Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Frequency Reconfigurability in Microstrip Patch Antennas for Iot Applications

Sanjeev Kumar Singh[1], Puneet Khanna[2], Neelu Trivedi[3]
[1, 2,3]*Department of Electronics & Communication Engineering, IFTM University, Moradabad. (U.P) India-244102*
Email: sanjeevbtechmba@gmail.com

ARTICLE INFO	ABSTRACT

Received: 30 Dec 2024

Revised: 05 Feb 2025

Accepted: 25 Feb 2025

Introduction: This paper presents various frequency reconfigurability techniques for Microstrip Patch Antennas. It discusses the choice of substrates, as well as the shape and size of the patch as key factors influencing reconfigurability. The proposed microstrip patch antenna is designed and simulated using different patch shapes and sizes, including stubs and resonators, to assess its frequency reconfigurability, reaching up to 60 GHz, which falls within the millimeter-wave frequency range. A comparison and validation of the proposed antenna are provided through graphical results, contrasting it with other patch antennas from existing literature. S11 simulations of various designs are compared, including the basic patch antenna, improved patch antenna, patch antenna with a shunt inductor placed 32mm above the feed point, antennas with microstrip resonators and symmetrical microstrip resonators, as well as those with and without harmonic suppressions. These are all presented in tables and graphs for detailed analysis.

Keywords: Microstrip Patch Antenna, 5G, Frequency reconfigurability and Internet of Things (IoT)

I. INTRODUCTION

The third decade of the 21st century marks the beginning of the Internet of Things (IoT), with 5G mm-wave [1] frequency signals enabling data flow across networks that support the massive demand for wireless devices in homes, offices, and public spaces. The connection of billions of wireless devices over these networks requires a robust IoT infrastructure to meet this demand. A key feature of 5G networks is the ability to provide high data transmission rates over limited bandwidth, facilitating highly connected and distributed IoT systems. However, connecting billions of devices also demands a significant amount of power, which can be constrained by the microstrip patch antennas (MPAs) used in these wireless devices. Therefore, a low-profile, high-gain, and high-efficiency MPA is essential for wireless devices and networks. The flexibility in choosing various substrates for patch antennas offers engineers the opportunity for reconfiguration and bandwidth enhancement [2].

Dual-band wideband MPAs with bandwidth extensions up to 2.45/5 GHz are suitable for WLAN applications [3]. These antennas enable frequency or bandwidth reconfiguration through design flexibility, such as incorporating two cuts at the antenna's edges. Recently, MPA antennas designed for 5G applications, featuring multiple-input multiple-output (MIMO) systems, have been reconfigurable up to 32-46 GHz, offering higher data rates and improved gain [4]. MPAs can also be frequency-reconfigured [5] by adjusting parameters of the patch antenna, enabling operation up to 60 GHz. The flexibility of MPAs in terms of frequency reconfigurability and gain enhancement is achieved through design changes such as modifying the shape of the patch antenna or using switching techniques.

For 5G applications, such as IoT at 28 GHz, [6] reconfigurable MPAs have been designed using finite integration and finite element method-based simulations. Additionally, multiple-cut MPAs with metamaterial substrates provide frequency reconfigurability for 5G applications in the 26.5 to 40 GHz range. Some MPAs achieve wideband frequency reconfigurability for 5G applications (24 to 29.5 GHz) [7] by modifying the shape of the patches into eleven different configurations [8]. Patch antennas can also achieve radiation, polarization, and hybrid reconfigurability. For example, polarization reconfigurability can be achieved using graphene substrates [9-15]. This article focuses specifically on frequency reconfigurability and is organized into five sections: I. Introduction, II. Patch antenna design, III. Proposed patch antenna parameters and its measurements, IV. Results and discussion V. Conclusion.

II. PROPOSED PATCH ANTENNA DESIGN AND ITS VARIATIONS

(a) Basic Patch Antenna: This configuration features a square patch with dimensions $L = W = 26$ mm $l_t = 32$ mm and $w_t = 2.6$ mm)

(b) Improved Patch Antenna with Asymmetrical Cuts: This design introduces asymmetrical cuts at the left and right edges of the patch to modify the current distribution and enhance bandwidth.

