Design of Wide-Band PIFA (GSM 850 to WiMAX) for Mobile Handset

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Abstract A novel planar inverted-F antenna (PIFA) with dual-shorting point is proposed for multiband mobile communication applications. The antenna comprises a main strip, a parasitic strip, and a slotted ground plane. For enhancing the bandwidth of DCS/PCS/UMTS and LTE 2 300/2 500, the antenna applies dual-shorting point design to generate multimode between 1 707～2815 MHz. The antenna upper band is formed by the higher-order resonant mode contributed by the parasitic strip and can cover the desired 3387～3627 MHz. The proposed antenna has good impedance matching characteristics for GSM (824～960 MHz)/DCS (1 710～1 880 MHz)/PCS (1 850～1 990 MHz)/UMTS (1 920～2 170 MHz)/LTE (2 300～2 400 MHz, 2 500～2 690 MHz)/802.11b (2.4～2.48 GHz) and Wi-MAX (3.4～3.6 GHz). The measured radiation efficiency of proposed antenna is higher than 52% in GSM 850/900, DCS/PCS, UMTS, LTE 2 300/2 500, and IEEE 802.11 b, and is up to 50% in Wi-MAX.

Key words dual shorting points; PIFA; radiation efficiency; Wi-MAX

适用于移动手持终端的宽带PIFA设计(GSM850-WiMAX)

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【摘要】该文展示了一种应用于移动通信的新型的双端短路点平面倒F天线，该天线可实现多频且宽带工作。天线主要由主辐射带状天线、寄生天线和开槽地板构成。为了拓展在DCS/PCS/UMTS/LTE 2 300/2 500频段上的带宽，该天线采用了双短路点设计，该设计在1 707～2 815 MHz频段上实现多模工作。同时，由于充分利用寄生天线的高次谐振模，实现了对3 387～3 627 MHz的覆盖。经过加工测试，该天线在GSM/DCS/PCS/UMTS/LTE/802.11b/Wi-MAX频段上均展现了很好的阻抗匹配特性，并均能获得高于50%的辐射效率。

关 键 词 双短路点; PIFA; 辐射效率; Wi-MAX

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Introduction

Recently, the long-term evolution (LTE) system is introduced to afford better mobile services to the wireless wide area network (WWAN) and worldwide interoperability for microwave access (Wi-MAX). Owing to the overall size limited for placing of mobile terminal antenna, it becomes more difficult to achieve wide bandwidths. Generally, PIFA is used in mobile devices due to its easy fabrication, low profile, and low implementation cost. In order to obtain a wide frequency band, the coupled-fed structure is usually applied[1-3]. However, the performance, especially the high frequency band, is susceptible to the width of coupling gap. It is difficult to manufacture, and the cost will be increased significantly. Also, it isn't suitable for the Wi-MAX (3.4～3.6 GHz) operation. In order to obtain a compact size antenna with large and multiple frequency band, many other constructions for PIFA are applied with probe feeding[4-5]. But, in these designs, it is difficult to realize multi-band and wide band operation simultaneously. Besides, with micro-electromechanical systems (MEMS) elements[5], the cost is increased inevitably.

In this letter, a compact and low profile antenna is presented. The presented PIFA occupies 47 mm×

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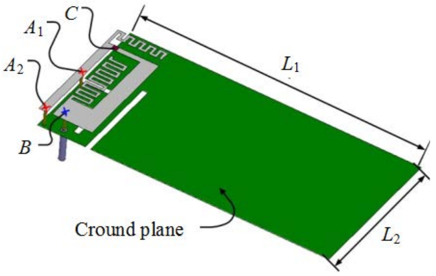
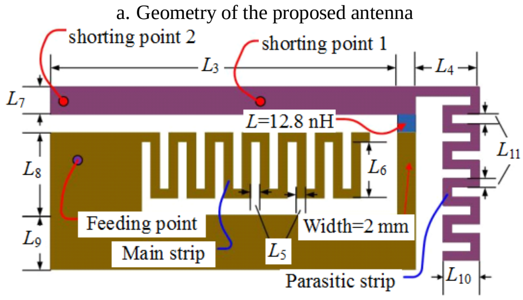
20 mm×5.5 mm. In particularly, low band frequency operation is achieved by two parallel open-end slots in the ground plane. Based on the joint disposition of the PIFA and a meandered monopole in the structure, the multiband operation is realized. Reflection coefficient less than −6 dB is obtained in 745～1 175 MHz (44.8% relative bandwidth, GSM 850/900), 1 707～2 815 MHz (49% relative bandwidth, DCS/PCS/UMTS/LTE2 300/2 500 and WWAN 11b), and 3 387～3 627 MHz(6.85% relative bandwidth, Wi-MAX) respectively.

