IJMRSET

e-ISSN:2582-7219

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY

Volume 7, Issue 3, March 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.521

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| Monthly Peer Reviewed & Referred Journal |

| Volume 7, Issue 3, March 2024 |

| DOI:10.15680/IJMRSET.2024.0703020 |

Design and Analysis of two elements MIMO Antenna with Enhanced isolation for WiMAX/WLAN/5G Applications

Mr. G. Naveen Kumar[1], Suddapalli Naga Harshita[2] , Shaik Hasiya[3] ,Velagacharla Sai Chandrika Smitha Venkat[4],Tullimilli Niharika[5]

Associate Professor, Department of ECE, Vasireddy Venkatadri Institute of Technology, Nambur, Guntur, A.P., India[1]

Undergraduate students, Department of ECE, Vasireddy Venkatadri Institute of Technology, Nambur, Guntur,

A.P., India[2-5]

ABSTRACT: The need for sophisticated Multiple-Input Multiple-Output (MIMO) antenna systems is rising due to the quick spread of wireless communication technologies like WiMAX, WLAN, and 5G. MIMO technology offers higher spectral efficiency and faster data speeds .The potential for higher data speeds and greater spectrum efficiency lies at the heart of MIMO technology. In order to improve isolation for WiMAX, WLAN, and 5G networks, this project involves the design and study of a two-element MIMO antenna system. The aim of this project is to develop and analyse a novel two-element MIMO antenna that is compact in size and should provide a promising solution to improve isolation. This will ensure improved wireless communication performance for WiMAX (5.5GHz), WLAN (5.2GHz), and 5G (3.95-4.19 GHz) applications, addressing the changing needs of the modern wireless landscape .It is necessary to examine and make sure that the MIMO diversity parameters such as the Envelope Correlation Coefficient (ECC), Diversity Gain (DG), Total Active Reflection Coefficient (TARC), Channel Capacity Loss (CCL), and Mean Effective Gain (MEG) are in excellent agreement with the ideal values.

KEYWORDS: MIMO, WiMax,WLAN,5G,ECC,DG,TARC,CCL,MEG

I.INTRODUCTION

MIMO technology offers higher spectral efficiency and faster data speeds, making it crucial for improving wireless communication performance. This project focuses on designing and studying a two-element MIMO antenna system with the aim of providing a compact solution to enhance isolation for WiMAX, WLAN, and 5G networks. The proposed antenna aims to address the challenges of designing small, high-isolation antenna elements within constrained spaces .Key MIMO diversity parameters such as Envelope Correlation Coefficient (ECC), Diversity Gain (DG), Total Active Reflection Coefficient (TARC), Channel Capacity Loss (CCL), and Mean Effective Gain (MEG) will be analysed to ensure alignment with ideal values. The proposed antenna aims to contribute to the growing demand for multiple-input-multiple-output multiband antennas, addressing challenges like low signal correlation, good impedance characteristics, high efficiency, and isolation in a modern wireless landscape.

MIMO antenna signal correlation should be low with good impedance characteristics, and individual elements possess high efficiency and isolation[1-3].So researchers to attain high isolation they used various techniques. In [4], a MIMO antenna with a dual band resonance and a size of 74x47.3 mm2 is designed for WLAN applications. In further researches used [5] three techniques ,orientation, space between elements, and introduction of L-shaped strips in the DGS, are used to achieve the isolation of −17 dB . The meander line with a semicircular patch is designed for the WLAN application. It covers 2.4/5.2 GHz, and shorting meander line is employed between patches to enhance isolation around −25 Db [9]. A dumbbell-shaped parasitic structure is employed between circular patch antenna elements to reduce mutual coupling less than −25 dB [13], where it can be used for C band applications .A compact two element dual-band MIMO antenna uses simple decoupling slots in the ground plane and helps to improve the isolation to less than 20 dB for the first resonance frequency [14] .A slotted microstrip patch antenna is presented in [16] for WLAN/WiMAX application with dimension of 70 × 60 mm2, and simple slots are introduced between antenna

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| Monthly Peer Reviewed & Referred Journal |

| Volume 7, Issue 3, March 2024 |

| DOI:10.15680/IJMRSET.2024.0703020 |

elements to achieve an isolation of −29 dB. For further Improvement of isolation between two elements is achieved by optimizing its orientation and spacing with an isolation of less than −50 dB in [17] , −15dB in [18] and −24 dB in [19].

