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A Small Size Three-Band Multi-Functional Antenna for LTE/GSM/UMTS/WIMAX Handsets

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Abstract—In this paper, a three-band antenna with small size $50 \times 15 \times 0.8\,\text{mm}^3$ is developed. The multi-broadband antenna consists of strip-1, strip-2, Br-1, Br-2 and S-strip. The lengths of strip-1, strip-2 are close to $\lambda/4$ at 680 MHz, 850 MHz and $\lambda 3/4$ at 2.04 GHz, 2.55 GHz, respectively. S-strip is close to λ at 5.2 GHz and $\lambda 3/4$ at 3.7 GHz. In addition, two tuning stubs Br-1 and Br-2 connected to strip-2 can further improve the impedance matching. Then six key resonances are excited: 680 MHz, 850 MHz, 2.04 GHz, 2.55 GHz, 3.7 GHz and 5.2 GHz. There exists electromagnetic coupling (EMC) among them. As a result of the effect of the structure, three wide-bands are produced: 660–1050 MHz, 1.60–3.75 GHz, and 5.25–6.50 GHz. That is, the operation band covers full LTE700/2300/2500(1710–2690 MHz)/GSM850/900/(680 MHz–960 MHz) GSM1800/1900/WiMAX3.5 GHz (3400 $\sim$ 3650 MHz)/5.4-GHz (5250 $\sim$ 5850 MHz)/UMTS (1710–2170 MHz). The return loss is better than -6 dB. The peak gains also satisfy the requirement for practical application.

1. INTRODUCTION

Nowadays, developing multi-band antennas have becomes a necessity in wireless communication systems. The long term evolution (LTE) system for 4G wireless wide area network (WWAN) has three operating bands LTE700 (698 $\sim$ 787 MHz), LTE2300 (2300 $\sim$ 2400 MHz) and LTE2500 (2500 $\sim$ 2690 MHz). Incorporating LTE with GSM/UMTS operations in mobile devices has attracted considerable attention in [1]. These antennas cover only two or three frequency bands. For example, the printed loop of dual-band antenna formed in [2] covers the band (890–1050 MHz) for GSM900 and the frequency band (1650–2250 MHz) for DCS/PCS/UMTS. Another antenna with triple-band formed in [3] covers the band ranges from 870 MHz to 970 MHz for GSM900, 1685–2050 MHz for DCS1800/PCS and 2600–2670 MHz for S-DMB applications. In [3, 4], two wider bands for GSM850/GSM900 (824–960 MHz) and DCS/PCS/UMTS (1710–2170 MHz) were covered by the two printed dual-band antennas. In [5, 6], a proposed antenna with folded monopole also covers two frequency bands, including the LTE700/GSM850/GSM900 band (698–960 MHz) and GSM1850/GSM1900/UMTS2100 band (1710–2170 MHz). In [7–10], a proposed dual-broadband planar antenna covers the frequency ranges 818–1190 MHz for the GSM850/GSM900 and 1710–3000 MHz for the GSM1800 (1710–1880 MHz), GSM1900 (1850–1990 MHz), UMTS (1920–2170 MHz), LTE2300 (2305–2400 MHz), and LTE2600 (2500–2690 MHz). A planar monopole antenna is proposed also covers two broad frequency bands: 690–1050 MHz and 1670–2890 MHz for LTE700/GSM/UMTS handsets.

Recently, it is a tendency for multifunctional wireless handsets, such as "smart phones" to get multifunctional services (e.g., wireless access through WLAN/WiMAX), and to have an ultra-slim module [8]. Thus, it is desirable for antennas to have a planar configuration and to cover the

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WLAN/WiMAX frequency bands which include the 2.4 GHz band (2.4–2.5 GHz), the 3.5-GHz band (3.2–3.7 GHz), and the 5.65-GHz band (5.4–5.9 GHz) [11–14]. A quad-band planar inverted-F antenna (PIFA) proposed in [15] offers four frequency bands: 870–960 MHz for GSM900, 1150-MHz bandwidth for the 2-GHz band, 3400–3650 MHz for 3.5-GHz WiMAX, and 5120–5900 MHz for 5-GHz WLAN. The PIFA antenna has a narrow bandwidth for GSM900, thus can't cover the frequency band for GSM850. In addition, the geometry of the PIFA is not full planar, not suitable for an ultra-slim handset. The multi-band antenna proposed in [15, 16] also has a non-planar configuration and cannot cover the 3.5-GHz band.

