International Journal of Reconfigurable and Embedded Systems (IJRES)
Vol. 14, No. 2, July 2025, pp. 328~338
ISSN: 2089-4864, DOI: 10.11591/ijres.v14.i2.pp328-338

Design and development of multiband multi-mode frequency reconfigurable CPW-fed antenna for 5G wireless communication

Annu Tiwari[1], Muhammed Yasir Yilmaz[2], Gaurav Kumar Soni[1], Dinesh Yadav[1]
[1]Department of Electronics and Communication Engineering, Manipal University Jaipur, Jaipur, India
[2]Department of Electronics and Communication Engineering, Istanbul Technical University, Istanbul, Turkey

Article Info

Article history:

Received Nov 26, 2024
Revised Apr 8, 2025
Accepted Jun 10, 2025

Keywords:

5G wireless communication
Coplanar waveguide fed
Frequency reconfigurable
Multiband
Multimode
PIN diode

ABSTRACT

This research develops, simulates, fabricates and measured a coplanar waveguide (CPW)-fed multiband multi-mode frequency reconfigurable antenna for 5G wireless communication. The antenna is design on Rogers RT5880 substrate with a dielectric constant of 2.2, a thickness of 0.508 mm, and a loss tangent (tanδ) of 0.0009 and the dimension is 30×28×0.508 mm^3. The presented antenna has shown good impedance matching with reflection coefficients ranging from -14.82 to -50.36 dB at different frequencies between 6 GHz to 24 GHz. The presented frequency reconfigurable antenna design includes four PIN diodes, resistors, and inductors, enabling 16 different configurations. The simulated outcomes showed varied S-parameter values and gains, demonstrating the antenna's flexibility. Measurements were taken using vector network analyzer (VNA) and anechoic chamber to assess reflection coefficient ($|S_{11}|$) and gain, confirming the antenna's performance. The antenna's ability to reconfigure dynamically without losing signal integrity makes it suitable for 5G wireless applications. It meets and exceeds the requirements for multiband operation, validated by comprehensive simulations and measurements, showing its potential for wide use.

Corresponding Author:

Dinesh Yadav
Department of Electronics and Communication Engineering, Manipal University Jaipur
Jaipur, Rajasthan, India
Email: dinesh.yadav@jaipur.manipal.edu

1. INTRODUCTION

The rapid progress in wireless communication technology has greatly increased the need for flexible and adaptable antenna systems [1], [2]. Reconfigurable antennas have become a promising solution to meet the changing demands of modern wireless communication systems, offering flexibility and better performance in various applications [3], [4]. Reconfigurable antennas are designed to change their operating characteristics, such as frequency, radiation pattern, polarization, and impedance. This can be done through mechanical adjustments, electrical tuning, and material changes [5]. The ability to change these parameters in real-time allows a single antenna to work efficiently under different conditions and requirements, optimizing performance and resource use [6]. One major benefit of reconfigurable antennas is their ability to support multiple functions within a compact and lightweight design. This is particularly useful in applications where space and weight are limited, such as in mobile devices, satellite communications, and military systems. By replacing multiple fixed-function antennas with one reconfigurable unit, overall system complexity and cost can be significantly reduced [7], [8]. These antennas typically achieve reconfigurability through the use of tunable elements like varactor diodes, micro-electro-mechanical systems (MEMS) switches, PIN diodes, and advanced materials such as liquid crystals and smart polymers. These elements allow precise control over the antenna's parameters, enabling it to adapt to changing environments and communication protocols [9], [10].

In modern wireless communication systems, reconfigurable antennas offer several important benefits [11], [12]:

- Frequency reconfigurability: the ability to switch between different frequency bands makes the antenna more versatile, suitable for various communication standards, and reduces interference.
- Radiation pattern reconfigurability: adjusting the radiation pattern improves signal coverage, directional communication, and reduces interference, which is crucial for applications like beamforming in 5G networks.
- Polarization reconfigurability: changing the antenna's polarization helps combat multipath fading and improves signal clarity in complex environments.
- Impedance reconfigurability: modifying impedance matching optimizes power transfer between the antenna and the transmitter/receiver, enhancing overall efficiency.

Reconfigurable antennas are expected to play a vital role in the future of wireless communications. Their ability to adapt to different requirements and operating conditions makes them key components in developing advanced communication systems, including the internet of things (IoT), 5G and beyond networks, and next-generation satellite communications [13]-[17]. As research and technology continue to advance, reconfigurable antennas will likely become even more important in the design and implementation of versatile, high-performance communication infrastructures [18]. For the antenna reconfigurability different techniques are discussed by the different researchers some of them are mostly used that are electronic switching circuit [19], varactor-loaded reconfigurable [20], and PIN diode [21], [22].

This work introduces a multiband, multi-mode coplanar waveguide (CPW)-fed antenna designed for 5G wireless communication. Built on a Rogers RT5880 substrate with dimensions of $30\times28\times0.508$ mm^3, the antenna operates across a wide frequency range of 6 GHz to 28 GHz, with reflection coefficients between -14.82 dB and -50.36 dB. It uses four PIN diodes, resistors, and inductors to achieve 16 different frequency configurations. Simulations with computer simulation technology (CST) Microwave Studio show flexibility in performance, including variations in S-parameters, gains, and radiation patterns. Measurements using a vector network analyzer (VNA) and anechoic chamber confirm its reflection coefficient (|S11|) and gain, making it a reliable option for 5G applications.

2. ANTENNA DESIGN AND SIMULATION ANALYSIS

The design stages for the basic multiband antenna are shown in Figure 1, which illustrates three different structures of the multiband antenna with CPW feed. These antennas are designed using the Rogers RT5880 substrate, featuring a dielectric constant of 2.2, a thickness of 20 mil, and a loss tangent (tanδ) of 0.0009. Following the design process in CST Studio, the antennas were simulated to obtain their reflection coefficients (S11). The simulated values of the reflection coefficient (S11) for these three antennas are presented in Figure 2.

