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Design and Development of Multiband Double T-Shaped Frequency Reconfigurable Antenna for 5G Wireless Communication

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ABSTRACT: The rapid development of wireless technology has increased interest in multiband reconfigurable antennas, especially as devices and satellites move toward miniaturization. Reconfigurable antennas must be capable of adapting to their environment by dynamically altering their operating frequency, polarization, and/or radiation pattern. The fifth generation (5G) of wireless communication represents a significant advancement over 4G networks, aiming to meet the growing demand for data and connectivity in today's digital world. To achieve the performance required for supporting a wide range of use cases across both local and global markets, 5G must integrate various existing communication technologies. This work presents a multiband double T shaped frequency reconfigurable antenna for 5G wireless communication on a Rogers RT5880 substrate, designed and simulated using the CST Microwave Studio. In this antenna, two MA4SPS402 PIN diodes are used to make the antenna reconfigurable. By using these PIN diodes, the antenna works on four different modes based on both the diodes ON/OFF conditions. By using this configuration of the PIN diodes, the presented antenna operates at five different operating frequencies 10.8 GHz, 16.47 GHz, 17.03 GHz, 17.07 GHz, and 21.2 GHz. The presented antenna provides the best reflection coefficient $|S_{11}|$ value which is -24.76 dB at 21.2 GHz, and peak gain is 7.81 dBi at 16.47 GHz. The measurements of the fabricated antenna are done using a Vector Network Analyzer (VNA) and an anechoic chamber, confirming its reflection coefficient ($|S_{11}|$) and gain, making it a reliable option for 5G applications.

1. INTRODUCTION

The fifth-generation New Radio (5G NR) communication systems demand high data rates, wide bandwidth, and reliable connectivity across the spectrum [1, 2]. These requirements can be achieved through antenna systems that support multiple frequency transformations and beam steering capabilities. As a result, reconfigurability becomes a crucial feature, enabling antennas to operate across multiple frequencies and directions [3, 4]. A reconfigurable antenna (RA) is defined as an antenna that can dynamically and reversibly change its operating frequency and radiation characteristics in a controlled manner. Reconfigurable antennas have mainly three types based on which parameters can be reconfigured like frequency, radiation pattern, and polarization [5, 6].

Reconfigurable antennas have emerged as a promising solution to address the evolving needs of modern wireless communication systems, offering greater flexibility and improved performance across a wide range of applications [7, 8]. They are specifically designed to adapt their characteristics, such as frequency, radiation pattern, polarization, and impedance, via mechanical adjustments, electrical tuning, or material modifications [9]. These antennas typically achieve reconfigurability through the use of tunable elements like varactor diodes, MEMS (Micro-Electro-Mechanical Systems) 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 [10, 11]. This ability to reconfigure in real-time allows a single antenna to perform efficiently under varying conditions, thereby optimizing system performance and resource usage [6].

One of the key advantages of reconfigurable antennas is their capacity to support multiple functionalities within a compact and lightweight form factor. This is especially important in environments where space and weight are limited, such as in mobile devices, satellite communications, and military systems. By replacing multiple fixed-function antennas with a single reconfigurable unit, overall system complexity and costs can be significantly reduced [6, 7].

The reviewed literature from [12] to [24] highlights notable advancements in the development of frequency reconfigurable antennas tailored for diverse 5G and wireless communication applications. Various design techniques such as PIN diode switching, MEMS integration, defected ground structures (DGSs), complementary split ring resonators (CSRRs),

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TABLE 1. Parameters values used in double T shaped reconfigurable antenna.

Parameter	L	W	L_p	W_p	$L1$	$L2$	$L3$	$L4$	L_t	$W1$	W_t	L_f	W_f	L_g
Value (mm)	12	12	8	10	3.85	2.85	2	0.8	0.6	1	5	3	0.2	8

and metamaterials have been employed to enable multiband, wideband, and polarization reconfigurability. Early studies [12–14] focus on achieving multiband and band-notched functionalities using slot-based structures and diodes for applications like long term evolution (LTE), wireless local area network (WLAN), and ultra-wideband (UWB). Subsequent works [15, 16] introduce performance enhancements using MEMS switches and circular polarization switching. Designs presented in [17–19] aim for compact, millimeter-wave, and multimode capabilities suitable for modern 5G systems, although some remain limited to simulation-based validation. From [20] onwards, the focus shifts to compact, practical designs with experimental verification, including multiple-input multiple-output (MIMO) antennas with beam and frequency reconfiguration, miniaturized antennas for Wi-Fi 6E/7 and C/X bands, and structures offering omnidirectional or bidirectional radiation patterns. Notably, studies like [23] and [24] demonstrate high configurability with up to eight switching modes using PIN diodes. Collectively, these works mark the transition from theoretical models to application-ready, compact, and reconfigurable antennas that support a wide range of communication standards such as 5G, Wi-Fi, worldwide interoperability for microwave access (WiMAX), Industrial, Scientific, and Medical (ISM), military, radar, and satellite. They reflect ongoing trends in achieving high gain, wideband efficiency, and reliable radiation performance within minimal form factors critical for integration into next-generation portable and wireless systems.

In this work, a multiband double T-shaped frequency reconfigurable antenna is presented for 5G wireless communication, designed on a Rogers RT5880 substrate with a dielectric constant of 2.2, a loss tangent ($\tan\delta$) of 0.0009, and a thickness of 0.79 mm. The overall dimensions of the proposed antenna are $12 \times 12 \times 0.79\,\text{mm}^3$, and it operates across the frequency range of 10 GHz to 22 GHz. The antenna incorporates two MA4SPS402 PIN diodes [25] to enable frequency reconfigurability. By switching the diodes ON and OFF, the antenna operates in four different modes, corresponding to various diode states. This configuration enables the operation at five distinct resonant frequencies: 10.8 GHz, 16.47 GHz, 17.03 GHz, 17.07 GHz, and 21.2 GHz. The antenna achieves a best reflection coefficient ($|S_{11}|$) of -24.76 dB at 21.2 GHz, with a peak gain of 7.81 dBi at 16.47 GHz. The design and simulation were performed using Computer Simulation Technology (CST) Microwave Studio, demonstrating flexibility in S-parameters, gain, and radiation pattern characteristics. To validate the simulated results, the fabricated antenna was tested using a Vector Network Analyzer (VNA) and measured in an anechoic chamber. The measured results for reflection coefficient ($|S_{11}|$) and gain confirm the antenna's performance, making it a reliable and effective solution for 5G wireless communication applications.

