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

(57) The present application provides an antenna assembly and an electronic device comprising the antenna assembly. The antenna assembly comprises: a first radiation branch, a second radiation branch, and a first feed source. The first radiation branch comprises a first ground end, a first feed point, and a first open end that are successively arranged. The second radiation branch comprises a second open end and a second ground end, and a gap is present between the first open end and the second open end. The first feed source is electrically

connected to the first feed point and used for exciting the first radiation branch to generate a first resonant mode. The length from the first feed point to the first open end is less than or equal to 20% of the length of the first radiation branch, and the first feed source excites at least one coupled resonant mode on the second radiation branch. The antenna assembly provided in the present application can achieve independent tuning of multiple frequency bands in a limited space.

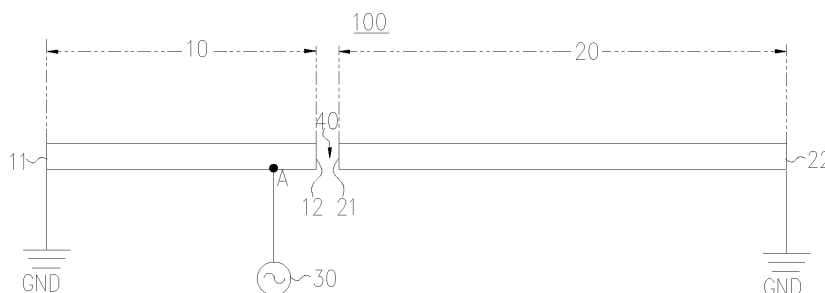


FIG. 1

return loss (dB)

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Description

[0001] The present application claims priority to Chinese Patent Application No. 202211152115.3, entitled "ANTENNA ASSEMBLY AND ELECTRONIC DEVICE", filed September 21, 2022, which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to the technical field of communication, and in particular to an antenna assembly and an electronic device.

BACKGROUND

[0003] With the development of network technology, the demand for transmitting data with a high transmission rate is increasing. Multi-band coverage technology can improve throughput by simultaneously covering multiple frequency bands, thereby increasing the amount of transmitted data and improving the data transmission rate. For an antenna design on an electronic device, in multi-band coverage, tuning some frequency bands can cause a large shift in other frequency bands, which cannot independently tune multiple frequency bands, and a support rate for a multi-band combination is low. Therefore, how to flexibly design antennas covering multiple frequency bands in a limited space, while meeting the independent tuning of the multiple frequency bands and improving the support rate of the multi-band combination, has become a technical problem that needs to be solved.

SUMMARY OF THE DISCLOSURE

[0004] The present disclosure provides an antenna assembly capable of independently tuning multiple frequency bands in a limited space, and an electronic device including the antenna assembly.

[0005] On the one hand, the present disclosure provides an antenna assembly including a first radiation branch, a second radiation branch, and a first feed source. The first radiation branch includes a first ground end, a first feed point, and a first open end arranged in sequence. The second radiation branch includes a second open end and a second ground end, and a gap is defined between the first open end and the second open end. The first feed source is electrically connected to the first feed point and configured to excite the first radiation branch to generate a first resonant mode. A length from the first feed point to the first open end is less than or equal to 20% of a length of the first radiation branch, and the first feed source is configured to excite at least one coupling resonant mode on the second radiation branch.

[0006] In the antenna assembly of the present disclosure, the first radiation branch couples with the second radiation branch through the coupling gap, and the length from the first feed point to the first open end of the first radiation branch is less than or equal to 20% of the length of the first radiation branch, so that the position of the first feed point is close to the second radiation branch, which is beneficial for the first feed source to excite at least one coupling resonant mode on the second radiation branch. Since the coupled resonance mode and the first resonance mode are generated in different radiation branches, when the first resonance mode is tuned, the coupled resonance mode cannot be greatly affected by the first resonance mode and cannot have a significant offset. That is, the coupling resonant mode and the first resonant mode can be tuned independently of each other, so as to independently tune multiple frequency bands in the limited space, improve the support rate of the multi-band combination, thereby increasing the transmission rate.

[0007] On the other hand, the present disclosure further provides an electronic device including the above antenna assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] In order to more clearly describe the technical solutions in some embodiments of the present disclosure, hereinafter, the accompanying drawings that are used in the description of some embodiments will be briefly described.

FIG. 1 is a structural schematic view of a first antenna assembly of an electronic device in some embodiments of the present disclosure.

FIG. 2 is a schematic view illustrating a resonant mode generated by the antenna assembly of FIG. 1.

FIG. 3a is a current distribution view of a first resonant mode shown in FIG. 2.

FIG. 3b is a structural schematic view of a second antenna assembly in some embodiments of the present disclosure.

FIG. 4 is a structural schematic view of a third antenna assembly in some embodiments of the present disclosure.

FIG. 5 is a schematic view illustrating a resonant mode generated by the antenna assembly of FIG. 4.

FIG. 6 is a current distribution view of a second resonant mode shown in FIG. 5.

FIG. 7 is a structural schematic view of the third antenna assembly of FIG. 4, and the third antenna assembly includes a first matching circuit, a first matching network, a second matching circuit, and a second matching network.

FIG. 8 is a current distribution view of a third resonant mode shown in FIG. 5.

FIG. 9 is a current distribution view of a fourth resonant mode shown in FIG. 5.

FIG. 10 is a current distribution view of a fifth resonant mode shown in FIG. 5.

FIG. 11 is a structural schematic view of the third antenna assembly of FIG. 7, and the third antenna assembly includes a first tuning circuit and a second tuning circuit.

FIG. 12 is a structural schematic view of the first tuning circuit in some embodiments of the present disclosure.

FIG. 13 is a structural schematic view of the second tuning circuit in some embodiments of the present disclosure.

FIG. 14 is a structural schematic view of a third tuning circuit in some embodiments of the present disclosure.

FIG. 15 is a state view illustrating the first resonant mode, the third resonant mode, the fourth resonant mode, and the fifth resonant mode when the second resonant mode is tuned among B32, B3, and B1/B41.

FIG. 16 is a current distribution view of the third resonant mode excited by a second feed source.

FIG. 17 is a structural schematic view of the antenna assembly applied to the electronic device in some embodiments of the present disclosure.

FIG. 18 is a structural schematic view of the antenna assembly applied to a foldable electronic device in some embodiments of the present disclosure.

DETAILED DESCRIPTION

[0009] The technical solutions in some embodiments of the present disclosure are clearly and completely described in conjunction with accompanying drawings in some embodiments of the present disclosure. Obviously, the described embodiments are only a part of the embodiments of the present disclosure, and not all embodiments. Based on the embodiments in the present disclosure, all other embodiments obtained by those of ordinary skill in the art without creative effort are within the scope of the present disclosure.

[0010] The reference to "embodiment" in the present disclosure means that, specific features, structures, or characteristics described in conjunction with some embodiments may be included in at least one embodiment of the present disclosure. The phrase appearing in various positions in the specification does not necessarily refer to the same embodiment, nor is it an independent or alternative embodiment that is mutually exclusive with other embodiments. Those of ordinary skill in the art explicitly and implicitly understand that the embodiments described in the present disclosure can be combined with other embodiments.

[0011] The terms "first", "second" or the like in the specification, claims, and the accompanying drawings of the present disclosure, are configured to distinguish different objects and not to describe a specific order. In addition, the terms "including", "comprising", and "having" as well as any variations thereof, are intended to cover non-exclusive inclusions. For example, a component or a device that contains one or more parts is not limited to the listed one or more parts, but optionally further includes one or more parts that are not listed but are inherent to the illustrated product, or one or more parts that should be included based on the described functionality.

[0012] As illustrated in FIG. 1, FIG. 1 is a structural schematic view of an electronic device 100 in some embodiments of the present disclosure. The electronic device 100 includes but is not limited to a device with a communication function, such as a mobile phone, a tablet computer, a notebook computer, a computer, a wearable device, a drone, a robot, a digital camera, etc. The embodiments of the present disclosure are illustrated with a mobile phone as an example, and other electronic devices can refer to the present embodiments.

[0013] For an antenna design on the electronic device such as the mobile phone, a space of the electronic device is limited, and multiple resonant modes are often generated on the same antenna. For example, a mode in a frequency band from 1.45 GHz to 2.5 GHz resonates with a mode in a low frequency band (less than 1GHz) on the same antenna. When tuning among B32 (1452-1495.9 MHz), B3 (1710-1880 MHz), B1 (1920-2170 MHz), and B40 (2300-2400 MHz) in the frequency band from 1.45 GHz to 2.5 GHz, the mode in the low frequency band also has a significant offset towards a higher frequency or a lower frequency. When a specific carrier aggregation (CA) combination or an eNB NR dual connection (ENDC) combination needs to be met, a special frequency ratio needs to be designed. For example, in order to meet a B20+B3+B1+B40 combination, when the mode in the frequency band from 1.45 GHz to 2.5 GHz is switched between B3 and B1, the mode in the low frequency band may be moved to the higher frequency band of B20, such as B5, which cannot meet B20. At the same time, it may also limit a feeding position, make the design lack flexibility in limited space, or require more antenna switches to maintain the frequency ratio, which may increase costs.

[0014] In addition, an available bandwidth of a N78 frequency band is usually wider than that of low frequency and medium frequency, and the amount of data transmission of the N78 frequency band plays a dominant role. How to support the N78 frequency band and ensure the N78 frequency band constant presence has become a technical problem that needs to be solved. In the case where the mode in the frequency band from 1.45 GHz to 2.5 GHz resonates with the mode of N78 on the same antenna, when tuning among B32 (1452-1495.9 MHz), B3 (1710-1880 MHz), B1 (1920-2170 MHz),

and B40 (2300-2400 MHz) in the frequency band from 1.45 GHz to 2.5 GHz, the mode of N78 also has a significant offset, such as a 200-400 MHz offset, which may prevent the N78 frequency band of the medium frequency (1.7-2.4 GHz) from being met simultaneously during switching. It is too low for the combination of ENDC and CA, which may result in the user's throughput not being improved.

[0015] The antenna assembly 100 provided in the present disclosure can at least achieve independent tunability of a low frequency antenna and medium and high frequency bands, so as to support more frequency band combinations and improve throughput. In addition, the present disclosure also provides at least independent tunability of the medium and high frequency bands and the N78 frequency band. N78 remains constant presence during tuning in the medium and high frequency bands, so as to meet the demand for N78 constant presence and to tune more combinations of ENDC and CA, thereby improving user's throughput.

[0016] As illustrated in FIG. 1, the antenna assembly 100 includes a first radiation branch 10, a second radiation branch 20, and a first feed source 30. In some embodiments, as illustrated in FIG. 1, the first radiation branch 10 includes a first ground end 11, a first feed point A, and a first open end 12 arranged in sequence. The second radiation branch 20 includes a second open end 21 and a second ground end 22. The first open end 12 is opposite to the second open end 21, and a gap is defined between the first open end 12 and the second open end 21, and the gap is a coupling gap 40. The first radiation branch 10 is coupled with the second radiation branch 20 through the coupling gap 40.

[0017] As illustrated in FIG. 1, the first feed source 30 is electrically connected to the first feed point A.

[0018] As illustrated in FIG. 2, the first feed source 30 is configured to excite the first radiation branch 10 to generate a first resonant mode a. A length from the first feed point A to the first open end 12 is less than or equal to 20% of a length of the first radiation branch 10, so that the first feed source 30 excites at least one coupling resonant mode on the second radiation branch 20. In some embodiments, the length from the first feed point A to the first open end 12 may be 20%, 19%, 18%, 10%, 5%, 1% or the like of the length of the first radiation branch 10, so that a position of the first feed point A is close to the second radiation branch 20, which is beneficial for the first feed source 30 to excite at least one coupling resonant mode on the second radiation branch 20. As illustrated in FIG. 2, a mode c, a mode d, and a mode e are coupling resonant modes. In some embodiments, the number of the coupling resonant mode can be one, such as the mode c, the mode d, or the mode e, which is not limited in the present disclosure.

