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(54) GROUNDED ANTENNA HAVING U-SHAPED HIGH-IMPEDANCE SURFACE METAL STRIPS AND WIRELESS COMMUNICATION DEVICE HAVING SAID ANTENNA

(57) Disclosed are a grounded antenna having U-shaped high-impedance surface metal strips and wireless communication device having said antenna. The antenna is disposed inside of a housing, and comprises an antenna radiation unit and a ground plate thereof; disposed in intervals on the ground plate are multiple high-impedance surface units; each high-impedance surface unit consists of three high-impedance surface metal strips connected to one another, arranged to form a U-shape; a high-impedance surface through hole is made at the bottom of the U-shape, and through holes connect the high-impedance surface metal strips of the high-impedance surface units. By means of multiple U-shaped high-impedance surface units, surface waves are repressed or deterred from transmitting along the surface, and incident plane waves perpendicular to the surface are reflected at the same phase. High-impedance surface has the characteristics of suppressing surface waves, and can therefore, when placed around an antenna, reduce the radiation toward a person's head, lower the specific absorption rate without reducing the radiation capability of the antenna or compromising communication quality. The present invention is universally applicable.

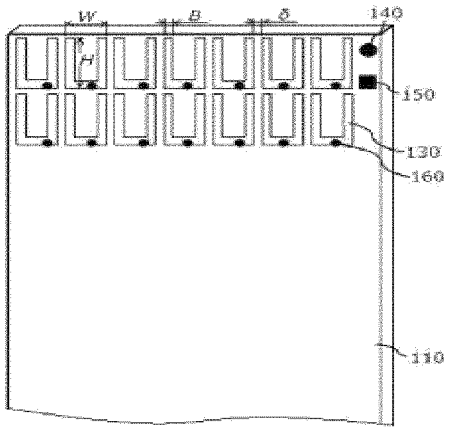

Figure 2

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Description

[0001] Field of the Invention

[0002] The present invention relates to the antenna field of wireless communication devices, and more specifically to an antenna grounded with U-shaped high-impedance surface metal strips and its wireless communication device.

[0003] Background Technology

[0004] The radio waves transmitted by a wireless communication device during communications expose the user to measurable radio frequency (RF) radiation. When a user uses a mobile terminal such as a mobile phone to make a call, the head of the user is always within the electromagnetic radiation field emitted by the mobile phone. Therefore, many countries including the People's Republic of China have issued complete and safe standards and specifications to manage and restrict the problem of exposure of RF energy. Here, the specific absorption rate (SAR) is an important evaluation parameter, which refers to the electromagnetic wave energy absorption rate of mobile phones or wireless communication products. Popularly, SAR is used to measure whether the influence of mobile phone radiation upon the body of a user, especially, the head of the user conforms to the relevant standards. SAR is also a unit for measuring the amount of RF energy absorbed by the body when using a mobile phone, and is used as a criterion for body protection.

[0005] Presently, mobile terminals have been designed for use in such very rigid limitations, so various devices and methods are being developed to reduce the SAR, for example, materials for absorbing electromagnetic waves are added to mobile terminals, or metal parts are arranged properly to optimize the RF- induced current, complicated antenna design is used to reduce the SAR, and so on. However, these design methods are easily to be affected by the type of mobile terminals, so they do not have generality and universal applicability.

[0006] Therefore, there is a need to improve and develop the prior art.

[0007] Description of the Invention

[0008] The purpose of the present invention is to provide an antenna grounded with U-shaped high-impedance surface metal strips and its wireless communication device, which not only can reduce the antenna radiation on human body, but also can avoid the influence upon communication quality, and furthermore, it has the universal applicability.

[0009] The technical scheme of the present invention is as follows: an antenna grounded with U-shaped high-impedance surface metal strips, comprising an antenna radiation unit and its ground plate, wherein a plurality of high-impedance surface units are set on the ground plate at relevant intervals; each high-impedance surface unit consists of three high-impedance surface metal strips connected to each other in U shape; high-impedance surface through holes are set at the bottom side of the U shape; and the high-impedance surface units are connected to each other by means of the high-impedance surface through holes.

[0010] In said antenna grounded with U-shaped high-impedance surface metal strips, the ground plate is a printed circuit board (PCB), the high-impedance surface units are located on the surface of the PCB, and the high-impedance surface through holes are set to pass through the PCB.

