Design Of Two Port Antenna With Enhanced Isolation For WIFI Applications

P.Ganesh Vardhan[1], Y.Vamsi Krishna[2], Joshi Vamsi[3] and A.Ajay Reddy[4]
[1,2,3,4]*Department of Electronics and Communication Engineering, Vasireddy Venkatadri Institute of Technology,Nambur, Guntur*

Abstract—**In this paper, the compact two port MIMO microstrip patch antenna at 5.8 GHz band is designed and simulated for Wi-Fi application. The main focus of this work is to improve the isolation between closely placed antenna while keeping good radiation performance. One of major challenges in MIMO is mutual coupling which degrade the performance parameters like return loss, efficiency and connection. In order to mitigate mutual coupling, stub based isolation approach is used. Designed antenna consists of Rogers RT5880 substrate with a dielectric constant of 2.2 and substrate thickness 1.6mm. Configuration of single patch, MIMO without Isolation and MIMO with Stub are considered for analysis and simulation using CST Studio suite software. Simulated results show that proposed structure is able to achieve return loss better than -25dB and isolation of -16dB at desired resonating frequency of 5.8 GHz along with stable radiation pattern, low Envelope Connection Coefficient (ECC) and efficiency. The proposed antenna can be applied to modern wireless communication system including Wi-Fi, 5G and IoT.**

Index Terms—**MIMO antenna, Microstrip patch, Mutual coupling, Isolation, Stub technique, Wi-Fi.**

I. INTRODUCTION

Microstrip patch antenna is popularly used in modern wireless systems because of their advantages such as low-profile, lightweight, easy fabrication and integration with integrated circuits [9], [12]. When integrating two or more antenna elements into a compact MIMO antenna system, mutual coupling among the closely located antenna elements is an important factor affecting the antenna's performance, such as impedance matching, radiating efficiency and connection between antenna elements [4], [7].

Several techniques have been reported in the literature such as defected ground structure (DGS) technique, parasitic elements, slot techniques and electromagnetic bandgap (EBG) structures [14], [24], [25] to overcome the problem of mutual coupling in the patch antennas.

But these methods either add more complexity to the design or degrades the antenna's some other characteristics. Some recent work also explores the idea to employ metasurface based design and complex decoupling structure [6] to improve the isolation between antenna.

Stub based isolation method draws more attention since it adds no extra complexity while achieves sufficient isolation by creating out of phase currents in between the radiating structures [4], [7]. The designed antenna is simulated on CST studio suite [10] and the results are analyzed on the basis of S-parameters, radiation pattern, gain, efficiency and Envelope connection coefficient (ECC). Designed antenna shows good isolation and efficient performances that make it applicable to current wireless communication systems.

II. LITERATURE REVIEW

A. Overview of Microstrip Patch Antennas

Microstrip patch antennas have been widely applied in modern wireless communication systems because of their low-profile, compact, light and easy fabrication via printed circuit technology [9, 12]. Various techniques to improve the performance of microstrip patch antennas such as using low dielectric constant substrate, increasing the thickness of the substrate, introducing slots and notches or adding some parasitic patches were proposed [21] which could achieve good impedance matching, large bandwidth and favorable radiation characteristics. They can be applied to Wi-Fi, satellite scommunications and 5G.

B. MIMO Antenna System

Today, Multiple Input Multiple Output (MIMO) technology is commonly used in wireless communication system due to its ability of increasing spectral efficiency, data rate and link reliability [1], [3]. In a MIMO system, more than one transmitter and receiver antenna are employed to take advantage of multipath propagation to increase system performance without consuming more bandwidth. The MIMO antenna's performance is measured by using some parameter like S-parameter, Envelope Connection Coefficient (ECC), Diversity Gain and Radiation Efficiency [2], [7].

C. Techniques for Mutual Coupling

Other examples involve increasing distance between antenna elements, which is not feasible in compact designs; using defected ground structure (DGS) to cut off the surface currents by introducing defects on ground plane [24]; applying parasitic elements to alter the direction of EM waves and reduce mutual coupling [14], [25]; employing electromagnetic band gap (EBG) structures to manipulate the properties of EM waves and control the isolation characteristics [6], [24]. Although above mentioned methods have certain advantages, they complicate the design and manufacturing process. In comparison with existing works, stub based approaches strike a proper balance between performance enhancement and design simplicity, so they would be more suitable for compact MIMO designs, where space limitations restrict their applications.

