Planar Multi-band Monopole Antenna for WWAN/LTE Operation in a Mobile Device

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***Abstract*- By using the loop parasitic shorted strip, a small-size uniplanar antenna with multi-band WWAN/LTE operation in the mobile device is proposed. The obtained impedance bandwidths across dual operating bands approach 277 MHz and 1176 MHz at the LTE and WWAN bands, respectively. The proposed uniplanar antenna reduces the antenna size by at least 22 % since the overall antenna size is only 35 × 10 × 0.8 mm^3. The measured peak gains and antenna efficiencies are approximately 2.6 / 3.8 dBi and 83 / 81 % for the LTE/WWAN bands, respectively. Moreover, with a compact structure, the proposed planar antenna can be deposited inside the mobile device and complies with the body specific absorption rate (SAR) requirement (< 1.6 W/kg for 1-g body tissue) for practical applications.**

I. Introduction

The long term evolution (LTE) system with three operating bands in the LTE700 (698 ~ 787 MHz), LTE2300 (2300 ~ 2400 MHz) and LTE2500 (2500 ~ 2690 MHz) [1] has attracted considerable attention for use in 4G wireless wide area network (WWAN) systems to incorporate the LTE system with GSM/UMTS operations in mobile devices, because of significantly higher data rate than that of 3G wireless wide area network (WWAN) operations for mobile broadband services. Meanwhile, owing to that an internal LTE/GSM/UMTS antenna occupies a large amount of space, the physical distance from the other embedded antennas (e.g., GPS, WLAN and Bluetooth antennas) decreases, which is a prerequisite for achieving an acceptable isolation between those embedded antennas. Thus, to fulfill the bandwidth specifications of the 4G system and ensure the ability to embed into a limited space, compact multi-band antennas appear to have the potential for providing commercial broadband coverage in the 698–960 / 1710–2690 MHz bands in LTE/WWAN environments. Several planar LTE/WWAN internal monopole antennas (MAs) have been developed for mobile phone [2-13]. However, limitations include a larger antenna size for the above MAs with a greater planar dimension [2-9] or insufficient operating bandwidth [10-13] for LTE/WWAN operations in the mobile phones. To overcome this limitation, this study presents a novel loop shorted strip as the parasitic element, to generate dual 0.25-wavelength resonant modes at approximately 750/940 MHz bands to cover the LTE700/GSM850/900 operating bandwidth. A F-shaped driven monopole strip is devised to excite a resonant mode in the upper (1710–2690 MHz) band of the desired antenna. Meanwhile, in contrast with the schemes developed in [2-13], all monopole strips in this study have the same width (0.6 mm) to simplify the dimensional parameters and minimize manufacturing defects. As for the overall antenna volume, the proposed antenna with a small size of 35 × 10 × 0.8 mm^3 (280 mm^3) has an antenna size at least 22 % less than that of the smallest LTE/WWAN internal antenna with a dimension of 30 × 15 × 0.8 mm^3 [6] for the mobile phone. Moreover, the body SAR [14] for the internal antenna must be tested, and should be less than 1.6 W/kg for 1-g body tissue [15-16]. To comply with this requirement, simulated body SAR results of the proposed antenna are also analyzed.

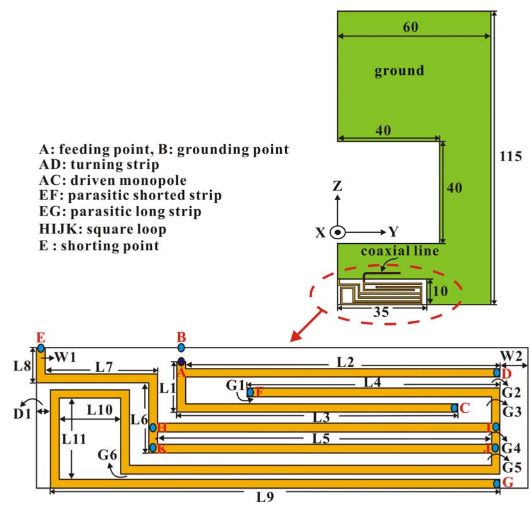


Figure 1. Geometry of the proposed planar multi-band monopole antenna with a F-shaped driven monopole strip for the mobile phone.

