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Design and Analysis of a CPW-Fed Slit-Loaded MIMO Antenna for Wi-Fi Applications

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Abstract: This paper proposes the design and evaluation of a compact coplanar waveguide (CPW)-fed multi-band MIMO antenna specifically optimized for contemporary Wi-Fi applications, encompassing IEEE 802.11b/g/n as well as the latest Wi-Fi 6 and 6E (802.11ax) standards. The proposed antenna comprises a CPW-fed circular patch radiator with a strategically embedded slit to enable multi-band operation. The design evolution—from a basic circular patch to a slit-loaded configuration—demonstrates how resonant modes in the 2.4 GHz, 5-7.1GHz bands are efficiently excited within a compact planar footprint. The final single-element antenna achieves effective impedance matching across the target bands with reflection coefficients better than -10 dB, making it suitable for integration in compact wireless systems. A four-port MIMO configuration is realized by optimizing element placement and incorporating spatial and polarization diversity to ensure low mutual coupling (< -20 dB) and high isolation. The proposed antenna achieves high diversity gain (> 9.9 dB) and envelope correlation coefficient (ECC < 0.005), confirming its suitability for robust multi-band MIMO performance. Simulated and measured results validate that the design meets the requirements for next-generation Wi-Fi communication systems in terms of bandwidth, compactness, isolation, and diversity performance.

Keywords: CPW-fed antenna, multi-band antenna, MIMO systems, Wi-Fi, Compact antenna design, Mutual coupling reduction

1. Introduction:

The exponential growth of wireless communication technologies has driven the need for compact, efficient, and wideband antenna systems. Among various wireless technologies, Wi-Fi—particularly IEEE 802.11b/g/n and the advanced Wi-Fi 6/6E (802.11ax)—plays a crucial role in delivering high-speed, low-latency connectivity for applications such as smart homes, industrial automation, healthcare, and mobile communication devices [1], [2]. These standards operate across multiple frequency bands: 2.4 GHz for legacy Wi-Fi and 5–7 GHz for the latest Wi-Fi 6/6E, necessitating antenna designs capable of multiband operation while maintaining high efficiency, good isolation, and minimal form factor [3].

To meet the demands of high data throughput, reliable connectivity, and high spectral efficiency, Multiple-Input Multiple-Output (MIMO) technology is widely adopted. MIMO antenna systems exploit spatial diversity to improve channel capacity and reduce multipath fading, without increasing bandwidth or transmission power [4]. However, integrating multi-band MIMO antennas into compact wireless devices is challenging due to space limitations and mutual coupling effects, which can significantly degrade system performance [5].

The use of Coplanar Waveguide (CPW) feeding techniques offers a promising solution for compact antenna integration. CPW-fed structures feature low radiation loss, broad bandwidth, uniplanar geometry, and simplified fabrication, making them suitable for printed MIMO antenna designs [6]. Additionally, CPW-fed antennas provide better impedance matching and are well-suited for integration with monolithic microwave integrated circuits (MMICs) [7-9].

In [10], a compact 4-port ultra-wideband (UWB) MIMO antenna based on CPW feed and orthogonal element placement was proposed. Although it achieved good isolation and wide bandwidth, it lacked selective multi-band operation, leading to unnecessary interference in targeted Wi-Fi bands. Similarly, in [11] presented a metasurface-based 4T4R MIMO antenna operating in the 2.7–4.7 GHz range, utilizing dumbbell-shaped slots and artificial surfaces. While this approach yielded high isolation (>23 dB) and low ECC, the design required a large substrate size (178×178 mm²), making it unsuitable for space-constrained applications.

The paper [12] proposed a sub-6 GHz MIMO antenna with compact size and good isolation; however, it only covered the 3.2–5.6 GHz band, omitting the 2.4 GHz band critical for legacy Wi-Fi systems. A more recent study by paper [13] addressed triple-band operation for Wi-Fi 5/6, but relied on complex P-stub structures and multilayer layouts, increasing fabrication complexity and cost.

Fractal and monopole-based CPW-fed MIMO designs [14,15] have also been reported for Wi-Fi and UWB applications. These antennas benefit from wide impedance bandwidth but generally suffer from high mutual coupling, unless advanced decoupling structures like defected ground or electromagnetic bandgap (EBG) surfaces are incorporated. These additional features often increase the profile and cost of the antenna system. In [16], a filtering monopole MIMO antenna was introduced using microstrip resonators for band suppression and isolation enhancement, but the design again required large substrate space and precision tuning.

Transparent and flexible MIMO antennas for wearable and IoT applications have gained interest [17], but their limitations in terms of gain and efficiency at Wi-Fi 6E frequencies make them less applicable to high-throughput indoor networks. On the other hand, designs like [18] explored slot-based antennas with reasonable gain and isolation, but they lacked consistency across the desired multi-band spectrum and required intricate feed networks.

In comparing to the recent research, articles have focused on improving the performance and efficiency of modern communication and sensing systems through advanced computational and electromagnetic techniques. A hybrid optimization-based deep learning model (HGGO-XCovNet) has been proposed to enhance energy-efficient resource allocation in MIMO wireless networks by optimizing parameters such as SINR, data rate, and power consumption [25]. Another study presents a hybrid technique-based circularly polarized MIMO antenna designed to achieve low mutual coupling and improved performance for millimeter-wave communication systems [26]. Further work investigates advanced optical and photonic approaches to enhance signal processing and device performance in optical communication and sensing applications [27]. Machine learning-driven frameworks have also been introduced to improve the efficiency and reliability of intelligent next-generation wireless communication systems [28]. In addition, recent studies explore advanced computational and electromagnetic techniques for improving signal processing and overall system performance in communication platforms [29]. Innovative modeling and optimization strategies have also been proposed to enhance the efficiency and reliability of emerging sensing and communication technologies [30].

Based on this literature review, it is evident that most existing MIMO antenna designs either: Focus on wideband/UWB without targeting specific Wi-Fi sub-bands, require large size or complex structures, or fail to support all multi-bands simultaneously with high isolation and low ECC.

To address these gaps, this work proposes a compact 4-port CPW-fed circular patch antenna with a slit-loaded structure that:

- Supports multi-band operation for Wi-Fi 2.4/5-7.1 GHz,
- Offers excellent diversity performance with $ECC < 0.005$ and $DG > 9.99$ dB,
- Uses a simple geometry suitable for low-cost mass production.