III. ANTENNA DESIGN AND SYNTHESIS

The proposed antenna is a compact two-port MIMO microstrip patch antenna designed to operate at 5.8 GHz for Wi-Fi applications. The Rogers RT5880 substrate with a dielectric constant of 2.2 and thickness of 1.6 mm, selected for its low loss and stable performance at microwave frequencies [20]. The overall structure consists of a radiating patch, dielectric substrate, ground plane, and microstrip feed line, which together form the fundamental elements of a microstrip antenna [9], [12]. The initial dimensions of the rectangular patch are calculated using standard transmission line model equations, where the patch width is determined effective dielectric constant is computed to account for fringing field effects [16]. The antenna design is modeled and optimized using CST Studio Suite [10], where parameters such as return loss (S11), mutual coupling (S21), radiation pattern, gain, efficiency, and Envelope Correlation Coefficient (ECC) are analyzed. The synthesized design achieves good impedance matching and enhanced isolation, making it suitable for compact wireless communication systems.

$$W_p = \frac{C}{2\,f_r\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \quad (1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W_p}\right]^{-\frac{1}{2}} \quad (2)$$

$$L_{eff} = \frac{c}{2\,f_r\sqrt{\varepsilon_{eff}}} \quad (3)$$

$$\Delta L = 0.412h\,\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W_p}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W_p}{h} + 0.8\right)} \quad (4)$$

$$L_p = L_{eff} - 2\Delta L \quad (5)$$

TABLE I. PHYSICAL DIMENSION OF SINGLE ELEMENT

Parameter	Dimensions (mm)	Parameter	Dimensions (mm)
Wp	19.8	Lp	16.4
εeff	2.03	Leff	18.15
Wf	3.8	Lf	12
W	40	L	40

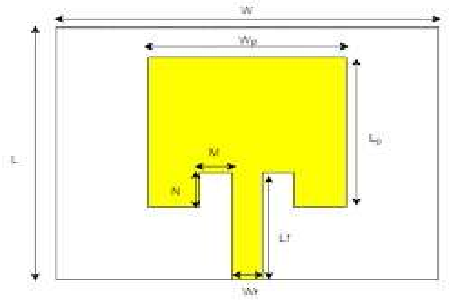

Figure 1- Single Element Geometry

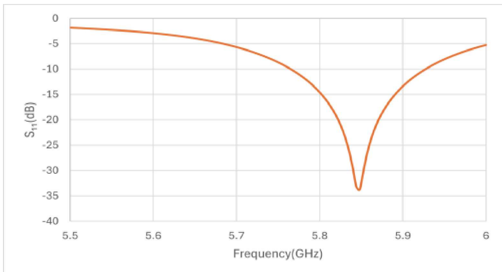

Figure 2- S_{11} of Single Patch

The introduction of a second antenna element in close proximity leads to strong electromagnetic interaction between the patches, resulting in increased mutual coupling, indicating poor isolation between the ports. Although the antenna still resonates near the desired frequency, a slight frequency shift is observed due to the coupling effects and altered current distribution. The return loss (S11) also shows impedance matching is affected by the presence of the adjacent element.

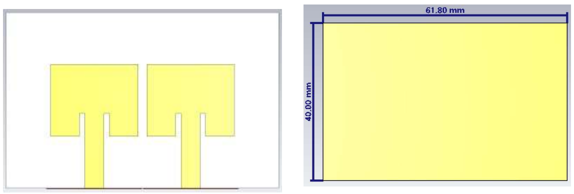

Figure 3- MIMO Antenna without stub

The separation between the two antenna elements is maintained at 2 mm. Such a small inter-element spacing is desirable for compact designs but significantly increases mutual coupling due to strong near-field interaction and surface current coupling.The return loss (S_{11}) also degrades due to impedance mismatch caused by the presence of the adjacent element. Additionally, the antenna exhibits slight frequency detuning, distortion in radiation pattern, and reduced efficiency due to non-uniform current distribution.

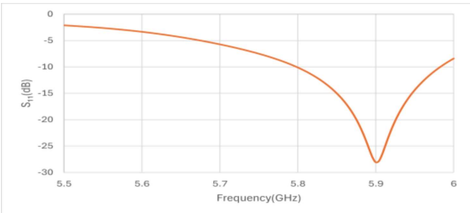

Figure 4- S_{11} before placing stub

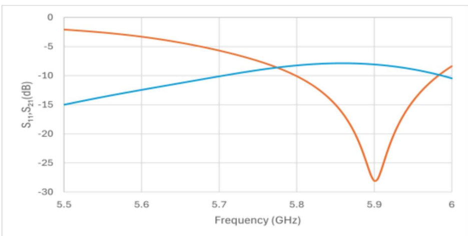

Figure 5- S_{11} & S_{21} before placing stub

The introduction of the stub structure significantly improves antenna performance by effectively reducing mutual coupling. The stub acts as a reactive decoupling element that generates opposite phase currents, thereby canceling the coupled signals between the antenna elements. As a result, the isolation improves considerably. The return loss also improves, achieving values better, which indicates excellent impedance matching. Moreover, the radiation pattern remains stable, and the efficiency of the antenna is preserved and better independence

