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DESIGN OF FREQUENCY RECONFIGURABLEMICROSTRIP PATCH ANTENNA FOR ULTRA WIDE BANDCOMMUNICATION SYSTEM

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***Abstract*—In contemporary communication systems, there's a growing need for antennas that are both portable and versatile, covering a broad range of frequencies. The proposed antenna features a dual-notch-band rectangular configuration, utilizing microstrip feed lines and printed on a Rogers RT Duroid 5880 substrate with a permittivity (εr) of 2.2 and dimensions measuring 30 × 26.40 mm². To achieve dual-band notched characteristics, the antenna structure incorporates notches or gaps, typically arranged in a three step staircase pattern. The measured performance indicates that the antenna provides bandwidth coverage for VSWR < 2 across the entire UWB band from 3.1 GHz to 10.6 GHz. Its suitability extends to various applications. At 5.734 GHz, it is used for Wi-Fi communication for networks in residential, commercial, and public settings, as well as wireless LANs in enterprise environments and point-to-point links for outdoor networking. At 9.343 GHz, it is used in radar systems for weather monitoring, air traffic control, and military applications, and in satellite communications for uplink and downlink operations within specific satellite bands. The antenna's reconfigurability allows for adjustments in radiation pattern, frequency response, polarization, and other characteristics without the need for physical modifications. The simulated results, obtained using CST STUDIO SUITE 2023, demonstrate various parameters such as return loss, VSWR, gain, and radiation pattern. This research contributes significantly to the evolution of wideband antennas, meeting the escalating demand for dependable and high-performance communication systems across diverse modern applications.**

***Keywords*—VSWR, FR4, dual-notch band, bandwidth, reconfigurability.**

I. INTRODUCTION

In today's landscape of wireless communication systems, the demand for rapid data transmission with minimal interference has skyrocketed, necessitating the development of efficient antenna systems. Ultra-wideband (UWB) communication, characterized by its transmission across a broad spectrum with low power spectral density, has unlocked diverse applications such as high-data-rate wireless networks and radar systems. Microstrip patch antennas is used for UWB applications due to their compactness, ease of fabrication, and compatibility with integrated circuits. Reconfigurability in this context denotes the antenna's ability to dynamically adjust its parameters to adapt to different operating conditions. Leveraging advanced design techniques and optimization algorithms, the study aims to elevate antenna performance specifically for UWB applications.

Moreover, the International Society of Automation (ISM) band, particularly the 5.734 GHz frequency range, plays a pivotal role in modern wireless communication. The 5.734 GHz band is widely utilized for various applications, including but not limited to Wi-Fi networks, point-to-point communication links, and unmanned aerial vehicle (UAV) control systems. Additionally, the 9.34 GHz frequency band is gaining traction for high-frequency point-to-point communication, especially in scenarios where heightened throughput and performance are imperative. These frequency bands offer unique opportunities for deploying reconfigurable microstrip patch antennas, further emphasizing the significance of advancing UWB applications.

II. FEEDING TECHNIQUE

Microstrip inline feeding is a feeding technique commonly used in antenna design, where the signal is fed directly into the antenna structure via a microstrip transmission line as shown in fig 1.

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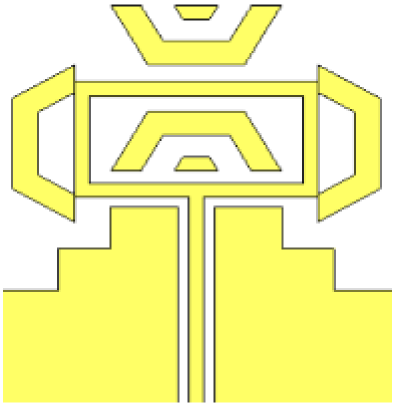


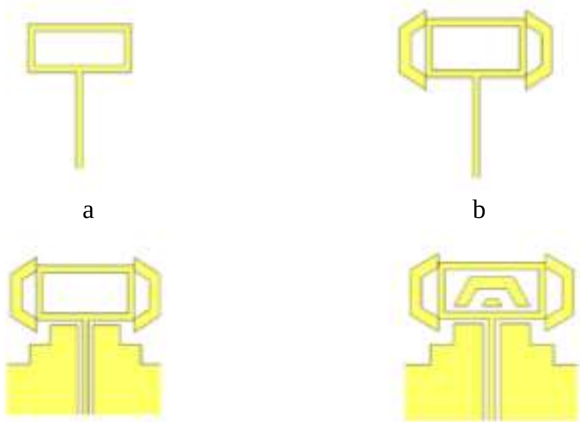
Fig. 1. Design of proposed patch antenna showing inline feed.

