A Multiple Band Planar Inverted−F Antenna Using the Modified Ground Plane

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1. Introduction

Nowadays smart mobile handsets proving various services come into the spotlight. Thus, development of a small, light and thin antenna becomes more important. In addition, antennas have been required to cover multiple bands. In modern mobile handsets, planar inverted-F antennas (PIFA) are generally used as built-in antennas because the PIFA has a number of advantages [1]. However, conventional PIFAs have a narrow and single band impedance bandwidth. In order to overcome these defects, numerous studies related to PIFAs for multiple bands operation have been devised. These studies generally focused on designing shape of the upper patch [2]-[3] and adjusting the location of the feeding line and shorting pin [4].

In this paper, a novel PIFA having multiple bands, which simultaneously resonates in different bands when excited by the same voltage feeding source, is proposed. The PIFA operates at 1.75GHz band while the slot antenna on the ground plane operates at 2.4GHz. The proposed antenna is designed to operate at Digital Communication System (DCS1800, 1710–1880 MHz), Wireless Broadband in Korea (Wibro in Korea, 2300–2390 MHz), Bluetooth (2400–2480 MHz), and Satellite Digital Multimedia Broadcasting (S-DMB, 2630–2655 MHz) frequency bands. The simulations are carried out by a finite-element-method (FEM)-based commercial software, Ansoft HFSS.

2. Antenna Design and Theory

The three-dimensional structure of the proposed antenna is shown in Fig. 1. The antenna patterns are printed on a FR4 PCB with $\varepsilon r = 4.9$, $\tan \delta = 0.025$ and the ground plane of 40 mm × 100mm was used. Figure 2 shows the schematic geometry of the proposed antenna, including a side-view, upper patch, and the modified ground plane, respectively. As shown in Fig. 2(c), a conventional ground plane of the PIFA was modified to include the horizontal slot with parameter S_L and S_W and a vertical slot with parameters S_F and S_W. Although the feeding voltage source simultaneously excites the both upper patch and ground slot, the proposed antenna can be treated as two independent antennas. One antenna is the general PIFA for lower band (1.75 GHz) and the other is the slot antenna on the ground plane for higher band (2.4 GHz). Typically, a PIFA consists of an upper patch, a ground plane, the feeding line and shorting pin, and the upper patch operates at the size of nearly its quarter wavelength. The conventional PIFA operation can be understood by the equivalent circuit [5]. In case of the PIFA, the loop structure formed by the shorting pin and feeding line is modeled as a shunt inductance and impedance matching of the PIFA can be achieved by controlling the required amount of the shunt inductance, which is generated by the loop structure. In the case of the slot antenna on the ground plane, the above mentioned loop structure can be modeled as a series inductance in contrast with the shunt inductance in the PIFA. The slot antennas of half-wavelength structures are generally used to operate at the fundamental resonant mode [6]. The electrical length of the proposed slot is shorter than a half of a guided wavelength. However, its half-wavelength resonance at 2.4GHz can be achieved because the impedance of the slot antenna is transformed to the series resonance by the loop structure. The two resonant frequencies of the proposed antenna can be controlled by adjusting the distance parameter d in Fig. 2 because the amount of the shunt inductance and series inductance is dependent on the loop size formed by the feeding line and shorting pin. The parameter d for the desired resonant frequency is chosen by parametric studies to be 14.5 mm and the parameters S_L and S_W are decided to be 36 mm and 5 mm, respectively, and the parameter S_F is decided to be 8.5 mm.

3. Results and Discussion

The height of the upper patch is fixed at 6.5 mm from the ground plane, and the other parameters are kept constant except for the slot of the ground plane. The simulations of the ordinary PIFA without the modified ground plane and the PIFA with modified ground plane are carried out. Figure 3 shows the comparison of the simulated voltage standing wave ratios (VSWR). It is clearly shown that the lower band (1.75 GHz) by the PIFA as well as the additional higher band (2.4GHz) by the slot on the ground plane is achieved. In the case of the PIFA with the modified ground plane, the resonant frequency of the PIFA is slightly decreased, and its impedance matching is efficiently achieved because the shunt capacitance between the upper patch and ground plane is decreased, and inductance of ground plane is slightly increased. Figure 4 shows the simulated and measured VSWR of the proposed antenna. It is shown that reasonable agreement between simulation and measurement data was obtained. The measured impedance bandwidth (VSWR <2) of the PIFA and the slot antenna on the ground plane are 220 MHz (1.66–1.880 GHz) for DCS and 660 MHz (2.24–2.90 GHz) for Wibro in Korea, Bluetooth and S-DMB, respectively. Figure 5 depicts radiation patterns of H, E1, and E2 which are measured in the x-y, x-z and y-z planes at 1.75GHz and 2.4GHz, respectively. The peak gain and radiation efficiency of the proposed antenna are 3.8 dBi and 75% at 1.75 GHz and 2.9 dBi and 71% at 2.4 GHz, respectively. Figure 6 shows the photograph of the fabricated antenna.

