Dual-band internal antenna of PIFA type for mobile handsets and the effect of the handset case and battery

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This paper presents a novel compact internal antenna with the modified planar inverted F antenna (PIFA) type and investigates the influence of the handset case and battery. The proposed antenna operates at KPCS (1750-1870 MHz), and Bluetooth (2400-2483.5 MHz) bands in a practical handset. The represented antenna can be easily installed in practical handsets with the small size. The bandwidth of the proposed antenna (VSWR < 2) shows 140 MHz in KPCS band and 90 MHz in Bluetooth. Numerical simulation and experiment results are performed considering the antenna and the phone case and battery.

Introduction

Recently, internal antennas for handset applications are increasingly demanded due to not only improving good aesthetic appearance but also simple terminal design, compactness, serviceability, and robustness. However, in order to be applied in real handset situations, the internal antennas should have the improved characteristics in terms of gain, efficiency, bandwidth, and radiation pattern, and be smaller than external type ones in size. As a result, there has been a surge in PIFA for mobile handsets due to its compactness, low profile, ease of manufacture, reduction of SAR(Special Absorption Rate), and good electrical performance [1]. In an early stage, even though only the antenna itself is designed to satisfy the desired operation, its performances have been affected by the practical handset case and battery [2]. Therefore, the antenna should be modified to obtain the desired characteristics in most cases.

In this paper, a novel dual-band internal antenna of PIFA type is proposed and built in the practical handset case with battery by modifying the antenna and ground design to check their effects. The simulation is performed with HFSS, MWS, and SEM CAD. The effect of the handset case and battery are investigated and the measured and the simulated results are compared with each other.

Antenna Design and Experimental Result

The dual-band antenna for PCS/Bluetooth applications is proposed, as shown in Fig. 1. The size of the proposed antenna is $27.5\times12\times1$ mm^3 and its total height from the ground is 9 mm. It is made of FR-4 (ε_r = 4.6) substrate and etched on the top and bottom faces. Particularly, this antenna utilizes the side coating technology on the each side and edge corner of FR-4 radiating element. The ground substrate with dimension of $40\times75\times1$ mm^3 is made of FR-4

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and has via holes. The antenna fed by a 50 Ω coaxial cable has two radiating elements on the top and bottom faces pointed at A and B, and a parasitic part marked on C in Fig. 1. Due to utilizing both faces, the size of the antenna can be further reduced and each radiating patch has more available room. Fig. 2 shows the measured and simulated return losses related with different gap spaces. When the gap spaces are 0.5 mm, the antenna covers both the KPCS and Bluetooth bands in the measured result. The gap space has a greater effect on the Bluetooth band than in KPCS band because the parasitic element of the bottom face is relatively larger than the top one. As a result, the gap spaces have an effect on impedance matching and resonant frequency. Fig. 3 shows the surface current distributions and the trace of reflection coefficient on the Smith chart. As shown in Fig. 3 (a)-(d), the current distributions are dominant on the top face in KPCS and on the bottom face in the Bluetooth band, respectively. The electrical length of each associated radiating element corresponds to quarter-wavelength ($\lambda_g/4$) from the feed point to open end in Fig. 3 (a) and (d). Their lengths are about 22 mm at 1.8 GHz and 14.5mm at 2.44 GHz. In Fig. 3, the measured points of 1.8GHz and 2.44GHz are concentrated and the trace of KPCS and Bluetooth band are rolled in the center vicinity of the Smith chart. This means the antenna is well matched in each desired band. The measured and simulated radiation patterns at 1.8 GHz and 2.44 GHz are plotted together in Fig. 4 and show a good agreement with each other. In particular, Fig. 4 (b) and (e) show that the radiating E-field is less in the back side of the ground than in the front one, where the head is located. This means the proposed antenna has little effect on the head. The measured and simulated maximum radiation gain is 1.91 dBi and 1.84 dBi at 1.8GHz, and 1.21 dBi and 1.18 dBi at 2.44 GHz.

Antenna Built In a Handset Case with Battery and Experimental Result

After designing the proposed antenna, in order to install in a practical handset case, the shape and size of the antenna and ground are changed, as shown in Fig. 5 and the total height of the antenna is fixed to 7 mm. Fig. 6 shows the return loss of the original proposed antenna built in the handset case with battery. The center frequency of the KPCS band is shifted down about 200 MHz due to the handset case with battery, but the one of Bluetooth band is only slightly changed because the substrates(ε_r=4.6) of the antenna and ground affect the radiating element of the bottom face more than the handset case(ε_r=2.8) due to the position of the bottom face. The configuration of the modified antenna is represented in Fig.5. The length of the radiating element of the top face is reduced from 26 mm to 22 mm and the vertical gap size is also reduced from 0.5 mm to 0.3 mm. The final result of the measured and simulated return loss is shown in Fig. 6. The bandwidth (VSWR < 2) is 140 MHz (1740 - 1880 MHz) in KPCS band and 90 MHz (2400 - 2490 MHz) in Bluetooth. Fig. 7 represents the geometry of the handset case with battery. The relative permittivity and conductivity of each material is presented in Table I. The handset case is made of Acetal(ε_r=2.8, σ_E=0.002), one of the materials most commonly used for the commercial phone case. The radiation patterns for the modified antenna in the handset case with a battery are shown in Fig. 8. The radiation patterns between those with and without are similar to each other. The radiating E-field is also less in the backside of the ground. The measured maximum radiation gain is 1.69 dBi at 1.8 GHz and 1.28 dBi at 2.44 GHz, respectively.