In this configuration, the microstrip feed line is placed in-line with the antenna element, typically located at the edge or along one side of the antenna substrate. The feed line is usually constructed from a thin strip of conductive material, such as copper, printed on a dielectric substrate. This feeding method offers several advantages. Firstly, it simplifies the antenna design, allowing for compact and lightweight structures suitable for various applications, including mobile devices, satellite communication systems, and radar systems. Additionally, microstrip inline feeding provides impedance matching between the transmission line and the antenna, enhancing signal transmission efficiency and reducing losses. Moreover, it enables precise control over the feeding point and impedance characteristics of the antenna, facilitating optimization for desired performance metrics such as bandwidth, gain, and radiation pattern.

III. ANTENNA DESIGN AND ANALYSIS

The depicted design, illustrated in Figure 1, employs Rogers RT Duroid 5880 as its substrate material. With a dielectric constant of 2.2 and a loss tangent of 0.0009, the substrate boasts a thickness of 0.408 mm. Notably, the antenna's dimensions are kept compact, measuring 30 mm x 26.4 mm x0.41 mm. Furthermore, 50 Ω microstrip feed lines serve as the means of feeding the antenna.

1. *Design Process*



a b

c d

e f

Fig. 2(a)(b)(c)(d)(e)(f). Design flow of the proposed antenna model

The process of designing the antenna encompasses a series of iterative steps aimed at refining performance and achieving specific design objectives.

Commencing with Fig. 1(a), the initial stage involves creating a fundamental hollowed rectangular patch antenna, serving as a foundational reference for subsequent enhancements.

In Fig. 1(b), further modification is introduced with the addition of an outer resonator featuring semi-hexagonal arcs, expanding the antenna's resonance capabilities. This addition not only broadens the frequency bandwidth but also enhances the antenna's impedance matching with the feedline, contributing to improved overall performance.

Progressing to Fig. 1(c), refinement continues with the implementation of three-step staircase cuts flanking the feed, refining impedance matching and radiation characteristics. These cuts help to reduce unwanted radiation patterns and improve the antenna's directivity.

Fig. 1(d) introduces inner resonators in the form of two semi-circular patches within the hollow rectangle, enhancing resonance and directional properties. These inner resonators aid in shaping the radiation pattern and increasing the antenna's gain, particularly in specific directions of interest.

In Fig. 1(e), the design evolves further with the addition of outer resonators, comprising two semi-circular patches positioned above the hollow rectangle to broaden resonance and directional coverage. These outer resonators serve to further shape the radiation pattern and enhance gain, particularly in other desired directions.

In Fig. 1(f), the integration of two lumped elements below each other contributes to fine-tuning impedance and resonance characteristics. Lumped elements, discrete components representing inductors or capacitors, are strategically placed to adjust electrical properties without distributed effects. These components enable precise control over impedance matching and resonance, which is crucial for optimizing antenna performance.

The finalization phase involves selecting an optimal microstrip feed for seamless integration and superior performance.

2. *Design of proposed antenna*

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The CPW feed line, with a width of 1 mm, is linked to the main radiator. Connection between the inner and outer radiators to the main radiator is facilitated by switches S1 and S2. The introduction of semi-hexagonal structures inside and outside the main radiator aims to broaden resonance frequencies. The slot width serves to regulate current intensity and minimize return loss, thereby optimizing antenna performance. In the design process, the implementation of switches using the lumped element boundary condition in CST Studio Suite 2023 enhances versatility and control over antenna characteristics. The absence of lumped elements results in S-parameter values of -45.580 and -45.334 at 5.734 GHz and 9.343 GHz, respectively. The corresponding VSWR values are 1.0105 and 1.0108. A gain of 3.86 is achieved at 5.5 GHz.