II. Antenna Design

Figure 1 displays the geometrical configuration of the proposed planar compact antenna for LTE/WWAN operations in a mobile phone. While printed on the same side of an FR4 substrate with the dimension of 35 × 10× 0.8 mm^3, the antenna is mounted along the top-right edge of the C-shaped system ground with the dimension of 115 × 60× 0.8 mm^3. The proposed antenna consists of a F-shaped driven monopole and a loop parasitic strip shorted at point E. The antenna is fed by a 50-Ω mini coaxial line connected to the feeding point (point A) of the F-shaped driven monopole and the system grounding point (point B). The F-shaped driven strip is first arranged as a quarter-wavelength monopole to generate the fundamental resonant mode at approximately 2085 MHz. The lower meandered arm of the loop parasitic shorted strip (section EKJG) then contributes to its fundamental (0.25-wavelength) resonant mode at around 793 MHz with a higher-order resonant mode at approximately 1580 MHz. Moreover, the impedance bandwidth for the lower operating band (LTE700/GSM900 MHz) is widened by introducing the upper meandered arm of loop parasitic shorted strip (section EHIF) to generate the fundamental (0.25-wavelength) resonant mode at approximately 956 MHz band with a higher-order resonant mode at approximately 2658 MHz. Moreover, the antenna is optimized based on the above guidelines and by using Ansoft HFSS, a commercially available software package based on the finite element method [17]. Return loss is measured with an Agilent N5230A vector network analyzer.

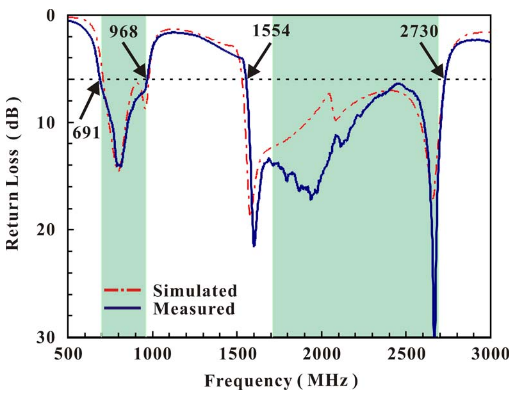
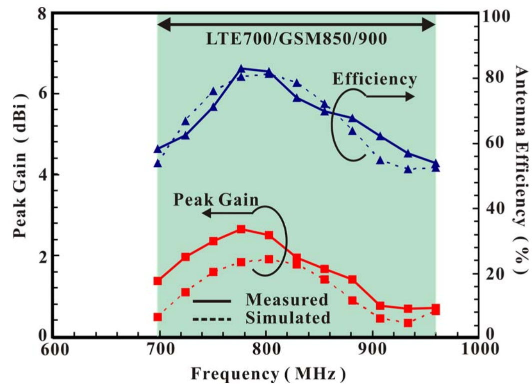


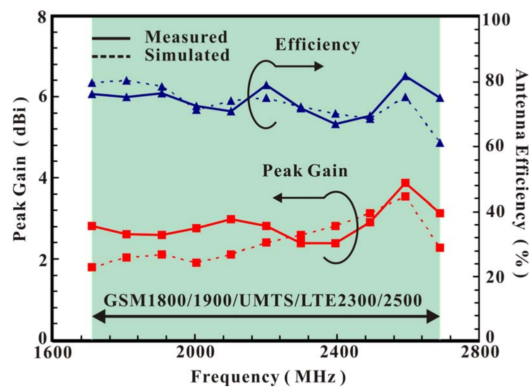
Figure 2. Simulated and measured results against frequency for the proposed planar multi-band monopole antenna. L1 = 3.6 mm, L2 = 22.4 mm, L3 = 20 mm, L4 = 18 mm, L5 = 23.8 mm, L6 = 5 mm, L7 = 8 mm, L8 = 2.5 mm, L9 = 32 mm, L10 = 4.4 mm, L11 = 5.8 mm, W1 = 0.6 mm, G1 = 0.5 mm, G2 = 0.8 mm, G3 = 1.9 mm, G4 = 0.9 mm, G5 = 0.9 mm, G6 = 0.4 mm, D1 = 1 mm

