
**E-ISSN:** 2708-3977
**P-ISSN:** 2708-3969
IJEDC 2024; 5(1): 12-19

www.datacomjournal.com
Received: 10-11-2023
Accepted: 15-12-2023

**Ayad Muslim Hamzah**
Najaf Technical Institute
Al-Furat Al-Awsat Technical University, Najaf, Iraq

**Nameer Falih Mhaidi**
Najaf Technical Institute
Al-Furat Al-Awsat Technical University, Najaf, Iraq

**Correspondence**
**Ayad Muslim Hamzah**
Najaf Technical Institute
Al-Furat Al-Awsat Technical University, Najaf, Iraq

# Dual Band MIMO Antenna for 5G Wireless Communication using DGS Technique

## Ayad Muslim Hamzah and Nameer Falih Mhaidi

**Abstract**
In this research, we have proposed the design of a MIMO antenna using Defected Ground Structure that is able to bring about high isolation, high efficiency, and best performance. A compact MIMO has been designed on a low cost FR-4 substrate of 1.6 mm thickness having a dimension of 24 mm×24 mm. The proposed antenna comprises two identical T-shaped patches and defected ground structure which reduces mutual coupling. Our proposed MIMO Antenna has proved that it is highly efficient at desired frequencies of 3.4 GHz and 5.1 GHz which shows return loss of -23 dB and -26 dB, while S21 which is the decoupling parameter is -28 dB, hence enough isolation has been achieved. The maximum gain at 3.4 GHz is 2.6 dBi and at 5.1 GHz is 3.2 dBi. Therefore, it can be said that our proposed antenna has overcome the shortcomings of the present MIMO Antenna and it is best for 5G Communications.

**Keywords:** 5G, MIMO antenna, DGS technique, mutual coupling

## Introduction

The emergence of 5G Wireless Communication has fascinated research fields due to its potential to keep everything in touch and break through the restraints of time and space. 5G is going to meet the unprecedented needs of users beyond the capacity of earlier generations. MIMO Antenna has grabbed the attention in wireless communication technology due to its extensive capacity, higher reliability, and ability to serve a large proportion of users. Currently, available 4G Technology along with the antennas that are coupled with it are unable to meet users' needs. The combination of upcoming 5G technology and MIMO Antenna is set forth to meet users' expectations in terms of data speeds and data transmissions [1-2]. Previous generations are failed to build a sustainable environment for wireless communications. In recent times 5G, a forthcoming generation in technology is all set to put forward higher speeds as compared to previous generations. In the upcoming 5G network, the role of MIMO Antenna cannot be ignored because of its numerous applications. MIMO Antennas perform a crucial role in 5G technology. MIMO Antenna helps data to reach maximum users at high speed [3]. MIMO Antenna is an indispensable part of the upcoming 5G Communication System, but a great challenge of mutual coupling stands in the way of its efficiency.

The Defected Ground Structure (DGS) technique is a popular method used in the design of microstrip antennas and other microwave components. The process entails the introduction of a regular arrangement of carved slots or patches in the antenna's ground plane, resulting in the creation of a bandstop or bandpass response at a certain frequency. The DGS technique has several advantages in antenna design, including (Size reduction, Frequency agility, Isolation improvement and Performance improvement) [4].

A MIMO Antenna consists of two or more two antennas that are normally placed concurrently which ultimately results in a major problem of Mutual Coupling [5]. This problem has a negative impact on the effectiveness of MIMO Antenna because when many antennas are simultaneously placed, it has a deteriorating impact on the channel's capacity.

Therefore, this problem must be solved. Many techniques have been proposed for decreasing mutual coupling by different researchers, but our proposed Antenna is Dual Band MIMO Antenna which is capable to achieve enough isolation by using an advanced defected ground structure technique [5-6]. Defected ground structure technique can be used in MIMO Antenna for isolation purposes. The structural design of our proposed defected ground structure is very simple which is why it is very reliable to be used in MIMO Antenna.

In simple words, defected ground structure can be defined as the slots on the general ground. In our proposed model different slots are planted among nearly positioned antennas in the ground which help to achieve enough isolation. When different slots are placed between the elements of the MIMO Antenna, only less amount of current has the ability to overlap with another element [7]. Therefore, higher isolation could be achieved through this method.

In this research, defected ground structures have been proposed which are planted nearby among two patches, working at 5 GHz frequency. In our proposed antenna, T-shaped patches and a circular defected ground slot have been employed. Defected ground structures can be of different shapes like I, H, T, or circular shapes which ultimately enable us to achieve a low insertion loss as well as low return loss [8]. However, in our proposed antenna, a circular-shaped slot has been used as a defected ground structure.

Our proposed antenna is highly valuable whenever there is a greater requirement of reduced mutual coupling. On a whole MIMO Antenna with reduced mutual coupling among its elements, high efficiency, and best performance have been proposed in this research [9].

