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

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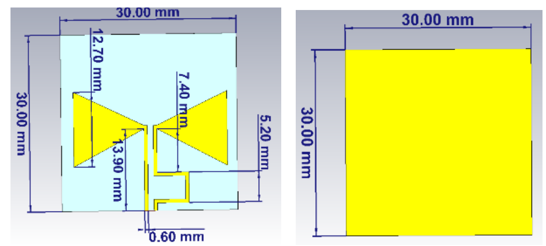
***Abstract*—This paper presents design of a wearable flexible patch antenna and its corresponding SAR (specific absorption rate) analysis when placed on a human body. The substrate material used is polyimide with a thickness of 0.1 mm, and gold is used for the patch and ground material with 200 nm thickness. The dielectric 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 wireless communication systems necessitates the effective ultra-wide band antenna design [3]. 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. [4,5] 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 SAR is a measurement of how much power is absorbed per unit mass of the human body. 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). Even though there are few prior works which contributed antenna designs for wearable applications, there are very few which actually worked on ultra-wide band operability of the designed antenna maintaining the SAR value of the antenna in the safe limit as suggested by ICNIRP. This work targets to achieve the wide-band operability by simultaneously maintaining the SAR value within safe limit.



(a) (b)

Fig 1. Design of the antenna (a) Front view (b) Back view.

The UWB (Ultra-wide band) is essential for low-power wearable sensors, as the UWB applications enable a lot of new services for consumers and enterprises like faster wireless data transfer and precise analytics in real time. As the name suggests, it also uses a wider frequency. UWB is very efficient in terms of power consumption and uses wide frequency range which allows it to send lot of data within no time. The novelty of our work is that the convential bow-tie antenna is modified to make it an ultra-wide band operable. Also, suitable materials are chosen to achieve the low SAR value making it suitable for wearable electronics.

II. ANTENNA DESIGN AND SIMULATION

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 high conductivity and good performance with respect to the gain of the antenna. The dimension of the designed flexible antenna is 30×30×0.1004 mm^3. The proposed antenna design is shown in the Fig. 1(a). 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 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. The shape of the conventional bow-tie antenna is modified by introducing a loop strip with 5.2 mm gap to the bow-tie design to boost the gain in the low frequency region.

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) and bone (12 mm). The properties

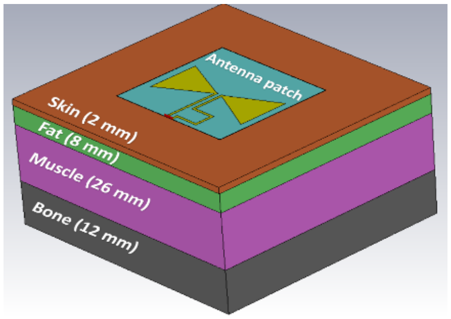


Fig 2. The antenna patch placed on the human body.

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

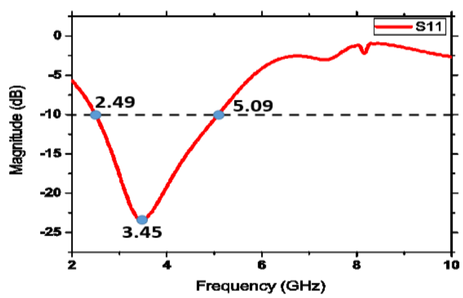


Fig 3. Simulated S_{11} parameter.

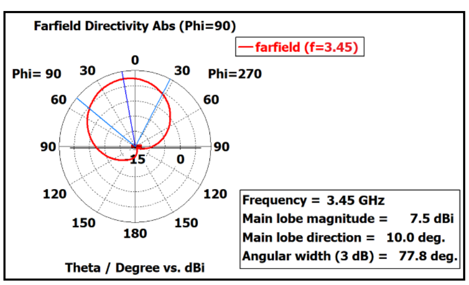


Fig 4. Far field directivity of the designed antenna.

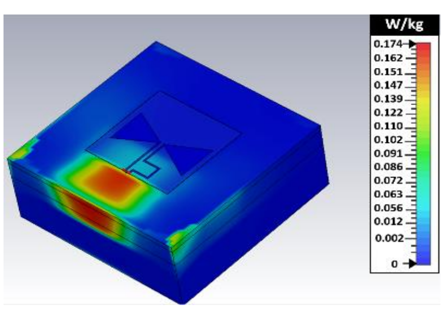


Fig 5. SAR simulation result.

Table 2. Comparison among prior works.

Parameters	[1]	[2]	This work
Dimensions L×W (mm^2)	34.46×23.8	21×12	30×30
Bandwidth (GHz)	0.64	3	2.6
Resonating frequency (GHz)	4.76	3.2	3.45
SAR value	1.27	0.19	0.174

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.

The S_{11} simulation result shown in the Fig. 3 portrays the wide operational bandwidth value of 2.6 GHz and the center frequency of the antenna at 3.45 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. 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. When compared with similar prior works, the dimensions and the SAR value of the proposed antenna design are relatively better. This indicates that our proposed design has its advantages in the aspects of compactness, high gain, wide bandwidth and low SAR value.

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. As a future work, we plan to fabricate the design of the proposed antenna to conduct a thorough analysis by comparing the simulated and practically measured values.

ACKNOWLEGMENT

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REFERENCES

[1] A. Hossain and M. K. Hosain, "Design and Simulation of a Compact Bow-tie Antenna for Cancer Detection and Treatment," 2019 4th International Conference on Electrical Information and Communication Technology (EICT), 2019, pp. 1-4, doi: 10.1109/EICT48899.2019.9068829.

[2] A. M. Hediya, A. M. Attiya and W. S. El-Deeb, "New Design of High-Efficiency Low-SAR Coupled Folded Antenna for 5G Applications," 2020 8th International Japan-Africa Conference on Electronics, Communications, and Computations (JAC-ECC), 2020, pp. 24-28, doi: 10.1109/JAC-ECC51597.2020.9355858.

[3] H. Zhang and H. Li, "Flexible Dual-polarized UWB Antennas for Breast Tumor Imaging," 2020 IEEE MTT-S International Conference on Numerical Electromagnetic and Multiphysics Modeling and Optimization (NEMO), 2020, pp. 1-2, doi: 10.1109/NEMO49486.2020.9343495.

[4] Ping Li, Guang-hua Zhang and Shuang-shuang Han, "Analysis on UHF SAR antenna," 2005 Asia-Pacific Microwave Conference Proceedings, 2005, pp. 2 pp.-, doi: 10.1109/APMC.2005.1606834.

[5] A. Sabban, "Small New Wearable Antennas for IOT, Medical and Sport Applications," 2019 13th European Conference on Antennas and Propagation (EuCAP), 2019, pp. 1-5.