# Design and Implementation of Internal Multi-Band Monopole Antenna for Mobile Phones

Woon Geun Yang*★, Ling Zhi Cai* , Cheol Yong Yang*


## Abstract

In this paper, we proposed an internal multi-band monopole antenna for mobile phone that can be used for smart phones. The proposed antenna has a small volume of 38×8.5×5 $mm^3$, ground size is 100×60 $mm^2$, and covers the GSM900 (Global System for Mobile communications : 880-960 MHz), DCS (Digital Communications System : 1710-1880 MHz), K-PCS (Korea-Personal Communications Service : 1750-1870 MHz), US-PCS (US Personal Communications Service : 1850-1990 MHz), Bluetooth (2400-2483 MHz), Wibro (2300-2390 MHz) and WLAN (Wireless Local Area Network : 2400-2483.5 MHz) bands. The measured peak gains of the implemented antenna are 1.15 dBi at 920 MHz, 3.58 dBi at 1795 MHz, 3.46 dBi at 1810 MHz, 2.91 dBi at 1920 MHz, 5.18 dBi at 2345 MHz, 3.37 dBi at 2442 MHz.


Key words: Monopole, Multi-Band, Internal antenna, Folded

## I. Introduction

With the development of the mobile communication technology, the function of the mobile phone has been changed more and more diverse. The essentially required characteristic is to support multiple frequency bands for the third generation mobile system[1-2]. In addition to multi-band capability, due to the modern mobile phone design, there are strong demands for small-sized, light weight, and compact mobile stations, easy to manufacture and flexible structure.

Various multi-band planar inverted-F antennas (PIFAs), monopoles, and slot antennas have been reported in the literature for mobile phone applications[1-5]. Monopole antennas have been employed widely in various mobile and ground-based communication systems due to its simple topology, omnidirectional radiation pattern and moderate efficiency[6-8]. Number of frequency bands covered with a single antenna is increasing, and each design covers specific required frequency band set. For our case, smart phone size is also considered.

In this paper, we propose an internal monopole antenna for multi-band operation covering the GSM900 (Global System for Mobile communications : 880-960 MHz), DCS (Digital Communications System : 1710-1880 MHz), K-PCS (Korea-Personal Communications Service : 1750-1870 MHz), US-PCS (US Personal Communications Service : 1850-1990 MHz), Bluetooth (2400-2483 MHz), Wibro (2300-2390 MHz) and WLAN (Wireless Local Area Network : 2400-2483.5 MHz) with three branch lines.

Basic structure for the proposed antenna is described in chapter 2. Simulation and measurement results for the proposed antenna will be in chapter 3. Finally, conclusion follows in chapter 4.

## II. Proposed Antenna

Fig. 1 depicts the proposed internal multi-band

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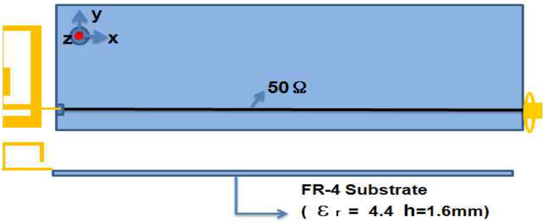
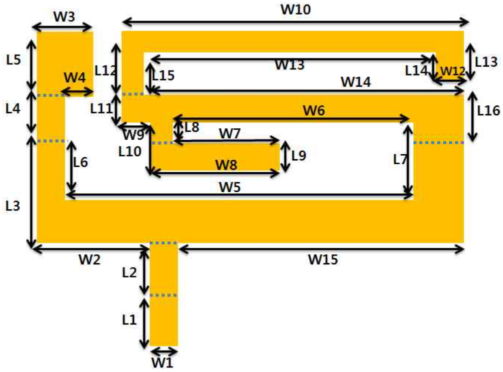
※ Acknowledgement
This work was supported by University of Incheon Research Grant in 2011.

Manuscript received Dec.12,2011;revised Dec.26, 2011 accepted Dec. 27, 2011

monopole antenna. For the design studied here, the antenna volume of example design is 38×8.5×5 $mm^3$, and it has folded structure. The ground size is 100 ×60 $mm^2$. The monopole is located at the left end corner of the FR-4 substrate with the dielectric constant of 4.4 and the substrate thickness of 1.6 mm.




