A compact tri – band antenna at GPS and WLAN a/b/g bands for tablet with full metal housing

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***Abstract*—A very small antenna for full metal housing tablet that can provide GPS and WLAN 2.4/5.2/5.8 GHz operations is presented. The dimension of the proposed antenna is 6×7 mm^2, and it is only 0.03λ at GPS frequency. Antenna size miniaturization and multiband resonances are achieved by combining the monopole antenna self-resonant mode, PCB ground mode and cavity mode with proper excitation and impedance matching. The measured efficiencies at 1.575, 2.4 and 5.5 GHz were 37%, 63% and 88%, respectively. The proposed antenna has very competitive size for applications in this operation environment.**

Keywords—WLAN antenna; cavity mode; tablet antenna

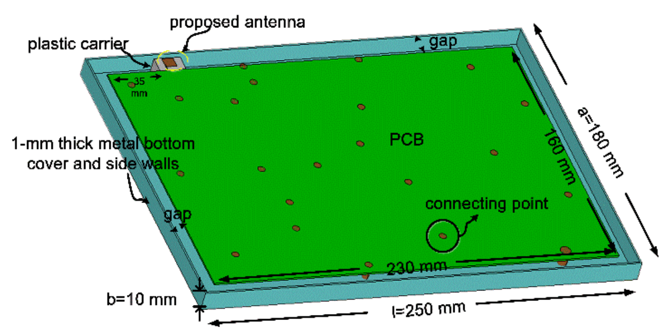
I. INTRODUCTION

There is an increasing demand from the industry to design mobile device with full metal housing (FMH), however, to successfully design an antenna in this environment, so that multiband and high efficiency can be attained is presently a challenging topic. In [1], a compact loop-slot mode combined antenna is presented. Instead of using the metal housing as radiation element, the method used in this case is to decrease the coupling effects from metal housing. In this paper, a very small size antenna (6×7 mm2) for FMH environment is proposed, and it can induce three separate modes. The upper mode is a monopole antenna self-resonance at 5.5 GHz, while the middle mode is a cavity mode (mentioned in [2]) excited from the metallic tablet at 2.4 GHz, as a results from the proposed antenna that acts as a coupling feed. The lower mode is a PCB ground mode at 1.575 GHz, and it is excited by adding a matching circuit near the feeding location. Sufficient bandwidths and efficiencies are achieved to cover both GPS and WLAN a/b/g bands.

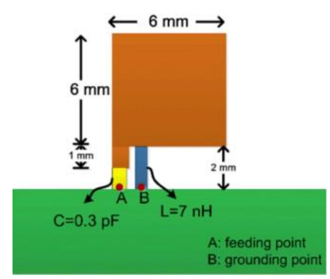
II. ANTENNA DESIGN

Fig. 1 (a) shows the model of proposed FMH tablet that is comprised of PCB board, metal housing, plastic antenna carrier and small antenna. The metal housing includes full metal cover and metal side walls (without any slot), and the FMH tablet has a standard size of 250×180×10 mm^3. The PCB (230×160×0.8 mm3) is positioned in the middle of metal housing with a gap distance of 10 mm away from each side wall, and it is supported at 8 mm above the metal bottom cover.

The small antenna is positioned on a plastic carrier of 8 mm height at the same horizontal level with PCB. The plastic carrier dielectric constant is 2.3 and loss tangent is 0.01. As shown in Fig. 1 (b), the small antenna is similar to a monopole type that is composed of a square (6×6 mm^2) radiator and a feeding line (1×1 mm^2) extended in the right bottom corner linked in series to a capacitor C = 0.3 pF and feeding point A, which therefore excited a 1/4 wavelength monopole self-resonance mode at 5.5 GHz. Here, a shunt inductance L = 7 nH is also used to link between the grounding point B and square radiator, in which the series C and shunt L forms a matching circuit that allow the antenna to effectively induce a PCB ground mode (also reported in [3]) at 1.575 GHz for GPS operation, with minimum impact to the 5 GHz band. To excite a resonant mode at 2.4 GHz, it is feasible to use the characteristic mode around this frequency created by the cavity between the metal housing and conductive PCB board of tablet.