Our proposed Dual Band MIMO Antenna is based on a low-cost substrate and its efficiency has been substantiated through measurement as well as simulation [10]. Our proposed antenna is best for 5G Wireless Communications due to its high isolation among patches, high gain, less return loss, and high efficiency at low cost

**Antenna Design**

The detailed procedure to design a novel shape two elements antenna for the implementation of MIMO operations is debated in this section. The simulations and o Ptcokj imizations of our proposed antenna have been done with the help of computer simulation technology (CST) software. The proposed design is intended for 5G applications. The proposed MIMO antenna comprises of two patches and a defected ground structure so it has certain design constraints. The Figure (1) displays the precise dimensions and geometry of our proposed Dual Band MIMO Antenna [11-12].

A FR-4 substrate with a relative permittivity of 4.4, a loss tangent of 0.025, and a thickness of 1.6 mm [13-14] is used to build the two T-shaped patch antenna components that make up the proposed antenna.

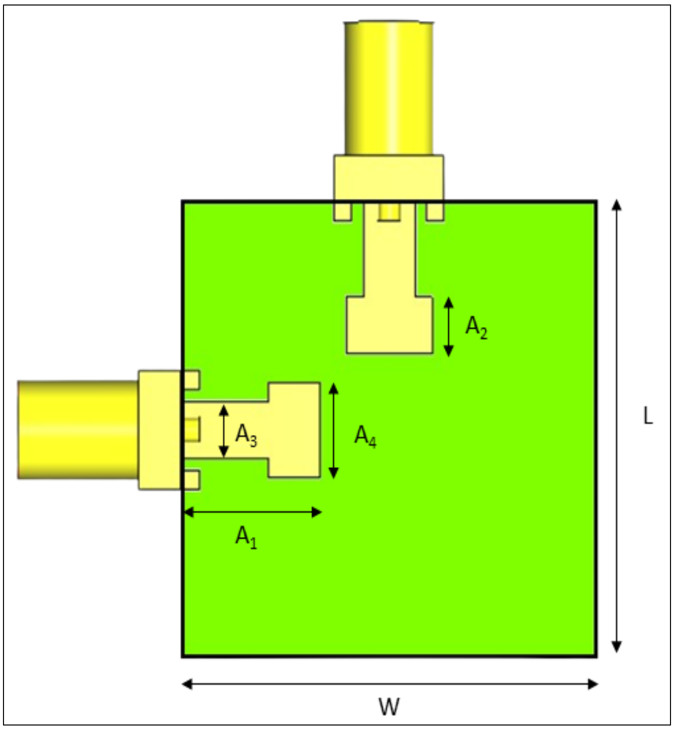


**Fig 1:** The front view of the proposed antenna shows two elements of MIMO.

**Table 1:** Specifications of the Proposed Antenna

| Optimized Parameters of the Proposed Antenna | | |
|---|---|---|
| **Parameter** | **Value (mm)** | **Description** |
| L | 24 | Substrate length |
| W | 24 | Substrate width |
| H | 1.6 | Height of substrate |
| A1 | 7 | Patch length |
| A2 | 3 | Patch length |
| A3 | 3 | Patch length |
| A4 | 5 | Patch length |
| R1 | 11 | Radius of slot |
| R2 | 1.4 | Radius of Slot |
| D1 | 1.4 | Width of Slot |
| D2 | 2 | Width of Slot |

In the proposed design, a defected ground is nothing but the slot. A circular slot defect is introduced on the ground showing as parameter D1 as mentioned in Table 1. Along with this slot another circular slot having a width of parameter D2 is loaded exactly. These two slots are united together and act as a defected ground structure. The preliminary values depend on the following equations [15-16].

$$L = L_{eff} - 2 \quad (1)$$

$$\Delta L = 0.412h \frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \quad (2)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{w}\right)^{-0.5} \quad ,\frac{w}{h} > 1 \qquad (3)$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \qquad (4)$$

$$Lst = Lx + Ly - 2Wst = \frac{c}{2f\sqrt{\varepsilon_{eff}}} \qquad (5)$$

$$\varepsilon_{eff} = \frac{e_r+1}{2} \qquad (6)$$

A parasitic element is used to increase port-to-port isolation. A microstrip line connects two L-shaped stubs that make up the parasitic structure. Initially, the length of a T-shaped stub was thought to be determined by [17] in order to design the stubs.

Here are the variables that make up the equation: f is the band center frequency, Lx is the horizontal axis length, Ly is the vertical axis length, and Wst is the width of the microstrip line. Additionally, eeff represents the effective dielectric constant, er represents the relative permittivity, and c represents the speed of light. Therefore, according to equations (5) and (6) [18].

The patches are linked to the feeding point is called the feeding patch for enhanced impedance matching. Each antenna is stimulated via SMA feeding in order to achieve 50 Ω impedance matching [19-20]. The optimized parameters of the proposed antenna are listed in Table 1.

