

A Low Profile Modified Rectangular MIMO Antenna for UWB Applications

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Abstract: The article presents a low profile modified rectangular MIMO antenna for UWB applications. It consists of modified rectangular radiating patch etched with single rectangular slots on the top surface and partial ground plane on the bottom surface. Both slots and modified partial ground plane are used to enhance the impedance bandwidth of the proposed MIMO antenna. The orthogonal arrangement of the proposed modified rectangular MIMO antenna is analyzed with a distinct gap of $d > \lambda/2$ between individual antenna elements. The proposed MIMO antenna has an overall size of 55mm × 55mm × 0.8mm and exhibits the simulation results covering 3.9-10.9 GHz with good isolation and other parameter.

Keywords: Rectangular Patch; MIMO Antenna; Orthogonal arrangements; UWB Applications

Introduction

The explosive growth of wireless communication, particularly with the emergence of 5G and the Internet of Things (IoT), has ushered in an era of devices demanding high-speed, low-latency, and reliable data transfer across congested electromagnetic environments [1, 2]. Traditional single-element antennas, while suitable for legacy systems, are increasingly inadequate due to limitations in gain, bandwidth, and resilience against multipath fading. In response, Multiple Input Multiple Output (MIMO) antenna technology has emerged as a cornerstone for achieving enhanced data throughput, link reliability, and spectral efficiency [3–5]. MIMO systems deploy multiple antennas at both the transmitter and receiver ends, enabling simultaneous signal transmission and reception through spatial multiplexing. However, a fundamental challenge in MIMO design lies in minimizing the mutual coupling among closely spaced antenna elements, which can significantly deteriorate performance metrics such as Envelope Correlation Coefficient (ECC), Diversity Gain (DG), Channel Capacity Loss (CCL), and Total Active Reflection Coefficient (TARC) [6–9]. To address these challenges, various techniques have been explored, including defected ground structures (DGS), electromagnetic band gap (EBG) materials, neutralization lines, artificial magnetic conductors (AMC), and orthogonal arrangements of radiators [10–13]. The implementation of partial or interconnected ground planes, in particular, has proven effective in enhancing isolation without the complexity of additional decoupling networks [14–16]. In recent works, compact quad-element MIMO antennas have attracted attention for 5G and beyond, owing to their ability to provide spatial and polarization diversity within a constrained form factor. Bhalavi et al. [17] presented a dual-band quad-element MIMO antenna designed with interconnected ground structures, achieving isolation >27 dB and >32 dB in C-band (4.23–4.55 GHz) and X-band (6.30–10.22 GHz), respectively. The design utilized a deformed rectangular patch loaded with circular slots and a partial ground plane to enhance bandwidth, yielding a peak gain of 5.73 dBi and ECC < 0.001. Complementing this approach, Ramal et al. [18]

developed a compact 4-port circular-slot MIMO antenna for sub-6 GHz 5G applications, including n79, WLAN, and Wi-Fi 6E bands (4.4–7.25 GHz). This design employed a miniaturized footprint ($20 \times 17.6 \text{ mm}^2$), achieved ECC < 0.02 , diversity gain up to 9.98 dB, and radiation efficiency up to 85%. The orthogonal port layout effectively minimized coupling, ensuring isolation $>20 \text{ dB}$ across the band, making it highly suitable for portable 5G terminals.

In this article, a modified rectangular patch MIMO antenna is presented for UWB applications. Initially, the unit rectangular antenna is designed with 50Ω transmission line feed. Later, rectangular patch is etched by implementing the rectangular stub to enhance the impedance bandwidth of the antenna. In addition, a partial ground plane is also implemented on bottom side of the substrate to enhance the bandwidth of the proposed antenna. From the simulation results, this antenna can be a favorable candidate in MIMO for UWB applications.

MIMO Antenna Geometry

The geometry of modified rectangular MIMO antenna is shown in Figure 1. It consists of a modified rectangular patch having length and width of 8.5mm, Fr-4 substrate with permittivity of 4.3. Dimension of the ground plane are length 4.7mm \times width 55mm \times thickness 0.035mm, partially printed below of the FR-4 substrate. The proposed MIMO antenna is fed by a $50\text{-}\Omega$ Microstrip transmission line placed on a center of the patch with optimized dimensions of $L_f = 5.8 \text{ mm}$ and $W_f = 2.4 \text{ mm}$. In addition, a small rectangular stub is used at the corner of the rectangular radiating patch which lead the impedance bandwidth of the overall antenna. The proposed antenna simulations are performed by using EM solver, which works on Finite Difference Time Domain (FDTD solver) computer simulation technology microwave studio (CST-MWS).