The uniqueness of the proposed work lies in its ability to deliver multi-band operation for modern Wi-Fi, high isolation and excellent MIMO performance, —all while maintaining a compact size and low design complexity. The design does not rely on external decoupling structures, complex multilayer geometries, or active components, distinguishing it from many recent designs. This makes the proposed antenna a practical and scalable solution for integration into compact wireless devices, routers, access points, and smart IoT systems using Wi-Fi 6 and 6E technologies.

2. Proposed Antenna Design

2.1. Single element antenna geometry

The single-element antenna is designed to provide multiband performance within a compact footprint, serving as the building block for the subsequent MIMO configuration. The structure is developed using a CPW feed approach to support wideband impedance matching and facilitate a planar, integration-friendly layout.

The antenna is printed on a Rogers RT-duroid 5880LZ substrate, chosen for its efficiency and widespread availability in consumer electronics. The chosen substrate possesses a relative permittivity (ϵ_r) of 2, a thickness of 0.254 mm, and a low loss tangent of 0.0021. The proposed single element antenna geometry is shown in figure 1. The overall antenna dimensions are compact, measuring 27 mm × 20 mm, making it suitable for embedded Wi-Fi modules and its parameter values are shown in table 1.

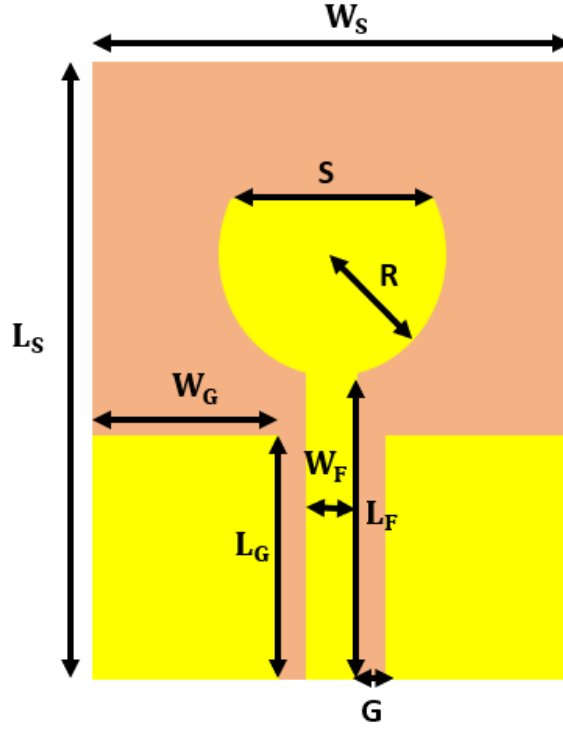


Figure 1. Proposed Single element antenna geometry

Table 1 Parameter values of proposed antenna geometry

Parameter	W_S	L_S	W_G	L_G	W_F	L_F	R	S	G
Descriptions	Width of the substrate	Length of the substrate	Width of ground	Length of ground	Width of feed	Length of the feed	Radius	Slit	Gap between feed and ground
Dimensions (mm)	20	27	6.64	8.10	4.20	13.85	6.5	11.91	1.26

The radiating element consists of a modified monopole with carefully engineered patch that induce multiple resonant modes. An inset notch is used to support operation at both the 2.4 GHz band and the 5.0–7.1 GHz band, covering Wi-Fi 802.11b/g/n and Wi-Fi 6/6E standards. The tuning of these features enables independent control over each resonant frequency.

The antenna is excited using a 50-ohm CPW feedline, which includes:

- A central signal strip of width
- Two symmetrical ground planes spaced by a gap

This arrangement supports low return loss and a simplified fabrication process, without requiring via connections or multilayer structures. CPW feeding also enhances radiation stability and suppresses spurious currents near the feed region.

Initial simulation results using CST Microwave Studio show that the antenna achieves:

- A first resonance at approximately 2.4 GHz (for 802.11b/g/n)
- A second resonance at 6 GHz (5.0 GHz and 7.1 GHz band) (for Wi-Fi 6/6E)
- Reflection coefficients better than -10 dB across all bands of interest

Figure 2 confirms that the single-element design offers effective coverage of the required Wi-Fi bands, with sufficient bandwidth and spectral separation for MIMO deployment.

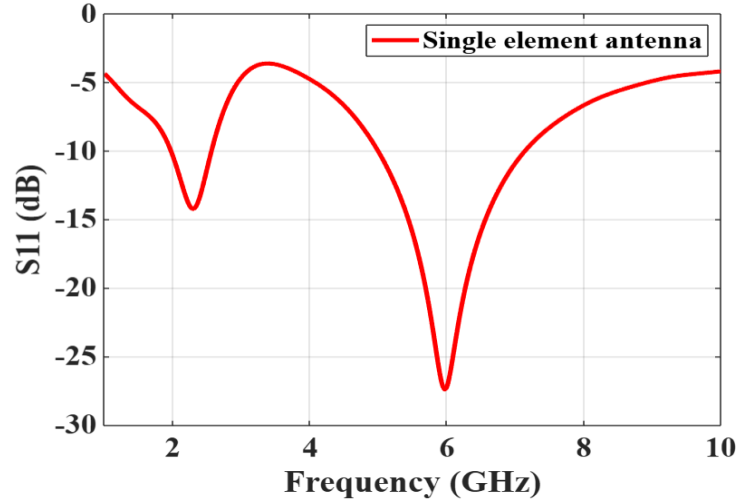


Figure 2. S-Parameter (S_{11} dB) of single port antenna

2.2. Evolution of single element antenna:

The evolution of the proposed single-element antenna design was carried out through three distinct stages to achieve compactness, multi-band operation, and enhanced impedance bandwidth required for modern Wi-Fi applications (802.11b/g/n and Wi-Fi 6/6E). The transformation process involved progressive enhancements to the radiator geometry and feeding structure.