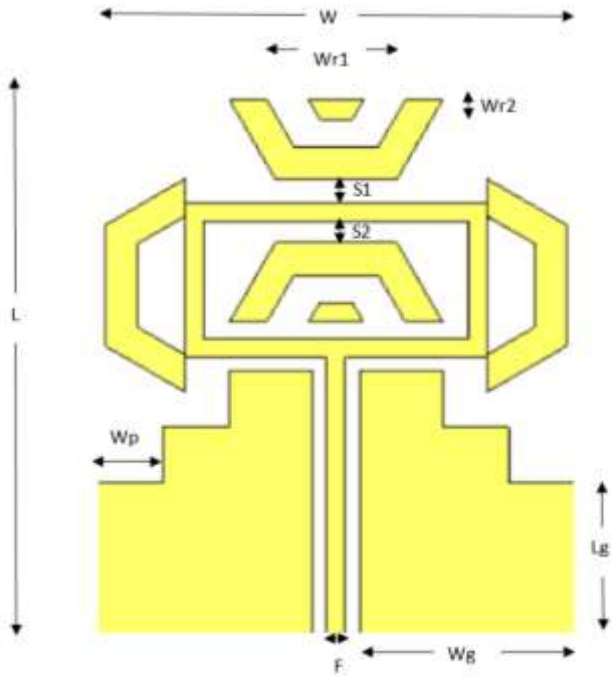

Fig. 3. Geometry of the proposed reconfigurable antenna

TABLE 1.

PARAMETER DESCRIPTION

S No.	Description	Parameter	Value/ mm
1	Length of the substrate	L	30.00
2	Width of the substrate	W	26.40
3	Length of the single step	Lg	10.14
4	Width of the staircase cut	Wg	11.19
5	Width of the single step	Wp	3.80
6	Outer diameter of the radiator	Wr_1	2.91
7	Inner diameter of the radiator	Wr_2	1.75
8	Width of the feed line	F	1.00
9	Spacing between the outer radiator and feed	S_1	1.24
10	Spacing between the inner radiator and feed	S_2	1.16

IV. SIMULATION AND RESULT

1. *Enhancing Reconfiguration for Optimal Performance*

In this section, the simulated results for S-parameters, voltage standing wave ratio (VSWR), gain, and radiation fields are presented.

TABLE2.

DIFFERENTOPERATINGSTATESWITHTHEIRCHARACTERISTICS

Switch States	Operating Frequency (GHz)	Return loss (dB)	VSWR	Gain (dBi) At 5.5 GHz
OFF-OFF	5.617, 9.316	-51.522, -66.695	1.005, 1.0009	3.86
OFF-ON	8.901	-18.119	1.283	3.29
ON-OFF	4.159, 6.784	-22.810, -15.857	1.156, 1.384	2.3
ON-ON	3.593, 6.396 8.9014	-14.400, -24.760 -21.044	1.470, 1.127 1.194	6.03

When both switches are off, the antenna operates at frequencies of 5.617 GHz and 9.316 GHz. The S-parameter values at these frequencies are -51.522 dB and -66.695 dB respectively. The VSWR values are 1.005 at 5.617 GHz and 1.0009 at 9.316 GHz, indicating excellent impedance matching. Additionally, the gain of the antenna at these frequencies is 3.86 dBi, demonstrating its ability to efficiently radiate electromagnetic energy. At 5.617 GHz, the antenna is ideal for point-to-point communication links in wireless networks, enabling high-speed data transfer over long distances, commonly used in telecommunications and backhaul connections. On the other hand, at 9.316 GHz, the antenna finds application in satellite communication systems, facilitating communication between satellites and ground stations for satellite television broadcasting, internet connectivity, and satellite phone services. Additionally, both frequencies are suitable for radar systems used in surveillance, weather monitoring, and military applications, where the antenna's performance ensures efficient signal transmission and reception.

