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On-Body Monopole Antenna Design and Analyses for the UWB Applications

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Abstract: In this paper, design and analysis of a polygonal shaped patch antenna for on-body applications is presented. The patch antenna simulated to operate on ultra-wide band (UWB) frequency range with the dimensions of the 22.5 mm x 38 mm x 0.5 mm. The substrate material of antenna is Roger-RO4003, which has a relative permittivity of 3.55 and loss tangent of 0.0027. The antenna resonates from the 1.26 GHz to 11.1 GHz efficiently. In the paper, characteristic specifications of antenna such as return loss, gain and radiation patterns are given and interpreted successively. In the simulation, 3 biological layers consisting of skin, fat and muscle defined to represent the human body and the simulation has been done using these layers. Proposed antenna can be used in the applications such as medical, industrial, information systems, positioning systems etc. In addition to this, the small profile of the antenna makes it portable and suitable for ultra-wide band on-body applications.

Keywords: Wearable Antenna, Polygonal Antenna, UWB Antenna

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1. INTRODUCTION

With the developing technology, many new methods and tools are being developed which can be easily adopted to the modern healthcare systems for the aim of using in the diagnosis and treatment of patients [1]. In addition to this, the new technological devices could be used for the improving the efficiency of the healthcare resources. It is a reality that using of the technological devices for the aim of the remote monitoring in the daily, weekly or monthly applications in the healthcare has an excellent opportunities and facilities for the patients [2]. The frail, elderly and housebound patients can take advantage of the new opportunities and facilities.

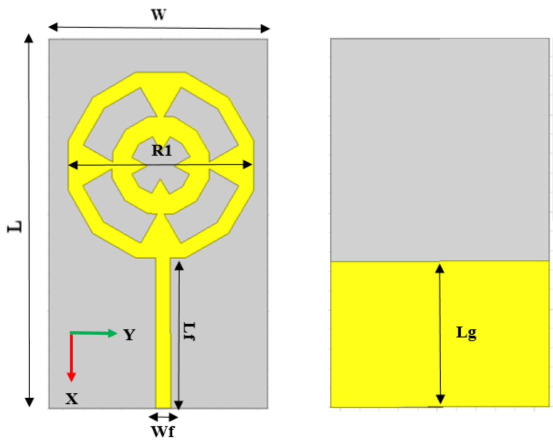
In the last years, it is given importance to the healthcare systems by the antenna community since the antennas have a lot of application opportunities in the field of health [3]. For instance, wearable antennas can be used for the transmitting and receiving of the biomedical signals. In addition to this, it can be stated that body-centric wireless communications have the high possibility for the improving of the quality of live which can be used in the commercial, military and medical applications [4].

Wearable antennas should have some characteristic features such as easy fabrication, physical durability, high gain and efficiency as possible as much, and low specific absorption rate [5-6]. The more information about the wearable antennas can be found in the literature.

In this paper, the novel UWB on-body patch antenna was proposed which one consists of nested polygonal shaped radiator with the slots inside it. The simulations of the antenna were performed using ANSYS HFSS. The proposed antenna works successfully on the frequency of 1.26 GHz and above. In addition to the return loss, the radiation patterns values at the UWB bands were also added and interpreted.

2. THE CONCEPT AND ANTENNA DESIGN

In this section, the novel UWB on-body antenna was presented. The general structure of the antenna was illustrated in Figure 1(a) and Figure 1(b) and the parameters were given in Table 1. The proposed antenna mainly consists of nested polygonal shaped radiator with the slots inside it. The radius of the main circle is 19.1 mm (R1), the length of the ground is 14 mm, the length and width of the feeding line are 15.5 mm and 1.5 mm, respectively. And the whole size of the antenna is 22.5 mm x 38 mm x 0.5 mm.



(a) *(b)*

Figure 1. Model and dimensions of antenna

Table 1. The Design variables of the antenna.

Parameter	Dimension (mm)
R1	19.1
W	22.5
L	38
Lg	14
Wf	1.5
Lf	15.5
h	0.5

The effective width of the antenna can be calculated by the Equation 1 [8-9] and in this equation; f_r is the operating frequency, c is the speed of light and the ε_r is the value of substrate permittivity.