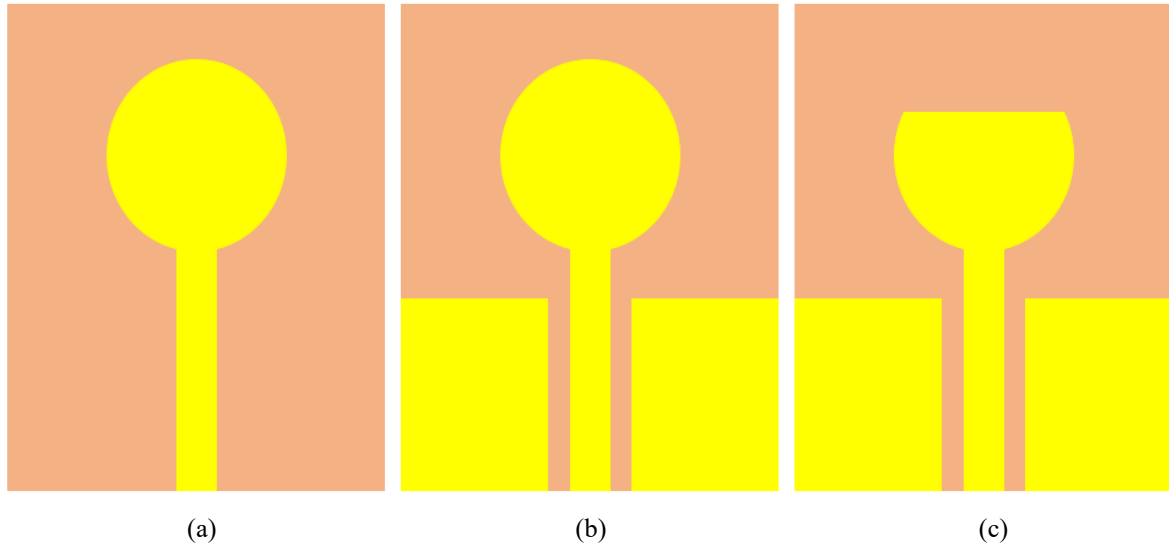


Figure 3. Stages of proposed antenna design (a) Ant_1 (b) Ant_2 (c) Ant_3

2.2.1. Stage 1: Circular Patch Antenna (Ant_1)

The initial configuration consists of a conventional circular microstrip patch antenna designed to resonate in the 2.4 GHz band. This structure was excited using a microstrip line feed shown in Figure 3a.

From figure 4,

- Achieved a single resonance at ~2.45 GHz
- Narrow bandwidth due to conventional microstrip design
- Limited tunability and unsuitable for higher-frequency Wi-Fi bands
- Inconvenient for compact device integration due to backside feeding

2.2.2. Stage 2: CPW-Fed Circular Patch Antenna (Ant_2)

To improve fabrication ease and increase bandwidth, the antenna was re-designed with a CPW feed while retaining the circular patch shown in figure 3b. The CPW-fed structure enables uniplanar configuration and eliminates the need for backside vias.

From figure 4,

- Resonance remains at 2.4 GHz with slight improvement in return loss

- CPW feed simplifies integration and enhances bandwidth marginally
- Still limited to a single-band response
- Better impedance matching and radiation stability compared to Stage 1

2.2.3. Stage 3: Slit-Loaded CPW Circular Patch Antenna (Ant_3)

To enable multi-band operation, a narrow vertical slit was introduced at the top of the circular patch shown in figure 3c. This structural modification perturbs the current distribution, thereby introducing additional resonant modes in the 5–7.1 GHz region suitable for Wi-Fi 6E.

From figure 4,

- Multi-resonant behaviour achieved: ~2.4 GHz, and ~6.0 GHz
- Enhanced impedance bandwidth in all bands
- Stronger S_{11} performance (< -15 dB) and better spectral separation

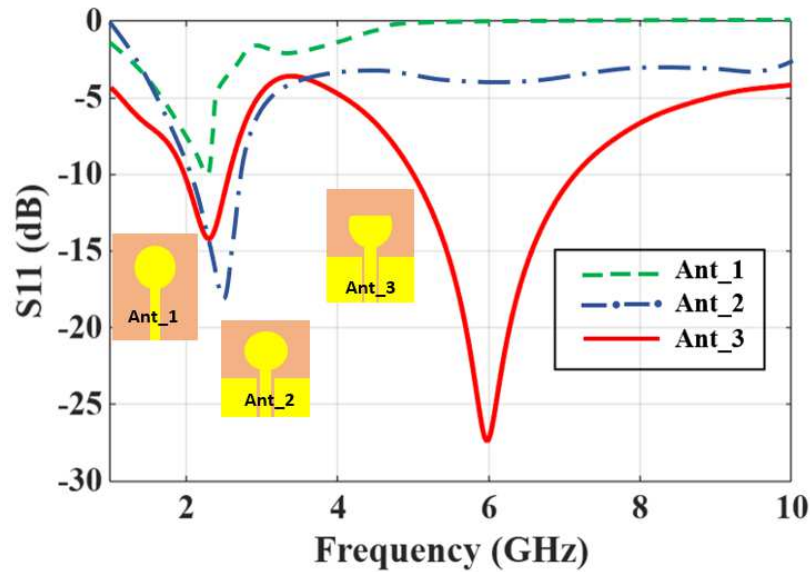


Figure 4. S-Parameter results of every stage of antenna design

Table 2. Comparison table for the three stages of antenna design.

Design Stage	Antenna Type	Feeding Method	Frequency Bands	Performance
Ant_1	Circular patch	Microstrip line	~2.4 GHz	Narrowband, single resonance
Ant_2	CPW-fed circular patch	CPW	~2.4 GHz	Moderate bandwidth, planar, Ease of integration
Ant_3	CPW-fed circular patch + slit	CPW	~2.4 GHz, ~6.0 GHz	Multi-band, improved matching

2.2.4. Parameter analysis

The proposed antenna design was optimized through several parametric studies on various variables, as illustrated in Figure 5. Initial parametric analysis focused on the ground plane's dimensions. Increasing the length of the ground plane (L_G) from 6.10 mm to 8.10 mm enhanced the antenna's impedance matching and maintained an acceptable bandwidth. Additionally, a parametric study was conducted on the slit within the radiator. Modifying the slit dimension from 9.91 mm to 11.91 mm led to an increase in the antenna's bandwidth, as depicted in Figure 5.

