Multi-band Monopole Antenna Design Using Folded and Parasitic Strips for Laptop Applications

#Chichang Hung [1], Chaohsu Wu[1], Tsenchieh Chiu[1]
[1] Department of Electrical Engineering, National Central University
Jhong-Li City, Taiwan, 32001, ROC, 985401021@cc.ncu.edu.tw

1. Introduction

Conventional metal-plate antennas have been widely applied in the laptop computer as internal antennas for the dual-band or multiband mobile communications. For wireless wide area network (WWAN) and LTE communications, antennas are often required to cover several or all operating bands for the LTE700, GSM850, GSM900, DCS1800, PCS 1900, UMTS, LTE2300 and LTE2500 systems. Therefore, multiband antennas for wireless terminals and small size are emerging in the laptop computer industry. Many studies and works have been conducted to obtain single feed antennas supporting multiband operation, such as metal-plate antenna [1] parasitic branches [2] or coupled-fed [3].

In the paper, we propose a multiband monopole with a parasite strip. The design is rather simple and very suitable for mass production. Instead of using a single parasitic stub as in [4], short stub is used here to further enhance the impedance matching and bandwidth of the lower frequency band of the antenna, and therefore the proposed antenna can cover LTE700, GSM850, GSM900, DCS1800, PCS 1900, UMTS, LTE2300 and LTE2500 systems. The measured results of the fabricated antenna are compared by the simulated ones which were obtained by using Ansoft HFSS (High Frequency Structure Simulator) based on the finite element method [5].

2. Antenna Design

In Fig. 1(a), the antenna is located at the edge of the laptop ground plane (260 x 200 x 0.8 mm^3) with 25 mm offset from the center point and is fabricated on a FR-4 substrate of 65 x 14 x 0.8 mm^3. Figure 1(b) shows the configuration of the proposed antenna formed by a monopole and a parasite folding stub. The dielectric constant and loss tangent of the PCBs are 4.4 and 0.015, respectively. The antenna on the PCB is fed with a 50 Ω coaxial cable shown in figure 1(b). Figure 1(c) shows the detailed dimensions of the proposed antenna.

The total length of the monopole from the feeding point to the open end is about 40.5 mm (about 0.175 λ at 1300 MHz), which makes it promising to generate a quarter-wavelength resonant mode at about 1300 MHz and half wavelength resonator mode at 2100 MHz. With the strip L_1 and L_2 in the monopole, the resonant mode at 2.37 and 2.15 GHz is excited, respectively. Hence, the quarter-wavelength and the half wavelength resonant mode is shifted to 930 MHz and 2340 MHz, respectively. The bandwidth of the lower band is enhanced by using a parasitic strip. The fields are induced in the parasitic strip due to the capacitive coupling, which results in impedance matching and the bandwidth broadening [2]. The position of the parasitic strip is chosen to be around the place where the current density is small at 2.4 GHz. Therefore, the effect of the parasitic strip on the radiation in the upper band can be as small as possible.

3. Results And Discussion

The proposed antenna with dimensions given in Fig. 1(c) is fabricated and tested. Fig. 2 shows the measured and simulated reflected coefficient for the fabricated antenna. Good agreement between the measurement data and simulation is demonstrated. There are two operating bands generated. The lower band is excited around 700 MHz as designed. The lower band has a $|S_{11}| < -6$ dB bandwidth of 262 MHz (698-960 MHz), which covers LTE700, GSM850 and GSM900 operations. Note that the impedance bandwidth definition is generally accepted for practical applications. For the upper band, a much wider bandwidth is obtained, which reaches 980 MHz (1710-2690 MHz) for $|S_{11}| < -6$ dB and covers DCS1800, PCS1900, UMTS2100, LTE2300 and LTE2500. For comparison, the simulated reflection coefficient of the proposed monopole and the reference monopole (without parasite) are shown in Fig. 3. The $|S_{11}|$ of reference monopole at lower band is not less than -6 dB, which is not reach the requirement for LTE and GSM operation. The upper-band bandwidth of reference monopole is 980 MHz (1710-2690 MHz), which is the same as that of the proposed monopole. This simulation demonstrates that the parasitic strip can enhance impedance matching and bandwidth of lower-band without affecting upper-band performance.