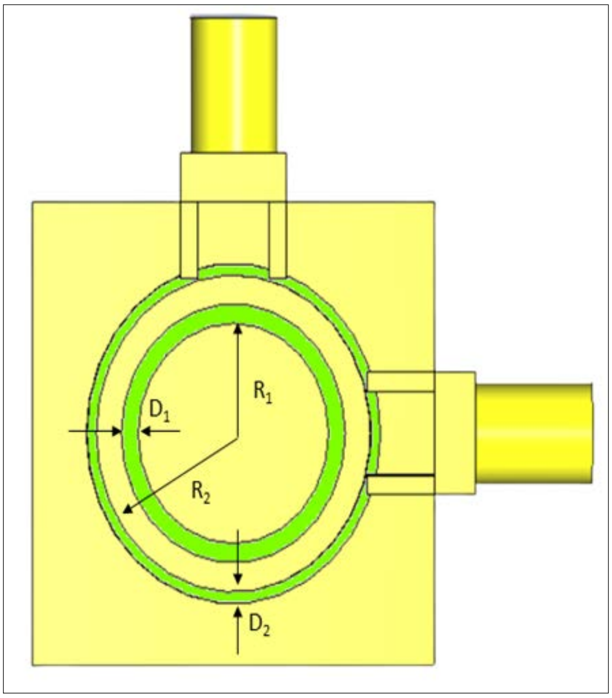


**Fig 2:** The back view of the proposed Antenna indicates Defected Ground Structure.

**Results and Discussion**

This section deals with the analysis of the performance of the proposed antenna using different results. The impact of defected circular slot as a ground structure on the MIMO Antenna has been investigated in order to get less return loss, high isolation, and the best performance.

Multiple visual representations demonstrate that the MIMO antenna with the DGS technique implemented has significantly outperformed the MIMO antenna without the DGS approach. The simulation and optimization proposed MIMO Antenna is completed using Computer Simulation Technology (CST) Software. The performance of our proposal has been investigated on the bases of the Radiation pattern, S-Parameters, Gain, Efficiency, and ECC.

**A. S-parameter Analysis**

The S parameter is a very important metric to analyze the performance of the proposed antenna. Scattering parameters have been introduced in order to trace the relationship among various ports of the antenna. These parameters are able to explicate energy propagation within the electric network. The relationship that exists between incident wave reflected wave, and transmitted wave over different frequencies can be described through S parameters. Scattering parameters analysis is done on the basis of propagated waves in spite of current or voltage, we also see the effect of the parameter in the following figures. 3 and 4.

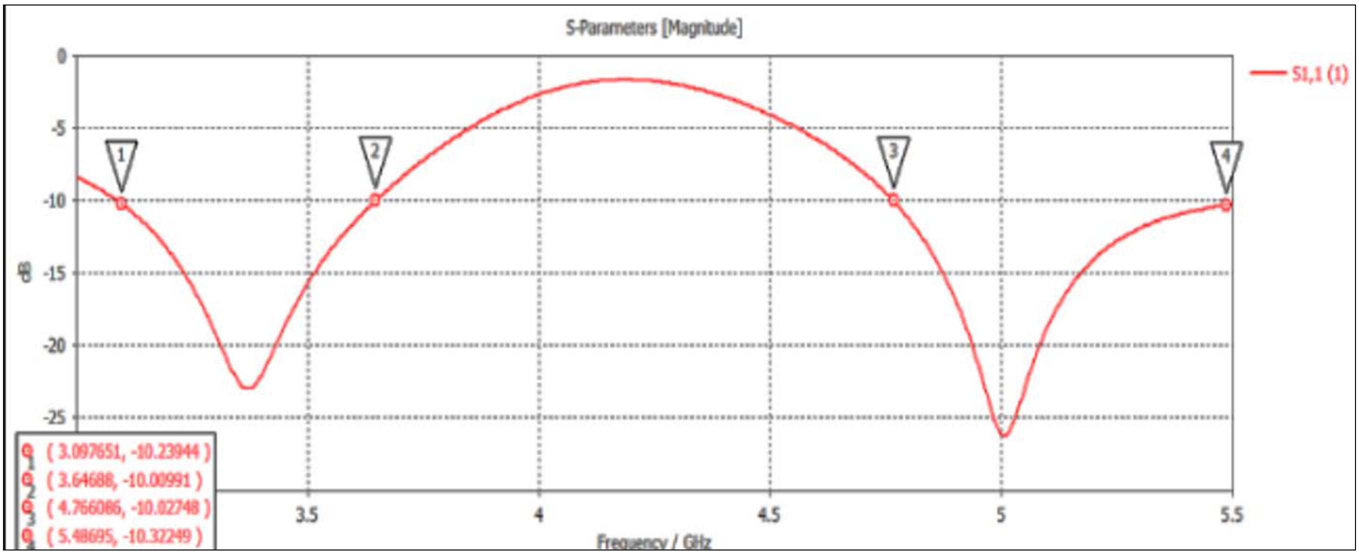


**Fig 3:** Simulated S11

Return loss (S11) portrays the ratio of the waves that are arrived at the input of the antenna and are accepted against those of the rejected waves. The proposed MIMO antenna is resonating at 3.4 GHz and 5.1 GHz and shows return loss of -23 db and -26db respectively. High return loss of our proposed antenna means less insertion loss that is advantageous.

However, S21 depicts power that is transferred from one port of the antenna to another. The transmission coefficient of the proposed antenna is showing -28 db. In our proposed dual-band MIMO Antenna, S21 being the decoupling parameter represents the isolation between the patches of the antenna. Therefore, due to the importance of both of these parameters, they have been explicated in our research work.