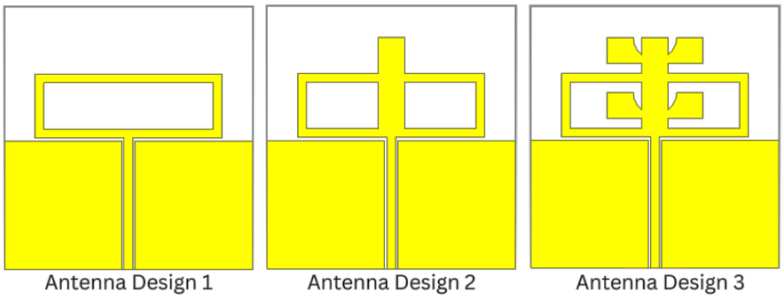


Figure 1. Three different structures of the multiband antenna with CPW feed

Figure 2 presents the simulated values of the reflection coefficient (S11) for the three antenna designs.

- For antenna design 1, the reflection coefficients are -15.49 dB at 11.502 GHz, -11.34 dB at 13.75 GHz, -17.93 dB at 16.8 GHz, -24.68 dB at 21.65 GHz, and -14.67 dB at 25.9 GHz.

– For antenna design 2, the reflection coefficients are -13.49 dB at 10.675 GHz, -26.49 dB at 12.45 GHz, -19.27 dB at 16.025 GHz, -21.1 dB at 22.3 GHz, and -15.65 dB at 27.175 GHz.
– For antenna design 3, the reflection coefficients are -20.2 dB at 8.95 GHz, -25.07 dB at 12.2 GHz, -17.87 dB at 16.275 GHz, -26.43 dB at 21.825 GHz, and -19.07 dB at 27.25 GHz.

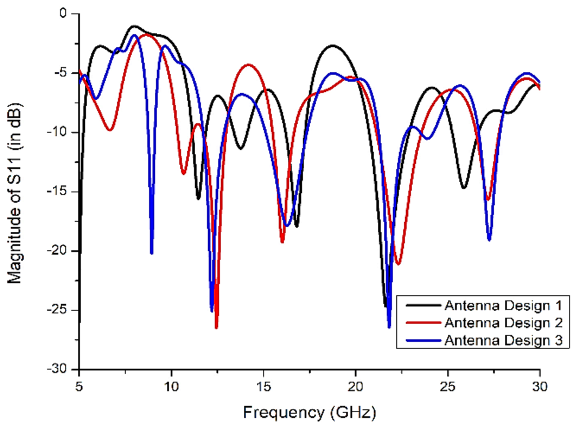


Figure 2. Simulated values of the reflection coefficient (|S11|) for antenna design 1, 2 and 3

The obtained simulated reflection coefficient results from Figure 2 indicate that antenna design 3 provides the best response for multiband applications. Therefore, antenna design 3 will be used for further analysis. The parameters of antenna design 3 are illustrated in Figure 3.

The values of the parameters used to design the final multiband antenna design (antenna design 3) that is shown in the Figure 3 are as: Lp1 is 7.3 mm, Lp2 is 5.3 mm, and Lp3 is 3 mm. The width parameters are Wp1 at 10.2 mm, Wp2 at 4 mm, and Wp3 at 3 mm. The width of the resonator, Wr, is 2.5 mm. The substrate dimensions are Ls at 30 mm and Ws at 28 mm. The ground plane dimensions are Lg at 14.642 mm and Wg at 13.45 mm. The feed line dimensions are Lf at 15 mm and Wf at 1 mm. Additionally, the gap sizes are g1 at 0.25 mm and g2 at 0.358 mm.

To achieve reconfigurability, four PIN diodes, two resistors, and five inductors were added to antenna design 3, transforming it into a reconfigurable multiband antenna, as shown in Figure 4. Capacitors C1 and C2 are used for DC blocking, which ensures that the PIN diodes (D1, D2, D3, and D4) can operate independently by preventing DC currents from interfering with radio frequency (RF) signals. The inductors (L1, L2, L3, L4, and L5) function as RF choke inductors, allowing necessary DC control currents to pass through while blocking unwanted high-frequency signals. This crucial role of RF choke inductors enables dynamic adjustments without compromising the integrity of the RF signals, ensuring that the reconfiguration process is effective and does not interfere with the antenna's performance.

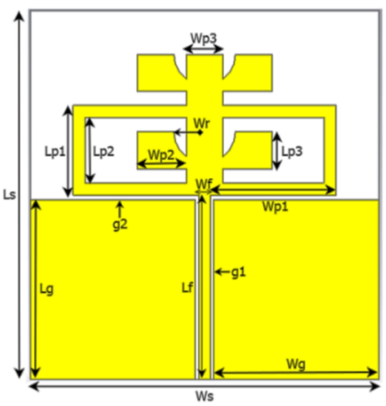


Figure 3. Final multiband antenna design (antenna design 3)

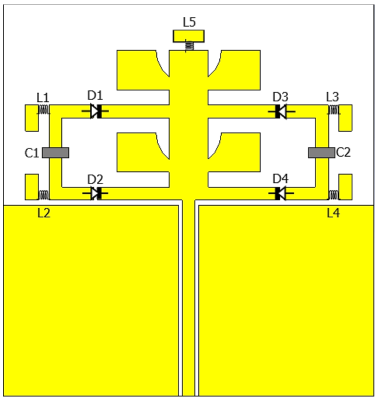


Figure 4. Proposed reconfigurable multiband antenna design

In this proposed multiband reconfigurable antenna design, 16 combinations (ranging from 0000 to 1111) are possible by using the four diodes (D1, D2, D3, and D4). In these combinations, a value of 0 means the respective diode is off, and a value of 1 means the respective diode is on. Through simulation analysis using CST studio suite, it was found that some combinations produce similar results. Therefore, the results of similar combinations can be grouped together.

Figure 5 shows four different combinations of the proposed antenna: 0101, 0111, 1101, and 1111. Table 1 obtained simulated values of 0101, 0111, 1101, and 1111. The obtained S-parameter values for these combinations are similar, as shown in Figure 6. Figure 7 illustrates the radiation patterns of the proposed antenna for the input combinations 0101, 0111, 1101, and 1111 at different frequencies: Figures 7(a) at 12.36 GHz, Figure 7(b) at 16.59 GHz, Figure 7(c) at 21.75 GHz, and Figure 7(d) at 27.27 GHz.

