International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

A Novel Design of Mm-Wave Antenna for WBN Use Cases

Sasikala S. [1], Sakthisudhan K. [2], Dr. Kannan R. [3], Kowsalya P. [4], Dr. Anand Karuppannan [5], Dr. A. Kingsly Jabakumar [6], Dr. R. Senthil Ganesh[7]

Submitted: 04/02/2024 **Revised**: 12/03/2024 **Accepted**: 18/03/2024

Abstract: This research article proposes a novel Computer-Aided Design (CAD) inspired microstrip patch antenna. The antenna is configured in the cross-sectional view of an equilateral triangle-shaped structure, resembling a six-pointed star polygon. It consists of a middle layer made of 1.5-millimeter (mm) thickness of the Rogers substrate material (RT 6010TM) with a dielectric strength of 2.2; an upper layer made of a conductive patch strip (proposed CAD design); and bottom layers made of ground material, both 0.45 millimeters thick with copper conductive materials.The antenna exhibits a resonance frequency of 3.3 GHz with a return loss of 34.02 dB and a Standing Wave Ratio (SWR) of 1.4 dB. It operates in the S bandwidth, ranging from 3 GHz to 3.9 GHz, within the microwave spectrum. This design plays a significant role in high-speed internet connectivity and enables various 5G use cases such as mid-band 5G deployment, Enhanced Mobile Broadband (eMBB), IoT, and machine-to-machine communication. The simulated structure effectively characterizes antenna design parameters including bandwidth, impedance bandwidth, return losses, SWR, gain, and radiation pattern within the S-band microwave spectrum. The Finite Element Method (FEM) proves to be a reliable configuration in CAD design, and the six-pointed star polygon-shaped structure achieves good agreement with a resonance frequency of 3.3 GHz as observed and plotted in the results.Moreover, the proposed CAD-inspired antenna features a compact profile and is highly relevant for 5G use cases.

Keywords: *Microstrip patch antennas, 5G use cases, Six-pointed star polygon-shaped antenna, CAD-inspired Microstrip patch antenna.*

1. Introduction

The microstrip patch antenna provides crucial role in enabling the different 5G uses cases by providing efficient and reliable connectivity across various industry sectors and applications. Such as smart phone, Internet of Things (IoT), Wearable Body-area Network (WBAN), machine to machine communication, public safety and privacy communications. The microstrip patch antennas in 5G use cases could include investigating on the following key aspects such as design pattern and analysis of design parameters (S. N. Mahmood et al., (2021); Wael Ali et al., 2017; Srinivasan & Gopalakrishnan, 2019). The primary design concepts on related to 5G use cases. It included the following design parameters, dielectric substrate selection, patch strips dimensions, connectives of the feeding techniques, antenna pattern, and impedance matching section. Analyse the deliverable bandwidth characteristics with frequency ranges for 5G (it involves the sub-6 GHz and mmWave bands). The desired radiation characteristics are estimating the radiation patterns, polarization properties, desired coverage by beamforming techniques, gain, diversity of receptor coverage and efficiency. Moreover, these above antenna aspects and their design parameters have integrated in 5G networks ((Zhong & Jiang, 2020), Kapoor et al., 2021); Prasad et al., 2018; Allin Joeet al (2019), UmamaheswariS et al (2023). The various current research is going on the microstrip patch antenna design. It has included the emerging applications related to the 3GPP standards. Moreover, the microstrip antenna has utilized in the following wireless communication systems and devices. Such as MIMO, LTE, Edge networks, 4G, 5G, sub-6 GHz and beyond 5G networks (Zong-zuo& Guo., (2017); Haripriya K et al (2023), Pei et al., 2020; Rajawat et al., (2020); Wang et al., 2021; et al (2020); Varma et al., 2021, Sakthisudhan et al (2016 & 2024).

