

Quad band Frequency Tunable Patch Antenna for Different Wireless Applications

Vijayluxmi¹, Prem Pal Singh², Sudhir Kumar Sharma³, Chetan Singh Meena⁴

¹Assistant Professor, Department of Electronics & Communication Engineering, RPIIT, Bastara, Haryana, India.

²Assistant Professor, Department of Electronics & Communication Engineering, Parul University, Vadodara, Gujarat, India.

³Head, Department of Electronics & Communication Engineering, Jaipur National University, Jaipur, India

⁴Scientist, Defence Research and Development Organization, New Delhi, India

Corresponding authors, email address: vijayluxmimeena@gmail.com, prempal.singh38023@paruluniversity.ac.in and Sudhir.732000@gmail.com

Article History:

Received: 12-01-2025

Revised: 15-02-2025

Accepted: 01-03-2025

Abstract: This paper describes the design and development of a 14mmx23mm tiny quad-band reconfigurable antenna. Four different bands are covered by the antenna's efficient operation design: 4.10 GHz, 3.75 GHz, 5.60 GHz, and 4.60 GHz. Through simulation the antenna's performance characteristics—such as radiation pattern, gain, and impedance matching are thoroughly examined. Innovative tuning techniques using the BAR50-02V PIN diode enable the antenna to be reconfigured, providing reliable performance in all designated bands. This antenna can be integrated into modern wireless communication systems that require flexible frequency operation due to its compact size and multi-band flexibility.

Keywords: Reconfigurable antenna, PIN diode, Cognitive radio, Tunable antenna, Multiband antenna.

1. Introduction

The potential to vary features like radiation pattern and frequency spectrum makes reconfigurable antennas important for present communication organization. They make it promising to operate flexible across a range of frequency bands, which improve the use of spectrum and encourage compatibility between system types [1] Reconfigurable antennas improve performance parameters including impedance matching, gain, and efficiency by dynamically changing their configuration. This enables dependable signal transmission under a range of propagation situations. Because of their flexibility, which combines several functions into a single antenna, they support valuable use of existing space and minimize the equipment costs. Reconfigurable antennas also enhance communication confidentiality and reduce interference, which both improve security. In software-defined radio and cognitive radio applications, they play a critical role in enabling dynamic spectrum access and standardization of communication protocols. Overall, reconfigurable antennas provide features that are future-proof, flexible, and efficient [2]. The antenna is 120x120 mm in size and shows good performance with -28 dB return loss at 0.98 GHz and -14 dB at 1.84 GHz. It uses fractal designs to work effectively in two frequency bands [5]. A new dual band antenna configuration with a compact dimension of 55x50mm², which has a 0.882dB and 2.108dB gain, respectively, at 4.2 GHz and 5.6 GHz frequency featuring T-shaped and small rectangular gaps in the ground plane [3]. The aim of this

new design is enhancing each band's bandwidth and resonant frequencies for both WiMAX and IMT frequency bands. CST MW was used in the design and optimization of this quasi-omnidirectional antenna. Triband 53.37x75.20 sized modified fractal slot antenna with CPW feeding is tailored for achieving multiple resonant frequencies 1.8 GHz, 3.5 GHz and 5.2 GHz with Return loss $S(1,1)$ dB-17.2, -22.5, -35.5 suitable for DCS1800, WiMAX, IMT-Advanced, and 4G mobile communication systems. Its design allows for a bidirectional radiation pattern across the specified frequency bands, making it a versatile choice for digital communication applications [4].

In [6] introduces a compact, frequency-reconfigurable printed patch antenna measuring 35x47, utilizes a microstrip feed connected to a circular radiating element divided into three patches. These patches incorporate silicon PIN diodes as switches for achieving frequency reconfigurability. The antenna includes slots of various shapes etched into the patches to cover multiple WLAN frequency bands (2.4 GHz, 3.6 GHz, 4.9 GHz, 5.1 GHz, and 5.9 GHz). A bias tee is designed to supply DC bias to the PIN diodes, essential for their function. An experimental result from a fabricated prototype and simulated data reveals good agreement, confirming the antenna's effectiveness in achieving reconfigurability across the specific frequency bands. [7] While optical switches are simple to integrate, their placement in the antenna's plane may compromise the radiating structure's efficiency. It does not include the DC bias into the antenna or cover the lower WLAN bands. It is 50x46 in dimension and covers the frequencies 3.6 GHz, 4.9 GHz, and 5.1 GHz. Its expense and complexity are a drawback.