(c) Improved Patch Antenna with Shunt Inductor: A shunt inductor is placed 30 mm above the feed point to adjust the impedance characteristics and improve matching.

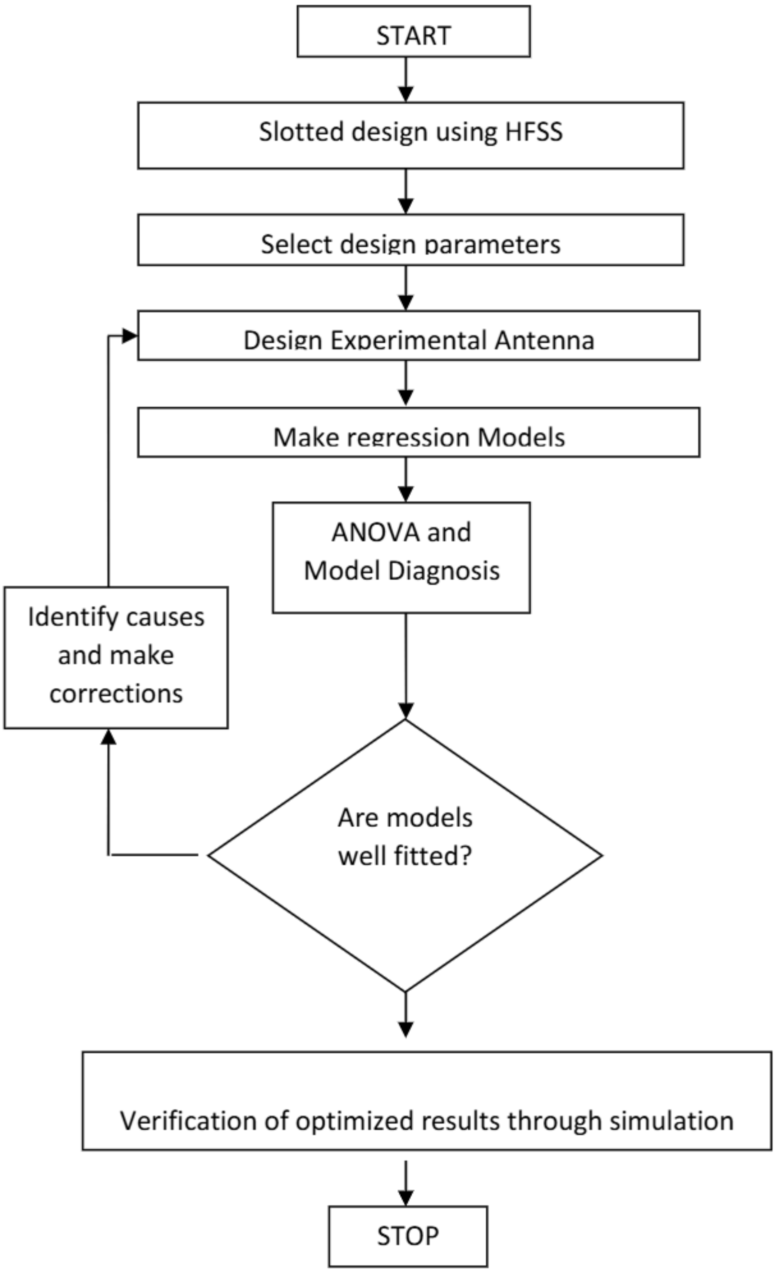
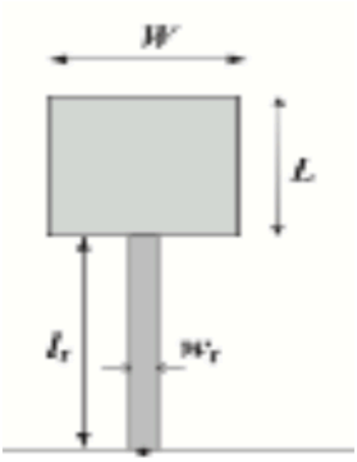


Figure 1 Illustrates an optimization algorithm designed to ensure efficient energy utilization in Internet of Things (IoT) systems, as detailed in reference [11].