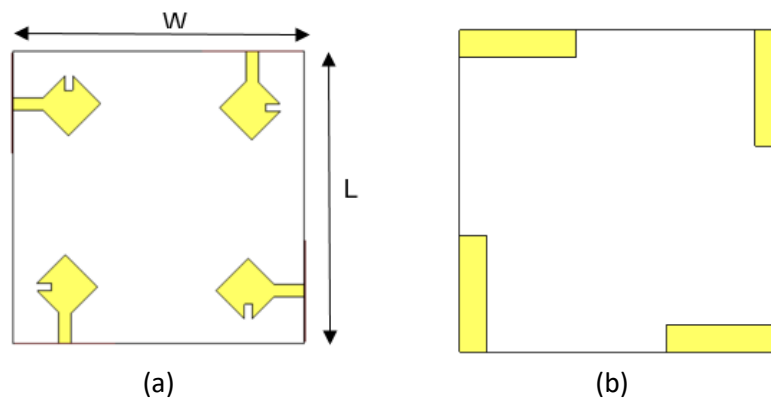


Figure1. Proposed MIMO antenna structure: (a) front side, (b) back side.

Evolution of Proposed MIMO Antenna

Figure 2 shows the evolution of the modified rectangular MIMO antenna. The proposed structure is transformed from a rectangular patch into a modified rectangular patch. Initially, a rectangular radiating patch with partial ground plane is designed and optimized with their length and width in step-1. In order to enhance the impedance bandwidth of the antenna, a small rectangular stub is etched at the corner of the rectangular patch as shown in step-2. Finally, 2×2 MIMO antenna is designed by considering 4

elements with more than 0.5λ inter-element distance as shown in step-3. The simulation results of different steps are presented in figure 3. As observed, the impedance bandwidth of step-2 is enhanced as compare to step-1. The isolation of the proposed MIMO antenna is $>25\text{dB}$ within the operating frequency bandwidth as shown in figure 4.

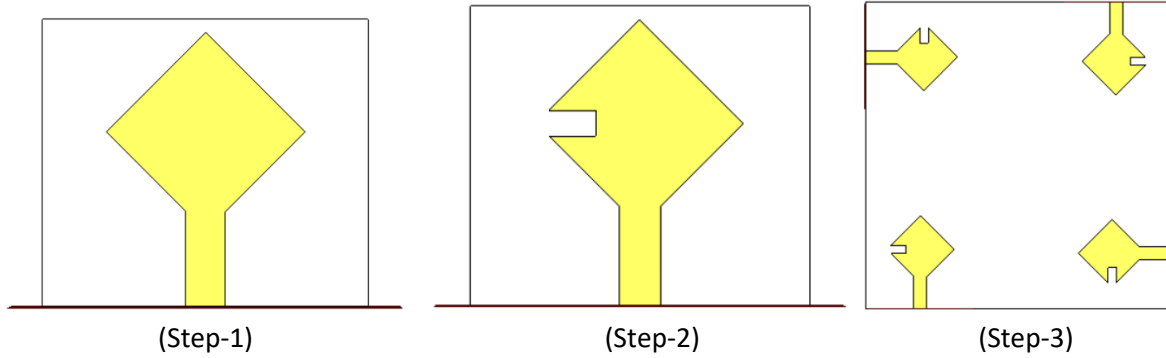


Figure2. Evolution of Proposed MIMO antenna with different steps.