respectively. But has a backdrop as the frequency range increases from 1.8 GHz to 5.4GHz, its radiation efficiency degraded from 73% to 59% simultaneously. A small size 22x26mm² reconfigurable patch antenna for wireless communication applications designed and can be tuned in four different frequencies 3.6GHz, 4.1GHz, 6.6GHz and 8.8GHz with 1.14dBi, 0.58dBi, 2.46dBi, 2.95dBi gains respectively in [1].

2. Antenna Design Methodology

2.1. Geometry of the Antenna

The proposed antenna has two-layer geometry. The top layer is a patch made up of a rectangular radiator fed by a 50 Ω microstrip line of resistance and featuring a slotted construction. With dimensions of 14x23 mm² and a dielectric constant of 4.4, the antenna was simulated and fabricated on FR-4 substrate material, which has superior insulating qualities and can increase antenna efficiency. The ground plane was also altered to control the bandwidth. Two PIN diodes in total are integrated for the purpose of reconfiguration. PIN diodes are designed using lumped elements during the design simulation.

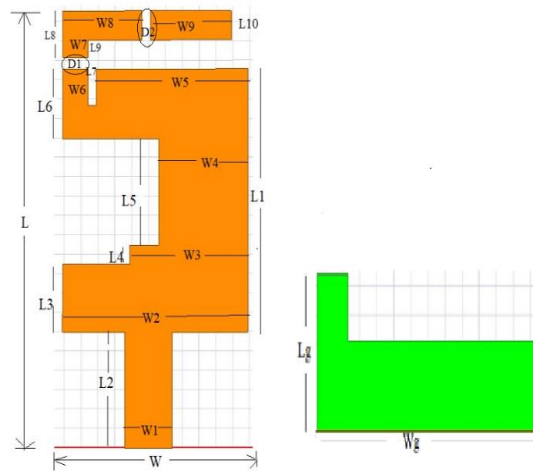


Figure 1. Geometry of the Antenna

Dimensions of final design summarized in table

Table 1: Optimized parameters of the suggested antenna

Parameter	Value (mm)	Parameter	Value (mm)
L	23	W	14
L ₁	13.6	W ₁	2.8
L ₂	6	W _g	13
L ₄	0.9	L _g	5.4
L ₅	5.5	L ₁₀	1.5
L ₆	3.6	W ₂	10.8
L ₈	2.4	W ₃	7
L ₉	0.9	W ₄	5.3
W ₆	1.3	W ₅	9
W ₈	4.7	W ₉	4.8

Equivalent circuit of the used PIN diode and parameter values BAR50-02V is shown in figure.2 and table 2 respectively.

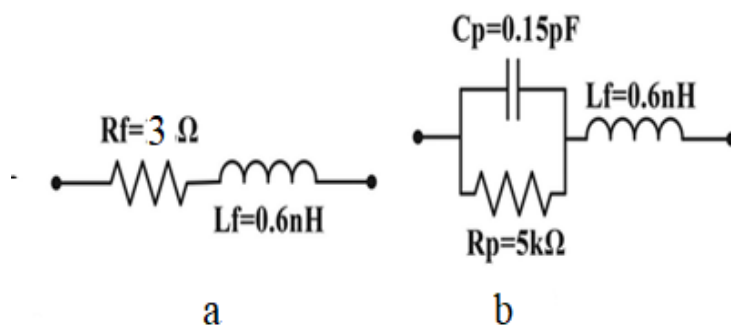


Figure 2. PIN diode equivalent diagrams (a) ON state (b) OFF state

Table 2: Element values of BAR50-02V

PIN Diode Model	State	L ₁	C _T	R _P	R _s
BAR50-02V	OFF		0.15pF	3KΩ	
	ON	0.6nH			3Ω