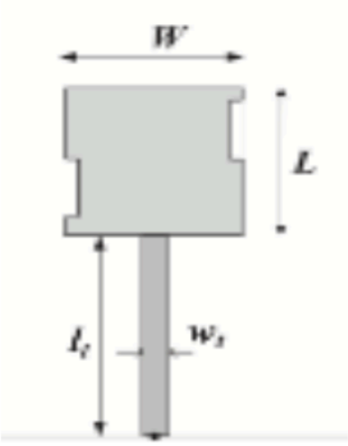
(d) Improved Patch Antenna with Microstrip Resonators: This configuration incorporates microstrip resonators to create additional resonant modes, thereby broadening the operational bandwidth.

(e) Improved Patch Antenna with Microstrip Symmetrical Resonators: Symmetrical microstrip resonators are added to the design to achieve balanced radiation patterns and further enhance bandwidth.

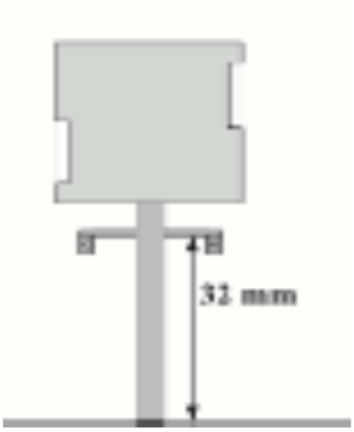
(f) Improved Patch Antenna with Parasitic Patch and Slot: This design includes a parasitic patch and a slot to introduce additional resonant frequencies, improving the antenna's performance across multiple bands.



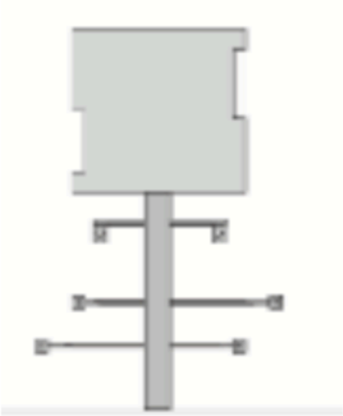
(a)



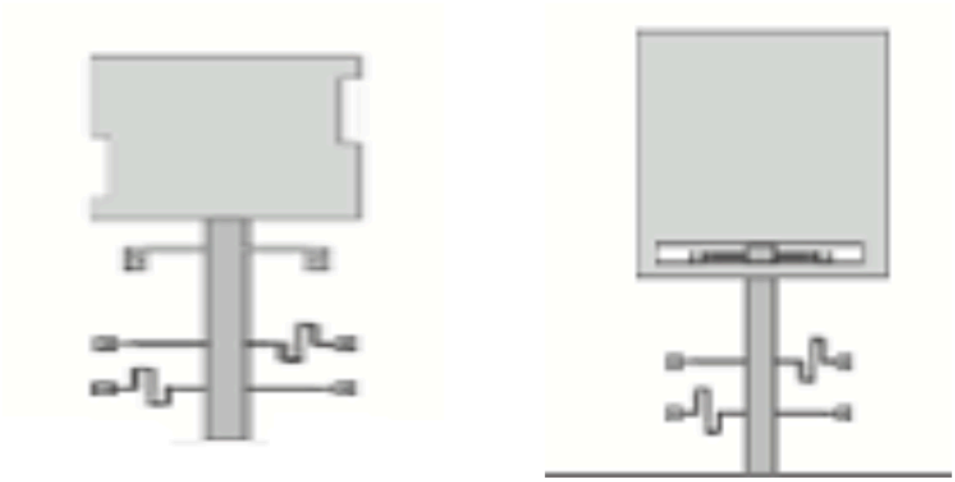
(b)



(c)



(d)



(e) (f)

Figure 2 Presents various configurations of the proposed patch antenna, each designed to enhance performance through specific modifications:

Each modification aims to optimize the antenna's performance for specific applications, such as enhancing bandwidth, improving impedance matching, or achieving desired radiation patterns.