[0019] In FIG. 2, f_1 , f_2 , and f_3 represent different frequency bands, and the present disclosure does not make specific limitations on the values of f_1 , f_2 , and f_3 . In FIG. 2, the frequency bands supported by the mode c, the mode d, and the mode e are higher than the frequency band supported by the mode a. In some implementations, the frequency band supported by the mode a may be higher than the frequency bands supported by the mode c, the mode d, and the mode e.

[0020] Because the coupling resonant mode and the first resonant mode a are generated in different radiation branches, the coupling resonant mode and the first resonant mode a can be tuned independently of each other.

[0021] In the antenna assembly 100 of the present disclosure, the first radiation branch 10 couples with the second radiation branch 20 through the coupling gap 40, and the length from the first feed point A to the first open end 12 of the first radiation branch 10 is less than or equal to 20% of the length of the first radiation branch 10, so that the position of the first feed point A is close to the second radiation branch 20, which is beneficial for the first feed source 30 to excite at least one coupling resonant mode on the second radiation branch 20. Since the coupled resonance mode and the first resonance mode a are generated in different radiation branches, when the first resonance mode a is tuned, the coupled resonance mode cannot be greatly affected by the first resonance mode a and cannot have a significant offset. That is, the coupling resonant mode and the first resonant mode a can be tuned independently of each other. In addition, when the first resonant mode a is tuned, the coupling resonant mode can remain constant presence, so as to independently tune multiple frequency bands in the limited space, improve the support rate of the multi-band combination, thereby increasing the transmission rate.

[0022] The radiation branch described in the present disclosure (such as the first radiation branch 10 and the second radiation branch 20) may also be referred to as a radiator. In some embodiments, a material of the radiation branch is conductive. The radiation branch is a port of the antenna assembly 100 for transmitting and receiving a radio frequency signal, and the radio frequency signal is transmitted in the form of an electromagnetic wave signal in an air medium. The present disclosure does not make specific limitations on specific form of the radiation branch. The radiation branch includes but is not limited to a metal frame of the mobile phone or a metal bracket radiator located near the frame. The bracket radiator is disposed inside the electronic device 1000, including but not limited to a flexible printed circuit board (FPC) antenna formed on FPC, a laser direct structuring (LDS) antenna formed by LDS, a print direct structuring (PDS) antenna formed by PDS, a conductive sheet antenna, etc.

[0023] The present disclosure does not make specific limitations on a shape of the radiation branch. For example, the shape of the radiation branch includes but is not limited to strip-shaped, sheet-shaped, rod-shaped, coating, film-shaped, etc. The radiation branch shown in FIG. 1 is only an example and cannot limit the shape of the radiation branch in the present disclosure. In some embodiments, the radiation branches are all strip-shaped, the ground end and the open end are two opposite ends of the radiation branch, respectively. The present disclosure does not limit an extension trajectory of the radiation branch. In some embodiments, the radiation branch is straight -line-shaped. In some embodiments, the

radiation branch may also extend in a bent or curved trajectory. The radiation branch may be a line with uniform width on its extension trajectory, or a strip with a varying width, such as gradually changing width, disposing a widened area, or the like.

[0024] In some embodiments, the first radiation branch 10 is capacitively coupled with the second radiation branch 20 through the coupling gap 40. The term "capacitive coupling" refers to generation of an electric field between the first radiation branch 10 and the second radiation branch 20, and an electrical signal on the second radiation branch 20 can be transmitted to the first radiation branch 10 through the electric field, so that the electrical signal conduction can be achieved between the first radiation branch 10 and the second radiation branch 20 when the first radiation branch 10 is not in direct contact with or not directly connected to the second radiation branch 20. In some embodiments, the first radiation branch 10 and the second radiation branch 20 may be arranged along a straight line or roughly along a straight line (i.e. with small tolerances in the design process). In some embodiments, the first radiation branch 10 and the second radiation branch 20 may also be staggered in their extension direction to form an avoidance space.

[0025] As illustrated in FIG. 1, both the first ground end 11 and the second ground end 22 are grounded. The term "grounding" in the present disclosure refers to electrical connection to a reference ground or electrical connection to a reference ground system GND. An electrical connection mode includes but is not limited to direct welding, or indirect electrical connection through a coaxial line, a microstrip line, a conductive spring, a conductive adhesive, etc. The reference ground system GND may be an independent overall structure or multiple mutually independent but electrically connected structures.

[0026] The first feed source 30 is electrically connected to a radio frequency transceiver chip. The first feed source 30 feeds the radio frequency signal emitted by the radio frequency transceiver chip into the first radiation branch 10 through the first feed point A. The radio frequency signal can excite the first radiation branch 10 to generate a resonant current, forming a first resonant mode a to support the frequency band corresponding to the resonant current. In addition, because the position of the first feed point A is close to the coupling gap 40, the first feed source 30 can also excite and generate the resonant current on the second radiation branch 20, forming a coupling resonant mode to support the frequency band corresponding to the resonant current. The frequency band supported by the first resonant mode a is different from the frequency band supported by the coupling resonant mode. For example, the frequency band supported by the first resonant mode a includes but is not limited to the electromagnetic wave signal in at least one of a LB frequency band, a MHB frequency band, a UHB frequency band, a Wi-Fi frequency band, and a GNSS frequency band. The LB frequency band refers to the frequency band less than 1000 MHz (excluding 1000 MHz). The MHB frequency band refers to the frequency band from 1000 MHz to 3000 MHz (including 1000 MHz and excluding 3000 MHz). The UHB frequency band refers to the frequency band from 3000 MHz to 10000 MHz (including 3000 MHz). The Wi-Fi frequency band includes but is not limited to at least one of Wi-Fi 2.4G, Wi-Fi 5G, Wi-Fi 6E, etc. The full name of GNSS is global navigation satellite system. GNSS includes a global positioning system (GPS), Beidou, a global navigation satellite system (GLONASS), a Galileo satellite navigation system (Galileo), or a regional navigation system, etc.

[0027] In some embodiments, as illustrated in FIG. 3a, there are dashed arrows. The resonant current of the first resonant mode a flows from the first feed source 30 through the first feed point A and returns to ground from the first ground end 11. The first resonant mode a is generated by a loop antenna that is formed by the first feed source 30, the first radiation branch 10, and the first ground end 11. In some embodiments, the resonant current of the first resonant mode a operates in a 1/4 wavelength mode of the supported frequency band.

[0028] In some embodiments, the frequency band supported by the first resonant mode a includes at least a part of the frequency band from 1.45 GHz to 2.4 GHz. For example, the frequency band supported by the first resonant mode a covers at least one of B32 (1452-1495.9 MHz), B3 (1710-1880 MHz), B1 (1920-2170 MHz), B40 (2300-2400 MHz), etc. By designing an effective electrical length of the first radiation branch 10, the first resonant mode a of the 1/4 wavelength mode in the medium frequency band (1450-2400 MHz) can be resonated between the first ground end 11 and the first feed point A of the first radiation branch 10.

[0029] In some embodiments, the first radiation branch 10 is a part of a side frame of a middle frame of the mobile phone. A width of the first radiation branch 10 is relatively wide, for example, the width of the first radiation branch 10 ranges from 7 mm to 8 mm. A length of the first radiation branch 10 may be less than or equal to 18 mm. For example, the length of the first radiation branch 10 may be 17.2 mm. Therefore, the first resonant mode a of the 1/4 wavelength mode in the medium frequency band (1450-2400 MHz) can be resonated between the first ground end 11 and the first feed point A of the first radiation branch 10, and the first radiation branch 10 has a relatively short physical length. The length of the first radiation branch 10 in some embodiments is less than that of a typical radiation branch supporting the medium frequency band, which is beneficial for miniaturization of the antenna assembly 100 and can reduce the space occupied on the electronic device 1000.

[0030] In some embodiments, the length of the first radiation branch 10 may be 17.2 mm (just an example, not limited to this value), and a distance between the first feed point A and the first open end 12 is 3.5 mm (just an example, not limited to this value). On the one hand, the first feed point A is close to the coupling gap 40, which is beneficial for the first radiation branch 10 to couple energy to the second radiation branch 20 through the coupling gap 40, and different modes can be excited through the second ground end 22 and a matching design, such as exciting the subsequent third resonant mode

and fifth resonant mode. On the other hand, by designing the first feed point A to be close to the first open end 12, there is a relatively large space between the first feed point A and the first ground end 11, which can install a button circuit board and other components, improving space utilization and compactness of component layout in the electronic device 1000.

[0031] In some embodiments, the frequency band supported by the coupling resonant mode includes at least one of 2.5-2.69 GHz (N41), 3.3-3.8 GHz (N78), and 4.8-5 GHz (N79).

[0032] The coupled resonance mode generated by the antenna assembly provided in FIG. 3a may be the mode d in FIG. 2, and a current distribution view of the mode d can be referred to FIG. 9. For example, it supports the 3.3-3.8 GHz (N78) frequency band.

[0033] As illustrated in FIG. 3b, a matching circuit M is disposed on the second radiation branch 20 and is grounded, so that partial current on the second radiation branch 20 returns to ground through the matching circuit M. A position where the matching circuit M is electrically connected may be located between the second open end 21 and a middle point of the second radiation branch 20. A structure of the antenna assembly of FIG. 3b can support three coupling resonant modes, the frequency bands supported by the three coupling resonant modes are different, including the mode d, and the mode c (refer to the current distribution view of FIG. 8) and the mode e (refer to current distribution view of FIG. 10). For example, these three modes respectively support three frequency bands: 2.5-2.69 GHz (N41), 3.3-3.8 GHz (N78), and 4.8-5 GHz (N79), which are not limited in the present disclosure. By providing a signal source in the corresponding frequency band and designing the effective electrical length of the first radiation branch 10, the first radiation branch 10 can generate the first resonant mode a that supports the frequency band of 1.45-2.4GHz. The effective electrical length of the second radiation branch 20 can be designed, so that the second radiation branch 20 can be excited by the first feed-in 30 to generate the third resonant mode c that supports the frequency band of 2.5-2.69 GHz, the fourth resonant mode d that supports the frequency band of 3.3-3.8 GHz, and the fifth resonant mode e that supports the frequency band of 4.8-5 GHz. Since the first resonant mode a, the third resonant mode, the fourth resonant mode, and the fifth resonant mode are generated by different radiation branches, when the first resonant mode a is tuned, for example, the first resonant mode a is tuned among B32 (1452-1495.9 MHz), B3 (1710-1880 MHz), B1 (1920-2170 MHz), and B40 (2300-2400 MHz), the third resonant mode c, the fourth resonant mode d, and the fifth resonant mode e can remain constant presence. That is, the antenna assembly 100 in the present disclosure can support a CA combination of B32+B41+N78+N79, a CA combination of B3+B41+N78+N79, a CA combination of B1+B41+N78+N79, a CA combination of B40+B41+N78+N79, and a CA combination of B1+B3+B41+N78+N79, etc. Therefore, the antenna assembly 100 in the present disclosure supports multi-band CA combinations, has a wide frequency band coverage, and can effectively improve data transmission rate.

[0034] In some embodiments, the coupling frequency band may also include one frequency band, for example, the coupling resonant mode supports one of B41, N78, and N79. Alternatively, the coupled frequency band may also include two frequency bands, for example, the coupling resonant mode supports B41 and N78, etc.

[0035] The present disclosure provides a multimodal antenna design that not only covers multiple operating frequency bands, but also allows for relatively independent tuning of the first resonant mode a in the medium frequency band and the third resonant mode, the fourth resonant mode, and the fifth resonant mode in the medium and high frequency bands. In terms of design, a feed position can be selected to meet limited design space, and frequency tuning can be chosen to meet the requirements of various CA and ENDC combinations.

[0036] In some embodiments, as illustrated in FIG. 4, the second radiation branch 20 also includes a second feed point B located between the second open end 21 and the second ground end 22. The second feed point B is a position where the matching circuit M of FIG. 3b is electrically connected to the second radiation branch 20. The antenna assembly 100 further includes a second feed source 50.

[0037] As illustrated in FIG. 4 and FIG. 5, the second feed source 50 is electrically connected to the second feed point B for exciting the second radiation branch 20 to generate the second resonant mode b. The frequency band supported by the second resonant mode b is less than 1GHz. That is, the second radiation branch 20 and the second feed source 50 can serve as low-frequency antennas. The low-frequency antenna can be configured to support a B20 frequency band, a B5 frequency band, a B8 frequency band, and a B28 frequency band, etc. Because the first resonant mode a and the second resonant mode b are generated in different radiation branches, the second resonant mode b and the first resonant mode a can be tuned independently of each other.