2. PROPOSED ANTENNA DESIGN

The proposed double T shaped antenna is designed using a Rogers RT5880 substrate, featuring a dielectric constant of 2.2, loss tangent ($\tan\delta$) of 0.0009, and thickness of 0.79 mm. The proposed antenna is composed of a vertically aligned double T-shaped structure, a $50\,\Omega$ microstrip feed, and a partial ground plane. For double T shaped elements and a partial ground plane of the proposed antenna configuration, copper is utilized as a conducting material with a thickness of 0.035 mm. The proposed antenna configuration has an overall footprint of $L \times W \times h = 12\,\text{mm} \times 12\,\text{mm} \times 0.79\,\text{mm}$.

Optimized length of the 50-Ω microstrip feed line is fixed at $L_f = 3\,\text{mm}$, and its width $W_f = 0.2\,\text{mm}$ is calculated using the following expression [26].

$$\frac{W_f}{d} = \begin{cases} \frac{8e^A}{e^{2A}-2} & for\ \frac{W_f}{h} < 2 \\ \frac{2}{\pi}\Big[B - 1 - \ln(2B-1) + \frac{\epsilon_r - 1}{2\epsilon_r} & \\ \Big\{\ln(B-1) + 0.39 - \frac{0.61}{\epsilon_r}\Big\}\Big] & for\ \frac{W_f}{h} > 2 \end{cases} \tag{1}$$

$$A = \frac{Z_0}{60}\sqrt{\frac{\epsilon_r + 1}{2}} + \frac{\epsilon_r - 1}{\epsilon_r + 1}\left(0.23 + \frac{0.11}{\epsilon_r}\right)$$

$$\&B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}} \tag{2}$$

For the reconfigurability purpose, two MA4SPS402 PIN diodes (D1 and D2) are used in the proposed antenna design. The antenna configuration is optimized using the CST Microwave Studio software. The proposed double T shaped reconfigurable antenna is shown in Figure 1, and the dimensions of the proposed double T shaped antenna are summarized in Table 1.

In the proposed double T-shaped reconfigurable antenna, two diodes (D1 and D2) are employed. By controlling these two diodes, four possible configurations are achieved: (i) both diodes ON, (ii) D1 ON and D2 OFF, (iii) D1 OFF and D2 ON, and (iv) both diodes OFF. These diode configurations for the double T-shaped antenna are illustrated in Figure 2. The corresponding reflection coefficients for all four cases are presented in Figure 3.

When both diodes are OFF, the antenna resonates at 16.47 GHz with a reflection coefficient of -12.37 dB. When one diode is ON (either D1 or D2) and the other OFF (D2 or D1), the antenna resonates at 17.07 GHz with a reflection coefficient of -24.85 dB. When both diodes are ON, the antenna resonates at three different frequencies: 10.8 GHz, 17.03 GHz, and 21.2 GHz, with reflection coefficients of -16.39 dB, -13.4 dB, and -24.76 dB, respectively.

The directivity gain of the proposed antenna at 16.47 GHz, when both diodes are OFF, is 7.81 dBi. When one diode is ON

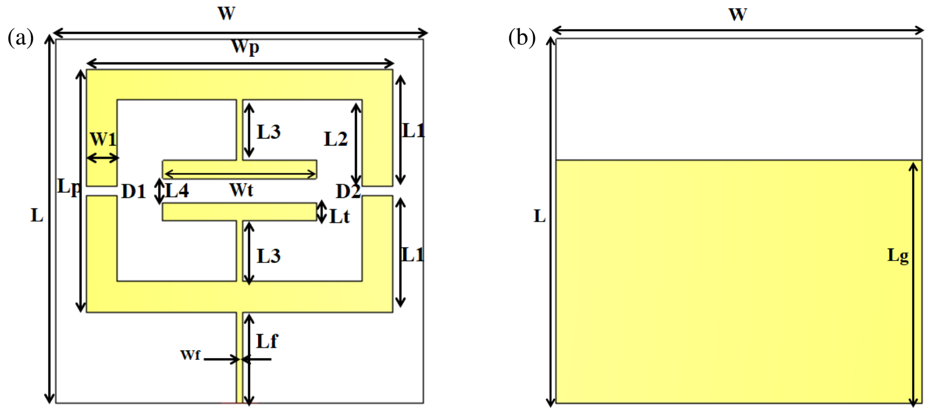


FIGURE 1. Proposed double T shaped reconfigurable antenna, (a) front view and (b) back view.

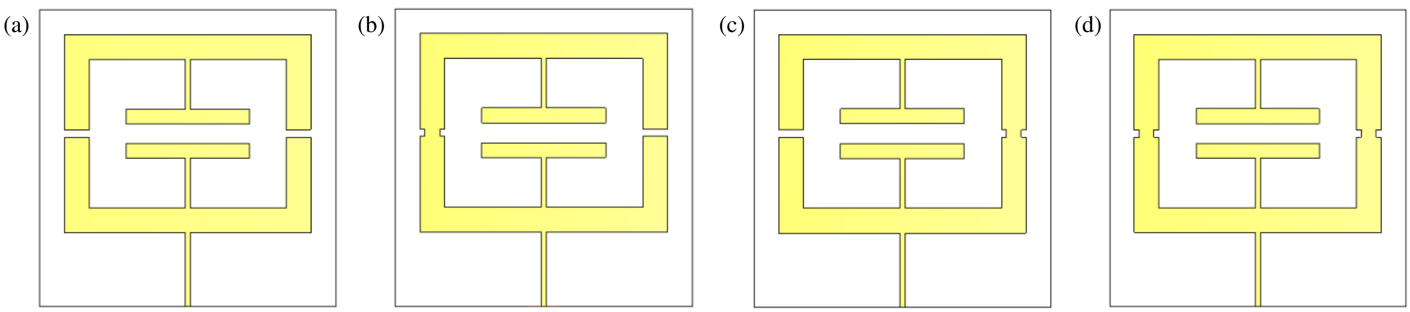


FIGURE 2. Proposed double T shaped reconfigurable antenna configuration (a) both diodes are off, (b) diode D1 is ON and D2 is OFF, (c) diode D1 is OFF and D2 is ON, (d) both diodes are ON.

