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Small-Size 11-Band LTE/WWAN/WLAN Planar Handset Antenna

Hui-Fen Huang* and Wei Zhao

Abstract—This work presents a planar handset antenna having a small size $47 \times 15 \times 0.8\,\mathrm{mm}^3$ and providing four wide operating bands of at least 698–960, 1710–2690, 3100–3900 and 5150–5850 MHz for the 11-band LTE700/GSM850/900, GSM1800/1900/UMTS/LTE2300/LTE2500, WiMAX 3.5 GHz/5.4 GHz, WLAN 5.8 GHz. The multi-broadband antenna consists of Br-1, Br-2, Br-3, C-strip and ground plane. The structure is analyzed by S_{11} and surface current distribution. The simulated and measured results agree well. The gain of the proposed antenna is 1.51–4.12 dBi, and the radiation efficiency is about 75%–94%.

1. INTRODUCTION

Recently, the ever increasing need of multi-band antennas with light weight and small size has become a tendency and excited research for multi-band wireless handsets, for instance GSM, UMTS, WLAN, WIMAX and LTE [1–4]. The 4G wireless wide area network (WWAN) systems have further excited the attentions for higher data rate in the wireless communication system. The 4G wireless wide area network (WWAN) includes LTE700 (698–787 MHz), LTE2300 (2305–2400 MHz), and LTE2500 (2500–2690 MHz) operation bands. In [5–9], the small planar LTE/WWAN internal mobile device antennas cover the LTE/WWAN operation bands. The antenna in [10] covers triple-broad operation bands. The three wide operation bands include the 900 MHz band for GSM850/900, 2-GHz operation band for GSM1800/GSM1900/UMTS/LTE2300/LTE2500 and 5-GHz band for WLAN/WIMAX. The dual-band antenna of printed loop proposed in [11] covers only two operation bands: 890–1050 MHz for GSM900 and 1650–2250 MHz for DCS/PCS/UMTS. However, LTE700 band is not covered because it is difficult to obtain LTE700 band in an electrical small antenna [12, 13]. Theoretically, it is quite difficult to acquire a wide band at a lower operation band due to the electrically small size at a lower frequency for the same physical size [14]. Lots of efforts have been made to improve the impedance of operation bandwidth. In order to improve the bandwidth enhancement, many techniques require a considerable thickness and size. The planar inverted-F antenna (PIFA) in [15] can produce four wide bands: 870–960 MHz for GSM850/900, 2-GHz operation band covering a bandwidth for 1150 MHz, 3400–3650 MHz for 3.5 GHz WiMAX, and 5120–5900 MHz for 5 GHz WLAN. However, GSM850 and LTE700 are not covered. Although some antennas may have enough bandwidths, the thickness or size of these antennas is not suitable for integrating them in the mobile devices [16, 17]. Therefore, it is a tendency to propose a small size antenna which can cover the LTE/GSM/UMTS and WLAN/WIMAX bands.

This work presents a planar handset antenna having a small size $47 \times 15 \times 0.8\,\mathrm{mm}^3$ and providing four wide operating bands of at least 698–960, 1710–2690, 3100–3900 and 5150–5850 MHz for the 11-band LTE700/GSM850/900, GSM1800/1900/UMTS/LTE2300/LTE2500, WiMAX 3.5 GHz/5.4 GHz, WLAN 5.8 GHz. The multi-broadband antenna consists of Br-1, Br-2, Br-3, and C-strip and ground plane. The paper is organized as follows. Section 2 is the antenna description. Section 3 presents the structure analysis. Section 4 shows the measured results, and the conclusion is in Section 5.

