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# An Internal Planar Inverted-F Antenna for PCS/IMT-2000/Bluetooth Bands Application

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## 1. Introduction

Recently, the mobile handsets have been demanding that those are small, lightweight, and compact. These demands are brought on the development of low-profile internal antenna with superior performances in terms of the impedance bandwidth and gain. However, to design an internal antenna is technically challenged due to the limited antenna volume and influence of plastic case of the mobile handset. The several types of internal antennas have proposed as Planar Inverted-F Antenna (PIFA) [1]-[2], ceramic chip antenna with meander lines [3]-[4], and monopole antenna [5]-[6].

In this paper, we propose a novel planar inverted-F antenna which combines the advantage of PIFA which is small, low-profile and the merit of the monopole antenna that has the broad impedance bandwidth. This proposed antenna has the radiating element with thickness instead of a height from substrate to ground for matching and via hole instead of additional shorting pins in PIFA. These result into a reduced size and broad bandwidth. The proposed antenna has enough bandwidth to cover the PCS (1.75-1.87 GHz), IMT-2000 (1.92-2.17 GHz), and Bluetooth (2.402-2.48 GHz) bands.

## 2. Antenna Design

The geometry of the proposed internal planar inverted-F antenna for operating at PCS/IMT-2000/Bluetooth bands is shown in Fig. 1. The radiating element is made of a copper and is a rectangular shape with slits which adjust to the surface current paths and its size is 30 mm $\times$ 10 mm $\times$ 2 mm. The proposed planar inverted-F antenna is mounted on the FR4 substrate with the thickness of 0.5 mm, relative permittivity of 4.6 and the size of substrate is 76 mm $\times$ 38 mm. A 50 $\Omega$ microstrip line is used to feed this proposed PIFA and etched on the FR-4 substrate. On the other side of the substrate, the ground plane is cut at d = 1 mm away from the end of the microstrip feed line. The additional ground (1.3 mm $\times$ 9.65 mm) is used to connect the patch and ground through via hole. Though the PIFA is usually used to shorting pin for reaching the surface current to the ground, this proposed antenna is used to via hole instead of shorting pin to connect the patch to the ground plane. In addition, the air gap between patch and substrate of PIFA is required more than 6 mm to match [1]-[2]. However, this proposed antenna takes off the air gap for matching between the patch and substrate. The total height of proposed antenna is 2 mm by using a metal with the thickness and via hole. The overall volume of proposed antenna can be attractive features in the internal antenna.

As the thickness of radiating element is increased, the impedance bandwidth is more broaden. However, the gain is decreased. So the thickness of radiating element is optimized in considering the impedance bandwidth and the gain simultaneously. Note that the resonant frequencies and impedance matching are mainly determined by the value of the thickness of metal, the location of via hole, and the offset gap (d = 1 mm) between the ground and metal when the other parameters of the antenna are fixed. In order to obtain the triple bands, the parameters of antenna are tuned and optimized. The optimized dimensions are shown in Fig. 1.

## 3. Results

An HP8510C network analyzer is used for measurement. The commercial program HFSS based on the finite element method (FEM) is used for analyzing the behavior of proposed model and determining suitable values of parameters. The measured and simulated return losses of the proposed planar inverted-F antenna are shown in Fig. 2. As seen in Fig. 2, the broad impedance bandwidth can be obtained. The dual resonant frequencies are obtained by optimizing the slit lengths which adjust the

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surface current path and the location of via hole. The used width of slits are all 0.5 mm. Although the measured and simulated results have a good agreement with each others, there is a slight discrepancy. This is due to the facts the height of radiating element is increased due to the lead which is in the space between the radiating element and substrate. This fact is confirmed by the simulation. The proposed internal antenna operates from 1.65 GHz to 2.53 GHz within -10 dB return loss. The center frequency of operation is 2.09 GHz with the bandwidth about 42.1 %. This operating bandwidth can cover PCS (1.75-1.87 GHz), IMT-2000 (1.92-2.17 GHz), and Bluetooth (2.402-2.48 GHz) bands. The measured and simulated radiation patterns at the resonant frequencies of 1.8 GHz, 2.0 GHz, and 2.44 GHz are shown in Figs. 3, 4, and 5, respectively. This slight difference can be attributed that the feeding cable influences the radiation patterns. The simulated and measured antenna gains in the x-z plane have 1.38 and 1.34 dBi at 1.8 GHz in PCS band, 1.68 and 1.49 dBi at 2.0 GHz in IMT-2000 band, and 3.0 and 2.64 dBi at 2.44 GHz in Bluetooth band, respectively. This slight difference of gain can be attributed to the effects of conductor and dielectric loss.

