Journal of Ubiquitous Computing and Communication Technologies (ISSN: 2582-337X)
www.irojournals.com/jucct/

Analysis of Hexagonal Shape Slot Loaded Antenna for the usage of ISM band

Muskan Singh[1], Shubham Shukla[2], Vijay Kumar Pandey[3], Vaibhav Singh[4], Shilpee Patil[5], Vaishali Singh[6]

[1,2,3,4,5,6]Department of Electronics and Communication Engineering, Noida Institute of Engineering and Technology, Greater Noida, India

E-mail: [1]hmsingh.muskan@gmail.com, [2]shubhamthebest2@gmail.com, [3]drvkpandey@niet.co.in, [4]vaibhav24052000@gmail.com, [5]shilpee.patil@niet.co.in, [6]vaishalisingh8004@gmail.com

Abstract

This work proposes a compact, wideband, hexagonal-shape slot antenna with a feeding type of CPW, covering the ISM frequency band range for the bio-medical application. The proposed antenna size is 10x10x0.4 mm composed of hexagonal ring slots in a plane and using substrate material like Kapton Polyimide. Simulation is processed to attain the biocompatibility and antenna characteristics such as return loss, radiation pattern, gain, etc. Graphical-based simulated results of antenna parameters are obtained using the High-Frequency Simulation Software that covers the "Industrial Scientific and Medical" band range.

Keywords: Hexagonal Slot, Kapton Polyimide, ISM Band

1. Introduction

A device that can induce as a receiver when it transforms electromagnetic waves into V/I waves and also radiates as a transmitter when transforming alternating current waves into radiofrequency waves is known as the antenna. An antenna can be used for a wide range of applications.

Implantable devices can be referred to as those devices which are set up over the body during the medical examination process to form a link between medical devices. Research and development in implanted devices have seen rapid growth all over the world. The main applications of such devices are for hyperthermic treatments, and monitoring purposes, and can also work with sensors for implantable devices. Fabrication of this type of antenna

DOI: https://doi.org/10.36548/jucct.2022.1.006
Received: 17.03.2022, received in revised form: 19.04.2022, accepted: 03.05.2022, published: 13.05.2022

requires miniature size, flexibility, broader bandwidth, and a Specific Absorption Rate of low value.

The layout for an effective and high-throughput antenna for biomedical devices has been developed by several research works. The use of a metamaterial (MTM) array for improvement of gain by 3dB in [1] and by introducing a slot on a compact implantable antenna. Xiongying Liu et al. [2] studied the radiation patterns left-handed circular polarization was demonstrated and to widen the current path by V-shape slots inserted in the patch. In some research antenna parameters are obtained by placing the antenna in different human body models like in [3], the designed compact antenna resonates in the ISM band range and at 2.45 GHz attained a gain of -12dB. In [4] presents a 94% efficient antenna design resonating at two different frequencies at 2.4GHz and 4.2 GHz using superstrate layer Rogers 6010 to enhance the antenna parameters.

To achieve miniaturization in biomedical applications implantable antenna of clover shape is designed which resulted in a 72% size reduction [5]. For polarization in different radical directions, corners of diagonals are also truncated in the design and the proposed antenna exhibits a gain of -6dB in a lossy medium. Yi Fan 1 et al,[6] observed that slots of V-shape introduced into the patch along with small dimensions can increase the current flow path of an antenna working in the ISM band range. Recently in, 2020 [7] proposed a 91.9mm3 volume implantable antenna analyzed in a lossy medium muscle tissue. For the realization of circular polarization (CP), on the circular patch cross slots were introduced. Although impedance matching is affected due to the analysis which is in a lossy medium, LC elements are added to fulfill the requirements and the antenna exhibits a bandwidth of 18.3% in the range of 2.18 GHz to 2.62 GHz.

In [8] this layout a reduced dimension monopole circularly polarized antenna with microstrip feed and resonates in the ISM Band Range. The antenna achieved a 3 dB AR bandwidth of about 5.3% and an impedance bandwidth of about 13.87% simulated at 10dB by making an L shape stub in the ground plane. Along with the analysis of SAR, obtained peak gain is nearby to -7.79 dBi. To make Body area Network (BAN) application-based devices cost-efficient use of Teflon as a substrate is seen in [9]. The antenna design comprises a triangular patch constructed on a Teflon-based cylindrical substrate resonating at 4.78 GHz, simulated results show the maximum gain and valid radiation characteristics. In [10] represented a comparison between the patch and folded slot implantable antenna and notably latter provided better gain. The antenna is inserted in Polydimethylsiloxane for biocompatibility and covers the ISM band range.

