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Inventor(s)	Kuo; Li-Kai et al.

Antenna structure and mobile device

Abstract

An antenna structure includes a ground element, a feeding radiation element, a first radiation element, a second radiation element, a shorting radiation element, a third radiation element, a filter circuit, a proximity sensor, and a tuning circuit. The ground element provides a ground voltage. The feeding radiation element has a feeding point. The first radiation element and the second radiation element are coupled to the feeding radiation element, or are disposed adjacent to the feeding radiation element. The first radiation element is also coupled through the shorting radiation element to the ground voltage. The third radiation element is disposed adjacent to the first radiation element. The third radiation element is coupled through the filter circuit to the proximity sensor. The filter circuit is also coupled through the tuning circuit to the ground voltage.

Inventors: **Kuo; Li-Kai (Hsinchu, TW), Ho; Wen-Pin (Hsinchu, TW), Chiang; Cheng-Wei (Hsinchu, TW), Zhu; Jia-Le (Hsinchu, TW)**

Applicant: **Wistron NeWeb Corp.** (Hsinchu, TW)

Family ID: **1000008764500**

Assignee: **WISTRON NEWEB CORP. (Hsinchu, TW)**

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2015/0171911	12/2014	Yang	455/280	H04W 4/80
2016/0065260	12/2015	Heikura	455/575.5	H04B 1/3838
2021/0351509	12/2020	Lin et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
202143554	12/2020	TW	N/A

Primary Examiner: Duong; Dieu Hien T

Attorney, Agent or Firm: McClure, Qualey & Rodack, LLP

Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

(1) This application claims priority of Taiwan Patent Application No. 112105906 filed on Feb. 18, 2023, the entirety of which is incorporated by reference herein.

BACKGROUND OF THE INVENTION

Field of the Invention

(2) The disclosure generally relates to an antenna structure, and more particularly, to a wideband antenna structure.

Description of the Related Art

(3) With the advancements being made in mobile communication technology, mobile devices such as portable computers, mobile phones, multimedia players, and other hybrid functional portable electronic devices have become more common. To satisfy consumer demand, mobile devices can usually perform wireless communication functions. Some devices cover a large wireless communication area; these include mobile phones using 2G, 3G, and LTE (Long Term Evolution) systems and using frequency bands of 700 MHz, 850 MHz, 900 MHz, 1800 MHz, 1900 MHz, 2100 MHz, 2300 MHz, and 2500 MHz. Some devices cover a small wireless communication area; these include mobile phones using Wi-Fi systems and using frequency bands of 2.4 GHz, 5.2 GHz, and 5.8 GHz.

(4) Antennas are indispensable elements for wireless communication. If an antenna used for signal

reception and transmission has insufficient bandwidth, it will negatively affect the communication quality of the mobile device in which it is installed. Accordingly, it has become a critical challenge for antenna designers to design a small-size, wideband antenna element.

BRIEF SUMMARY OF THE INVENTION

(5) In an exemplary embodiment, the invention is directed to an antenna structure that includes a ground element, a feeding radiation element, a first radiation element, a second radiation element, a shorting radiation element, a third radiation element, a filter circuit, a proximity sensor, and a tuning circuit. The ground element provides a ground voltage. The feeding radiation element has a feeding point. The first radiation element and the second radiation element are coupled to the feeding radiation element, or are disposed adjacent to the feeding radiation element. The first radiation element is also coupled through the shorting radiation element to the ground voltage. The third radiation element is disposed adjacent to the first radiation element. The third radiation element is coupled through the filter circuit to the proximity sensor. The filter circuit is also coupled through the tuning circuit to the ground voltage.

(6) In another exemplary embodiment, the invention is directed to a mobile device that includes an upper cover housing, a display frame, a camera element, and an antenna structure as mentioned above. The antenna structure is adjacent to the camera element. The camera element and the antenna structure are disposed between the upper cover housing and the display frame.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) The invention can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

(2) FIG. **1** is a diagram of an antenna structure according to an embodiment of the invention;

(3) FIG. **2** is a diagram of an antenna structure according to an embodiment of the invention;

(4) FIG. **3** is a diagram of an antenna structure according to an embodiment of the invention;

(5) FIG. **4** is a diagram of an antenna structure according to an embodiment of the invention; and

(6) FIG. **5** is a diagram of a mobile device according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

(7) In order to illustrate the purposes, features and advantages of the invention, the embodiments and figures of the invention are shown in detail as follows.