Ref.	Antenna Size (mm)	Applications	Isolation method	Isolation (dB)	ECC	Frequency (GHz)
[4]	74 × 47.3	WLAN	Decoupling structure	−20 dB	0.005	2.46–2.7, 5.04–5.5
[5]	50 × 50	WLAN/WiMAX	DGS with two MP lines	−17.8 dB	0.011	2.09–2.86, 5.05–5.94
[7]	100 × 100	LTE	DRA slot	−20 dB	0.02	1.63–1.84, 2.43–2.71, 3.27–3.75
[8]	52 × 77.5	WLAN	Inverted T slot in ground	−15 dB	0.2	2.4–2.48, 5.15 to 5.825
[9]	60 × 60	WLAN	meandering-line	−25 dB		2.4–2.48, 5.15–5.825
[10]	40 × 40	WLAN/WiMAX/5G	SRR	−14 dB		2.4, 3.45, 5.5
[11]	50 × 30	WLAN	parasitic elements and DGS	−24 dB	0.027	2.4–2.4835, 5.15–5.35, 5.725–5.875
[12]	50 × 50	WLAN/WiMAX	stepped slot ended with an ellipse in ground	−18 dB	0.03	2.3–2.75, 3.4–3.75, 4.8–6.0
[13]	40 × 40	WiMAX/C-band	dumb-bell shaped slot	−35 dB	0.005	3.10–3.19, 6.11–6.43, 7.50–8.04
[14]	25 × 24	WLAN	slots	−20 dB	0.004	2.40–2.67, 5.46–5.73
[15]	37 × 38		Stub in ground and feed line	−20 dB	0.05	2.1–2.7, 3.3–3.7, 4.9-5.35
[16]	70 × 60	WLAN and WiMAX	Ground slots	−24.98 dB		2.37–2.42, 3.33–3.39
[17]	60 × 20	WLAN and Wi-Fi.	orientation	−50 dB	0.0002	4.3–6.0
[18]	37 × 56	Bluetooth/C-band/ WLAN/WiMAX/Wi-Fi	DGS	−15 dB	0.08	2.24–2.50, 3.60–3.99, 4.40–4.60, 5.71–5.90
[19]	65 × 21	WiFi/WiMAX/WLAN	Orientation	−24 dB	0.001	2.22–2.54, 3.14–3.9, 5.3-5.7
Proposed antenna	23.5 × 83	WLAN/WiMAX/5G	Orientation	−29.3 dB	0.001	3.95-4.19GHz,5.2-5.55GHz

Table 1: Various MIMO antenna characteristics comparison.

various MIMO antennas have been developed using diverse methodologies, as outlined in Table 1. Many of these encounter challenges such as low isolation, large size, and the necessity for intricate techniques to enhance isolation. MIMO antenna's simplistic antenna design and compact form factor facilitate multi-band resonance, offering a viable solution for modern wireless communications. In this study, we introduce decagon ring-shaped two-element MIMO antennas characterized by their compact size and enhanced isolation, achieved without the utilization of any decoupling structures. These antennas demonstrate multiband resonance, covering frequencies from 5.2GHz to 5.5GHz (WLAN,WiMAX), and 3.95 GHz to 4.19 GHz (5G) applications.

