The Design and SAR Analysis of a Flexible Ultrawideband Bow-tie Antenna for Wireless Wearable Sensors

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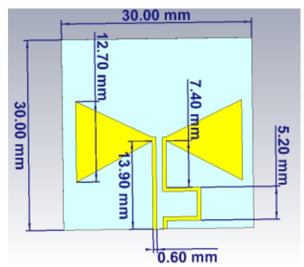
***Abstract*—This paper presents design of a wearable flexible patch antenna and its corresponding SAR (specific absorption rate) analysis when placed on a human body. The substrate material used is polyimide with a thickness of 0.1 mm, and gold is used for the patch and ground material with 200 nm thickness. The di-electric constant and the tangent loss of the polyimide substrate are 3.5 and 0.0002, respectively. The dimensions of the proposed antenna are 30×30×0.1004 mm^3. The designed antenna has the resonating frequency at 3.45 GHz and a bandwidth of 2.6 GHz. The far field gain of the designed antenna is 7.5 dBi. The SAR analysis generated an SAR value of 0.174 W/kg, which is within the safe limit of 2W/kg averaged over 10g of tissue as specified by the ICNIRP (International Commission of Non-Ionization Radiation Protection). This suggests that the designed antenna is safe and can be utilized for wireless wearable sensors.**

I. INTRODUCTION

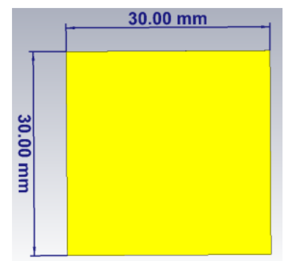
In the construction of a wireless communication system, the antenna is the most important component. The rapid evolution of mobile communication systems, especially Body Area Networks (BANs) and Personal Area Networks (PANs), necessitates effective antenna design [5, 6]. In recent years, there has been a lot of interest in the topic of flexible electronics from both academics and industry. In fact, numerous national research bodies have requested this research at the top of their research priority pyramid. Nowadays there are variety of sensors that are attached directly to the human body, or even implanted within it. Wearable technologies allow for remote patient monitoring, which aids clinicians in disease diagnosis and management while working from home or in the clinic. Wearable antennas must be flexible and conformable to the human body without interfering with the daily activities.[1-4] The majority of researchers in the literature have suggested that Microstrip patch antennas are the best candidate for wearable applications because of their low profile, conformal, and cheap cost properties. Aside from material selection, the design of wearable antennas is a difficult task due to the bending, crumpling, stretching, and folding effects caused by the presence of the human body. The side and back lobe radiations are penetrated and absorbed in bodily tissues when these antennas are employed in close proximity to the human body. The mitigation of sidelobe issues is an important factor that is needed to be taken into account while designing the antenna. The SAR is a measurement of how much power is absorbed per unit mass of the human body. The time derivative of incremental energy (dW) wasted in an incremental mass (dM) in a volume (dV) with a particular density (ρ) can also be expressed as SAR. The US standard specifies a maximum acceptable limit of SAR of 1.6 W/kg for 1 g of tissue as the maximum safe limit. The maximum amount of SAR for any 10 g of tissue has been set at 2 W/kg by the International Commission on Non-Ionization Radiation Protection (ICNIRP) for Europe.

II. ANTENNA DESIGN AND SIMULATION

This section deals with the details related to the flexible antenna design. The details such as the preferred design dimensions, software used for simulation, materials used are discussed in this section.



(a) Front view



(b) Back view

Fig 1. Design of the flexible bow-tie antenna.

The antenna's substrate material is chosen as polyimide due to its flexible nature and the gold is used as the radiating patch and the ground material due to its efficiency in the performance with respective to the gain of the antenna. The dimension of the designed flexible antenna is 30×30×0.1004 mm^3. The SAR analysis generated a value of 0.174 W/kg which is in the safe limit of 2W/kg averaged over 10g of tissue as specified by the ICNIRP. The gain of the antenna is 7.5 dB. The proposed antenna design is shown in the Fig. 1. The thickness of the polyimide substrate used is 0.1 mm and the thickness for both the patch and ground material is 200 nm. The di-electric constant and the tangent loss of the polyimide substrate are 3.5 and 0.0002, respectively. The design and simulation of the antenna are performed using the CST (computer simulated technology) studio suite. The designed antenna is edge-fed using CPW (Coplanar Waveguide) port.