III. RESULTS AND DISCUSSION

Figure 2 summarizes the simulation and experimental results for return loss in the proposed monopole antenna. The lower band reveals a measured 3:1 VSWR (6-dB return loss) bandwidth of 277 MHz (691–968 MHz), whereas the upper band has a bandwidth of 1176 MHz (1554–2730 MHz). Dual wide bands can comply with the bandwidth requirements of the desired eight-band LTE/WWAN (LTE700/GSM850/900/ GSM1800/1900/UMTS/LTE2300/2500) operations. Figure 3 presents the measured antenna gain and efficiency (mismatching loss included, [18]) for the proposed compact printed antenna. This figure also shows the simulation results for comparison. For frequencies over the LTE700/GSM850/ 900 bands, the measured antenna gain is approximately 0.8 ~ 2.6 dBi. Meanwhile, that for the GSM1800/1900/UMTS/ LTE2300/2500 bands ranges from approximately 2.4 to 3.8 dBi. The measured antenna efficiency is approximately 54 ~ 83 % over the LTE700/GSM850/900 bands, while that over the GSM1800/1900/UMTS/LTE2300/2500 bands is around 67 ~ 81 %. Figure 4 shows the measured 3-D and 2-D radiation patterns at typical frequencies. At frequencies (740 and 925 MHz) in the antenna's lower band, the radiation patterns are close to the dipole-like patterns. At higher frequencies (1795, 1920 and 2350 MHz) in the antenna's upper band, more dips and more variations are found in the radiation patterns than those at lower frequencies. This is largely owing to that more surface current nulls are excited in the system ground at higher frequencies than at lower ones. Furthermore, the body SAR [14] is tested to verify that the proposed monopole antenna fulfills the requirements for device use. Table 1 lists the SAR results for 1-g body tissue at the central frequencies of the lower and upper operating bands. The SAR results are less than the limit of 1.6 W/kg.