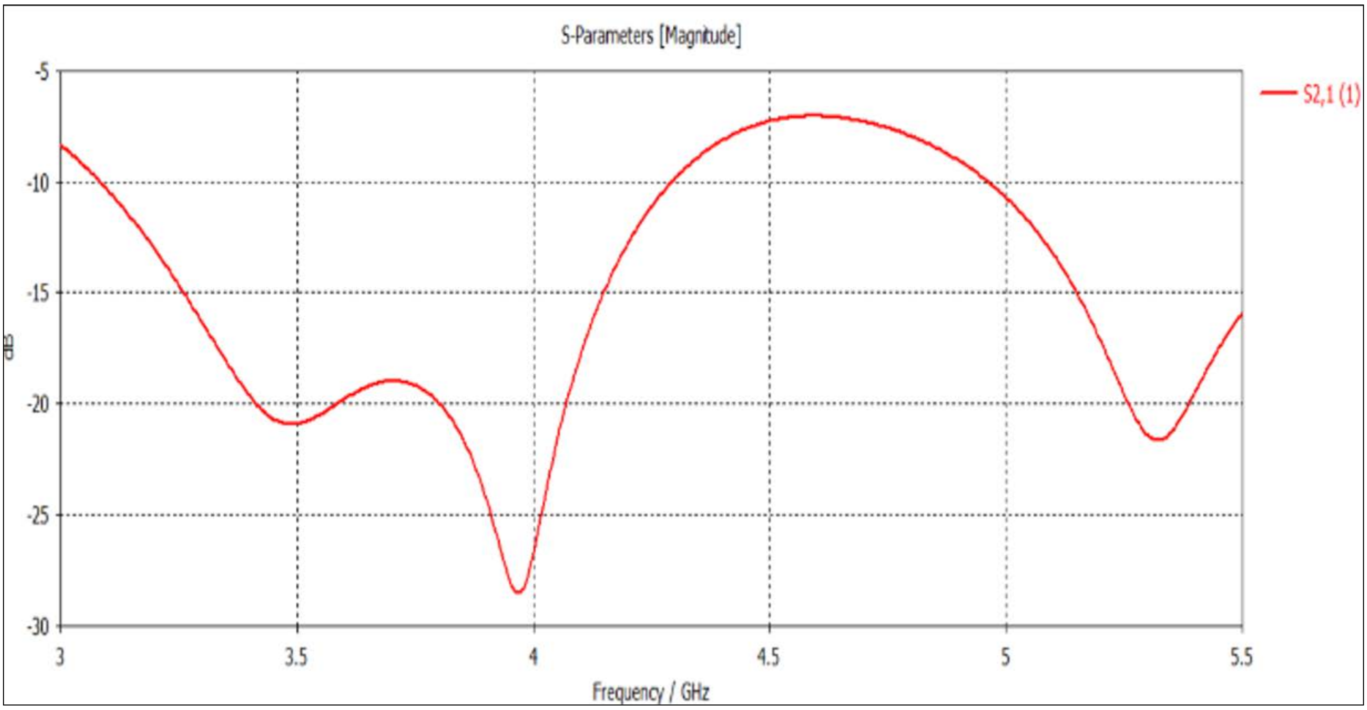


**Fig 4:** Simulated S21

**B. Radiation Pattern**

The radiation pattern is a crucial concept in the realm of antenna design since it illustrates the directional dependence of wave intensity. The radiation pattern depicts the distribution of energy emitted by the antenna. The radiation patterns in certain directions can provide information about both the reception and transmitting qualities of an antenna. In addition to this information, the radiation pattern in our proposed dual-band MIMO represents a gain of the antenna in specific directions as well as the efficiency of this antenna.

The radiation pattern of our suggested antenna is visible at frequencies of 3.4 GHz and 5.1 GHz, as shown in figure 5. Two distinct patterns for each frequency have been demonstrated, one in the E-Plane and one in the H-Plane.