Conclusion

A novel antenna of PIFA type suitable for KPCS and Bluetooth bands has been proposed and experimentally studied. In addition, the antenna is applied to the practical handset with battery. This paper presented the effects of the handset case and battery on antenna performance. The characteristics of the proposed antenna are changed through being built in the handset case, and the design of the original antenna is modified. These features make the proposed antenna attractive for mobile handsets.

Acknowledgement

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References:

[1] L. Z. Dong, P. S. Hall, and D. Wake, "Dual-frequency planar inverted-F antennas," *IEEE Trans. Antennas Propagat.*, vol. 45, pp. 1451-1458, Oct. 1997

[2] D. U. Sim, S. O. Park, "The effects of the handset case, battery, and human head on the performance of a triple-band internal antenna," *Antennas Propagat.*, vol. 2, pp. 1951 – 1954, June 2004

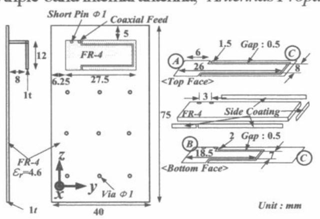


Fig 1.Configuration of the proposed antenna

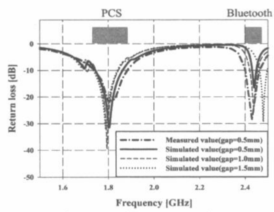
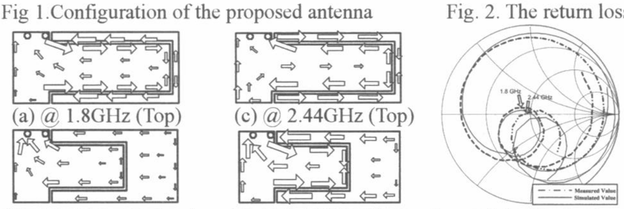


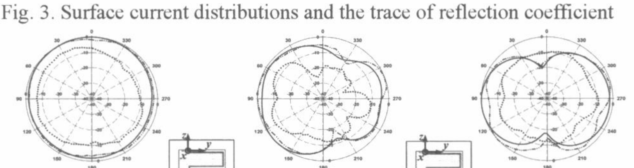
Fig. 2. The return loss



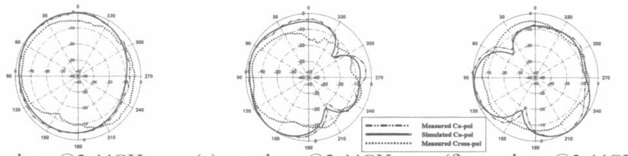
(a) @ 1.8GHz (Top) (c) @ 2.44GHz (Top)

(b)@ 1.8GHz (Bottom) (d) @ 2.44GHz (Bottom) (e) Smith chart

Fig. 3. Surface current distributions and the trace of reflection coefficient



(a) x-y plane @1.8GHz (b) x-z plane @1.8GHz (c) y-z plane @1.8GHz



(d) x-y plane @2.44GHz (e) x-z plane @2.44GHz (f) y-z plane @2.44GHz

Fig. 4. Radiation patterns for the proposed antenna at 1.8 GHz and 2.44 GHz

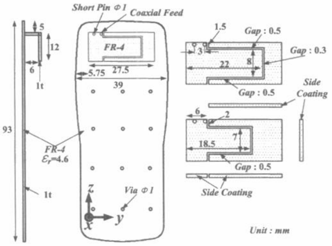


Fig. 5. Configuration of the modified antenna

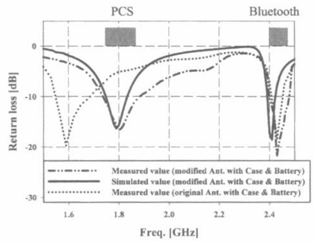


Fig. 6. The return loss

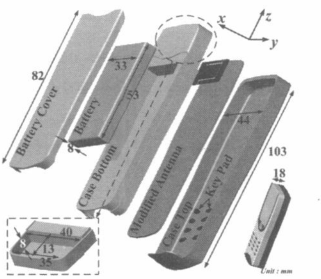
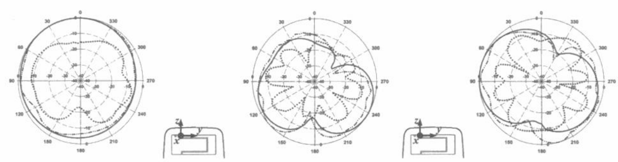


Fig. 7. Geometry of the handset case with battery

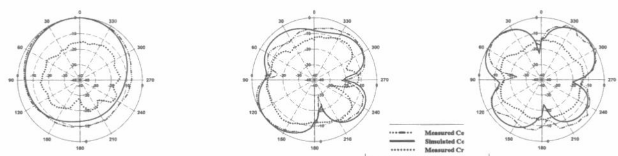
TABLE I

Parameters of the Substrate, Handset case, and Battery

	ε_r	σ_E (S/m)
FR-4	4.6	
Case	2.8	0.002
Battery	3.0	0.5



(a) x-y plane @1.8GHz (b) x-z plane @1.8GHz (c) y-z plane @1.8GHz



(d) x-y plane @2.44GHz (e) x-z plane @2.44GHz (f) y-z plane @2.44GHz

Fig. 8. Radiation patterns for the modified antenna at 1.8 GHz and 2.44 GHz