(a)




(b)

Fig. 1. Proposed antenna
(a) Top and side view,
(b) Parameters of the proposed antenna

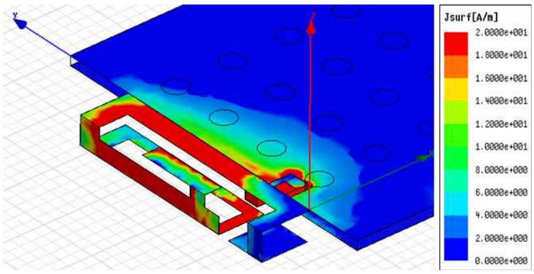
Table 1. Design parameters of the proposed antenna (unit : mm)

| Parameter | Length | Parameter | Length |
|---|---|---|---|
| L1 | 5.0 | W1 | 2.5 |
| L2 | 5.0 | W2 | 11.0 |
| L3 | 8.5 | W3 | 7.0 |
| L4 | 5.0 | W4 | 4.0 |
| L5 | 8.0 | W5 | 31.0 |
| L6 | 5.0 | W6 | 19.0 |
| L7 | 7.0 | W7 | 10.0 |
| L8 | 2.0 | W8 | 13.0 |
| L9 | 3.0 | W9 | 3.0 |
| L10 | 5.0 | W10 | 29.0 |
| L11 | 3.0 | W11 | 2.0 |
| L12 | 8.0 | W12 | 3.0 |
| L13 | 6.0 | W13 | 24.0 |
| L14 | 4.0 | W14 | 27.0 |
| L15 | 6.0 | W15 | 24.5 |
| L16 | 5.0 | | |

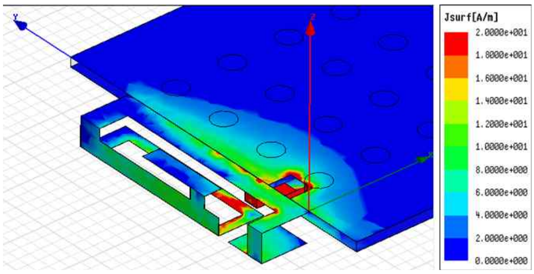
Table 1 shows values of the design parameters which were derived through the simulation.

## III. Simulation and Measurment

The commercial program HFSS (High Frequency Structure Simulator) based on the FEM (Finite Element Method) is used to obtain suitable values of parameters and analyze the behavior of the proposed antenna.




(a)

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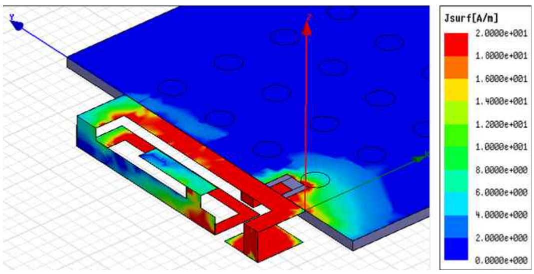
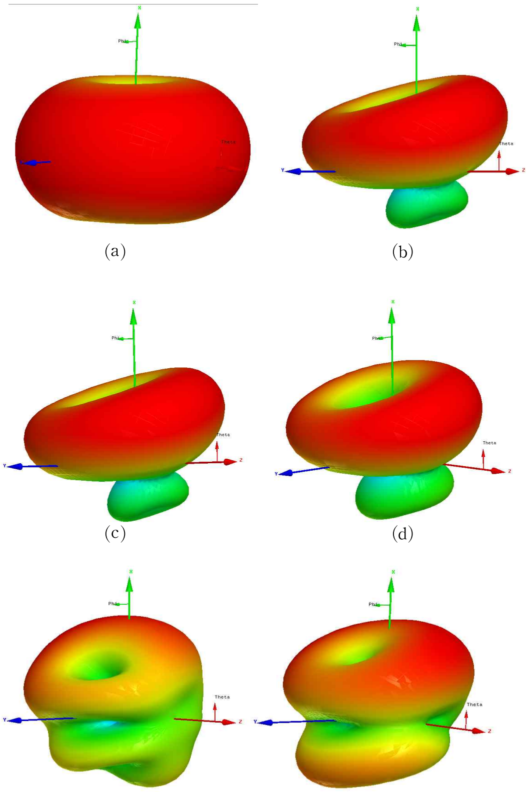



(c)

Fig. 2. Current distribution of the proposed antenna (a) at 920 MHz, (b) at 1795 MHz, (c) at 2442 MHz.

Fig. 2 shows the excited surface current distributions obtained from the HFSS simulation in



(a) (b) (c) (d) (e) (f)

Fig. 3 Simulated 3D radiation patterns of the proposed antenna
(a) at 920 MHz, (b) at 1795 MHz, (c) at 1810 MHz, (d) at 1920 MHz, (e) at 2345 MHz, (f) at 2442 MHz.

the radiation element of the proposed antenna at 920 MHz, 1795 MHz, 2442 MHz. The proposed antenna has three branch lines. On the right side, the longest branch is the major radiation element for the proposed antenna at 920 MHz. On the left side, a short branch plays a major role for 2442 MHz.

Fig. 3 shows simulated 3D radiation patterns at 920 MHz, 1975 MHz, 1810 MHz, 1920 MHz, 2345 MHz, 2441 MHz.

