Design and SAR Analysis of Broadband PIFA with Triple Band

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Abstract

This paper proposed a novel broadband Planar Inverted-F Antenna(PIFA) for IMT-2000/WLAN/DMB terminal. Two branch lines for meander line were utilized in order to improve the characteristics of PIFA which usually has a narrow band. The shorting strip between the ground plane and meander-type radiation elements were used in order to minimize the size of the antenna. The $-10dB$ return loss bandwidth of a realized antenna was $38.2\%(1.84 - 2.71GHz)$, which contains the broadband bandwidth with triple band. And the simulated and measured values of the $1g$ and $10g$ averaged peak SAR on human head caused by the triple band PIFA mounted on folder-type handsets were analyzed and discussed. As a result, the measured $1g$ and $10g$ averaged peak SARs of PIFA were similar with the simulated values and were lower than the $1.6W/kg$ and $2W/kg$ of the $1g$ and $10g$ averaged peak SAR limits.

1. Introduction

In recent years, the rapid growth in mobile communication system has lead to a great demand in developing small size antenna with multi-band functions. Also, future wireless communication systems such as Cellular, PCS(Personal Communication Services), IMT-2000(International Mobile Telecommunications-2000), WLAN(Wireless LAN), PDA and satellite DMB(Digital Multimedia Broadcasting) will likely forecast feature, the mobile phone antenna will be designed the multi-band applying to the present mobile communication system[1].

The interest of the internal antenna has been increased in the mobile handset antenna applications. Antenna must be small enough to be built in the practical mobile handsets and have a good performance with respect to the bandwidth and gain. Most of internal antenna proposed up to now consist of PIFA type, the chip antenna of the meander type, and the planar monopole antenna[1].

The gain and radiation pattern of the PIFA is similar to those of the $\lambda/4$ monopole antenna. And the bandwidth of PIFA is narrow. However, the reduction of radiated field toward the direction of the human head, low cost and low-profile are very attractive merits of PIFA. The low-profile characteristic of PIFA is suitable as the internal antenna for the mobile phone.

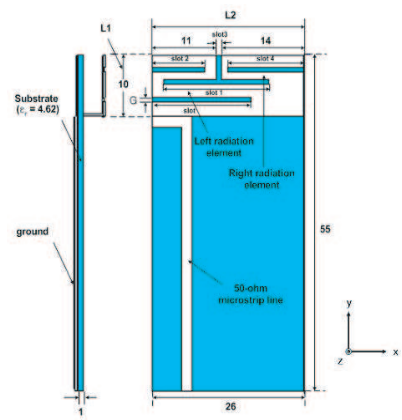


Figure 1: Structure of the proposed PIFA.

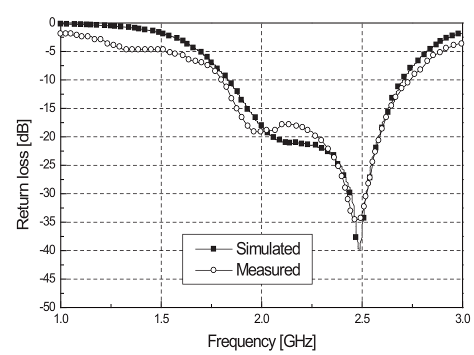


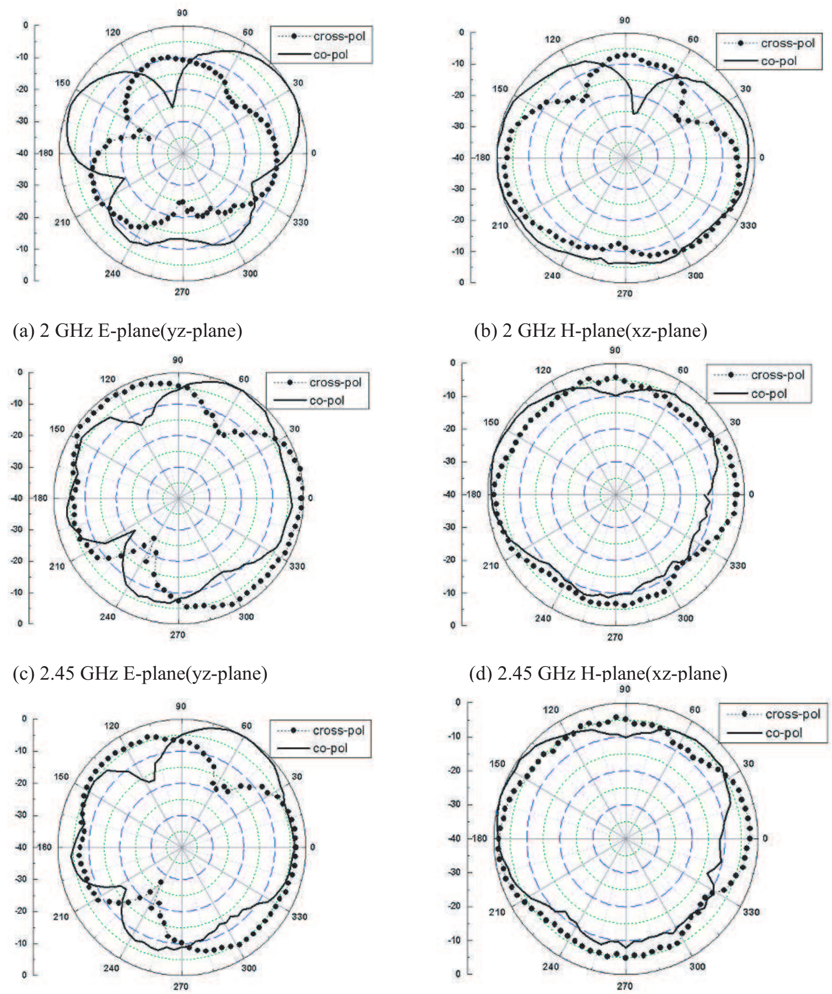
Figure 2: The return loss results of the simulated and measured.