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2. ANTENNA DESCRIPTION

The developed antenna with size 47 mm × 15 mm is shown in Figure 1. The developed antenna is fabricated on an FR4 substrate with dielectric constant 4.4, loss tangent 0.02 and thickness 0.8 mm. The proposed antenna consists of Br-1, Br-2, Br-3, C-strip and ground plane. Br-1, Br-3 and C-strip are on one side of the substrate, and Br-2 and ground plane are on the other side. The antenna is fed by a microstrip line. Br-1 generates a fundamental resonant mode $\lambda/4$ at 0.95 GHz and three higher-order modes $1.9(\lambda/8)/3.8(\lambda/16)/5.35$ GHz. Br-2 is responsible for $\lambda/4$ at 0.8 GHz and high-order modes at 3.5/5.35 GHz. Br-4 generates a resonance at 2.3 GHz. C-strip generates two modes at 2.56/5.35 GHz. The lengths of Br-1, Br-2, Br-3 and C-strip are 72 mm (close to $\lambda/4$ at 0.95 GHz), 123.5 mm (close to $\lambda/4$ at 0.8 GHz), 33 mm ($\lambda/4$ at 2.3 GHz), and 37 mm, respectively. Geometric parameters are adjusted by software HFSS [18]. The geometry parameters are marked in Figures 1(b), (c) and as follows (units in mm): $H = 0.8$, $W_g = 47$, $L_g = 125$, $L = 110$, $L_1 = 14.5$, $L_2 = 10$, $L_3 = 27$, $L_4 = 24.5$, $L_5 = 12$, $L_6 = 4.5$, $L_7 = 10.5$, $L_8 = 15$, $L_9 = 3.7$, $L_{10} = 29.8$, $L_{11} = 10.1$, $L_{12} = 3.2$, $L_{13} = 35$, $L_{14} = 6.8$, $W_1 = 2$, $W_2 = 1$, $W_3 = 1.5$, $W_4 = 0.95$, $W_5 = 1.2$, $W_6 = 0.7$, $W_7 = 0.5$, $W_8 = 1$, $W_9 = 0.7$, $W_{10} = 1.2$, $W_{11} = 0.5$, $W_{12} = 1.2$, $W_{13} = 0.5$. The structure of the developed antenna is also clearly shown by the prototype in Figure 2.

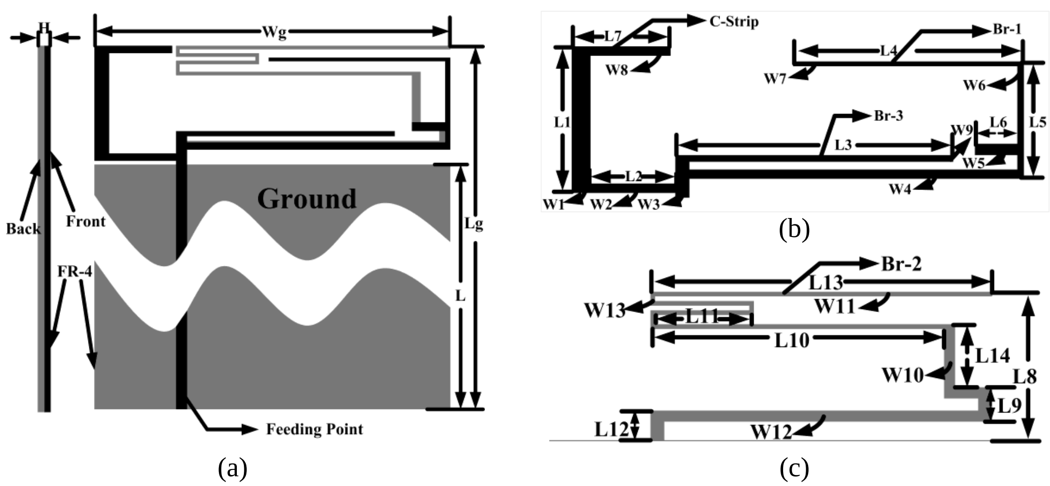


Figure 1. (a) Configuration of the proposed antenna, (b) top view, (c) bottom view.

