A Compact Frequency-Reconfigurable MIMO Antenna with Corner-Chamfered L-Shaped Radiators for Improved Bandwidth

M.Gowtham
Department of ECE,
JNTUA CE,Ananthapuramu,
Andhra Pradesh, India.
mopurigowtham@gmail.com

Dr. M. Madhu Babu
Department of ECE,
JNTUA CE,Ananthapuramu,
Andhra Pradesh, India.
madhu07vlsi@gmail.com

M. Sreedhar
Department of ECE,
JNTUA CE,Ananthapuramu,
Andhra Pradesh, India.
sreedhar470@gmail.com

***Abstract*—A compact frequency-reconfigurable four-element multiple-input multiple-output (MIMO) antenna for 5G and Wi-Fi applications is presented. The proposed antenna is fabricated on an FR-4 substrate with compact dimensions and operates at two selectable frequency bands of 3.5 GHz and 4.6 GHz using PIN-diode-based frequency reconfiguration. To enhance the antenna performance, triangular corner chamfers of size 0.5 mm × 0.5 mm are introduced at the inner corners of the L-shaped radiating elements. The chamfered geometry smooths the surface current distribution, reduces current crowding at sharp corners, and improves impedance matching characteristics. As a result, the modified antenna exhibits enhanced impedance bandwidth while maintaining good isolation between MIMO elements and preserving its compact size. Simulated results demonstrate that the proposed corner-chamfered design provides improved bandwidth performance compared with the conventional structure, making it a promising candidate for reconfigurable 5G and Wi-Fi applications.**

***Keywords*—MIMO, 5G, Wi-Fi, PIN Diode, L-shaped radiating element**

I. INTRODUCTION

Compact, high-performance, and multipurpose antenna systems are in high demand due to the quick expansion of fifth-generation (5G) wireless communication systems and high-speed wireless local area networks (WLANs). It is anticipated that contemporary wireless devices would support several communication standards while being small, inexpensive, and capable of processing large amounts of data. Without requiring more transmission power or bandwidth, multiple-input multiple-output (MIMO) antenna technology has become a viable way to increase channel capacity, link dependability, and spectrum efficiency [1]–[4].

Frequency-reconfigurable antennas have gained significant attention due to their ability to operate at multiple frequency bands using a single radiating structure. By incorporating switching elements such as PIN diodes, varactor diodes, or MEMS switches, the operating frequency of an antenna can be dynamically adjusted according to application requirements [2], [5]. This capability reduces the need for multiple antennas and improves spectrum utilization in modern wireless systems.

Among various wireless communication bands, the 3.5 GHz spectrum has been widely adopted for sub-6 GHz 5G applications, while the 5.2 GHz band is extensively used for WLAN and Wi-Fi services [6]–[9]. Therefore, the development of compact reconfigurable antennas capable of operating efficiently at both frequency bands has become an important research topic. However, achieving wide impedance bandwidth, good isolation, stable radiation characteristics, and compact size simultaneously remains a challenging task in MIMO antenna design [6], [7].

Several reconfigurable MIMO antennas have been reported in the literature to support dual-band and multiband operations. Although many of these designs provide satisfactory frequency-switching capabilities, they often suffer from limited impedance bandwidth, increased structural complexity, or performance degradation due to current crowding around sharp radiator corners [5]–[8]. The abrupt changes in current flow at these corners can introduce additional reactive effects that negatively influence impedance matching and bandwidth performance.

To address these limitations, this work presents a modified compact frequency-reconfigurable four-port MIMO antenna operating at 3.5 GHz and 4.6 GHz. The antenna employs PIN diodes to achieve frequency reconfiguration between the two operating bands. The implemented design is based on the compact reconfigurable MIMO antenna reported in [9], with additional geometric optimization to improve bandwidth characteristics. Triangular corner chamfers of dimensions 0.5 mm × 0.5 mm are introduced at the inner corners of the L-shaped radiating elements. This modification smooths the surface current distribution, reduces current concentration at sharp edges, and enhances impedance matching characteristics. As a result, improved bandwidth performance is achieved without increasing the antenna size or affecting the frequency reconfiguration mechanism

II. RELATED WORK

Reconfigurable antennas offer attractive solutions for cognitive radio systems due to their ability to dynamically switch radiation patterns, operating frequencies, and polarization characteristics. A frequency-reconfigurable E-shaped patch antenna utilizing RF-MEMS switches and particle swarm optimization was presented in [1]. By dynamically varying the slot dimensions using RF-MEMS switches, the antenna achieved a bandwidth nearly twice that of the conventional E-shaped patch antenna, demonstrating the effectiveness of reconfiguration techniques for bandwidth enhancement.