[0038] In FIG. 5, f0, f1, f2, and f3 represent different frequency bands, and the present disclosure does not make specific limitations on the values of f0, f1, f2, and f3. In FIG. 5, the frequency bands supported by the mode c, the mode d, and the mode e are higher than the frequency band supported by the mode a, and the frequency band supported by the mode a is higher than the frequency band supported by the mode b. In some embodiments, the frequency band supported by the mode b may be higher than the frequency band supported by one or more of the mode a, the mode c, the mode d, and the mode e.

[0039] In some embodiments, as illustrated in FIG. 6, there are dashed arrows. The resonant current of the second resonant mode b flows from the second open end 21 to the second ground end 22. The second resonant mode b is generated by an inverted F antenna that is formed by the second feed source 50, the second open end 21, and the second ground end 22. The resonant current of the second resonant mode b operates in the 1/4 wavelength mode of the supported

frequency band.

[0040] In some embodiments, the frequency band supported by the second resonant mode b is the frequency band less than 1 GHz. By designing the effective electrical length of the second radiation branch 20, the second resonant mode b of the 1/4 wavelength mode in the low frequency band (790-1000MHz) can be resonated between the second ground end 22 and the second open end 21 of the second radiation branch 20.

[0041] In some embodiments, the first radiation branch 10 is the part of the side frame of the middle frame of the mobile phone, and the width of the first radiant branch 10 is relatively wide, for example, the width of the first radiant branch 10 ranges from 7 mm to 8 mm. The length of the second radiation branch 20 can be less than or equal to 35 mm. For example, the length of the second radiation branch 20 may be 33.4 mm, so that the second resonant mode b of the 1/4 wavelength mode in the low frequency band (less than 1 GHz) can resonate between the second ground end 22 and the second open end 21 of the second radiation branch 20, and the second radiation branch 20 has a relatively short physical length.

[0042] For example, the length of the second radiation branch 20 may be 33.4 mm (just an example, not limited to this value), and a distance between the second feed point B and the second open end 21 is 12.1 mm (just an example, not limited to this value).

[0043] When the feed point is located in a middle position between the open end and the ground end, its input impedance can have better matching and the radiation performance is better. The closer the feed point is to the open end, the better it is to excite the loop antenna mode. The distance from the second feed point B of the present disclosure to the second open end 21 is approximately 12.1 mm. In this case, the mode excited by the second feed source 50 is at low frequency, which meets the radiation performance of low frequency and can excite an IFA antenna mode, such as the coupling resonant mode, etc.

[0044] The length of the second radiation branch 20 in some embodiments is less than that of the typical radiation branch supporting the low frequency band, which is beneficial for the overall miniaturization of the antenna assembly 100 and can reduce the space occupied on the electronic device 1000. The length of the first radiation branch 10 and the length of the second radiation branch 20 in some embodiments are both relatively short, and the overall size of the antenna assembly 100 is small. For the foldable electronic device 1000, the antenna assembly 100 cannot be designed to cross or span the shaft. Therefore, a relatively small antenna assembly 100 needs to be designed. However, the antenna assembly 100 in some embodiments is relatively short and can be applied to the foldable electronic device 1000.

[0045] In some embodiments, as illustrated in FIG. 7, the antenna assembly 100 further includes a first feed port 13 and a second feed port 23. One end of the first feed port 13 is electrically connected to the first feed point A, and the other end of the first feed port 13 is electrically connected to the first feed source 30. One end of the second feed port 23 is electrically connected to the second feed point B, and the other end of the second feed port 23 is electrically connected to the second feed source 50.

[0046] In some embodiments, as illustrated in FIG. 7, the antenna assembly 100 further includes a first matching circuit M1 and a second matching circuit M2.

[0047] One end of the first matching circuit M1 is electrically connected to the second feed point B, and the other end of the first matching circuit M1 is grounded. Specifically, one end of the first matching circuit M1 is electrically connected to the second feed port 23, and the other end of the first matching circuit M1 is grounded. By designing the first matching circuit M1, the first matching circuit M1 is in a band blocking state for some frequency bands and in a bandpass state for some frequency bands. For example, the first matching circuit M1 is in the band blocking state for the low frequency signal generated by the second feed source 50, and in the bandpass state for the medium and high frequency signals generated by the first feed source 30. Therefore, the low frequency signal generated by the second feed source 50 may not be transmitted to the ground through the first matching circuit M1, but may be transmitted to the second radiation branch 20 through the second feed port 23. The medium and high frequency signals generated by the first feed source 30 may be transmitted to the second radiation branch 20 through the first feed port 13, the first feed point A, and the coupling gap 40. Due to the bandpass state of the first matching circuit M1 for the medium and high frequency signals, some of the medium and high frequency signals on the second radiation branch 20 can be grounded through the first matching circuit M1, so as to avoid the medium and high frequency signals on the second radiation branch 20 from affecting the second feed source 50.

[0048] In some embodiments, the first matching circuit M1 may be a capacitor, an inductor, a series device of the capacitor and the inductor, or a parallel device of the capacitor and the inductor. The first matching circuit M1 may also be the series device in parallel with the capacitor, the series device in parallel with the inductor, two aforementioned series devices in parallel, or two aforementioned parallel devices in series, etc.

[0049] In some embodiments, the first matching circuit M1 is the capacitor.

[0050] One end of the second matching circuit M2 is electrically connected to the first feed point A, and the other end of the first matching circuit M1 is grounded. Specifically, one end of the second matching circuit M2 is electrically connected to the first feed port 13, and the other end of the second matching circuit M2 is grounded. By designing the second matching circuit M2, the second matching circuit M2 is in the band blocking state for some frequency bands and in the bandpass state for some frequency bands. For example, the second matching circuit M2 is in the band blocking state for the medium and

high frequency signals generated by the first feed source 30, and in the bandpass state for the low frequency signals generated by the second feed source 50. Therefore, the medium and high frequency signals generated by the first feed source 30 may not be transmitted to the ground through the second matching circuit M2, but may be transmitted to the first radiation branch 10 through the first feed port 13. Due to the bandpass state of the second matching circuit M2 for low frequency signals, some low frequency signals on the first radiation branch 10 may be grounded through the second matching circuit M2, so as to avoid the low frequency signals on the first radiation branch 10 from affecting the first feed source 30.

[0051] In some embodiments, the second matching circuit M2 may be a capacitor, an inductor, a series device of the capacitor and the inductor, or a parallel device of the capacitor and the inductor. The second matching circuit M2 may also be the series device in parallel with the capacitor, the series device in parallel with the inductor, two aforementioned series devices in parallel, or two aforementioned parallel devices in series, etc.

[0052] As illustrated in FIG. 7, the antenna assembly 100 further includes a first matching network P1 and a second matching network P2.

[0053] The first matching network P1 is electrically connected between the first feed port 13 and the first feed source 30. The first matching network P1 is configured to adjust the impedance of the first radiation branch 10, so that the impedance of the first radiation branch 10 has a better match with the medium and high frequency bands, so as to generate the resonance mode in the required frequency band and have good radiation performance in the required frequency band. The first matching network P1 may include a tuning circuit configured for tuning the first resonant mode a (medium and high frequency bands), and a resonant frequency point configured for tuning the first resonant mode a, so that the antenna assembly 100 supports different medium and high frequency bands, and the frequency band combinations supported by the antenna assembly 100 are increased. In some embodiments, the first matching network P1 includes a circuit structure composed of multiple components, such as the capacitor, the inductor, and a resistor.

[0054] The second matching network P2 is electrically connected between the second feed port 23 and the second feed source 50. The second matching network P2 is configured to adjust the impedance of the second radiation branch 20, so that the impedance of the second radiation branch 20 has a better match with the low frequency band, so as to generate the resonance mode in the required frequency band and have good radiation performance in the required frequency band. The second matching network P2 may include a tuning circuit configured for tuning the second resonant mode b (low frequency band), a resonant frequency point configured for tuning the second resonant mode b, so that the antenna assembly 100 supports different low frequency bands and the frequency band combinations supported by the antenna assembly 100 are increased. In some embodiments, the second matching network P2 includes the circuit structure composed of multiple components, such as the capacitor, the inductor, and the resistor.

[0055] In some embodiments, the first matching circuit M1 may be a part of the second matching network P2. The second matching circuit M2 may be a part of the first matching network P1.

[0056] In some embodiments, the position of the second feed point B on the second radiation branch 20 is closer to a middle position of the second radiation branch 20 relative to the end. That is, the distance between the second feed point B and a midpoint of the second radiation branch 20 is less than the distance between the second feed point B and the end of the second radiation branch 20. Because when the position of the second feed point B is chosen to be in the middle position between the second open end 21 and the second ground end 22, the input impedance of the second feed point B can be better matched, and the second radiation branch 20 has better radiation performance. Generally, the second feed point B is in the middle position of the second radiation branch 20, and the performance is better.

[0057] In some embodiments, the second feed point B is located between the midpoint of the second radiation branch 20 and the second open end 21. That is, the second feed point B is close to the first radiation branch 10, so that the first feed source 30 excites the antenna mode of the loop mode on the first radiation branch 10 and the second radiation branch 20, such as exciting the coupling resonant mode of the loop mode, so as to achieve independent tuning of the coupling resonant mode and the first resonant mode a.

[0058] In some embodiments, the length from the second feed point B to the second open end 21 is 30%-40% of the length of the second radiation branch 20. On the one hand, it is beneficial for the first feed source 30 to excite the coupling resonant mode of the loop mode on the first radiation branch 10 and the second radiation branch 20. On the other hand, the input impedance of the second feed point B can be better matched, and the second radiation branch 20 has relatively good radiation performance.

[0059] Because the length from the first feed point A to the first open end 12 is less than or equal to 20% of the length of the first radiation branch 10. That is, the first feed point A is close to the first open end 12. In this case, the radio frequency energy transmitted by the first feed source 30 is mostly transmitted to the second radiation branch 20 through the coupling gap 40. The length from the second feed point B to the second open end 21 is 30%-40% of the length of the second radiation branch 20, that is, the first matching circuit M1 is electrically connected to the position of 30%-40% of the length of the second radiation branch 20. Therefore, the medium and high frequency signals transmitted to the second radiation branch 20 are transmitted to the first matching circuit M1 through the second feed port 23 from the second feed point B of the second radiation branch 20, and is grounded through the first matching circuit M1, so as to excite the coupling

resonance mode of the loop antenna mode.

[0060] In some embodiments, the coupling resonant mode includes the third resonant mode c.

[0061] As illustrated in FIG. 8, there are dashed arrows. The resonant current of the third resonant mode c flows from the first feed source 30 to the ground through the first feed point A, the coupling gap 40, and the first matching circuit M1. That is, the frequency band supported by the first matching circuit M1 for the third resonant mode c is in a low impedance state, that is, in a shortcircuit state.

[0062] The third resonant mode c is generated by the loop antenna formed by the first feed source 30, the first feed point A, the second feed point B, and the first matching circuit M1. The third resonant mode c is the loop antenna mode. The resonant current of the third resonant mode c operates in the $1/4$ wavelength mode of the supported frequency band.

[0063] In some embodiments, the third resonant mode c supports the frequency band of 2500-2690 MHz.

[0064] By designing the effective electrical length of the first radiation branch 10, the position of the first feed point A on the first radiation branch 10, the effective electrical length of the second radiation branch 20, and the position of the second feed point B on the second radiation branch 20, the third resonant mode c is generated between the first feed point A of the first radiation branch 10 and the second feed point B of the second radiation branch 20. The resonant frequency band of the third resonant mode c ranges from 2500 MHz to 2690 MHz, and the resonant current of the third resonant mode c operates in the $1/4$ wavelength mode of the supported frequency band.