[0011] In said antenna with grounded with U-shaped high-impedance surface metal strips, wherein the line breadth of the high-impedance surface metal strip is 1 mm, the width of the U-shaped high-impedance surface unit is 6 mm, the height of the U-shaped high-impedance surface unit is 8 mm, and the interval between the high-impedance surface units is 0.5 mm.

[0012] In said antenna grounded with U-shaped high-impedance surface metal strips, the U-shaped high-impedance surface units are set on the ground plate to form rows.

[0013] In said antenna grounded with U-shaped high-impedance surface metal strips, wherein the high-impedance surface metal strips on the bottom side of the U shape are set to be in parallel with the rows formed by the high-impedance surface units.

[0014] In said antenna grounded with U-shaped high-impedance surface metal strips, wherein the U-shaped high-impedance surface units are set on the ground plate to form columns.

[0015] In said antenna grounded with U-shaped high-impedance surface metal strips, wherein the high-impedance surface metal strips on both sides of the U shape is set to be in parallel with the columns formed by the high-impedance surface units.

[0016] In said antenna grounded with U-shaped high-impedance surface metal strips, wherein the corresponding high-impedance metal strips between the U-shaped high-impedance surface units are set to be in parallel with each other.

[0017] In said antenna grounded with U-shaped high-impedance surface metal strips, wherein characterized in that the antenna radiation unit is a planar inverted F-type antenna.

[0018] A wireless communication device, which comprises a case and an antenna for communications, the antenna being set outside the case and comprising the antenna radiation unit and its ground plate; wherein a plurality of high-impedance surface units are set on the ground plate at relevant intervals; each high-impedance surface unit consists of three high-impedance surface metal strips connected to each other in U shape; high-impedance surface through holes are set at the bottom side of the U shape; and the high-impedance surface units are connected to each other by means of the high-impedance surface through holes.

[0019] The antenna grounded with U-shaped high-impedance surface metal strips and its wireless communication device according to the present invention uses a

plurality of high-impedance surface units connected to each other by means of high-impedance surface through holes and formed to a U shape by three high-impedance surface metal strips, such that on one hand the propagation of surface waves along its surface is suppressed or blocked, and on the other hand the same phase reflects the incident plane wave perpendicular to its surface; the capability of the high-impedance surface in suppressing surface waves is utilized, and said high-impedance surface is placed around the antenna, which reduces the radiation in the head direction (that is, the radiation of the antenna of the wireless communication device in the human body direction is reduced), decreases the SAR, and meanwhile, it does not weaken the energy of the plane wave, avoids the influence upon the signal strength, does not reduce the antenna radiation performance, does not affect the communication quality, and has generality and universal applicability.

[0020] Brief Description of the Drawings

[0021] Figure 1 is the schematic diagram of the spatial structure of the antenna grounded with U-shaped high-impedance surface metal strips in the present invention.

[0022] Figure 2 is the schematic diagram of the U-shaped high-impedance surface unit set on the ground plate in the present invention.

[0023] Figure 3 is the side view of the structure of the antenna grounded with U-shaped high-impedance surface metal strips in the present invention.

[0024] Figure 4 is the schematic diagram of operating principle of the U-shaped high-impedance surface unit set on the ground plate in the present invention.

[0025] Figure 5 is the schematic diagram of equivalent circuit of the U-shaped high-impedance surface unit set on the ground plate in the present invention.

[0026] Figure 6 shows the comparison between the return loss test curves of the antenna with the U-shaped high-impedance surface units and the antenna without the U-shaped high-impedance surface units in the wireless communication unit of the present invention.

[0027] Figure 7 shows the comparison between the SAR test curves of the antenna with the U-shaped high-impedance surface units and the antenna without the U-shaped high-impedance surface units in the wireless communication unit of the present invention.

[0028] Particular Embodiments

[0029] In the following, particular implementation modes and embodiments of the present invention will be further described with the combination of the drawings. The particular embodiments described here are used only for explaining the present invention and are not intended to limit the specific modes of implementing the present invention.

[0030] In one embodiment as shown in Figure 1, the antenna grounded with U-shaped high-impedance surface metal strips of the present invention comprises an antenna radiation unit 120 and its ground plate 110; wherein a plurality of high-impedance surface units are set on the ground plate 110 at relevant intervals; each high-impedance surface unit consists of three high-impedance surface metal strips 130 connected to each other in U shape; high-impedance surface through holes 160 are set in the high-impedance surface metal strips 130 at the bottom side of the U shape; and the high-impedance surface metal strips 130 between the high-impedance surface units are connected to each other by means of the high-impedance surface through holes 160.