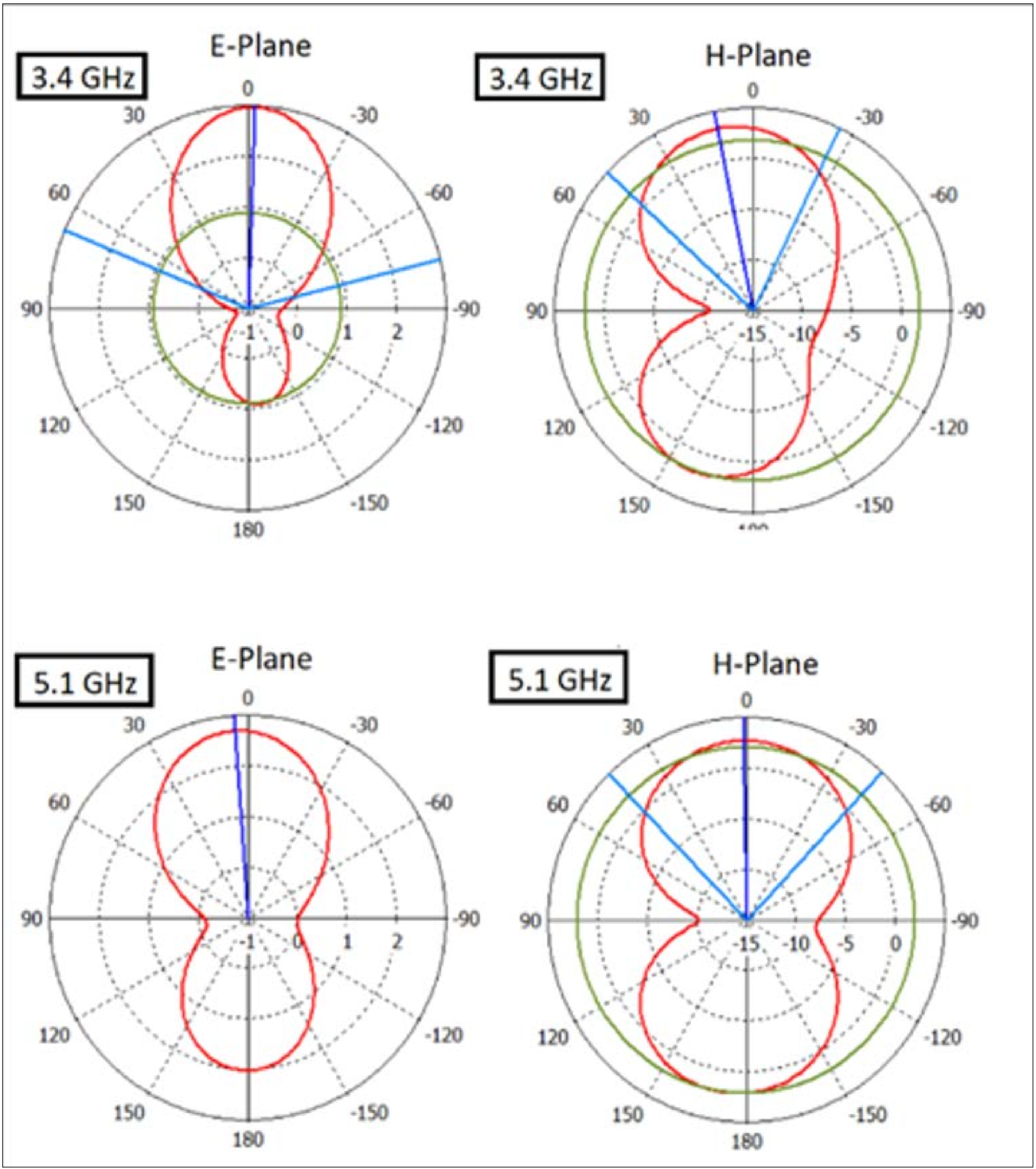


**Fig 5:** Simulated 2D Radiation Pattern (azimuth phi = 0 deg and elevation phi = 90 deg) and 3D Radiation Pattern at 3.4 GHz and 5.1 GHz.

### C. Gain

The gain of an antenna represents the effectiveness of an antenna by which it radiates power. In a particular direction, antenna gain is its capacity of radiating energy in comparison to that of a theoretical antenna. Sometimes, the antenna can radiate in all directions equally if it is constructed perfectly. An antenna with a high gain is always better than a low gain antenna. If the gain of the antenna is high, it ultimately results in an increase in signal strength. Antenna gain takes the efficiency of the antenna and directivity into its account. From Figure.6, it has been observed that gain of our proposed antenna at 3.4 GHz is 2.6 dBi and 5.1 GHz is 3.2 dBi.