[0065] The present disclosure can be used in the following scenarios: when the antenna assembly 100 is disposed in the mobile phone, due to limited design space inside the mobile phone, the space between the first open end 12 and the first ground end 11 of the first radiation branch 10 is occupied by other components (such as a power button), and the first feed source 30 cannot be disposed between the first open end 12 and the first ground end 11, but is forced to be designed close to the first open end 12. The first feed point A is close to the coupling gap 40, which facilitates the coupling of energy from the first radiation branch 10 to the second radiation branch 20 through the coupling gap 40, and different modes can be excited through the second feed point B and the matching design (first matching circuit M1). In addition, by designing the effective electrical length from the first feed point A to the second feed point B, the effective electrical length from the first feed point A to the second feed point B is close to $1/4$ of the medium wavelength of the required frequency band. Therefore, the first feed source 30 excites and generates the current distribution from the first feed point A to the second feed point B and the ground of the first matching circuit M1, thereby exciting and generating the third resonant mode c.

[0066] In order to avoid interference from the modes of the higher frequency of the second feed source 50 on the relatively higher frequency band that the first feed source 30 is responsible for, the feeding of the second feed source 50 is usually designed with a bandpass circuit or a low-pass circuit (first matching circuit M1), so as to eliminate or minimize the impact of modes in the relatively high frequency band. Therefore, when the third resonant mode c is excited by the first feed source 30 (responsible for the relatively high frequency band) in the present disclosure, due to the low impedance of the first matching circuit M1 to the relatively high frequency band, the resonant current of the third resonant mode c may be grounded from the first matching circuit M1. The third resonant mode c can be retained due to the matching design characteristic of the first matching circuit M1. That is, the third resonant mode c utilizes the first matching circuit M1 originally configured to filter the relatively high frequency band, and the first matching circuit M1 is matched with the second feed source 50. There is no need to set an additional first matching circuit M1, thereby saving space, manufacturing processes, and costs.

[0067] In some embodiments, the medium and high frequency signals generated by the first feed source 30 can also be grounded through the second ground end 22 of the second radiation branch 20, so as to form the coupling resonant mode. In some embodiments, the coupling resonant mode is referred to as the fourth resonant mode d.

[0068] The fourth resonant mode d is generated by the loop antenna formed by the first feed source 30, the first feed point A, the first radiation branch 10, the coupling gap 40, the second radiation branch 20, and the second ground end 22. The fourth resonant mode d is the loop antenna mode.

[0069] As illustrated in FIG. 9, there are the dashed arrows. A part of the resonant current of the fourth resonant mode d flows from the first feed source 30 through the coupling gap 40 to a first current zero point Q1, and another part of the resonant current of the fourth resonant mode d flows from the second ground end 22 to the first current zero point Q1. The first current zero point Q1 is located between the second ground end 22 and the second feed point B. The resonant current of the fourth resonant mode d operates in a $1/2$ wavelength mode of the supported frequency band. The first current zero point Q1 refers to a point where the current intensity is relatively small.

[0070] The minimum value of the frequency band supported by the fourth resonant mode d is greater than the maximum value of the frequency band supported by the third resonant mode c. For example, the frequency band supported by the third resonant mode c ranges from 2500 MHz to 2690 MHz. The frequency band supported by the fourth resonant mode d ranges from 3.3 GHz to 3.8 GHz. By designing the effective electrical length of the first radiation branch 10, the position of the first feed point A on the first radiation branch 10, and the effective electrical length of the second radiation branch 20, the fourth resonant mode d of the $1/2$ wavelength mode in the frequency band from 3.3 GHz to 3.8 GHz can be resonated between the first feed point A of the first radiation branch 10 and the second ground end 22 of the second radiation branch 20.

[0071] As illustrated in FIG. 10, there are dashed arrows. The coupling resonant mode also includes the fifth resonant mode e. The minimum value of the frequency band supported by the fifth resonant mode e is greater than the maximum value of the frequency band supported by the fourth resonant mode d. A part of the resonant current of the fifth resonant mode e flows from the first ground end 11 to a second current zero point Q2, and another part of the resonant current of the fifth resonant mode e flows from the second feed point B to the second current zero point Q2. The second current zero point Q2 is located between the first open end 12 and the first ground end 11. The second current zero point Q2 refers to the point where the current intensity is relatively small. As illustrated in FIG. 10, the resonant current of the fifth resonant mode e can be grounded through the first matching circuit M1.

[0072] The present disclosure can be used in the following scenarios: when the antenna assembly 100 is disposed in the mobile phone, due to the limited design space inside the mobile phone, the space between the first open end 12 and the first ground end 11 of the first radiation branch 10 is occupied by other components (such as the power button), and the first feed source 30 cannot be disposed between the first open end 12 and the first ground end 11, but is forced to be designed close to the first open end 12. The first feed point A is close to the coupling gap 40, which facilitates the coupling of the energy from the first radiation branch 10 to the second radiation branch 20 through the coupling gap 40, and different modes can be excited through the second feed point B and the matching design. In addition, by designing the effective electrical length of the first radiation branch 10, the effective electrical length from the second open end 21 to the second feed point B, and the effective electrical length of the second feed point B through the first matching circuit M1, the effective electrical length of the path is close to 1/2 of the medium wavelength of the required frequency band. Therefore, the first feed source 30 excites and generates the current distribution that the current flows from the reference ground through the first ground end 11 to the second current zero point Q2, and the current distribution that the current flows from the reference ground through the first matching circuit M1 and the second feed point B to the second current zero point Q2, thereby exciting and generating the fifth resonant mode e that supports the frequency band.

[0073] In order to avoid interference from the modes of the higher frequency of the second feed source 50 on the relatively higher frequency band that the first feed source 30 is responsible for, the feeding of the second feed source 50 is usually designed with the bandpass circuit or the low-pass circuit (first matching circuit M1), so as to eliminate or minimize the impact of modes in the relatively high frequency band. Therefore, when the fifth resonant mode e is excited by the first feed source 30 (responsible for the relatively high frequency band) in the present disclosure, due to the low impedance of the first matching circuit M1 to the relatively high frequency band, the resonant current of the fifth resonant mode e may be grounded from the first matching circuit M1. The fifth resonant mode e can be retained due to the matching design characteristic of the first matching circuit M1. That is, the fifth resonant mode e utilizes the first matching circuit M1 originally configured to filter the relatively high frequency band, and the first matching circuit M1 is matched with the second feed source 50. There is no need to set the additional first matching circuit M1, thereby saving space, manufacturing processes, and costs.

[0074] As illustrated in FIG. 11, the antenna assembly 100 further includes a first tuning circuit T1. The first tuning circuit T1 is electrically connected to the first feed point A. Alternatively, the first tuning circuit T1 is electrically connected to the first radiation branch 10 between the first feed point A and the first ground end 11. Specifically, the first tuning circuit T1 may be electrically connected to the first feed port 13. The first tuning circuit T1 is configured to tune the frequency band of the first resonant mode a. For example, during a certain period of time, the first resonant mode a supports the B1 frequency band, and the first resonant mode a can support the B3 frequency band by tuning of the first tuning circuit T1. In this way, by setting the first tuning circuit T1, the first resonant mode a can support multiple frequency bands, thereby increasing the frequency band combinations supported by the antenna assembly 100, and improving throughput and data transmission rate of the antenna assembly 100.

[0075] In some embodiments, the first tuning circuit T1 includes an antenna switch and/or an adjustable capacitor.

[0076] In some embodiments, the first tuning circuit T1 includes but is not limited to a capacitor, an inductor, a series device of the capacitor and the inductor, or a parallel device of the capacitor and the inductor. The first tuning circuit T1 may also be the series device in parallel with the capacitor, the series device in parallel with the inductor, two aforementioned series devices in parallel, or two aforementioned parallel devices in series, etc.

[0077] In a first implementation of the first tuning circuit T1, as illustrated in FIG. 12, the first tuning circuit T1 also includes multiple first tuning branches T11. One end of each of the multiple first tuning branches T11 is electrically connected to one end of the first switch circuit K1, and the other end of the first switch circuit K1 is electrically connected to the first feed port 13. The first switch circuit K1 is a single pole multi throw switch. The other end of each of multiple first tuning branches T11 is grounded. The multiple first tuning branches T11 are configured to tune the size of the frequency band supported by the first resonant mode a.

[0078] An impedance value of each first tuning branch T11 is different. For example, the multiple first tuning branches T11 are multiple capacitors with different capacitance values. Alternatively, the multiple first tuning branches T11 are multiple inductors with different inductance values. Alternatively, the multiple first tuning branches T11 may include multiple capacitors with different capacitance values and multiple inductors with different inductance values. By adjusting the electrical connection of the first switch circuit K1 to different components, the equivalent electrical lengths of the first

tuning branches T11 can be adjusted, and the effective electrical length of the first radiation branch 10 can be further adjusted, thereby adjusting the size of the frequency band supported by the first resonant mode a.

[0079] In a second implementation of the first tuning circuit T1, as illustrated in FIG. 13, the first tuning circuit T1 includes a first adjustable capacitor C1, the capacitance value of the first adjustable capacitor C1 is adjustable, and first adjustable capacitor C1 is configured to tune the frequency band supported by the first resonant mode a. The first adjustable capacitor C1 is a capacitor with adjustable capacitance value. By adjusting the capacitance value of the capacitor, the impedance value of the first tuning circuit T1 can be adjustable, thereby adjusting the effective electrical length of the first tuning circuit T1, further adjusting the effective electrical length of the first radiation branch 10, and adjusting the size of the frequency band supported by the first resonant mode a.

[0080] In some embodiments, the first tuning circuit T1 may also be a combination of the first implementation and the second implementation. For example, as illustrated in FIG. 14, the first tuning branch T11 includes the first adjustable capacitor C1.

[0081] Due to the connection of the first tuning circuit T1 to the first radiation branch 10, the first tuning circuit T1 can tune the effective electrical length on the first radiation branch 10, thereby tuning the first resonant mode a generated on the first radiation branch 10, while the impact on the second resonant mode, the third resonant mode, the fourth resonant mode, and the fifth resonant modes e mainly generated on the second radiation branch 20 is relatively small. Therefore, when the first resonant mode a is tuned by the first tuning circuit T1, the frequency bands supported by the second resonant mode, the third resonant mode, the fourth resonant mode, and the fifth resonant modes e can be kept constant presence, thereby supporting the frequency bands supported by the second resonant mode, the third resonant mode, the fourth resonant mode, and the fifth resonant mode e, and tuning the frequency band supported by the first resonant mode a. The frequency band combinations supported by the antenna assembly 100 are increased, thereby improving throughput and data transmission rate.

[0082] In some embodiments, the first tuning circuit T1 may be a part of the second matching circuit M2 or a part of the first matching network P1. The second tuning circuit T2 may be a part of the first matching circuit M1 or a part of the second matching network P2.

[0083] As illustrated in FIG. 11, the antenna assembly 100 further includes a second tuning circuit T2. The second tuning circuit T2 is electrically connected to the second radiation branch 20. In some embodiments, the second tuning circuit T2 may be electrically connected to the second feed port 23, or directly connected to the branch of the second radiation branch 20. The second tuning circuit T2 is configured to tune the frequency band of the third resonant mode c and/or the frequency band of the second resonant mode b. The second tuning circuit T2 can tune the third resonant mode c, so that the third resonant mode c can be designed with a frequency ratio to the second resonant mode b, thereby supporting more CA combinations, or improving antenna efficiency in a single frequency band (such as the frequency band supported by the third resonant mode c) as a matching design.

[0084] In addition, the second tuning circuit T2 can also allow the second resonant mode b of the low frequency antenna to obtain tuning freedom, thereby supporting more ENDC and CA combinations.

[0085] The structure of the second tuning circuit T2 can refer to the structure of the first tuning circuit T1, which is not be repeated here.

[0086] As illustrated in FIG. 15, FIG. 15 is an S-parameter curve view of the antenna assembly 100 in some embodiments of the present disclosure. The antenna assembly 100 generates the first resonant mode a, the second resonant mode b, the third resonant mode c, the fourth resonant mode d, and the fifth resonant mode e.

[0087] As illustrated in a curve S2, 2_B32, a curve S2, 2_B3, and a curve S2, 2_B1_B41 of FIG. 15, it can be seen that when the first resonant mode a is tuned, for example, when the first resonant mode a is tuned among the frequency band B32 (1452-1495.9 MHz), the frequency band B3 (1710-1880 MHz), and the frequency band B1 (1920-2170 MHz), the second resonant mode b can remain constant presence. In addition, the third resonant mode c, the fourth resonant mode d, and the fifth resonant mode e can all remain constant presence.