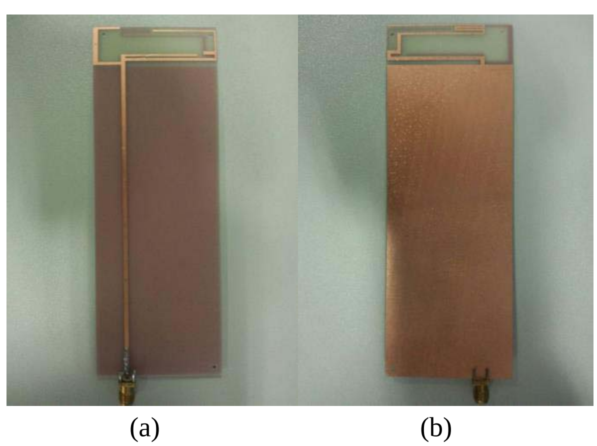


Figure 2. Prototype for the developed antenna: (a) top view and (b) bottom view of proposed antenna.

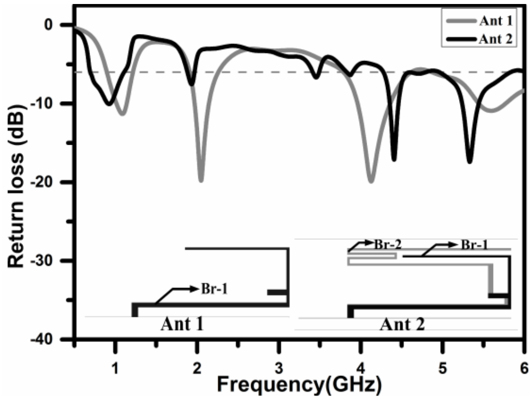


Figure 3. Simulated return loss for antenna Ant1 and Ant2.

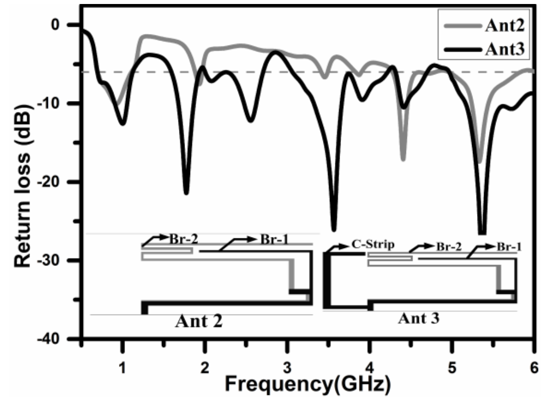


Figure 4. Simulated return loss for antenna Ant2 and Ant3.

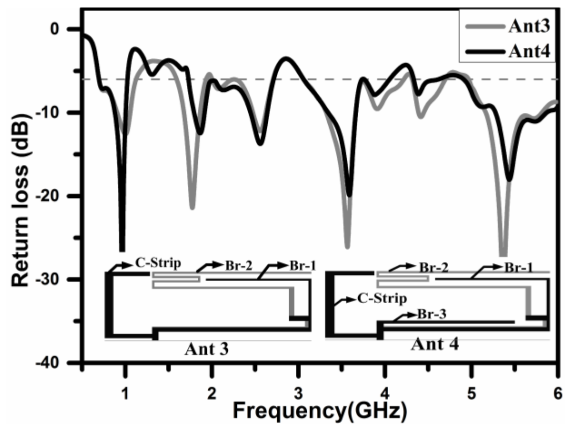


Figure 5. Simulated return loss for Ant3 and Ant4.