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{1+\varepsilon_r}} \quad (1)$$

The effective dielectric (ε_{eff}) constant value of the antenna system is an important parameter and calculated using the Equation 2 [7-9]:

$$\varepsilon_{eff} = \frac{1+\varepsilon_r}{2} - \frac{1-\varepsilon_r}{2}\left[\frac{1}{\sqrt{\frac{1}{1+12\frac{h}{w}}}}\right] \qquad (2)$$

Because of the fringing on the patch, electrical size of the antenna increases and it is represented by amount of ΔL which is given in Equation 3[8-9]. In this equation, h is the height of the substrate.

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+0.3)\left(\left(\frac{W}{h}\right)+0.264\right)}{(\varepsilon_{eff}+0.258)\left(\left(\frac{W}{h}\right)+0.8\right)} \qquad (3)$$

The length of the antenna also can be calculated from Equation 4 [8-9]:

$$L = \frac{c}{2f_{r\sqrt{\varepsilon_{eff}}}} - 2\Delta L \qquad (4)$$

The model that illustrates the human body tissue modelled using the three dielectric layers. These layers represent the skin, fat and muscle of the human body and the relative permittivity values of the layers taken from web site of Federal Communications Commission and given in Table 2 [10].

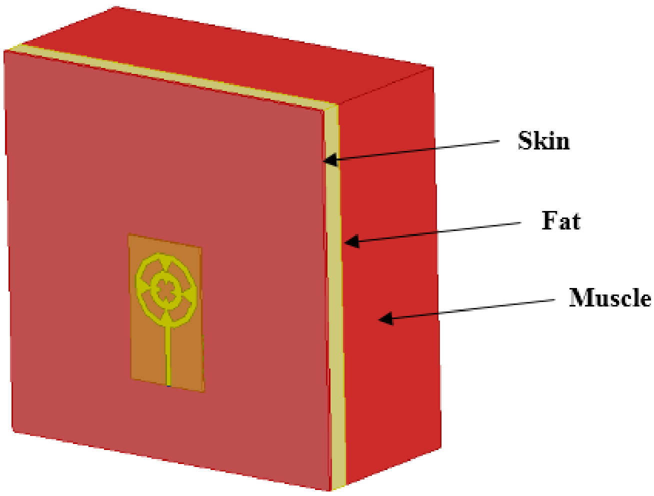


Figure 2. The designed three-layer model of the human body in HFSS

Table 2. The parameters of dielectric layers.

Layer	Relative Permittivity (ε_{eff})	Bulk Conductivity (Siemens/m)
Fat	10.84	0.262
Muscle	53.64	1.77
Skin	38.006	1.466

The reflection coefficient of the designed antenna was given in Figure 3. According to the figure, it is clear that the antenna covers the frequency range of 1.26 GHz-11.1 GHz. In addition to this, the radiation pattern of the antenna at the different frequencies and planes were depicted in Figure 4. According to the figure 4, the antenna has a uniform patterns at the low frequencies such as 2.4 GHz. With the increasing of the frequency, the radiation patterns are disrupted and at some directions the gain of the antenna decreases drastically.