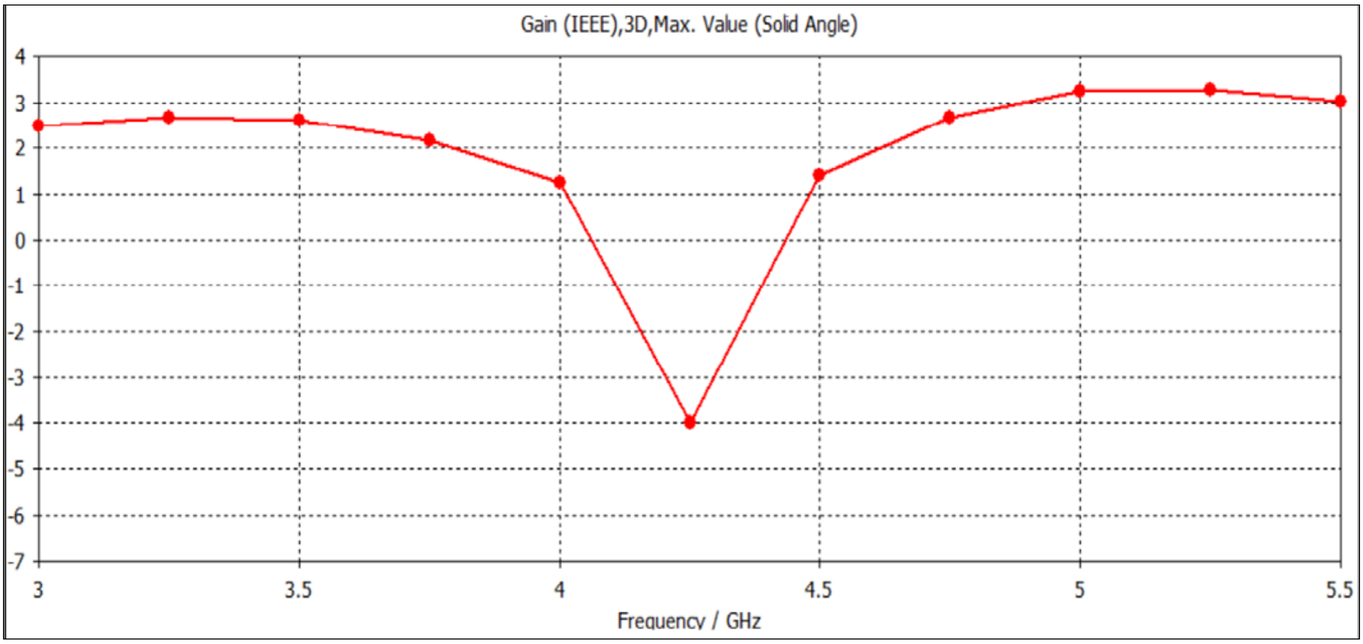


**Fig 6:** Gain of the proposed MIMO Antenna.

### D. Radiation Efficiency

Another essential parameter in antenna design is radiation efficiency which represents radiated energy of an antenna in proportion to that of accepted energy at conduction. High electrical power will be radiated if the efficiency of the antenna is high and low electrical power will be radiated in case of poor efficient antenna dissipating some of its electrical power in different forms of energy such as heat. Ultimately, an antenna with more efficiency has much better performance as well as better results as compared to that an antenna with low efficiency. Mostly, the radiation efficiency of an antenna is represented in the form of percentages and sometimes-in decibels From Figure.7; it has been found that the efficiency of the antenna is 78%. Therefore, it's a good value.

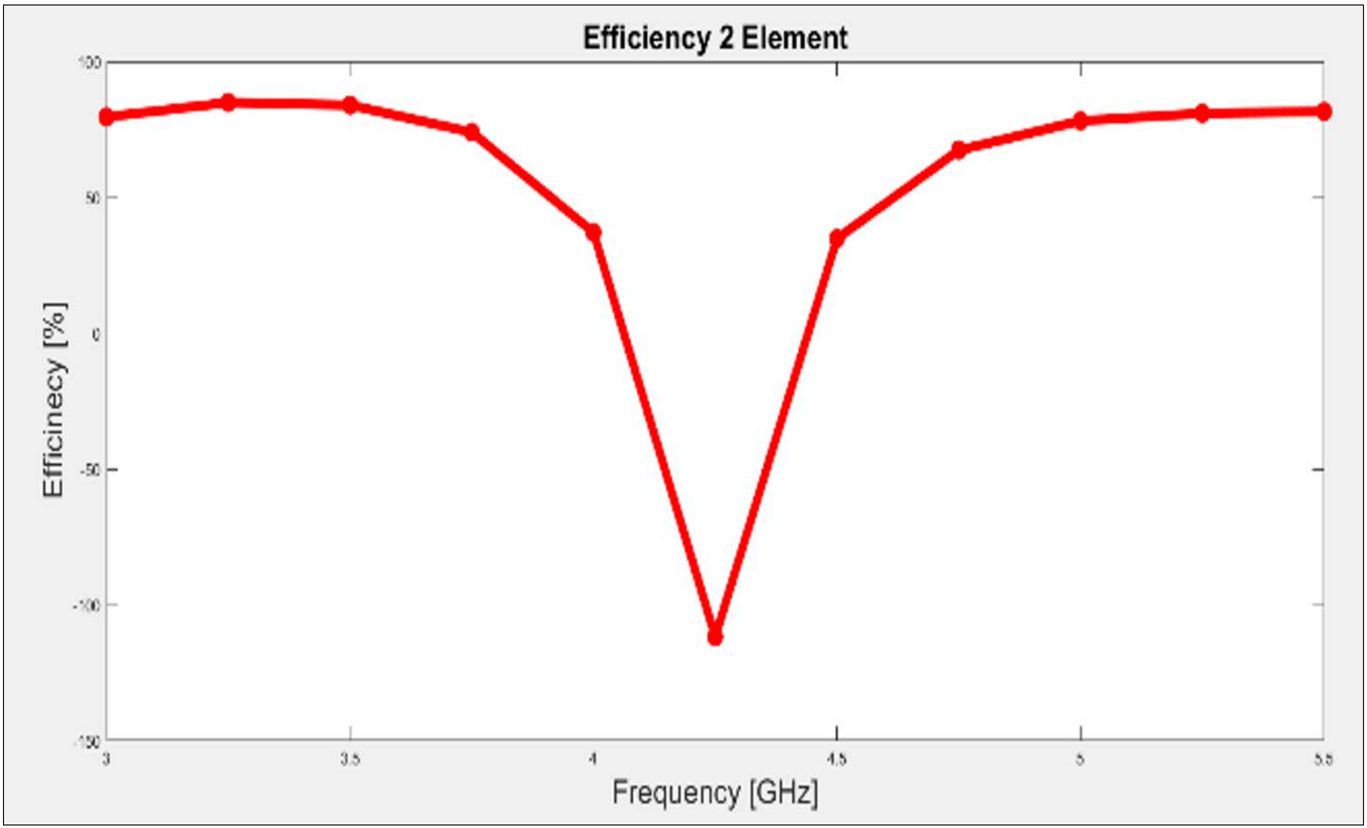


**Fig 7:** Simulated Radiation Efficiency of the proposed Antenna.

### E. Envelope Correlation Coefficient

Wireless communications can be improved through MIMO Antenna because multiple streams of data could be received simultaneously by using it.