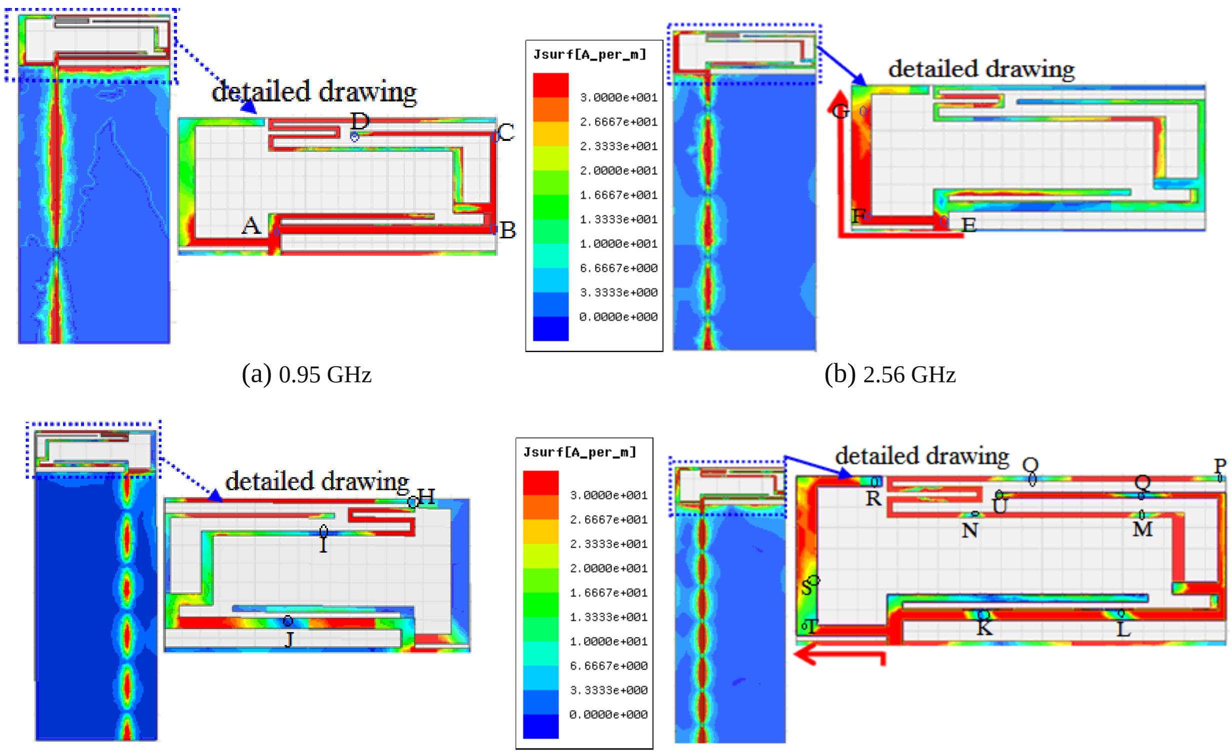
3. STRUCTURE ANALYSIS

3.1. S_{11} Analysis

The structure is analyzed by the following steps. The first step is marked by Ant1. The length of Br-1 is close to $\lambda/4$ at 0.95 GHz and generates a fundamental mode at 0.95 GHz, and three higher-order modes $\lambda/8$ (1.9 GHz), $\lambda/16$ (3.8 GHz) and 5.35 GHz are indicated in S_{11} curve in Figure 3. The second step is marked by Ant2. Br-2 is added on the basis of Ant1. The length of Br-2 is close to $\lambda/4$ at 0.8 GHz. Moreover, two resonance modes at 0.8 GHz and 3.5 GHz are introduced. Therefore, the low operation band 698–960 MHz is formed as shown in Figure 3. The third step is Ant3. C-strip is added on the basis of Ant2. The C-strip introduces a resonance mode at 2.56 GHz. The impedance matching in all operation bands is greatly improved after the C-strip is added, and then the operation bands (1710–2690 MHz), WiMAX 3.5 GHz (3400∼3650 MHz)/5.4 GHz/WLAN 5.8 GHz (5250∼5850 MHz) are formed as clearly shown in Figure 4. The fourth step is the developed antenna (Ant4). The impedance matching is further improved in operation bands GSM1800/1900/UMTS/LTE 2300/LTE 2500, WiMAX 3.5 GHz, WLAN 5.8 GHz due to the introduced Br-3 on the basis of Ant3 as indicated in Figure 5.