[0031] Based on the antenna grounded with U-shaped high-impedance surface metal strips 130, the present invention also provides a wireless communication unit, which in one embodiment comprises a case and an antenna for communications; the antenna is set inside the case and comprises an antenna radiation unit 120 and its ground plate 110; wherein a plurality of high-impedance surface units are set on the ground plate 110 at relevant intervals; each high-impedance surface unit consists of three high-impedance surface metal strips 130 connected to each other in U shape; high-impedance surface through holes 160 are set in the high-impedance surface metal strips 130 at the bottom side of the U shape; and the high-impedance surface metal strips 130 between the high-impedance surface units are connected to each other by means of the high-impedance surface through holes 160.

[0032] Said high-impedance surface of the present invention refers to the surface structure that is built on the ground plate 110 of the antenna and can block the propagation of electromagnetic waves, that is, it has high-impedance characteristics to surface waves at a certain band; specifically, on one hand, it can suppress surface waves of frequencies propagated on its surface within its stopbands or does not support the propagation of surface waves of certain bands within its stopbands; on the other hand, it has the same-phase reflection effect for plane waves of incident frequencies perpendicular to its surface within its stopbands, that is, the phases of the reflection wave and incident wave do not change. Specifically, said ground plate 110 refers to the whole PCB, and the high-impedance surface replaces the partial ground plate 110 under the antenna.

[0033] For the incident plane wave perpendicular to the metal surface, the metal surface will make the phase of the plane wave changes for 180 degrees. If the ground plate 110 of the antenna is a complete metal plate, its surface propagates surface waves, and its impedance to surface waves is zero, no matter whether the frequency is within its stopband. Compared with an antenna grounded with a complete metal plate and its wireless communication device in the prior art, the antenna grounded with U-shaped high-impedance surface metal strips and its wireless communication device of the present invention can suppress or block the propagation of surface waves along its surface on one hand and can also reflect the incident plane waves perpendicular to its surface on the other hand, because it has the high-impedance surface units connected to each other by means of a plurality of high-impedance surface through holes 160 and three

high-impedance surface metal strips 130 form a U shape. The characteristic of the high-impedance surface to suppress surface waves is utilized, and said high-impedance surface is placed around the antenna, which reduces the radiation in the head direction (that is, the radiation of the antenna of the wireless communication device in the human body direction is reduced), decreases the SAR, and meanwhile, it does not weaken the energy of the plane wave, avoids the influence upon the signal strength, does not reduce the antenna radiation performance, does not affect the communication quality, and has generality and universal applicability.

[0034] Suppose that the antenna radiation unit 120 is a planar inverted F-type antenna, as shown in Figure 1, there are two branches parts with open circuits at terminals in the antenna radiation unit 120. Its operating principle is one-fourth wavelength resonance; the wider and shorter one on the external side is the high-frequency branch part, and the narrower and longer one on the internal side is the low-frequency branch part. It is connected to the FR transmit/receive circuit of the PCB by means of the ground pin 140 of the antenna radiation unit 120 and the feed pin 150 of the antenna radiation unit 120.

[0035] In a preferred embodiment of the antenna grounded with U-shaped high-impedance surface metal strips 130 and its wireless communication device of the present invention, as shown in Figure 2, the ground plate 110 is a PCB; the high-impedance surface units are located on the surface of the PCB; the high-impedance surface through holes 160 are set to pass through the PCB; the copper-clad layer on the surface of the PCB is used to make the U-shaped high-impedance surface metal strips 130, and the through holes on the PCB are used to make the high-impedance surface through holes 160.

[0036] Preferably, as shown in Figure 3, the high- impedance surface through holes 160 are set to pass through the PCB, the U- shaped high- impedance surface metal strips 130 are electrically connected to the lower surface metal layer of the PCB by means of the high-impedance surface through holes 160 at the bottom side, to implement grounding of the high- impedance surface units.

[0037] Specifically, the U- shaped high- impedance surface metal strips 130 are set on the upper surface of the PCB, and the lower surface of the PCB is composed of a complete metal layer. The U- shaped high- impedance surface metal strips 130 are laid on the upper surface of the metal PCB as much as possible, especially in the lower region covered by the antenna radiation unit 120 to replace the original complete metal layer to serve as the new ground plane of the antenna radiation unit 120, to implement the transition of a zero- ohm ground plane to a ground plane with infinite impedance.