II.ANTENNA DESIGN

The basic antenna structure is depicted in Figure 1 with its parameters and dimensions, and an FR4 substrate is used to design the antenna with a dielectric constant ($\varepsilon_r = 4.3$) and 1.6 mm as thickness. The initial antenna design with a single decagon ring has radius of 4.8 mm, and to achieve multiband resonance additional rings of smaller dimensions are added inside the initial design. The addition of the second ring with radius of 3.6 mm enhances previous resonance by single ring and the third ring with radius of 2.4 mm ,and a slot in the ground improves the reflection coefficient value. The basic antenna's design evolution is shown in Figure 2, and optimized antenna parameters are represented in Table 2.

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| Monthly Peer Reviewed & Referred Journal |

| Volume 7, Issue 3, March 2024 |

| DOI:10.15680/IJMRSET.2024.0703020 |

The conventional ring circular antenna can be designed using Equation below based on [20].

$$F = \frac{c}{\lambda} = \frac{c}{\pi(l_1 + l_2)\sqrt{\varepsilon_{eff}}}\,\text{GHz}$$

with radius of the outer ring l_1 and radius of the inner ring l_2.

Figure 3 depicts the proposed comparison of the S11 characteristics of the antenna. Introducing ring-2 and ring-3 to Antenna #1 results in mutual coupling between the rings, thereby generating a multiband response, as depicted. This modified antenna exhibits coverage across multiple frequencies below -15dB including 4.15-4.5GHz, 5.25-6 GHz Figure 3(a)-(c) represents the S-parameters of all three antennas.

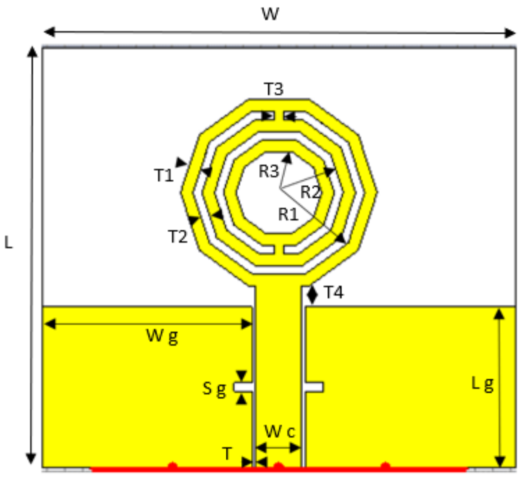
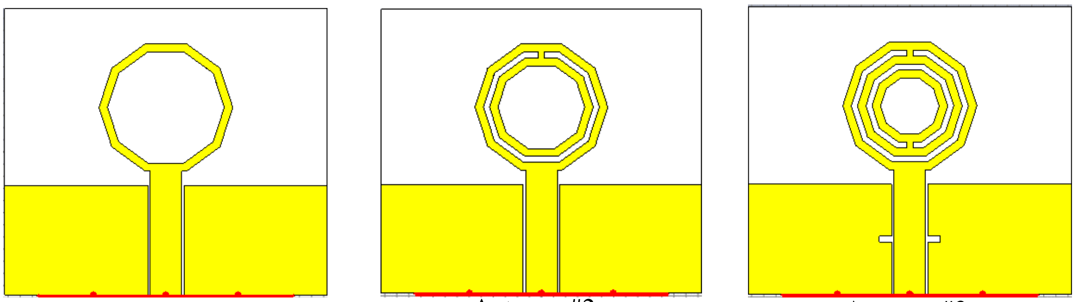


Figure1 : Basic Antenna design with parameters



Antenna #1 Antenna #2 Antenna #3

Figure2 : Evolution in Antenna Design

Parameter	L	W	Wg	Lg	Wc	T	$T4$
Dimension (in mm)	23.5	26.5	11.715	9	2.6	0.235	1.6
Parameter	$T1$	$T2, T3$	$R1$	$R2$	$R3$	Sg	
Dimension (in mm)	0.7	0.5	4.8	3.6	2.4	0.5	