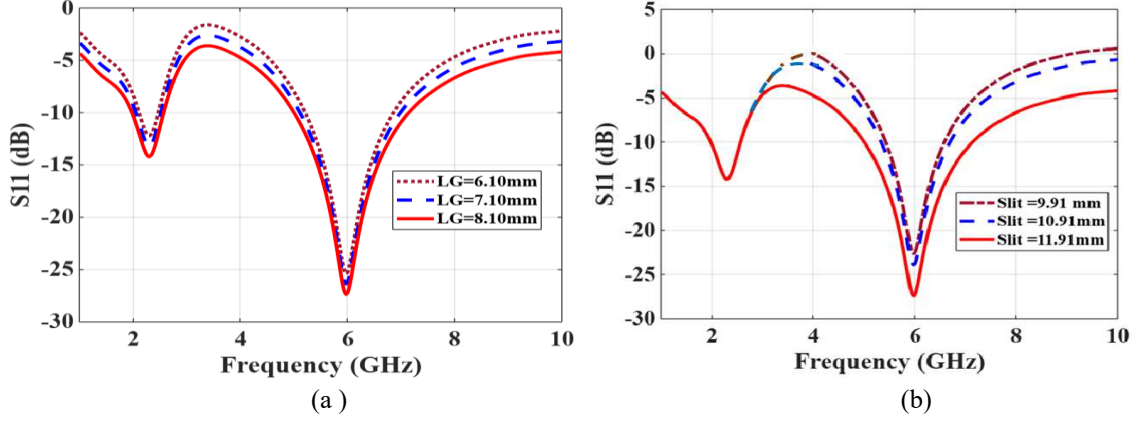


Figure 5. Parametric analysis (a) Ground length analysis (b) Patch slip analysis

3. Design of 4 Element MIMO antenna

The fundamental concept of MIMO involves deploying multiple antenna elements at both the transmitter and receiver to improve system capacity and reliability. By leveraging spatial multiplexing, MIMO allows the simultaneous transmission of multiple independent data streams, thereby significantly boosting data rates without consuming extra bandwidth. Additionally, it enhances link reliability through spatial diversity, effectively mitigating the impact of multipath fading—an issue commonly encountered in indoor wireless environments [31].

For Wi-Fi applications, where devices are often used in densely populated environments with numerous reflections and interference sources, MIMO ensures better signal reception and increased throughput. However, implementing MIMO in practice poses several challenges. One of the major design considerations is minimizing the mutual coupling between antenna elements to preserve the independence of signals. Therefore, careful design of antenna geometry, orientation, and feed configuration is essential to achieve low correlation and high isolation between ports, ensuring optimal performance of the MIMO system.

3.1. 4 Element MIMO antenna

The MIMO antenna is constructed by replicating the optimized single-element CPW-fed slit-loaded circular patch antenna. The four identical elements are strategically placed in a symmetric orthogonal configuration to maximize spatial and polarization diversity. Each element operates in two distinct frequency bands corresponding to 2.4 GHz, and 6.0 GHz, covering both traditional Wi-Fi bands and the extended bands introduced in Wi-Fi 6E.

The antenna is fabricated on a Rogers RT-duroid 5880LZ substrate and shown in figure 6. This material choice ensures cost-effectiveness and ease of prototyping. The antenna elements are positioned at the corners of a rectangular configuration, with each element oriented at a 90° rotation relative to its adjacent counterpart. This orthogonal placement introduces polarization diversity, helping to reduce signal correlation. The inter-element spacing is carefully optimized to balance compactness and mutual coupling, with a typical edge-to-edge spacing in the range of 0.3λ to 0.5λ at the lowest operating frequency (2.4 GHz). The antenna maintains a compact overall size, making it suitable for integration in small wireless access points and portable devices.

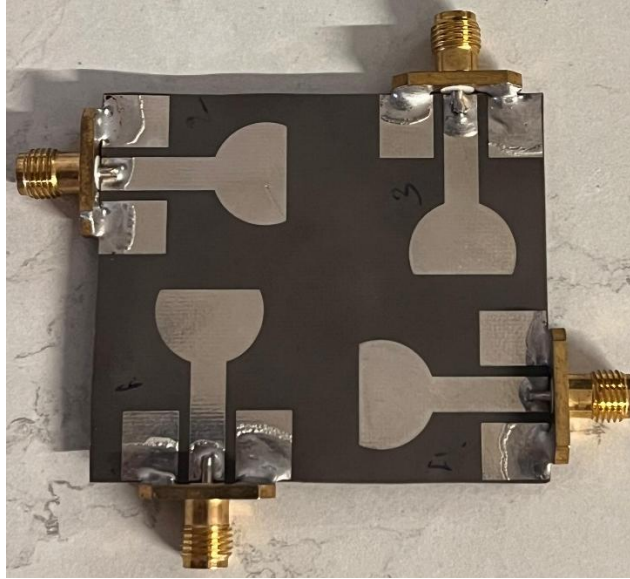


Figure 6. Prototype of 4-Port proposed MIMO antenna

3.2. Experimental Results and Discussions

3.2.1. S-parameters

S-parameters are essential for evaluating the performance of multi-port antennas, especially in terms of return loss and inter-port isolation in MIMO systems. The proposed four-port CPW-fed multi-band MIMO antenna was first analyzed through full-wave electromagnetic simulations and then physically fabricated. Its performance was experimentally validated using a Vector Network Analyzer (VNA), as illustrated in Figure 7.



Figure 7. The proposed MIMO antenna validated using VNA

The simulated and measured values of S_{11} (input reflection coefficient of Port 1) show good agreement across the desired frequency bands. All four ports (S_{11} , S_{22} , S_{33} , and S_{44}) exhibit return loss values below -10 dB, indicating effective impedance matching across the 2.4 GHz, and 6.0 GHz bands. The key resonant points for each port align well between simulation and measurement, with minor shifts shown in figure 8 attributed to fabrication tolerances and connector losses.

- At 2.4 GHz, the measured S_{11} was observed around -18 dB, indicating strong resonance.
- At 6.0 GHz, return losses of -35 dB was recorded in simulation, with measured values.
- All ports exhibit similar performance due to the symmetrical and orthogonal design of the antenna elements.

