GSM/DCS/IMT-2000 Triple-Band Built-In Antenna for Wireless Terminals

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***Abstract*—The development of electrically small antennas play an important role in rapidly growing mobile communication market. This paper presents a novel design technique of the triple-band small internal antenna which covers GSM/DCS/IMT-2000 bands. The proposed antenna consists of the double shorting posts, feed post, and the dual-crossed C-slot patch radiators. The high-frequency structure simulator simulation is employed for optimizing the design parameters, and the simulation results agree with the measured data. The IE3D simulation is also used to obtain the current distribution at the resonant frequencies. The maximum gains at the frequencies 950 and 1860 MHz are measured about 1.58 and 1.3 dBi, respectively. These positive antenna gains and triple-bands of the proposed antenna are very attractive features for GSM/DCS/IMT-2000 bands handset applications.**

***Index Terms*—Double-crossed C-slot, double-short posts, planar inverted-F antenna (PIFA), triple-band.**

I. Introduction

As mobile communications grow rapidly, multiple frequency bands are used. It is desirable for a single handset to access the additional several services such as voice, data, and video at anytime and anyplace. As a result, the demand of wireless terminals capable to operate at the triple band is increasing. At the same time, the wireless handset adapts popularly the internal antenna structure also. Therefore, small size and multiband internal antenna for wireless terminal is an explosive issue.

The planar inverted-F antenna (PIFA) has a desirable multiband feature with higher efficiency, low profile and lightweight internal antenna. This structure can be easily incorporated into personal communication equipment, reported in [1]–[5], using the shorting posts in [6], [7]. Due to these advantages, PIFA become attractive candidates in wireless communications. But the narrow bandwidth characteristic of PIFA is one of the limitations for its commercial application for wireless mobile terminals.

With the extension of PIFA type structure, the novel broadband internal antenna which operates at the GSM/DCS/IMT-2000 triple-band is introduced. The proposed antenna is derived from PIFA-type antenna, and the bandwidth is improved by adjusting the location and the spacing between two shorting posts and the width of double-crossed C-shape slots. The shorting post near the feed probe point of usual PIFA types is good method for reducing the antenna size, but this results into the narrow impedance bandwidth. It is difficult, especially at global system for mobile (GSM) band, that very small antenna produces the required bandwidth if the current distribution would be restricted into the vicinity of the antenna element [8].

The proposed two shorting posts inside of dual-crossed C-shape slotted patch can contribute to improve the high-frequency dual-resonance bandwidth by adjusting the spacing (d) between two shorting posts. The bandwidths of antenna for VSWR < 3 can be achieved about 11.5% (880–990 MHz) at the low frequency (GSM band) and 25% (1710–2200 MHz) at the high frequency [digital cordless system/international mobile telecommunication (DCS/IMT)-2000 band].

This paper presents the experimental results of the impedance bandwidth and radiation characteristics compared to simulations.

II. Antenna Configuration

The built-in antenna mounted on main the printed circuit board (PCB) part of mobile terminal is shown in Fig. 1(a). Main PCB layer has a FR-4 composite ($\varepsilon_r = 4.6$) with the size $45\ \mathrm{mm} \times 100\ \mathrm{mm} \times 1\ \mathrm{mm}$. The proposed antenna is supported by the acrylonitrite butadrene styrene (ABS), which has relative permittivity ($\varepsilon_r = 2.6$). Especially, the top view of patch radiator is shown in Fig. 1(b).

They form the crossed dual slots by C-shapes, where the high-frequency resonator is due to the middle of patch and the lower frequency resonator is attributed to the outer patch. By carefully optimizing the physical antenna parameters, the antenna can be turned to triple bands. The dimension of outer patch is designed for GSM band and the inner patch is optimized at DCS/IMT-2000 frequency bands.

Two shorting posts inside of the middle of the patch are used for current terminating circuit with very small resistance [6]. So there is current traveling path between feed point and shorting post, and it contributes resonance characteristics of DCS and IMT-2000 bands. Increasing the separation distance between two shorting posts, the spacing between two resonance frequencies is decreased. So we can improve the bandwidth of antenna by using dual-resonance characteristic with the proper spacing (d) between two shorting posts. This technique is utilizing the maximum current traveling path within the antenna volume from feed point, unlike the general shorting post of PIFA-type antenna, which place on the adjacent to feed point.