In this paper, we propose a multi-band full planar antenna for emerging ultra-slim GSM/UMTS/LTE/WiMAX handsets. This antenna covers the 900-MHz band with a bandwidth of 45% (660–1050 MHz), the 2/3-GHz band with a bandwidth of 80% (1600–3750 MHz), and the 5.4 GHz band with a bandwidth of 22% (5250–6500 MHz). That is, the operation band covers full LTE700/2300/2500/GSM850/900/1800/1900/WiMAX3.5G/5.5G/UMTS. The compact three operation band antenna gives omnidirectional radiation patterns and good antenna gains over the operating bands. Description of the antenna is in Section 2. Experimental results are presented in Section 3. Conclusion is in Section 4.

2. DESIGN OF THE ANTENNA

The configuration of the proposed antenna is illustrated in Fig. 1. The antenna is constructed on an FR4 substrate with dielectric constant of 4.4, loss tangent 0.02, thickness of 0.8 mm, and size of 15 mm $\times$50 mm. The multifunctional antenna consists of strip-1, strip-2, Br-1, Br-2 and S-strip. Strip-1, strip-2, Br-1and Br-2 are on the front side, while S-strip is on the back side of the substrate. S-strip connects the ground plane at point A (as shown in Figs. 1(a), (c)). Strip-2 and S-strip are connected through a metal via with the radius of R_1 (as shown in Fig. 1(b)). The lengths of strip-1, strip-2, are close to $\lambda/4$ at 680 MHz, 850 MHz, and $\lambda 3/4$ at 2.04 GHz, 2.55 GHz respectively. S-strip is close to λ at 5.2 GHz and $\lambda 3/4$ at 3.7 GHz. In addition, the Br-1 and Br-2 are impedance matching to the strip-1 and strip-2. Then six key resonances are excited: 680 MHz, 850 MHz, 2.04 GHz, 2.55 GHz, 3.7 GHz and 5.2 GHz. There exist the electromagnetic coupling (EMC) among them. The parasitic interactions of the EMC are the impedance matching; moreover other resonance modes can be excited at the same time. The Br-1 and Br-2 connected to strip-2 can improve the impedance matching because the Br-1 and Br-2 can change the current densities on the device. The S-strip can further improve the impedance matching resonances at 3-GHz. As a result of the effect of the structure, three wide-bands are produced: 660–1050 GHz, 1.60–3.75 GHz, 5.25–6.50 GHz. The multifunctional planar antenna is designed by the Ansoft HFSS v11 [17]. The optimized geometric parameters are as follows (units in mm): $H = 0.8$, $L_1 = 11.5$, $L_2 = 47$, $L_3 = 14$, $L_4 = 11.5$, $L_5 = 39$, $L_6 = 11$, $L_7 = 34.6$, $L_8 = 35.9$, $L_9 = 25$, $L_{10} = 40$, $W_1 = 0.5$, $W_2 = 1.5$, $W_3 = 2.35$, $W_4 = 11.5$, $W_5 = 1$, $W_6 = 4$, $W_7 = 1.2$, $W_8 = 1.5$, $W_9 = 0.5$, $W_{10} = 4$, $W_{11} = 40$, $R_1 = 1$, $R_2 = 0.6$, $W_g = 50$, $L_g = 100$. The optimized antenna height is 15 mm, and the total size of the antenna with the ground plane is 115 mm $\times$60 mm.

Figure 2 is the return loss of the developed antenna for the case with strip-1 and strip-2. Strip-1 and strip-2 generate resonances at 680 MHz and 850 MHz, respectively. Thus a broadband feature is observed 660–1050 MHz. A parasitic resonance is excited about 2.04 GHz and 2.55 GHz. In the mean time, there are parasitic bands in higher frequencies due to the complicated EMC interaction.