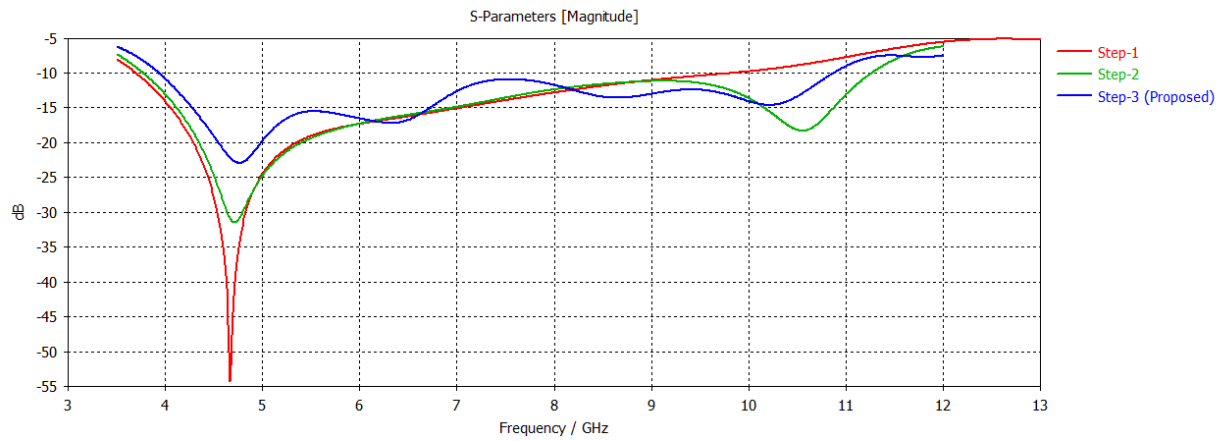


Figure3. Return loss Vs frequency of different steps.

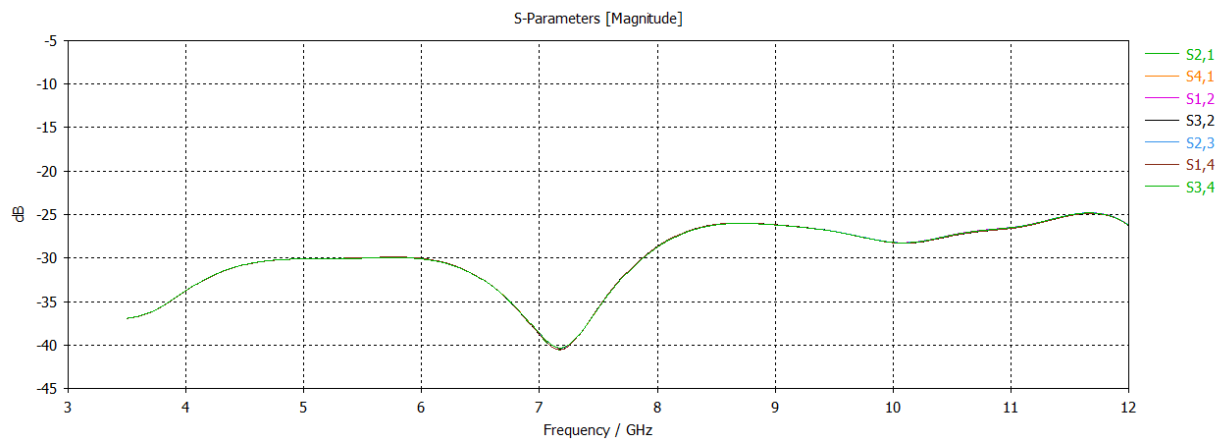


Figure 4. Isolation Vs Frequency of the proposed antenna.

Results and Discussion

The proposed modified rectangular MIMO antenna is simulated, optimized and reported. The simulation -10dB impedance bandwidth is 3.9-10.9 GHz. Similarly, other parameters like isolation and maximum realized gain are >25dB and 4dBi respectively as shown in figure 5 and 6. The simulated radiation pattern is presented for 5.5 GHz and 6.2 GHz frequency. In addition, different diversity parameter of the proposed MIMO antenna is analyzed and reported. The MIMO diversity parameters Diversity Gain (DG) and Channel Capacity Loss (CCL) are presented. The simulated DG and CCL by using full wave simulator CST-MWS solver is shown in figure 8 and 9 respectively. Maximum diversity gain is almost 10dB (>9.99dB) over the operating frequency band. Similarly, CCL is varying from 0 to 0.25 bits/sec/Hz. CCL values are below 0.3 bits/sec/Hz over the operating frequency band. It indicating satisfactory data rates over the operating bandwidth for the proposed UWB MIMO antenna. The CCL simulation outcomes corroborate these values, confirming the antenna's effectiveness.