The wearable device built on the body centric application, it has a low-profile antenna, patient comfortable and dielectric substrate material utilized for

[1] *Assistant Professor, Department of Electronics and Communication Engineering, Dr. N.G.P. Institute of Technology, Coimbatore, India Mail id: sasikala27.ece@gmail.com*
[2] *Professor, Department of Electronics and Communication Engineering, Dr. N.G.P. Institute of Technology, Coimbatore, India Mail id: drkssece@gmail.com*
[3] *Assistant Professor, Department of Electronics and Communication Engineering, RVS College of Engineering and Technology, Coimbatore, India Mail id: kannanvlsi@gmail.com*
[4] *Assistant Professor, Department of Electronics and Communication Engineering, Info Institute of Engineering, Coimbatore, India Mail id: kowsiece2024@gmail.com*
[5] *Assistant Professor, Department of Electronics and Communication Engineering, Gnanamani College of Technology (Autonomous),Pachal, Namakkal, India Mail id: anandped2012@gmail.com*
[6] *Associate Professor, Department of Electronics and Communication Engineering, Christ the King Engineering College, Coimbatore, India Mail id: kingslyjkumar@gmail.com*
[7] *Associate Professor, Department of Electronics and Communication Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India Mail id: drsenthilganesh@gmail.com*

medical diagnosis features, such as monitoring, detection of signals from body, Ex-vivo, In-vivo and implantable... etc. The primary objectives of permittivity, dielectric strength, usage of spectrum and dielectric substate are essential parameter to design the wearable antenna. The excitation signal applied to antenna can be transmitting copper patch on the body. Consequently, extracting features from the body. The proposed antenna consists of the three-layered architecture, they are conductor plane and dielectric substrate. The conductor plane laminates of top and bottom layers. The top layer proposes the patch-strip and bottom layer includes the ground plane. The middle layer includes the non-conductive materials. It provides the efficient coupling between the two conductive strips on top and bottom layers. (saranraj N et al (2023), Allin Joe et al (2022)).

This research article delivers the six-pointed star polygon shaped microstrip patch antenna for various 5G uses cases. The proposed structure etched on the top radiating surface and the partial ground surface on the bottom layer. The Roger dielectric substrate included in the middle of layer. The proposed antenna produces the 3.3 GHz resonance frequency, which covers the ISM bands. The simulation was performed by HFSS simulator. Section 2 describes the research methodology about the design; Section 3 investigates the design parameters and analysis related parameters; and Section 4 describes the conclusion and future scope of antenna.

2. **Materials And Methods**

The proposed antenna consists of three-layered components, such as, conductive patch strip, dielectric substate and partial ground plane. The conductive patch strip is illustrated in Figure 1. It consists of the 3D CAD inspired geometric structure like as six-pointed star polygon. The middle layer includes the Rogers dielectric substrate material (RT-6010TM) with dielectric ratio of 2.2. It provides the significant coupling effect on the top and bottom layers. The last layer as a partial ground plane is shown in Figure 2. It has a 40x30x0.6 mm^3. total dimension of structure is mm^3. The Surface Mount Adaptor (SMA) connects the conductive strip and partial ground plane and acts as feedline.