Table 2: Parameter of the antenna proposed

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| Monthly Peer Reviewed & Referred Journal |

| Volume 7, Issue 3, March 2024 |

| DOI:10.15680/IJMRSET.2024.0703020 |

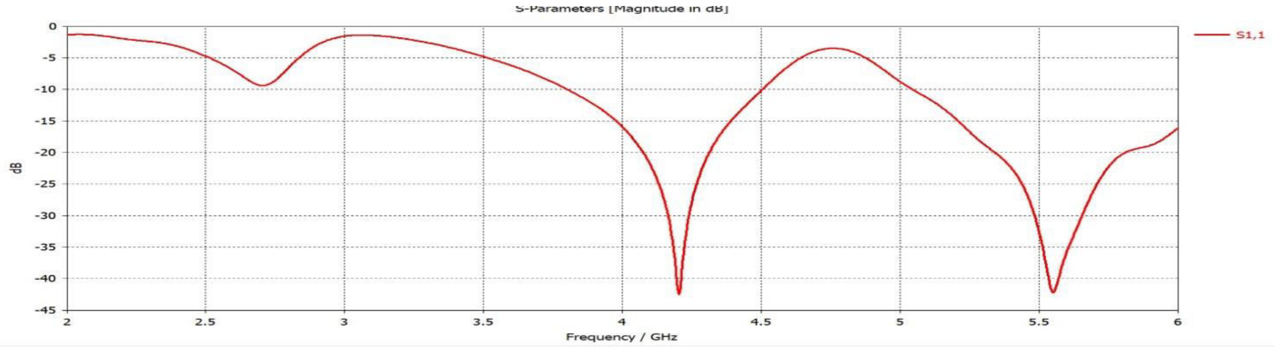


Figure 3: S-parameters of Antenna

III. TWO ELEMENT DESIGN

Figure 1 illustrates the geometry of the single-element multi-band antenna, featuring compact dimensions of 23.5 × 26.5 mm² and resonance across two distinct frequency ranges: 4.15-4.5 GHz, and 5.25–6 GHz. A two-element MIMO antenna is investigated across three different orientations, labelled 1, 2, and 3, as depicted in Figures 4(a)–(c), maintaining a separation of 30 mm between the elements. Subsequently, their S-parameter responses are showcased in Figures 5(a)-5(c).

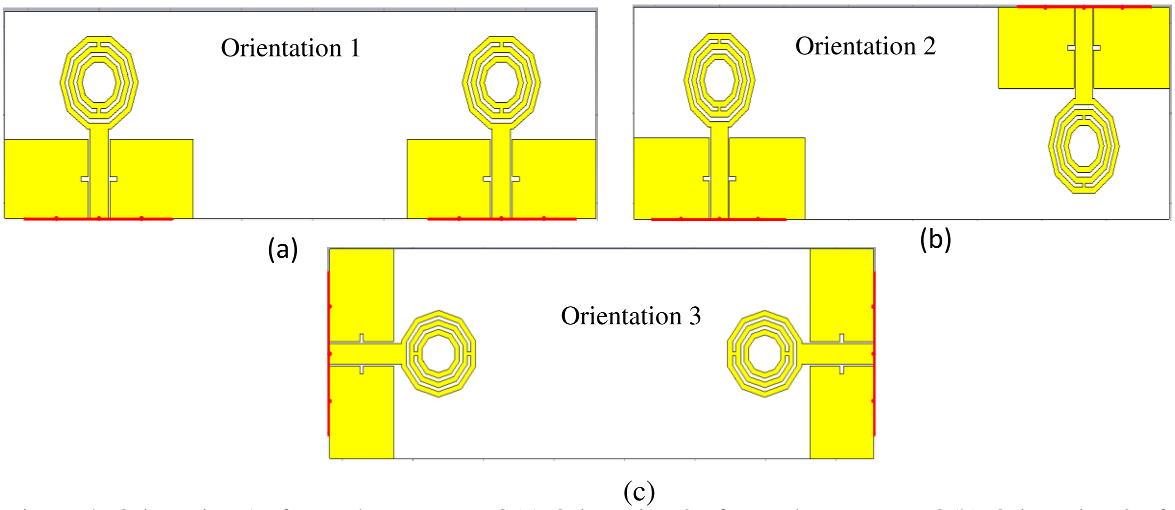


Figure 4: Orientation 1 of two element MIMO(a) Orientation 2 of two element MIMO(b) Orientation 3 of two element MIMO(c)