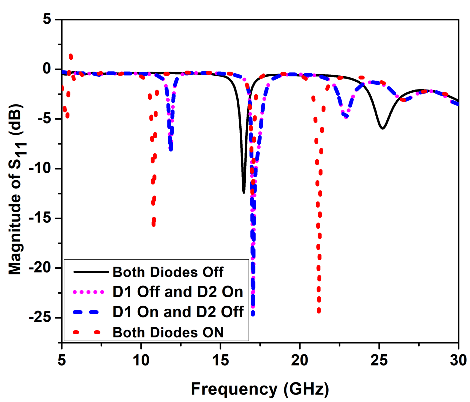


FIGURE 3. Simulated reflection coefficient (S_{11}) of the proposed double T shaped reconfigurable antenna in all the configurations of both the diodes (D1 and D2).

(either D1 or D2) and the other diode OFF (D2 or D1), the directivity gain at 17.07 GHz is 5.37 dBi. When both diodes are ON, the directivity gains at 10.8 GHz, 17.03 GHz, and 21.2 GHz are 7.28 dBi, 4.37 dBi, and 6.53 dBi, respectively. The 3D far-field radiation pattern of the proposed double T-shaped reconfigurable antenna is illustrated in Figure 4.

The surface current of the presented double T-shaped reconfigurable antenna in different configurations is shown in Figure 5. The gain vs frequency plot is shown in Figure 6. Table 2 presents all the simulated results of the proposed double T-shaped reconfigurable antenna under different configurations of the diodes (D1 and D2).

3. PROPOSED ANTENNA FABRICATION AND MEASUREMENT

The proposed double T-shaped reconfigurable antenna is fabricated on a Rogers RT/Duroid 5880 substrate with a thickness of 0.79 mm. The fabricated prototype, equipped with a 50 Ω SMA connector mounted to the microstrip feed and two MA4SPS402 PIN Diodes, is shown in Figure 7(a) (front view) and Figure 7(b) (back view). After fabrication, the reflection coefficient ($|S_{11}|$) of the antenna was measured using a calibrated 2-port N5247A PNA. The measurement setup is illustrated in Figure 7(c), and the diode used in the antenna for reconfigurability is powered by a DC biasing circuit through radio frequency (RF) chock inductor of 0.7 V for forward bias state that controls the PIN diodes switching. By applying DC voltages, the diodes are turned ON, and unbiased diode keeps it at OFF state, adjusting the antenna's frequency and radiation. This setup allows for efficient reconfiguration with low power usage, with each diode controlled separately based on the mode.

The simulated and measured reflection coefficients ($|S_{11}|$) for various configurations of diodes D1 and D2 are shown in Figure 7(d) to Figure 7(f). Figure 7(d) shows the simulated and measured reflection coefficients ($|S_{11}|$) when both diodes are OFF; Figure 7(e) shows the simulated and measured reflection

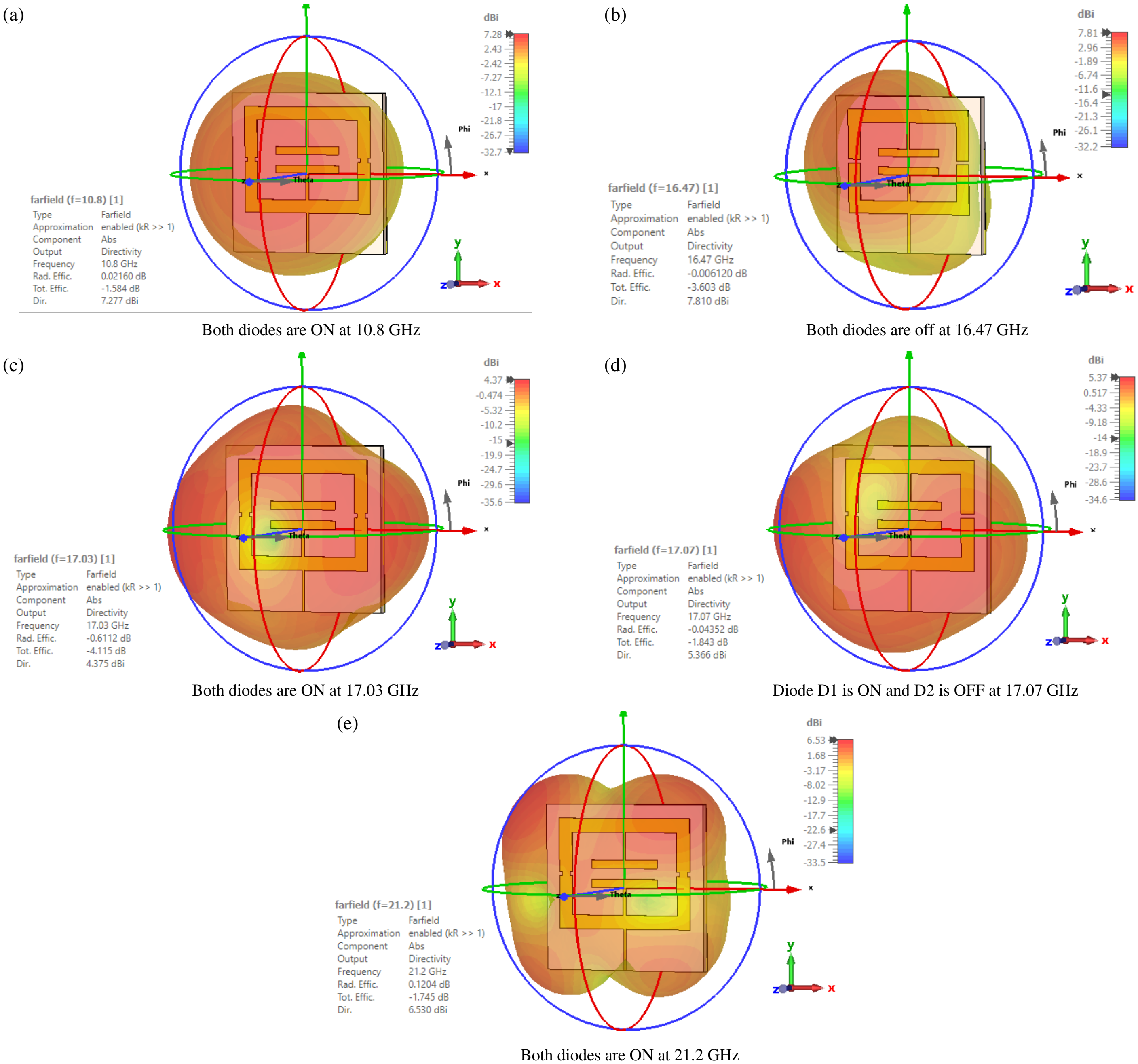


FIGURE 4. 3D far field of the presented double T-shaped reconfigurable antenna in different configurations.