In section II, the proposed patch antenna structure having different shapes starts with the fundamental patch antenna and improves the properties of antenna with the asymmetrical cut at left and right edges. Also, there is an improvement in patch antenna with shunt inductor at 32 mm above from feed point, microstrip resonators, and parasitic patch and slot. In section III various patch antenna parameters are shown in Table 1, Table 2.

III. PROPOSED PATCH ANTENNA PARAMETERS AND ITS VARIOUS MEASUREMENTS

Table 1. Simulated and measured gain of a basic patch antenna

Frequency (GHz)	Simulated Gain (dBi)	Measured Gain (dBi)
2.4	-0.44	-0.38
2.45	-0.15	-0.13
2.5	-1.85	-1.85
5	-9.66	-9.33
5.2	1.09	1.12
5.4	-0.24	-0.19
5.6	-0.16	-0.13
5.8	0.11	0.13
6.0	-1.71	-1.65

Table 2. Average Simulated and measured gain of enhanced patch antenna

Frequency (GHz)	Simulated gain (dBi)	Measured gain (dBi)	Measured S_{11} (dBi)	Simulated S_{11} (dBi)
2.4	1.72	1.05	-3.69	-3.29
2.45	3.48	2.88	-7.01	-5.59

2.5	4.2	4.55	-25.89	-14.19
5	-9.88	-1.08	-2.34	-2.30
5.2	-5.147	1.6	-5.82	-8.77
5.4	1.8	3.85	-15.49	-15.33
5.6	3.22	4.5	-21.87	-24.74
5.8	5.01	5.12	-18.8	-15.77
6.0	2.05	2.93	-4.91	-5.80

IV. RESULTS AND DISCUSSIONS

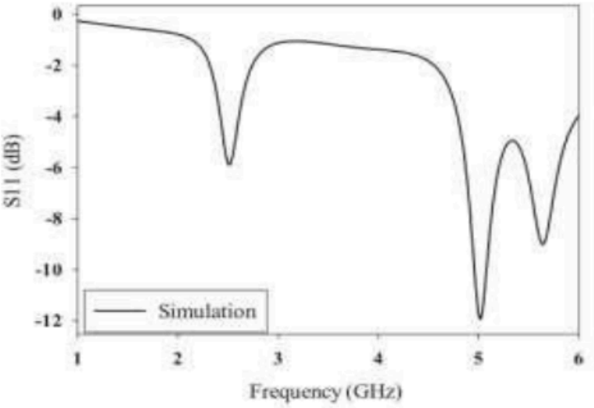


Figure 3. (a) Input reflection coefficient S_{11} Simulation of a basic patch antenna

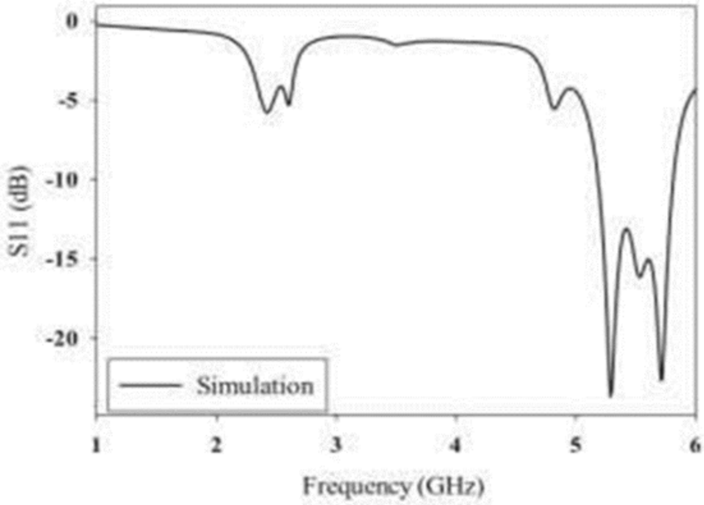


Figure 3. (b) Input reflection coefficient S_{11} Simulation of improved patch antenna with the asymmetrical cut at left and right edges