[0038] Preferably, as shown in Figure 2, the line breadth (B) of the high- impedance surface metal strip 130 is 1 mm, the width (W) of the U- shaped high- impedance surface unit is 6 mm, the height (H) of the U-shaped high- impedance surface unit is 8 mm, and the interval (δ) between the high- impedance surface units is 0.5 mm.

[0039] Further, the U- shaped high- impedance surface units are set on the ground plate 110; wherein, the high- impedance surface metal strips 130 on the bottom side of the U shape are set to be in parallel with the rows formed by the high- impedance surface units. And the U-shaped high- impedance surface units are set on the ground plate 110 to form columns; wherein, the high-impedance surface metal strips 130 on both sides of the U shape are set to be in parallel with the columns formed by the high- impedance surface units.

[0040] Preferably, the corresponding high- impedance metal strips between the U- shaped high- impedance surface units are set to be in parallel with each other.

[0041] Of course, the high-impedance surface metal strips 130 at both sides and/or at the bottom in the U-shaped high-impedance surface units can form slanted rows or columns with the high-impedance surface units.

[0042] The dielectric constant and thickness of the PCB will affect the structural size of the U-shaped metal strips, so during the design the length and width of the U-shaped metal strips and the intervals among the U-shaped metal strips can be adjusted properly to optimize the operating band of the high-impedance surface unit so that it is located within the transmit (Tx) channel range of the communication mode.

[0043] The antenna and its wireless communication device of the present invention uses the U-shaped high-impedance surface metal strips 130 for grounding, and the electromagnetic characteristics of this structure can be described with IC components, capacitance and inductance. Its equivalent circuit parameter is presented with a parallel resonance LC circuit, as shown in Figure 5, its function can be regarded as a two-dimensional electric filter to block the current from flowing along its surface.

[0044] As shown in Figure 4, when the U-shaped metal strips and the ground through holes interact with electromagnetic waves, an induced current is generated on the U-shaped metal strips, which is in parallel with the voltage function at the top surface, resulting in accumulative charges at both ends of the U-shaped metal strips. Therefore, it can be equivalent to the capacitive effect. However, charges flow from and to the metal through holes and the lower surface of the PCB to form a current loop, which is connected to the magnetic field and inductance. Figure 4 shows its capacitance and inductance, and Figure 5 shows its equivalent resonance circuit.

[0045] When lower than the resonance frequency, the surface impedance presents inductance; when higher than the resonance frequency, the surface impedance presents capacitance; at the proximity of the resonance frequency, the surface impedance is a very large value, which is equivalent to an infinite value. During design, if the resonance of the unit structure of the U-shaped metal strips and through holes is made be within the wireless Tx channel band of the communication mode, the struc-

ture will generate an infinite impedance within this band to block the pass of the RF surface current, so as to reduce the SAR within this band.

[0046] As shown in Figure 6, the dotted line A shows the return loss test curve of the planar inverted F-type antenna when the high-impedance surface units are grounded; the solid line B shows the return loss test curve of the planar inverted F-type antenna when the high-impedance surface units are not grounded. The curve A shows that the U-shaped high-impedance surface metal strips 130 and the high-impedance surface through holes 160 do not have great influence. Therefore, the radiation performance is basically not affected.

[0047] As shown in Figure 7, the dotted line A shows the SAR test curve of the planar inverted F-type antenna when the high-impedance surface units are grounded; the solid line B shows the SAR test curve of the planar inverted F-type antenna when the high-impedance surface units are not grounded. The curve A shows that the U-shaped high-impedance surface metal strips 130 and the high-impedance surface through holes 160 can effectively reduce the SAR, and the SAR of the same frequency can be reduced by about 30%.

[0048] It should be understood that the above are only preferred embodiments of the present invention and are not intended to limit the technical scheme of the present invention. Without departing from the spirit and principle of the present invention, those skilled in the art can add, decrease, replace, change or improve the present invention according to the preceding descriptions, for example, the antenna radiation unit 120 includes but is not limited to the planar inverted F-type antenna (e.g., it can be a multi-band antenna). Therefore, all technical schemes after such addition, decrease, replacement, change or improvement should fall within the protection scope defined by the accompany claims of the present invention.