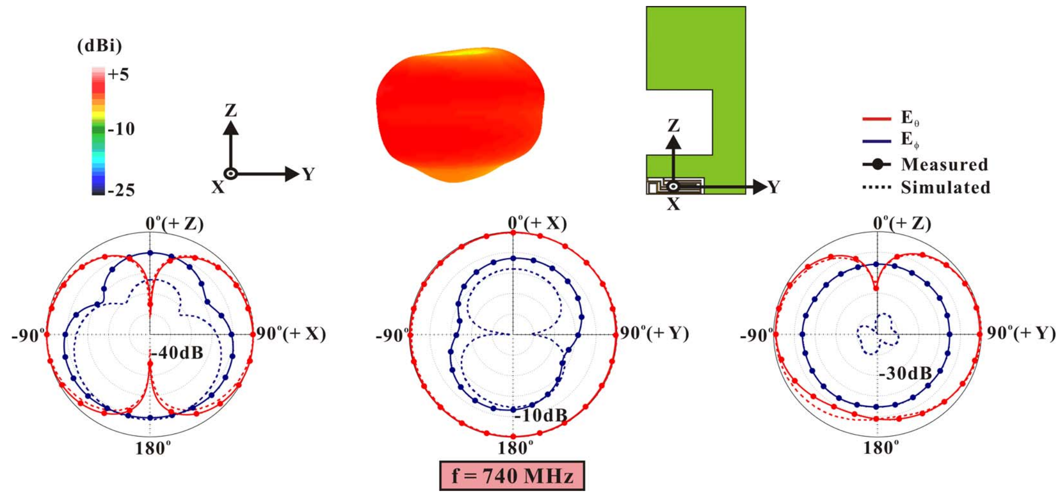


(a) Low band

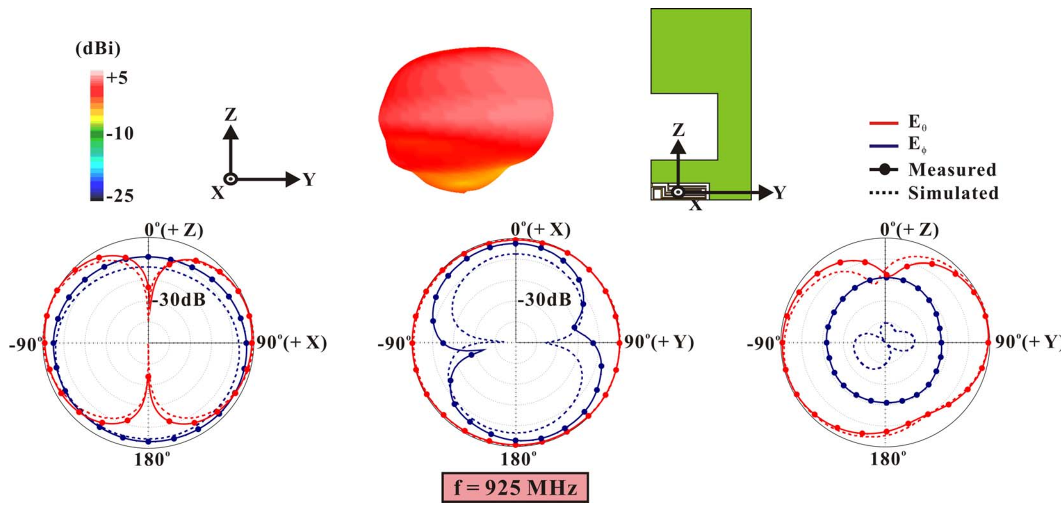


(b) High band

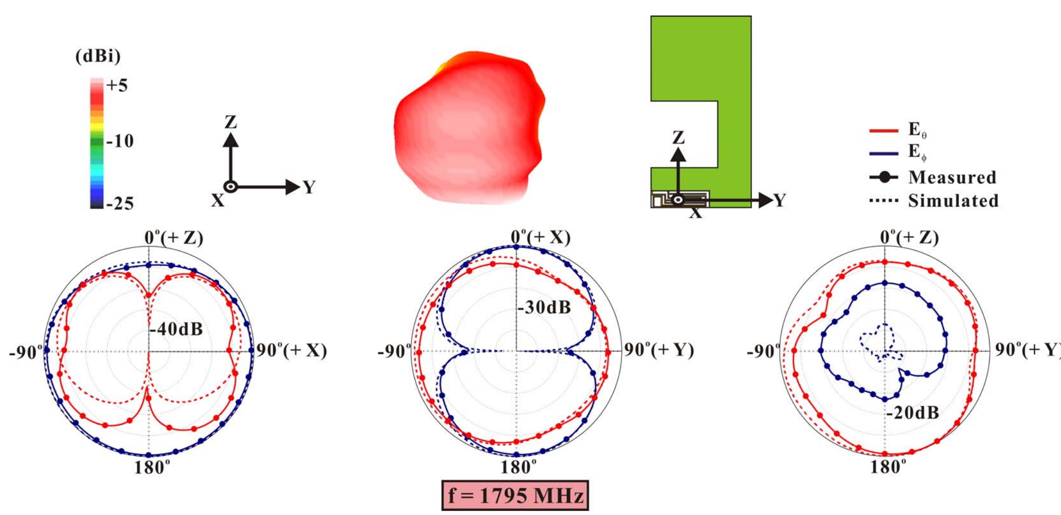
Figure 3. Measured and simulated antenna gain and efficiency for the proposed planar multi-band monopole antenna studied in Fig. 2.