1. Antenna Design

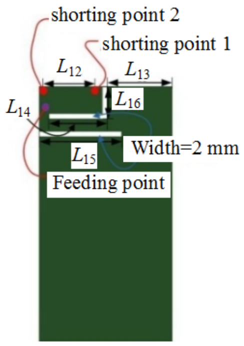
The proposed antenna structure is shown in Figure 1. The length of handset boxes model used in the simulation and measurement is as those used today.



a. Geometry of the proposed antenna



b. Detailed dimensions of the patch



c. Detailed dimensions of ground plane

Figure 1 Proposed antenna configuration

Its dimensions are given as follows: L_1=110 mm, L_2=55 mm, L_3=38 mm, L_4=6 mm, L_5=1 mm, L_6=6.2 mm, L_7=3 mm, L_8=9 mm, L_9=6 mm, L_{10}=4 mm, L_{11}=1 mm, L_{12}=22.5 mm, L_{13}=27 mm, L_{14}=24 mm, L_{15}=32 mm, L_{16}=13 mm.

Figure 1a shows the 3D mode of the proposed antenna. Point *A* (A_1 and A_2) and point *B* are the shorting point and feeding point, respectively. For the practical mobile handset application, the PIFA is fed by using a 50 ohm mini coaxial line at point *B*.

At point *C*, there is a chip-inductor-loaded strip which contributes to a wide band covering the DCS/PCS/UMTS/LTE 2 300/2 500 and WLAN 11b operation. In the design, there is double-layer PCB structure. Therefore, it is inevitably made to more capacity between the slotted ground and radiation strips. The chip inductor used in the PIFA has an inductance of 15.6 nH. The proposed PIFA comprises a main strip, a parasitic strip, and a slotted ground plane. With the shorting point A_1 and A_2 in Figure 1a, the parasitic strip is proposed as a printed λ/2-PIFA with two shorting points. The width of the two strips (main strip and parasitic strip) in the Figure 1b are the same, the lengths of them are 74.4 mm and 42 mm, which are close to λ/2 at 2 020 MHz and λ/4 at 1 785 MHz. Also, λ/2 mode (3 570 MHz) of parasitic strip is used for WLAN 11.a. In Figure 1c, the two slots of the ground plane are applied for the low resonant frequency band and enhancing the antenna return loss in the lower part of the band [6-8].

2. Simulated and Measured Results

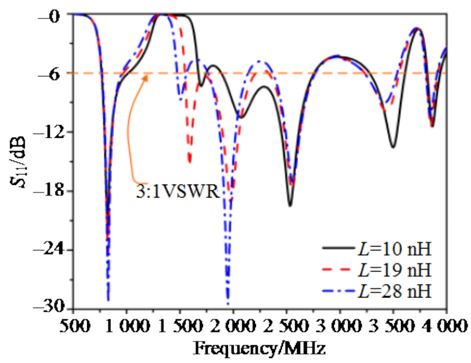
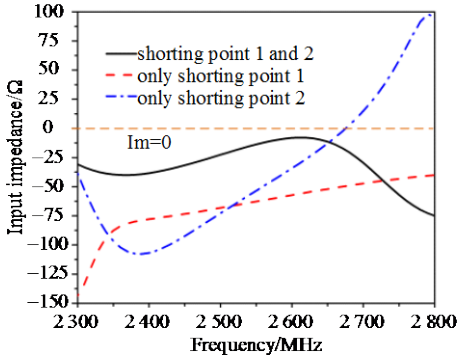
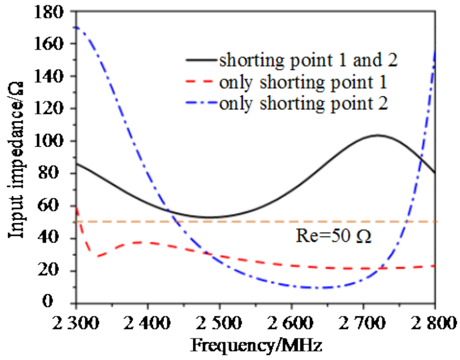


