Design and SAR Analysis of a Meander Slot Antenna for Backscattering RFID Applications

Karthik Kakaraparty and Ifana Mahbub
Department of Electrical and Computer Engineering
The University of Texas at Dallas
Dallas, Texas-75080, USA
Karthik.Kakaraparty@utdallas.edu

***Abstract*— The technology known as RFID, or "Radio Frequency Identification", uses RF signals to enable wireless identification and tracking. This paper presents the design of a meander slot monopole antenna for backscattering RFID (radio frequency identification) applications. The substrate material used is PET (polyethylene terephthalate) with a thickness of 0.110 mm, and silver is used for patch material with a thickness of 0.065 mm. The dielectric constant and the tangent loss of the PET are 2.1 and 0.0002, respectively. The proposed antenna's dimensions are 43×72.5×0.175 mm3. The complementary structures of the meander line are incorporated into the design to enhance bandwidth and achieve a lower |S11| value of -55 dB at 2.45 GHz. The designed antenna has a resonating frequency of 2.45 GHz and a bandwidth of 1 GHz, i.e., from 1.95 GHz to 2.95 GHz. The gain of the designed antenna is 6.25 dBi. The SAR analysis generated a SAR value of 0.90 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). The antenna design and simulation are performed using CST (computer simulated technology) studio suite. The antenna design is edge fed using a designed SMA (sub-miniature coaxial connector) model in order to obtain more realistic simulation results. For material selection, the factors such as flexibility and safe wearability on the human body. The proposed antenna covers the unlicensed 2.4 to 2.5 GHz RFID band and is suitable for an efficient RFID backscattering application.**

Keywords*— *Monopole patch antenna; RFID; meander slot; backscattering; PET; computer simulation technology; 2.4 GHz RFID band.

I. Introduction

Recent years have seen a tremendous increase in interest in the field of body-area applications for RFID technology, specifically for wearable devices. The direct proximity of the human body to the RFID device presents a number of design, fabrication, and testing difficulties as well as gives hope for a whole new range of possibilities for health care and other body-area applications. The passive RFID equipment is entirely battery-free. As a result, body-area applications are particularly appealing for passive RFID devices. The antenna design is a crucial step in achieving an efficient RFID system. Wearable antennas need to be adaptable to the human body and free from interference with daily activities. Because of its low profile, conformal design, and low cost, the majority of researchers in the literature contend that microstrip patch antennas are the ideal option for wearable applications [1-3]. This work aims to

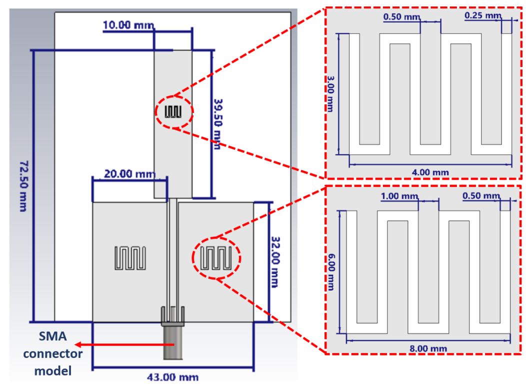

Figure 1. The Design of the antenna.

achieve high gain and wide bandwidth and better resonance at the 2.4-2.5 GHz RFID band, as it is an unlicensed band and facilitates high wave propagation. The novelty of our work is that the meander slots are incorporated into the design to enhance the bandwidth and achieve lower reflection loss at 2.45 GHz. In addition, suitable materials are chosen in such a way that the design is highly flexible and achieves high gain and SAR value within safe limits.

II. Antenna Design and Simulation

The designed antenna's substrate material is chosen as PET (polyethylene terephthalate) due to its distinctive qualities, including its low cost, flexible film screen, outstanding thermal stability, and exceptional moisture resistance which is highly suitable for wearable applications. The dimension of the proposed antenna is 43×72.5×0.175 mm^3. The design of the antenna is presented in Fig. 1. The substrate thickness is chosen as 0.1 mm. Silver is chosen as the patch material as it exhibits excellent conductivity and is responsible for the high gain achievement. The thickness of the patch material of the antenna is 0.065 mm. The antenna design is edge fed using a designed SMA (sub-miniature coaxial connector). The complementary structures of the meander line are incorporated into the design to enhance the bandwidth. A full bottom layer with a slightly varied thickness of 0.035 mm is utilized to mitigate the back lobe radiation.

III. SAR Analysis and Simulation Results

The SAR analysis is carried out by placing designed antenna was placed to a human body model as shown in Fig. 2, which consists of different layers such as skin (2 mm), fat (8 mm),

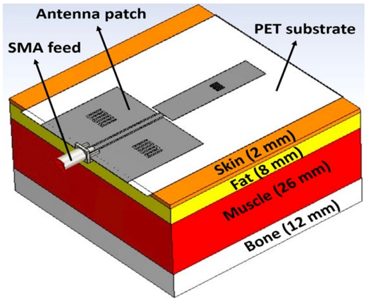

Figure 2. The antenna patch is placed on a human body model.