2. Antenna Design and Results

The proposed internal triple-band antenna of the novel PIFA type for IMT-2000/WLAN/DMB application is shown in Fig. 1[2, 3]. The dimension of the proposed antenna is $10 \times 26 \times 0.3mm^3$. The proposed antenna is mounted on the FR4 substrate ($\varepsilon r = 4.62$) with thickness of $1mm$ and dimensions of $55 \times 26mm^2$, as shown in Fig. 1. The optimum height of the proposed antenna is only $3.5mm$ less than that of most of PIFA. And the vertical segment length, G has tuned at $0.7mm$, and the width of feeding wire has $1.8mm$.

A 50Ω microstrip line is used to feed the internal antenna, and is printed on the same substrate. By adjusting the width, W, of the microstrip line, we can achieve a good 50Ω matching between input impedance of antenna and microstrip feed line.

The proposed antenna with two branch lines for the meander structure was utilized in order to improve the characteristics of PIFA which usually has a narrow band as shown in Fig. 1. The shorting strip between the ground plane and meander-type radiation elements was used in order to minimize the size of antenna. Overall size of antenna and the substrate are small enough to be built in practical mobile handsets.



(a) 2 GHz E-plane(yz-plane) (b) 2 GHz H-plane(xz-plane)

(c) 2.45 GHz E-plane(yz-plane) (d) 2.45 GHz H-plane(xz-plane)

(e) 2.65 GHz E-plane(yz-plane) (f) 2.65 GHz H-plane(xz-plane)

Figure 3: The radiation patterns of the fabricated antenna.

By using the two branches for the meander structure, rectangular patch is separated into two radiating elements, left radiating element for IMT-2000/WLAN bands and right radiating element for satellite DMB band. As shown in Fig. 1, the size of right radiating element is broadband characteristic due to the large current distribution. The resonant frequencies can be controlled by adjusting the lengths of the meander line, slot, height and width of the shorting strip. The broadband characteristic of most of PIFA can be achieved by ensuring enough length and width of the patch, which are regulated to the resonant wavelength at the operating frequency.

Fig. 2 shows the simulated and measured return loss results of the proposed antenna. The broadband return loss with the IMT-200/WLAN/DMB bands are obtained. There is good agreement with the measured and simulated results. The simulation was carried out using CST/MWS to design the antenna model and optimize the suitable parameters at the operating frequencies. The $-10dB$ return loss bandwidth of a realized antenna was 38.2%(1.84 to 2.71GHz) , which is enough to cover IMT-2000 ($1.920 - 2.170GHz$) and WLAN ($2.4 - 2.483GHz$) and DMB ($2.605 - 2.655GHz$) bands.

Fig. 3 is shown the measured radiation patterns at 2, 2.45 and $2.65GHz$, respectively. The maximum antenna gain, $3.62dBi$ is measured at $2GHz$.

It shows the omni-directional characteristic similar to the general PIFA and is suitable for the mobile communication handset because of noting the difference between the cross-pol and co-pol radiation patterns. And PIFA with the meander structure, the difference between the co-pol and cross-pol is small because the electric field stands to all direction of the x and y-axis. So the radiation patterns of the proposed antenna is suitable for the internal antenna.