Figure 3 shows the return loss for the developed antenna after two branches (marked Br-1 and Br-2 as shown in Fig. 1(b)) are introduced on the basis of the structure for Fig. 2. The operation bands move to a lower frequency from 1.75 GHz to 1.7 GHz and move to a higher frequency from 3.7 GHz to 3.8 GHz due to the impedance matching of Br-1 and Br-2 as shown in Fig. 2 and Fig. 3.

Figure 4 shows the return loss for the developed antenna after the S-strip is introduced on the basis of the structure for Fig. 3. The resonances at 5.2 GHz and 3.7 GHz are excited. There exist the electromagnetic coupling (EMC) among strip-1, strip-2, Br-1 and S-strip, and as a result of the comprehensive effect of the structure, three wide-bands are produced: 660–1050 MHz, 1.60–3.75 GHz, and 5.25–6.50 GHz. In other words, the operation band covers full LTE700/2300/2500/GSM850/900/1800/1900/WiMAX3.5G/5.5G/UMTS.

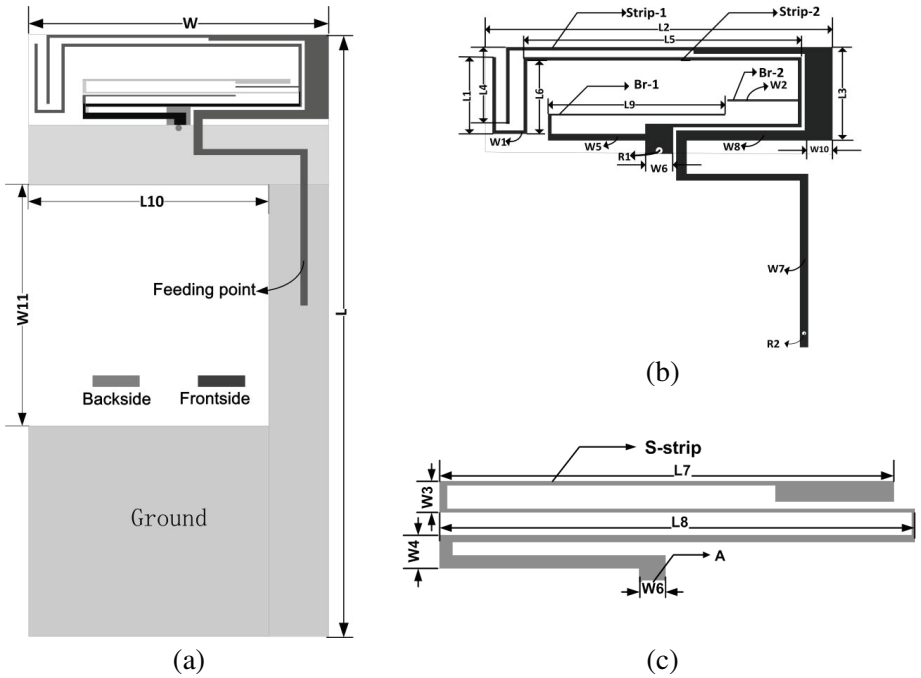


Figure 1. (a) The geometry of the proposed antenna. (b) Front side. (c) Back side.

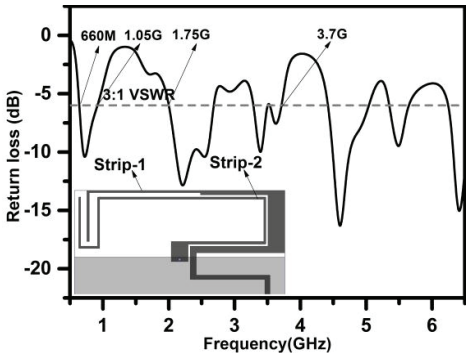


Figure 2. Return loss simulated when there is only a strip-1 coupling with a strip-2.