[0088] The frequency band point positions of the resonant modes of FIG. 15 are merely examples. In some embodiments, one second resonant mode can simultaneously support two frequency bands, such as simultaneously supporting B3 and B32, etc.

[0089] When the second resonant mode b is tuned, for example, when the second resonant mode b is tuned among the B20 frequency band, the B5 frequency band, the B8 frequency band, and the B28 frequency band, the first resonant mode a can remain constant presence.

[0090] Based on the above embodiments, when the first resonant mode a is tuned, the second resonant mode, the third resonant mode, the fourth resonant mode, and the fifth resonant mode can all remain constant presence, and the second resonant mode b can be independently tuned. In this way, it can support the CA combination of B20+B32+B41+N78+N79, the CA combination of B20+B3+B41+N78+N79, the CA combination of B20+B1+B41+N78+N79, the CA combination of B20+B40+B41+N78+N79, the CA combination of B20+B1+B3+B41+N78+N79, etc. The frequency band B20 can be replaced with the low frequency band, such as the B5 frequency band, the B8 frequency band, or the B28 frequency band, etc. Therefore, the antenna assembly 100 in the present disclosure can support more frequency bands of CA and ENDC

combinations, improve throughput, thereby improving the transmission rate.

[0091] In addition, since the generation of the coupling resonance mode utilizes the radiation branches of the original low frequency antenna, the antenna assembly 100 generates the required coupling resonance mode without adding new branches. The antenna assembly 100 can achieve independent tuning of the second resonance mode b supporting the low frequency and the first resonance mode a supporting the frequency band of 1.45-2.4 GHz. The first resonance mode a supporting the frequency band of 1.45-2.4 GHz and the coupling resonance mode supporting the frequency bands of 2.5-2.69 GHz, 3.3-3.8 GHz, and 4.8-5 GHz can be independently tuned. In practical applications, it can tune multiple frequency bands formed by combining multiple low frequency bands with multiple medium frequency bands, while maintaining the constant presence of the N78 frequency band without occupying additional space. An independently tunable multi-band antenna can be formed in the limited space of the electronic device 1000.

[0092] In some embodiments, as illustrated in FIG. 16, the third resonant mode c may also be excited by the second feed source 50. Specifically, the structure of the antenna assembly 100 in the present embodiment is roughly the same as that of the antenna assembly 100 in the above embodiments. The main difference is that the second matching network P2 is in the low impedance state for the frequency bands supported by the second resonant mode b and the third resonant mode c, and in the band blocking state for other frequency bands. The second matching circuit M2 is in the low impedance state for the frequency band supported by the third resonant mode c.

[0093] The second feed source 50 is also configured to excite the second radiation branch 20 to generate the third resonant mode c. As illustrated in the dashed arrows of FIG. 16, the resonant current of the third resonant mode c flows from the second feed source 50 to the ground through the second feed point B, the coupling gap 40, and the second matching circuit M2.

[0094] As illustrated in Table 1, Table 1 shows the efficiency of each frequency band when the third resonant mode c is excited by the first feed source 30 and the second feed source 50, respectively. The third resonant mode c is excited by the first feed source 30 and the second feed source 50, respectively, so that the impedance matching of the radiation branch to each frequency band is different. When the third resonant mode c is excited by the first feed source 30, the efficiency absolute value of the N78 frequency band and the efficiency absolute value of the medium frequency (1.9-2.4 GHz) corresponding to the third resonant mode c are relatively small, thereby having good performance. When the third resonant mode c is excited by the second feed source 50, the efficiency absolute value of the medium frequency (1.4-2.2 GHz) mode corresponding to the second resonant mode b is relatively small, thereby having good performance.

Table 1

Frequency band	Efficiency of the third resonant mode excited by the second feed source (dB)	Efficiency of the third resonant mode excited by the first feed source (dB)
0.76-0.82 GHz	-5.5	-5.5
1.45-1.5 GHz	-4.5	-5.4
1.71-1.88 GHz	-4.8	-5.3
1.92-2.17 GHz	-4.6	-3.8
2.3-2.4 GHz	-4.5	-2.3
2.5-2.69 GHz	-4.5	-3.4
3.3-3.8 GHz	-4.5	-3.2
4.8-5 GHz	-12.0	-6.8

[0095] In the present disclosure, regardless of how the first resonant mode a and the second resonant mode b are switched through the tuning circuit, the third resonant mode c and the fourth resonant mode d can always maintain constant presence, which greatly meets higher-order CA combinations (at least four CA combinations or more).

[0096] As illustrated in FIG. 17, for the electronic device 1000 in the present disclosure, the electronic device 1000 also includes a conductive side frame 200. The second radiation branch 20 and the first radiation branch 10 are both parts of the conductive side frame 200. That is, the conductive side frame 200 serves as the radiation branch of the antenna assembly 100, reducing the space occupied by the antenna assembly 100 of the electronic device 1000. The conductive side frame 200 is reused, facilitating the miniaturization of the entire device. In some embodiments, taking the electronic device 1000 being the mobile phone as an example, the conductive side frame 200 is the frame connected between a display screen and a back cover, and the conductive side frame 200 is made of a conductive material. Furthermore, the material of the conductive side frame 200 may be a metal conductive material, which meets the requirements of antenna design, improves structural strength, and increases metallic texture.

[0097] In some embodiments, the electronic device 1000 may be a non-foldable device, a foldable electronic device, or a

stretchable electronic device, etc.

[0098] Multiple antennas, such as eight antennas or twelve antennas, are generally required in the mobile phone. Therefore, multiple antennas need to be disposed on the conductive side frame 200 of the mobile phone. For the foldable mobile phone, setting of a rotating shaft may divide a long side into two parts: an upper part and a lower part. The radiation branch of the antenna assembly 100 cannot cross or span the rotating shaft, resulting in limited length of the radiation branch on the long side. The length of the long side of the mobile phone ranges from 140 mm to 170 mm. When the long side of the mobile phone is foldable, the size of the long side after folding is relatively small, for example, the size of the long side after folding ranges from 65 mm to 80 mm. Generally, the long side of the radiation branch of the antenna assembly 100 that supports low, medium, and high frequencies is relatively long. For example, the radiation branch of the low frequency antenna is 57.8 mm, and the length of the radiation branch of the medium-and-high frequency antenna is 21.8 mm. Therefore, the antenna cannot be disposed on the long side of the foldable mobile phone. Therefore, in order to allow the antenna assembly 100 to be disposed on the long side of the foldable mobile phone, how to design the antenna assembly 100 has become an urgent technical problem that needs to be solved.

[0099] In the antenna assembly 100 of the present disclosure, by designing the positions of the first feed point A and the second feed point B of the antenna assembly 100, the first resonant mode a to the fifth resonant mode e are designed on the antenna assembly 100. It can be independently tuned between the low frequency and the medium frequency, and between the medium frequency and the medium-and-high frequency. Under the condition of meeting the above modal support, the length of the first radiation branch 10 is less than or equal to 18 mm, and the length of the second radiation branch 20 is less than or equal to 35 mm. In this way, the antenna assembly 100 can be well compatible with the foldable mobile phone without crossing the rotating shaft, and can support more CA and ENDC combinations.

[0100] As illustrated in FIG. 18, when the antenna assembly 100 is applied to the electronic device 1000, the specific structure of the electronic device 1000 includes the conductive side frame 200 and a rotating shaft 230. The conductive side frame 200 includes a pair of long sides 210, a pair of short sides 220. The pair of long sides 210 refers to two long sides 210 arranged along a Y-axis direction and opposite to each other, and the pair of short sides 220 refers to two short sides 220 arranged along an X-axis direction and opposite to each other. The size of the long side 210 is greater than the size of the short side 220.

[0101] The pair of short sides 220 are parallel to the rotating shaft 230. The rotating shaft 230 is disposed along the X-axis direction. In some embodiments, the rotating shaft 230 may divide the long side 210 into two parts with the same size. In some embodiments, the rotating shaft 230 may divide the long side 210 into two parts with different sizes.

[0102] The pair of long sides 210 are foldable with the rotation of the rotating shaft 230. The second radiation branch 20 and the first radiation branch 10 are located on the long side 210 and located on the same side of the rotating shaft 230. The rotating shaft 230 divides the pair of long sides 210 into four parts, and the second radiation branch 20 and the first radiation branch 10 may be arranged in any one of these four parts.

[0103] In some embodiments, the first radiation branch 10 and the second radiation branch 20 may be located on the short side 220, or a corner, etc.

[0104] The conductive side frame 200 of the electronic device 1000 is also provided with buttons, such as a volume button and a power button, etc. The circuit boards corresponding to these buttons are disposed, and the circuit boards are in contact with these buttons. When the first radiation branch 10 and the second radiation branch 20 of the antenna assembly 100 are disposed on the conductive side frame 200, the first ground end 11 is electrically connected to the reference ground inside the electronic device 1000. The first feed point A is electrically connected to the second matching circuit M2, the first matching network P1, the first feed source 30 or the like on the circuit board through the first feed port 13 (such as a grounding spring). The first feed point A is relatively close to the first open end 12, therefore, there is a certain space between the first feed point A and the first ground end 11. Similarly, the second feed point B is close to the second open end 21, therefore, there is a certain space between the second feed point B and the second ground end 22. The button circuit boards may be disposed between the feed point and the ground end, or between the open end and the ground end, so as to improve the space utilization in the electronic device 1000 and the compactness of the arrangement of various components.

[0105] In some embodiments, as illustrated in FIG. 18, the electronic device 1000 further includes a first button circuit board 300 and a second button circuit board 400 arranged inside the conductive side frame 200. In some embodiments, the first button circuit board 300 is a flexible circuit board for the volume button, and the second button circuit board 400 is a flexible circuit board for the power button. The first button circuit board 300 is adjacent to the second radiation branch 20, and an orthographic projection of the first button circuit board 300 on the second radiation branch 20 is located between the second ground end 22 and the second open end 21. An orthographic projection of the second button circuit board 400 on the first radiation branch 10 is located between the first ground end 11 and the first feed point A.

[0106] Due to the relatively long length of the second radiation branch 20 and the relatively long length of the volume button, the flexible circuit board of the volume button can be disposed adjacent to the second radiation branch 20. The flexible circuit board of the power button can be disposed adjacent to the first radiation branch 10, so as to form suitable matching pairs according to different sizes, improving the compactness and rationality of the arrangement of various

components.

[0107] Although the embodiments of the present disclosure have been shown and described above, it can be understood that the above embodiments are exemplary and should not be construed as limiting the present disclosure. Those skilled in the art may make changes, modifications, substitutions, and variations to the above embodiments in the scope of the present disclosure. These improvements and embellishments are also considered in the protection scope of the present disclosure.

Claims

1. An antenna assembly, comprising:

a first radiation branch, comprising a first ground end, a first feed point, and a first open end arranged in sequence;
a second radiation branch, comprising a second open end and a second ground end, wherein a gap is defined between the first open end and the second open end; and
a first feed source, electrically connected to the first feed point and configured to excite the first radiation branch to generate a first resonant mode;
wherein a length from the first feed point to the first open end is less than or equal to 20% of a length of the first radiation branch, and the first feed source is configured to excite at least one coupling resonant mode on the second radiation branch.

2. The antenna assembly as claimed in claim 1, wherein a frequency band supported by the first resonant mode comprises at least a part of a frequency band of 1.45-2.4 GHz; and a frequency band supported by the coupling resonant mode comprises at least a part of a frequency band of 2.5-2.7 GHz, a frequency band of 3.3-3.8 GHz, and a frequency band of 4.8-5 GHz.

3. The antenna assembly as claimed in claim 1, wherein a resonant current of the first resonant mode flows from the first feed source through the first feed point and returns to ground from the first ground end.

4. The antenna assembly as claimed in claim 3, wherein the resonant current of the first resonant mode operates in a $1/4$ wavelength mode of a supported frequency band.

5. The antenna assembly as claimed in claim 1, wherein the antenna assembly further comprises a first tuning circuit electrically connected to the first feed point or to the first radiation branch between the first feed point and the first ground end, and the first tuning circuit is configured to tune a frequency band of the first resonant mode.