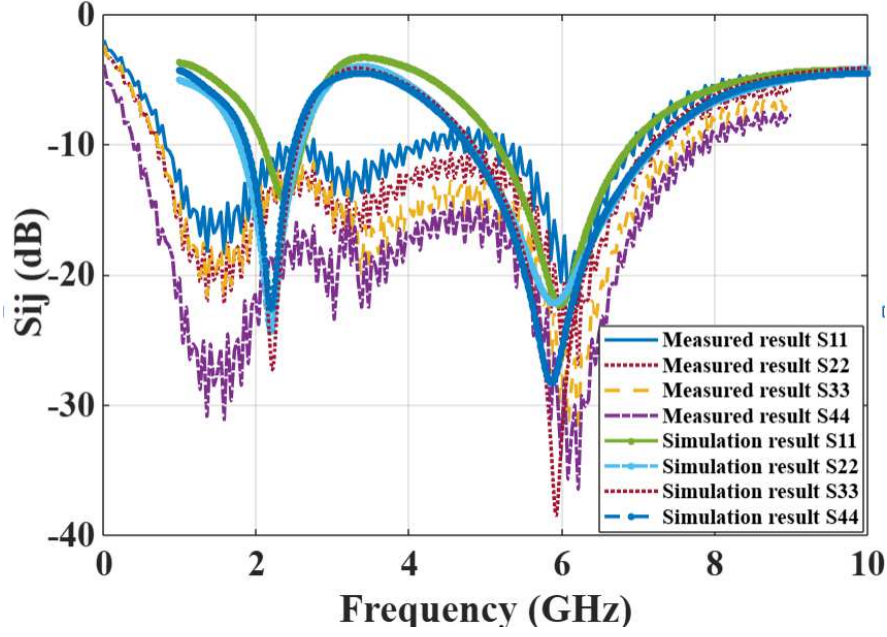


Figure 8 Comparison of simulated and measured reflection coefficients

Isolation between MIMO ports is a critical performance parameter. In the proposed design, simulated isolation between adjacent and diagonal ports (e.g., S21, S31, S41) was found to be better than -20 dB across all target bands. This high level of isolation ensures minimal mutual coupling and excellent diversity performance. Measured values confirm the simulation, showing in figure 9 with the isolation of >-20 dB for Port 1 to Port 2,3,4:

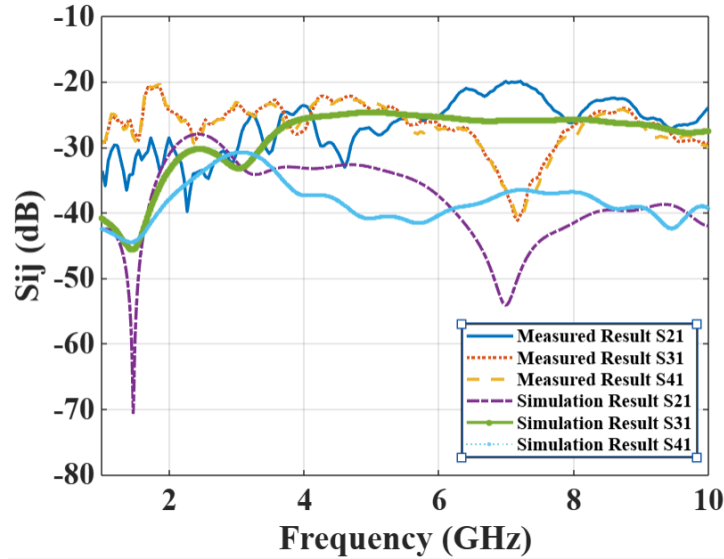


Figure 9. S-parameters of 4 Element MIMO antenna. (a) S21 (b) S31 (c) S41

This performance is achieved using a simple and passive slit-based decoupling mechanism, embedded in the circular patch geometry, without requiring additional decoupling structures or complex ground modifications.

The measured S-parameters closely match the simulated results, with slight deviations due to:

- SMA connector losses
- Fabrication tolerances of Rogers substrate
- Hand-soldering inaccuracies or copper etching limitations

Despite these minor discrepancies, the overall response shows consistent multi-band performance with acceptable return loss and high port isolation, validating the proposed antenna's effectiveness.

3.2.2. Surface Current

Surface current distribution analysis plays a critical role in understanding the radiation behaviour, coupling characteristics, and resonance mechanisms of an antenna. By observing how the current flows across the

antenna structure at resonating frequencies, insights can be gained into how various geometric features contribute to multi-band operation and port isolation in the proposed design.

In this study, surface current distributions were simulated using CST Microwave Studio by exciting one port at a time (e.g., Port 1) while terminating the remaining ports with a matched load ($50\ \Omega$). The currents were observed at the two primary operating frequencies 2.4 GHz (Wi-Fi 802.11b/g/n) and 6.0 GHz (Wi-Fi 6E / 802.11ax)

At 2.4 GHz:

- Strong current concentrations observed along the outer edges of the circular patch.
- The CPW ground planes also show moderate current flow, indicating effective coupling.

At 6.0 GHz:

- The surface current is mainly confined to inner feed region, demonstrating localized resonance.
- Currents are minimal on adjacent patches, confirming high isolation between ports.
- The slit and CPW ground spacing contribute to efficient current confinement.

Each figure clearly shows the current vector direction and magnitude using colour intensity and contour fields. By comparing the current flow on passive ports and neighbouring patches: Minimal induced current is observed on non-excited elements, confirming low mutual coupling, Orthogonal placement and symmetrical structure reduce backward surface wave propagation and the design benefits from balanced mode excitation and radiation pattern diversity, critical for MIMO performance. At 2.4 GHz, the dominant current path flows along the outer circumference of the circular patch, forming a current path approximately equal to half-wavelength resonance. At 6 GHz, the vertical slit introduces additional current perturbation, creating a shorter current path near the CPW feed and slit edges, generating the higher-frequency resonance.

These characteristics are essential for reliable and efficient operation in Wi-Fi MIMO systems, especially under real-world multipath conditions.

