Low-profile Tunable WWAN Antenna for Whole-Metal-Covered Mobile Phone Applications

Chun-Yih Wu[1], Yen-Liang Kuo[1] and Keng-Chih Lin[1]
[1]HTC, No. 88, Sec. 3, Zhongxing Rd. Xindian Dist., New Taipei City 231, Taiwan

***Abstract* - A novel tunable coupled-fed dual inverted-L antenna (ILA) antenna suitable for the penta-band WWAN operation in the Whole-Metal-Covered (WMC) slim handset is presented. The antenna mainly comprises a variable chip-capacitor-loaded vertical radiating strip, which is co-existed with part of the metallic bezel on the corner of mobile handset and planar L-shaped radiating strip with a parallel resonant circuit (PRC) integrated therein to achieve multiband operation. The vertical radiating strip generate first resonant modes at about 850 MHz and 1700 MHz and the planar radiating strip generate second resonant modes at about 900 MHz and 1800 MHz respectively, and thereby resulting in dual-wide band operating modes.**

***Index Terms* — Mobile antennas, planar inverted-F antennas (PIFAs), parallel resonant circuit, tunable capacitors**

I. INTRODUCTION

Handset devices with metallic back-cover made by conductive materiel bring the sense of touch and are a symbol of vogue since these years [1]. WMC appearance is not only a soul of HTC in the top tier product series but also the achievement of perfection, which gives both good user experience and bullet-proof grade body [2]. However, the antenna performance is being shackled by such kind of EM-cage and being seriously degraded both in the lower and upper operation bands of the antenna impedance bandwidths. Recently, several integration approaches by applying distributed/lumped parallel resonant circuit (PRC) can enhance the bandwidths of both lower and upper bands of antenna are demonstrated [3-4].

In this article, we propose a low profile coupled-fed antenna structure using a tunable PRC to generate multiple resonant modes for the WMC mobile phone applications. By applying part of metallic bezel as vertical radiating radiator excited by the planar L-shaped radiating strip, the physical antenna structure occupies small design space of only 35 mm × 8 mm. Owing to the tunable PRC, the lower and upper operation bands of the proposed antenna can be controlled by selecting specific capacitance in the range of 0.8 pF – 1.2 pF for GSM850/900/DCS/PCS/UMTS applications.

II. ANTENNA DESIGN

Fig. 1(a) shows the geometry of the mechanical stackup, which is including LCD panel (not taken into consideration in EM modeling here), LCD frame and metallic back cover, respectively. Fig. 1(b) shows the proposed antenna architecture integrated on a metallic plate of size 70 mm x 132 mm with vertical metallic sidewall, which is used as the bezel of LCD panel. Under the metallic plate with a 5.2-mm distance is another metallic plate of size 70 mm x 140 mm treated as a whole metal back cover. All the dimensions are reasonably selected for practical mobile phones.

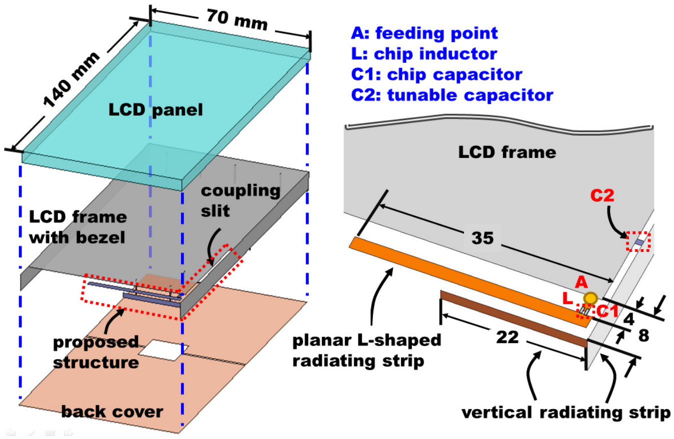
The proposed antenna has a very simple structure and mainly comprises a planar L-shaped radiating strip and a vertical radiating strip as shown in Fig. 1. The antenna is fed at point A on the planar L-shaped strip with a lumped PRC which is formed by a 5.1-nH chip inductor in parallel connection with a 3.3-pF chip capacitor and can generate a parallel resonance near 1085 MHz to excite an additional resonant mode at about 900 MHz as shown in Fig. 2. A shorting point of the proposed antenna is at the vertical radiating strip with a matching capacitor C_2 (0.8 pF – 1.2 pF in simulation and 0.4 pF in experiment) connecting across a coupling slit (2 mm width approximately) to the bezel plane. When the vertical radiating strip is integrated with the planar L-shaped radiating strip structure, however, more resonant modes are generated at lower band around 850 MHz and upper band around 1700 MHz, respectively.

The presence of the vertical radiating strip turns the L-shaped one from a simple monopole into an L-shaped coupling feed, while the vertical strip itself operates as a radiating structure. Owning to the multi-modes generated from coupled-fed dual inverted-L antenna structure, a dual-wideband performance is achieved to cover the GSM850/900/DCS/PCS/UMTS penta-band operation.

III. RESULTS AND DISCUSSION

The proposed antenna is not only simulated with the aid of Ansys HFSS, but fabricated and measured as well. Fig. 3 shows the simulated and measured reflection coefficients with different value of matching capacitor (C_2). With the aids of C_2, the input impedance of the proposed antenna is tunable for different operating frequencies. Decreasing the value of C_2 may shift the impedance bandwidth toward the higher frequency. A different value of C_2 in measurement is to conquer the frequency shift form the FR4 substrate of the handmade mockup. Based on the results of various C_2, a tunable mechanism can be established for different frequency requirement. Fig. 4 shows the total radiation efficiency (measured by Bluetest RTS60) corresponding to the result in Fig. 3 in measurement with good in-band performance. Over the lower band and higher bands, the measured total antenna efficiency is about -4.1 to -2.7 dB and -5.3 to -2.5 dB, respectively.