TABLE 2. Obtained simulated results of the proposed double T-shaped reconfigurable antenna in different configuration.

Diode Configurations	Operating Frequency (GHz)	$\lvert S_{11}\rvert$ (dB)	Gain (dBi)	Radiation Efficiency (%)	Total Efficiency (%)
Both Diodes OFF	16.47	−12.37	7.81	95.87	73.62
One Diode is ON and One Diode is OFF	17.07	−24.85	5.37	90.2	70.4
Both Diodes ON	10.8	−16.39	7.28	92.8	69.5
	17.03	−13.4	4.37	84.8	71.8
	21.2	−24.76	6.53	90.2	67

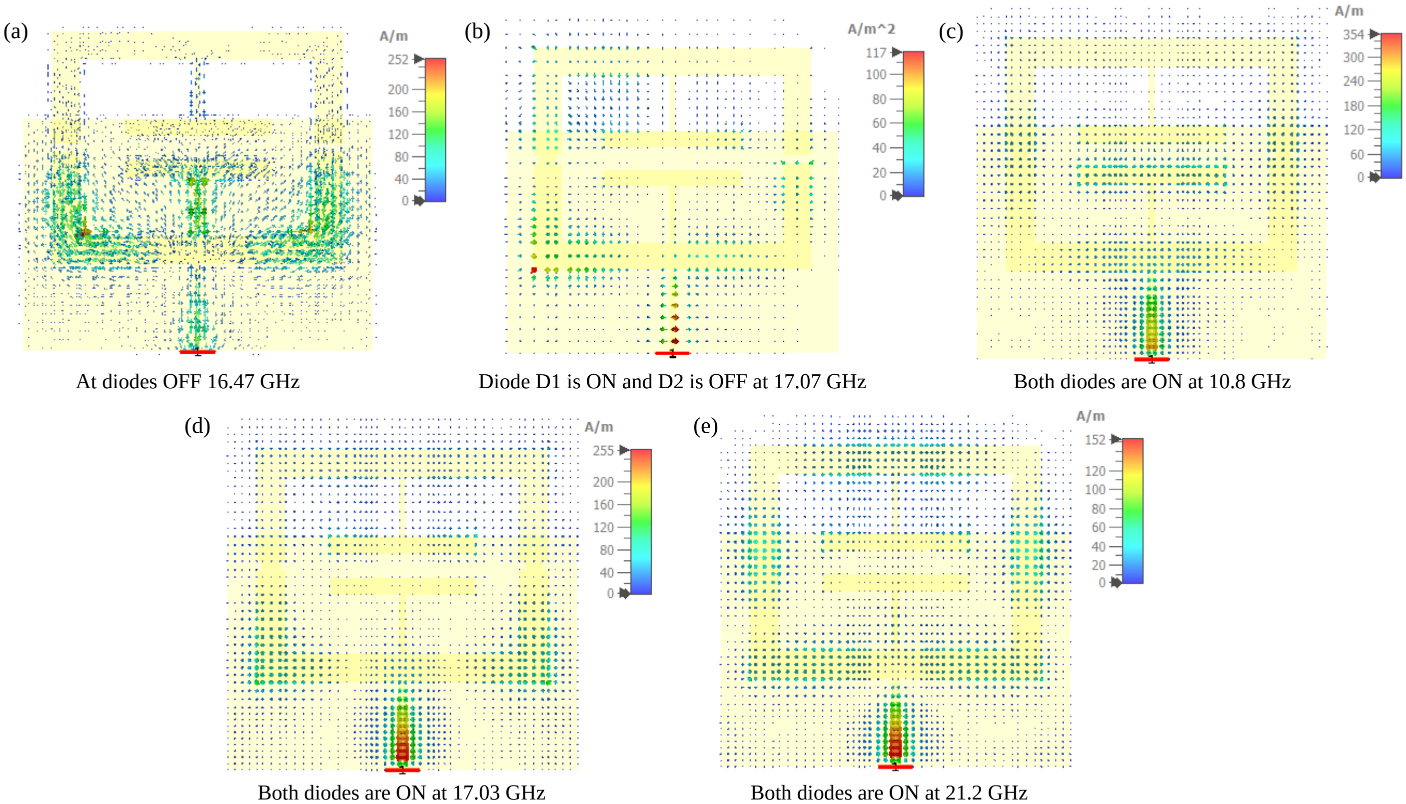


FIGURE 5. Surface current distribution of the Presented double T-shaped reconfigurable antenna in different configuration.

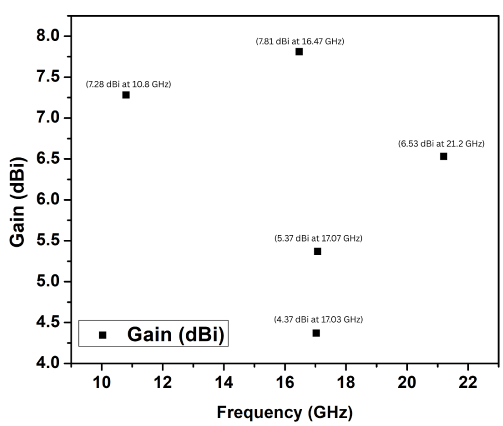


FIGURE 6. Gain vs frequency plot of the presented double T-shaped reconfigurable antenna in different configurations.

coefficients ($|S_{11}|$) when one diode is ON, and the other diode is OFF; and Figure 7(f) shows the simulated and measured reflection coefficients ($|S_{11}|$) when both diodes are ON.