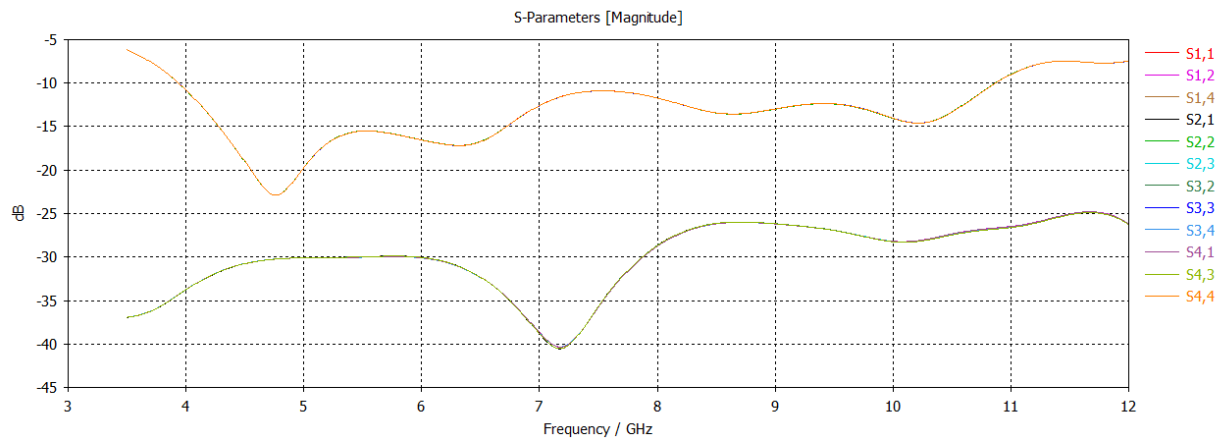


Figure 5. S-Parameters Vs Frequency of the proposed antenna.

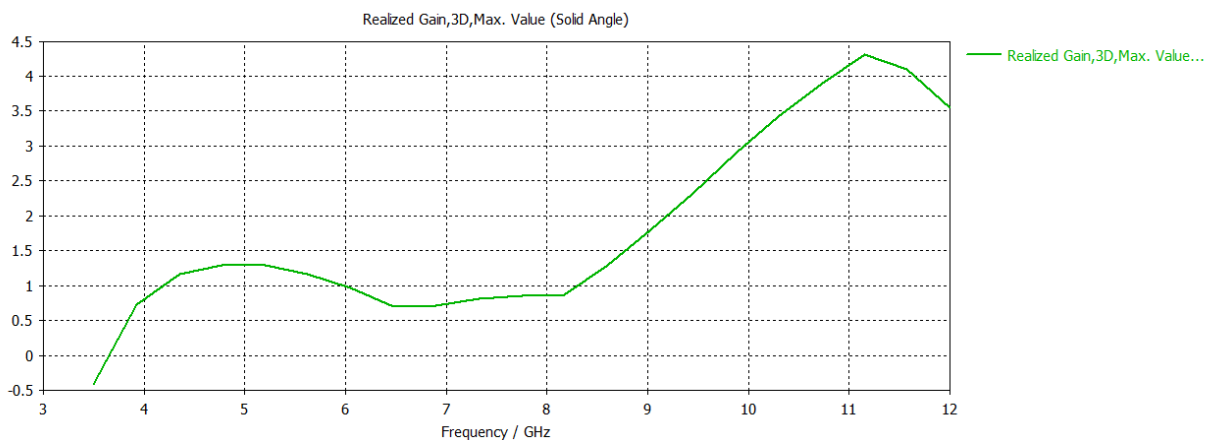


Figure 6. Realized Gain Vs Frequency of the proposed antenna.