## 4. Conclusion

A novel internal planar inverted-F antenna (PIFA) for PCS/ IMT-2000/ Bluetooth bands has been proposed and verified with measurement and simulation. The size of proposed antenna can be reduced by using the metal with thickness and via hole than the established PIFA. The proposed antenna has a small size (30 mm × 10 mm × 2 mm) and wide impedance bandwidth about 42 % which cover with the PCS/IMT-2000/Bluetooth bands. These features are attractive for PCS/IMT-2000/Bluetooth internal antenna applications.

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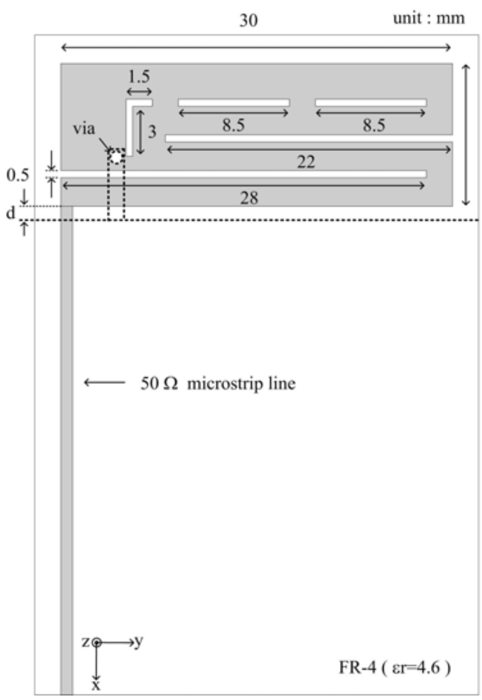
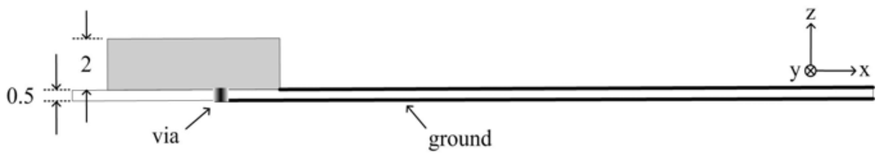



(a) Top view




(b) Side view

Fig. 1. The Geometry of the proposed internal planar inverted-F antenna
(a) Top view (b) Side view