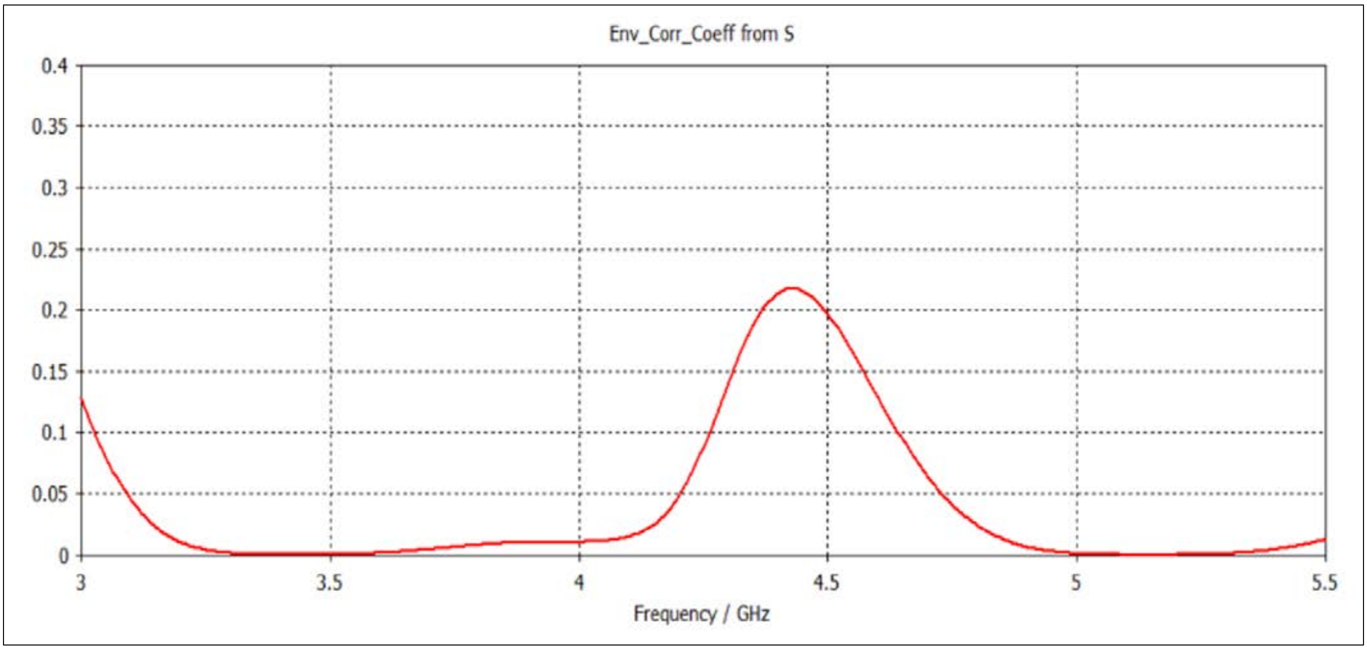


**Fig 8:** Simulated Radiation Efficiency of the proposed Antenna.

For this reason, multiple antennas are used in MIMO Antenna, there should be enough isolation among antennas, and their radiation patterns should not be correlated which leads us to define the term envelope correlation coefficient. ECC quantifies the degree of mutual independence between radiation patterns of antennas. If one antenna emits radiation in an upward direction and the second antenna emits radiation in a downward direction, the correlation efficiency between them will be zero. ECC greatly affects the working of MIMO Antenna. Figure 8 illustrates that the ECC has a very low value at 3.5 GHz and 5.1 GHz. As the value of ECC is low, then the performance of the MIMO Antenna will be very good.

## Comparison

The performance of the suggested dual-band MIMO antenna is compared to that of existing two-element antennas recently reported in the literature, as shown in Table 2.

As in the table below, a comparison was made with some previous research, and some existing factors were pointed out, such as the band of frequencies on which the antenna operates in the fifth generation. As well as indicating the S parameter and the size on which the antenna is manufactured.

**Table 2:** A comparison between the proposed work and the mentioned two-element MIMO antennas.

| Reference | Band (GHz) | S11 | Size (mm2) |
|---|---|---|---|
| [21] | 3.1–5.2 | >10 | 35 x 35 |
| [22] | 3.4–3.7<br>5.15–5.35 | >13<br>>16 | 50 x50 |
| [23] | 1.27–1.43<br>1.8–2.133 | >15 | 50 x 120 |
| This work 3.4–3.6 | 3.4 - 5.1 | >23 | 24×24 |

## Conclusion

In this article, an enhancement shape of dual Band MIMO antenna is presented having low cost substrate, T-shaped patches, and a circular slot as defected ground structure. The performance of the proposed antenna is analyzed with Scattering parameters, radiation efficiency, gain, radiation efficiency, and envelope correlation coefficient at desired frequencies of 3.4 GHz and 5 GHz. The primary obstacle faced by the MIMO Antenna is achieving optimal performance in terms of mutual coupling. However, we have successfully addressed this issue in our suggested antenna design by using a circular slot as a ground structure between T-shaped patches.