(a)



(b)

Fig. 1 Geometry of the proposed metal housing tablet, and detailed dimensions of proposed antenna. (a) Geometry of tablet. (b)Detailed dimension of antenna

Based on Eq. (1), the frequency of cavity mode can be calculated as follow:

$$f = \frac{c}{2}\sqrt{(\frac{m}{a})^2 + (\frac{n}{b})^2 + (\frac{p}{l})^2} \quad (1)$$

where f is the resonance frequency, c is the speed of light, a, b and l are the edge length of cavity, while m, n, and p are used to represent different TM modes or TE modes. Here, the parameters are listed as follows: a = 180 mm, l = 250 mm, b = 8 mm, m = 2, n = 0, p = 3, and the calculated result is 2.45 GHz. Because many other unwanted cavity modes are also induced, several connecting points are therefore inserted between the bottom metal housing and PCB board to eliminate them.

III. RESULTS AND DISCUSSION

Fig. 2 shows the simulated and measured S11 of the proposed antenna. The measured results based on 6 dB return loss threshold can cover the GPS (1565–1585 MHz) and entire WLAN operating bands (2400–2484 MHz, 5150–5875 MHz). Fig. 2 also shows the photo picture of fabricated antenna with the FMH tablet.

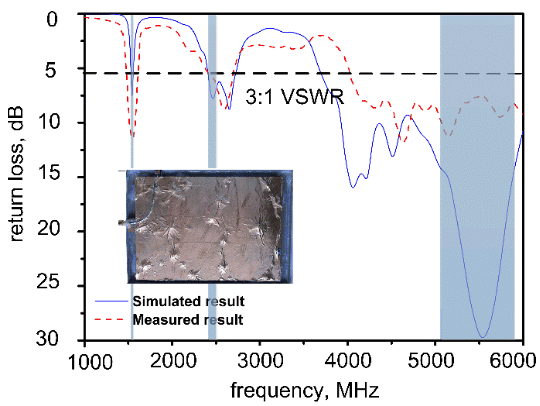


Fig. 2 Simulated and measured S11 of proposed antenna

The far-field radiation patterns at different frequencies were measured in a standard ETS AMS 8500 chamber, and the measured radiation patterns at 1.575, 2.45, 5.4 GHz are plotted in Fig. 3. The measured peak gains and radiation efficiencies are shown in Fig. 4, and the peak gains obtained in the 1.575, 2.45 and 5.4 GHz bands are 1.18, 6.49, 6.44 dBi, respectively, while its corresponding measured efficiencies were 36–37% for GPS, 60–63% for WLAN 802.11 b/g (2.4–2.4835 GHz), and 53–88% for WLAN 802.11 a (5.15–5.875 GHz). These results are acceptable for practical tablet application.

IV. CONCLUSION

In this paper, a wide tri-band antenna has been successfully proposed and fabricated for FMH tablet. The tri-band operation of proposed antenna is achieved by utilizing the monopole antenna self-resonant mode, and exciting the PCB ground mode and cavity mode from tablet full metal housing. Compared with traditional antenna, this proposed antenna design best utilized the metal housing and PCB for radiation, and therefore able to decrease the antenna volume significantly and achieve higher radiation efficiency. The fabricated antenna prototype has exhibited 6 dB return loss bandwidth of 1.49–1.6 GHz for GPS, 2.4–2.68 GHz for WLAN 802.11 b/g, and 4–6 GHz for WLAN 802.11 a. Because the antenna has exhibited very small size of 6×7 mm^2 (0.03λ at GPS frequency) under full metal environment for commercial tablet, it therefore shows great potential for industrial applications.

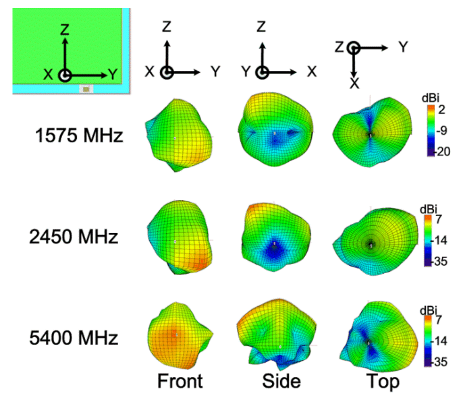


Fig. 3 Measured 3D radiation patterns of proposed antenna

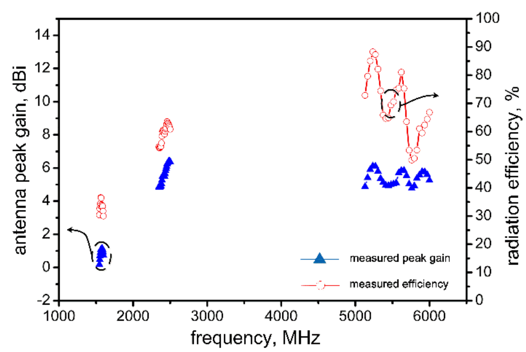


Fig. 4 Measured peak gains and efficiencies

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