A Compact Lower UWB Band PIFA for BAN Applications

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***Abstract*- A compact planar inverted-F antenna (PIFA) with a simple feed structure in lower ultra-wideband (3.1～4.9 GHz) is presented for BAN (Body Area Network) applications. A tapered patch and a folded ground plane are employed to improve the narrow bandwidth characteristics of traditional PIFA, in addition, the proposed antenna is low-profile with the thickness of 7 mm and compact with the area of 60 × 22 mm^2 , making it suitable for the integration in the medical devices. The radiation performance of the modified PIFA preserves well when placed on the human body.**

I. INTRODUCTION

Body area network (BAN) systems have received much more attention due to their potential in several areas [1], such as telemedicine and mobile-health. Low emission power and high data rate make ultra-wideband (UWB) technology a promising candidate for BANs. Besides having the requirements of light weight and low cost, UWB antennas should be with the characteristics of impedance matching and high radiation gain over a broad frequency range, typically, of 3.1～4.9 GHz, which corresponds to the lower UWB band [2].

Several papers with antennas design have been published for BAN applications [3-7]. Although planar antennas, which have advantages of being low profile and easy to be fabricated, are proposed by researchers [3-5], their performance will be deteriorated due to the presence of lossy human tissue. Planar inverted-F antennas (PIFAs) in [6-7] are good candidates with the reduced radiation on the human body, therefore lowering specific absorption rate (SAR). But they are complicated. In this letter, we adopt a kind of modified PIFA with tapered patch and folded ground plane, making it small size, fed conveniently and cover the lower band (3.1～4.9 GHz) in the UWB frequency range.

II. ANTENNA DESIGN STRUCTURE

Figure 1 shows the configuration of proposed PIFA with an SMA connector, having a dimension of 60 × 22 × 7 mm. An air gap of thickness h_f = 1 mm is filled to separate feeding plate from ground plane. Here Air ($\varepsilon_r = 1$; $\tan\delta \approx 0$) is used as substrate so that it could be free from problems relating to loss caused by other dielectric, in addition, the space can be to left for other electronic devices setup. A shorting plate is used

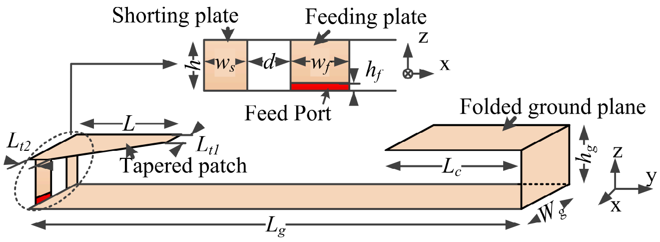


Fig. 1. Geometry of the proposed PIFA.

to connect ground plane with the tapered patch.

The following design procedure is simple and straightforward. Firstly, classical PIFA design techniques were implemented to make a quarter-wavelength resonant patch of PIFA, with the deficiency that higher frequency band is not covered entirely. The corresponding reflection coefficient is plotted with blue dotted line in Figure 2. Subsequently, the top patch was tapered with the characteristic of improved impedance matching, however, the reflection coefficient in 3.1～3.4 GHz band is above -10 dB, as shown with red dashed line in Fig. 2. Finally, the ground plane was lengthened and folded as illustrated in Figure 1, the total lower UWB band (3.1～4.9 GHz) is achieved, as depicted using dark solid line in Figure 2.

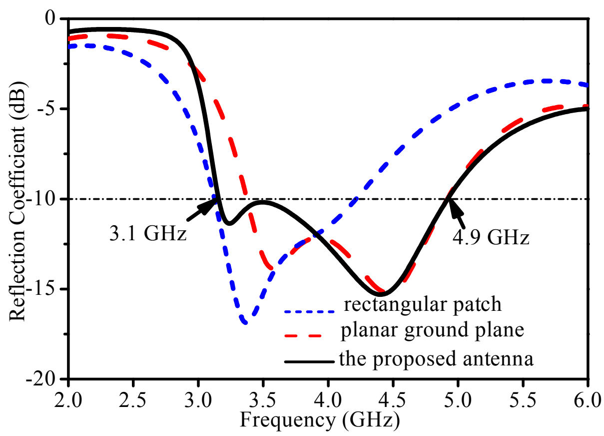


Fig. 2. Simulated reflection coefficients at the different stage of design procedure.

The software package used for simulation is Ansys High Frequency Structure Simulator (HFSS) based on the finite element method. Through adjusting the geometric parameters of the design, we, finally, obtain the optimal dimensions to be: W_g = 22 mm; L_g = 60 mm; L = 13 mm; h = 6 mm; L_{t1} = 7 mm; L_{t2} = 3 mm; w_s = 5 mm; d = 5 mm; w_f = 7 mm; h_f = 1 mm; hg = 7 mm; and L_c = 17 mm.