Manuscript received January 2, 2004; revised March 23, 2004. This work was supported by the National Research Laboratory (NRL) of Ministry of Science and Technology, Korea, under Contract M1-0203-00-0015.

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Digital Object Identifier 10.1109/LAWP.2004.830021

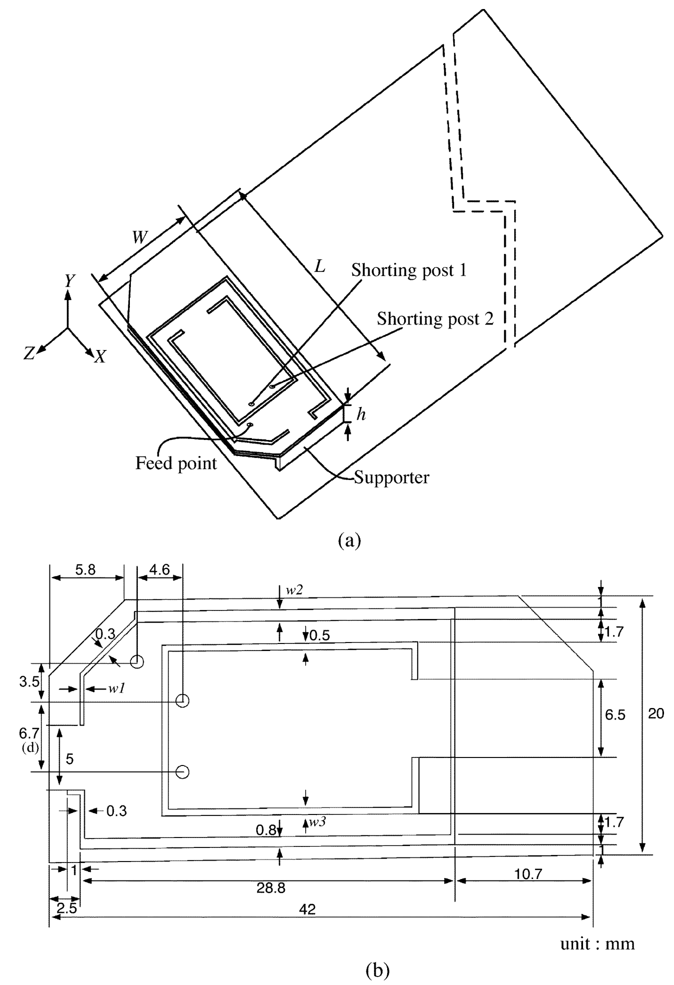


Fig. 1. Geometry of built-in antenna. (a) The three-dimensional prospective view. (b)Top view.

The size of antenna length (L), width (W), and height (h) is $42\ \mathrm{mm} \times 20\ \mathrm{mm} \times 7\ \mathrm{mm}$. And outer slot width $w1$ and $w2$ are 0.3 mm and 0.8 mm, respectively. Inner slot width $w3$ has 0.5 mm.

III. RESULTS

Fig. 2 shows the measured and simulated voltage standing wave ratio (VSWR) value of the proposed built-in antenna of Fig. 1. The simulation result is performed with high-frequency structure simulator (HFSS). There is a good agreement with each other. As seen in Fig. 2, antenna was characterized by a multibandwidth (less than 3 in VSWR value) and it is possible to use at GSM band (880–960 MHz) as well as DCS band (1710–1880 MHz) and IMT-2000 (1920–2170 MHz).

In order to check the current flows at the resonance frequencies, the simulation results of the excited patch surface currents at 950 MHz and 1860 MHz, which, obtained from the IE3D software, are presented in Fig. 3. At the resonance frequency of 950 MHz in Fig. 3(a), the upper current paths starting from shorting post 1 are passing through the upper inner strip and outer strip. These total length of the current paths are about 80 mm, an approximately quarter-wavelength at the GSM band. Similar procedure of current flow at lower paths starting from

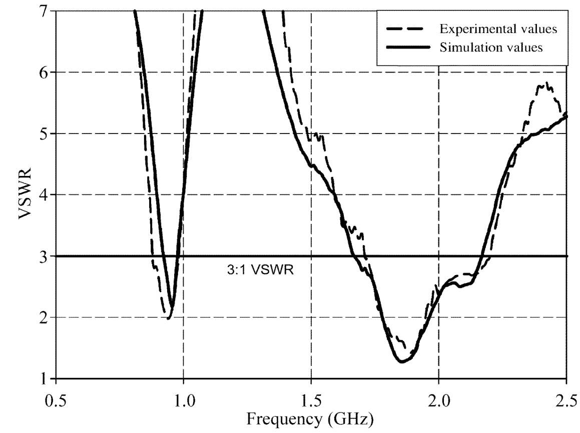


Fig. 2. Measured and simulated VSWR characteristics.