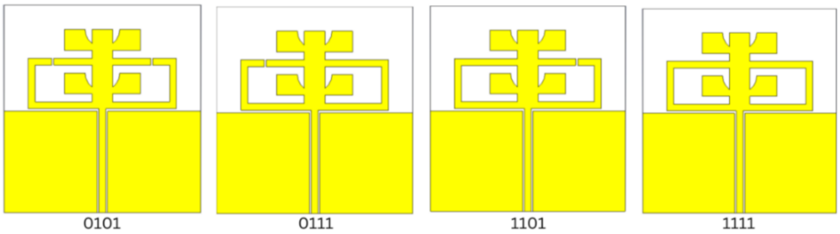


Figure 5. Four different combinations of the proposed antenna: 0101, 0111, 1101, and 1111

Table 1. Obtained simulated values of 0101, 0111, 1101, and 1111 combinations of the proposed reconfigurable multiband antenna

	Mode	Operating frequency (GHz)	Reflection coefficient |S11| (in dB)	Gain (in dBi)
Common operating frequency	0101	12.36	-37.13	3.15
	0111	16.59	-23.64	5.46
	1101	21.75	-41	7.42
	1111	27.27	-19.19	5.57
	0101	6.81	-20.05	4.27
	0111			
	1101			
Individual operating frequency	1111	8.94	-38.11	3.69

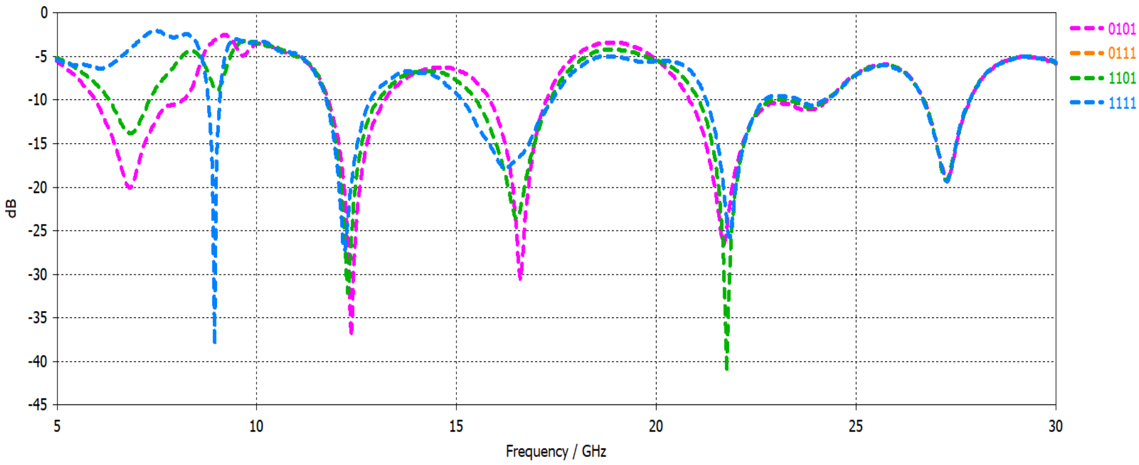


Figure 6. Reflection coefficient of 0101, 0111, 1101, and 1111 four different combinations of the proposed reconfigurable multiband antenna

Figure 8 illustrates eight distinct configurations of the proposed reconfigurable antenna, determined by the diode operations: 0001, 0011, 0100, 0110, 1001, 1011, 1100, and 1110. The simulated S-parameter values obtained for these configurations are comparable, as depicted in Figure 9. The values of the simulated S11 and gain for these eight combinations are shown in Table 2.

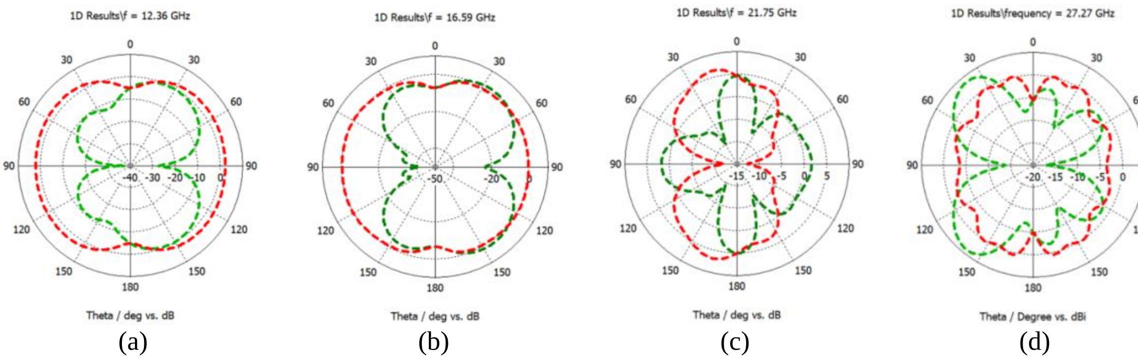


Figure 7. Different radiation pattern of 0101, 0111, 1101, and 1111 combinations of the proposed antenna at (a) 12.36 GHz, (b) 16.59 GHz, (c) 21.75 GHz, and (d) 27.27 GHz

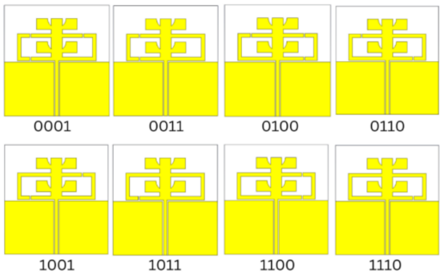


Figure 8. Eight different combinations of the proposed antenna: 0001, 0011, 0100, 0110, 1001, 1011, 1100, and 1110

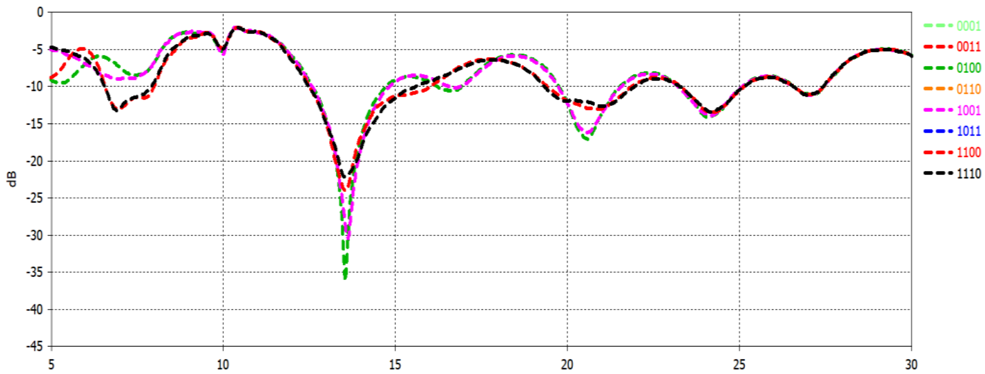


Figure 9. Reflection coefficient of 0001, 0011, 0100, 0110, 1001, 1011, 1100, and 1110 eight different combinations of the proposed reconfigurable multiband antenna