(8) Certain terms are used throughout the description and following claims to refer to particular components. As one skilled in the art will appreciate, manufacturers may refer to a component by different names. This document does not intend to distinguish between components that differ in name but not function. In the following description and in the claims, the terms “include” and “comprise” are used in an open-ended fashion, and thus should be interpreted to mean “include, but not limited to . . . ”. The term “substantially” means the value is within an acceptable error range. One skilled in the art can solve the technical problem within a predetermined error range and achieve the proposed technical performance. Also, the term “couple” is intended to mean either an indirect or direct electrical connection. Accordingly, if one device is coupled to another device, that connection may be through a direct electrical connection, or through an indirect electrical connection via other devices and connections.

(9) The following disclosure provides many different embodiments, or examples, for implementing different features of the provided subject matter. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. For example, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which

additional features may be formed between the first and second features, such that the first and second features may not be in direct contact. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

(10) Furthermore, spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper” and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. The spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

(11) FIG. **1** is a diagram of an antenna structure **100** according to an embodiment of the invention. The antenna structure **100** may be applied to a mobile device, such as a smart phone, a tablet computer, or a notebook computer. As shown in FIG. **1**, the antenna structure **100** includes a ground element **110**, a feeding radiation element **120**, a first radiation element **130**, a second radiation element **140**, a shorting radiation element **150**, a third radiation element **160**, a filter circuit **170**, a proximity sensor **180**, and a tuning circuit **190**. The ground element **110**, the feeding radiation element **120**, the first radiation element **130**, the second radiation element **140**, the shorting radiation element **150**, and the third radiation element **160** may all be made of metal materials, such as copper, silver, aluminum, iron, or their alloys.

(12) The ground element **110** is configured to provide a ground voltage VSS. For example, the ground element **110** may substantially have a rectangular shape, but it is not limited thereto. In some embodiments, the ground element **110** is implemented with a ground copper foil, which may be further coupled to a system ground plane (not shown) of the antenna structure **100**.

(13) The feeding radiation element **120** may substantially have a straight-line shape. Specifically, the feeding radiation element **120** has a first end **121** and a second end **122**. A feeding point FP is positioned at the first end **121** of the feeding radiation element **120**. The feeding point FP may be further coupled to a signal source **199**. For example, the signal source **199** may be an RF (Radio Frequency) module for exciting the antenna structure **100**.

(14) The first radiation element **130** may substantially have a relatively long straight-line shape, which may be substantially perpendicular to the feeding radiation element **120**. Specifically, the first radiation element **130** has a first end **131** and a second end **132**. The first end **131** of the first radiation element **130** is coupled to the second end **122** of the feeding radiation element **120**. The second end **132** of the first radiation element **130** is an open end.

(15) The second radiation element **140** may substantially have a relatively short straight-line shape (compared with the first radiation element **130**), which may also be substantially perpendicular to the feeding radiation element **120**. Specifically, the second radiation element **140** has a first end **141** and a second end **142**. The first end **141** of the second radiation element **140** is coupled to the second end **122** of the feeding radiation element **120**, and is also coupled to the first end **131** of the first radiation element **130**. The second end **142** of the second radiation element **140** is an open end. For example, the second end **132** of the first radiation element **130** and the second end **142** of the second radiation element **140** may substantially extend in opposite directions and away from each other. In some embodiments, the combination of the feeding radiation element **120**, the first radiation element **130**, and the second radiation element **140** substantially has a T-shape.