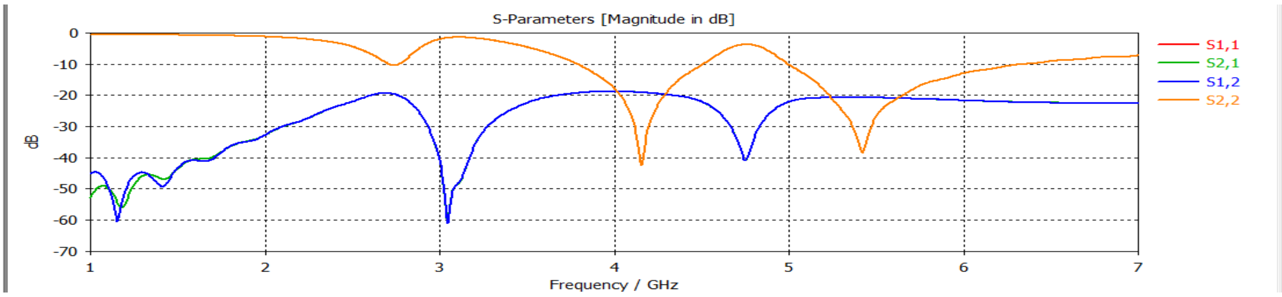
In Orientation 1 of the two-element MIMO antenna, two antenna elements are positioned side by side with a 30 mm separation, as depicted in Figure 4. This configuration exhibits superior reflection coefficient and isolation characteristics across all frequency bands. Specifically, the measured reflection coefficient remains below -30 dB the frequency ranges of, 3.95–4.19 GHz, and 5.2–5.55 GHz, with isolation values measuring less than -25.7 dB in the lower band, and -26.6 dB in the higher band as shown in Figure 5(a).

Orientation 2 is achieved by maintaining the position of Antenna I while inverting the position of Antenna II. Notably, it demonstrates coverage across the frequency ranges of, 3.95–4.19 GHz, and 5.2–5.55 GHz, having measured reflection coefficient below -40 dB with isolation values measuring less than -25.3 dB in the lower band, and -25.8 dB in the higher band represented in figure 5(b).In Orientation 3, both Antenna I and Antenna II are rotated 90 degrees, as depicted in Figure 5(c). This positioning causes the radiating elements of the antennas to face each other.

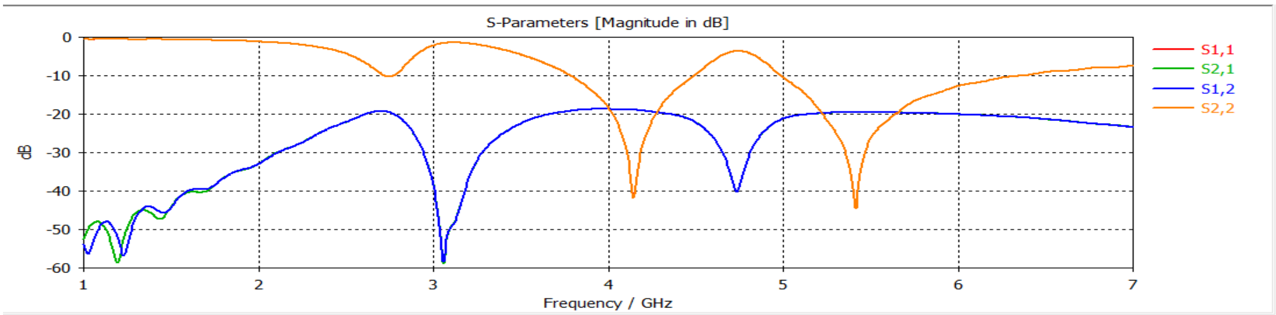
| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| Monthly Peer Reviewed & Referred Journal |