3.2. Current Distributions

Figure 6 shows the current distributions at 0.8/2.56/3.5/5.4 GHz. The length of Br-1 is $\lambda/4$ at 0.95 GHz, and there exists a strong current distribution along points A-B-C-D as in Figure 6(a), which is in line with the S_{11} in Figure 3. There exists a 0.25 wavelength at 2.56 GHz and a surface current distribution in C-strip (along points E-F-G) as in Figure 6(b), indicating that the C-strip excites a resonance at 2.56 GHz, which agrees with the S_{11} analysis in Figure 4. At 3.5 GHz, there exist three current null points (H, I, J) in Br-2 as in Figure 6(c), indicating that the high-order mode at 3.5 GHz is excited by Br-3, which accords with the S_{11} analysis in Figure 5. At 5.35 GHz, there exist surface current null points (at points K, L, M, N, O, P, Q, R, U, S, T) in Br-1, Br-2 and C-strip, and the surface current distribution length between two current null points is 0.25 wavelength at 5.35 GHz. Br-1, 2 and C-strip are all responsible for 5.35 GHz mode, which agrees with the S_{11} analysis in Figure 4. There is a current distribution in C-strip at 0.8/2.56/3.5/5.35 GHz, indicating that C-strip participates in the radiation and improves the impedance matching in all operation bands, which is in line with the S_{11} analysis in Figure 4.



(a) 0.95 GHz (b) 2.56 GHz

(c) 3.5GHz (d) 5.35 GHz

Figure 6. Current distributions at 800 MHz 2.56/3.5/5.35 GHz.

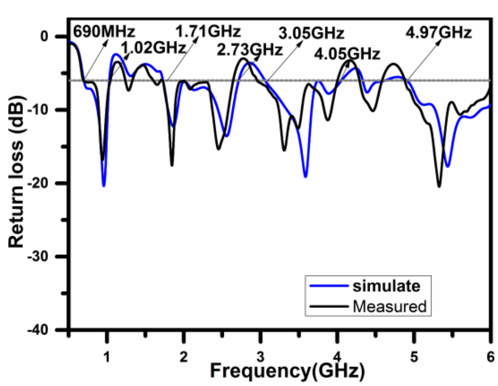


Figure 7. Measured return loss compared to simulated result for the proposed antenna.

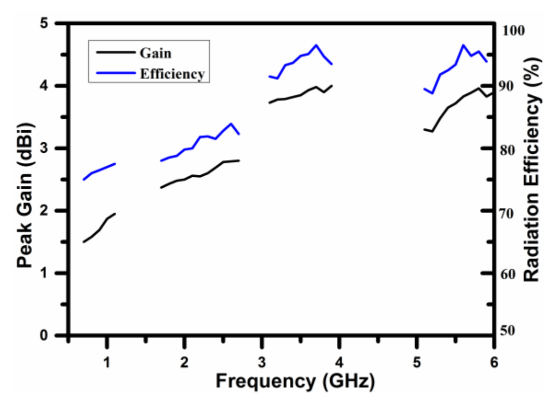
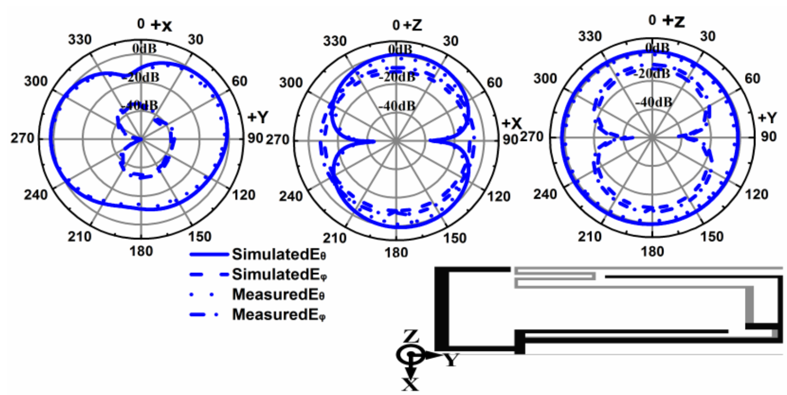


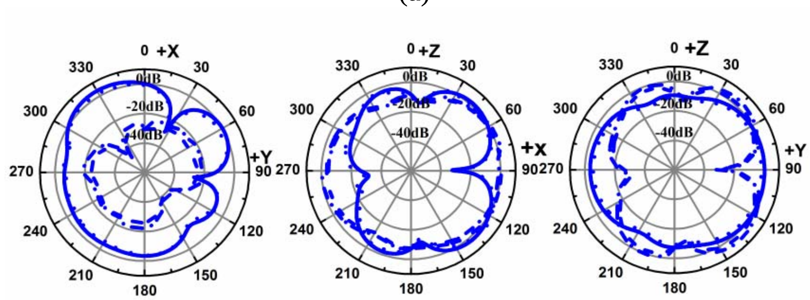
Figure 8. Measured gain and simulated radiation efficiency of the proposed antenna.