6. The antenna assembly as claimed in claim 5, wherein the first tuning circuit comprises an antenna switch and/or an adjustable capacitor.

7. The antenna assembly as claimed in any one of claims 1 to 6, wherein the second radiation branch further comprises a second feed point located between the second open end and the second ground end, the antenna assembly further comprises a second feed source electrically connected to the second feed point and configured for exciting the second radiation branch to generate a second resonant mode.

8. The antenna assembly as claimed in claim 7, wherein a frequency band supported by the second resonant mode is less than 1 GHz, a resonant current of the second resonant mode flows through the second open end to the second ground end, and the resonant current of the second resonant mode operates in the $1/4$ wavelength mode of the supported frequency band.

9. The antenna assembly as claimed in claim 7, wherein a length from the second feed point to the second open end is 30%-40% of a length of the second radiation branch; the antenna assembly further comprises a first matching circuit, one end of the first matching circuit is electrically connected to the second feed point, and the other end of the first matching circuit is grounded; and the coupling resonant mode comprises a third resonant mode, and a resonant current of the third resonant mode flows from the first feed source to the ground through the first feed point, the coupling gap, and the first matching circuit.

10. The antenna assembly as claimed in claim 7, wherein the antenna assembly further comprises a second matching circuit, one end of the second matching circuit is electrically connected to the first feed point, and the other end of the

second matching circuit is grounded;

a length from the second feed point to the second open end is 30%-40% of a length of the second radiation branch; the second feed source is further configured to excite the second radiation branch to generate a third resonant mode, and a resonant current of the third resonant mode flows from the second feed source to the ground through the second feed point, the coupling gap, and the second matching circuit.

11. The antenna assembly as claimed in claim 9 or 10, wherein the resonant current of the third resonant mode operates in the 1/4 wavelength mode of the supported frequency band.

12. The antenna assembly as claimed in claim 9 or 10, wherein the coupling resonant mode further comprises a fourth resonant mode, and a minimum value of a frequency band supported by the fourth resonant mode is greater than a maximum value of a frequency band supported by the third resonant mode; a part of a resonant current of the fourth resonant mode flows from the first feed source through the coupling gap to a first current zero point, and another part of the resonant current of the fourth resonant mode flows from the second ground end to the first current zero point; and the first current zero point is located between the second ground end and the second feed point, and the resonant current of the fourth resonant mode operates in a 1/2 wavelength mode of the supported frequency band.

13. The antenna assembly as claimed in claim 12, wherein the coupling resonant mode further comprises a fifth resonant mode, and a minimum value of a frequency band supported by the fifth resonant mode is greater than a maximum value of the frequency band supported by the fourth resonant mode; a part of a resonant current of the fifth resonant mode flows from the first ground end to a second current zero point, and another part of the resonant current of the fifth resonant mode flows from the second feed point to the second current zero point; and the second current zero point is located between the first open end and the first ground end.

14. The antenna assembly as claimed in claim 9, wherein the antenna assembly further comprises a second tuning circuit electrically connected to the second radiation branch, and the second tuning circuit is configured to tune a frequency band of the third resonant mode and/or a frequency band of the second resonant mode.

15. The antenna assembly as claimed in any one of claims 1 to 6, 8 to 10, 13, and 14, wherein the length of the first radiation branch is less than or equal to 18 mm, and the length of the second radiation branch is less than or equal to 35 mm.

16. An electronic device, comprising:
an antenna assembly as claimed in any one of claims 1 to 15.

17. The electronic device as claimed in claim 16, wherein the electronic device further comprises a conductive side frame, and the second radiation branch and the first radiation branch are parts of the conductive side frame.

18. The electronic device as claimed in claim 17, wherein the electronic device is a foldable device; the conductive side frame comprises a pair of long sides, a pair of short sides, and a rotating shaft; the pair of short sides are parallel to the rotating shaft, and each long side is foldable with rotation of the rotating shaft; and the second radiation branch and the first radiation branch are located on the same long side and on the same side of the rotating shaft.

19. The electronic device as claimed in claim 18, wherein the electronic device further comprises a first button circuit board and a second button circuit board arranged inside the conductive side frame, the first button circuit board is adjacent to the second radiation branch, an orthographic projection of the first button circuit board on the second radiation branch is located between the second ground end and the second open end, and an orthographic projection of the second button circuit board on the first radiation branch is located between the first ground end and the first feed point.

20. The electronic device as claimed in claim 19, wherein the first button circuit board is a flexible circuit board for a volume button, and the second button circuit board is a flexible circuit board for a power button.