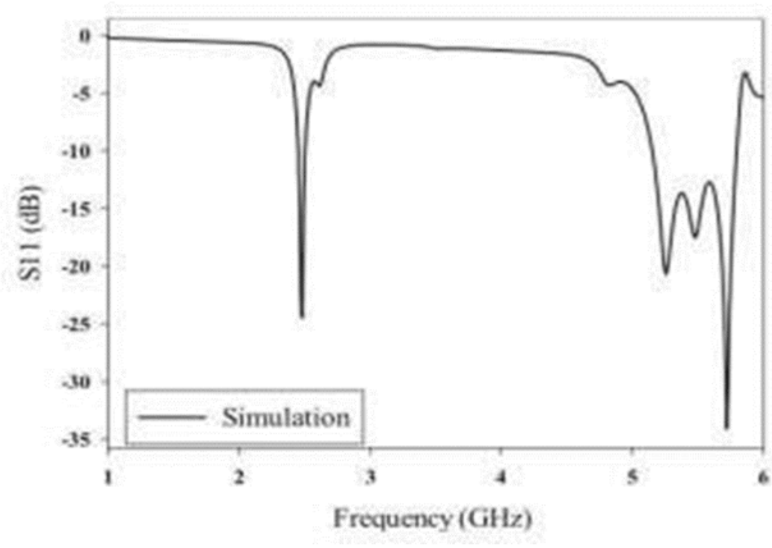


Figure. 3. (c) Input reflection coefficient S_{11} Simulation of improved patch antenna with shunt inductor at 32mm above from feed point

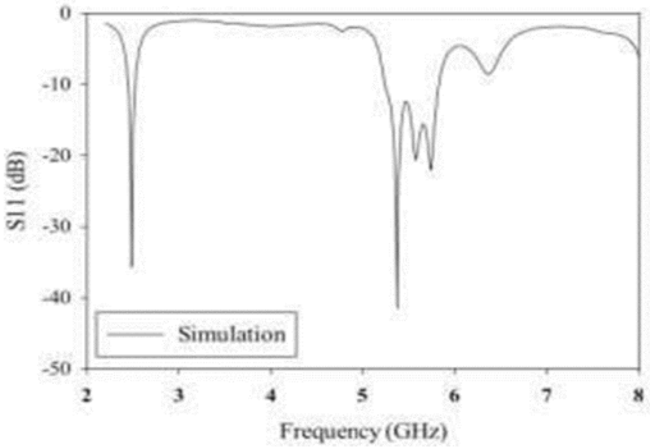


Figure. 3. (d) Input reflection coefficient S_{11} Simulation of improved patch antenna with microstrip resonators

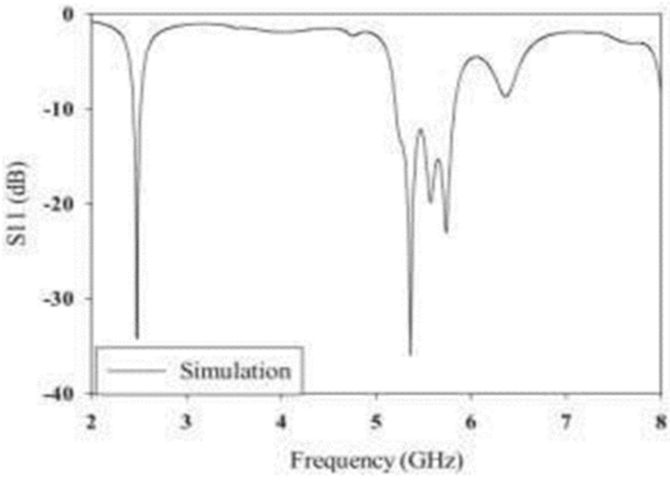


Figure. 3. (e) Input reflection coefficient S_{11} Simulation of improved patch antenna with microstrip symmetrical resonators