DIODE TEST CASE ANALYSIS

Case 1: Diode 1 is OFF and Diode 2 is OFF

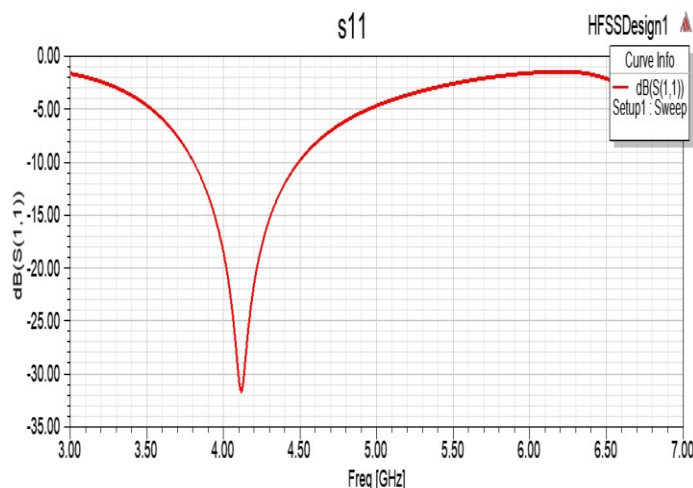


Figure 3. Return Loss v/s Frequency

The graph predicts that frequency 4.10GHz is obtained whenever Diode 1 and Diode 2 are in OFF condition.

Case 2: Diode 1 is OFF and Diode 2 is ON

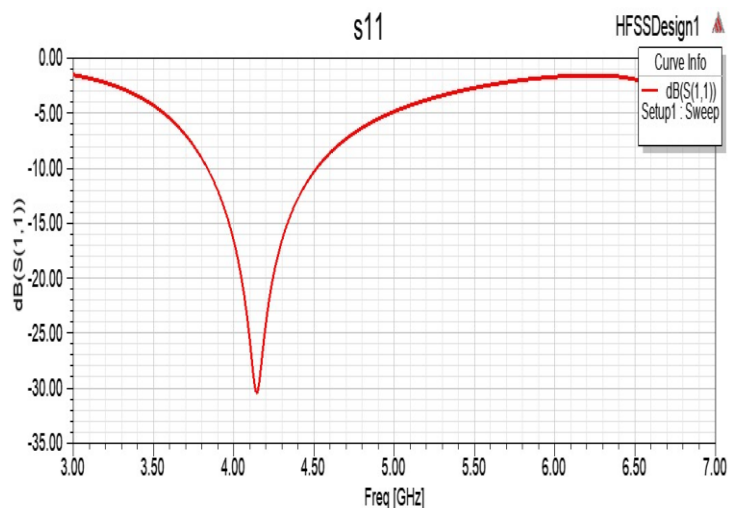


Figure 4. Return Loss v/s Frequency

The frequency of 4.13GHz is obtained which can be used as a WLAN channel is obtained in 01 condition.

Case 3: Diode 1 is ON and Diode 2 is OFF

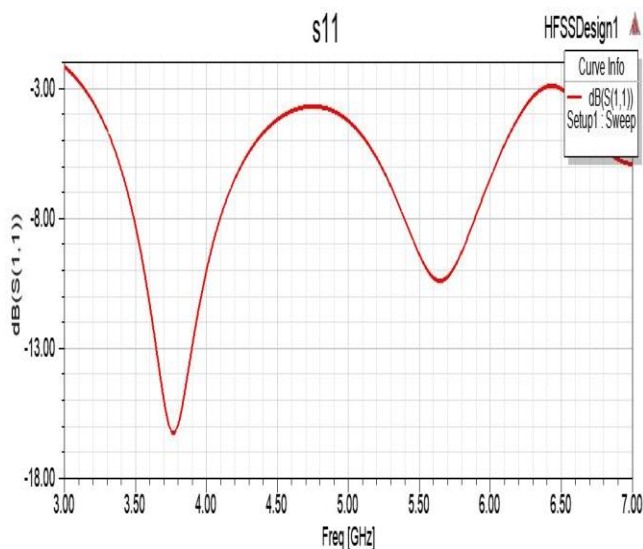


Figure 5. Return loss v/s Frequency

The frequencies are of 3.75GHz and 5.60 GHz is obtained when Diode 1 is ON and Diode 2 is OFF. Both 3.75 GHz and 5.60 GHz are important for modern wireless communication, including 5G, wi-fi, and radar systems. Their selection depends on the balance needed between range, data rate and interference resistance.

