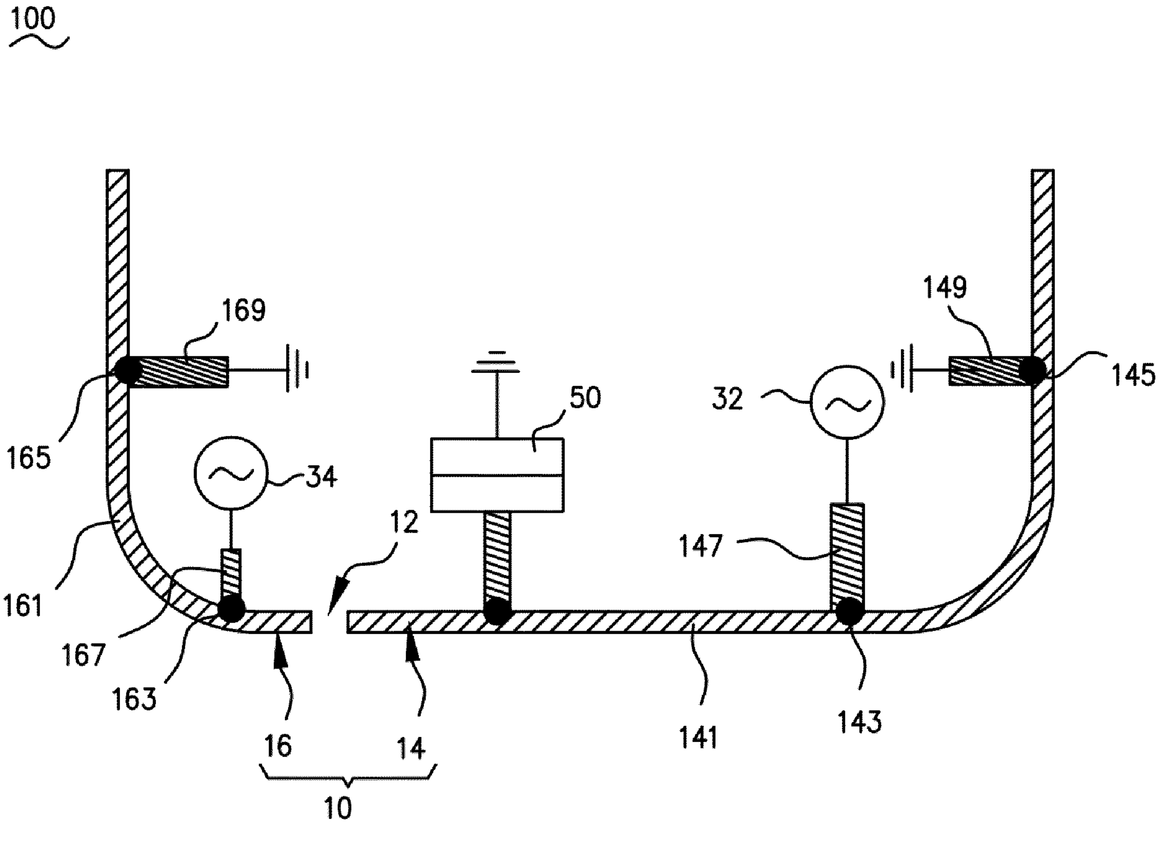
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FIG. 12