This antenna is best to use where a great reduction in mutual coupling is needed. 5G Wireless communication along with our proposed dual-band MIMO Antenna will be able to meet the unprecedented demands of users.

## References

1. Ahmad A, Choi DY, Ullah S. A compact two elements MIMO antenna for 5G communication. Scientific Reports. 2022;12(1):3608.
2. Design of a small ultra wideband antenna using a genetic algorithm approach. In: 2015 Internet Technologies and Applications (ITA), Wrexham, UK; 2015. p. 461-465. DOI: 10.1109/ITechA.2015.7317448.
3. Ren Z, Zhao A. Dual-band MIMO antenna with compact self-decoupled antenna pairs for 5G mobile applications. IEEE Access. 2019;7:82288-82296.
4. Sehrai DA, *et al.* A novel high gain wideband MIMO antenna for 5G millimeter-wave applications. Electronics. 2020;9(6):1031.
5. Podilchak SK, Pishchikov OM. Dual-band and multi-band MIMO antennas: A review. IET Microwaves, Antennas & Propagation. 2018;12(9):1442-1449.
6. Al Abbas E, *et al.* MIMO antenna system for multi-band millimeter-wave 5G and wideband 4G mobile communications. IEEE Access. 2019;7:181916-181923.
7. Abdulbari AA, Zakaria Z, Rahim SKA, Hussein YM, Jawad MM, Hamzah AM. Design and development broadband monopole antenna for in-door application. TELKOMNIKA (Telecommunication Computing Electronics and Control). 2020;18(1):51-56.
8. Desai A, *et al.* Compact wideband four element optically transparent MIMO antenna for mm-wave 5G

applications. IEEE Access. 2020;8:194206-194217.
9. Yuan XT, *et al*. Ultra-wideband MIMO antenna system with high element-isolation for 5G smartphone application. IEEE Access. 2020;8:56281-56289.
10. Abdullah M, *et al*. Future smartphone: MIMO antenna system for 5G mobile terminals. IEEE Access. 2021;9:91593-91603.
11. Ghadeer SH, *et al*. An innovative fractal monopole MIMO antenna for modern 5G applications. AEU-International Journal of Electronics and Communications. 2023;159:154480.
12. Abdulmahdi M, Hamzah A, Albatat H, Audah L. Edge-truncated Square Ultra-Wide Band Antenna with Dual Notches; c2019.
13. Ibrahim SK, *et al*. Design, Challenges and Developments for 5G Massive MIMO Antenna Systems at Sub 6-GHz Band: A Review. Nanomaterials. 2023;13(3):520.
14. Balanis C. Antenna Theory: Analysis and Design. New York, NY: Wiley; c1997.
15. Ahmad A, Choi DY, Ullah S. A compact two elements MIMO antenna for 5G communication. Scientific Reports. 2022;12(1):3608.
16. Hamzah AM, Audah L, Alkhafaji N, Albattat HJM, Abdulbari AA. Substrate Integrated Waveguide SIW Technology-based Miniaturization and Performance Enhancement of Antennas: A Review. International Journal of Advanced Science and Technology. 2020;29(6):1739-1754.
17. Sohi AK, Kaur A. Sextuple band rejection functionality from a compact Koch anti-snowflake fractal UWB-MIMO antenna integrated with split-ring resonators and slots. AEU-International Journal of Electronics and Communications. 2021;138:153898.
18. Paiva SB, Junior AGDA, Neto VPS, D’Assunção AG. A new compact dual-polarized MIMO antenna using slot and parasitic element decoupling for 5G and WLAN applications. Electronics. 2022;11(13):1943.
19. Tu DTT, Phuong NTB, Son PD, Van Yem V. Improving Characteristics of 28/38GHz MIMO Antenna for 5G Applications by Using Double-Side EBG Structure. J Commun. 2019;14(1):1-8.
20. Cuneray K, *et al*. 28/38 GHz dual-band MIMO antenna with wideband and high gain properties for 5G applications. AEU-International Journal of Electronics and Communications. 2023;162:154553.
21. Oliveira JGD, D’Assunção Junior AG, Silva Neto VP, D’Assunção AG. New compact MIMO antenna for 5G, WiMAX and WLAN technologies with dual polarisation and element diversity. IET Microwaves, Antennas & Propagation. 2021;15(4):415-426.
22. Khan AA, *et al*. Dual-band MIMO dielectric resonator antenna for WiMAX/WLAN applications. IET Microwaves, Antennas & Propagation. 2017;11(1):113-120.
23. Jehangir SS, Sharawi MS, Shamim A. Highly miniaturised semi-loop meandered dual-band MIMO antenna system. IET Microwaves, Antennas & Propagation. 2018;12(6):864-871.