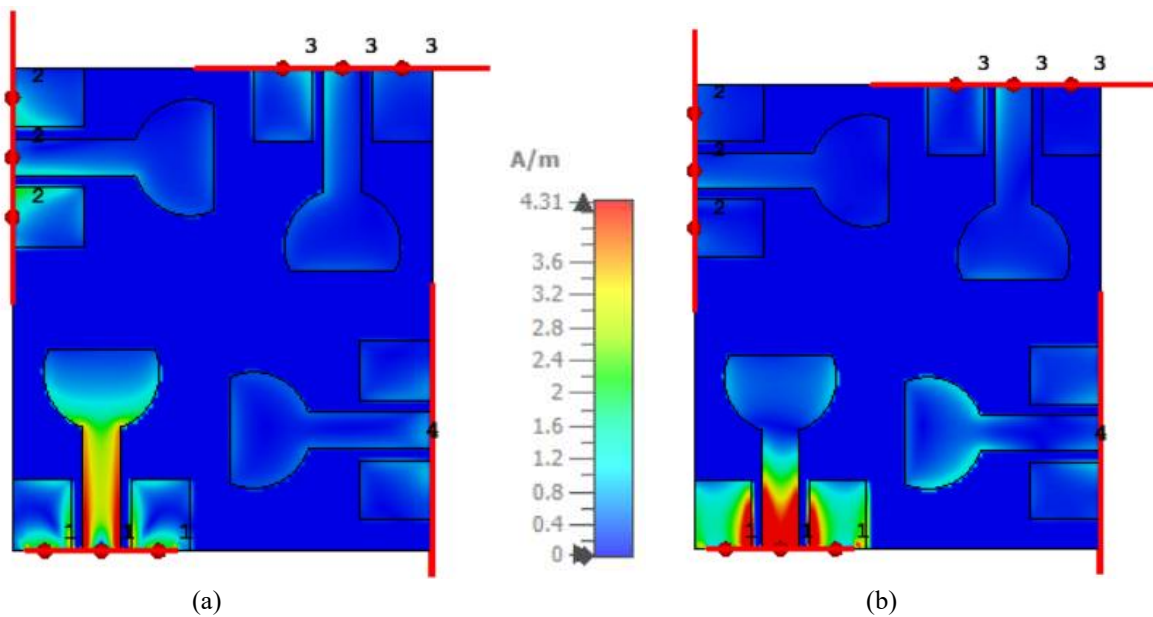


Figure 10. Surface Current Flow Pattern at (a) 2.4 GHz and (b) 6.0 GHz

3.2.3 Radiation Pattern

The Figure 11, below shows the radiation pattern of the proposed antenna at frequencies 2.4 GHz and 6 GHz respectively

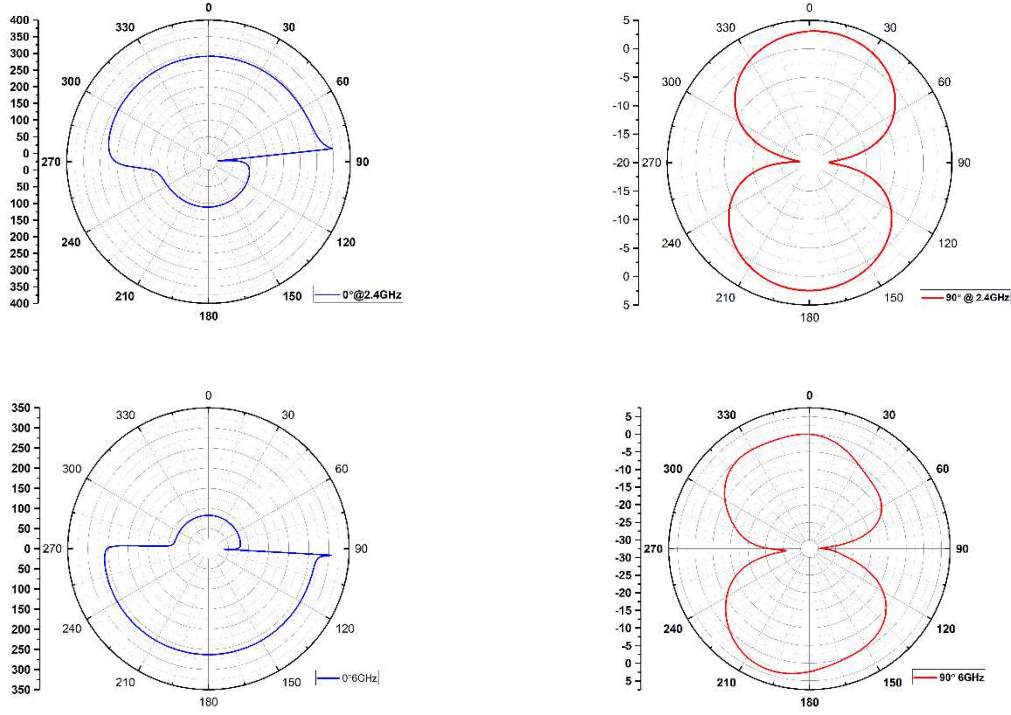


Figure 11. Radiation Pattern

3.2.3. ECC and DG

The Envelope Correlation Coefficient (ECC) is a crucial parameter for assessing the diversity performance and mutual coupling in MIMO antenna systems. A low ECC value signifies minimal correlation between antenna elements, which leads to enhanced channel capacity, improved signal decorrelation, and better overall system performance—particularly in rich multipath environments. For optimal MIMO operation, the ECC should generally remain below 0.5, while high-performance wireless standards like Wi-Fi 6/6E demand values lower than 0.01. In the proposed four-port CPW-fed multi-band MIMO antenna, the ECC was computed using Equation (1), as referenced in [26]. For practical purposes, ECC can also be approximated using S-parameters as follows (for a 2-port case):

$$ECC = \left| \frac{s_{11}^* s_{12} + s_{21}^* s_{22}}{(\sqrt{1 - |s_{11}|^2 - |s_{21}|^2})(\sqrt{1 - |s_{22}|^2 - |s_{12}|^2})} \right| \quad (1)$$

For the 4-port case, pairwise ECC values (between Port 1 & 2, Port 1 & 3, and port 1 & 4) were computed using full-wave simulations.