III. SAR ANALYSIS AND SIMULATION RESULTS

The SAR analysis has been performed by placing the designed antenna onto a human body model, where the human body model consists of different layers such as Skin (2 mm), fat (8 mm), and Muscle (26 mm). The properties of the human body tissues are assigned as mentioned in the Table 1. The model designed for SAR analysis is shown in the Fig. 2.

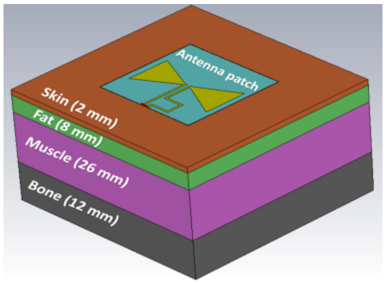


Fig 2. The antenna patch placed on the human body.

The SAR analysis generated a value of 0.174 W/kg which is in the safe limit of 2W/kg averaged over 10g of tissue as specified by the ICNIRP. The S_{11} simulation result shown in the Fig. 3 portrays the fact that the designed antenna has the wide operational bandwidth value of 2.6 GHz. The far-field radiation simulation has been performed to calibrate the gain of the antenna as shown in the Fig. 4. The farfield results showed that the antenna has good performance with respective antenna's gain.

Table 1. Properties of the human body tissues.

Tissue	Permittivity (ε_r)	Conductivity (S/m)	Loss Tangent	Density (Kg/m^3)
Skin	31.29	5.013	0.283	1100
Fat	5.27	0.12	0.192	1100
Muscle	52.79	1.8	0.242	1060
Bone	12.62	3.85	0.252	1850

The SAR simulation is shown in the Figure 5. The attained simulated value of SAR is 0.174 W/kg, which indicated that the designed antenna is safe as its value is within the safe limit of 2 W/kg as suggested by ICNIRP and this clearly suggests that it is human wearable.

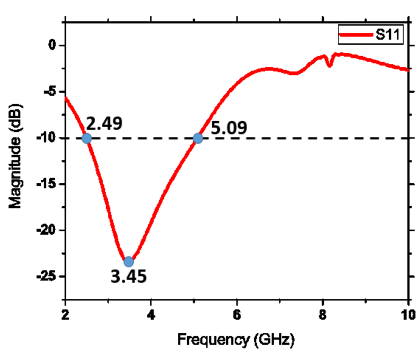


Fig 3. Simulated S_{11} parameter.

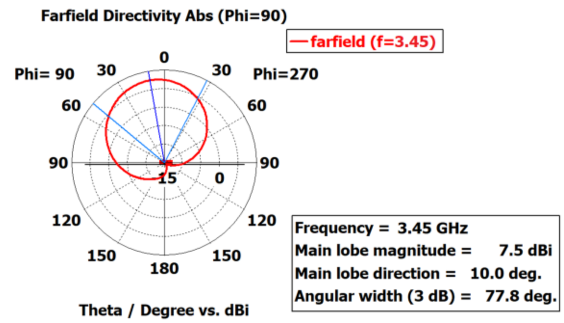


Fig 4. Far field directivity of the designed antenna.

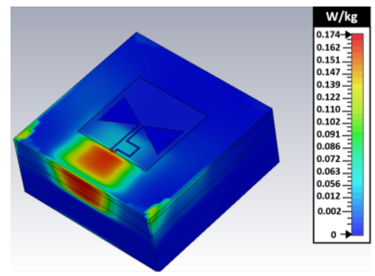


Fig 5. SAR simulation result.

IV. CONCLUSION

The simulation results portray the suitability of the designed antenna for placement on the human body. The SAR value of 0.174 W/kg indicates that it is safe to wear on human body. The high gain value of 7.5 dBi and wide operation band width of 2.6 GHz portray the best performance capability of the designed antenna.

ACKNOWLEGMENT

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