Case 4: Diode 1 is ON and Diode 2 is ON

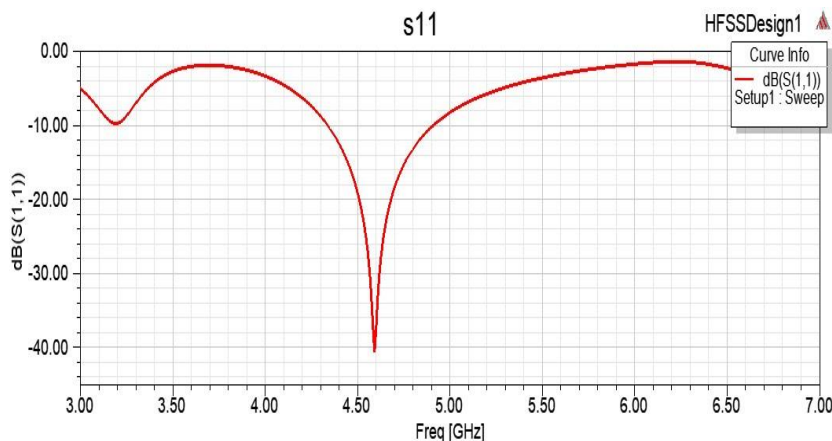


Figure 6. Return loss v/s Frequency

The above graph is plotted between Freq v/s. S11. Frequency 4.60 GHz obtained in this condition.

3. Results and Discussion.

Table 3: Resonating Frequency and Gain for Different combinations of Diode

Case	Configuration of Diodes		Resonating Frequency (GHz) (Simulated)	S11	Gain (dBi)
	D ₁	D ₂			
Case 1	0	0	4.10	-31.99	1.2
Case 2	0	1	4.15	-30.99	1.2
Case 3	1	0	3.75,5.60	-16.20	1.8
Case 4	1	1	4.60	-41.41	1.6

The table shows how different diode configuration affect the resonating frequency and gain of a reconfigurable antenna. In case 1 (D₁=0, D₂=0) and case 2 (D₁=0, D₂=1), the antenna resonates at around 4.10-4.15 GHz, suitable for mid-band 5G, radar, and satellite communication.

Case 3 (D₁=1, D₂=0) gives dual frequencies of 3.75GHz and 5.60 GHz, which are useful for Wi-Fi applications. This case also shows the highest gain of 1.8 dBi, making it ideal for strong, efficient signal transmission.

Case 4 (D₁=1, D₂= 1) resonates at 4.60GHz, supporting advanced 5G and military communication systems. It has the best S11 value, indicating excellent impedance matching and low reflection.

4. Radiation and Gain Pattern

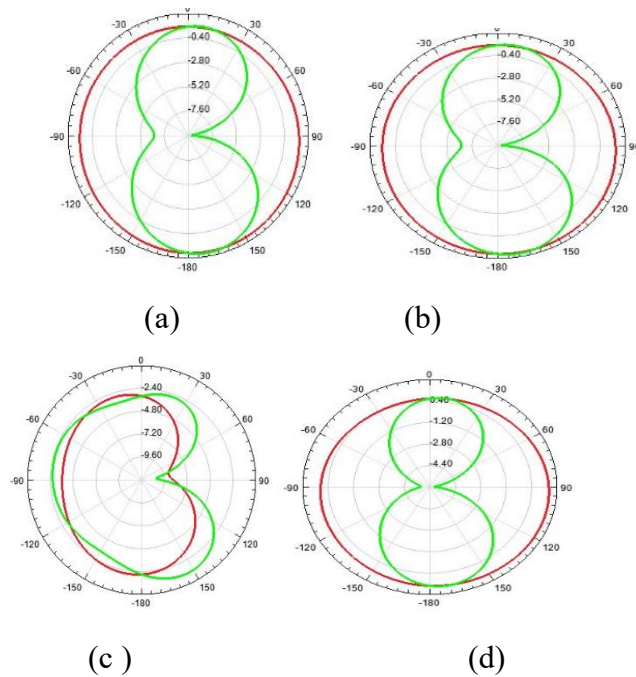


Figure 7. Radiation Pattern of Proposed Antenna for Diodes configuration (a) 00 (b) 01 (c) 10 (d) 11