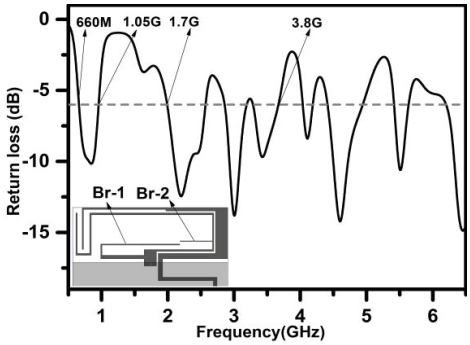


Figure 3. Return loss simulated with added Br-1 and Br-2 on the basis of the Fig. 2.

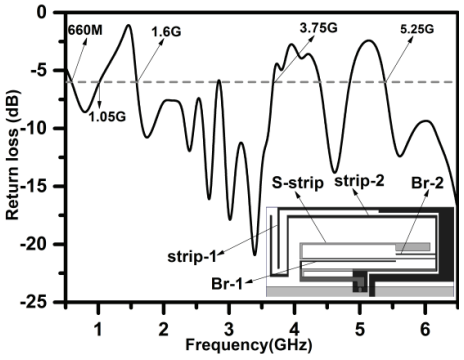
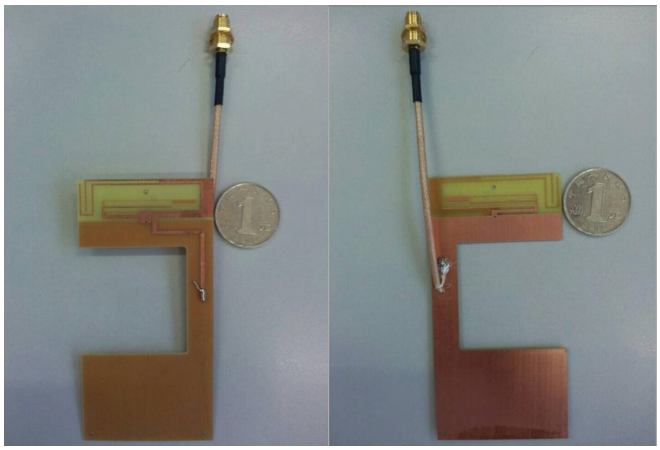


Figure 4. Return loss simulated with added S-strip on the basis of the Fig. 3.

3. EXPERIMENTAL RESULTS

The developed antenna is fabricated as in Fig. 5. The measured result agrees well with the simulated one as shown in Fig. 6. It is seen that the bandwidths for return loss better than −6 dB (or VSWR < 3) are 45% (660–1050 MHz) for the 900-MHz band, 80% (1600–3750 MHz) for the 2/3-GHz band, and the 5.4 GHz band with a bandwidth of 22% (5250–6500 MHz) covering most frequency bands for GSM/UMTS/LTE/WiMAX applications. The measurement and simulation of omnidirectional radiation patterns at 800 MHz, 2.2 GHz, 3.5 GHz, and 5.4 GHz are shown in Fig. 7. The requirement of the peak gain for practical smart phone is 0–2 dB, and the measured and simulated gains are from 1 dB to 5 dB as shown in Fig. 8.



(a) (b)

Figure 5. The prototype of the multifunctional planar antenna: (a) Top view. (b) Bottom view.