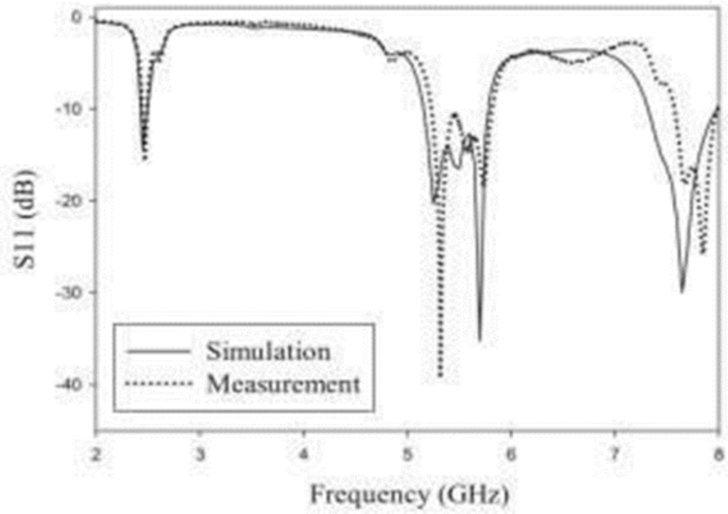


Figure 3. (f) Input reflection coefficient S11 Simulation and measured of improved patch antenna without harmonic suppressions

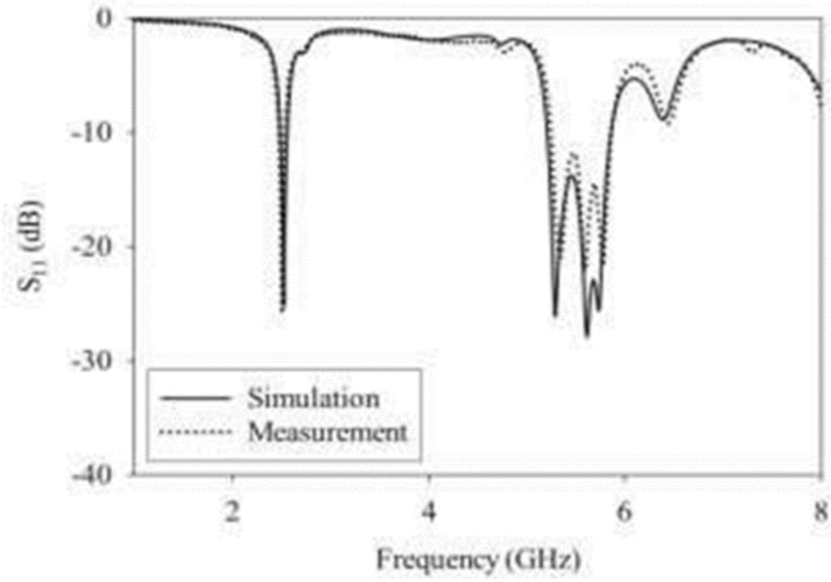


Figure. 3. (g) Input reflection coefficient S_{11} Simulation and measured of improved patch antenna with harmonic suppressions

The antenna structure diagrams present the input reflection coefficient S_{11} for both the basic patch antenna and the improved patch antenna, incorporating cuts at the left and right edges.

Input reflection coefficient S_{11} for the basic patch antenna and improved patch antenna for the cuts-in patch at the left and right edges are presented in the antenna structure diagrams. The cut in the patch alters its size, enabling frequency reconfigurability but also complicating the antenna geometry. Variations in patch size primarily impact the reflection coefficient and gain. Adding a shunt inductor 32 nm above the feed point enhances the peak gain at 2.45 GHz and improves the antenna's overall gain.