(16) The shorting radiation element **150** may substantially have an N-shape. Specifically, the shorting radiation element **150** has a first end **151** and a second end **152**. The first end **151** of the shorting radiation element **150** is coupled to the ground voltage VSS. The second end **152** of the shorting radiation element **150** is coupled to a connection point CP on the first radiation element **130**. In other words, the first radiation element **130** is coupled through the shorting radiation

element **150** to the ground voltage VSS.
(17) The third radiation element **160** may substantially have a variable-width straight-line shape, which may be adjacent to the first radiation element **130**. Specifically, the third radiation element **160** has a first end **161** and a second end **162**. The first end **161** of the third radiation element **160** is coupled to the filter circuit **170**. The second end **162** of the third radiation element **160** is an open end. For example, the second end **142** of the second radiation element **140** and the second end **162** of the third radiation element **160** may substantially extend in the same direction. In some embodiments, the third radiation element **160** includes a wide portion **164** adjacent to the first end **161** and a narrow portion **165** adjacent to the second end **162**. The narrow portion **165** is coupled through the wide portion **164** to the filter circuit **170**. In some embodiments, a first coupling gap GC**1** is formed between the first radiation element **130** and the wide portion **164** of the third radiation element **160**, and a second coupling gap GC**2** is formed between the first radiation element **130** and the narrow portion **165** of the third radiation element **160**. It should be noted that the term “adjacent” or “close” over the disclosure means that the distance (spacing) between two corresponding elements is smaller than a predetermined distance (e.g., 10 mm or the shorter), but often does not mean that the two corresponding elements directly touch each other (i.e., the aforementioned distance/spacing between them is reduced to 0).
(18) The internal structures of the filter circuit **170** and the tuning circuit **190** are not limited in the invention, and they are adjustable according to different requirements. For example, each of the filter circuit **170** and the tuning circuit **190** includes one or more inductors, one or more capacitors, and one or more resistors. The third radiation element **160** is coupled through the filter circuit **170** to the proximity sensor **180**. The filter circuit **170** is also coupled through the tuning circuit **190** to the ground voltage VSS. Generally, the third radiation element **160** is used as a sensing pad relative to the proximity sensor **180**, and the filter circuit **170** is configured to prevent the existence of the proximity sensor **180** from negatively affecting the radiation performance of the antenna structure **100**. In addition, the incorporating of the tuning circuit **190** can help to increase the operational bandwidth of the antenna structure **100**.
(19) In some embodiments, the antenna structure can cover a first frequency band, a second frequency band, a third frequency band, and a fourth frequency band. For example, the first frequency band may be from 617 MHz to 960 MHz, the second frequency band may be from 1452 MHz to 2000 MHz, the third frequency band may be from 2000 MHz to 2690 MHz, and the fourth frequency band may be from 3300 MHz to 5925 MHz. Accordingly, the antenna structure **100** can support at least the wideband operations of the next-generation 5G (5th Generation Mobile Networks) communication.
(20) In some embodiments, the operational principles of the antenna structure **100** will be described as follows. The feeding radiation element **120** and the first radiation element **130** can be excited to generate a fundamental resonant mode, thereby forming the first frequency band. The feeding radiation element **120** and the first radiation element **130** can also be excited to generate a higher-order resonant mode, thereby forming the second frequency band. The feeding radiation element **120** and the second radiation element **140** can be excited to generate another fundamental resonant mode, thereby forming the third frequency band. The feeding radiation element **120** and the second radiation element **140** can also be excited to generate another higher-order resonant mode, thereby forming the fourth frequency band. Furthermore, the third radiation element **160** can be excited by the first radiation element **130** using a coupling mechanism. According to practical measurements, the third radiation element **160**, the filter circuit **170**, and the tuning circuit **190** can fine-tune the impedance matching of the first frequency band and the second frequency band, so as to effectively increase the operational bandwidths thereof.
(21) In some embodiments, the element sizes of the antenna structure **100** will be described as follows. The total length LA of the feeding radiation element **120** and the first radiation element **130** may be shorter than 0.25 wavelength (λ/4) of the first frequency band of the antenna structure

100. The total length LB of the feeding radiation element **120** and the second radiation element **140** may be substantially equal to 0.25 wavelength (λ/4) of the third frequency band of the antenna structure **100**. In the third radiation element **160**, the width W**1** of the wide portion **164** may be at least twice the width W**2** of the narrow portion **165**. The width of the first coupling gap GC**1** may be wider than or equal to 3 mm. The width of the second coupling gap GC**2** may be shorter than or equal to 3 mm. The above ranges of element sizes are calculated and obtained according to many experiment results, and they help to optimize the operational bandwidth and impedance matching of the antenna structure **100**, and to reduce the interference between the proximity sensor **180** and other radiation elements.