Claims

1. An antenna grounded with U-shaped high-impedance surface metal strips, comprising an antenna radiation unit and its ground plate, wherein a plurality of high-impedance surface units are set on the ground plate at relevant intervals; each high-impedance surface unit consists of three high-impedance surface metal strips connected to each other in U shape; high-impedance surface through holes are set at the bottom side of the U shape; and the high-impedance surface units are connected to each other by means of the high-impedance surface through holes.

2. The antenna grounded with U-shaped high-impedance surface metal strips according to claim 1, wherein the ground plate is a printed circuit board (PCB), the high-impedance surface units are located on the surface of the PCB, and the high-impedance surface through holes are set to pass through the PCB.

3. The antenna grounded with U-shaped high-impedance surface metal strips according to claim 1, wherein the line breadth of the high-impedance surface metal strip is 1 mm, the width of the U-shaped high-impedance surface unit is 6 mm, the height of the U-shaped high-impedance surface unit is 8 mm, and the interval between the high-impedance surface units is 0.5 mm.

4. The antenna grounded with U-shaped high-impedance surface metal strips according to claim 1, wherein the U-shaped high-impedance surface units are set on the ground plate to form rows.

5. The antenna grounded with U-shaped high-impedance surface metal strips according to claim 4, wherein the high-impedance surface metal strips on the bottom side of the U shape are set to be in parallel with the rows formed by the high-impedance surface units.

6. The antenna grounded with U-shaped high-impedance surface metal strips according to claim 1, wherein the U-shaped high-impedance surface units are set on the ground plate to form columns.

7. The antenna grounded with U-shaped high-impedance surface metal strips according to claim 6, wherein the high-impedance surface metal strips on the both sides of the U shape are set to be in parallel with the columns formed by the high-impedance surface units.

8. The antenna grounded with U-shaped high-impedance surface metal strips according to claim 1, wherein the corresponding high-impedance metal strips between the U-shaped high-impedance surface units are set to be in parallel with each other.

9. The antenna grounded with U-shaped high-impedance surface metal strips according to claims 1 through 8, wherein the antenna radiation unit is a planar inverted F-type antenna.

10. A wireless communication device, which comprises a case and an antenna for communications, the antenna being set outside the case and comprising an antenna radiation unit and its ground plate, wherein a plurality of high-impedance surface units are set on the ground plate at relevant intervals; each high-impedance surface unit consists of three high-impedance surface metal strips connected to each other in U shape; high-impedance surface through holes are set at the bottom side of the U shape; and the high-impedance surface units are connected to each

other by means of the high-impedance surface through holes.