In the next improved patch antenna with a microstrip resonator, the introduction of resonators increases the antenna gain from 5.01 dB to 5.12 dB at a frequency of 5.8 GHz. A patch antenna with resonators can shift the resonant frequency, making the antenna reconfigurable. The improved patch antenna with symmetrical resonators, as shown in Figure 3(e), also enables frequency reconfigurability. The final improved patch antenna, shown in Figure 3(g), incorporates a parasitic patch and parasitic slot for frequency reconfigurability. In total, six types of patch antennas are considered in this study, all designed for frequency reconfigurability within the 2.4 to 6 GHz range.

The fundamental parameters of a patch antenna, such as the operating frequency (f_o), substrate thickness (t), and relative permittivity, plays a crucial role in its performance. A larger bandwidth, improved radiation pattern, and higher efficiency depend on the appropriate selection of the substrate, particularly its low permittivity and thickness [11-13]. The simulation, patch antenna design, and reflection coefficient analysis in this study are inspired by previous literature [3]. An algorithm for IoT applications, as shown in Figure 1, is implemented for determining the optimal wireless sensor network of the proposed antenna. Table 3 depicts the comparison of proposed antenna parameters with the previous patch antennas parameters.

Table 3. Comparison of the proposed work with previous works

Parameters	**Proposed work**	**Reference [3]**	**Reference [9]**	**Reference [10]**
Antenna type Frequency (GHz)	Operating range is 2.45 to 5 GHz for dual bands	Operating range is 2.45 to 5 GHz for dual bands	Operating range is 2.45 to 5 GHz for single band	Operating range is 2.45 to 5 GHz for dual bands
S_{11} at 4.9	-1.9 dB	-2.0 dB	-3.0 dB	-2.0 dB
S_{11} at 5.2	-5.8 dB	-5.9 dB	NA	-5.9 dB
Peak gain at 2.45	3.55 dB	3.48 dB	NA	-2.08 dB
Peak gain at 5.8	5.0 dB	5.03 dB	NA	5.03 dB
Gain enrichment	Yes	No	No	No

V. CONCLUSION

The proposed microstrip patch antenna is designed and simulated with various shapes and sizes, incorporating stubs and resonators to achieve frequency reconfigurability up to 60 GHz, within the millimeter-wave range. The comparison and validation of the proposed microstrip patch antenna against existing designs in the literature are presented through graphical results. The S11 simulation results for different configurations, including the basic patch antenna, improved patch antenna, patch antenna with a shunt inductor placed 32 mm above the feed point, patch antenna with microstrip resonators, patch antenna with symmetrical microstrip resonators, patch antenna without harmonic suppression, and patch antenna with harmonic suppression, are analyzed and compared in tables and graphs.

REFERENCES

[1] D.K. Harysandi, R. Oktaviani, L. Meylani, M. Vonnisa, H. Hashiguchi, T. Shimomai, L. Luini, S. Nugroho, N.A.M. Aris, et al., International telecommunication union-radio communication sector (ITU-R) p. 837-6 and p. 837-7 performance to estimate Indonesian rainfall, Telkomnika, vol.18, no.5, pp. 2292–2303, 2020.

[2] Saini, A., Thakur, A. & Thakur, P. “Miniaturization and Bandwidth Enhancement of a Microstrip Patch Antenna Using Magneto-Dielectric Materials for Proximity Fuze Application”, J. Electron. Mater. vol.46, pp. 1902-1907, 2017.

[3] F. C. Acıkaya, and Bahadır S. Yıldırım. “A dual-band microstrip patch antenna for 2.45/5-GHz WLAN applications. “AEU-International Journal of Electronics and Communications”, 141, 153957, 2021.

[4] Yadav, J., Sharma, S., & Arora, M. “A paper on microstrip patch antenna for 5G applications”, Materials Today: Proceedings, 66, 3430-3437, 2022.

[5] Shereen, M. Kamran, M. I. Khattak, and Jamel Nebhen. "A review of achieving frequency reconfiguration through switching in microstrip patch antennas for future 5G applications", Alexandria Engineering Journal 61, no. 1, pp. 29-40, 2022.