| Volume 7, Issue 3, March 2024 |

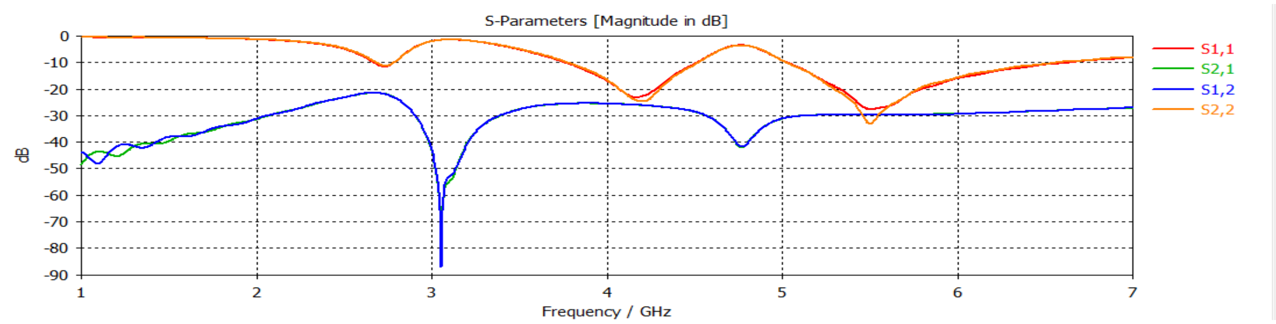
| DOI:10.15680/IJMRSET.2024.0703020 |



(a)



(b)



(c)

Figure 5: S-parameters of Orientation 1 (a) S-parameters of Orientation 2 (b) S-parameters of Orientation 3 (c)

The measured reflection coefficient of this antenna orientation spans across the measured reflection coefficient remains below -15 dB in frequency ranges of 3.95–4.19 GHz and 5.2–5.55 GHz, with isolation values measuring less than -27.9 dB in the lower band, and -29.2 dB in the higher band. Figure 5(c) depicts the measured S-parameter values of Orientation 3.Based on these observations, MIMO antenna Orientation 3 exhibits notably high isolation values, measuring less than -27 dB across all operating frequencies, surpassing the performance of antenna Orientations 1 and 2.

IV. TWO ELEMENT MIMO ANTENNA PARAMETERS

Evaluation of MIMO antenna performance involves assessing various parameters such as ECC (Envelope Correlation Coefficient), DG (Diversity Gain), TARC (Total Active Reflection Coefficient), MEG (Mean Effective Gain), and CCL (Channel Capacity Loss). A lower correlation coefficient indicates better support for higher data rates. For practical purposes, an acceptable ECC value is typically less than 0.05. The ECC for the proposed antenna is calculated using Equation below as referenced in [22].

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| Monthly Peer Reviewed & Referred Journal |

| Volume 7, Issue 3, March 2024 |

| DOI:10.15680/IJMRSET.2024.0703020 |

$$ECC_{(i,j,\ldots,N)} = \frac{\left|\sum_{n=1}^{N} S_{i,n}^{*} S_{n,j}\right|^2}{\prod_{k=i,j}\left[1-\sum_{n=1}^{N} S_{k,n}^{*} S_{n,k}\right]}$$

where i and j are antennas 1 and 2, and N is the number of antennas.