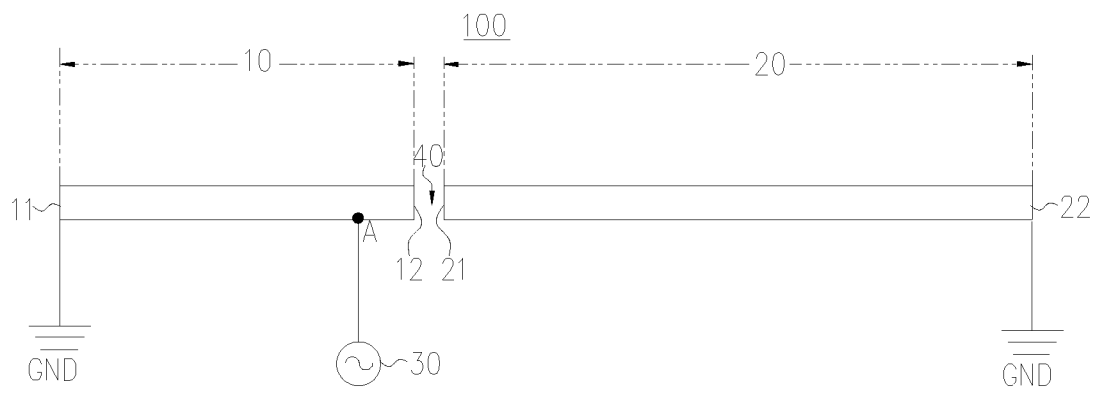


FIG. 1

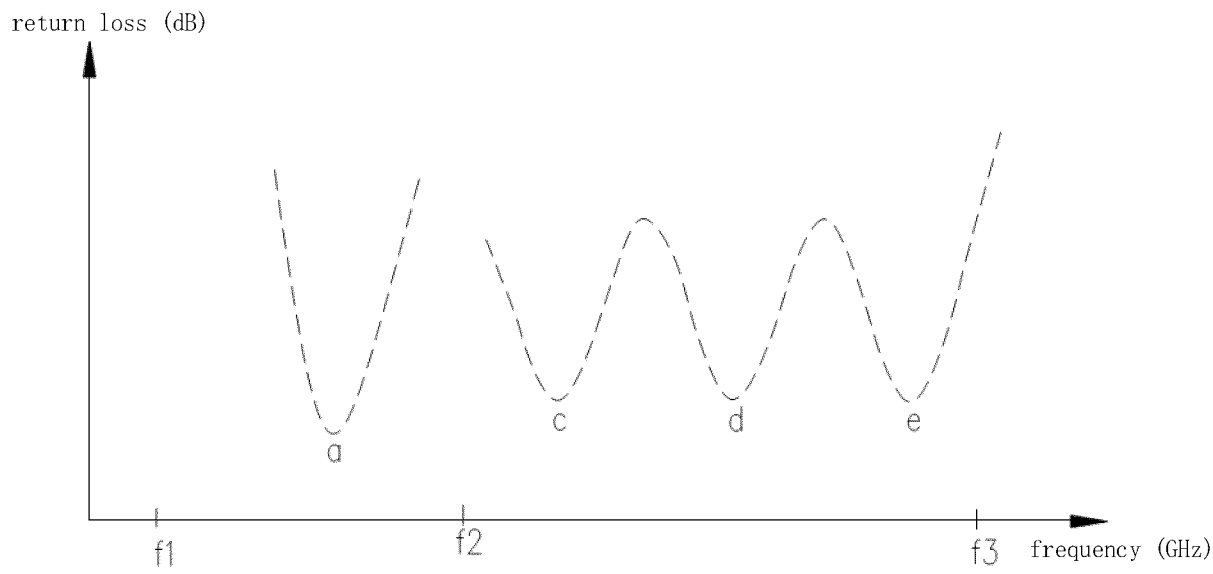


FIG. 2

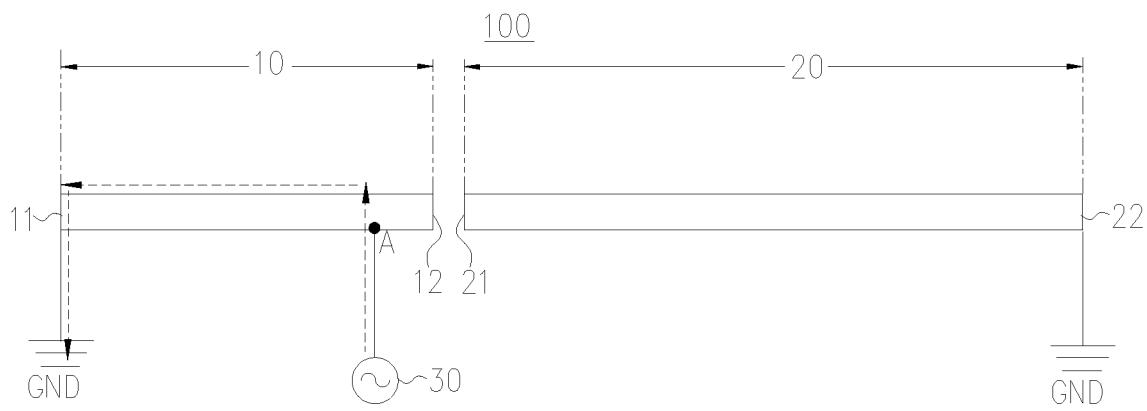


FIG. 3a

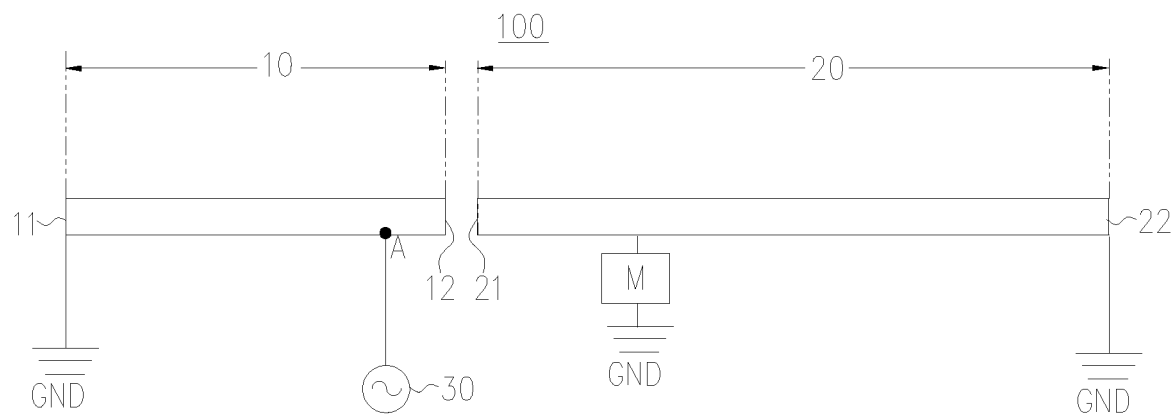


FIG. 3b

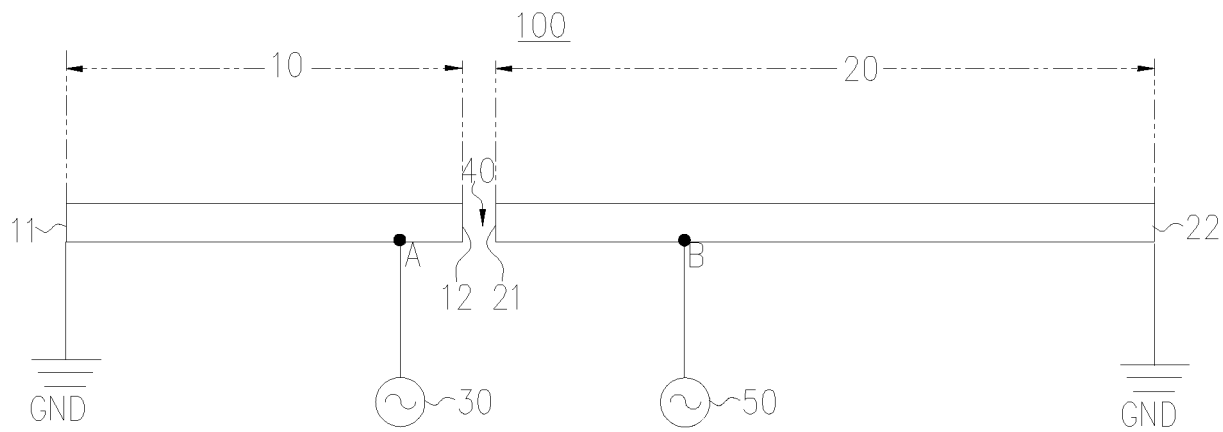


FIG. 4

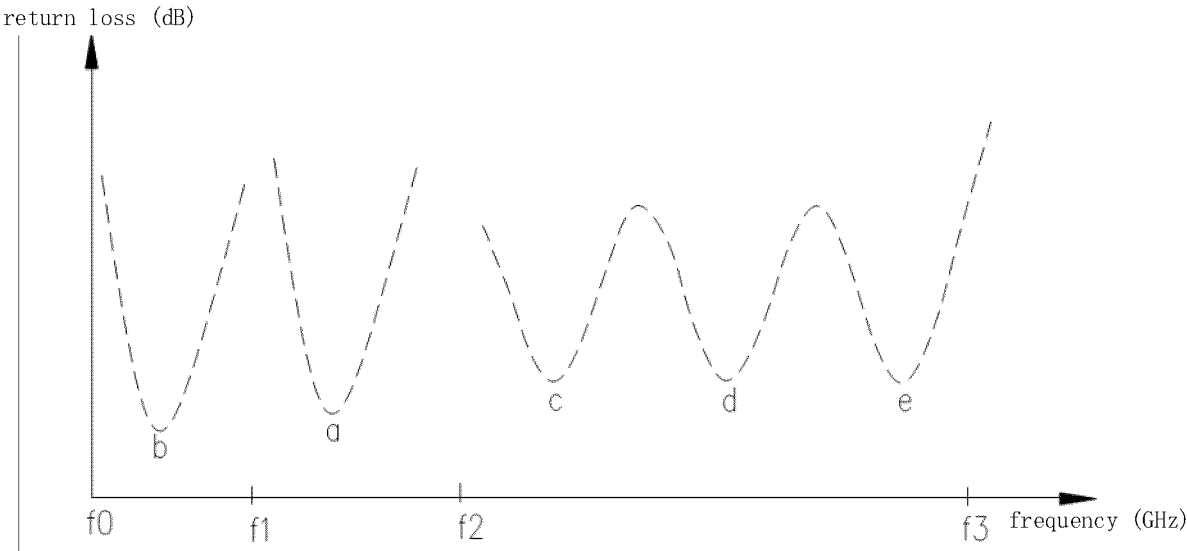


FIG. 5

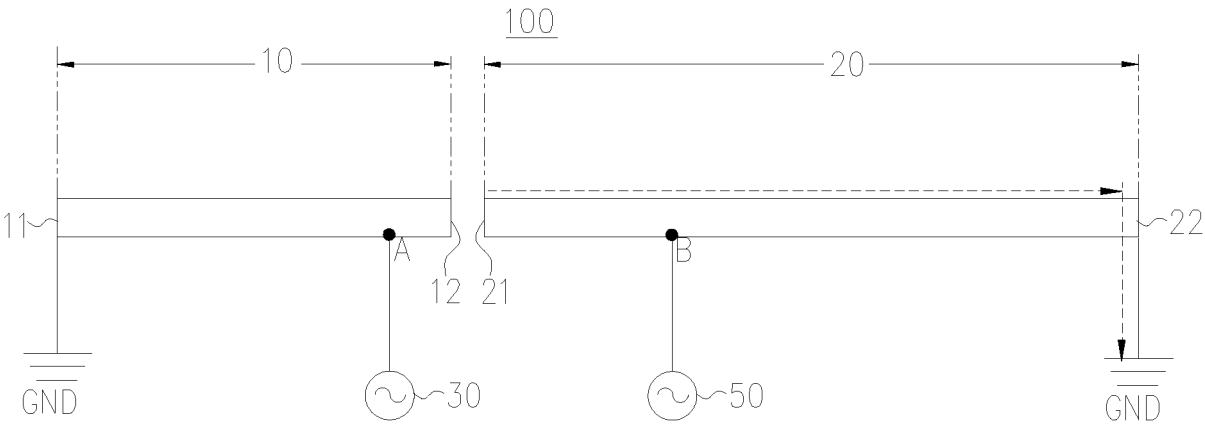


FIG. 6

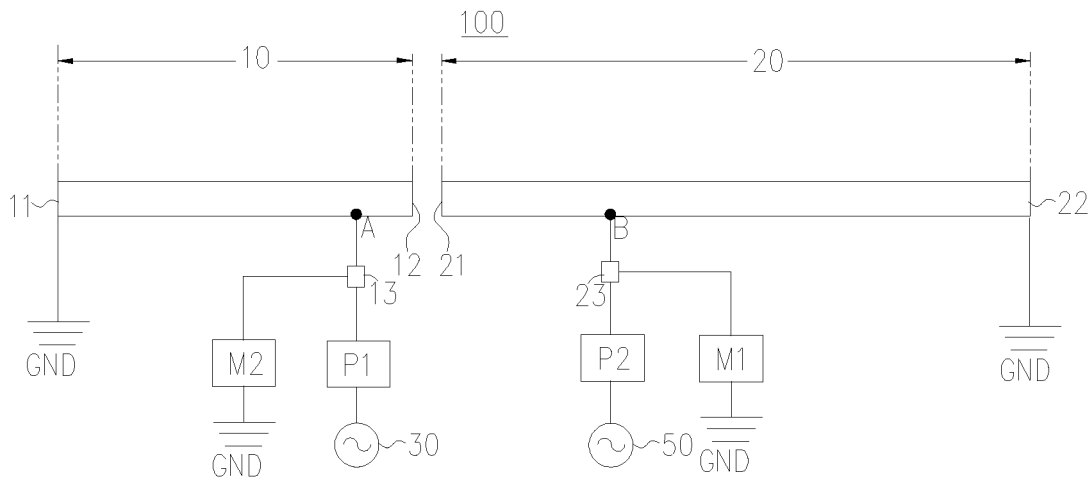


FIG. 7

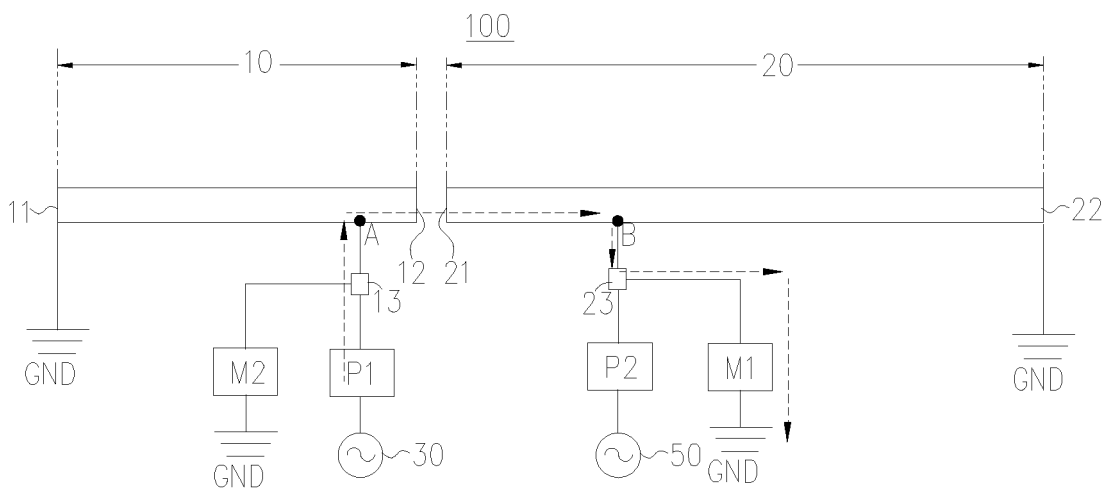


FIG. 8

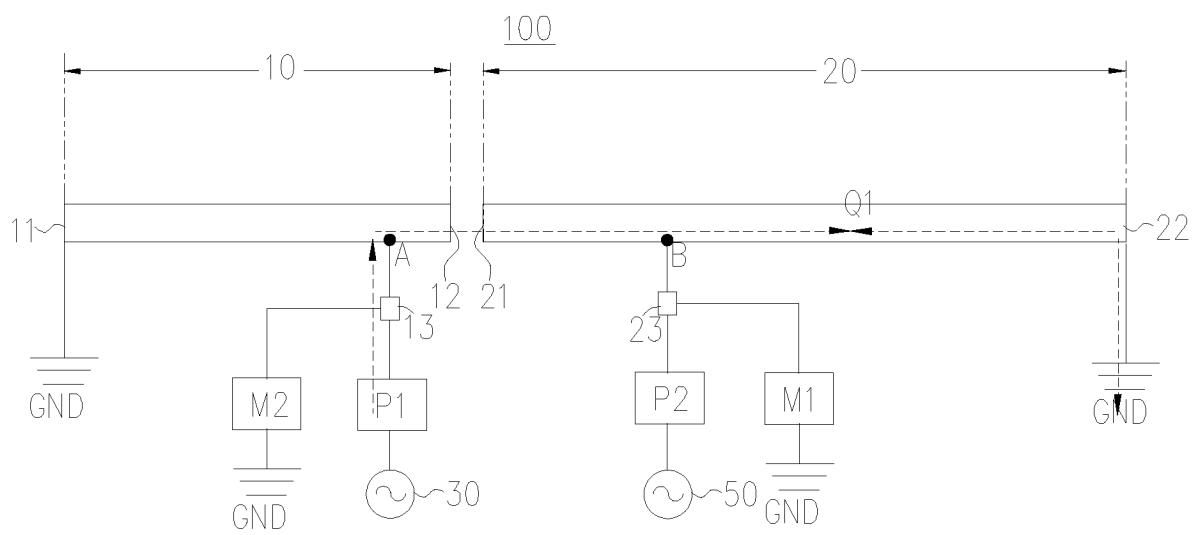


FIG. 9

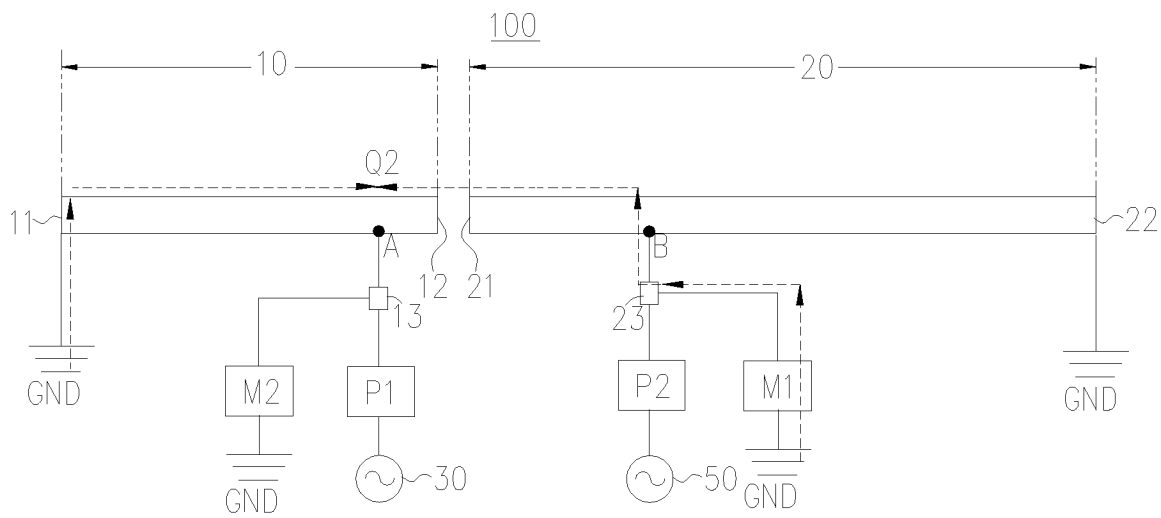


FIG. 10

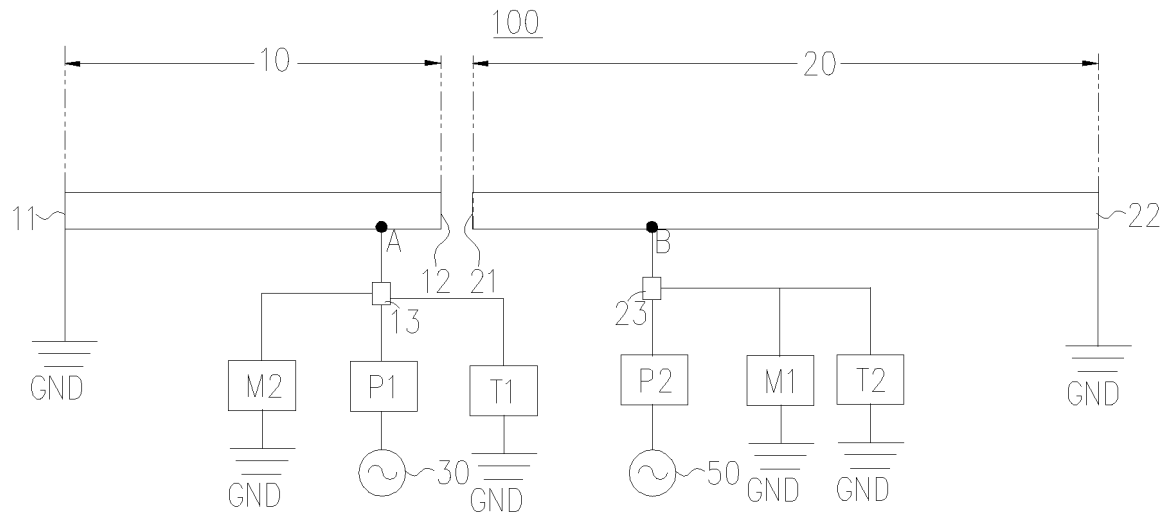


FIG. 11

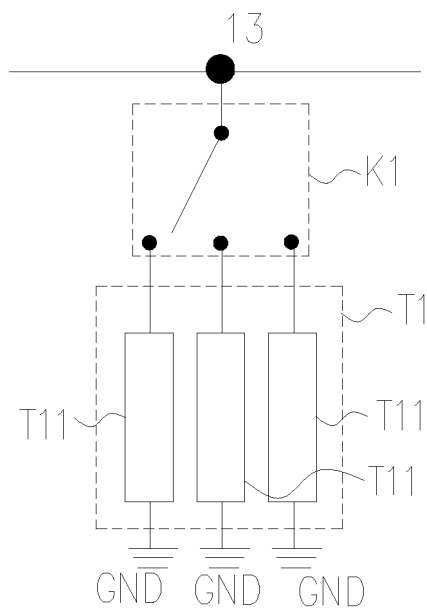


FIG. 12

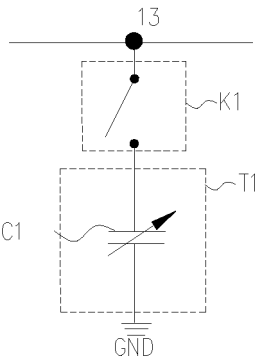


FIG. 13

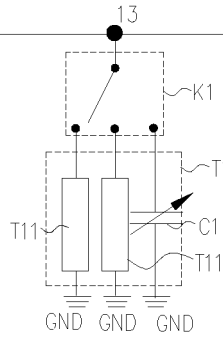


FIG. 14

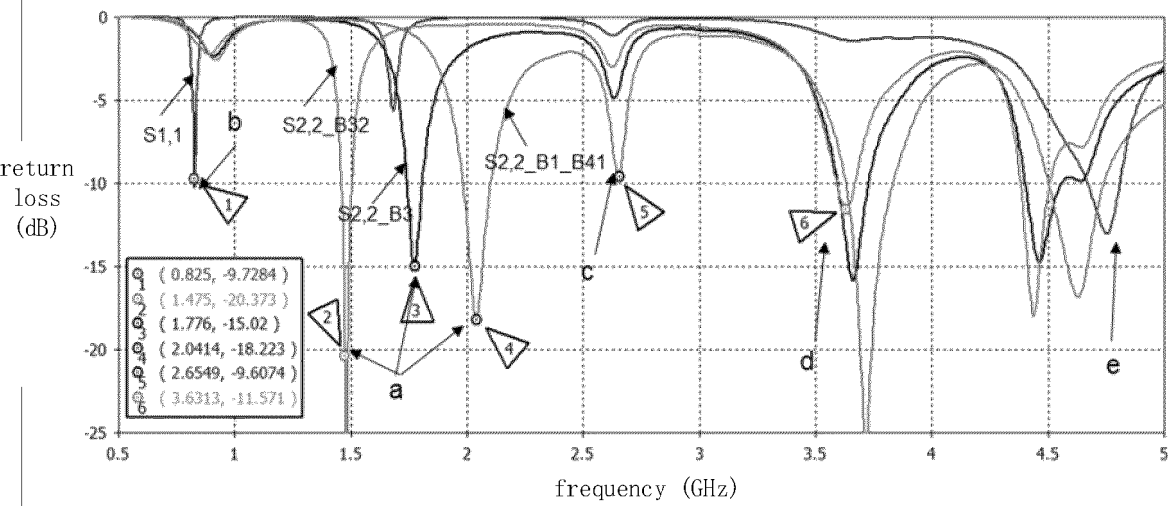


FIG. 15

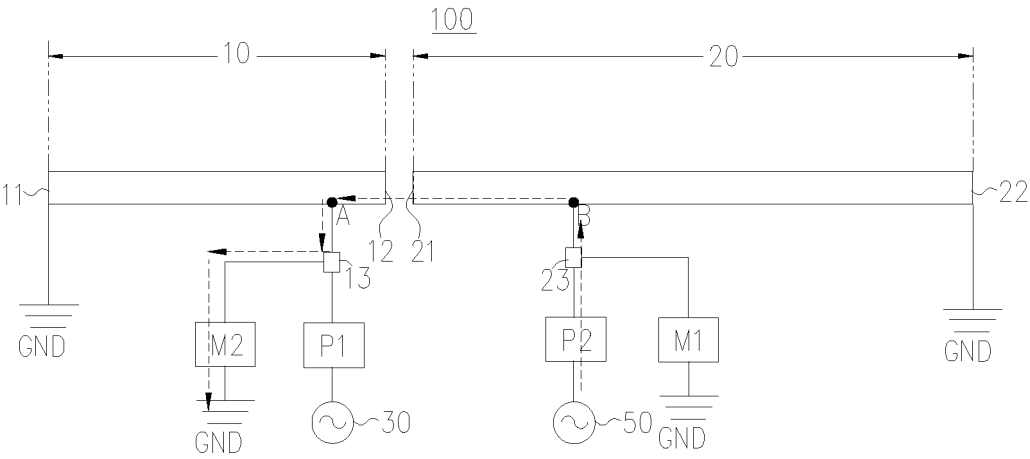


FIG. 16

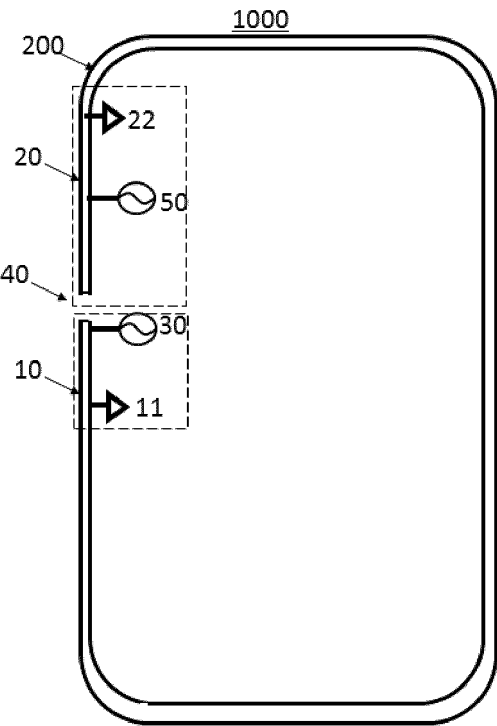


FIG. 17

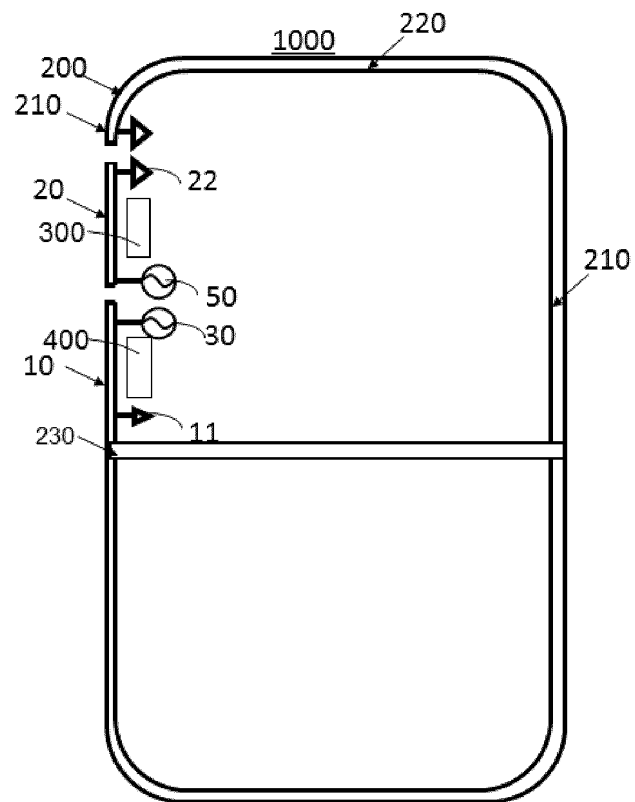


FIG. 18

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/108922

A. CLASSIFICATION OF SUBJECT MATTER

H01Q1/36(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)

IPC: 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)

CNTXT, CNKI, IEEE, EPTXT, USTXT, WOTXT, VEN: 天线, 匹配电路, 馈点, 辐射段, 辐射体, 馈点, 馈电点, 频段, 接地, 射频, 间隙, 耦合; antenna, matching, circuit, feeding, point, frequency, band, ground, grounding, matching, point, radio, RF, gap, coupl+, radiat+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 115224475 A (HONOR TERMINAL CO., LTD.) 21 October 2022 (2022-10-21) description, paragraphs 35-126, and figures 1-16	1-20