[6] Ezzulddin, Saman Khabbat, Sattar Othman Hasan, and Mudhaffer Mustafa Ameen. "Microstrip patch antenna design, simulation and fabrication for 5G applications", Simulation Modelling Practice and Theory, vol. 116, 102497, 2022.

[7] Singh, Dhananjay, Surya Deo Choudhary, and B. Mohapatra. "Design of microstrip patch antenna for Ka-band (26.5-40 GHz) applications", Materials Today: Proceedings, vol. 45 pp. 2828-2832, 2021.

[8] Maity, Smarajit, Tapas Tewary, Surajit Mukherjee, Avisankar Roy, P. P. Sarkar, and Sunandan Bhunia. "Super wideband high gain hybrid microstrip patch antenna", AEU-International Journal of Electronics and Communications, vol. 153, 154264, 2022.

[9] Batista FF, De Souza LL, Fernandes da Silva JP, Silva HPF, De Oliveira MA, Fontgalland G. "Harmonic suppression in microstrip patch antenna using spur-line filters", SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC) pp. 1-5, 2017.

[10] S. K. V. Das and T. Shanmuganantham, "Design of multiband microstrip patch antenna for IOT applications", IEEE International Conference on Circuits and Systems, Thiruvananthapuram, India, pp. 87-92, 2017. doi: 10.1109/ICCS1.2017.8325968.

[11] Hsieh, Chin-Yuan, Cheng-Hsun Wu, and Tzyh-Ghuang Ma. "A compact dual-band filtering patch antenna using step impedance resonators", IEEE Antennas and wireless propagation letters vol. 14 pp. 1056-1059, 2015.

[12] Amar Sharma, Puneet Khanna, Arun Kumar, "A CPW-Fed Structure Shaped Substrate Wideband Microstrip Antenna for Wireless Applications", Journal of Microwaves, Optoelectronics and Electromagnetic Applications, Vol. 16, No. 2, pp. 419-433, June 2017.

[13] Kiani, Narges, Farzad Tavakkol Hamedani, and Pejman Rezaei. "Reconfigurable graphene-gold-based microstrip patch antenna: RHCP to LHCP", Micro and Nanostructures, 207509, 2023.

[14] Kiani, N., Hamedani, F.T. and Rezaei, P., "Polarization controlling plan in graphene-based reconfigurable microstrip patch antenna", Optik, 244, p.167595, 2021.

[15] Kiani, Narges, Farzad Tavakkol Hamedani, and Pejman Rezaei "Realization of polarization adjusting in reconfigurable graphene-based microstrip antenna by adding leaf-shaped patch", Micro and Nanostructures, vol. 168, 207322, 2022.

[16] Liliana Anchidin, Alexandru Lavric, Partemie-Marian Mutescu, Adrian I. Petrariu and Valentin Popa "The Design and Development of a Microstrip Antenna for Internet of Things Applications", Sensors, vol. 23, issue 03, pp. 1-14, 2023. https://doi.org/10.3390/ s23031062

[17] M. S. Rana, O. Islam, S. A. Shikha and M. Faisal, "IoT Application using a Rectangular 2.4 GHz Microstrip Patch Antenna", International Conference for Advancement in Technology (ICONAT), Goa, India, pp. 1-4, 2023.

[18] Punith S, Praveen Kumar SK, Abhinandan Ajit Jugale, Mohammed Riyaz Ahmed, "A Novel Multiband Microstrip Patch Antenna for 5G Communications", Procedia Computer Science, vol. 171, pp. 2080-2086, ISSN 1877-0509, 2020, doi: 10.1016/j.procs.2020.04.224.

[19] Muhammad Fitra Zambak. Samir Salem Al-Bawri, Hamsakutty Vettikalladi, Ali M. Albishi, Muzammil Jusoh and Mohamed Himdi, Ali Hanafiah Rambe, "A compact 2.4 GHz L-Shaped Microstrip Patch Antenna for ISM-Band Internet of Things (IoT) Applications", Electronics vol. 12, issue 09, 2023. https://doi.org/ 10.3390/electronics12092149