A good agreement between the simulated and measured $|S_{11}|$ values is observed, as depicted in Figure 7(d) to 7(f). When both diodes (D1 and D2) are OFF, the measured resonant frequency is 16.52 GHz with an $|S_{11}|$ of -11.51 dB, while the simulated result shows 16.47 GHz with -12.37 dB. When both diodes are ON, the measured resonant frequencies are 11 GHz, 16.8 GHz, and 21.05 GHz with corresponding $|S_{11}|$ values of -15.37 dB, -12.2 dB, and -18.6 dB. The simulated results for this configuration indicate resonances at 10.8 GHz, 17.03 GHz, and 21.2 GHz with $|S_{11}|$ values of -16.39 dB, -13.4 dB, and -24.76 dB, respectively.

When one diode is ON (either D1 or D2), and the other is OFF, the measured resonant frequency is 16.875 GHz with an $|S_{11}|$ of -19.68 dB, while the simulated result shows a resonance at 17.07 GHz with an $|S_{11}|$ of -24.85 dB. These results demonstrate excellent impedance matching across all configurations.

The anechoic chamber measurement setup of the proposed antenna in the XZ and YZ planes, used to obtain the radiation pattern, is shown in Figure 8. Figure 9 presents the simulated and measured radiation patterns in the XZ and YZ planes of the proposed antenna for various diode configurations.

Figures 9(a)–(b) show the patterns when both diodes are OFF at 16.52 GHz, where the radiation pattern (polar plot) is directional. Figures 9(c)–(d) correspond to the case when one diode is ON, and the other is OFF at 16.87 GHz, resulting in an omnidirectional radiation pattern.

When both diodes are ON, the radiation patterns are illustrated in Figures 9(e)–(f) at 11 GHz, Figures 9(g)–(h) at 16.8 GHz, and Figures 9(i)–(j) at 21.05 GHz. The antenna exhibits an omnidirectional radiation pattern at 11 GHz [Figures 9(e)–(f)] and at 16.8 GHz [Figures 9(g)–(h)], whereas a directional pattern is observed at 21.05 GHz [Figures 9(i)–(j)].

The simulated and measured results of the proposed double T-shaped reconfigurable antenna under different diode configurations are presented in Table 3.

TABLE 3. Obtained simulated and measured results of the proposed double T-shaped reconfigurable antenna in different configurations.

Diode Configurations	Operating Frequency (GHz)		Reflection Coefficient $\|S_{11}\|$ (dB)		Gain (dBi)	
	Simulated	Measured	Simulated	Measured	Simulated	Measured
Both Diodes OFF	16.47	16.52	−12.37	−11.51	7.81	6.16
Both Diodes ON	10.8	11	−16.39	−15.37	7.28	5.57
	17.03	16.8	−13.4	−12.2	4.37	4.36
	21.2	21.05	−24.76	−18.6	6.53	6.57
One Diode is ON and One Diode is OFF	17.07	16.875	−24.85	−19.68	5.37	5.02