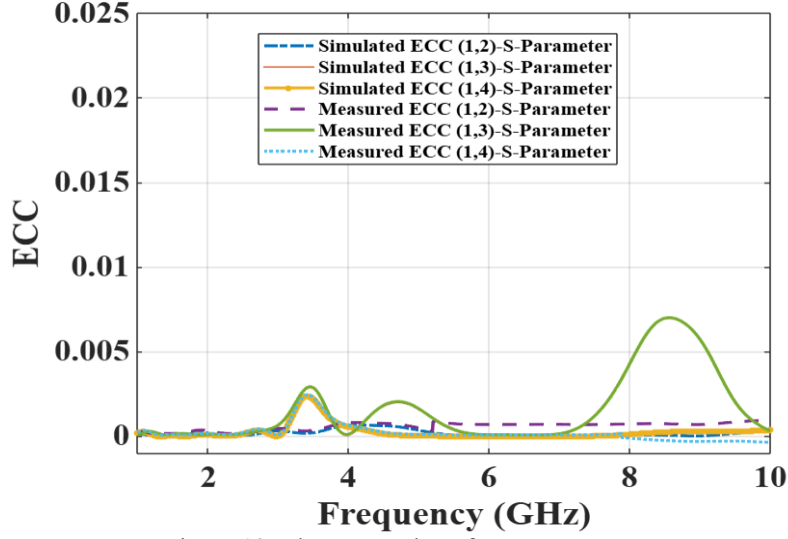


Figure 12. The ECC value of MIMO antenna

The simulated and measured ECC values for the proposed antenna are found to be below 0.005 across all target bands (2.4 GHz, and 6.0 GHz) shown in figure 12. Therefore, this proposed MIMO antenna is well within the acceptable range, indicating excellent isolation and pattern diversity between antenna elements.

Diversity Gain (DG) is a key metric used to assess the performance of MIMO antenna systems in multipath propagation environments. It quantifies the improvement in signal reception reliability when multiple antennas are used to transmit or receive the same signal over independent fading channels. A high diversity gain indicates that the antenna system is capable of effectively mitigating fading effects and enhancing the overall link quality. DG refers to the improvement in signal-to-noise ratio (SNR) at the receiver due to the use of spatially or pattern-diverse antenna elements. In practical terms, DG reflects how well the antenna elements can operate independently under multipath conditions.

For an ideal MIMO system with uncorrelated antenna elements, the theoretical maximum DG is 10 dB. However, mutual coupling and pattern correlation can reduce the actual DG. Therefore, a well-designed MIMO antenna should strive for DG values close to 10 dB across its operational bands.

DG is directly related to the ECC and can be estimated using the following equation 2 [32]:

$$DG = 10\sqrt{1 - (ECC)^2} \quad (2)$$

For ECC values close to 0 (ideal case), the DG approaches 10 dB. This is a simple and widely used method when the ECC is known. In the proposed 2 x 2 CPW-fed multi-band MIMO antenna, the ECC values between all port pairs were found to be < 0.005 across the targeted frequency bands (2.4 GHz, 6.0 GHz). Using the above relation, the corresponding DG values were computed and are consistently found to be in the range of:

- **9.998 dB to 9.999 dB** (indicating excellent diversity performance)

This confirms that the antenna elements are effectively decorrelated and capable of providing strong diversity benefits for high-data-rate and reliable wireless communication, particularly in Wi-Fi 802.11b/g/n and Wi-Fi 6/6E (802.11ax) environments.

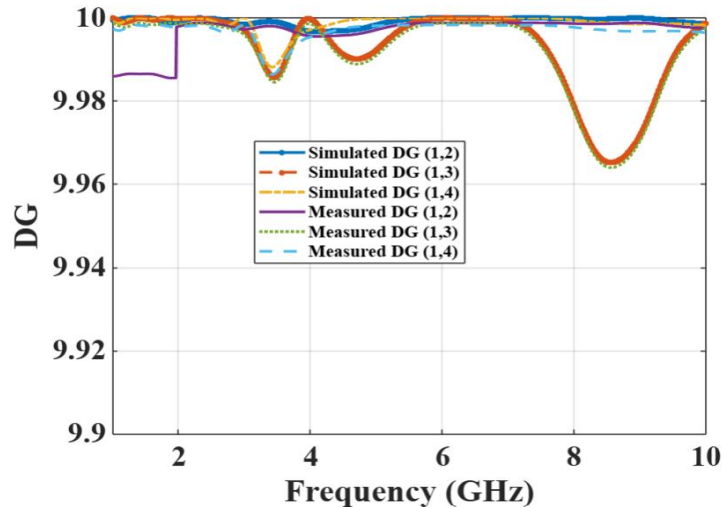


Figure 13. The DG value of Proposed antenna

3.2.4. TARC

The Total Active Reflection Coefficient (TARC) is an essential performance metric for multi-port MIMO antennas, especially in systems where multiple ports are excited simultaneously. Unlike traditional reflection coefficients which consider only single-port excitation, TARC evaluates how much power is reflected when all ports are excited simultaneously with specific phase conditions, offering a more realistic assessment of the antenna's performance in MIMO operation. Mathematically, for an N-port MIMO antenna, TARC is calculated by the equation 3 [32]:

$$TARC = N^{-0.5} \sqrt{\sum_{i=1}^N |\sum_{k=1}^N S_{ik} e^{j\theta_{k-1}}|^2} \quad (3)$$

TARC helps to evaluate the combined effect of mutual coupling and reflection when the antenna is operating in realistic scenarios. It is particularly useful for 4-port MIMO antennas like the one proposed in this work.

To calculate TARC, equal amplitude signals with progressive phase differences (e.g., 0°, 60°, 120°, 180°) are fed to the antenna ports. This procedure is carried out for multiple phase combinations to evaluate the antenna's behavior under different excitation scenarios.

For the proposed CPW-fed compact 4-port MIMO antenna, TARC was evaluated using CST post-processing with phase-excited port combinations. The simulated TARC values are found to be:

- Less than -10 dB across the operational bands (2.4 GHz, 6.0 GHz)
- This indicates that most of the incident power is accepted by the antenna, and very little is reflected back, even under active multi-port excitation.