This paper presents a different slot design having hexagonal-shaped rings with a Coplanar Waveguide Feed operating in the ISM band range and provides broad bandwidth characteristics for the proposed antenna. To make it suitable for implantation and flexibility, Kapton Polymide thin layer is considered as a substrate, the simulated results cover wide impedance bandwidth.

2. Structure and Design of Antenna and its Analysis

2.1 Hexagonal Slot Design

The dimensional layout of the muscle box is 80x80x40mm as shown in the layout in fig 1. The main structure is represented in fig 2. with a dimension of 10x10x0.4 mm and involves two hexagonal-shaped ring slots in the patch placed on a substrate made up of Kapton Polymide material with a loss tangent of 0.005(S/m). To gain 50 Ω impedance matching coplanar waveguide feeding technique is used with ground plane spacing, s of 0.5mm on a patch area of 100mm2.

Dimensions are presented in a detailed manner in Table I. Dielectric constant and loss tangent of Muscle tissue are 52.79 and 1.705 (S/m) respectively which provides an environment for the proposed antenna model.

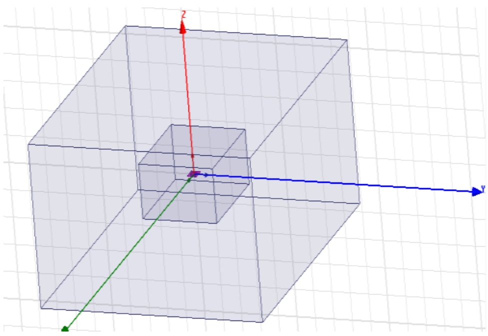

Figure 1. Antenna inside muscle and radiation box

Table 1. Antenna layout parameters

Parameters	l	s	w	d
Values(mm)	10	0.5	1	0.5

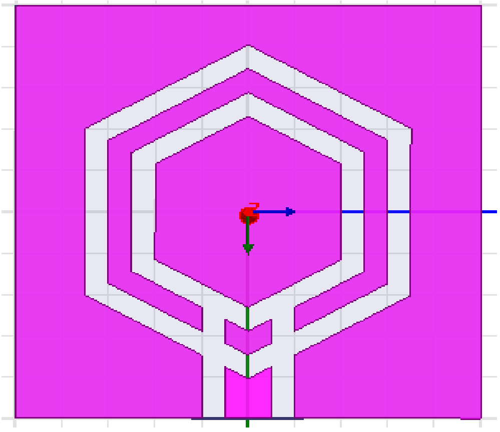

Figure 2. Layout of antenna

Simulation is executed in Ansys High-Frequency Simulation Software.

2.2 Return Loss Analysis

The S-parameter determines the antenna's reflected power. The more the graph is below -10 dB, the better will be the antenna performance as in this case most of the power around 90% is transmitted and 10% is reflected. The return loss curve is depicted in Fig 3 and the value is -27.43dB at 4.8GHZ also covers a broad bandwidth of 13.9246 GHz.

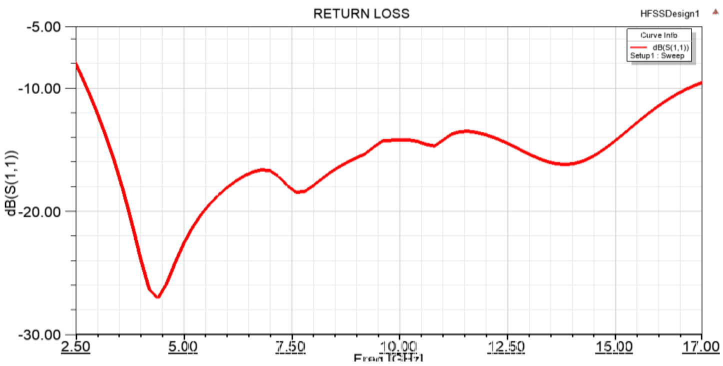

Figure 3. Return loss curve

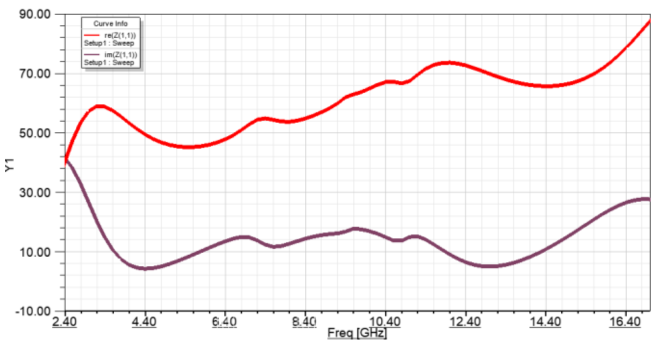

Figure 4. Input Impedance curve

2.3 Input Impedance

The antenna proposed covers a broad range of ISM bands and is useful for many other wireless applications. Fig. 4 represents the input impedance curve covering the desired band.