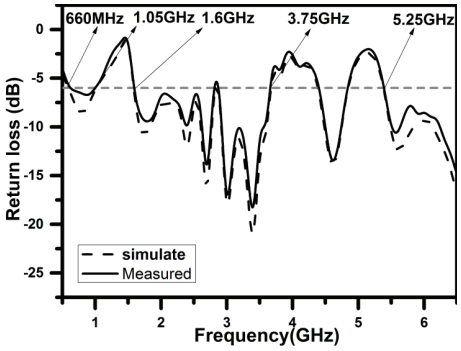
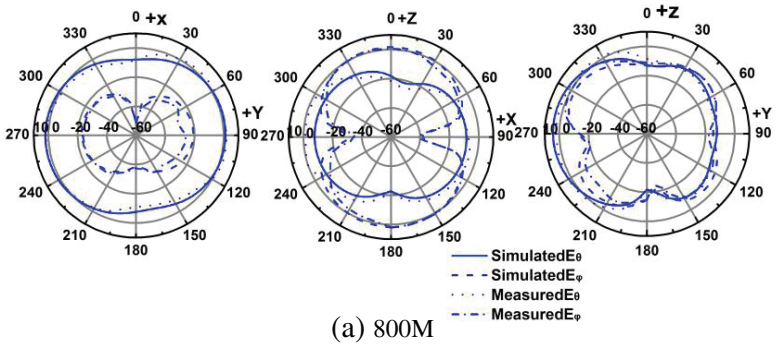
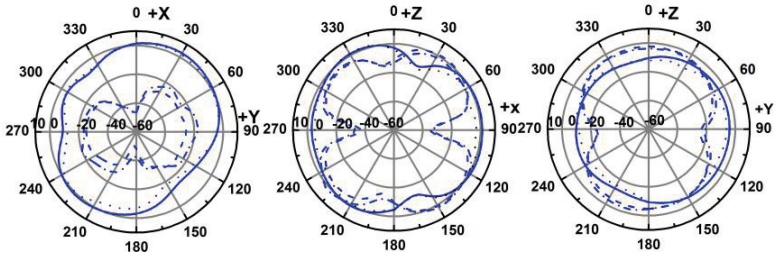


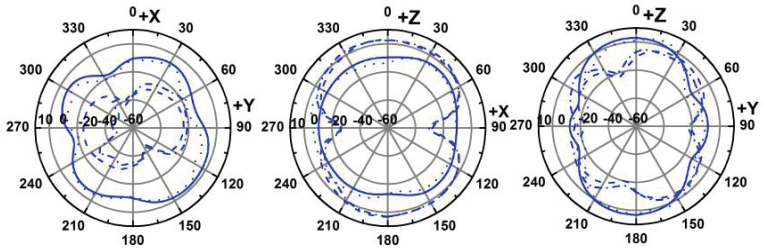
Figure 6. Measured return loss compared to simulated result for the multi-functional planar antenna.



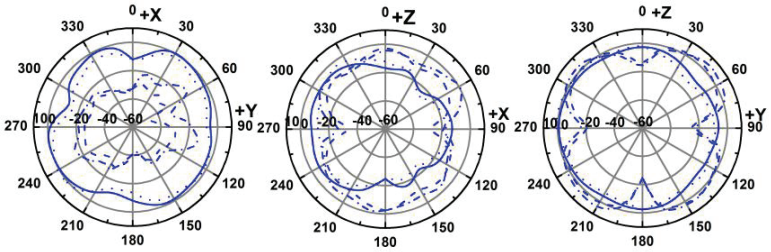
(a) 800M



(b) 2.2 GHz



(c) 3.5 GHz



(d) 5.4 GHz

Figure 7. Measured and simulated radiation patterns of the multi-broadband planar antenna at (a) 800 MHz, (b) 2.2 GHz, (c) 3.5 GHz, and (d) 5.4 GHz.

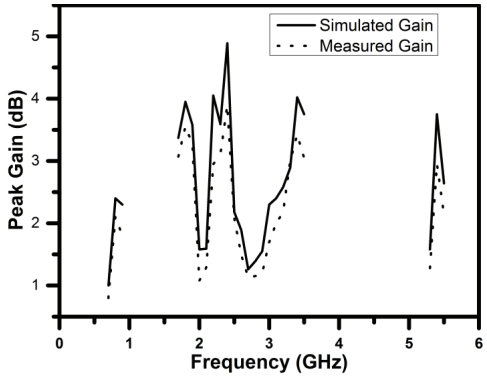


Figure 8. Simulated and measured peak gain of the antenna.

4. CONCLUSION

A multi-functional planar antenna has been developed for LTE/GSM/UMTS/WiMAX applications. The compact size multi-broadband antenna, with a full planar of 15 mm × 50 mm × 0.8 mm, has the advantage of relatively wide bandwidth. The compact three-operation-band antenna gives omnidirectional radiation patterns and good antenna gains over the operating bands, and it satisfies the requirement for the state-of-the-art wireless handsets.

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