The excited surface current distributions on the radiating element for the proposed antenna at 700, 900, 1800, 2100, 2300 and 2500 MHz are presented in Fig. 4. This simulation demonstrates that the main monopole resonates at 900 MHz and 2100 MHz, and the parasitic strip is in effect from 700 MHz to 900 MHz, since the parasitic strip controls the excitation of the lower bands for the proposed monopole.

Radiation characteristics of the antenna are also studied. Figure 5 presents the measured peak gain and measured radiation efficiency of the antenna in Fig. 1. In figure 5(a), (b) and (c), the measured frequency range is from 0.698-0.96 GHz, 1.71-2.17 GHz and 2.305-2.69 GHz, respectively. In figure 5(a), the measured gain is 1.4-2.3 dBi and the measured radiation efficiency is 50-67 %. In figure 5(b), the measured gain is 1.2-3.8 dBi and the measured radiation efficiency is 50-75 %. In figure 5(c), the measured gain is 3.5-4.8 dBi and the measured radiation efficiency is 61-78 %.Figure 6 shows the simulated and measured radiation patterns at 700, 850, 900, 1800, 1900, 2100, 2300 and 2500 MHz for the antenna in Fig. 1.

4. Conclusions

This paper presents a monopole antenna using a parasitic element for covering LTE700, GSM850, GSM900, DCS1800, PCS1900, UMTS2100, LTE2300 and LTE2500 bands. Especially, a parasitic strip is used to enhance the impedance matching and bandwidth of the lower-band covering three application bands. Moreover, the lower and upper band of the antenna can generally be controlled independently by the main monopole and the parasitic antenna. This feature makes it easy to fine-tune the octa-band operation. Good radiation characteristics at frequencies over the eight operating bands have also been obtained.

References

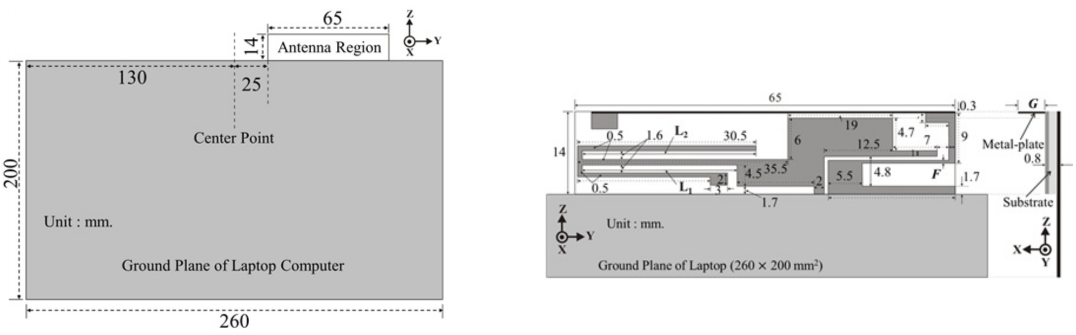
[1] K.L. Wong, L.C. Chou, and C. Wang, “Integrated wideband metal-plate antenna for WLAN/WMAN operation for laptops,” *IEEE AP-S Int. Symp.*, Washington DC, USA, vol. 4A, pp. 235-238, July 2005.

[2] C.L. Hu, D.L. Huang, H.L. Kuo, C.F. Yang, C.L. Liao, and S.T. Lin, “Compact multibranch inverted-F antenna to be embedded in a laptop computer for LTE/WWAN/IMT-E applications”, *IEEE Antennas and Wireless Propag. Lett.*, vol. 9, pp. 838–841, July 21, 2010.

[3] C.H. Kuo, K.L. Wong, and F.S. Chang, “Internal GSM/DCS dual-band open-loop antenna for laptop application,” *Microwave Opt. Technol. Lett.* , vol. 49, no. 3, pp. 680–684, March 2007.

[4] V. Voipio, J. Ollikainen and P. Vainikainen, “Quarter-wave patch antenna with 35 % bandwidth,” *1998 IEEE Antennas Propag Symp.,* pp. 790-793.