Figure 2 Simulated return loss as a function of *L*

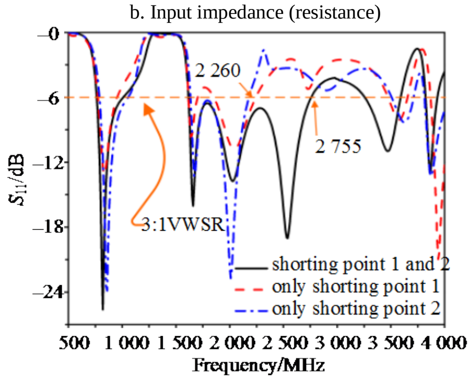
Based on the bandwidth specification of 3:1 VSWR (6 dB return loss), which is widely approved as the fundamental design requirement of the internal handset antenna, the simulated *S* parameter of proposed PIFA covers 745～1 175 MHz, 1 707～2 815 MHz, and 3 387～3 627 MHz. The chip inductor with an inductance of 15.6 nH (L) is applied in the proposed PIFA. This chip inductor is used to improve the bandwidth required for DCS/PCS with a $\lambda/2$ monopole resonant mode.



a. Input impedance (reactance)



b. Input impedance (resistance)

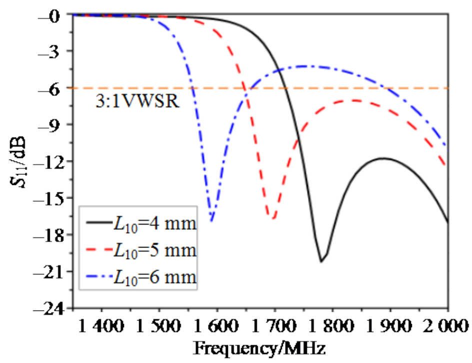


c. S_{11}

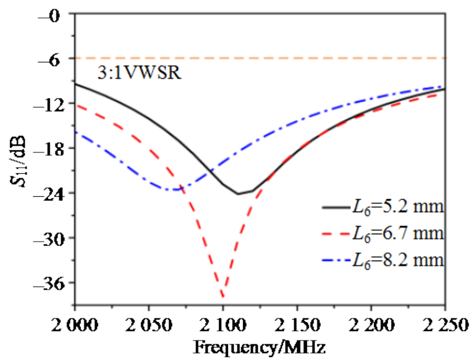
Figure 3　Simulated results with shorting point 1 and 2

Figure 2 shows the influence of the chip inductor L in S parameter. Stronger influence on the impedance matching of DCS/PCS can be observed when inductor L is changed from 10 to 30 nH. After the optimizing, the impedance matching is improved when L is 15.6 nH. Further, by using two shorting points, additional inductance is expected to be contributed to the antenna's input impedance, just as shown in Figure 3a～3c. The design of dual-shorting points means more inductance than just one. This causes the excited resonant modes for higher frequency (2 300～2 755 MHz), which is helpful in achieving better impedance matching for WWAN 11.b/LTE 2 300/2 500 operation.

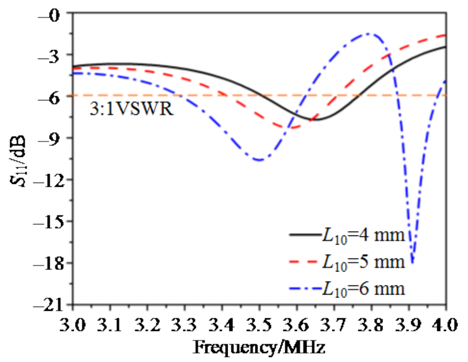
In Figure 4a, the simulated S_{11} (1 300～2 000 MHz) is presented when the length L_6 varies from 4 mm to 6 mm. It indicates that the resonant mode at 1 800 MHz shifts down with the increase of the length of driven strip. Similar results can be obtained from Figure 4b, and the length L_{10} of parasitic strip affects UMTS frequency band significantly. At last, Figure 4c also shows the influence of the varying of length L_{10}. The excited resonant effects on simulated return loss are shown (3.0～4.0 GHz, Wi-MAX).