4. MEASURED RESULTS

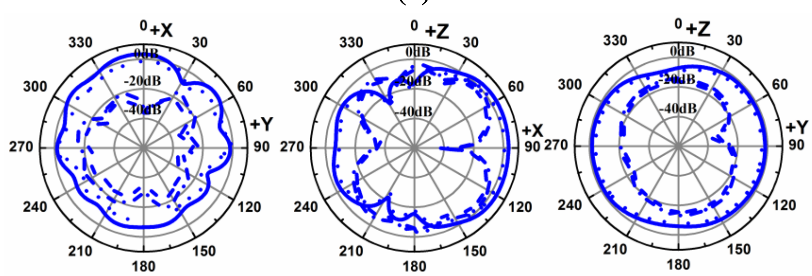
The measured S_{11} is in Figure 7. The measured and simulated results by Ansoft HFSS agree well. The S_{11} is better than -6 dB (or VSWR < 3) in all the operation bands. The bandwidth is 39% for 800 MHz band (690–1020 MHz), 46% for 2.2 GHz band (1710–2730 MHz), 28% for 3.5 GHz band (3050–4050 MHz), and 19% for 5.5 GHz band (4970–6000 MHz). Figure 8 shows antenna gains and radiation



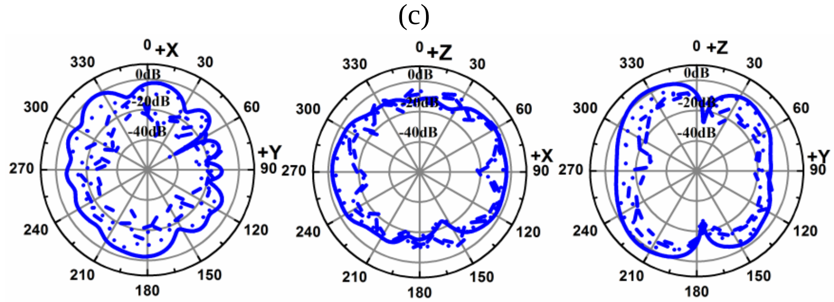
(a)



(b)



(c)



(d)

Figure 9. Radiation patterns of the proposed antenna at (a) 800 MHz, (b) 2.2 GHz, (c) 3.5 GHz, and (d) 5.4 GHz.

efficiency. The antenna gains are from 1.51–4.12 dBi, and the radiation efficiency ranges from about 75% to 94%. Figure 9 shows the measured and simulated radiation patterns at 800 MHz, 2.2 GHz, 3.5 GHz, and 5.4 GHz. All radiation patterns are almost omnidirectional in the Y-Z plane. Moreover, more variations and nulls in the radiation patterns can be seen for frequencies in the higher operation band. The patterns present higher directivity with increasing operation band. Therefore, the gains and radiation efficiency increase as the operating bands increase (as shown in Figure 8).

5. CONCLUSION

A multi-broadband planar antenna with a small size $47 \times 15 \times 0.8\,\mathrm{mm}^3$ is proposed for wireless handsets. The proposed antenna consists of Br-1, Br-2, Br-3, C-strip and ground plane. The developed antenna covers LTE700/GSM850/900/GSM1800/1900/UMTS/LTE2300/LTE2500/WiMAX 3.5/5.4 GHz/WLAN 5.8 GHz. The bandwidth is 39% for 800 MHz band (690–1020 MHz), 46% for 2.2 GHz band (1710–2730 MHz), 28% for 3.5 GHz band (3050–4050 MHz), and 19% for 5.5 GHz band (4970–6000 MHz). The proposed antenna has omnidirectional radiation patterns and good antenna gains. In addition, the radiation efficiency over the operating bands also satisfies the requirements for practical applications.

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