Fig. 4 shows the implemented antenna. Fig. 5 shows measurement and simulation results on the $S_{11}$ of the proposed antenna. The results show a good agreement between measurement and simulation. The implemented antenna satisfied multiple operating bands including GSM900 (880-960 MHz), DCS (1710-1880 MHz), K-PCS (1750-1870

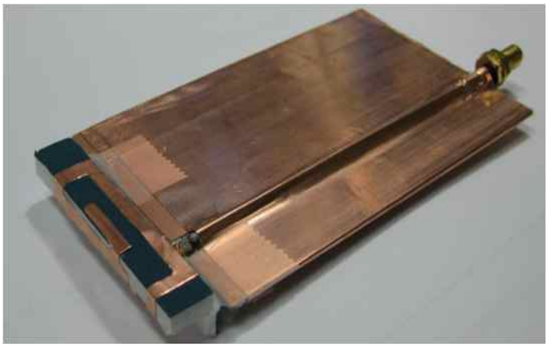


Fig. 4. Photo of the implemented antenna

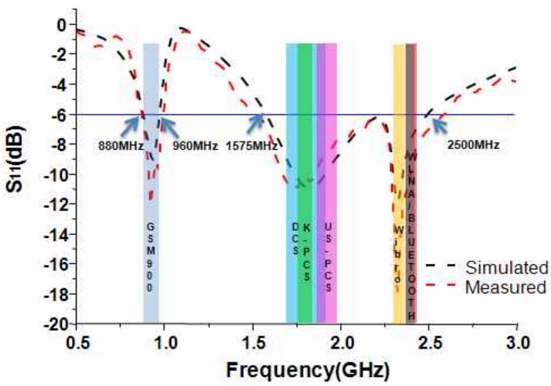
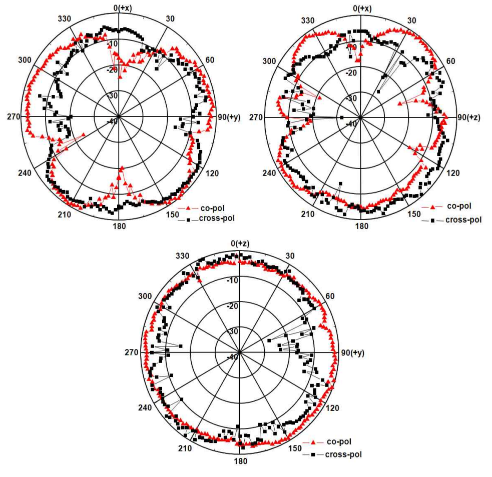



Fig. 5. Simulated and measured $S_{11}$

MHz), US-PCS (1850-1990 MHz), Bluetooth (2400-2483 MHz), Wibro (2300-2390 MHz) and WLAN (2400-2483.5 MHz) bands.

Fig. 6 shows the measured co-polarization and cross-polarization normalized radiation patterns of the implemented antenna in the x-y, z-y and x-z planes at seven different frequencies.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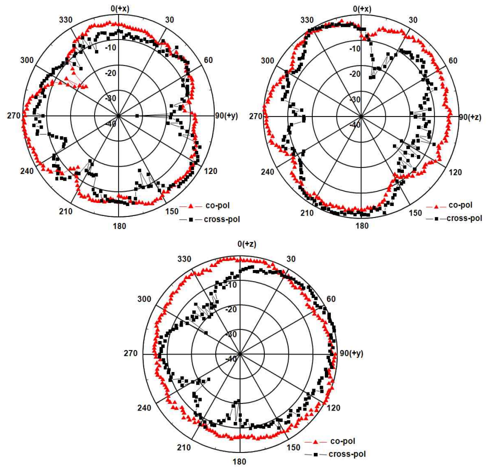
(a)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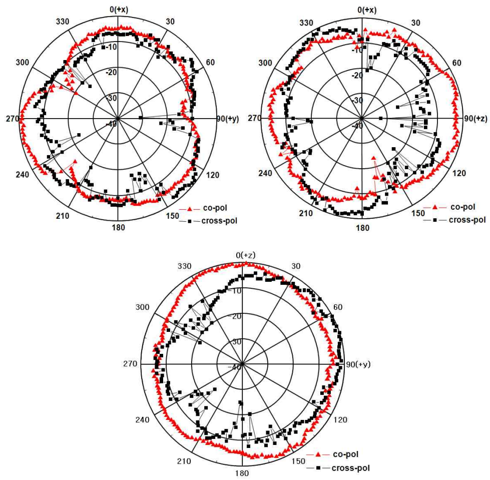
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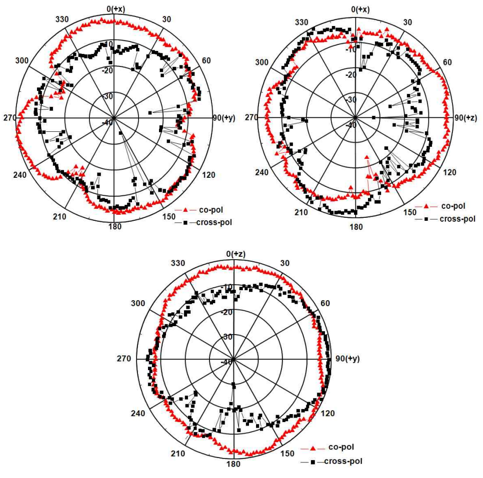
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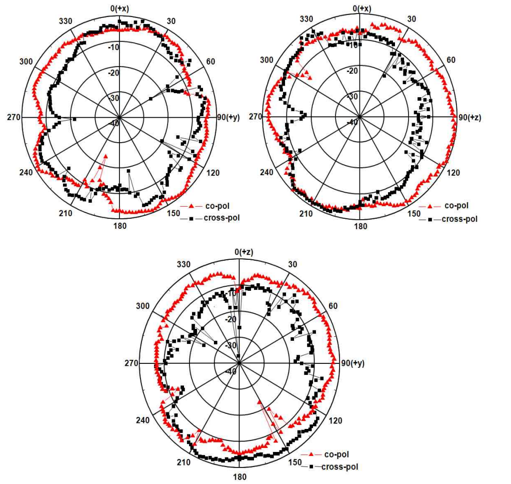