4. Conclusion

A novel PIFA having multiple bands with modified ground plane is proposed to cover DCS, Wibro, Bluetooth and S-DMB applications in this paper. Although the PIFA for 1.75 GHz and the slot antenna for 2.4GHz are fed by using the same feeding voltage source, the two resonant frequencies of the proposed antenna can be independently controlled by adjusting the shunt and series inductance of the loop structure formed by the feeding line and shorting pin. From the measured data, reasonable agreement between simulation results and measurement data was obtained, and good antenna performance was also achieved.

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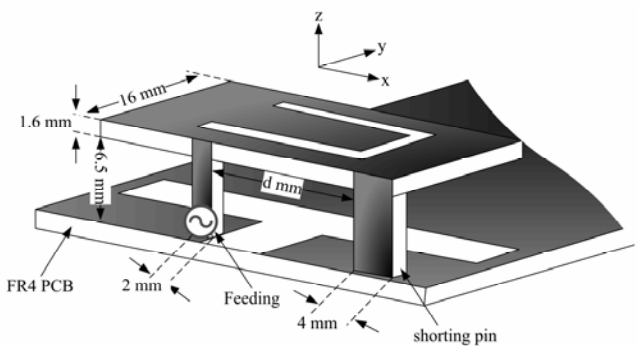

Figure 1: Three-dimensional view of the proposed antenna

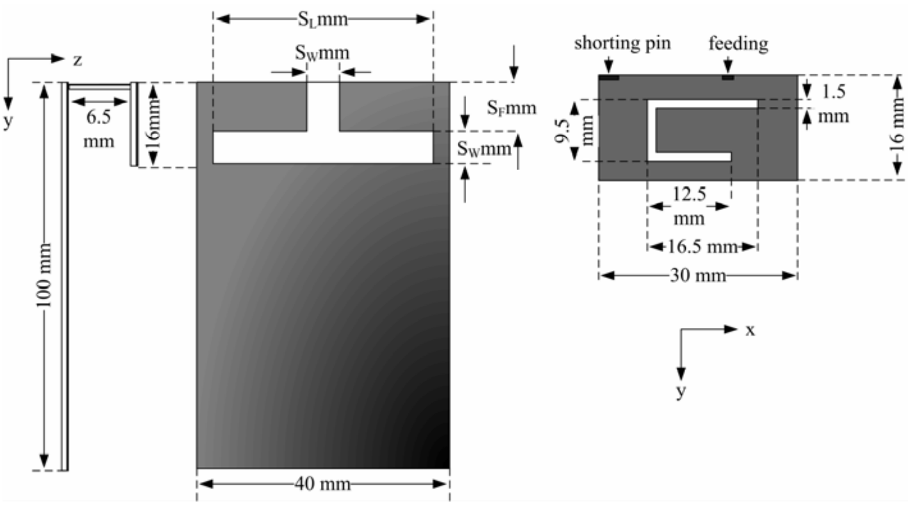

Figure 2: Detailed geometry of the proposed antenna (a) side-view
(b) the T- shaped slot antenna on the ground plane (c) upper patch