(dBi)
+5
-10
-25
Z
Y
X
E$_\theta$
E$_\phi$
Measured
Simulated
0°(+ Z)
-90°
90°(+ X)
-40dB
180°
0°(+ X)
90°(+ Y)
-10dB
-30dB
f = 740 MHz

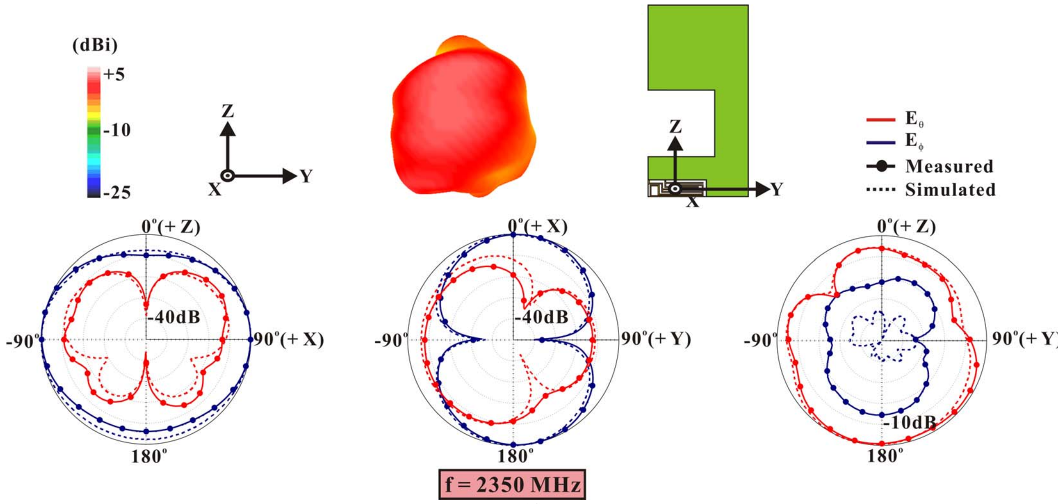
(a)


(dBi)
+5
-10
-25
Z
Y
X
E$_\theta$
E$_\phi$
Measured
Simulated
0°(+ Z)
-90°
90°(+ X)
-30dB
180°
0°(+ X)
90°(+ Y)
-30dB
f = 925 MHz

(b)


(dBi)
+5
-10
-25
Z
Y
X
E$_\theta$
E$_\phi$
Measured
Simulated
0°(+ Z)
-90°
90°(+ X)
-40dB
180°
0°(+ X)
90°(+ Y)
-30dB
-20dB
f = 1795 MHz

(c)



(d)

Figure 4. Measured three-dimensional (3-D) total-power and two-dimensional (2-D) radiation patterns for the proposed planar multi-band monopole antenna.

Table 1 : Simulated body SAR results obtained using SEMCAD X [19] for 1-g body tissue.

Frequency (MHz)	740	925	1795	1920	2350
Input power (Watt)	0.125	0.25	0.125	0.125	0.125
1-g SAR (W/kg)	0.96	1.06	0.51	0.47	0.39
Return loss (dB)	9.4	6.3	12.2	10.3	6.7

IV. Conclusions

This work presents a bandwidth enhancement approach to achieve a small-size eight-band LTE/WWAN internal mobile phone antenna. The impedance bandwidth across the operating bands can reach approximately 277 MHz and 1176 MHz at the LTE and WWAN bands, respectively. The measured peak gains and antenna efficiencies are approximately 2.6 / 3.8 dBi and 83 / 81 % for the LTE/WWAN bands, respectively. The proposed uniplanar antenna reduces the antenna size by at least 22% since the overall antenna size is only 35 × 10 × 0.8 mm^3. Moreover, the proposed uniplanar antenna design fulfills the requirement of the body specific absorption rate (SAR) (< 1.6 W/kg for 1-g body tissue) for device use.

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