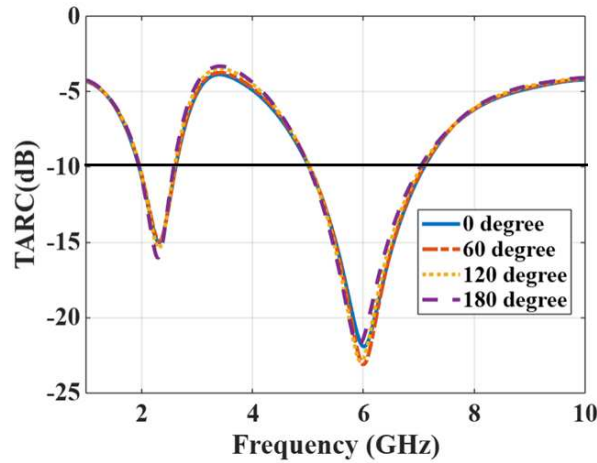


Figure 14. TARC of the Proposed antenna

Figure 14 validate the antenna's ability to handle multiple excitations efficiently and demonstrate its suitability for real-time MIMO operation in Wi-Fi 802.11b/g/n and 802.11ax (Wi-Fi 6/6E) applications.

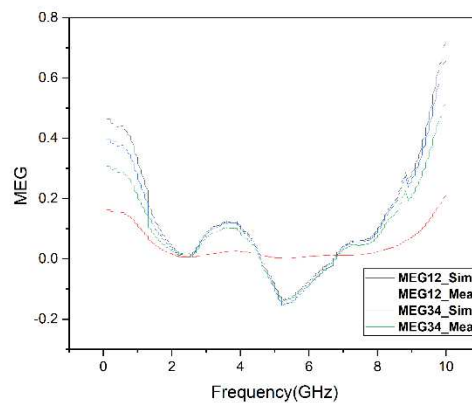


Figure 15. Mean Effective Gain

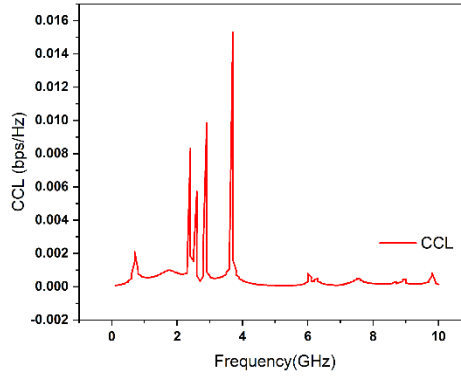


Figure 16. Channel Capacity Loss

3.3. Comparative Analysis

Table 3. Comparative analysis of proposed work with various existing works

Ref.	Ports	Bands (GHz)	Isolation	ECC / DG	Size (mm ²)	Decoupling Method
[27]	4	3.6–7.3	> 15 dB	Not Provided	56×56	P-stub + orthogonal placement
[28]	4	2.7–4.7	< −23 dB	ECC ≈ 0.001 / DG ~10 dB	178×178	Dumbbell slots + metasurface
[29]	4	3.9–18.4	> 18.5 dB	ECC < 0.015 / DG > 9.9 dB	Not specified	MSRR low-pass filter + orthogonal layout
[30]	4	3.2–5.6	< −17 dB	ECC < 0.05	40×40	Orthogonal L-shape + ground slots
[31]	4	Wi-Fi 6/5G sub-6 GHz	Not specified	Not specified	Not specified	CPW single-layer design
[32]	4	6 GHz range	Not specified	Not specified	Not specified	EBG reflector
[33]	4	6 GHz Wi-Fi 6E/7	Not specified	Not specified	Not specified	Printed dipole CPW-fed
[34]	4	3.1–11 GHz	> -16 dB	Not provided	Not specified	Connected ground + stub decoupler
This work	4	2.4 & 5-7.1 GHz	>-20 dB	ECC ≈ 0.005 / DG 9.9 dB	54 x 47	CPW single-layer slit method design

Table 3 describes the comparative analysis of recent multi-port MIMO antenna designs—spanning research from existing works [27-34]—clearly highlights the advantages of the proposed 4-port CPW-fed multi-band MIMO antenna for Wi-Fi applications. While most existing designs focus on either ultra-wideband (UWB) performance or dual-band operation, the proposed antenna is uniquely tailored for multi-band coverage at 2.4 GHz, 5-7.1 GHz, aligning perfectly with Wi-Fi 802.11b/g/n and Wi-Fi 6/6E (802.11ax) standards. Unlike several recent designs that rely on complex decoupling mechanisms such as metasurfaces, defected ground structures (DGS), or electromagnetic bandgap (EBG) materials, this work adopts a simpler, fabrication-friendly approach using strategically placed slits in a CPW-fed circular patch geometry. This results in high isolation (>-20 dB), extremely low envelope correlation coefficient (ECC < 0.005), and high diversity gain (~9.99 dB), all within a compact footprint of approximately 54×47 mm².

Compared to metasurface-based or filter-integrated designs, which often require additional layers, complex fabrication steps, or larger substrate areas, the proposed antenna achieves competitive or superior performance using a single-layer substrate and passive design methodology. Furthermore, the proposed work as a robust, compact, and efficient solution for modern Wi-Fi systems, outperforming many recent contributions in terms of simplicity, functionality, and scalability.

4. Conclusion

In this research, a compact and high-performance CPW-fed multi-band 4-port MIMO antenna has been successfully designed and evaluated for Wi-Fi applications spanning the 802.11b/g/n and Wi-Fi 6/6E (802.11ax) standards. Through a systematic design evolution—from a basic circular patch to a slit-loaded CPW-fed structure—the antenna achieves multi-band operation covering the 2.4 GHz and 6 GHz bands with excellent impedance matching and compact form factor. The final MIMO configuration demonstrates high port isolation (>20 dB) ensuring robust performance in dense wireless environments. Moreover, key MIMO parameters such as ECC (<0.005), diversity gain (~ 9.99 dB), and favourable TARC values validate its suitability for high-throughput communication. Compared to recent works, the proposed design offers a superior balance between compactness, multi-band operation, and low mutual coupling—without relying on complex decoupling structures or bulky elements. This makes it an ideal candidate for modern wireless platforms such as Wi-Fi 6 routers, smart home hubs, and next-generation IoT devices requiring compact multi-port antennas with enhanced data reliability and spectral efficiency.

Declarations

The authors certify that this material or similar material has not been and will not be submitted to or published in any other publication before. Furthermore, the authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript.

Ethical Approval: Not Applicable

Competing interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author's Contribution

A & B contributed to do Design, B & C contributed for Interpretation of results, A & B wrote the main manuscript, C contributed towards preparation of figures, all authors reviewed the results and approved the final version of the manuscript.

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