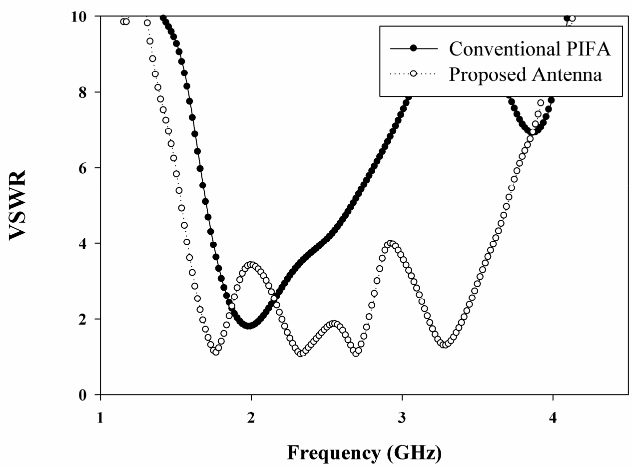

Figure 3: Comparison of simulated VSWR with the T-shaped slot and without the T-shaped slot

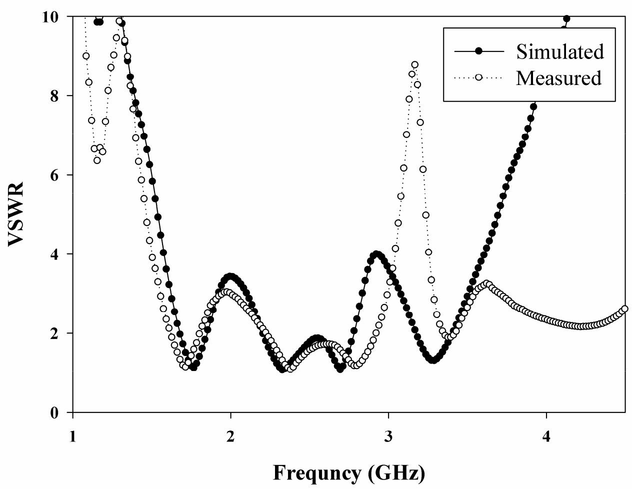

Figure 4: Simulated and measured VSWR

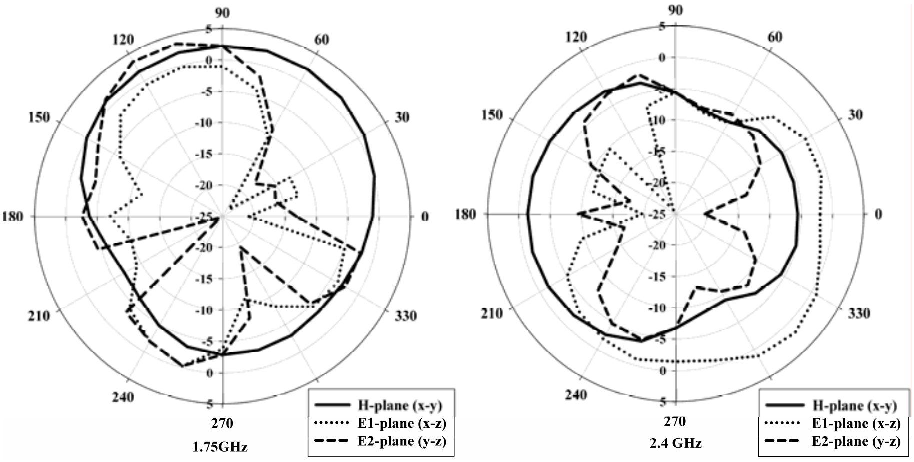

Figure 5: Measured radiation pattern at (a) 1.75 and (b) 2.4 GHz

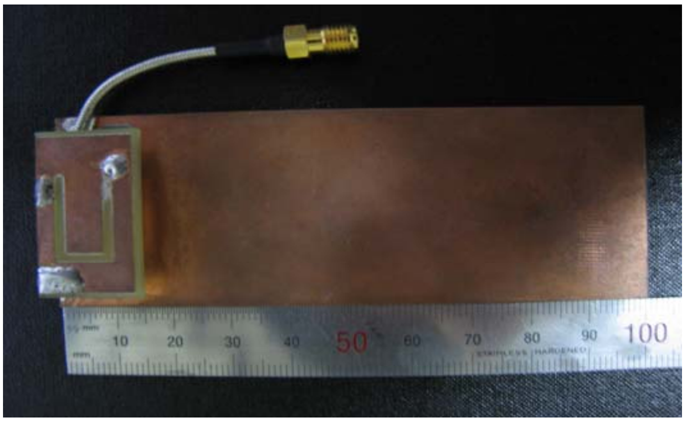

Figure 6: Photograph of the fabricated antenna

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