Fig. 5 plots the 3-dimensional radiation patterns at 850 MHz, 1850 MHz and 2140 MHz of operation frequencies which are measured by Satimo SG64 MC. Each frequency has four views of angle for better understanding of the radiation patterns. The dipole-like radiation patterns with omnidirectional radiation on the x-y plane is observed at the lower band, which shows good agreement with the conventional monopoles. In the upper band, the radiation patterns become more directional due to the short wavelength compared to the proposed structure.



(a) (b)

Fig. 1. Configuration of (a) Cross sectional view of mechanical stackup (b) Proposed antenna and the whole metal back cover.

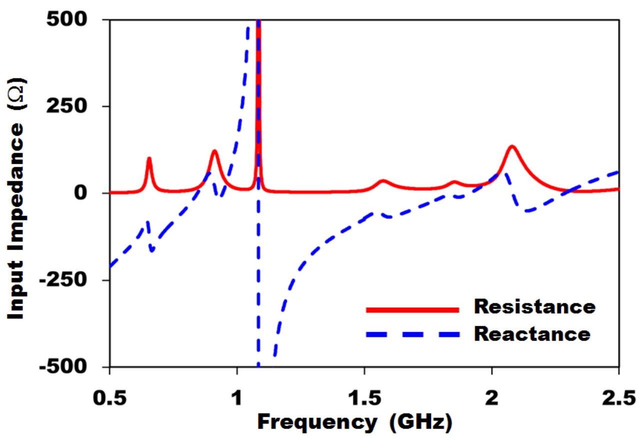


Fig. 2. Simulated input impedance for the proposed antenna.

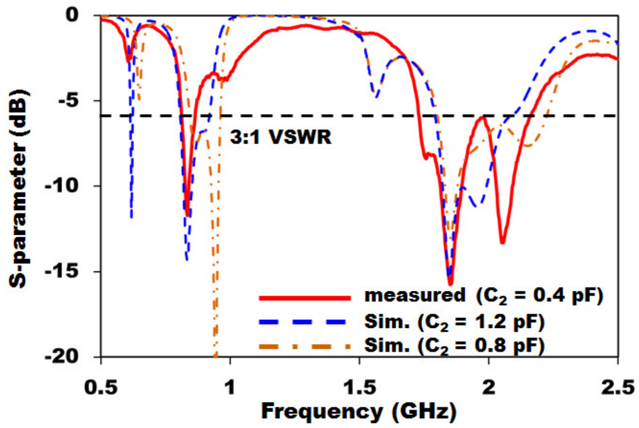


Fig. 3. Measured reflection coefficients with the variation of matching component C_2 on the vertical radiating strip.

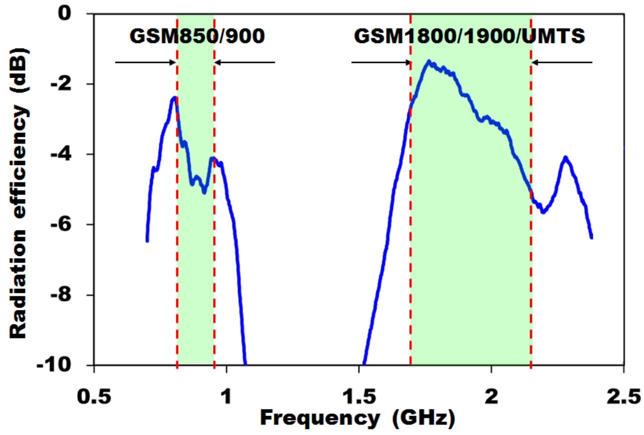


Fig. 4. Measured total radiation efficiency across the GSM850/900/DCS/PCS and UMTS bands.

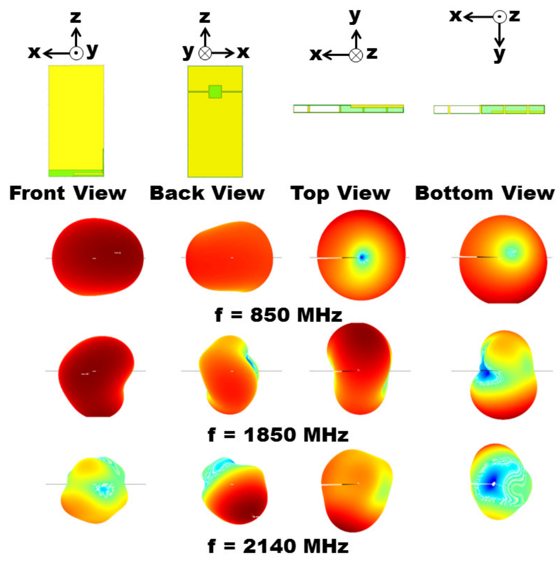


Fig. 5. Measured 3-D radiation patterns of the proposed antenna.

IV. Conclusion

A promising penta-band tunable antenna architecture with a size of 35 mm × 8 mm for whole metal back covered mobile phone application has been introduced and constructed. By incorporating the lumped PRC and tunable capacitor simultaneously, good impedance matching characteristic and radiating performance over the operation bands are obtained in this study. The results indicate that the proposed antenna structure can meet the requirements of whole-metal-covered mobile phone devices in the further engineering examination and mass production.

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