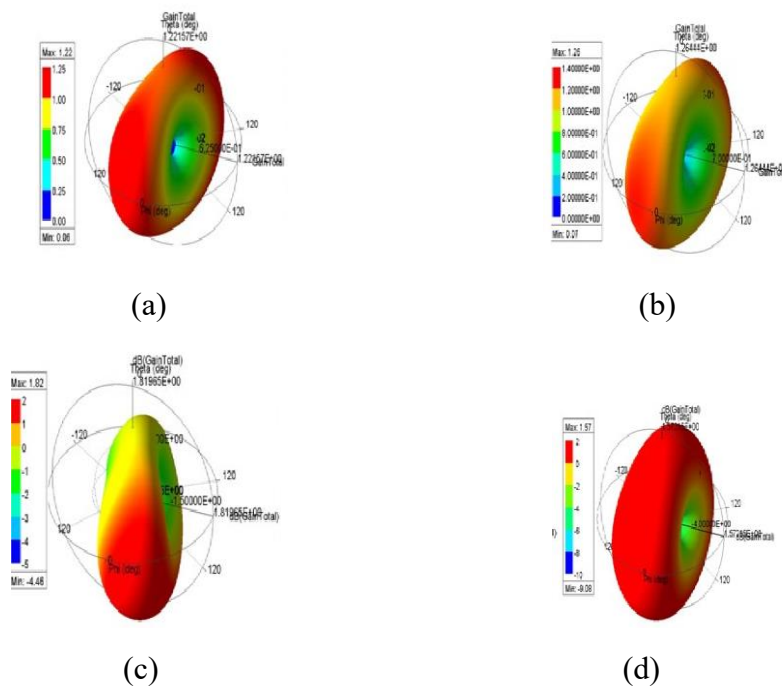


Figure 8. Gain plot of Antenna for Diodes configuration (a) 00 (b) 01 (c) 10 (d) 11

Table 4: Comparative Analysis

Paper	Size (mm ²)	Frequencies (GHz)	Reconfiguration Technique	Complexity
3	55x50	4.2,5.6	PIN	Simple
4	53.37x75.20	1.8,3.5,5.2	PIN	Moderate
5	120x120	0.98,1.84	PIN	Large
6	35 x 47	2.4,3.6, 4.9, 5.1, 5.9	PIN	Moderate
7	50x46	3.6,4.9,5.1	Physical Rotation Optical Switching	Complex and Costly
Proposed work	14x23	3.62, 4.02, 4.59 , 5.19	PIN	Simple

5. Conclusion

In this work, an extremely compact (14 mm × 23 mm) quad-band reconfigurable antenna that can function effectively in four different frequency bands—4.10 GHz, 3.75 GHz, 5.60 GHz, and 4.60 GHz—is designed and developed. Through modeling, all of the antenna's performance parameters—such as radiation pattern, gain, and impedance matching are carefully assessed. Innovative tuning methods that make use of the BAR50-02V PIN diode are essential to its adaptability since they allow for a smooth reconfiguration for dependable performance in all specified bands. The antenna's seamless integration into contemporary wireless communication systems that demand flexible frequency operation is made possible by this characteristic. Applications for wireless communication, radar systems, satellite communication, medical equipment, scientific instruments, industrial automation, and Internet of Things deployments are among the many that are served by the antenna's wide range of frequency bands.

Acknowledgements

I would like to thank Rajasthan University to provide testing facility and Jaipur National University to conduct research on this work.