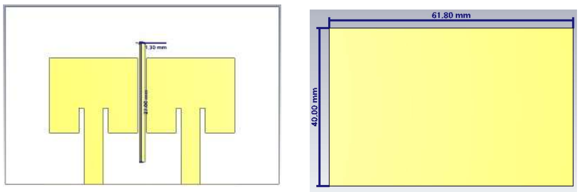

Figure 6- MIMO Antenna with stub

between antenna elements. Therefore, the incorporation of the stub structure provides a simple and effective solution for enhancing isolation in compact MIMO antenna systems without increasing design complexity.

A significant improvement in performance is observed even at the small spacing of 2 mm. The stub acts as a reactive decoupling element that generates opposite phase currents, effectively canceling the coupled fields between the patches. As a result, the isolation improves and demonstrating a substantial reduction in mutual coupling. The return loss also improves that to indicating enhanced impedance matching. Furthermore, the radiation pattern remains stable, and antenna efficiency is preserved.

TABLE II DIMENSIONS OF ANTENNA WITH STUB AND WITHOUT STUB

Parameter	Dimensions(mm)	
	With stub	Without stub
Antenna Size(mm^2)	61.8x40	61.8x40
L stub	27	--
W stub	1.3	--

The effect of the stub structure on isolation performance is clearly observed by comparing the S21 parameter of the MIMO antenna before and after its implementation. The stub acts as a reactive decoupling element that modifies the current distribution and generates opposite phase currents, effectively canceling the coupled signals.Therefore, the incorporation of the stub significantly improves isolation without increasing the antenna size or adding design complexity.

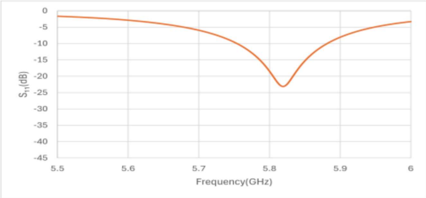

Figure 7- S_{11} after placing stub

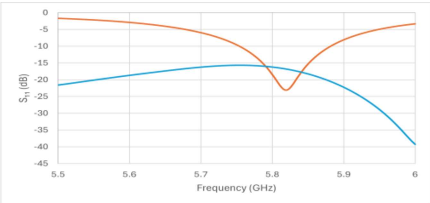

Figure 8- S_{11} & S_{21} after placing stub

Overall, the incorporation of the stub leads to better signal integrity, improved antenna efficiency, and lower correlation, making the MIMO system more suitable for high-performance wireless applications.

IV. RESULTS AND DISCUSSION

The performance of the proposed two-port MIMO antenna is evaluated using key radiation and system parameters, including radiation pattern.These parameters are analyzed for both configurations—without stub and with stub to understand the impact of the isolation technique.

When the antenna is converted into a MIMO configuration without any isolation technique, the radiation pattern becomes distorted due to strong mutual coupling between the closely spaced elements (2 mm separation). This distortion is caused by non-uniform surface current distribution and electromagnetic interference between antenna elements.

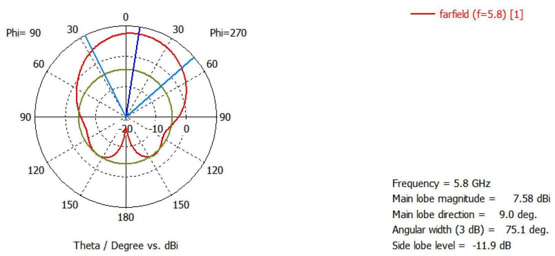

Figure 9- Radiation pattern without stub

After introducing the stub structure, the radiation pattern stabilizes and closely resembles that of the single patch antenna. The stub effectively suppresses unwanted coupling currents, thereby restoring uniform current distribution and maintaining consistent radiation characteristics.In the MIMO antenna without isolation, efficiency is reduced due to coupling losses and unwanted power transfer between antenna elements. With the implementation of the stub, efficiency improves significantly as the coupling is minimized and more power is radiated effectively.