(22) The following embodiments will introduce different configurations and detailed structural features of the antenna structure **100**. It should be understood that these figures and descriptions are merely exemplary, rather than limitations of the invention.

(23) FIG. **2** is a diagram of an antenna structure **200** according to an embodiment of the invention. FIG. **2** is similar to FIG. **1**. In the embodiment of FIG. **2**, a filter circuit **270** of the antenna structure **200** includes a first inductor L**1**, a second inductor L**2**, a capacitor C**1**, and a resistor R**1**. Also, a tuning circuit **290** of the antenna structure **200** includes a short-circuited path **291**, a capacitive path **292**, an open-circuited path **293**, an inductive path **294**, and a switch element **295**.

(24) The capacitor C**1** has a first terminal coupled to a first node N**1**, and a second terminal coupled to a second node N**2**. The first node N**1** may be further coupled to the first end **161** or the wide portion **164** of the third radiation element **160**. The first inductor L**1** has a first terminal coupled to the second node N**2**, and a second terminal coupled to the ground voltage VSS. The second inductor L**2** has a first terminal coupled to a third node N**3**, and a second terminal coupled to the first node N**1**. The resistor R**1** has a first terminal coupled to the third node N**3**, and a second terminal coupled to the proximity sensor **180**.

(25) In the filter circuit **270**, the first capacitor C**1** can be used as a high-pass filter element, so as to prevent low-frequency noise of the proximity sensor **180** from entering the tuning circuit **290**. According to practical measurements, the incorporation of the first inductor L**1** can reduce the probability of the proximity sensor **180** taking error actions when the tuning circuit **290** is switched. The second inductor L**2** can be used as a low-pass filter element, so as to prevent the proximity sensor **180** from negatively affecting the radiation performance of the antenna structure **200**. In addition, the resistor R**1** can reduce the interference between the proximity sensor **180** and other radiation elements.

(26) The short-circuited path **291**, the capacitive path **292**, the open-circuited path **293**, and the inductive path **294** are respectively coupled to the ground voltage VSS of the ground element **110**. A terminal of the switch element **295** is coupled to the second node N**2**. Another terminal of the switch element **295** is switchable between the short-circuited path **291**, the capacitive path **292**, the open-circuited path **293**, and the inductive path **294** according to a control signal SC. Thus, the second node N**2** can be coupled through the path selected by the switch element **295** to the ground voltage VSS. For example, the control signal SC may be generated by a processor (not shown) according to a user input, but it is not limited thereto.

(27) When the switch element **295** is switched between the short-circuited path **291**, the capacitive path **292**, the open-circuited path **293**, and the inductive path **294**, a grounding impedance value of the antenna structure **200** can be adjusted correspondingly. According to practical measurements, such a design can help to significantly increase the operational bandwidth of the antenna structure **200**, especially for the first frequency band and the second frequency band as mentioned above.

(28) In some embodiments, the element parameters of the antenna structure **200** will be described as follows. The inductance of the first inductor L**1** may be greater than or equal to 56 nH. The inductance of the second inductor L**2** may be greater than or equal to 56 nH. The capacitance of the capacitor C**1** may be from 10 pF to 180 pF. The resistance of the resistor R**1** may be from 0 Ω to 10 KΩ. The capacitance of the capacitive path **292** may be from 1 pF to 47 pF. The inductance of the

inductive path **294** may be from 10 nH to 56 nH. The above ranges of element parameters are calculated and obtained according to many experiment results, and they help to minimize the impact of the proximity sensor **180** and to optimize the radiation performance of the antenna structure **200**. Other features of the antenna structure **200** of FIG. **2** are similar to those of the antenna structure **100** of FIG. **1**. Therefore, the two embodiments can achieve similar levels of performance.

(29) FIG. **3** is a diagram of an antenna structure **300** according to an embodiment of the invention. FIG. **3** is similar to FIG. **2**. In the embodiment of FIG. **3**, a filter circuit **370** of the antenna structure **300** does not include the resistor R**1** as mentioned above, but further includes a third inductor L**3**. Specifically, the third inductor L**3** has a first terminal coupled to the third node N**3**, and a second terminal coupled to the proximity sensor **180**. For example, the inductance of the third inductor L**3** may be from 10 nH to 330 nH, but it is not limited thereto. According to practical measurements, the third inductor L**3** can also reduce the interference between the proximity sensor **180** and other radiation elements. Other features of the antenna structure **300** of FIG. **3** are similar to those of the antenna structure **200** of FIG. **2**. Therefore, the two embodiments can achieve similar levels of performance.