Table 2. Obtained simulated values of 0001, 0011, 0100, 0110, 1001, 1011, 1100, and 1110 combinations of the proposed reconfigurable multiband antenna

	Mode	Operating frequency (GHz)	Reflection coefficient |S11| (in dB)	Gain (in dBi)
Common operating frequency	0001	13.53	-36.12	4.18
	0011	20.55	-17.03	6.02
	0100	24.09	-14.10	5.95
	0110			
	1001			
	1011			
	1100			
	1110			
Common operating frequency	0011	6.96	-13.19	4.37
	1011			
	1100			
	1110			

Figure 10 shows the different radiation patterns of the proposed reconfigurable antenna for the diode operation combinations 0001, 0011, 0100, 0110, 1001, 1011, 1100, and 1110 at three frequencies; 13.53 GHz (Figure 10(a)), 20.55 GHz (Figure 10(b)), and 24.09 GHz (Figure 10(c)). These patterns vary based on the specific configuration of the antenna's diodes. Each combination produces a distinct radiation pattern at these frequencies, and these patterns are depicted in detail for comparison and analysis.

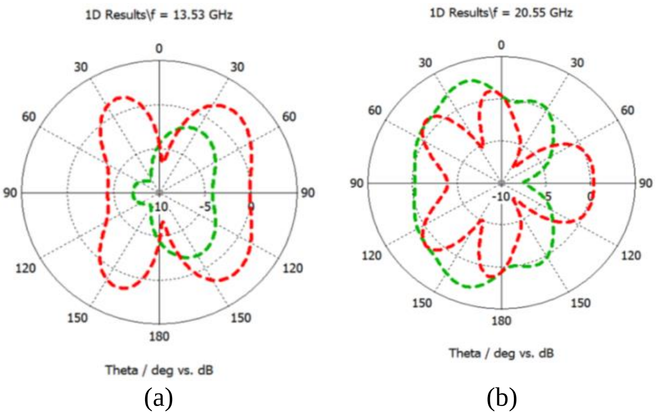


Figure 10. Different radiation pattern of 0001, 0011, 0100, 0110, 1001, 1011, 1100, and 1110 combinations of the proposed reconfigurable antenna at (a) 13.53 GHz, (b) 20.55 GHz, and (c) 24.09 GHz

Figure 11 illustrates the remaining four configurations of the reconfigurable antenna, represented by the diode operation combinations 0000, 0010, 1000, and 1010. These configurations are based on the operations of PIN diodes. Figure 12 presents the simulated S-parameter responses for these specific configurations at three different frequencies: 14.07 GHz, 19.74 GHz, and 24.57 GHz. The results of these simulations, detailing the performance of the proposed reconfigurable antenna for each of these combinations, are summarized in Table 3.

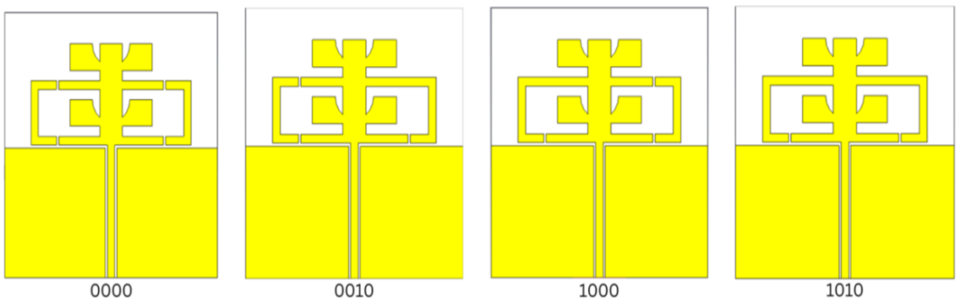


Figure 11. Four different combinations of the proposed reconfigurable antenna: 0000, 0010, 1000, and 1010

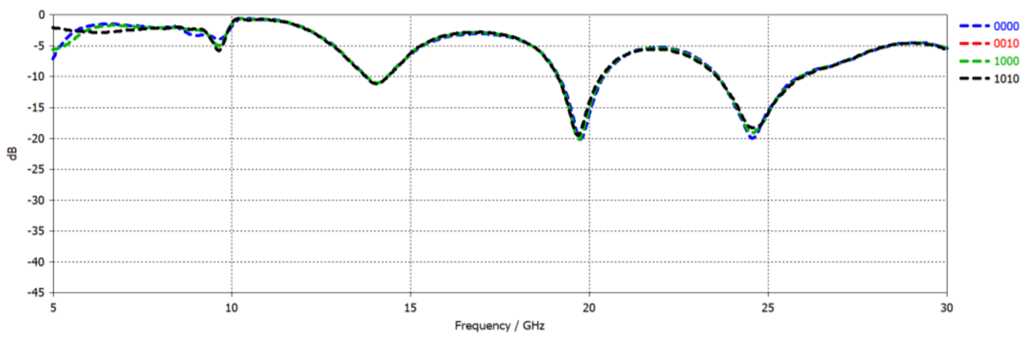
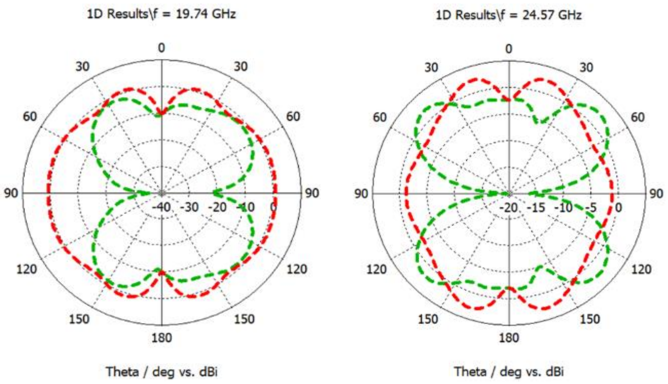