When the antenna is in the OFF-ON state, operating at a frequency of 8.901 GHz, it exhibits characteristics suitable for various applications. With a VSWR of 1.283, indicating good impedance matching, the antenna is well-suited for radar systems, where low reflection coefficients are crucial for accurate detection and tracking of targets in weather monitoring, air traffic control, and military surveillance. It also finds application in satellite communication systems, contributing to efficient uplink and downlink communication between satellites and ground stations. The antenna's performance in the OFF-ON state, with a gain of 3.29 dBi, ensures reliable signal transmission and reception across these diverse applications.

In the ON-OFF state, the antenna operates at frequencies of 4.159 GHz and 6.784 GHz. At 4.159 GHz, the antenna exhibits an S-parameter value of -22.810 dB and a VSWR of 1.156, while at 6.784 GHz, the S-parameter value is -15.857 dB with a VSWR of 1.384. The antenna's gain at these frequencies is2.3dBi. At 4.159 GHz, the antenna is suitable for short-range communication systems used in smart home devices, wearables, and industrial automation. With its moderate gain and good impedance matching, the antenna ensures efficient communication over short distances. At 6.784 GHz, the antenna is ideal for wireless sensor networks used in environmental monitoring, asset tracking, and industrial automation. Its characteristics enable reliable transmission of sensor data, contributing to efficient and accurate monitoring and control systems.

In the ON-ON state, the antenna operates at frequencies of 3.593 GHz, 6.396 GHz, and 8.9014 GHz. At 3.593 GHz, the antenna exhibits an S-parameter value of -14.400 dB and a VSWR of 1.470, while at 6.396 GHz, the S-parameter value is -24.760 dB with a VSWR of 1.127. Additionally, at 8.9014 GHz, the S-parameter value is -21.044 dB with a VSWR of 1.194. The antenna's gain at these frequencies is 6.03 dBi. These characteristics make the antenna suitable for applications such as broadband communication systems, satellite communication, and radar systems. At 3.593 GHz and 6.396 GHz, the antenna can be utilized in broadband communication systems for high-speed data transfer over a wide frequency range, ensuring efficient communication across different channels. At 8.9014 GHz, the antenna finds application in satellite communication systems, facilitating reliable uplink and downlink communication between satellites and ground stations. Moreover, the antenna's performance in the ON-ON state, with a high gain of 6.03 dBi and good impedance matching, makes it suitable for radar systems, where accurate detection and tracking of targets are essential for applications such as weather monitoring, air traffic control, and military surveillance.

2. *Results and discussion*

(a) S-parameters:

S-parameters describe how an antenna transmits and reflects signals. They are crucial for assessing signal integrity and antenna performance.

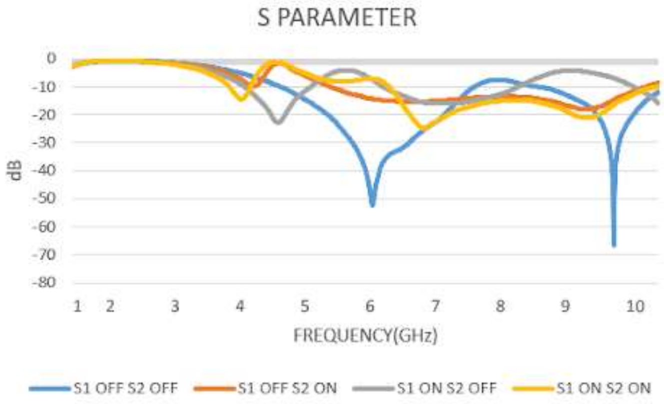

Fig. 4. S-parameter Analysis for Various Pin Diode Configurations

(b) VSWR (Voltage Standing Wave Ratio):

VSWR measures the extent of the impedance mismatch between the antenna and the transmission line. It directly affects signal transmission efficiency and power loss. This antenna design exhibits low VSWR values, indicating excellent impedance matching and minimal power loss.