A	CN 113394550 A (OPPO GUANGDONG MOBILE TELECOMMUNICATIONS CO., LTD.) 14 September 2021 (2021-09-14) entire document	1-20
A	CN 114284721 A (SHENZHEN REALME MOBILE COMMUNICATION CO., LTD.) 05 April 2022 (2022-04-05) entire document	1-20
A	CN 115133269 A (OPPO GUANGDONG MOBILE TELECOMMUNICATIONS CO., LTD.) 30 September 2022 (2022-09-30) entire document	1-20
A	CN 212136680 U (OPPO GUANGDONG MOBILE TELECOMMUNICATIONS CO., LTD.) 11 December 2020 (2020-12-11) entire document	1-20

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“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

13 October 2023

Date of mailing of the international search report

13 October 2023

Name and mailing address of the ISA/CN

China National Intellectual Property Administration (ISA/
CN)
China No. 6, Xitucheng Road, Jimenqiao, Haidian District,
Beijing 100088

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/108922

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2012218151 A1 (WONG KINLU et al.) 30 August 2012 (2012-08-30) entire document	1-20
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2023/108922

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CN 115133269 A	30 September 2022	None	
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		EP 2493011 A1	29 August 2012
		EP 2493011 B1	05 August 2020
		US 8836582 B2	16 September 2014
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		TWI 591893 B	11 July 2017

REFERENCES CITED IN THE DESCRIPTION

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