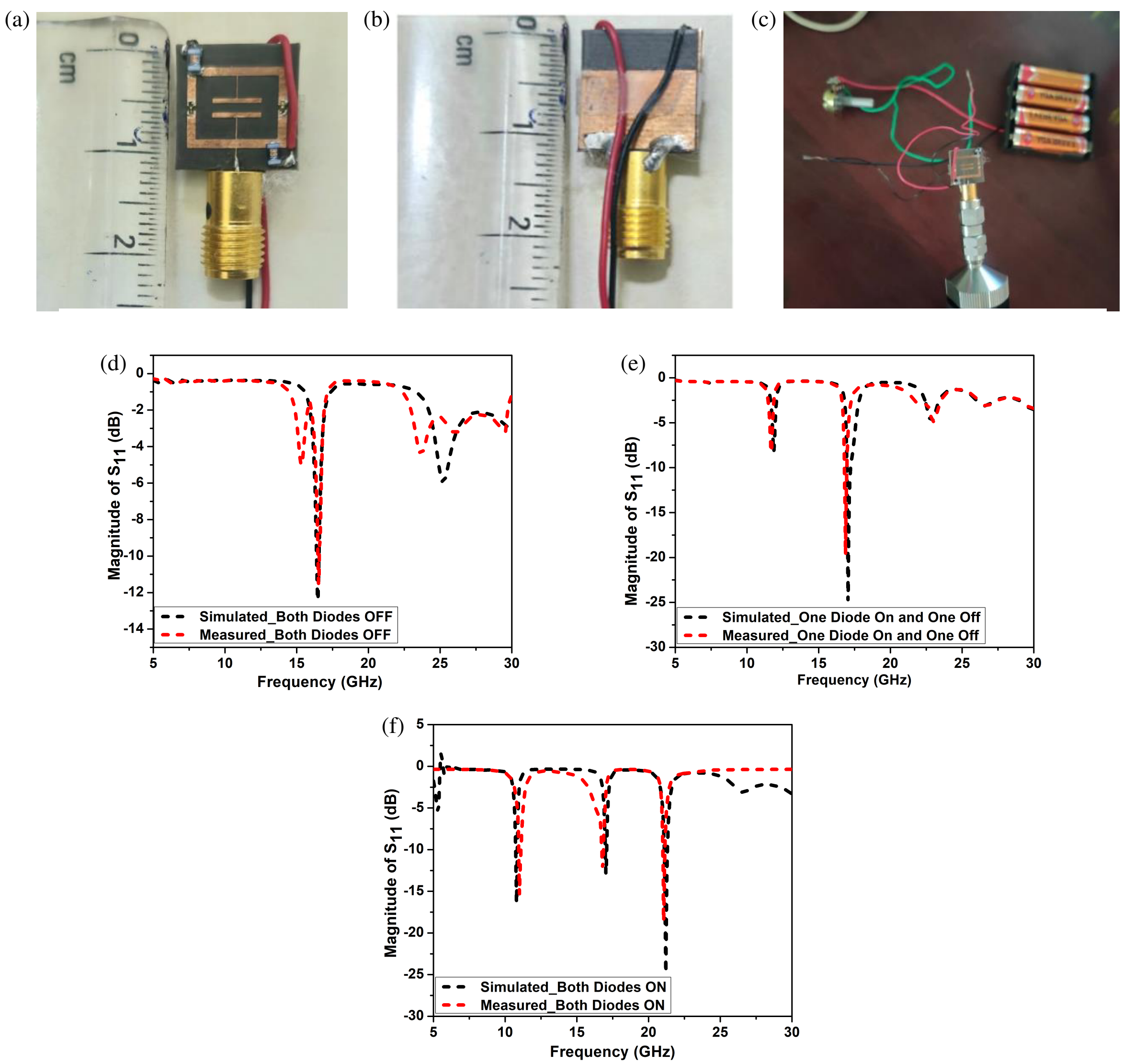


FIGURE 7. Proposed fabricated double T-shaped reconfigurable antenna, (a) front view, (b) back view, (c) antenna measurement setup for reflection coefficient ($|S_{11}|$), (d) simulated and measured reflection coefficient ($|S_{11}|$) when both diodes are OFF, (e) simulated and measured reflection coefficient ($|S_{11}|$) when one diode is ON and another diode is OFF, (f) simulated and measured reflection coefficient ($|S_{11}|$) when both diodes are ON.

TABLE 4. Comparative analysis of double T-shaped reconfigurable antenna work with existing works.

Ref/Year	Size (in mm^3)	No. of Operating Frequency	Operating Frequencies (in GHz)	Best Reflection Cofficient $\|S_{11}\|$ Value (in dB)	Peak Gain (in dBi)	Type of Reconfigurable Switch	No. of Switches	Applications
[18]/2020	30 × 15 × 1.6	5	2.4, 5.8, 3.3, 3.5, 5	−18 dB at 5.5 GHz	—	PIN Diode	3	Portable Devices
[19]/2021	30 × 23 × 1.6	5	26.3, 27, 27.2, 27.8, 28.7	−24 dB at 27.2 GHz	4 dBi at 27.8 GHz	PIN Diode	2	5G Wireless Communications
[20]/2022	120 × 60 × 1.575	6	0.94, 3.95, 4.75, 1.85, 2.55, 4.75	−38 dB at 0.94 GHz	2.97 dBi at 1.85 GHz	PIN Diode	2	Sub-6 GHz 5G Mobile Terminal
[21]/2024	22 × 18 × 1.6	10	3.16, 3.19, 3.27, 3.3, 7.57, 7.61, 7.84, 7.79, 10.55, 11.58	−40 dB at 11.58 GHz	3.04 dBi at 11.58 GHz	PIN Diode	2	5G sub-6 GHz Wireless Communication
[22]/2024	15 × 21 × 1.6	6	7.29, 2.47, 5.29, 7.2, 3.2, 5.42	−33 dB at 7.2 GHz	3.38 dBi at 7.2 GHz	PIN Diode	2	Wireless Communication
[27]/2025	40 × 70 × 1.6	4	3.70, 5.97, 9.72, 12.86	−37.5 dB at 9.72 GHz	5.36 dBi at 12.86 GHz	PIN Diode	2	Wireless Applications
double T Shaped reconfigurable antenna	12 × 12 × 0.79	5	10.8, 16.47, 17.03, 17.07, 21.2	−24.76 dB at 21.2 GHz	7.81 dBi at 16.47 GHz	PIN Diode	2	X band, Ku band, K band and 5G bands

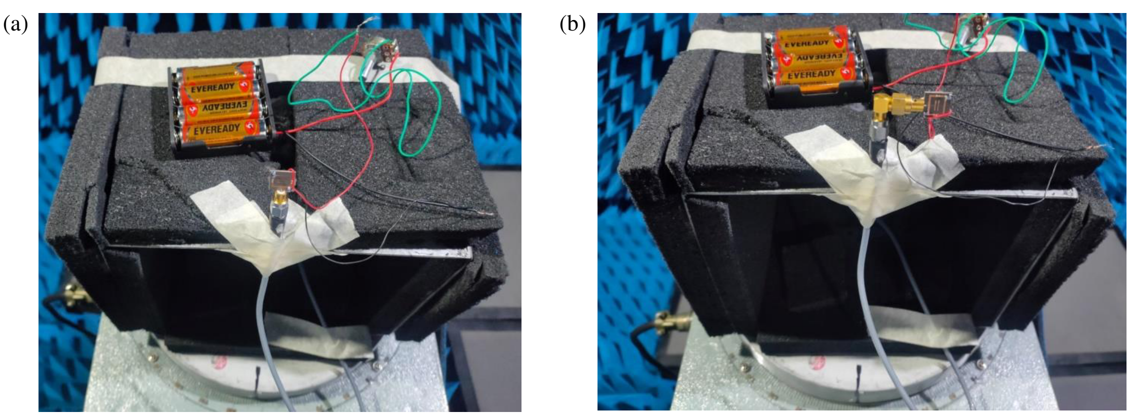
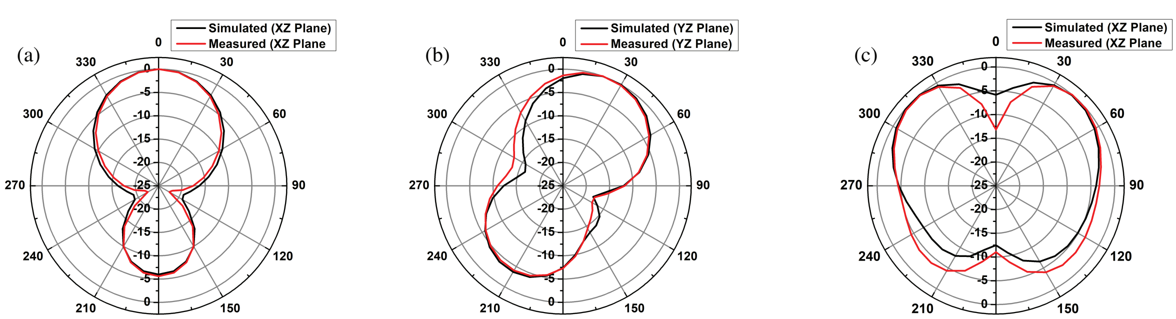


FIGURE 8. Proposed antenna measurement setup in aniconic chamber.



