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IMPEDANCE BANDWIDTH IMPROVEMENT OF BUILT IN ANTENNA BY NOVEL FEEDING STRUCTURE AT PRACTICAL MOBILE HANDSET

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Abstract—In this paper, we propose a wideband internal Planar Inverted-F Antenna (PIFA) by novel feeding structure at practical mobile handset. The proposed antenna by novel feeding structure shows 33.49% wideband impedance bandwidth, compared to 16.92% impedance bandwidth of normal feeding structure of PIFA. We explain novel feeding structure antenna by using equivalent circuit. The normal feeding structure of conventional PIFA has the inductive reactance structurally. To reduce its inductive reactance, a shunt inductive reactance using a novel feeding structure is added to normal feeding structure of conventional PIFA, structurally. So, reactance of PIFA is decreased and impedance bandwidth of PIFA is increased. The size of proposed antenna is $29.2 \times 8.2 \times 8.3\,\mathrm{mm}^3$. As well as, the implemented antenna has a good radiation pattern and high antenna gains despite very small volume.

1. INTRODUCTION

Recently, antenna technologies for impedance bandwidth improvement are strongly required for mobile handset to cover multi-band with a single internal type antenna because of supporting various global communication standards and services. And there are strong demands for small, lightweight, and compact mobile handset. These demands also require the development of a low-profile internal antenna with superior performances such as the good radiation pattern, low specific absorption rate (SAR) value and high gain. However, the design of an internal antenna is technically challenging due to the limited antenna volume, a lot of the components of the practical handset, battery

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and influence of plastic housing of the mobile handset disturbing the antenna radiation. To overcome these problems, the planar inverted-F antenna (PIFA) is a good candidate for practical handsets because of its simple structure, omni-directional radiation pattern, low profile, and lightweight characteristics. By the way, the PIFA has the critical problem, which the impedance bandwidth of conventional PIFA is narrow. So, many techniques of internal antennas to improve the impedance bandwidth have been studied to meet the needs for multi-band and multimedia handset antenna for the third generation mobile system, such as the stacked patch type PIFA [1], combination antenna of PIFA and planar inverted-L (PIL) [2–4], electro-magnetic feeding antenna type using ground slit and slot [5–7], monopole antenna type [8–14], and PIFA type using variation of feeding structure [15].

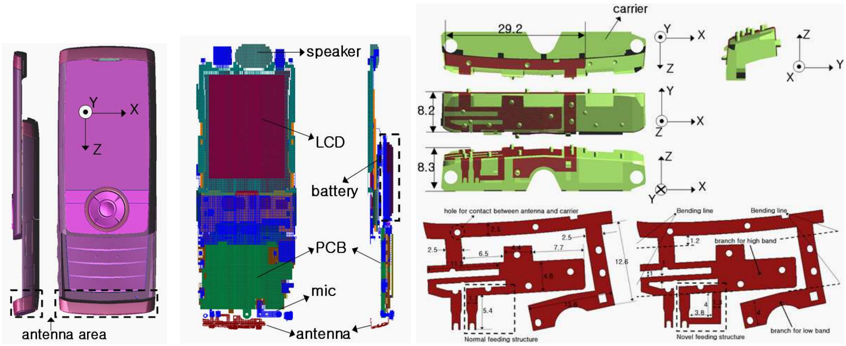
In this paper, a novel feeding structure PIFA is proposed to cover the quad band antenna system that has operation bandwidth such as 8.7% impedance bandwidth ranging from 860 MHz to 960 MHz for Global System for Mobile communications (GSM900, 880 $\sim$ 960 MHz) at the low band and 23.7% impedance bandwidth ranging from 1710 MHz to 2170 MHz for Digital communication System (DCS, 1,710 $\sim$ 1,880 MHz), Personal Communication Service (PCS, 1,880 $\sim$ 1,990 MHz) and Universal Mobile Telecommunications system (UMTS, 1,920 $\sim$ 2,170 MHz) at the high band. And the proposed antenna used the novel feeding structure, having the two current paths, to improve the impedance bandwidth. It shows that the proposed antenna has sufficient impedance bandwidth and gains to cover the GSM900, DCS, PCS and UMTS frequency bands.