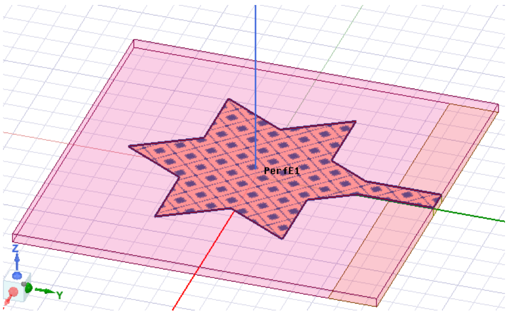


Fig. 1 Conductive patch strip

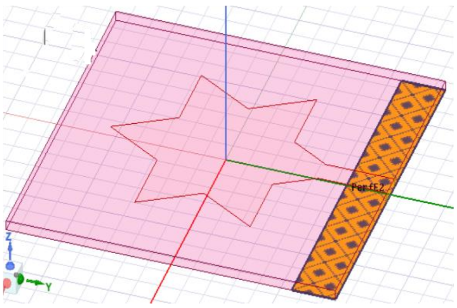


Fig 2. Partial ground plane

3. Results and Discussion

The proposed antenna has exclusively delivered for the ISM band applications. The proposed CAD structure etched with partial ground plane to obtain the S-band microwave spectrum. The patch strip dimension of 32x31 mm^2 labelled on 1.5-millimetre thickness of dielectric material. It has an achieved the 3.3 GHz desired resonance frequency. The resonance frequency, bands of spectrum has investigated with help of the return loss parameter of antenna shown in Figure 3. The desired resonance frequency produced at 3.3 GHz with indicated the return loss of -34.02 dB. The spectrum of the bands from lower and higher cut off frequencies at 2.9 GHz and 4 GHz respectively. Hence the coverage of spectrum lies on the S-band spectrum range with 1.1 MHz ranges of bandwidth. The fractional bandwidth of antenna covers at 30%. Hence, proposed antenna delivered the wideband spectrum among the utilization of users. The standing wave ratio (SWR) of antenna illustrates in Figure 4. The ratio of maximum to minimum voltage is obtained as a 1.4 dB. This SWR range lies between ideal ranges of 1 to 1.5 dB. Hence this proposed SWR ratio provides the significance value and is not reflected to back to incident wave port.

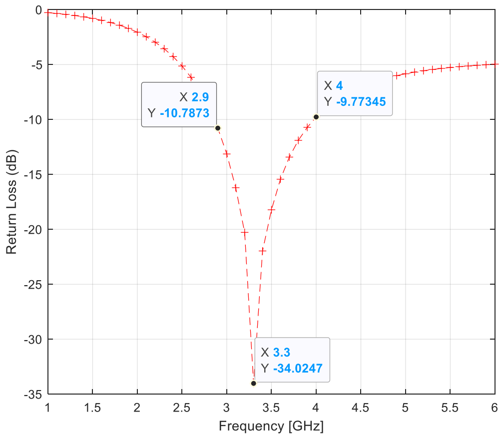


Fig 3. The return loss measurement

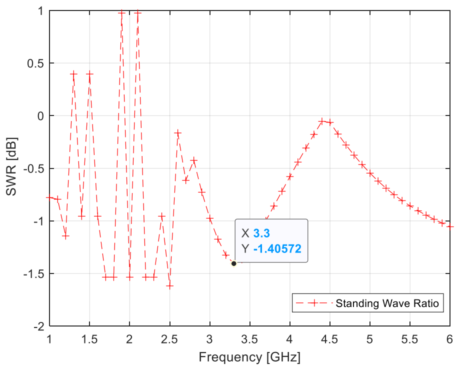


Fig 4. The voltage standing wave ratio measurement

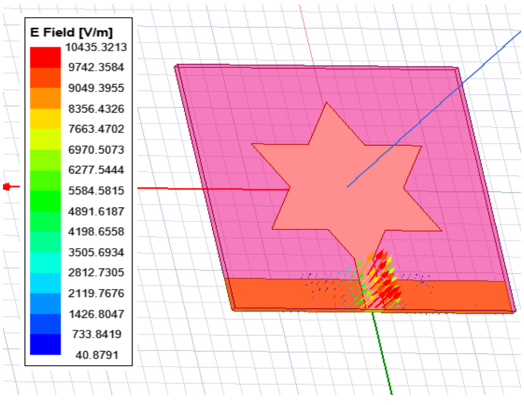


Fig 5. Electric field on the conductive strips

The electric and magnetic fields lie on the conductive strips have shown in Figure 4 and 5 respectively. In HFSS simulator, the perfect electric field with boundary condition on conductive strips causes the normal to the plane and magnetic field lies on the perpendicular to the plane. Figures 4 and 5 has annotated on their fields acting along the plane with respect to values. If the surface current falls on the structure (shown in Figure 8), the perfect magnetic fields generating aperture on the surface. So, the electromagnetic signal propagates their energy on the perpendicular axis.