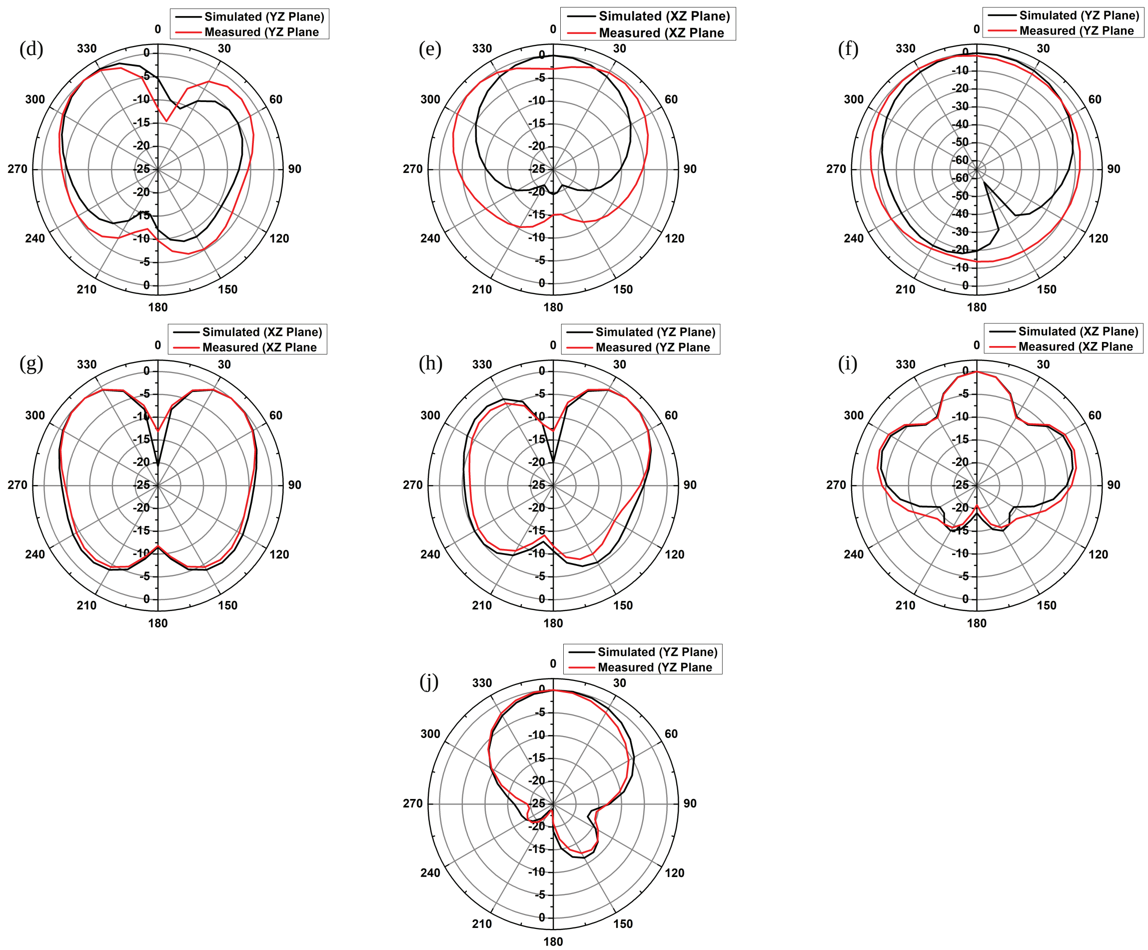


FIGURE 9. Simulated and measured radiation patterns in XZ and YZ planes of the proposed antenna (a)–(b) when both diodes are off at 16.52 GHZ, (c)–(d) when one diode is ON and one diode is OFF at 16.87 GHz, when both diodes are ON (e)–(f) at 11 GHz, (g)–(h) at 16.8 GHz, (i)–(j) at 21.05.

The presented double T-shaped reconfigurable antenna achieves five different operating frequencies through the functionality of two PIN diodes. The antenna has a compact overall dimension of $12 \times 12 \times 0.79\,\text{mm}^3$, making it smaller than the previously reported designs in [18–22, 27] as summarized in Table 4. The antenna exhibits a peak gain of 7.81 dBi at 16.47 GHz, which is a higher peak gain than the antennas reported in [18–22, 27]. While the number of operating frequencies in the presented design is equal to or greater than those reported in [18, 19, 27], the designs in [20–22] do offer a higher number of operating frequencies. However, those antennas suffer from lower gain and larger overall size than the proposed design. A comparative study of the proposed double T-shaped reconfigurable antenna's performance against various related existing works from different researchers is presented in Table 4, highlighting its advantages in terms of compact size, high gain, and efficient frequency reconfigurability.

4. CONCLUSION

Reconfigurable antennas play a crucial role in modern wireless communication systems due to their ability to dynamically adjust frequency, radiation patterns, and polarization, enabling multiple functions within a single device. With the continuous growth of applications and user demands, the need for versatile and multifunctional antennas has become increasingly important. In this work, a compact double T-shaped frequency reconfigurable antenna is presented for multiband 5G wireless communication, featuring an overall size of $12 \times 12 \times 0.79\,\text{mm}^3$. The antenna was designed and simulated using CST Microwave Studio software. To achieve frequency reconfigurability, two MA4SPS402 PIN diodes were integrated into the antenna design. By configuring these two PIN diodes in four different switching states (ON/OFF combinations), the antenna successfully operates at five distinct frequencies across the 10 GHz to 22 GHz range effectively covering various wireless communication modes: X band, Ku band, K band, and 5G bands. The proposed antenna achieves the best simulated reflection coefficient ($|S_{11}|$) of -24.76 dB at 21.2 GHz and a peak gain of 7.81 dBi at 16.47 GHz. The fabricated prototype was measured using a VNA and an anechoic chamber, with the measured $|S_{11}|$ and gain results closely matching the simulations, confirming the antenna's reliability and suitability for 5G applications.

REFERENCES

[1] Ramahatla, K., M. Mosalaosi, A. Yahya, and B. Basutli, "Multiband reconfigurable antennas for 5G wireless and CubeSat appli-

cations: A review," *IEEE Access*, Vol. 10, 40 910–40 931, 2022.