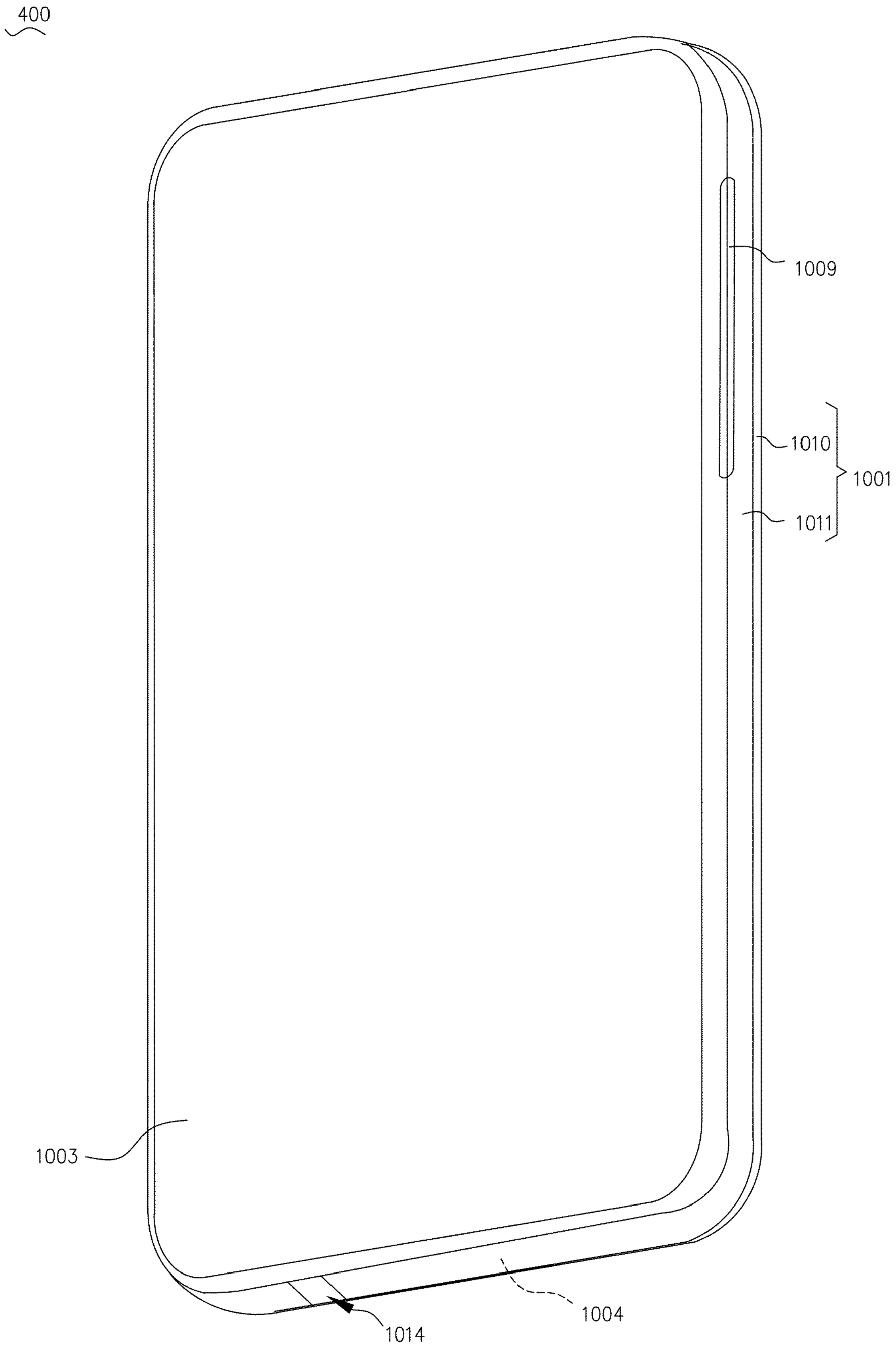

FIG. 13

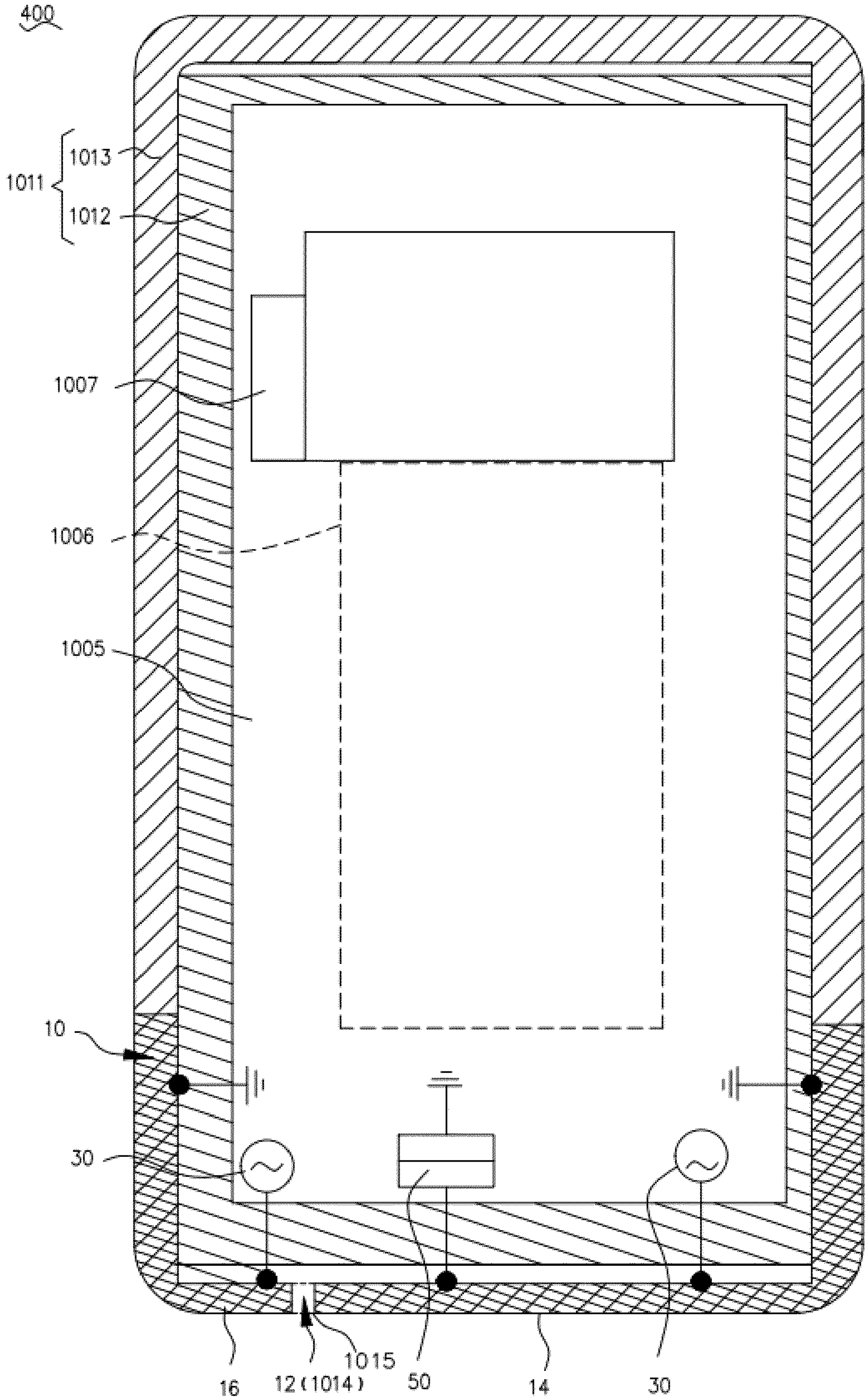

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No. **PCT/CN2021/120725**

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 1/36(2006.01)i; H01Q 1/50(2006.01)i; H01Q 1/22(2006.01)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)

CNABS, CNTXT; ENTXTC, VEN, DWPI, IEEE, CNKI: 天线, 辐射, 框, 壳, 开关, 切换, 接地, 馈电, antenna, radiate, frame, casing, on-off, switch, ground, feed.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 107634312 A (SHENZHEN FUTAIHONG PRECISION INDUSTRY CO., LTD. et al.) 26 January 2018 (2018-01-26) description, paragraphs [0100]-[0131], figures 1-17	1-20
X	CN 109390693 A (SHENZHEN FUTAIHONG PRECISION INDUSTRY CO., LTD. et al.) 26 February 2019 (2019-02-26) description, paragraphs [0115]-[0142], and figures 1-12	1-20
A	CN 211350951 U (OPPO GUANGDONG MOBILE COMMUNICATIONS CO., LTD.) 25 August 2020 (2020-08-25) entire document	1-20
A	CN 211350950 U (OPPO GUANGDONG MOBILE COMMUNICATIONS CO., LTD.) 25 August 2020 (2020-08-25) entire document	1-20
A	US 2018026340 A1 (CHIUN MAI COMMUNICATION SYSTEMS, INC.) 25 January 2018 (2018-01-25) 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
15 November 2021	**06 December 2021**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China**	
Facsimile No. **(86-10)62019451**	Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2021/120725

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				CN	107634313	A	26 January 2018
				TW	201804670	A	01 February 2018
				TW	I656688	B	11 April 2019
				TW	201804671	A	01 February 2018
				TW	I640127	B	01 November 2018
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				TW	I645614	B	21 December 2018
				EP	3273531	A1	24 January 2018
				US	2018026348	A1	25 January 2018
				IN	201714025435	A	26 January 2018
				IN	201714025471	A	26 January 2018
				US	10340581	B2	02 July 2019
				EP	3273531	B1	05 May 2021
				TW	645614	B1	21 December 2018
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				US	10644381	B2	05 May 2020
CN	211350951	U	25 August 2020		None		
CN	211350950	U	25 August 2020		None		
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				CN	108258390	A	06 July 2018

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

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