Figure 12. Reflection coefficient of 0000, 0010, 1000, and 1010 four different combinations of the proposed reconfigurable multiband antenna

Table 3. Obtained simulated values of 0000, 0010, 1000, and 1010 combinations of the proposed reconfigurable multiband antenna

	Mode	Operating frequency (GHz)	Reflection coefficient |S11| (in dB)	Gain (in dBi)
Common operating frequency	0000	14.07	-11.13	3.78
	0010	19.74	-20.16	3.83
	1000	24.57	-19.96	4.2
	1010			

Figure 13 illustrates the different radiation patterns of the proposed reconfigurable antenna for the diode operation combinations 0000, 0010, 1000, and 1010 at two frequencies: 19.74 GHz (Figure 13(a)) and 24.57 GHz (Figure 13(b)). These radiation patterns change based on the specific configuration of the antenna's diodes, demonstrating the antenna's adaptability to different frequency operations and configurations.



(a) (b)

Figure 13. Different radiation pattern of 0000, 0010, 1000 and 1010 combinations of the proposed reconfigurable antenna at (a) 19.74 GHz and (b) 24.57 GHz

3. MEASUREMENTS RESULTS OF THE PROPOSED FREQUENCY RECONFIGURABLE ANTENNA

In order to verify the simulated results of the proposed CPW feed reconfigurable multiband antenna design, the antenna is fabricated on a Rogers RT5880 substrate, featuring a dielectric constant of 2.2, a thickness of 20 mil, and a loss tangent (tanδ) of 0.0009. The overall dimension of the proposed CPW feed reconfigurable multiband antenna design 28.4 mm×30 mm×0.508 mm.

In Figure 14, several key aspects of the antenna design and its performance are presented. Figure 14(a) shows the fabricated antenna design, while Figure 14(b) displays the antenna with a DC supply to operate the diode modes. Figure 14(c) illustrates the measurement setup of the reflection coefficient |S11| parameter using a calibrated Agilent N5234A PNA-L network analyzer. Figure 14(d) presents the measured |S11| of the proposed CPW feed reconfigurable multiband antenna design in 0101 mode and 1111 mode. According to Table 1, these two modes cover all the frequency bands in the 0101, 0111, 1101, and 1111 combinations. The measured |S11| values in these modes are -25.98 dB at 6.84 GHz, -13.23 dB at 8.93 GHz, -50.36 dB at 12.36 GHz, -38.89 dB at 16.59 GHz, -29.55 dB at 21.75 GHz, and -23.18 dB at 27.27 GHz. Figure 14(e) shows the measured |S11| values of the proposed antenna for the 0011 combination. From Table 2, it is shown that the 0001, 0011, 0100, 0110, 1001, 1011, 1100, and 1110 combinations have similar |S11| values. The measured |S11| values for the 0011, 1011, and 1100 combinations are -14.32 dB at 6.96 GHz, -26.35 dB at 13.5 GHz, -14.19 dB at 20.55 GHz, and -14.82 dB at 24.09 GHz. Figure 14(f) presents the measured |S11| values of the proposed antenna for the 0000 combination. Table 3 indicates that the 0000, 0010, 1000, and 1010 combinations have similar |S11| values. The measured |S11| values for the 0000 combination are -16.9 dB at 14.07 GHz, -31.03 dB at 19.74 GHz, and -16.83 dB at 23.54 GHz. These measurements from the fabricated antenna demonstrate its performance across various frequency bands and mode combinations.

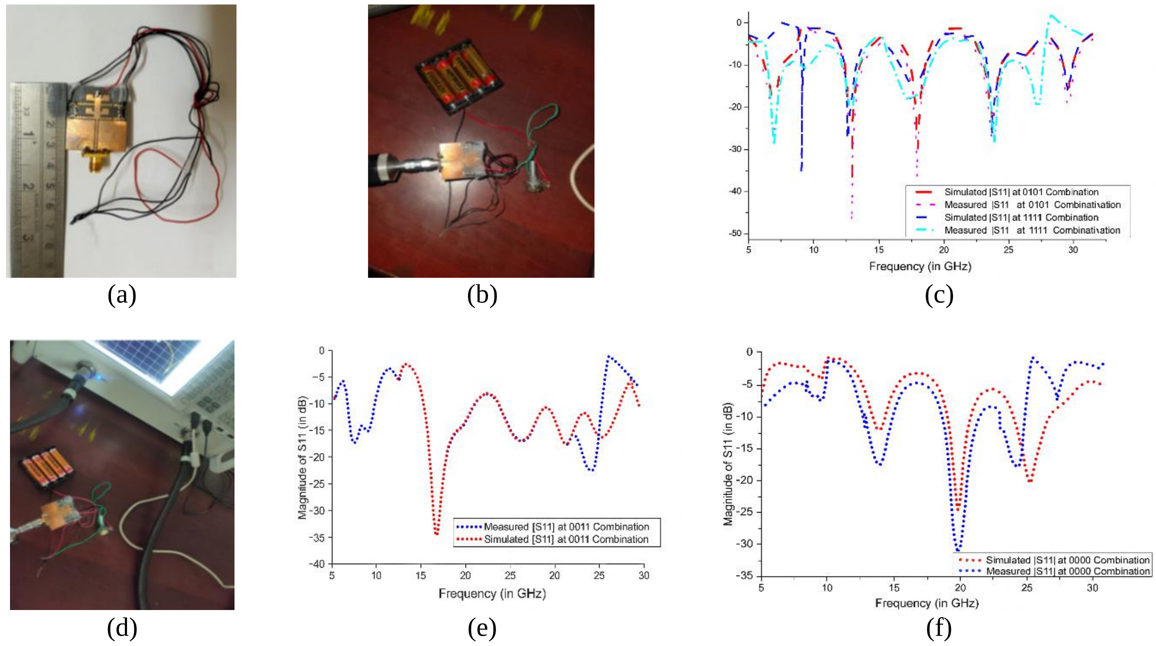


Figure 14. Fabricated CPW-fed reconfigurable multiband antenna and its measured $|S_{11}|$ for (a) prototype, (b) antenna with DC-bias network, (c) Agilent N5234A PNA-L measurement setup, (d) 0101 and 1111 modes, (e) 0011 mode, and (f) 0000 mode