[2] Rawat, A., G. K. Soni, D. Yadav, and M. Tiwari, "Design of high gain and wideband mmwave antenna for LMDS and Ka-band 5G applications," in *2023 International Conference on Sustainable Communication Networks and Application (ICSCNA)*, 117–121, Theni, India, 2023.

[3] Kumar, A., M. Aljaidi, I. Kansal, K. Alshammari, G. Gupta, and S. M. Alenezi, "Recent trends in reconfigurable antennas for modern wireless communication: A comprehensive review," *International Journal of Antennas and Propagation*, Vol. 2024, No. 1, 8816812, 2024.

[4] Shah, I. A., S. Hayat, A. Basir, M. Zada, S. A. A. Shah, S. Ullah, and S. Ullah, "Design and analysis of a hexa-band frequency reconfigurable antenna for wireless communication," *AEU — International Journal of Electronics and Communications*, Vol. 98, 80–88, 2019.

[5] Suryapaga, V. and V. V. Khairnar, "Review on multifunctional pattern and polarization reconfigurable antennas," *IEEE Access*, Vol. 12, 90 218–90 251, 2024.

[6] Jenath, M. and V. Nagarajan, "Review on frequency reconfigurable antenna for wireless applications," in *2017 International Conference on Communication and Signal Processing (ICCSP)*, 2240–2245, Chennai, India, 2017.

[7] Mohan, R. K. A. 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, 91–114, 2022.

[8] Tiwaria, A., M. Y. Yilmaz, G. K. Soni, and D. Yadav, "Multiband reconfigurable antenna with CPW feed and PIN diode switches: Design considerations and performance evaluation," in *2024 5th International Conference on Smart Electronics and Communication (ICOSEC)*, 125–128, Trichy, India, 2024.

[9] Kumar, P. R., P. Sunitha, and M. V. Prasad, "Compact reconfigurable patch antenna for wirelesss applications," *Progress In Electromagnetics Research C*, Vol. 138, 161–174, 2023.

[10] Fischer-Kennedy, S. B. and J. Hesselbarth, "Generalized approach to antenna reconfigurability by switching load admittances," *Progress In Electromagnetics Research B*, Vol. 102, 151–169, 2023.

[11] Tiwari, A., D. Yadav, P. Sharma, and M. V. Yadav, "Design of wide notched-band circular monopole ultra-wideband reconfigurable antenna using PIN diodes switches," *Progress In Electromagnetics Research C*, Vol. 139, 107–118, 2024.

[12] Tiwari, A., 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, 104339, 2025.

[13] Yadav, D., 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 *Optical and Wireless Technologies: Proceedings of OWT 2017*, 647–654, Singapore, 2018.

[14] Han, L., C. Wang, X. Chen, and W. Zhang, "Compact frequency-reconfigurable slot antenna for wireless applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 15, 1795–1798, 2016.

[15] Nafde, Y. and R. Pande, "Design and analysis of resistive series RF MEMS switches based fractal U-slot reconfigurable antenna," *Wireless Personal Communications*, Vol. 97, No. 2, 2871–2886, 2017.

[16] Kumar, P., S. Dwari, R. K. Saini, and M. K. Mandal, "Dual-band dual-sense polarization reconfigurable circularly polarized antenna," *IEEE Antennas and Wireless Propagation Letters*, Vol. 18, No. 1, 64–68, Jan. 2019.

[17] El Hadri, D., A. Zakriti, and A. Zugari, "Reconfigurable antenna for Wi-Fi and 5G applications," *Procedia Manufacturing*, Vol. 46, 793–799, 2020.

[18] Ghaffar, A., 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)*, 1–4, Glasgow, UK, 2020.

[19] Alekhya, B., N. A. Murugan, B. T. P. Madhav, and N. K. R. Reddy, "Millimeter-wave reconfigurable antenna for 5G wireless communications," *Progress In Electromagnetics Research Letters*, Vol. 101, 107–115, 2021.

[20] Padmanathan, S., A. A. Al-Hadi, A. M. Elshirkasi, S. S. Al-Bawri, M. T. Islam, T. Sabapathy, M. Jusoh, P. Akkaraekthalin, and P. J. Soh, "Compact multiband reconfigurable MIMO antenna for sub-6 GHz 5G mobile terminal," *IEEE Access*, Vol. 10, 60 241–60 252, 2022.

[21] El Aoud, S. E., H. Abbaoui, O. Benkhadda, S. Attioui, N. E. Assri, S. Ibnyaich, A. Zeroual, M. M. Ismail, and A. J. A. Al-Gburi, "Design of a crescent moon-shaped reconfigurable patch antenna using a PIN diode for 5G sub-6 GHz and multistandard wireless applications," *Progress In Electromagnetics Research B*, Vol. 109, 81–93, 2024.

[22] Benkhadda, O., M. Saih, A. Reha, S. Ahmad, K. Chaji, H. Singh, and A. J. A. Al-Gburi, "A miniaturized reconfigurable antenna for modern wireless applications with broadband and multi-band capabilities," *Progress In Electromagnetics Research M*, Vol. 127, 93–101, 2024.

[23] Varshney, A., T. M. Neebha, V. Sharma, J. G. Jency, and A. D. Andrushia, "Dodecagon-shaped frequency reconfigurable antenna practically loaded with 3-delta structures for ISM band and wireless applications," *IETE Journal of Research*, Vol. 69, No. 11, 7747–7759, 2023.

[24] Varshney, A., T. M. Neebha, V. Sharma, and A. D. Andrushia, "Low-cost L-band to Ku-band frequency reconfigurable BAR64-02V controlled antenna for satellite, military, and radar applications," *IETE Journal of Research*, Vol. 70, No. 6, 5558–5571, 2024.

[25] https://www.macom.com/products/product-detail/MA4SPS402.

[26] Gupta, K. C., R. Garg, I. J. Bhal, and P. Bhartia, *Microstrip Lines and Slotlines*, 2nd ed., 10–15, Artech House, 1996.

[27] Marzouk, M., I. H. Nejdi, Y. Rhazi, M. Saih, J. A. Nasir, A. Daher, M. Hussein, Z. Zakaria, and A. J. A. Al-Gburi, "Low-profile reconfigurable UWB fractal antenna enhanced by parasitic elements for wireless applications," *Progress In Electromagnetics Research Letters*, Vol. 126, 37–48, 2025.