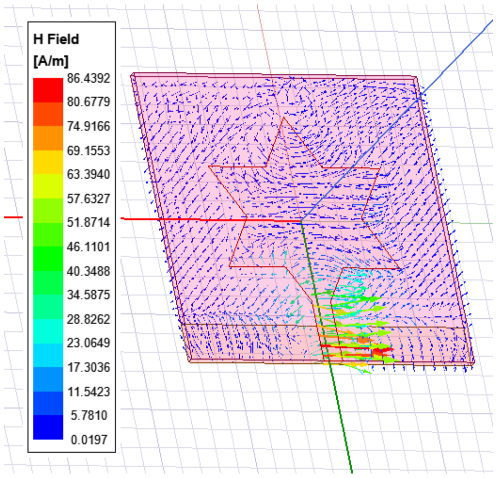


Fig 6. Magnetic field pattern on the conductive strips

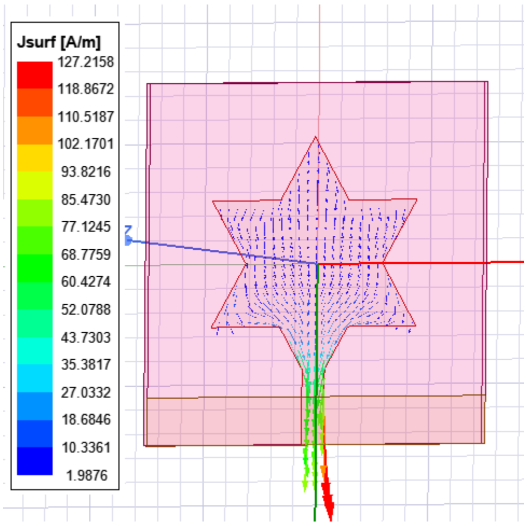
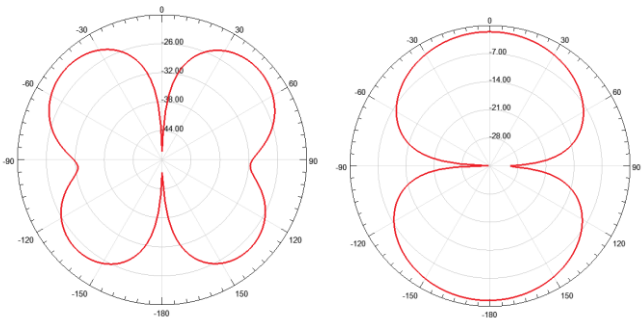


Fig 7. Surface current on the conductive strips



a) b)

Fig 8. Radiation patterns a) theta at 0-degree; b) theta at 90-degree

The graphical radiation pattern of the proposed antenna illustrates in Figure 7. It provides the maximum desired direction of the radiation expressed in Figure 7.a and achieved the maximum directivity of 44 dB. The minor lobes expressed in Figure 7.b and directivity of minor lobe is 28 dB then the resultant radiation pattern is obtained by main and minor lobes of graphical pattern (Figure 7-a & 7-b).

4.Conclusion

The wearable antenna has proposed in this article. it has a low-profile structure, able to detect the ISM band spectrum and use cases in WBN. It consists of Rogers substrate material (RT 6010TM) with conductive patch strip and total dimensional of 40x30x0.6 mm^3. It delivered at resonance frequency of 3.3 GHz and 2.9 GHz to 4 GHz spectrum of bandwidth. It has utilized the wearable body centric application and utilizes the 5G network. The simulated results justified with existing surveys. Hence, this wearable antenna delivers the significant gain, wider bandwidth, lesser SAR and high transmission efficiency. Thus, this antenna has a compact structure and suitable for use cases of WBN.

References

[1] Novel wideband microstrip monopole antenna designs for WiFi/LTE/WiMax devicesHHM Ghouz, MFA Sree, MA Ibrahim - IEEE Access, 2020 - ieeexplore.ieee.org

[2] High Isolated Four Element MIMO Antenna for ISM/LTE/5G (Sub-6GHz) Applications SANTOSH KUMAR MAHTO1 , AJIT KUMAR SINGH 1 , (Member, IEEE), RASHMI SINHA2 , (Member, IEEE), MOHAMMAD ALIBAKHSHIKENARI 3 , (Member, IEEE), SALAHUDDIN KHAN4 , AND GIOVANNI PAU 5 , (Member, IEEE)

[3] K. Hari Priya; S. Umamaheswari "Next Generation Optimized Patch Antenna for 5G Applications" 2023 2nd International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA), 16-17 June 2023.

[4] Kapoor, A., & Mishra, R. (2021).Design and optimization of compact wideband patch antenna using genetic algorithm for WLAN communication. 2021 6th International Conference on Signal Processing, Computing and Control (ISPCC), IEEE, pp. 56–61, https://doi.org/10.1109/ISPCC53510.2021.9609489 .

