P-shape Monopole Antenna Design for WBAN Application

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Abstract— This paper presents P-shaped monopole antenna for WBAN application for 3.1 to 5.1 GHz frequency band. The design and simulation of proposed antenna for WBAN applications in the free space and close proximity of body surface has been done using CST Microwave Studio. The proposed antenna was designed on the FR4 substrate with dielectric constant, ε_r of 4.4 and thickness of 1.6 mm. The final optimized design is $32 \times 28\,\text{mm}^2$. The antenna is suitable to be deployed for WBAN application.

1. INTRODUCTION

We are driven by communication systems in the future through the concept of being connected anywhere at any time. An essential part of this concept is an approach that focuses on the user in the services that are available continuously and provide systems re-configurable, modesty and the correct guidance of the human mind. A wireless body area network that focuses on networks consisting of the number of nodes, and units put on the human body or in the vicinity such as everyday clothing [1].

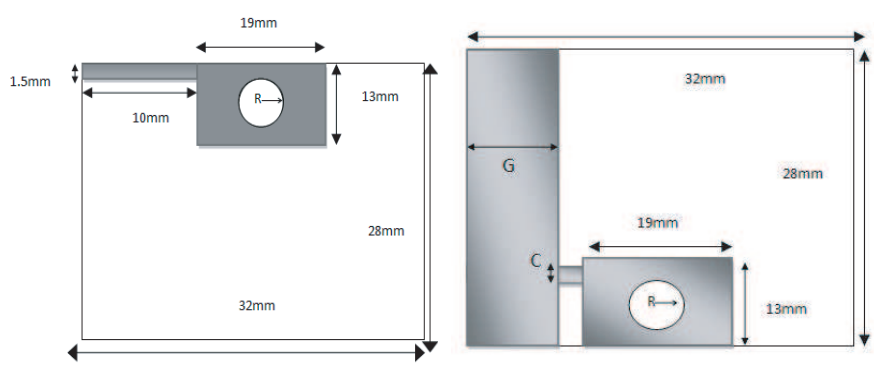
UWB technology full bandwidth covers from 3.1 to 10.6 GHz for UWB communication applications by the Federal Communication Commission (FCC) in 2002 [2], but the full bandwidth is inefficient system, so UWB system divided to the lower band at (3.1–5.1 GHz) and higher band at 6–10.6 GHz for more efficient system [3].

The antenna is an essential element of WBAN applications for off-body, in-body and on-body communication system [4]. The antenna designed must be considered a small size for human body application. In addition, The antenna designed must be a consideration three layers of body tissues (skin, fat and muscle) with relative permittivity and different thickness [5].

This paper presents a P-shaped monopole antenna for WBAN application for the lower frequency band from 3.1 to 5.1 GHz of the UWB band. The simulation results of the P-shaped monopole antenna in free space and close proximity to body tissues has been presented taken into consideration of different dimensions of the antenna and the human body tissues.

2. ANTENNA DESIGN

The P-shape monopole antenna is designed to be operated from 3.1 GHz to 5.1 GHz frequency band. The antenna is printed on the FR4 substrate with dielectric constant of 4.4, loss tangent of 0.02 a thickness of 1.6 mm. The optimized dimension of the propose antenna is $32 \times 28 \times 1.6\,\text{mm}^3$. The geometry and dimension of proposed P-shaped monopole antenna is shown in Figure 1.



(a) (b)

Figure 1: Geometry of the proposed P-shaped monopole antenna. (a) Front view. (b) Back view.

3. RESULTS AND DISCUSSION

The P-shaped monopole antenna is simulated in the free space and with the presence of numerical human body phantom. Figure 2 shows a comparison of VSWR of the proposed antenna in free space and close to the human body. It can be seen that, the P-shaped monopole antenna has achieved VSWR < 2 in the frequency range of 3.0 to 5.6 GHz in the free space and close to human body tissues. The distance between antenna and body surface is represented by d. In this analysis, the P-shaped antenna is placed very close to the body ($d = 2$ mm). The VSWR shown in Figure 2 is for d is about 2 mm. It can be concluded that the antenna VSWR or return loss is more stable although the distance is very much closer as long as the antenna is not directly touched with the human body.

In this work, three layers of human body tissues are consist of muscle, fat and skin. The human body dimensions are about $100 \times 100 \times 36\,\text{mm}^3$, in which the thickness of skin is 1 mm, fat is 5 mm and muscle is 30 mm.

This human body effect on the performances of P-shape monopole antenna in term of gain and SAR are tabulated in Table 1. It can be seen that the gain of the antenna when it is proximity to the body is degraded as expected when compared with the gain in free space. In addition, the