III. PRESENCE OF BIOLOGICAL TISSUE

Since the modified PIFA is designed for body area network applications, it is mandatory to study the effect of biological tissue. In this letter, the proposed PIFA was placed on a three-layered phantom: skin (ε_r = 36.6 ; σ = 2.3 S/m), fat (ε_r = 5.1 ; σ = 0.2 S/m) and muscle (ε_r = 50.8 ; σ = 3.0 S/m), with a dimension of 100 × 60 ×30 mm^3, as exhibited in Figure 3. The permittivity and conductivity are given at 4 GHz [8]. The space between the antenna and the human tissue model is set to 0 mm.

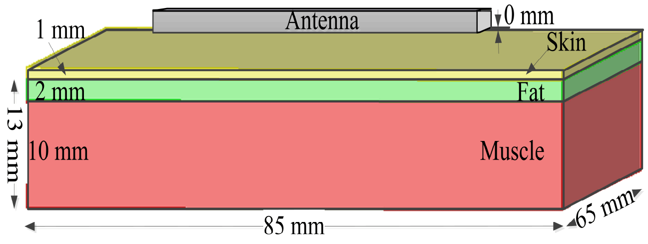


Fig. 3. A three-layered phantom.

IV. RESULTS AND DISCUSSION

The feed port lies in the air gap between feeding plate and ground plane, thus avoiding drilling a hole in the ground plane as other PIFAs [6-7]. The simulated values for reflection coefficients are compared in Figure 4. With reference to the figure, the antenna in free space covers frequency spectrum from 3.1 GHz to 4.9 GHz in simulation. When the proposed antenna is placed directly on the body, the simulated reflection coefficient below -10 dB is met in 3.5～4.7 GHz. Compared to free space, the modified PIFA's performance on the body is slightly affected by the presence of body tissue, but still acceptable.

Figure 5 shows the radiation patterns at 3.2, 4.4 GHz in free space and 4 GHz on the body for two principal planes, i.e. xoz and yoz planes. As can be seen, the simulated radiation patterns are in agreement well and nearly directional with the reduced backward radiation on the human skin.

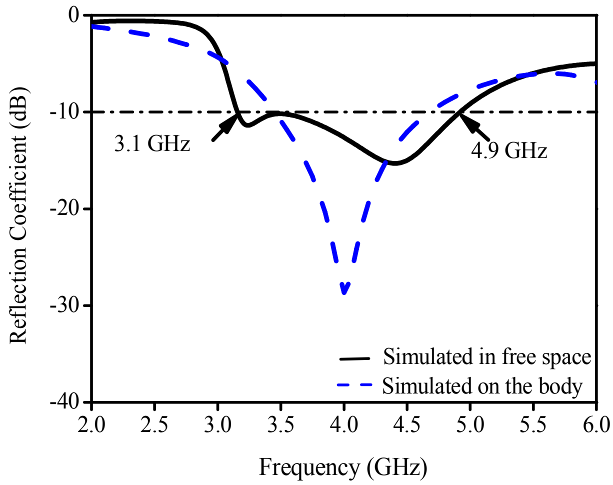
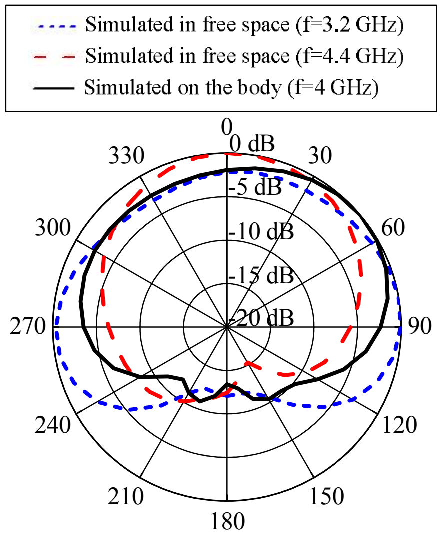
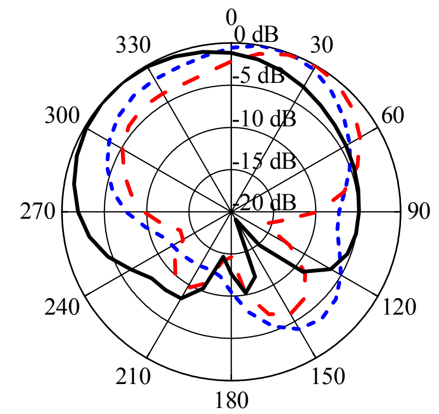


Fig. 4. Simulated reflection coefficients of the designed PIFA in free space and on the body.



(a)



(b)

Fig. 5. Simulated and measured radiation patterns of the designed PIFA
(a) xoz-plane. (b) yoz-plane.

V. CONCLUSION

A compact UWB PIFA with easily feed port for BAN applications has been proposed. Using tapered patch and folded ground plane, -10 dB bandwidths of 3.1～4.9 GHz in free space and 3.5～4.7 GHz on the body are achieved in simulation, respectively. The modified PIFA's performance on the body degrades a little, due to the effect caused by the lossy human body. The reflection coefficients and directional radiation patterns make the PIFA suitable for body-centric wireless communications.

In order to validate the simulated results, future work will focus on the prototype fabrication and performance measurements, such as gain and efficiency.

ACKNOWLEDGMENT

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