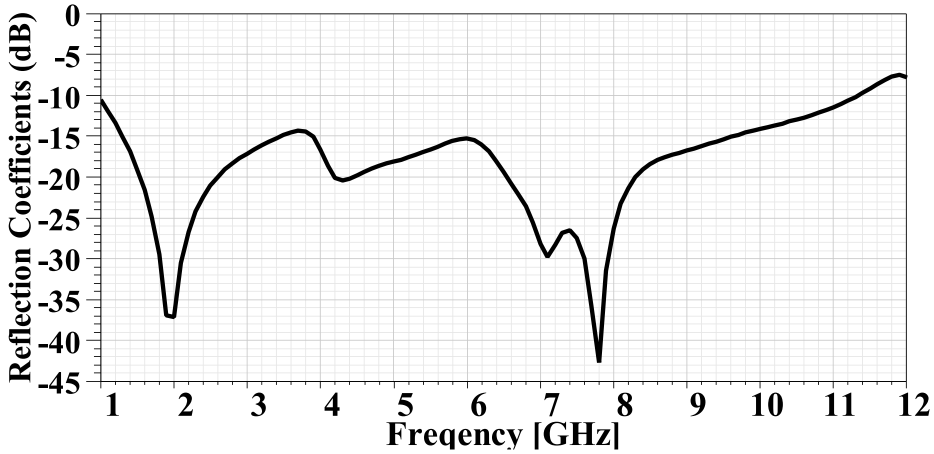
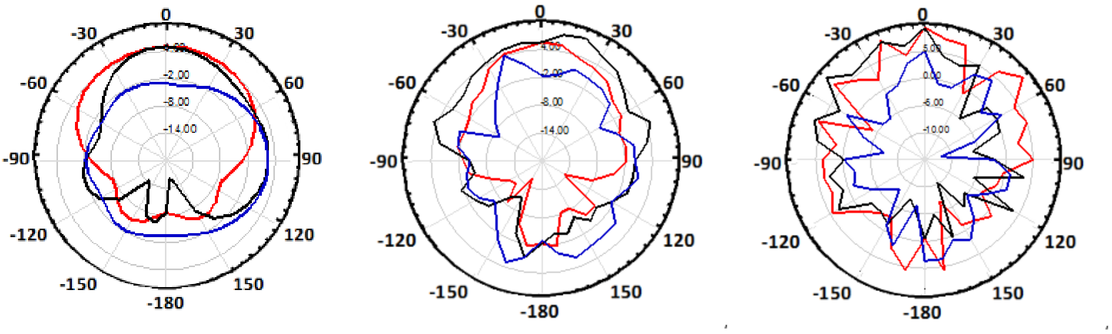


Figure 3. Return loss of the proposed antenna.



2.4GHz 5GHz 9GHz

Figure 4. Radiation patterns of the designed antenna (phi=0 (x-z), phi=90 (y-z), theta =90(x-y))

The parametric analyses of the antenna depending on the ground length was given in Figure 5. When the graph is examined, it can be clearly seen that, the increasing of the ground length from 12 mm to 14 mm, positively effects the reflection coefficient. The values above the 14 mm, deteriorates the impedance matching of the antenna.

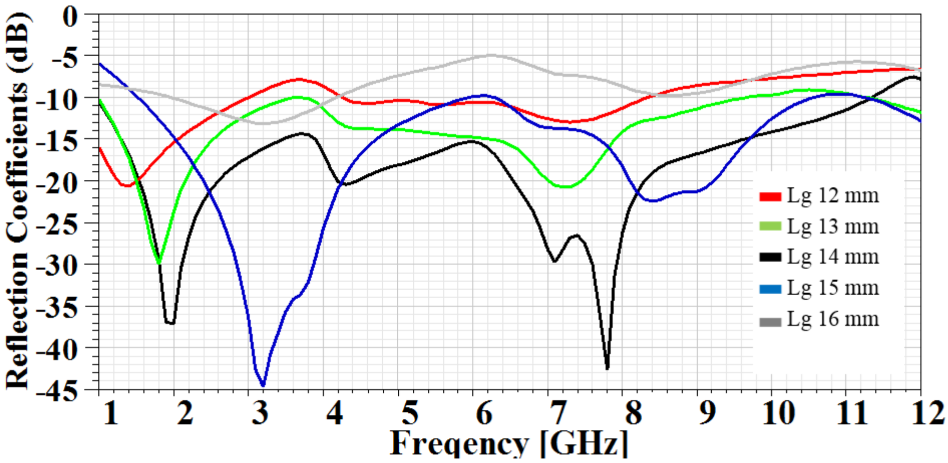


Figure 5. The chancing of the antenna return loss according to the ground width

CONCLUSION

In this paper, design and analysis of a polygonal shaped patch antenna for on-body applications was presented. The designed antenna has a compact size of 22.5 mm x 38 mm x 0.5 mm which one operates in the frequency range of 1.26 GHz – 11.1 GHz. The characteristic specifications of antenna such as return loss, gain and radiation patterns are given and interpreted successively. In the simulation, 3 biological layers consisting of skin, fat and muscle defined to represent the human body and the simulation of the antenna has been done using this model. Proposed antenna can be used in the applications such as medical, industrial, information systems, positioning systems etc. In addition to this, the small profile of the antenna makes it portable and suitable for ultra-wide band on-body applications.

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