The maximum antenna gain, $3.62dBi$ is measured at $2GHz$. Also, at $2.45GHz$ and $2.65GHz$, the measured gains have $2.11dBi$ and $2.36dBi$, respectively.

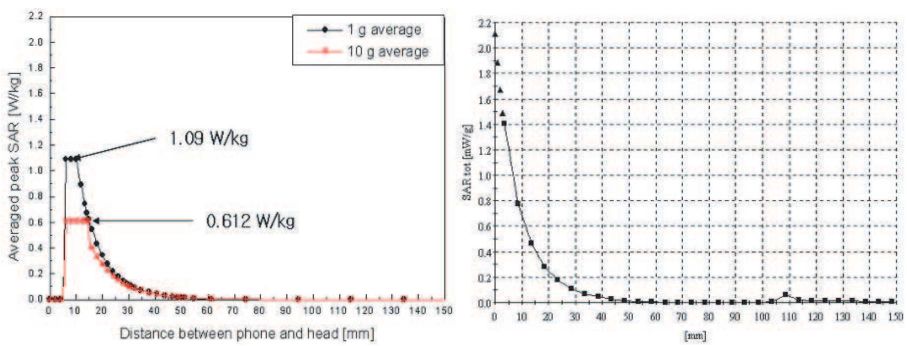


Figure 4: (a) The simulated value of the SAR (b) The measured value of the SAR of the proposed PIFA according to the separation distance between the human head and the phone .

3. SAR Computation and Measurement

The SAR, used in the assessment of mobile phones, is a measure of the amount of EM(ElectroMagnetic) energy absorbed by biological tissue. The SAR is obtained by measuring the electric field in the simulated human tissues in close proximity to the device and is calculated by the formula 3-1[4].

$$SAR = \frac{\sigma}{2\rho} |E|^2 [W/kg] \qquad (3\text{-}1)$$

E : rms value of the electric field strength in the tissue [V/m];
σ : conductivity of body tissue [S/m];
ρ : density of body tissues [kg/m^3]

The human head data consists of the types of tissues using Tissue Dielectric Properties program provided by FCC. Table 1 shows the electrical properties of the brain.

Table 1: The material parameters for the SAM phantom.

SAM Material	Frequency [GHz]	Relative Permittivity [εr]	Conductivity [S/m]	Density [kg/m^3]
SAM Liquid	1.9	40.0	1.40	1,000
SAM shell		3.5	0	1,000

The SEMCAD based on FDTD (Finite-Difference Time Domain) was used in order to simulate the SAR. And the simulated and measured results of 1 g and 10 g averaged peak SAR on human head caused by the triple band PIFA mounted on folder-type handsets were analyzed and discussed.

A sine wave of 1.9 GHz is considered as the wave source. The 1 g or 10 g peak averaged SAR are obtained through normalizing the input power of the wave at 1 W(conduction power at the feeding point). The position of the handset mounting PIFA is suggested that is tilted by 30 $^\circ$. The face of antenna is in the opposite direction from the human head.

As a result, the 1 g and 10 g peak averaged SAR values caused by the propoed antenna with two branch lines for the meander structure was 1.09, 0.61 [W/kg] and measured antenna was 1.17, 0.62 [W/kg] as shown in Fig. 4(a), (b). The measured 1 g and 10 g peak averaged SAR values of the proposed PIFA were similar with the simulated values and were lower than the 1.6 W/kg and 2 W/kg of the 1 g and 10 g averaged peak SAR limits.

Conclusion

In this study, it was demonstrated that a novel PIFA with two branch lines for the meander structure can serve as a broadband internal antenna for IMT-2000/WLAN/DMB mobile handsets applications. In the proposed antenna can be obtained the reduction of antenna length and broadband characteristic by using the two branches meander line. A good agreement between the measurement and simulation of the proposed PIFA mounted on the folder-type mobile phone has obtained. The SAR distribution and other antenna characteristics are so variable as the change of the parameters for the simulation. And we obtained the broadband property and the SAR reduction by this proposed PIFA, respectively.

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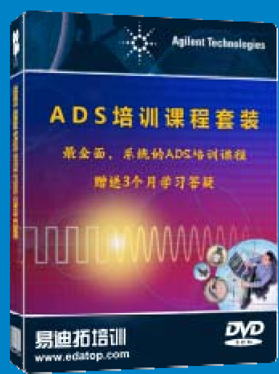

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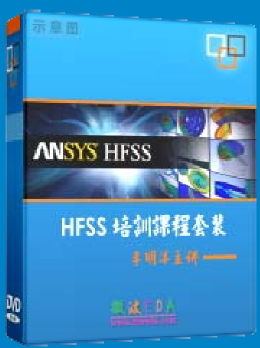

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