2.4 Antenna Radiation

The energy emitted by the antenna is in the form of electromagnetic waves and its radial distance from the center of the antenna to a point in space in any direction is referred to as its Radiation Pattern. Fig 5 and Fig. 6 represent 2.45 GHz co-polarization and cross-polarization in the x-z plane and y-z plane respectively. The polarization of an antenna is defined in terms of the polarization of waves in a particular direction.

The three-dimensional radiation pattern is represented in Fig 7 of the proposed antenna. The antenna is placed at a distance of 40 mm in the center from the skin surface (muscle box layer).

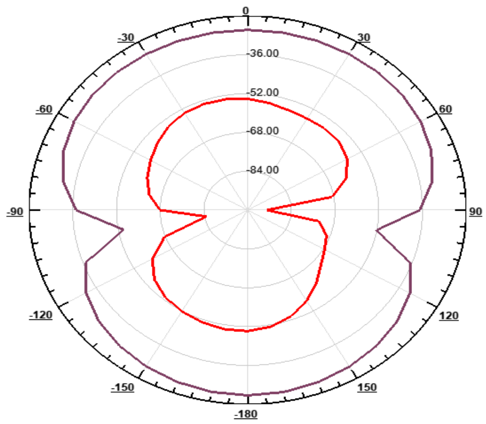

Figure 5. Polarization in the x-z plane at 2.45 GHz

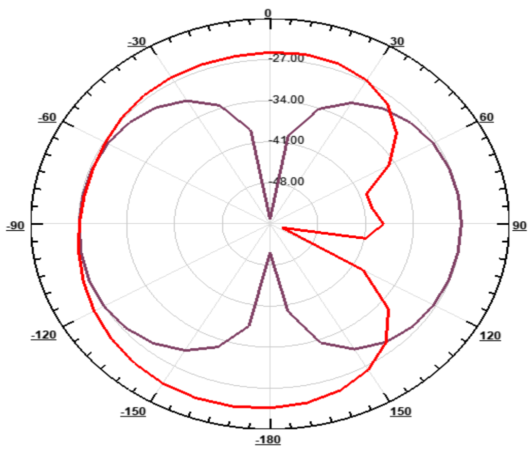

Figure 6. Polarization in the y-z plane at 2.45 GHz

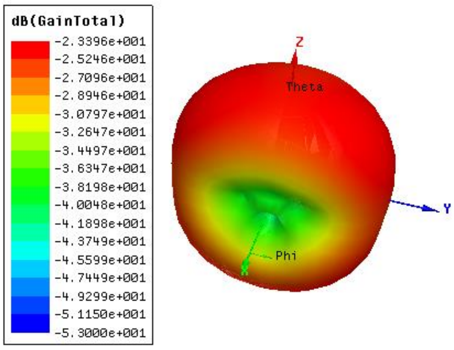

Figure 7. The 3-D Radiation pattern of the antenna

2.5 Simulated Current Distribution

The antenna must cover broad impedance bandwidth for an effective operation. To establish the current distribution perturbation on the surface of the proposed antenna, the dual hexagonal-shaped slots are cut into the plane with a CPW feed line to establish the current surface distribution on the proposed antenna. The simulated surface current distribution at 2.45 GHz for phase angles 0° and 90° is represented in Fig. 8(a) and Fig.8(b). Therefore, within the operating band, the current distribution is achieved.