[5] High Frequency Structure Simulator (HFSS), version 12.0, Ansoft Corporation.



(a) (b)

Fig. 1. (a) Accommodation of the proposed antenna in the laptop computer. (b) Configuration and detailed dimensions of the antenna, L_1=26.5, L_2=30, F=0.5 and G=1.5 mm. The Unit in the figure is mm.

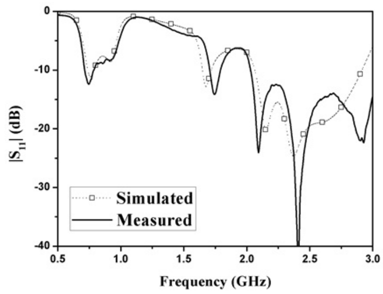


Fig. 2. Simulated and measured reflection coefficient versus frequency for the antenna in Fig. 1.

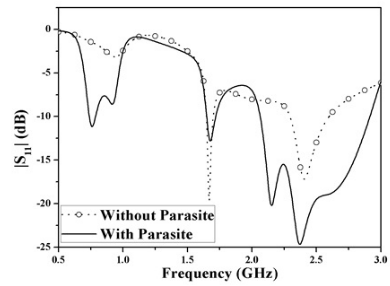
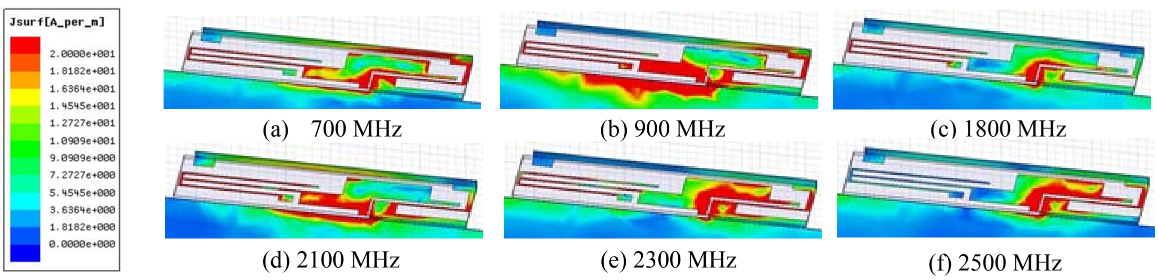


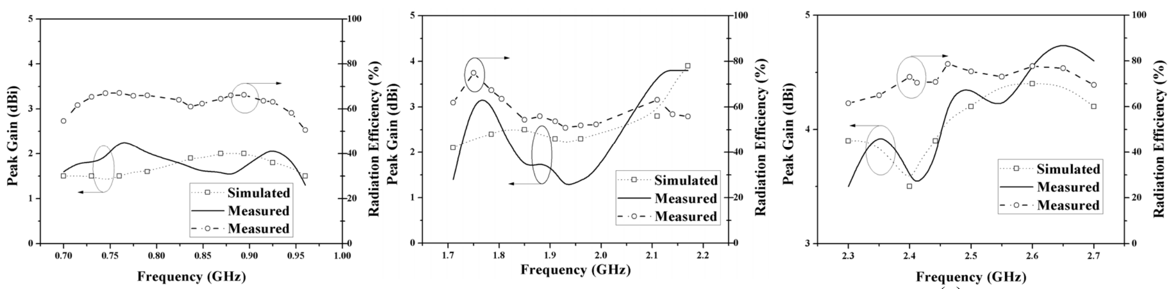
Fig. 3. Simulated and measured reflection coefficient with and without parasitic strip for the antenna in Fig. 1.



(a) 700 MHz (b) 900 MHz (c) 1800 MHz

(d) 2100 MHz (e) 2300 MHz (f) 2500 MHz

Fig. 4. Simulated current distributions for the antenna in Fig. 1 at (a) 700, (b) 900, (c) 1800, (d) 2100, (e) 2300 and (f) 2500 MHz.



(a) (b) (c)

Fig. 5. Simulated and measured gains and measured radiation efficiencies. The measured frequency range is (a) 0.698-0.96 (b) 1.71-2.17 (c) 2.305-2.69 GHz.