a. L_6 (1 000～2 000 MHz)



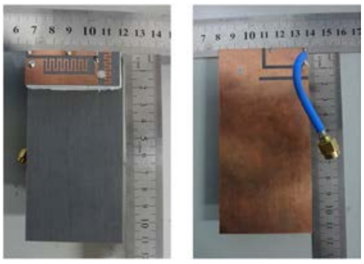
b. L_{10} (2 000～2 250 MHz)



c. L_{10} (3.0～4.0 GHz)

Figure 4　Simulated S parameter as a function

The prototype of PFIA is manufactured as shown in Figure 5. Figure 6 presents the measured and simulated S parameter of antenna. Three wide operating bands have been obtained for the antenna.



a. Top side b. Back side

Figure 5 Photos of the manufactured antenna

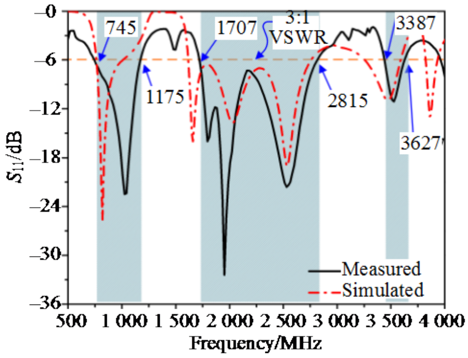
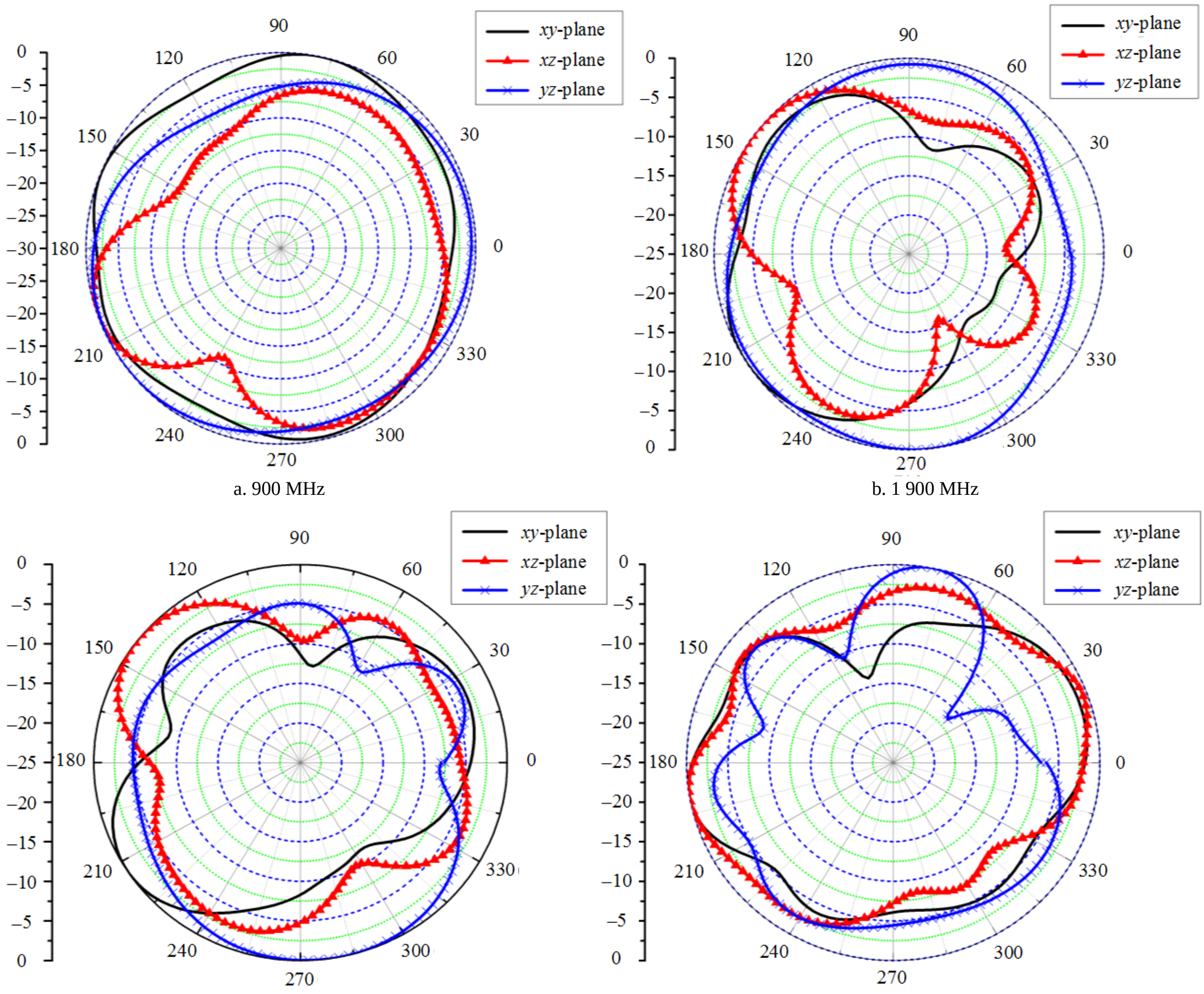