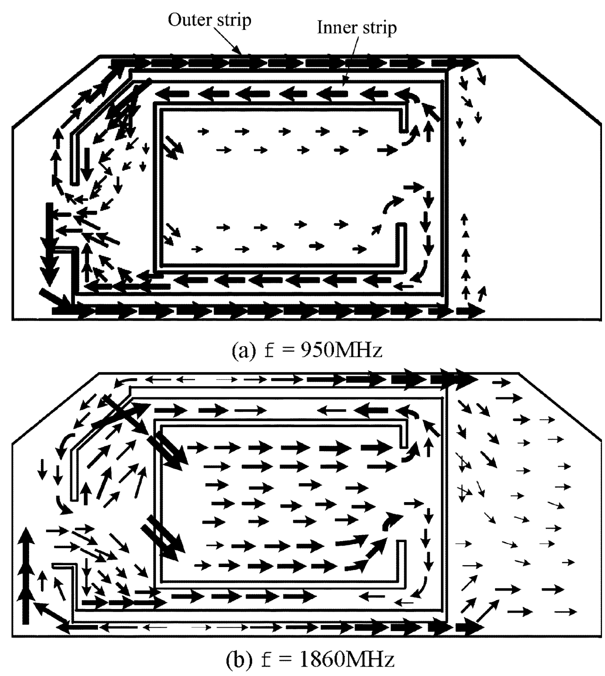
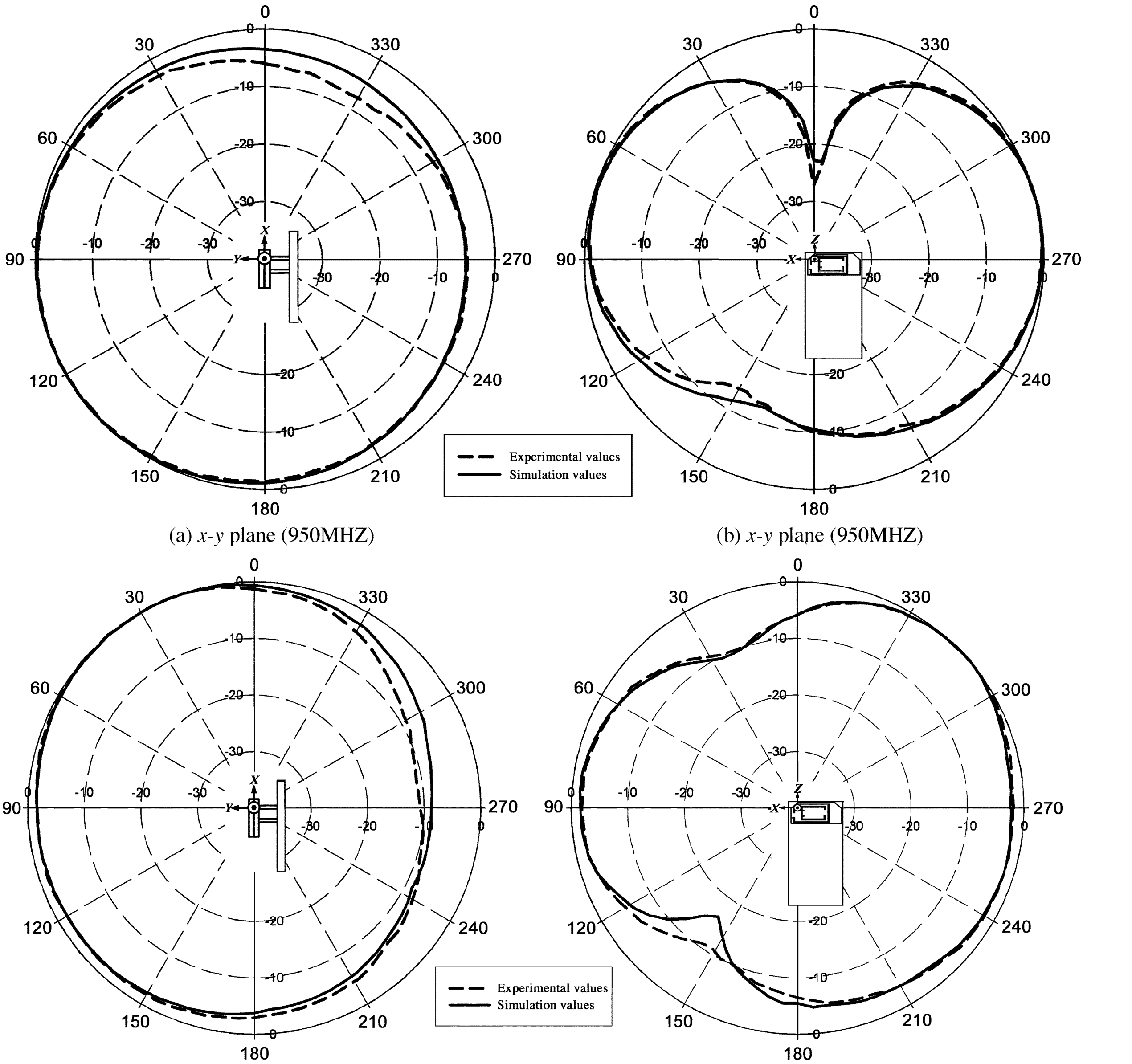