(30) FIG. **4** is a diagram of an antenna structure **400** according to an embodiment of the invention. FIG. **4** is similar to FIG. **1**. In the embodiment of FIG. **4**, a feeding radiation element **420** of the antenna structure **400** substantially has a T-shape, which is adjacent to but separate from the first radiation element **130** and the second radiation element **140**. Specifically, the feeding radiation element **420** has a first end **421**, a second end **422**, and a third end **423**. The first end **421** of the feeding radiation element **420** is coupled to the feeding point FP and the signal source **199**. Each of the second end **422** and the third end **423** of the feeding radiation element **420** is an open end. A third coupling gap GC**3** may be formed between the feeding radiation element **420** and the first radiation element **130** or the second radiation element **140**. The width of the third coupling gap GC**3** may be shorter than or equal to 3 mm. According to practical measurements, the first radiation element **130** and the second radiation element **140** can be excited by the feeding radiation element **420** using a coupling mechanism, such that the antenna structure **400** can still support the wideband operations as mentioned above. Other features of the antenna structure **400** of FIG. **4** are similar to those of the antenna structure **100** of FIG. **1**. Therefore, the two embodiments can achieve similar levels of performance.

(31) FIG. **5** is a diagram of a mobile device **500** according to an embodiment of the invention. In the embodiment of FIG. **5**, the aforementioned antenna structure **100** (or **200** or **300** or **400**) can be applied in the mobile device **500**. The mobile device **500** is a notebook computer which includes an upper cover housing **510**, a display frame **520**, a keyboard frame **530**, and a base housing **540**. It should be understood that the upper cover housing **510**, the display frame **520**, the keyboard frame **530**, and the base housing **540** are equivalent to the so-called “A-component”, “B-component”, “C-component” and “D-component” in the field of notebook computers, respectively. In addition, the mobile device **500** may further include a hinge element **550**, a display device **560**, a keyboard **570**, a touch control panel **580**, and a camera element **595**. The aforementioned antenna structure **100** may be disposed at a first position **591** and/or a second position **592** of the mobile device **500**. Both of the antenna structure **100** and the camera element **595** are disposed between the upper cover housing **510** and the display frame **520**. Furthermore, both of the first position **591** and the second position **592** are adjacent to the camera element **595** of the mobile device **500**. In some embodiments, the first distance D**1** between the first position **591** and the first edge **521** of the display frame **520** may be longer than or equal to 10 mm. Also, the second distance D**2** between the second position **592** and the second edge **522** of the display frame **520** may be longer than or equal to 10 mm. According to practical measurements, if the first distance D**1** and the second distance D**2** fall within the above ranges, they can help to maintain the good communication quality provided by the antenna structure **100**.

(32) The invention proposes a novel antenna structure. In comparison to the conventional design, the invention has at least the advantages of small size, wide bandwidth, and lower manufacturing cost. Therefore, the invention is suitable for application in a variety of mobile communication devices, in particular to the devices with narrow borders.
(33) Note that the above element sizes, element shapes, element parameters, and frequency ranges are not limitations of the invention. An antenna designer can fine-tune these settings or values in order to meet specific requirements. It should be understood that the antenna structure and the mobile device of the invention are not limited to the configurations depicted in FIGS. **1-5**. The invention may merely include any one or more features of any one or more embodiments of FIGS. **1-5**. In other words, not all of the features displayed in the figures should be implemented in the antenna structure and the mobile device of the invention.
(34) Use of ordinal terms such as “first”, “second”, “third”, etc., in the claims to modify a claim element does not by itself connote any priority, precedence, or order of one claim element over another or the temporal order in which acts of a method are performed, but are used merely as labels to distinguish one claim element having a certain name from another element having the same name (but for use of the ordinal term) to distinguish the claim elements.
(35) While the invention has been described by way of example and in terms of the preferred embodiments, it should be understood that the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