Figure 15 shows the fabricated proposed frequency reconfigurable CPW feed multiband multi-mode antenna measurement setup in an anechoic chamber for testing and evaluation. In this anechoic chamber, measurements of the E and H planes, radiation pattern, and gain were conducted for the reconfigurable antenna in different modes. According to Table 1, the 0101 mode and 1111 mode cover all the frequency bands in the 0101, 0111, 1101, and 1111 combinations. The measured gains at various frequencies are as follows: 4.3 dBi at 6.84 GHz, 3.72 dBi at 8.93 GHz, 3.8 dBi at 12.36 GHz, 5.3 dBi at 16.59 GHz, 8.2 dBi at 21 GHz, and 5.3 dBi at 27.27 GHz. From Table 2, it is shown that the 0001, 0011, 0100, 0110, 1001, 1011, 1100, and 1110 combinations have approximately the same operating frequencies. Therefore, the measurements were taken in the 0011 mode, and the results are approximately the same for all these combinations. The measured gains at various frequencies are as follows: 3.8 dBi at 6.96 GHz, 4.7 dBi at 13.5 GHz, 6.2 dBi at 20.55 GHz, and 5.7 dBi at 24.09 GHz. Table 3 indicates that the 0000, 0010, 1000, and 1010 combinations have similar operating frequencies. Therefore, the measurements were taken in the 0000 mode for all four combinations. The measured gains in the 0000 mode are 3.4 dBi at 14.07 GHz, 3.1 dBi at 19.74 GHz, and 3.9 dBi dB at 23.54 GHz.

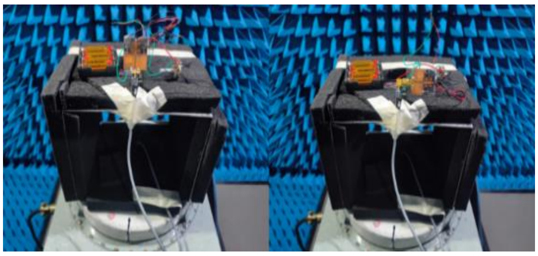


Figure 15. Fabricated proposed CPW feed multiband reconfigurable antenna measurement setup in an anechoic chamber for testing and evaluation

Table 4 presents the measurement results of the fabricated antenna obtained using a VNA and an anechoic chamber. A total of 13 distinct frequencies were achieved under different antenna configurations. The multiband frequencies range from 6 GHz to 28 GHz, with the measured gain of the reconfigurable multiband multimode antenna varying between 3.1 dBi and 8.2 dBi. Comparative analysis of presented multiband reconfigurable antenna work with existing research work as Table 5.

Table 4. Measured results of the presented frequency reconfigurable multiband multimode antenna

Operating frequencies (in GHz)	Reflection coefficient |S11| (in dB)	Gain (in dBi)
6.84	-25.98	4.3
8.93	-13.23	3.72
12.36	-50.36	3.8
16.59	-38.89	5.3
21.75	-29.55	8.2
27.27	-23.18	5.3
6.96	-14.32	3.8
13.5	-26.35	4.7
20.55	-14.19	6.2
24.09	-14.82	5.7
14.07	-16.9	3.4
19.74	-31.03	3.1
23.54	-16.83	3.9

Table 5. Comparative analysis of presented multiband reconfigurable antenna work with existing research work

Ref	Size (mm^3)	No. of operating frequency	Operating frequencies (GHz)	Reflection coefficient |S11| (dB)	Gain (dBi)	Type of reconfigurable switch
[14]	15×21×1.6	6	7.29, 2.47, 5.29, 7.2, 3.2, 5.42	-25, -26.5, -18, -33, -15.2, -23.5	3.21, 2.07, 2.41, 3.38, 2.3, 2.4	PIN diode (2)
[23]	37×47×1.6	9	1.36, 1.8, 3.0, 6.2, 6.4, 7.4, 7.9, 8.2, 8.6	-15.77, -14.03, -13.37, -31.98, -12.0, -12.68, -13.23, -16.50, -22.06	2.29, 3.65, 10, 6.1, 6.63, 1.83, 4.66, 7.9, 4.73	PIN diode (3)
[24]	30×15×1.6	5	2.4, 5.8, 3.3, 3.5, 5	-17.5, -15, -11.5, -15.7, -18	__	PIN diode (3)
[25]	120×60×1.575	6	0.94, 3.95, 4.75, 1.85, 2.55, 4.75	-38, -29.5, -20, -13.5, -11, -18	1.06, 1.23, 2.37, 2.97, 1.5, 1.87	PIN diode (2)
[5]	33×24×1.6	8	2, 2.3, 2.5, 2.7, 2.9, 4.2, 4.4, 5.5	-12, -24, -17.5, -16, -19, -16, -12.5, -18	5, 4, 4.8, 3.9, 5.2, 4.1, 6, 6.8	PIN diode (3)
[26]	26.5×30×1.6	2	2.4, 28	-22.39, -22.15	4.34, 8.57	PIN diode (2)
[27]	18×11.5×0.787	2	28, 38	-38.8, -37.2	6.72, 5.71	PIN diode (14)
		4	3.5, 4.3, 5, 5.1	-10.2, -21, -20, -18.5	___	PIN diode (4)
Presented multiband reconfigurable antenna work	30×28×0.508	13	6.84, 8.93, 12.36, 16.59, 21.75, 27.27, 6.96, 13.5, 20.55, 24.09, 14.07, 19.74, 23.54	-25.98, -13.23, -50.36, -38.89, -29.55, -23.18, -14.32, -26.35, -14.19, -14.82, -16.9, -31.03, -16.83	4.3, 3.72, 3.8, 5.3, 8.2, 5.3, 3.8, 4.7, 6.2, 5.7, 3.4, 3.1, 3.9	PIN diode (4)

4. CONCLUSION

This research successfully developed, simulated, and tested a CPW-fed multiband multi-mode frequency reconfigurable antenna for 5G wireless communication using the Rogers RT5880 substrate, known for its excellent dielectric properties, three initial designs were explored. Antenna design 3 performed the best between them, with reflection coefficients ranging from -20.2 dB to -26.43 dB at different frequencies. By adding four PIN diodes, resistors, and inductors, 16 configurations were enabled, demonstrating the antenna's flexibility across different frequency bands. The antenna was fabricated and its reflection coefficient (|S11|) and gain were measured using a VNA and an anechoic chamber. The fabricated antenna showed reflection coefficient |S11| values from -13.23 to -50.36 dB, confirming its performance in various modes and frequencies. The antenna could reconfigure dynamically without losing signal quality, achieving gains from 3.1 dB to 8.2 dB in different configurations.