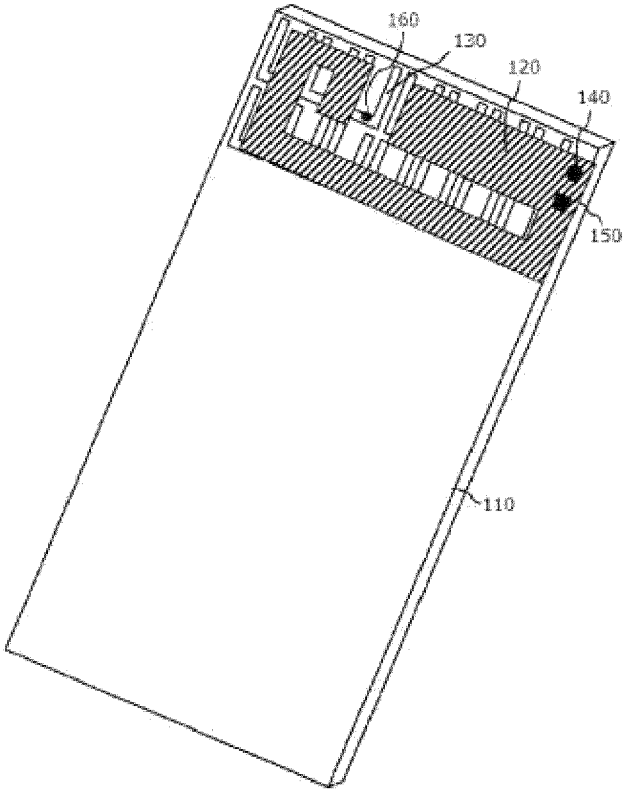

Figure 1

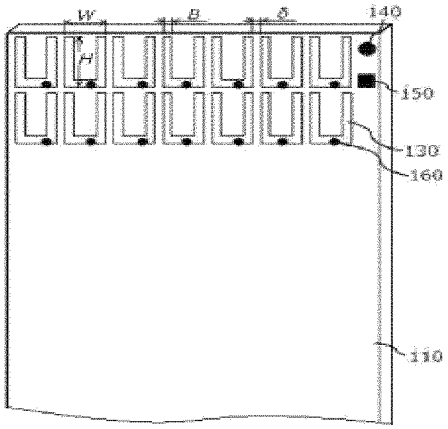

Figure 2

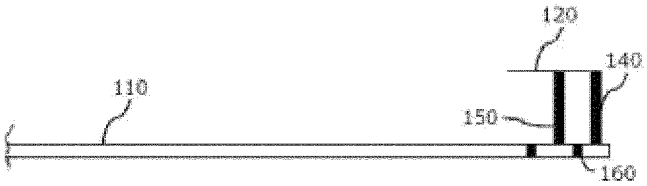

Figure 3

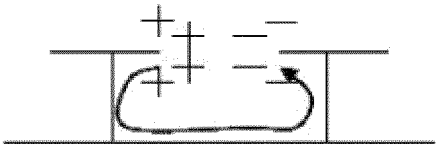

Figure 4

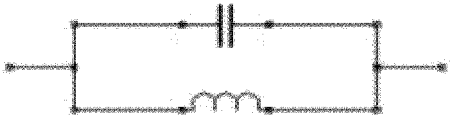

Figure 5

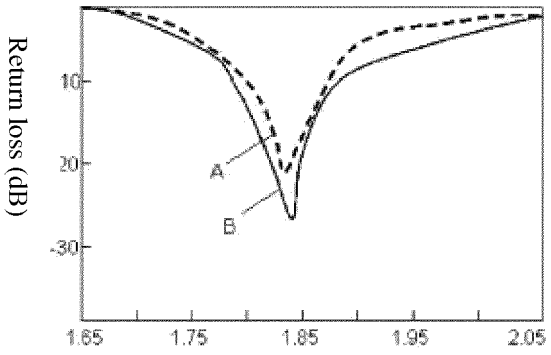

Figure 6

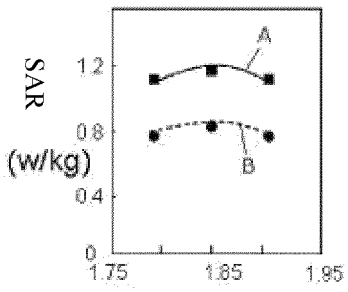

Figure 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2011/081837

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 1/48 (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; H01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, VEN, CNKI, IEEE: EBG, PBG, electromagnetic forbidden band, photonic forbidden band, photonic crystal, electromagnetic bandgap, photonic bandgap, FSS, via hole, metal post, shorting-pin, HIGH IMPEDANCE SURFACE, ELECTROMAGNETIC, PHOTONIC, BANDGAP, FREQUENCY SELECTIVE SURFACE, VIA, HOLE, SHORT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 101320845 A (THE INSTITUTE OF OPTICS AND ELECTRONICS, CHINESE ACADEMY OF SCIENCES), 10 December 2008 (10.12.2008), the whole document	1-10
A	CN 101188329 A (TONGJI UNIVERSITY), 28 May 2008 (28.05.2008), the whole document	1-10
A	CN 201084827 Y (DACHANG ELECTRONIC TECHNOLOGY (SUZHOU) CO., LTD. et al.), 09 July 2008 (09.07.2008), the whole document	1-10
PX	CN 102044752 A (HUIZHOU TCL MOBILE COMMUNICATION CO., LTD.), 04 May 2011 (04.05.2011), the whole document	1-10
PX	CN 201946752 U (HUIZHOU TCL MOBILE COMMUNICATION CO., LTD.), 24 August 2011 (24.08.2011), the whole document	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 January 2012 (20.01.2012)	**23 February 2012 (23.02.2012)**
Name and mailing address of the ISA/CN: State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Fax No.: (86-10) 62019451	Authorized officer **JIANG, Shan** Telephone No.: (86-10) **62411476**

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2011/081837

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 101320845 A	10.12.2008	None	
CN 101188329 A	28.05.2008	CN 101188329 B	22.06.2011
CN 201084827 Y	09.07.2008	None	
CN 102044752 A	04.05.2011	None	
CN 201946752 U	24.08.2011	None	

Form PCT/ISA/210 (patent family annex) (July 2009)