The paper is organized as follows. The practical handset model and geometry of the proposed antenna are described in Section 2. The simulation and measurement results for antenna analysis are given in Section 3. Finally, the conclusion of the paper is summarized in Section 4.

2. PIFA BY NOVEL FEEDING STRUCTURE

The geometry of the proposed PIFA for operating at GSM900/DCS/PCS/UMTS frequency bands is shown in Figure 1. The antenna size of example design is $29.2 \times 8.2 \times 8.3\,\mathrm{mm}^3$. We used a cell phone EV-W370 model of KT-Tech for this paper. It is shown in Figure 1. The cell phone was designed at KT-Tech using the ProEngineer CAD tool. The ground size of practical mobile handset is $45 \times 125\,\mathrm{mm}^2$ that is considered at the slide up state, and the proposed antenna is located at 2.5 mm away from the bottom portion of ground plane.

The proposed antenna has two radiation elements. The radiation



(a) (b) (c)

Figure 1. Geometry of practical handset and proposed antenna. (a) Handset feature, (b) metal part of the handset, (c) feature of the proposed antenna.

elements for the low band and high band are located inside and outside, respectively. In order to achieve the low band resonance, the outside branch has the long current path that is selected to be about 75.9 mm calculated from the feeding point to the open end of out side branch. It is very close to a quarterwave of 900 MHz frequency. Note that resonance frequency is affected by both the length of the current path and the width of the open end. It is enough to cover the low band for GSM900. Also, in order to achieve the high band resonance, the inside branch has the shorter current path that is selected to be about 30 mm calculated from the feeding point to the open end of inside branch. It is very close to a quarterwave of 2,000 MHz frequency. The slight difference is mainly because of the existence of the carrier, housing and components of the handset which shortens the resonating wavelength.

However, it is hard to cover the high band bandwidth because of the required wide impedance bandwidth for DCS, PCS and UMTS. In order to cover the high band bandwidth, the novel feeding structure was designed without any change of antenna feature. The novel feeding structure PIFA has two input current paths compare to normal feeding structure. It lets the proposed antenna have wide impedance bandwidth at the high band. The holes on the antenna pattern are made for contact to carrier

3. ANTENNA ANALYSIS

The commercial program SEMCAD-X [16] based on the FDTD (Finite Difference Time Domain) is used to obtain suitable values

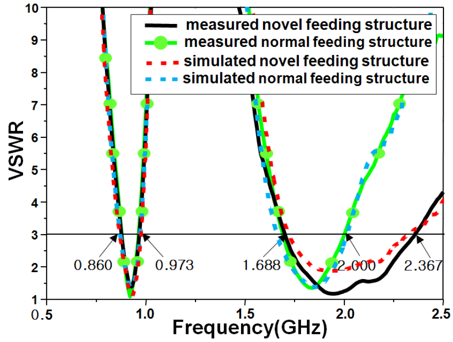
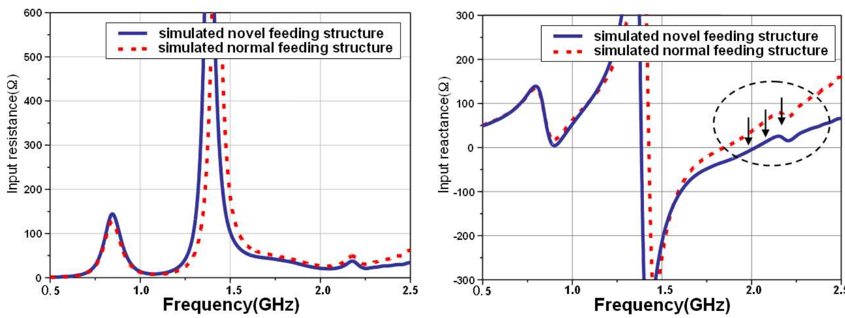


Figure 2. Simulation and measurement results on the VSWR of the proposed antenna.



(a) (b)

Figure 3. Simulation results on the input impedance of the proposed antenna. (a) Resistance, (b) reactance.

of parameters and analyze the behavior of the proposed antenna. And electrical characteristics are measured with HP8720C network analyzer.