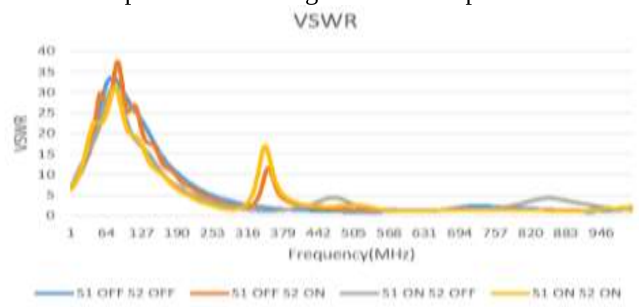

Fig. 5. Voltage Standing Wave Ratio Analysis for Various Pin Diode Configurations

(c) Gain:

Antenna gain quantifies its ability to direct power in a specific direction compared to an isotropic radiator. The design achieves satisfactory gain values, ensuring reliable signal propagation and reception. Variations in gain across different switch configurations highlight the antenna's adaptability and performance optimization capabilities.

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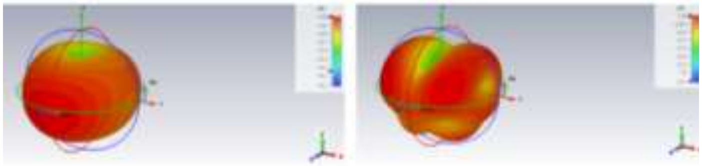
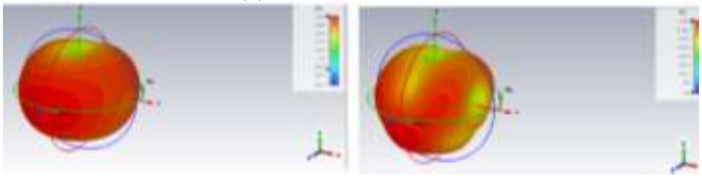
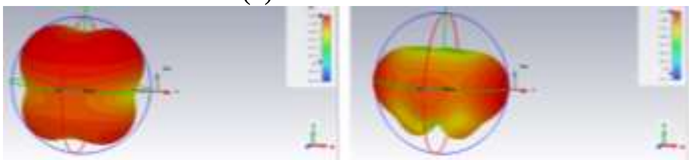


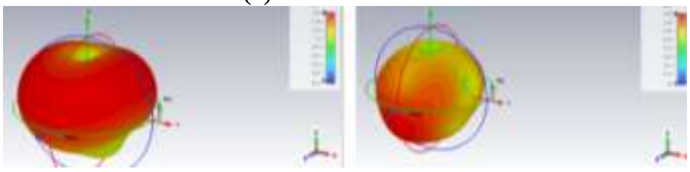
(a)S1 OFF S2 OFF



(b)S1 OFF S2 ON



(c)S1 ON S2 OFF



(d)S1 ON S2 ON

Fig. 6 (a)(b)(c)(d). GainAnalysis for Various Pin Diode Configurations at 5.5 GHz and 9.5 GHz, respectively.

V. CONCLUSION

VI. In this paper, a reconfigurable ultra-wideband (UWB) antenna design has been proposed using two PIN diodes. This antenna exhibits 7 resonant frequencies at 5.617 GHz and 9.316 GHz, 4.159 GHz, 6.784 GHz, 3.593 GHz, 6.396 GHz, and 8.9014 GHz. It achieves gains ranging from 2.3 dB to 6.03 dB, with low VSWR values between 1.01 and 1.49, indicating efficient bandwidth utilization and excellent impedance matching. The antenna's radiation patterns and directions are tailored for Wi-Fi, WiMAX, and radar wireless communications. Detailed S-parameter analysis confirms effective signal propagation and reception across the switch states, offering insights into its performance characteristics. The proposed design, with its simplicity and frequency reconfigurability, presents a promising solution for modern communication and radar applications. Its adaptability to various frequency bands and communication standards makes it ideal for multi-input, multi-output (MIMO) systems, ensuring flexibility and efficiency in wireless communication systems. Thus, this frequency-reconfigurable micro-strip patch antenna demonstrates outstanding performance across multiple configurations, presenting a unique and effective solution for diverse communication applications.

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