Figure 6 Measured and simulated *S* parameter

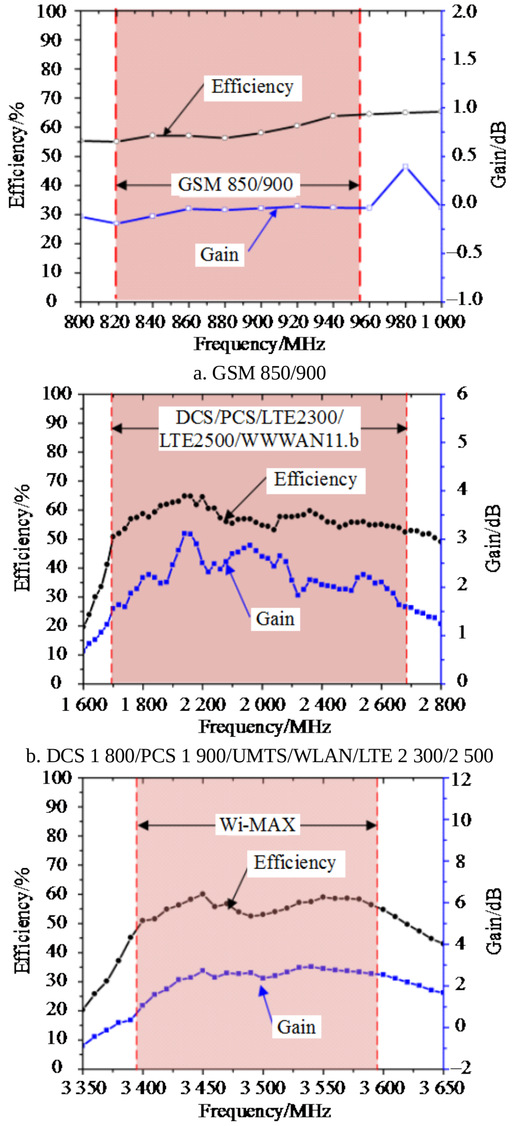
3. CONCLUSIONS

The radiation patterns, total efficiency, and peak gain are measured in the SATIMO measurement system. In the mobile phone antenna, the polarization direction is neglected. So, Figure 7 shows the normalized pattern in three principal planes (900, 1 900, 2 500 and 3 500 MHz), the measured total efficiency including the mismatching loss for the proposed antenna is presented in Figure 7. Over the lower band (500～3 000 MHz), the total efficiency and peak gain of the operation frequency band are 52%～69% and 1.3～2.8 dBi, respectively. For the upper band shown in Figure 7c, the antenna gain varies from 1.2 to 2.2 dBi, while the total efficiency is better than 50%. From the obtained results, the proposed design for PIFA is a good option for practical internal mobile applications.



a. 900 MHz b. 1 900 MHz c. 2 500 MHz d. 3.5 GHz

Figure 7 Measured 2-D radiation patterns



a. GSM 850/900

b. DCS 1 800/PCS 1 900/UMTS/WLAN/LTE 2 300/2 500

c. Wi-MAX

Figure 8　Measured antenna peak gain and radiation efficiency

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