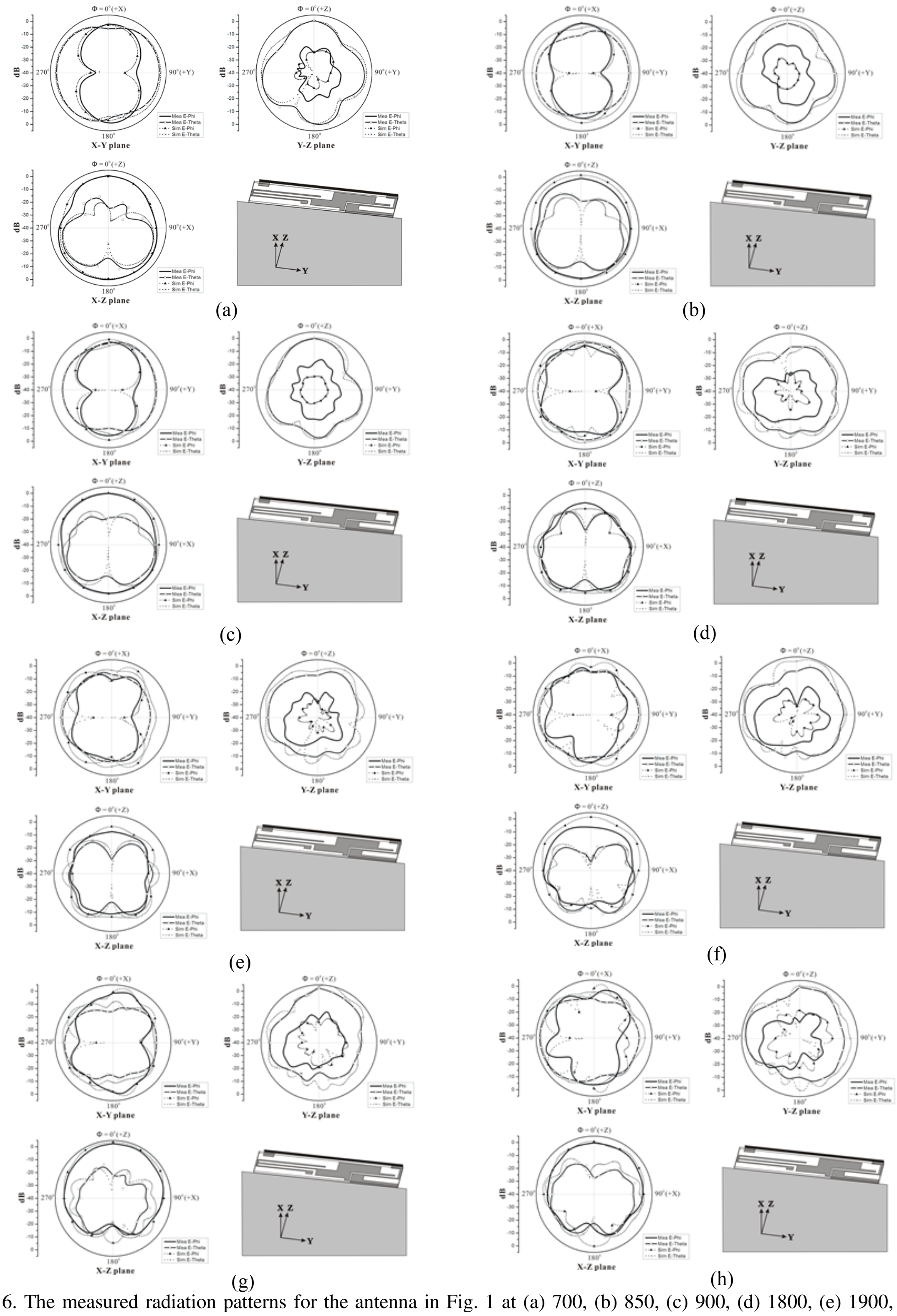


Fig. 6. The measured radiation patterns for the antenna in Fig. 1 at (a) 700, (b) 850, (c) 900, (d) 1800, (e) 1900, (f) 2100, (g) 2300 and (h) 2500 MHz.