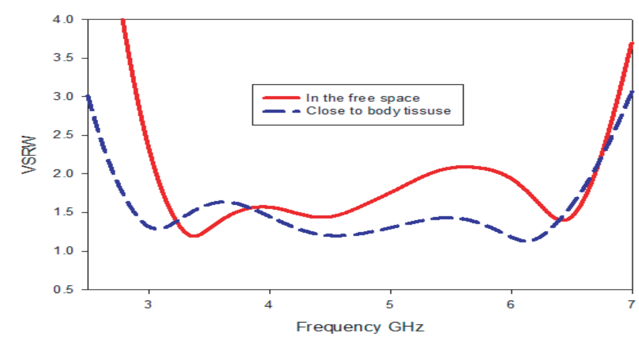
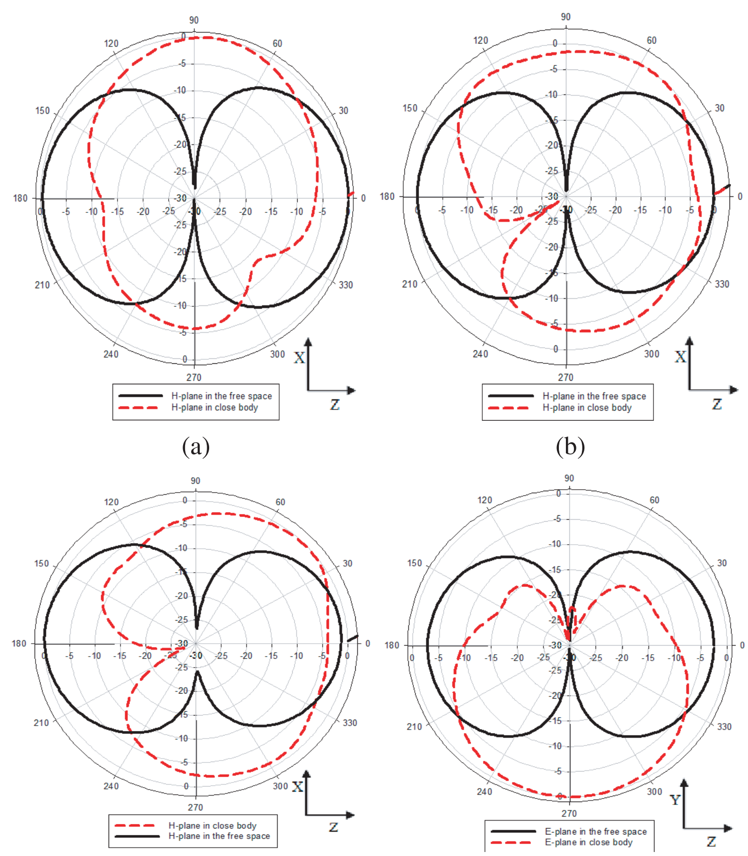
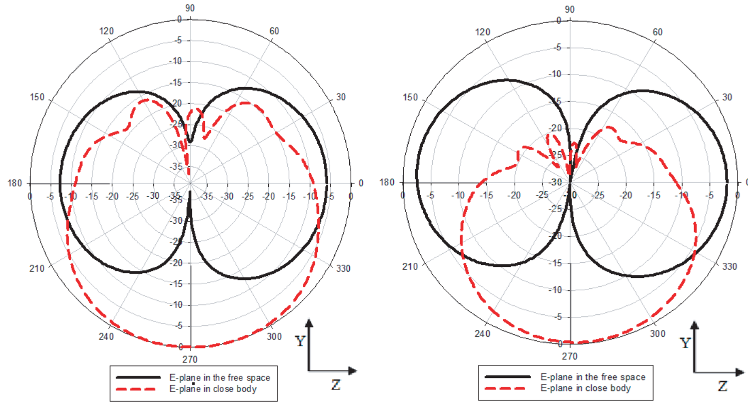


Figure 2: Comparison of VSWR of the antenna in the free space and close to human body.



(a) (b)

(c) (d)



(e) (f)

Figure 3: The radiation pattern of the P-shape antenna. (a) H-plane pattern at 3.1 GHz. (b) H-plane pattern at 4.1 GHz. (c) H-plane pattern at 5.1 GHz. (d) E-plane pattern at 3.1 GHz. (e) E-plane pattern at 4.1 GHz. (c) E-plane pattern at 5.1 GHz.

Table 1: Comparison of gain and SAR of the antenna in the free space and close to human body.

	Frequency	**3.1 GHz**	**4.1 GHz**	**5.1 GHz**
In the free space	**Gain**	2.4	3	2.4
In close body tissue	**Gain**	0.7	0.9	1.1
	SAR (10 g)	17.3 W/kg	18 W/kg	19.92 W/kg

numerical SAR value (reference is 1 W) can be seen increased from lower frequency (3.1 GHz) to higher frequency (5.1 GHz). If the reference power of 1 mW is used, the SAR values will be in the limit of allowable SAR.

Figure 3 shows that the E- and H-plane patterns in 3.1, 4.1 and 5.1 GHz of the proposed antenna in the free space and close to human body tissues at $d = 2$ mm. It can be seen that the E-plane and H-plane radiation pattern is affected when the antenna placed close to the body.

4. CONCLUSIONS

In this paper P-shaped monopole antenna has been presented investigating the VSWR, gain, radiation patterns and SAR in the free space and close proximity to the human body. The proposed antenna provided an impedance bandwidth VSWR <2 from 3.1 to 5.1 GHz. The VSWR was not affected by the proposed antenna in free space and when placed near the body at different distances from the body surface. In addition, SAR effect is increased when the antenna placed near the body surface and with increasing frequency. The SAR of the proposed antenna are 17.3, 18 and 19.92 W/kg at 3.1, 4.1 and 5.1 GHz respectively. The simulated gain obtained were 0.7, 0.9 and 1.1 to 3.1 GHz, 4.1 GHz and 5.1 GHz respectively. The value of gain was reduced when the proposed antenna is placed close to the body.

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