This research highlights the versatility and robustness of the proposed CPW-fed multiband multi-mode frequency reconfigurable antenna. By integrating PIN diodes and ensuring effective DC blocking and RF choking, the antenna can dynamically reconfigure without losing signal quality. This makes it ideal for various wireless communication applications, where flexibility and efficiency are crucial. The antenna not only meets but exceeds the requirements for multiband operation, validated through thorough simulations and experimental measurements, showing its potential for widespread use.

REFERENCES

[1] D. N. Gençoğlan, "ANFIS-SA-based design of a hybrid reconfigurable antenna for L-Band, C-band, 5G and ISM band applications," *Computers and Electrical Engineering*, vol. 123, p. 110054, Apr. 2025, doi: 10.1016/j.compeleceng.2024.110054.

[2] A. A. Deshmukh, A. Viswanathan, P. Nadkarni, V. A. P. Chavali, and H. Mistry, "Reconfigurable designs of equilateral triangular microstrip antennas for single and dual band circular polarized response in GSM and GPS applications," *AEU - International Journal of Electronics and Communications*, vol. 193, p. 155729, Mar. 2025, doi: 10.1016/j.aeue.2025.155729.

[3] R. K. A. Mohan and K. G. Padmasine, "A Review on materials and reconfigurable antenna techniques for wireless communications: 5G and IoT applications," *Progress in Electromagnetics Research B*, vol. 97, pp. 91–114, 2022, doi: 10.2528/PIERB22092005.

[4] I. A. Shah *et al.*, "Design and analysis of a hexa-band frequency reconfigurable antenna for wireless communication," *AEU - International Journal of Electronics and Communications*, vol. 98, pp. 80–88, Jan. 2019, doi: 10.1016/j.aeue.2018.10.012.

[5] P. R. Kumar, P. Sunitha, and M. V. S. Prasad, "Compact reconfigurable patch antenna for wireless applications," *Progress in Electromagnetics Research C*, vol. 138, pp. 161–174, 2023, doi: 10.2528/PIERC23090102.

[6] M. Jenath and V. Nagarajan, "Review on frequency reconfigurable antenna for wireless applications," in *Proceedings of the 2017 IEEE International Conference on Communication and Signal Processing, ICCSP 2017*, Apr. 2017, vol. 2018-January, pp. 2240–2245, doi: 10.1109/ICCSP.2017.8286815.

[7] A. Kumar, N. Kumar, and S. Dixit, "A review on reconfigurable antennas for wireless communication systems," *Turkish Journal of Computer and Mathematics Education*, vol. 12, no. 14, pp. 348–366, 2021, doi: 10.17762/turcomat.v12i14.10277.

[8] D. Yadav, M. P. Abegaonkar, S. K. Koul, V. Tiwari, and D. Bhatnagar, "A monopole antenna with reconfigurable notched characteristics from WLAN-band notched UWB to ITU-band notched UWB antenna," in *Lecture Notes in Electrical Engineering*, vol. 472, 2018, pp. 647–654, doi: 10.1007/978-981-10-7395-3_72.

[9] S. B. F. Kennedy and J. Hesselbarth, "Generalized approach to antenna reconfigurability by switching load admittances," *Progress in Electromagnetics Research B*, vol. 102, pp. 151–169, 2023, doi: 10.2528/pierb23071004.

[10] S. S. Tathare and P. Goswami, "Design and development of a reconfigurable antenna with varactor diodes for next-generation wireless communication systems," *Computers and Electrical Engineering*, vol. 123, p. 110091, Apr. 2025, doi: 10.1016/j.compeleceng.2025.110091.

[11] V. Suryapaga and V. V. Khairnar, "Review on multifunctional pattern and polarization reconfigurable antennas," *IEEE Access*, vol. 12, pp. 90218–90251, 2024, doi: 10.1109/ACCESS.2024.3420426.

[12] H. F. Abutarboush and A. Shamim, "A reconfigurable inkjet-printed antenna on paper substrate for wireless applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 9, pp. 1648–1651, Sep. 2018, doi: 10.1109/LAWP.2018.2861386.

[13] K. Ramahatla, M. Mosalaosi, A. Yahya, and B. Basutli, "Multiband reconfigurable antennas for 5G wireless and cubesat applications: a review," *IEEE Access*, vol. 10, pp. 40910–40931, 2022, doi: 10.1109/ACCESS.2022.3166223.

[14] O. Benkhadda *et al.*, "A miniaturized reconfigurable antenna for modern wireless applications with broadband and multi-band capabilities," *Progress in Electromagnetics Research M*, vol. 127, pp. 93–101, 2024, doi: 10.2528/PIERM24042801.

[15] F. Usman, M. G. Siddiqui, P. Yadav, S. Singh, and R. S. Yadav, "Reconfigurable antenna design for internet of medical things," *Progress in Electromagnetics Research C*, vol. 116, pp. 249–264, 2021, doi: 10.2528/PIERC21091302.

[16] A. K. Abd and J. M. Rasool, "Low-profile frequency-reconfigurable antenna for 5G applications," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 21, no. 3, pp. 486–495, Jun. 2023, doi: 10.12928/TELKOMNIKA.v21i3.24028.

[17] A. Tiwari, G. K. Soni, D. Yadav, S. V. Yadav, and M. V. Yadav, "Rectangular loaded ring shaped multiband frequency reconfigurable defected ground structure antenna for wireless communication applications," *Results in Engineering*, vol. 25, p. 104339, Mar. 2025, doi: 10.1016/j.rineng.2025.104339.

[18] M. M. Al-Saeedi, A. A. Hashim, O. H. Al-Bayati, A. S. Rasheed, and R. H. Finjan, "Design of dual band slotted reconfigurable antenna using electronic switching circuit," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 24, no. 1, pp. 386–393, Oct. 2021, doi: 10.11591/ijeecs.v24.i1.pp386-393.