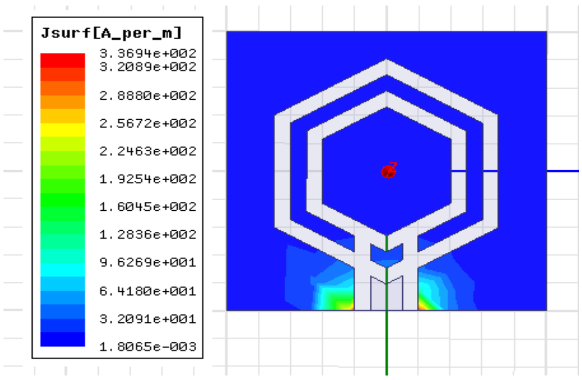

Figure 8(a). Phase angle 0° Surface current distribution at 2.45GHz

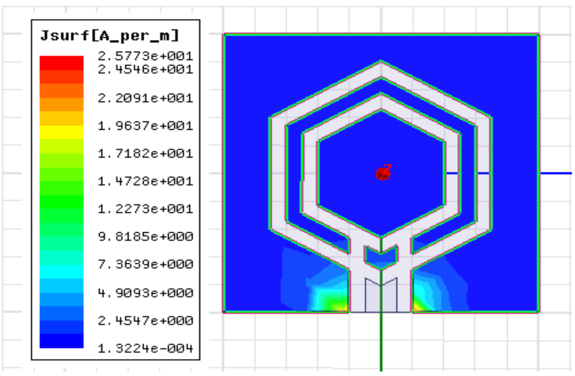

Figure 8(b). Phase angle 90° Surface current distribution at 2.45GHz

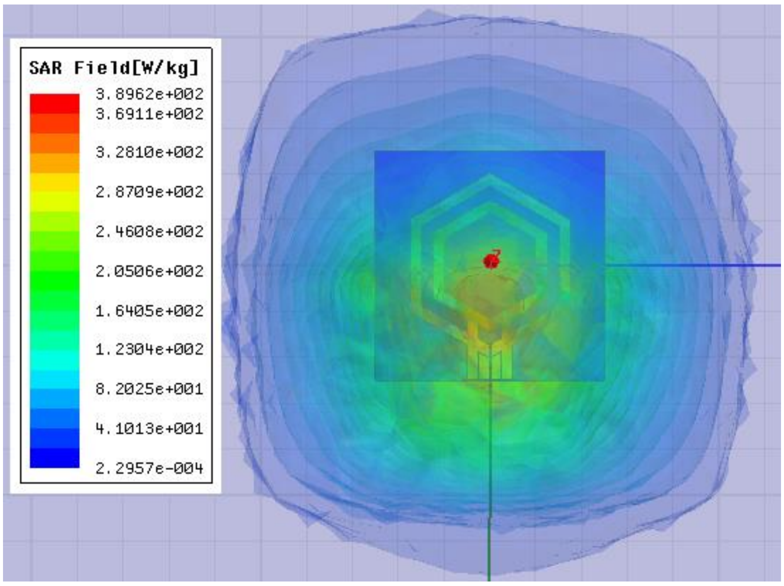

Figure 9. SAR analysis antenna placed in the muscle layer

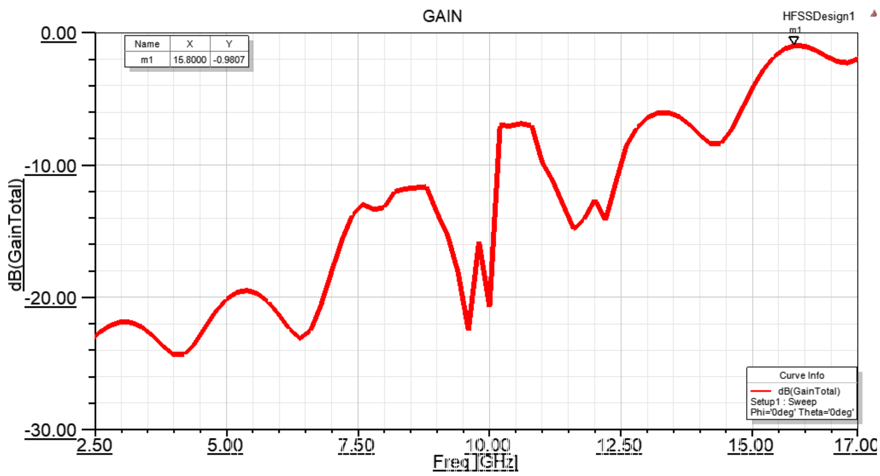

Figure 10. Antenna Gain

2.6 SAR Assessment

The proposed antenna is planted inside the diverse layer model to attain the Specific Absorption Rate (SAR). Fig 9. represents the SAR distribution in the muscle layer.

The SAR value is obtained to assess the human body safety and the average SAR value for a 1g model should be under 1.6 W/Kg.

2.7 Gain of Antenna

The antenna gain plot obtained from simulating the antenna in a muscle model is plotted in Fig. 10 and the maximum gain attained is -0.97 dB at 15.8 GHz frequency.