[5] Prasad, L., Ramesh, B., Kumar, K., & Vinay, K. (2018). Design and implementation of multiband microstrip patch antenna for wireless applications. Advanced Electromagnetics, 7(3), 104–107. https://doi.org/10.7716/aem.v7i3.646

[6] Kapoor, A., Mishra, R., & Kumar, P. (2021). Wideband miniaturized patch radiator for Sub-6 GHz 5G devices. Heliyon, 7(9), 2405–8440. https://doi.org/10.1016/j.heliyon.2021.e07931

[7] Umamaheswari.S, V.S.Akshaya,Vijayadharshini.R,Rohini.R,FrancisAjay.M "E -Slot Microstrip patch antenna for WLAN applications" 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS),17-18 March 2023. 584 – 588.

[8] Zong-zuo, Y., & Guo, G.-Z. (2017). Improvement of positioning technology based on RSSI in ZigBee networks. Wireless Personal Communications, 95(3), 1–20. https://doi.org/10.1007/s11277-016-3860-110.1109/ICACCS57279.2023.10112735

[9] . D. Allin Joe, S. Umamaheswari, S. R. Sriram, "A multiband antenna for GSM, WLAN, S-band radar and WiMAX applications", International Journal of Engineering and Advanced Technology, 8(6 Special Issue 3), pp. 1555–1558, 2019.

[10] K.Sakthisudhan, et al., "Design of miniatured MRI coils for MRI-guided tumor diagnosis and hyperthermia therapy", Microwave & Optical Technology Letters, Wiley, 66(2), 2024. (Q2)

[11] N. Saranraj &K.Sakthisudhan, "Microstrip coils for MR-imaging with induced RF heating for hyperthermia", International Journal of RF and Microwave Computer-Aided Engineering, Wiley, 32(12), 2022. (Q3)

[12] SakthiSudhan K, Saravana Kumar N, "Certain study on improvement of bandwidth in 3GHz microstrip patch antenna designs and implemented on monostatic radar approach for breast cancer diagnosis in microwave imaging system", Journal of circuits, systems and computers, Vol. 25(2), pp. 165006-1 to 32, 2016.

[13] D Allin Joe; R Karthi Kumar; S Umamaheswari, " A Defected Ground Structure (DGS) Antenna for WiMAX Applications," 2021 International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA), 18 January 2022.

[14] Mahmood, S. N., Ishak, A. J., Saeidi, T., Soh, A. C., Jalal, A., Imran, M. A., & Abbasi, Q. H. (2021). Full ground ultra-wideband wearable textile antenna for breast cancer and wireless body area net work applications. Micromachines, 12(3), 1–16.

[15] Srinivasan, D., & Gopalakrishnan. (2019). Breast cancer detection using adaptable textile antenna design. Journal of Medical Systems, 43(6), 177. https://doi.org/10.1007/s10916-019- 1314-5.

[16] Varma, S., Sharma, S., John, M., Bharadwaj, R., Dhawan, A., & Koul, S. K. (2021). Design and performance analysis of compact wearable textile antennas for IoT and body-centric communication applications. International Journal of Antennas and Propagation, 2021(Article ID 7698765), 12. https://doi.org/10.1155/2021/7698765.

[17] Zhong, M., & Jiang, Y. (2020). L-shaped slot-loaded stepped-impedance microstrip structure UWB antenna. Micromachines, 11(9), 828. https://doi.org/10.3390/mi11090828

[18] Pei, R., Leach, M. P., Lim, E. G., Wang, Z., song, C., Wang, J., Zhang, W., Jiang, Z., & Huang, Y. (2020). Wearable EBG-backed belt antenna for smart on-body applications. IEEE Transactions on Industrial Informatics, 16(11), 7177–7189. https://doi.org/10.1109/TII.2020.2983064

[19] Rajawat, A., & Singhal, P. K. (2020). Design and analysis of inset fed wide-band rectenna with defected ground structure. Journal of Circuits,

Systems and Computers, 29(3), 1–15. https://doi.org/10.1142/S0218126620500474

[20] Hussin, E. F. N. M., Soh, P. J., Jamlos, M. F., Lago, H., Al-Hadi, A. A., & Rahiman, M. H. F. (2017). A wideband textile antenna with a ring-slotted AMC plane. Applied Physics A, 123(1), 46. https://doi.org/10.1007/s00339-016-0627-1

[21] Wang, L., Jianguo, Y., Xie, T., & Kun, B. (2021). A novel multiband fractal antenna for wireless application. International Journal of Antennas and Propagation, 2021(Article ID 9926753), 9. https://doi.org/10.1155/2021/9926753