Fig. 3. Simulated patch surface current distributions at (a) 950 MHz and (b) at 1860 MHz.

shorting post 2 can be observed at Fig. 3(a). The current flows at GSM band have an opposite direction between inner strip and outer strip. This is one of the reasons for the poor performance of the VSWR values at GSM band. At the resonance frequency of 1860 MHz in Fig. 3(b), the current flows at inner patch and outer strip have a dominant role of radiation. As seen in Fig. 3(a) and (b), the current flows at upper and lower paths of radiator have the similar behavior at the both resonance frequencies.

By continuously adjusting the positions of two shorting posts, the width of inner and outer slots, and the size of inner and outer patches, it is possible to tune the impedance matching level and resonance frequencies.

We can observe the dual-resonance characteristics at the high frequencies 1820 MHz and 2120 MHz, due to shorting post 1 and 2, respectively. Antenna bandwidths have about 110 MHz in the GSM band and about 490 MHz in the DCS and IMT-2000 bands without additional matching units of chip inductance and/or chip capacitance. The dual-resonance points



(a) x-y plane (950MHZ)

(b) x-y plane (950MHZ)

(c) x-y plane (1860MHZ)

(d) x-y plane (1860MHZ)

Fig. 4. Measured and simulated patterns of the proposed built-in antenna at the (a) and (b) 950 MHz and (c) and (d) 1860 MHz.

at the high-frequency band can be easily tuned by adjusting the gap spacing (d) between two shorting posts.

Fig. 4 shows the measured and simulated results of x-y plane and x-z plane patterns at the frequencies 950 MHz and 1860 MHz. The maximum gains at GSM band (950 MHz) and DCS/IMT-2000 bands (1860 MHz) are measured about 1.58 and 1.3 dBi, respectively. The simulated maximum gains have 1.54 dBi at 950 MHz and 1.27 dBi at 1860 MHz. The gain values of the measured and simulated results are also agreed well. The radiation pattern at the GSM band works similar to a quasi omnidirectional antenna because of its electrically small finite size of the PCB.

IV. Conclusion

By modifying the PIFA design described in this paper, the triple-band internal antenna is demonstrated, which is simultaneously operating at the GSM/DCS/IMT-2000 bands. By adjusting the location and the spacing between two shorting posts, the feed-point, and the size of the inner and outer patch surrounding by crossed double C-shaped slots, the novel triple band internal antenna with broadband impedance and high-gain performance can be achieved.

Bandwidths (VSWR < 3) of the antenna are about 11.5% (880–990 MHz) and 25% (1710–2200 MHz), and the maximum gains at GSM/DCS/IMT-2000 bands have about 1.58 dBi at 950 MHz and 1.3 dBi at 1860 MHz, respectively.

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