Modern wireless communication systems require antennas capable of supporting multiple functionalities within limited physical dimensions. Reconfigurable antennas address this challenge by enabling frequency, pattern, and polarization adaptability through various switching mechanisms. Different reconfiguration approaches based on RF-MEMS switches, PIN diodes, varactor diodes, photoconductive elements, ferrites, and liquid crystals have been extensively investigated to achieve optimum antenna performance under varying operating conditions [2].

A frequency-reconfigurable slot-patch antenna capable of operating at six different frequency bands between 1.7 GHz and 3.5 GHz was reported in [3]. The antenna consisted of a microstrip patch and a slot antenna integrated through three switching elements. The design provided directional radiation characteristics across all operating bands by incorporating a reflector behind the antenna structure.

Additionally, a number of small MIMO antenna designs have been suggested for cognitive radio, 5G, and WLAN applications. For WLAN applications, Sharma et al. [4] created a three-element MIMO antenna with pattern and polarization diversity. A four-element planar reconfigurable MIMO antenna for cognitive radio systems was introduced by Hussain and Sharawi [5]. While Singh et al. [7] presented a frequency-reconfigurable quad-element MIMO antenna with enhanced isolation for 5G systems, Pant et al. [6] suggested a frequency-switchable MIMO antenna appropriate for LTE and early 5G applications. A dual-band Wi-Fi reconfigurable MIMO antenna that supports WLAN and 5G applications was disclosed by Verma [8].

More recently, Mshwat et al. [9] proposed a compact reconfigurable four-element MIMO antenna operating at 3.5 GHz and 5.2 GHz for 5G and Wi-Fi applications. The antenna demonstrated excellent isolation, low ECC, high diversity gain, and compact dimensions. However, further enhancement of impedance bandwidth remains an important research objective.

Motivated by the limitations of existing reconfigurable MIMO antennas, this work introduces triangular corner chamfers at the inner corners of the L-shaped radiating elements. The proposed modification reduces current crowding, improves impedance matching, and enhances bandwidth performance while preserving the compact size and frequency-reconfiguration capability of the original design [9].

III. IMPLEMENTED DESIGN

The implemented (3.5, 4.6) GHz reconfigurable MIMO antennas are printed on a 26 × 26 × 0.8 mm3 FR-4 dielectric substrate with a permittivity of 4.3, a loss tangent of 0.025, and a thickness of 0.8 mm. To further improve the impedance bandwidth and current distribution of the implemented reconfigurable MIMO antenna, triangular corner chamfers were introduced at the inner corners of each L-shaped radiating element. A chamfer size of 0.5 mm × 0.5 mm was selected after several optimization iterations. The proposed modified antenna incorporates optimized triangular corner chamfers at the inner corners of the L-shaped radiators. This simple geometrical modification improves current flow continuity, enhances impedance bandwidth, and maintains the compact size and reconfigurable operation of the antenna, making it suitable for modern 5G and Wi-Fi applications. The implemented antenna is fed via a 50-Ohm microstrip wire. The feed method was selected since it is simple to match and fabricate. The ideal feedline placement is chosen using a variety of optimization techniques. However, setting the feedline at either the middle or both edges has a big impact on the antenna reflection coefficient.

As a result, four single 50 ohm microstrip lines that are designed and printed on FR-4 substrate feed the constructed antenna.

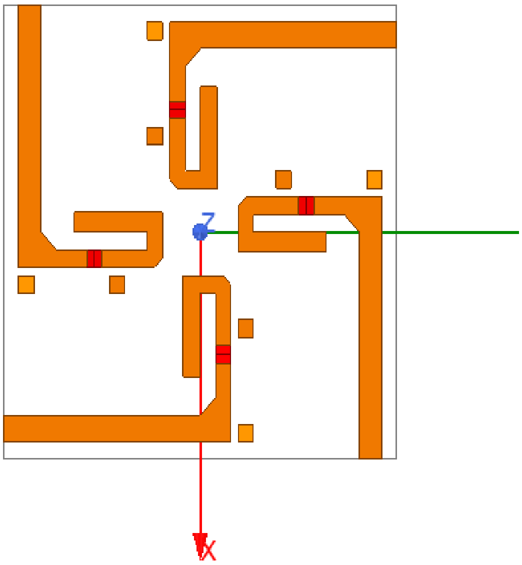

Fig. 1. Implemented Design

The introduction of corner chamfers reduces abrupt current discontinuities at the sharp bends of the radiating structure. Consequently, the surface current follows a smoother path, reducing localized current concentration and improving impedance matching over the operating bands. In addition, the modified geometry contributes to bandwidth enhancement while maintaining the compact dimensions of the antenna

The modified antenna preserves the original frequency reconfigurability characteristics, operating at 3.5 GHz in the PIN-diode ON state and 4.6 GHz in the PIN-diode OFF state**,** while providing improved bandwidth performance and stable radiation characteristics.