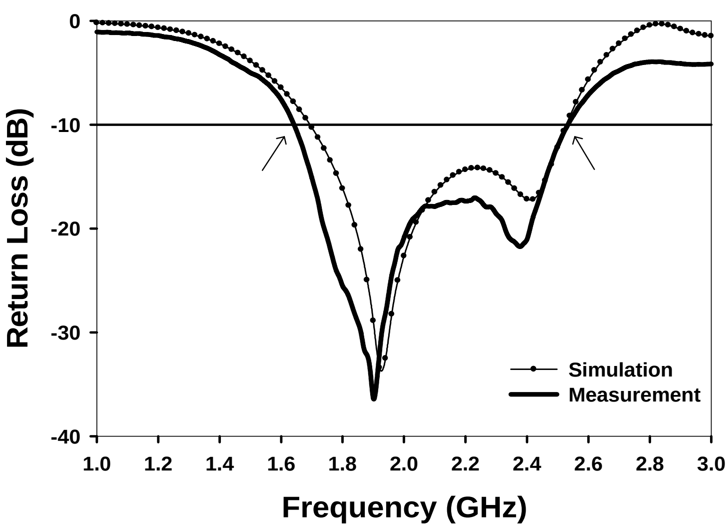
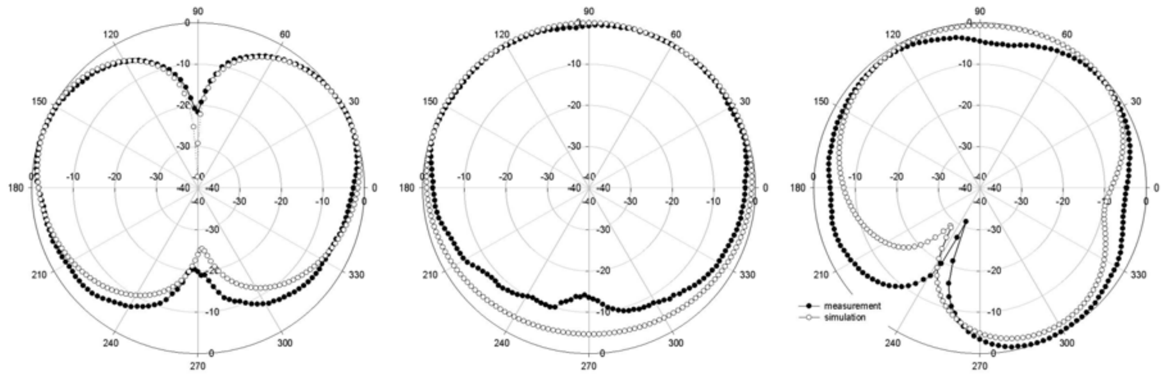
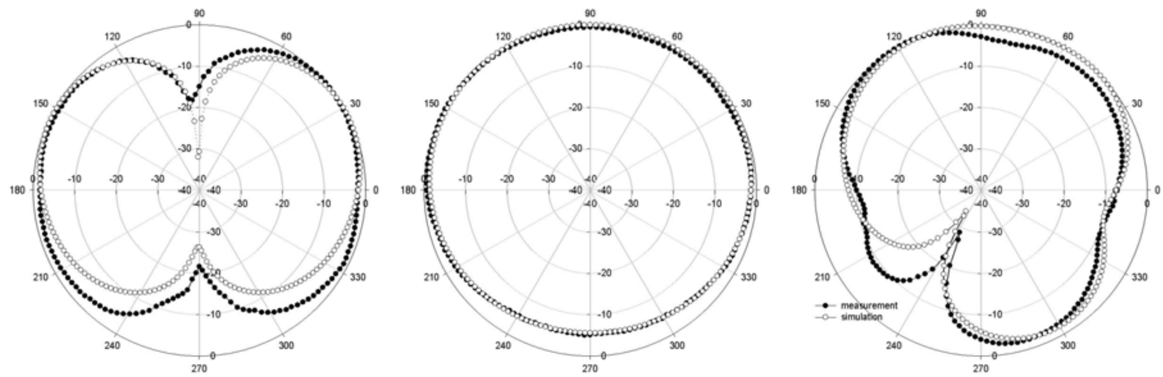



Fig. 2. Measured and simulated return losses of the proposed antenna



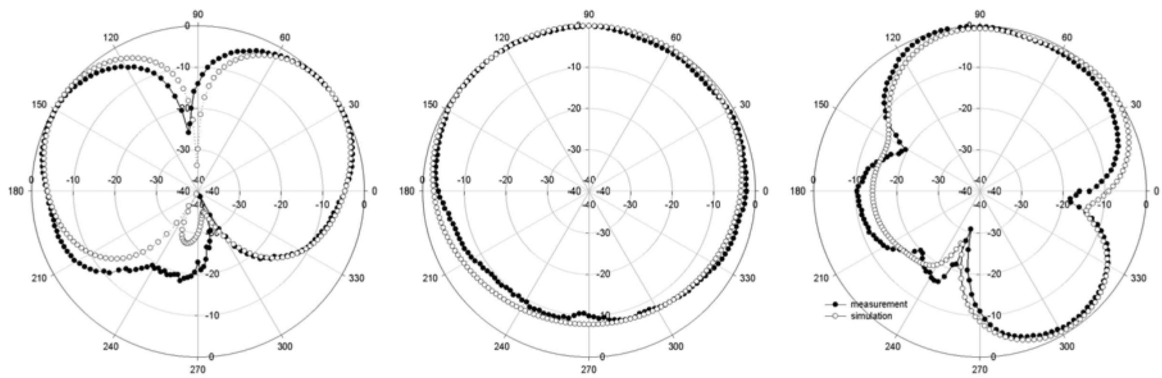

(a) (b) (c)

Fig. 3. Radiation pattern at the frequency of 1.8 GHz (a) x-z plane (b) y-z plane (c) x-y plane




(a) (b) (c)

Fig. 4. Radiation pattern at the frequency of 2.0 GHz (a) x-z plane (b) y-z plane (c) x-y plane




(a) (b) (c)

Fig. 5. Radiation pattern at the frequency of 2.44 GHz (a) x-z plane (b) y-z plane (c) x-y plane