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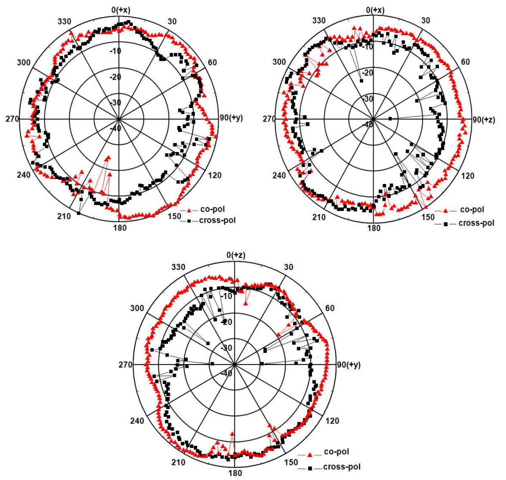


(f)

Fig. 6. Measured radiation patterns of the implemented antenna
(a) at 920 MHz, (b) at 1795 MHz, (c) at 1810 MHz, (d) at 1920 MHz, (e) at 2345 MHz, (f) at 2442 MHz.

Table 2 shows the results of maximum peak gain and average gain measurement of the implemented the antenna. On each band, the peak gain is the maximum measured gain of the antenna. And average gain is the averaged value of the measured gain for each frequency band measurement.

Table 2. Antenna gain measurement

| Frequency Band | Peak Gain(dBi) | Average Gain(dBi) |
|---|---|---|
| GSM900 | 1.15 | -2.01 |
| DCS | 3.58 | 1.42 |
| K-PCS | 3.46 | 0.77 |
| US-PCS | 2.91 | 0.81 |
| Bluetooth | 5.18 | 1.16 |
| Wibro/WLAN | 3.37 | -2.13 |

Through this table we can see that the maximum peak gain and average gain of GSM band are 1.15 dBi, -2.01 dBi, respectively. For the DCS band, the maximum peak gain and average gain are 3.58 dBi, 1.42 dBi, respectively. For the K-PCS band, the maximum peak gain and average gain are 3.46 dBi, 0.77 dBi, respectively. For the US-PCS band, the maximum peak gain and average gain are 2.91 dBi, 0.81 dBi, respectively. For the Bluetooth band, the maximum peak gain and average gain are 5.18 dBi, 1.16 dBi, respectively. For the Wibro and WLAN bands, the maximum peak gain and average gain are 3.37 dBi, -2.13 dBi, respectively.

## Ⅳ. Conclusion

We proposed an internal multi-band folded monopole for mobile phone. We designed and fabricated the multi-band monopole for GSM, DCS, K-PCS, US-PCS, Bluetooth, bands with three branch lines and measurement showed suitable performance. The antenna has a small volume of $38\times8.5\times5$ $mm^3$, and ground size is $100\times60$ $mm^2$. The proposed internal monopole antenna has proper gain performance and radiation pattern characteristics. We expect that the proposed monopole is applicable for multi-band mobile phone.

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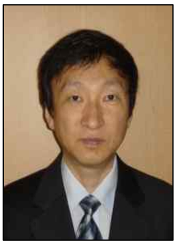

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