[19] S. M. Shah *et al.*, "Frequency tuning varactor-loaded reconfigurable antenna for m-WIMAX and WLAN applications," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 13, no. 2, pp. 779–786, Feb. 2019, doi: 10.11591/ijeecs.v13.i2.pp779-786.

[20] A. I. Al-Muttairi and M. J. Farhan, "Circular polarization reconfigurable antenna for mid-band 5G applications with a new reconfigurable technique," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 19, no. 2, pp. 802–810, Aug. 2020, doi: 10.11591/ijeecs.v19.i2.pp802-810.

[21] S. M. Shah *et al.*, "Frequency reconfiguration mechanism of a PIN diode on a reconfigurable antenna for LTE and WLAN applications," *International Journal of Electrical and Computer Engineering*, vol. 8, no. 3, pp. 1893–1902, Jun. 2018, doi: 10.11591/ijece.v8i3.pp1893-1902.

[22] M. J. Sathikbasha and V. Nagarajan, "DGS based multiband frequency reconfigurable antenna for wireless applications," in *Proceedings of the 2019 IEEE International Conference on Communication and Signal Processing, ICCSP 2019*, Apr. 2019, pp. 908–912, doi: 10.1109/ICCSP.2019.8698093.

[23] A. Ghaffar, X. J. Li, W. A. Awan, and N. Hussain, "A Compact multiband multi-mode frequency reconfigurable antenna for portable devices," in *2020 International Conference on UK-China Emerging Technologies, UCET 2020*, Aug. 2020, pp. 1–4, doi: 10.1109/UCET51115.2020.9205460.

[24] S. Padmanathan *et al.*, "Compact multiband reconfigurable MIMO antenna for sub- 6GHz 5G mobile terminal," *IEEE Access*, vol. 10, pp. 60241–60252, 2022, doi: 10.1109/ACCESS.2022.3180048.

[25] D. El Hadri, A. Zakriti, and A. Zugari, "Reconfigurable antenna for Wi-Fi and 5G applications," *Procedia Manufacturing*, vol. 46, pp. 793–799, 2020, doi: 10.1016/j.promfg.2020.04.007.

[26] S. A. Refaat, H. A. Mohamed, A. M. Abdelhady, and A. S. S. Mohra, "A 28/38 GHz tuned reconfigurable antenna for 5G mobile communications," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 31, no. 1, pp. 248–258, Jul. 2023, doi: 10.11591/ijeecs.v31.i1.pp248-258.

[27] V. Reji and C. T. Manimegalai, "S11 parameter results comparison in reconfigurable antennas under simulation and measurement," *International Journal of Reconfigurable and Embedded Systems*, vol. 12, no. 2, pp. 186–194, Jul. 2023, doi: 10.11591/ijres.v12.i2.pp186-194.

BIOGRAPHIES OF AUTHORS

Annu Tiwari received her B.Tech. from Sunderdeep Engineering College (UPTU) Ghaziabad, U.P., India in 2012 and M.Tech. from Manipal University Jaipur, Rajasthan, India in 2016. She is currently pursuing her Ph.D. from Manipal University Jaipur, Rajasthan, India. She is student member of IEEE, IEEE AP-S, IEEE MTT-S, IEEE Young Professionals, IEEE EMC, IEEE Aerospace and Electronic System Society. She is the author/co-author of more than 10 research papers published in the reputed journals and conferences. Her current research interest includes design and applications of microstrip patch antennas, reconfigurable antenna design, and antennas for wireless communication. She can be contacted at email: annutiwari48@gmail.com.

Muhammed Yasir Yilmaz currently pursuing his B.Tech. from Department of Electronics and Communication Engineering, Istanbul Technical University, Turkey. His current research interest includes design and applications of microstrip patch antennas, reconfigurable antenna design, antennas for wireless communication, antenna design for mmWave communication, and antenna for 5G communication. He can be contacted at email: yilmazmyasir@gmail.com.

Gaurav Kumar Soni obtained B.Tech. in Electronics and Communication Engineering from Rajasthan Technical University, India in 2014 and M.Tech. in VLSI, Embedded and System Design from Chhattisgarh Swami Vivekanand Technical University, Bhilai, India in 2016. He is currently pursuing Ph.D. from Manipal University Jaipur, India. He is student member of IEEE, IEEE AP-S, IEEE MTT-S, IEEE Young Professionals, IEEE EMC, IEEE Aerospace and Electronic System Society. He is the author/co-author of more than 28 research papers published in the reputed journals and conferences. His current research interest includes design and applications of microstrip patch antennas, antennas for wireless communication, flexible antennas, wearable antennas, and antennas for biomedical applications. He can be contacted at email: gksoni2709@gmail.com.

Dinesh Yadav obtained B.E. in Electronics and Communication Engineering from Rajasthan University and completed his M.Tech. in Digital Communication from Rajasthan Technical University. He received his Ph.D. from Manipal University Jaipur. Currently, working as Associate Professor in Department of Electronics and Communication Engineering, School of Electrical, Electronics and Communication, Manipal University Jaipur. Has an excellent academic career background of 13 years in teaching and have to his credit 86 research papers published in reputed journals and conferences. He is INAE fellowship awardee (Mentoring of Engineering Teacher by Indian National Academy of Engineers Fellow) INAE-2016 under the mentorship of eminent Professor Shiban K. Koul, CARE, IIT Delhi. Recipient of summer faculty research fellowship (SFRF)-2014 and (SFRF)-2017 form QIP-IIT Delhi and recipient of IEEE International travel grant to visit IEEE Asia Pacific Microwave Conference-2019 in Singapore. He has also received the IEEE International travel grant to visit IEEE International Microwave Symposium (IMS-2019), USA. Recipient of Short-term Research Fellowship under the Endowment fund scheme for visiting japan, in June 2019 and has visited Hiroshima University, NIMS, and KEIO University during his visit to Japan, to understand technical update of Microwave technology. Senior member of IEEE AP-S, IEEE MTT-S, IEEE Communication Societies, life member of IETE and life associate member of IE (I). His research interests include reconfigurable antennas, UWB antennas and MIMO antennas, MM-wave antennas, antennas for 5G systems, flexible antennas, and antennas for biomedical applications. He can be contacted at email: dinesh.yadav@jaipur.manipal.edu.