Figure 2 shows the simulated and measured results on the VSWR of the proposed antenna in the slide up of the handset. Simulated results agree well with measured ones. Figure 2 shows the electrical characteristic difference between normal feeding structure and novel feeding structure on the VSWR. The results in Figure 2 indicated that fabricated novel feeding structure antenna has the wider bandwidth characteristic than the fabricated normal feeding structure antenna for the high band.

Figure 3(a) shows the simulated results on the input resistance of the proposed antenna. The input resistance of the normal feeding agrees well with the input resistance of novel feeding antenna, but Figure 3(b) shows that the inductive reactance of the normal feeding antenna is dominant at the high band. So, the normal feeding antenna can not have wide impedance bandwidth at the high band.

In order to reduce the inductive reactance without impedance variation at another band, the antenna needs shunt inductive reactance at the high band. As novel feeding structure has the separated feeding structure, it makes the two current paths for excitation of antenna. The two current paths effectively make the shunt inductive reactance nearby feeding position at the high band. As a result of these two current paths, novel feeding antenna can have shunt inductive reactance at the high band. It means that the wide impedance bandwidth of the novel feeding antenna can be obtained at the high band. And, Figure 3(b) shows that reactance is zero at 1.4 GHz. But this is not resonance because resistance is very high.

Figure 4 shows the equivalent circuit of the novel feeding antenna. If the novel feeding antenna could be equivalent as two parallel resonance circuits, we can define that the left and right sides of the

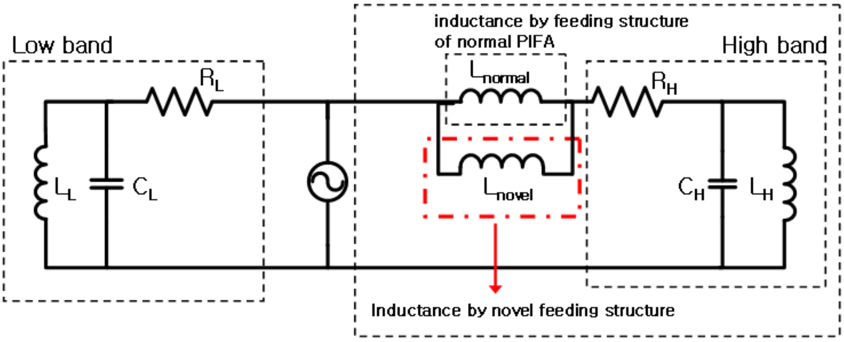


Figure 4. Equivalent circuit of novel feeding structure antenna.

Table 1. Measured bandwidth of antenna.

band	Feeding Type	Frequency band (VSWR≤3)	Bandwidth (%)
Low band	Normal	0.860 GHz∼0.973 GHz	12.33%
	Novel		
High band	Normal	1.688 GHz∼2.000 GHz	16.92%
	Novel	1.688 GHz∼2.367 GHz	33.49%

source is the RLC parallel resonance circuits of the low and high band, respectively. In a right side circuit of the source, the normal feeding structure has the inductance (L_{normal}) disturbing wide band resonance of the high band between source and RLC parallel resonance circuit. The inductance value can be reduced by adding shunt another inductance. In this paper, the shunt inductance (L_{novel}) by novel feeding structure was used to reduce the existing inductance (L_{normal}) disturbing wide band resonance. It means that wideband resonance was achieved by reducing existing inductance (L_{normal}).

Table 1 shows measured bandwidth of the normal and novel feeding antenna. The bandwidth of the low band, determined by 3 : 1 VSWR, reaches 113 MHz ranging from 0.860 GHz to 0.973 GHz. Bandwidth for high band of normal feeding antenna, determined by 3 : 1 VSWR, reaches 312 MHz ranging from 1.688 GHz to 2.000 GHz. Bandwidth for high band of novel feeding antenna, determined by 3 : 1