3. Conclusion

In this work, a compact hexagonal slot shape flexible antenna with coplanar waveguide feeding for the coverage of ISM band has been proposed. The proposed antenna has a significant gain and bandwidth which is favorable for biomedical application.

References

[1] Soumyadeep Das, and Debasis Mitra, “A Compact Wideband Flexible Implantable Slot Antenna Design with Enhanced Gain Wideband Flexible Implantable Slot Antenna Design with Enhanced Gain,” IEEE Transactions on Antennas and Propagation PP(99):1-11, May 2018.

[2] Dheeraj Bharadwaj, Sahil Tangri, and Komal Sharma, ‘‘Modified Stacked Compact Microstrip Patch Antenna for Implantable Medical Devices,” International Journal of Latest Trends in Engineering and Technology (IJLTET), Vol 7, 724-730, May 2016.

[3] Xiongying Liu, Zetao Wu, Yi Fan, E. Tentzeris, ,“ A Miniaturized CSRR Loaded Wide-Beamwidth Circularly Polarized Implantable Antenna for Subcutaneous Real-Time Glucose Monitoring,” IEEE Antennas and Wireless Propagation Letters, (), 1–1, 2017.

[4] Z. Bashir, M. Zahid, N. Abbas, M. Yousaf, S. Shoaib, M. A. Asghar, et al., “A Miniaturized Wide Band Implantable Antenna for Biomedical Application,” UK/China Emerging Technologies, October 2019, pp. 1-4.

[5] Dheeraj Bharadwaj, Sahil Tangri, and Komal Sharma, ‘‘Modified Stacked Compact Microstrip Patch Antenna for Implantable Medical Devices,” International Journal of Latest Trends in Engineering and Technology (IJLTET), Vol 7, 724-730, May 2016.

[6] S. Ashok Kumar and T. Shanmuganantham, “A Miniaturized Circularly Polarized Antenna for In-Body Wireless Communications,” Alexandria Engineering Journal, Volume 56, Pages 313-317, 2017.G. J. 2012.

[7] Yi Fan 1, Xiongying Liu, Jiming Li andTianhai Chang, “A Miniaturized Circularly-Polarized Antenna for In-Body Wireless Communications,” Micromachines, 10(1), 70, 2019.

[8] Li-Jie Xu; Jin-Peng Xu; Zhao-Jun Chu; Shuo Liu; Xiaowei Zhu, “Circularly Polarized Implantable Antenna With Improved Impedance Matching,” IEEE Antennas and Wireless Propagation Letters Volume:19, Matching,” IEEE Antennas and Wireless Propagation Page(s): 876 – 880, May 2020.

[9] Pujayita Saha, Debasis Mitra, and Susanta Kumar Parui, A Circularly Polarised, “Implantable Monopole Antenna for Biomedical Applications,” Progress In Electromagnetics Research C, Vol. 85, 167-175, 2018.

[10] Esha Johari, Sovan Mohanty, Dr. Pradyot Kala, Hardesh Kumar Singh, and H.B Baskey, “Study of a Microstrip Triangular Patch Antenna for Body Area Network Applications Mounted on Teflon Cylindrical Surface”, in ICIIS, May, 2016.

[11] Maria Lucia Scarpello, Divya Kurup, Hendrik Rogier, DriesVandeGinste, Fabrice Axisa, Jan Vanfleteren, Wout Joseph, LucMartens, and Gunter Vermeeren. “Design of an Implantable Slot Dipole Conformal Flexible Antenna for Biomedical Applications,” IEEE transactions on antennas and propagation, vol. 59, no. 10, October 2011.

[12] S. Patil, V. Kapse, S. Sharma, and A. K. Pandey, “Low Profile Wideband Dual-Ring Slot Antenna for Biomedical Applications”, Proc. eng. technol. innov., vol. 19, pp. 38-44, Jul. 2021.

[13] S. Patil, A. K. Pandey, and V. K. Pandey, “A Compact, Wideband, Dual Polarized CPW-Fed Asymmetric Slot Antenna for Wireless Systems,” Journal of Microwaves, Optoelectronics, and Electromagnetic Applications, vol. 19, no. 3, pp. 343-355, September 2020.

[14] S. Patil, A. K. Singh, B. K. Kanaujia, and R. L. Yadava, “A Low-Profile Triple-Band Circularly Polarized Wide Slot Antenna for Wireless Systems,” International Journal of Microwave and Wireless Technologies, vol. 11, no. 1, pp. 67-75, August 2019.