Claims

1. An antenna structure, comprising: a ground element, providing a ground voltage; a feeding radiation element, having a feeding point; a first radiation element; a second radiation element, wherein the first radiation element and the second radiation element are coupled to the feeding radiation element or are adjacent to the feeding radiation element; a shorting radiation element, wherein the first radiation element is coupled through the shorting radiation element to the ground voltage; a third radiation element, disposed adjacent to the first radiation element; a filter circuit; a proximity sensor, wherein the third radiation element is coupled through the filter circuit to the proximity sensor; and a tuning circuit, wherein the filter circuit is coupled through the tuning circuit to the ground voltage.
2. The antenna structure as claimed in claim 1, wherein the feeding radiation element substantially has a straight-line shape or a T-shape.
3. The antenna structure as claimed in claim 1, wherein the first radiation element and the second radiation element substantially extend in opposite directions and away from each other.
4. The antenna structure as claimed in claim 1, wherein the shorting radiation element substantially has an N-shape.
5. The antenna structure as claimed in claim 1, wherein the third radiation element substantially has a variable-width straight-line shape.
6. The antenna structure as claimed in claim 1, wherein the third radiation element comprises a wide portion and a narrow portion, and the narrow portion is coupled through the wide portion to the filter circuit.
7. The antenna structure as claimed in claim 6, wherein a first coupling gap is formed between the first radiation element and the wide portion of the third radiation element, and a width of the first coupling gap is wider than or equal to 3 mm.
8. The antenna structure as claimed in claim 6, wherein a second coupling gap is formed between the first radiation element and the narrow portion of the third radiation element, and a width of the

second coupling gap is shorter than or equal to 3 mm.
9. The antenna structure as claimed in claim 1, wherein a third coupling gap is formed between the feeding radiation element and the first radiation element or the second radiation element, and a width of the third coupling gap is shorter than or equal to 3 mm.
10. The antenna structure as claimed in claim 1, wherein the filter circuit comprises: a capacitor, wherein the capacitor has a first terminal coupled to a first node, and a second terminal coupled to a second node; wherein the first node is coupled to the third radiation element.
11. The antenna structure as claimed in claim 10, wherein the filter circuit further comprises: a first inductor, wherein the first inductor has a first terminal coupled to the second node, and a second terminal coupled to the ground voltage.
12. The antenna structure as claimed in claim 10, wherein the filter circuit further comprises: a second inductor, wherein the second inductor has a first terminal coupled to a third node, and a second terminal coupled to the first node.
13. The antenna structure as claimed in claim 12, wherein the filter circuit further comprises: a resistor, wherein the resistor has a first terminal coupled to the third node, and a second terminal coupled to the proximity sensor.
14. The antenna structure as claimed in claim 12, wherein the filter circuit further comprises: a third inductor, wherein the third inductor has a first terminal coupled to the third node, and a second terminal coupled to the proximity sensor.
15. The antenna structure as claimed in claim 10, wherein the tuning circuit comprises: a short-circuited path, coupled to the ground voltage; a capacitive path, coupled to the ground voltage; an open-circuited path, coupled to the ground voltage; an inductive path, coupled to the ground voltage; and a switch element, wherein a terminal of the switch element is coupled to the second node, and another terminal of the switch element is switchable between the short-circuited path, the capacitive path, the open-circuited path, and the inductive path according to a control signal.
16. The antenna structure as claimed in claim 1, wherein the antenna structure covers a first frequency band, a second frequency band, a third frequency band, and a fourth frequency band.
17. The antenna structure as claimed in claim 16, wherein the first frequency band is from 617 MHz to 960 MHz, the second frequency band is from 1452 MHz to 2000 MHz, the third frequency band is from 2000 MHz to 2690 MHz, and the fourth frequency band is from 3300 MHz to 5925 MHz.
18. The antenna structure as claimed in claim 16, wherein a total length of the feeding radiation element and the first radiation element is shorter than 0.25 wavelength of the first frequency band.
19. The antenna structure as claimed in claim 16, wherein a total length of the feeding radiation element and the second radiation element is substantially equal to 0.25 wavelength of the third frequency band.
20. A mobile device, comprising: an upper cover housing; a display frame; a camera element; and an antenna structure as claimed in claim 1; wherein the antenna structure is adjacent to the camera element; wherein the camera element and the antenna structure are disposed between the upper cover housing and the display frame.