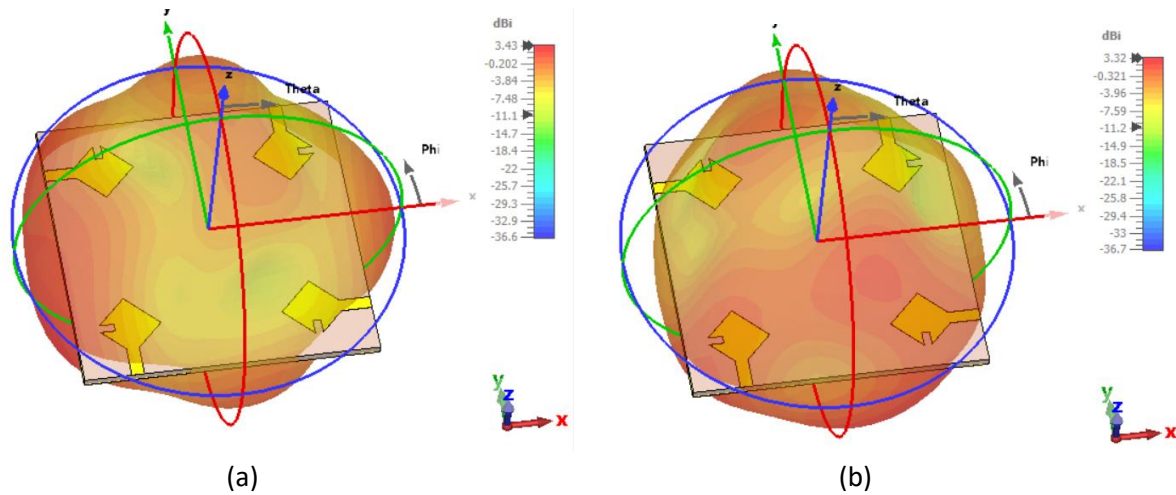


Figure 7. Radiation pattern of the proposed antenna (a) 5.5 GHz, (b) 6.2 GHz

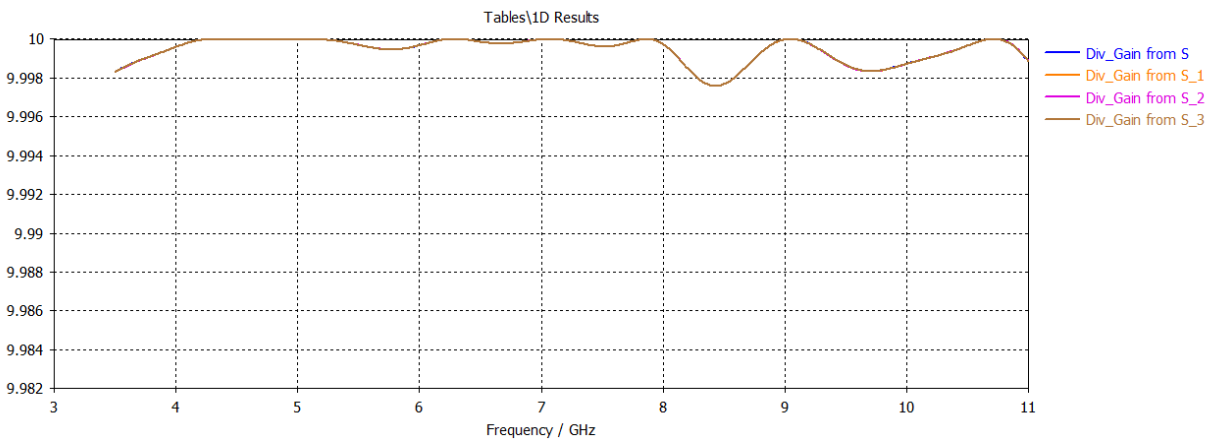


Figure 8. Diversity Gain Vs Frequency of the proposed antenna.

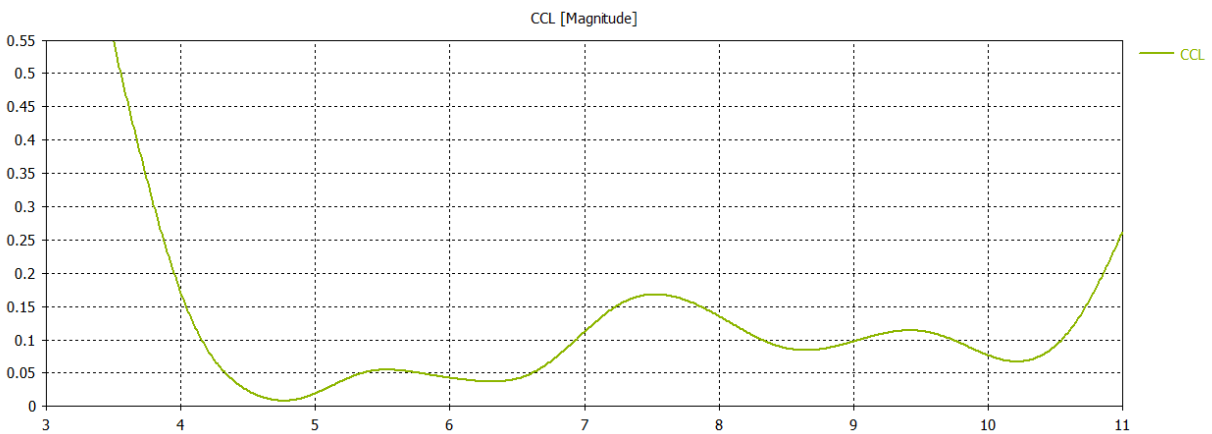


Figure 9. CCL Vs Frequency of the proposed antenna.

Conclusion

In conclusion, this article introduced a 4-port modified rectangular MIMO antenna designed for UWB applications, with operating frequency range, isolation and diversity gain of 3.9-10.9 GHz, >25dB and 20dB respectively. This low profile MIMO antenna is fabricated using FR-4 substrate that ensuring the robust performance in fabrication. Its compact size facilitated the integration of multiple-input-multiple-output (MIMO) system.

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