IV. RESULTS

A. *Effect of Corner Chambering*

The effect of the corner chamfers was investigated by comparing the reflection coefficient characteristics before and after modification. The chamfered structure exhibited improved impedance matching and a wider −10 dB bandwidth. This improvement is attributed to the smoother current transition around the inner corners of the L-shaped radiator, which minimizes current crowding and reduces reactive effects associated with sharp edges.

Furthermore, the modification did not significantly affect the antenna footprint or reconfiguration mechanism, making it an effective technique for bandwidth enhancement in compact MIMO antenna systems.

B. *Return Loss*

Figure 2 presents the simulated return loss performance of the implemented frequency-reconfigurable four-port MIMO antenna. Two resonant frequencies are observed at approximately 3.5 GHz and 4.6 GHz, representing the two operating states of the antenna. The obtained return loss values are well below the −10 dB reference level, indicating effective impedance matching and efficient transfer of power from the feed network to the radiating elements.

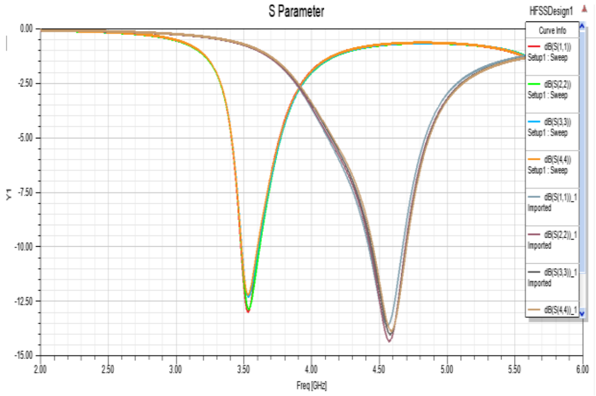

Fig. 2. Simulated return loss characteristics of the implemented frequency-reconfigurable four-port MIMO antenna operating at 3.5 GHz and 4.6 GHz.

At the lower operating band, the antenna resonates near 3.5 GHz with a return loss of approximately −12 dB. When the switching configuration is altered, the resonant frequency shifts to around 4.6 GHz, where a return loss close to −14 dB is achieved. This frequency transition confirms the successful operation of the PIN-diode-based reconfiguration mechanism.

The nearly identical responses of S11, S22, S33, and S44 indicate that all four antenna elements exhibit similar electrical behavior due to the symmetric structure of the proposed MIMO design. Such uniformity is desirable in MIMO systems because it ensures balanced performance across all antenna ports.

C. *VSWR (Voltage Standing Wave Ratio)*

Figure 3 illustrates the simulated Voltage Standing Wave Ratio (VSWR) characteristics of the implemented frequency-reconfigurable four-port MIMO antenna. VSWR is an important parameter used to evaluate the impedance matching between the antenna and the transmission line. Lower VSWR values indicate reduced reflected power and improved power transfer efficiency.

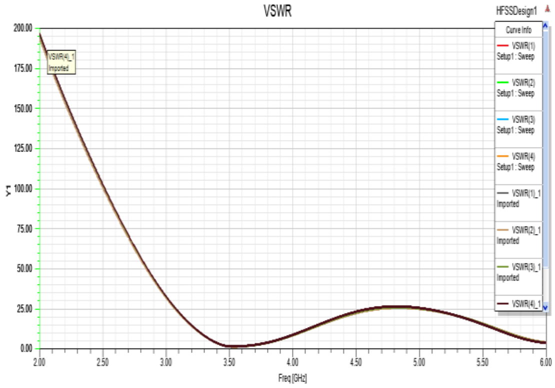

Fig. 3. Simulated VSWR Characteristics of the Proposed Antenna

As observed from the figure, the antenna exhibits minimum VSWR values at the resonant frequencies of approximately 3.5 GHz and 4.6 GHz. These frequencies correspond to the two operating states of the reconfigurable antenna. At both resonant bands, the VSWR approaches unity, indicating excellent impedance matching and minimal signal reflection.

The similar VSWR responses obtained for all four antenna ports demonstrate the symmetrical configuration of the proposed MIMO structure and confirm consistent performance among the radiating elements. Furthermore, the VSWR values remain within the acceptable operating range around both resonant frequencies, validating the effectiveness of the proposed reconfiguration mechanism.