TABLE I. MATERIAL PROPERTIES OF THE HUMAN BODY LAYERS.

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

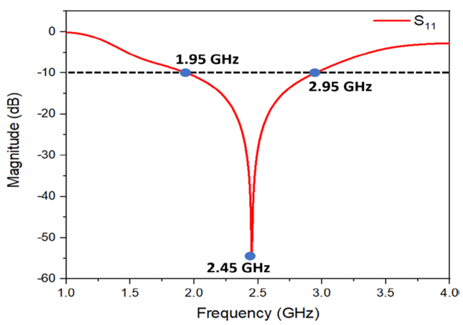

Figure 3. Simulated S_{11} parameter.

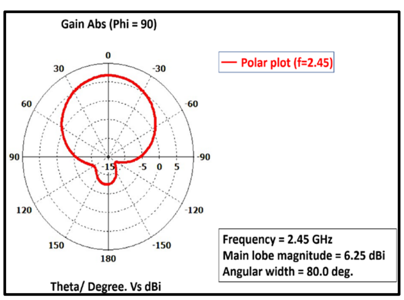

Figure 4. Polar plot of Theta vs Gain (dBi) at 2.45 GHz.

TABLE II. COMPARISON AMONG PRIOR WORKS

Parameters	[1]	[2]	This work
Dimensions L×W (mm^2)	15×14	30×40	43×72.5
Max. Bandwidth (GHz)	0.25	0.1	1.00
Resonating frequency (GHz)	5.6	2.40	2.45
Max. Gain (dBi)	1.3	3.5	6.25
SAR value (W/kg)	0.50	1.31	0.90

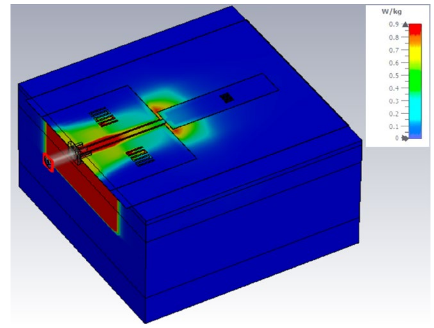

Figure 5. SAR simulation result.

And muscle (26 mm) and bone (12 mm). The material properties of the human body layers were assigned as mentioned in Table I. The simulation result for the S_{11} parameter is presented in Fig. 3 which portrays a good magnitude value of -55 Db at 2.45 GHz. The designed antenna has an operational bandwidth from 1.95 GHz to 2.95 GHz and covers the 2.4 GHz RFID band. The gain of the designed antenna is 6.25 dBi which is shown in Fig. 4. With 0.5 Watts input excitation, the SAR value obtained is 0.90 W/kg as shown in Fig. 5, which is within the safe limits of the 2W/kg averaged over 10g of tissue as standardized by ICNIRP. The proposed antenna has a significantly high gain and low SAR value when compared to similar prior works as shown in Table II.

IV. CONCLUSION

The designed antenna has shown a high gain of 6.25 dBi and a $|S_{11}|$ value of -55 dB at 2.45 GHz, which portrays its suitability for backscattering applications. The SAR analysis generated a value of 0.9 W/kg that indicates that it is safe to utilize for wearable applications. In future work, we plan to miniaturize the antenna size to further extend and fabricate the design to do a thorough analysis of simulated and measured results.

ACKNOWLEDGMENT

This work is based upon work supported by the National Science Foundation (NSF) under grant No. ECCS 1933502.

REFERENCES

[1] Gunamony, Shine Let, S. Rekha, and Benin Pratap Chandran. “Asymmetric microstrip fed meander line slot antenna for 5.6 GHz applications.” Materials Today: Proceedings 58 (2022): 91-95.

[2] Bhattacharjee, S., Mitra, M., & Chaudhuri, S. R. B. (2017). An effective SAR reduction technique of a compact meander line antenna for wearable applications. Progress In Electromagnetics Research M, 55, 143-152.

[3] 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.

[4] R. Simorangkir, A. Kiourti and K. P. Esselle, "UWB Wearable Antenna With a Full Ground Plane Based on PDMS-Embedded Conductive Fabric," in IEEE Antennas and Wireless Propagation Letters, March 2018, doi: 10.1109/LAWP.2018.2797251.

[5] N. Tangthong, P. Moeikham and S. Akatimagool, "A compact multi-band CPW-Fed monopole antenna using L-shaped and straight slots," 2016 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology,2016.

[6] T. Nishime et al, "Platform Excitation for Radiation Efficiency Enhancement Using Slot Antenna," 2021 International Symposium on Antennas and Propagation (ISAP), 2021, pp. 1-2, doi: 10.23919/ISAP47258.2021.9614589.