References

- [1] Dr. B. Baranidharan, Anu Maria Joykutty, Cognitive Radio Networks: Recent Advances in Spectrum Sensing Techniques and Security Proceedings of the International Conference on Smart Electronics and Communication (ICOSEC 2020) IEEE Xplore Part Number: CFP20V90-ART; ISBN: 978-1-7281-5461-9
- [2] T.Khan, M.Rahman, A. Akram, Y.Amin, and H. Tenhunen (2019) A Low-cost CPW-Fed Multiband Frequency Reconfigurable Antenna for Wireless Applications, Multidisciplinary Digital Publishing Institute, Electronics, vol. 8, 1-17, <https://doi.org/10.3390/electronics8080900>
- [3] Zahraoui, Issam & Ahmed, Errkik & ZBITOU, JAMAL & Tajmouati, Abdelali & Mediavilla, Angel. (2016). A novel design of a fractal antenna for IMT and WiMAX applications.

INTERNATIONAL JOURNAL OF MICROWAVE AND OPTICAL TECHNOLOGY, 428
VOL.11, NO.6, NOVEMBER 2016. 11. 428-434.

- [4] C. Mahatthanajatuphat and P. Akkaraekthalin, "A Bidirectional multiband Antenna With Modified Fractal Slot Fed By CPW", *Progress In Electromagnetics Research*, pp. 59-72, Jun. 2009.
- [5] D. C. Chang, B. H. Zeng and J. C. Liu, "CPW-Fed Circular Fractal Slot Antenna Design for Dual band Applications", *IEEE Transactions on Antennas and Propagation*, Vol. 56, pp. 3630-636, Dec. 2008
- [6] Chattha, Hassan Tariq et al. "Frequency reconfigurable patch antenna with bias tee for wireless LAN applications." *IET Microwaves, Antennas & Propagation* (2018): n. pag
- [7] Tawk, Y., Bkassiny, M., Howayek, G.E., Jayaweera, S.K., Avery, K., Christodoulou, C.G.: 'Reconfigurable front-end antennas for cognitive radio applications', *IET Microw., Antennas Propag.*, 2010, 5, (08), pp. 985-992.
- [8] Vijayluxmi Meena, P. P. Singh, S. K. Sharma, and Ravi Gupta, "A Hepta-band Frequency Tunable Patch Antenna for Cognitive Radio Applications," *Journal of Nano And Physics* , Vol. 12, pp. 149-162, 2024
- [9] Vijayluxmi Meena, P. P. Singh, S. K. Sharma, and Ravi Gupta, "An Efficient positioned Printed Aerial for UWB Applications," *Multidisciplinary Journal for Applied Research in Engineering and Technology*, Vol. III, Issue 7, JULY-2023, pp. 16-20, 2023
- [10] Prem P. Singh and Sudhir K. Sharma (2021). Design and Fabrication of a Triple Band Microstrip Antenna for WLAN, Satellite TV and Radar Applications, *Progress In Electromagnetics Research C*, Vol. 117, 277–289, <https://doi.org/10.2528/PIERC21121303>
- [11] S. W. Cheung, Y. F. Cao and T. I. Yuk. (2015, 13-17 April). *Compact Frequency Reconfigurable Slot Antenna with Continuous Tuning Range for Cognitive Radios [EuCAP 2015]*. The 9th European Conference on Antennas and Propagation Lisbon, Portugal, 1-4
- [12] Ramesh Garg, Prakash bhartiya, Inder bahl and Apisak ittipiboon, "Microstrip Antenna Design Handbook," Artech House, Artech House, Inc., Norwood MA, 2001
- [13] K.C Gupta, Ramesh Garg, Inder Bhal and Prakash Bhartia, "Microstrip lines and slot lines," 2nd Edition, Artech House, Artech House, Inc., Norwood MA, 1996
- [14] R.N. Awale and V.R. Borkar, "Frequency Reconfigurable Microstrip Patch Antenna using PIN Diodes", *International Journal of Engineering Research & Technology (IJERT)*, Vol. 3, Issue 4, 2014.
- [15] N. Kumar, "Reconfigurable Antennas: Design and Applications", *IEEE Antenna and Propagation Magazine*, 2020. DOI: 10.1109/MAP.2020.2973551