The obtained results confirm that the antenna efficiently radiates the supplied power at both operating bands, making it suitable for sub-6 GHz 5G and Wi-Fi wireless applications.

D. *3D Gain Distribution of The Praposed MIMO Antenna*

Figure 4 illustrates the simulated gain of the implemented frequency-reconfigurable four-port MIMO antenna. The antenna exhibits a maximum gain of approximately 2.5 dBi, demonstrating effective radiation performance despite its compact size. The three-dimensional radiation pattern indicates stable and directional energy distribution over the operating frequency band. The achieved gain is mainly attributed to the optimized L-shaped radiating elements and the improved current distribution obtained through the corner-chamfered geometry. The results confirm that the proposed antenna maintains satisfactory radiation characteristics while supporting frequency reconfiguration, making it suitable for sub-6 GHz 5G and Wi-Fi applications.

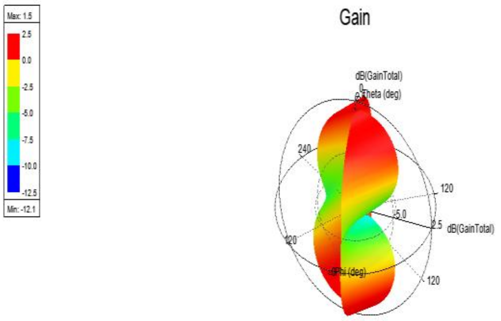

Fig. 4. 3D Gain Distribution of the proposed MIMO Antenna

E. *Radiation Pattern*

Figure 5 illustrates the simulated radiation pattern of the proposed frequency-reconfigurable four-port MIMO antenna. The radiation characteristics were evaluated to examine the directional behavior and stability of the antenna at the operating frequencies. The obtained pattern exhibits a stable and nearly bidirectional radiation response in the principal planes, which is desirable for reliable wireless communication.

The E-plane and H-plane patterns demonstrate smooth radiation characteristics without significant distortions, indicating effective radiation from the L-shaped radiating elements. The symmetrical structure of the antenna contributes to uniform field distribution and stable radiation performance. Furthermore, the introduction of triangular corner chamfers improves current flow continuity, helping to maintain consistent radiation behavior while enhancing impedance bandwidth.

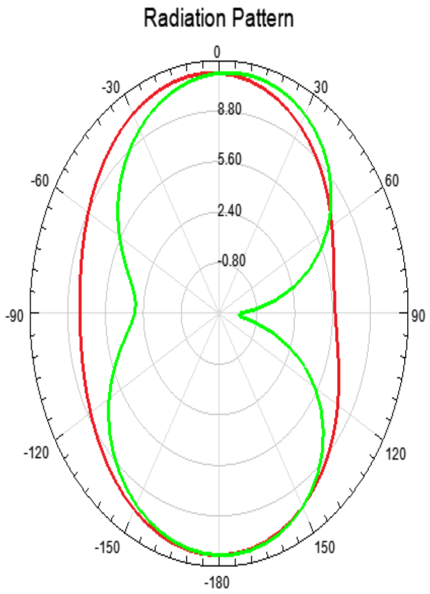

Fig. 5. Radiation pattern

The obtained radiation pattern confirms that the proposed antenna can provide adequate coverage and reliable signal transmission for 5G and Wi-Fi applications. The stable radiation characteristics also validate the suitability of the antenna for compact MIMO communication systems.

V. CONCLUSION

A compact frequency-reconfigurable four-port MIMO antenna for 5G and WLAN applications has been presented and investigated. The antenna operates at 3.5 GHz and 4.6 GHz through PIN-diode-based frequency reconfiguration, enabling flexible operation for modern wireless communication systems. To improve the antenna performance, a simple geometric modification in the form of 0.5 mm × 0.5 mm triangular corner chamfers was introduced at the inner corners of the L-shaped radiating elements.

The proposed corner-chamfered structure effectively smooths the surface current distribution, reduces current crowding at sharp edges, and enhances the impedance matching characteristics of the antenna. Simulation results demonstrate improved impedance bandwidth while preserving the compact dimensions and frequency reconfiguration capability of the original design. In addition, the antenna maintains satisfactory isolation, stable radiation patterns, low envelope correlation coefficient (ECC), and high diversity gain (DG), confirming its suitability for MIMO operation.

The achieved performance indicates that the incorporation of triangular corner chamfers is an effective and simple technique for bandwidth enhancement in compact reconfigurable MIMO antennas. Therefore, the proposed antenna can be considered a promising candidate for future sub-6 GHz 5G and WLAN wireless communication devices where compact size, frequency agility, and reliable MIMO performance are required.

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