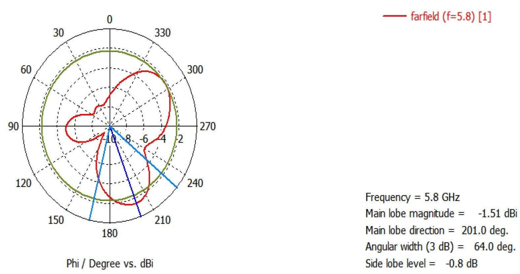

Figure 10- Radiation pattern with stub

From the figure9 and Figure10 the radiation pattern provides a two-dimensional view of the radiation characteristics in specific planes (E-plane and H-plane). For the MIMO antenna, the polar plot shows a smooth and well-defined main lobe with minimal side lobes, indicating stable and predictable radiation behavior. In contrast, the MIMO antenna without isolation exhibits irregular polar plots with increased side lobes and slight asymmetry due to coupling effects.After introducing the stub structure, both the radiation patterns show considerable improvement. The 3D pattern regains its symmetry, with a well-defined main lobe directed in the broadside direction. Similarly, the polar plots become smoother and more stable, with reduced side lobes and improved symmetry.

The efficiency of the proposed MIMO antenna is observed, indicating effective radiation of the input power with minimal losses. The antenna exhibits good radiation efficiency due to proper impedance matching and low dielectric losses of the RT5880 substrate. In the MIMO configuration without isolation, the efficiency slightly degrades as a portion of the input power is coupled to the adjacent element, leading to unwanted power dissipation. However, after introducing the stub structure, the efficiency improves. The optimized design ensures that the antenna maintains high radiation efficiency while achieving enhanced isolation, which is essential for reliable MIMO system performance [4], [16].

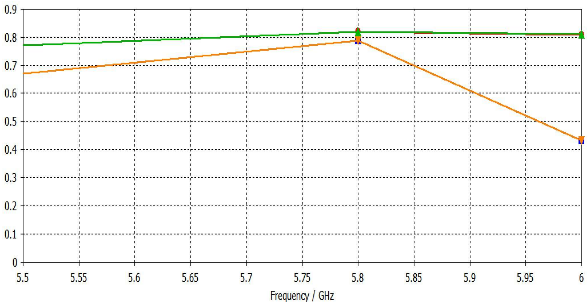

Figure 11- Efficiency pattern

The simulated results indicate that the ECC values are reduced to very low levels after applying the stub, confirming enhanced diversity performance and efficient operation of the MIMO system. Thus, the proposed antenna design achieves good isolation and low correlation, making it suitable for modern wireless applications such as Wi-Fi and 5G systems.

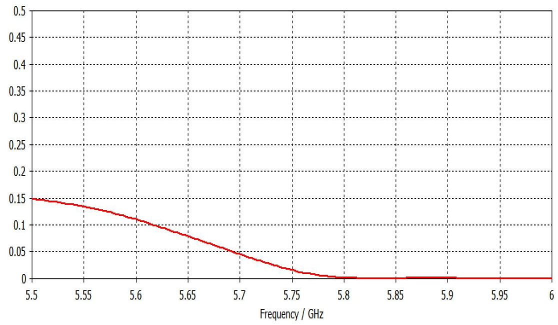

Figure 12- ECC Result of MIMO Antenna

V. CONCLUSION

In this work, a compact two-port MIMO microstrip patch antenna operating at 5.8 GHz for Wi-Fi applications has been successfully designed and analyzed. The antenna is implemented on a Rogers RT5880 substrate, and its performance is evaluated using CST Studio Suite. The primary challenge of mutual coupling in closely spaced antenna elements (2 mm separation) is addressed using a stub-based isolation technique.

The initial MIMO configuration without any isolation structure exhibits high mutual coupling, resulting in poor isolation and degraded overall performance. By introducing the stub structure, a significant improvement in isolation is achieved, with the S21 parameter improving from approximately −10 dB to −16 dB. Additionally, the antenna demonstrates excellent return loss (better than −25 dB), stable radiation patterns, satisfactory gain, and good radiation efficiency. The Envelope Correlation Coefficient (ECC) is also reduced, indicating improved diversity performance and effective independent operation of the antenna elements.

The results confirm that the proposed stub-based approach provides a simple and efficient solution for enhancing isolation in compact MIMO antenna systems without increasing design complexity or size. Therefore, the antenna is well suited for modern wireless communication applications such as Wi-Fi, 5G, and IoT devices.

"A compact 5.8 GHz two-port MIMO antenna with improved isolation using a stub structure is presented. The design achieves enhanced isolation, good return loss, stable radiation characteristics, and low ECC, making it suitable for modern wireless applications"

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