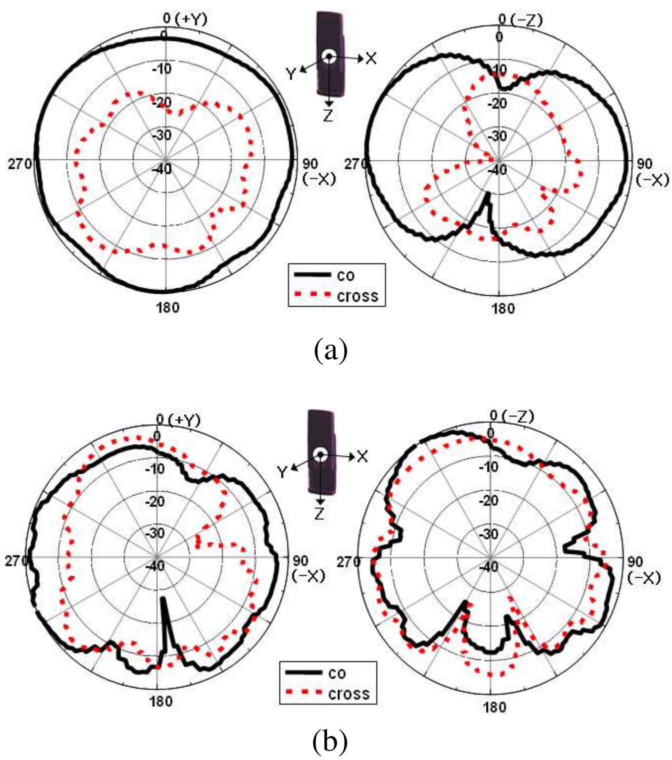


Figure 5. Measured radiation patterns of the proposed antenna. (a) 0.9 GHz at low band, (b) 2,000 MHz at high band.

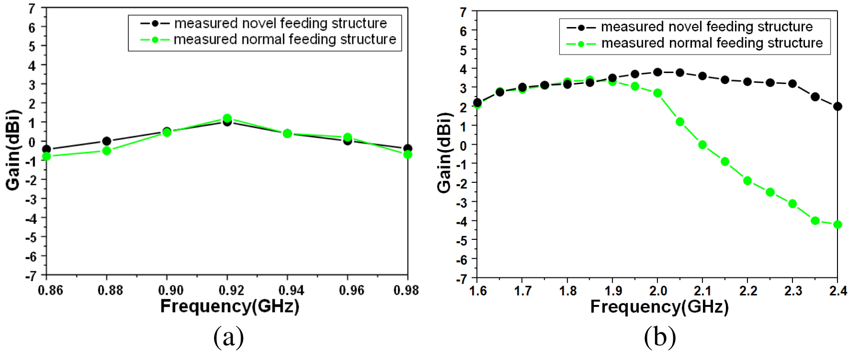


Figure 6. Measured gain and efficiency of the proposed antenna. (a) At low band, (b) at high band.

VSWR, reaches 679 MHz ranging from 1.688 GHz to 2.367 GHz. It shows that novel feeding antenna have wider band width than normal feeding antenna.

Figure 5 shows the measured radiation patterns in the x-y plane (azimuth plane) and x-z plane (elevation plane) for the proposed antenna at 0.900 GHz, and 2.000 GHz. At the low band, typical radiation pattern such as monopole was shown. Also, radiation pattern at the high band was shown such as a quarterwave resonance pattern because the ground size is much bigger than wave length of the resonance frequency.

Measured results on gain are indicated in Figure 6. In Figure 6(a), the measured gain range of the proposed antenna is from -0.43 dBi to 1.20 dBi for lower band. In Figure 6(b), the measured gain range of the proposed antenna is from 2.0 dBi to 3.8 dBi for high band and shows that gain of the novel feeding structure antenna at the high band is better than normal feeding structure antenna. Though the antenna was built in practical handset case with battery and many components of the handset, it shows good gain performances.

4. CONCLUSION

This paper propose a wideband antenna by the novel feeding structure at the practical handset. In order to improve the impedance bandwidth at the high band for DCS, PCS and WCDMA, shunt inductive reactance is applied by using two current paths of the novel feeding structure. Also, the novel feeding structure antenna has been explained by using the equivalent circuit. Measured radiation performances at the free space are good for practical handset.

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