Figure 6 displays the ECC graph for the proposed MIMO antenna, indicating ECC values below 0.05 across all operating frequencies. The formula for calculating directivity gain (DG) using ECC is represented below. Figure 7 illustrates the diversity gain of the proposed MIMO antenna for all three operating frequencies, exhibiting a favorable value of 10 dB.

$$DG = 10 \times \sqrt{1-|ECC|}$$

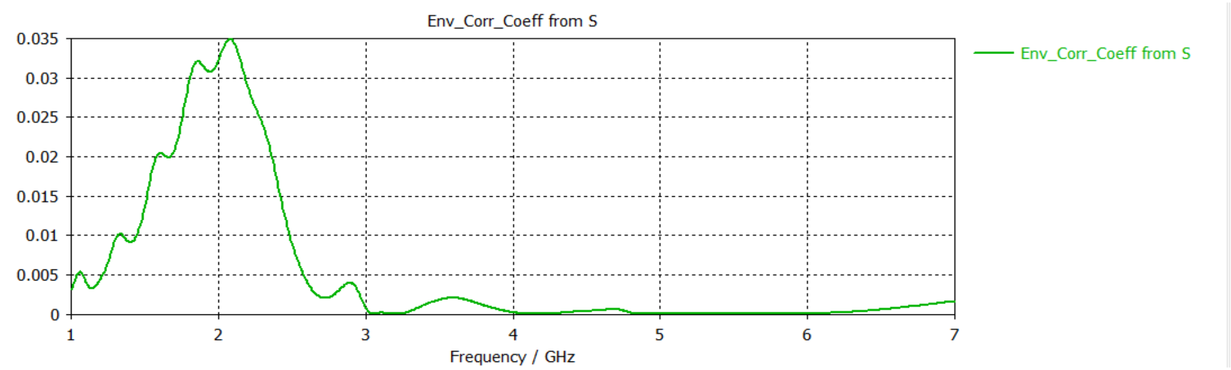


Figure 6:Envelope correlation coefficient of two element MIMO design

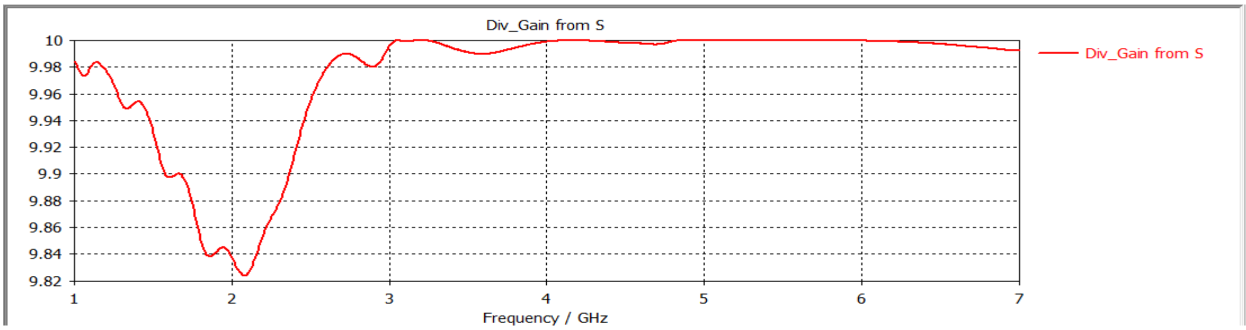


Figure 7: Directive Gain of two element MIMO design

The calculation of TARC value for the MIMO antenna can be performed using below equation as depicted in Figure 8.TARC accounts for the overall return loss of the MIMO antenna, factoring in mutual coupling and incident wave phase [21].

$$TARC = \frac{\sqrt{(|S_{11}+S_{12}e^{j\theta}|)^2(|S_{21}+S_{22}e^{j\theta}|)^2}}{\sqrt{2}}$$

Mean Effective Gain (MEG) represents the ratio of mean relative power received by the diversity antenna to the power incident on the isotropic antenna. Equations shown below are utilized for MEG calculation, which is dependent on the

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| Monthly Peer Reviewed & Referred Journal |

| Volume 7, Issue 3, March 2024 |

| DOI:10.15680/IJMRSET.2024.0703020 |

S- parameter. Figure 9 showcases the MEG for the proposed two-element antenna, where the MEG value remains below -3 dB across all operating frequencies, aligning with expectations for a MIMO antenna.

$$MEG_1 = \frac{1}{2}[1 - |S_{11}|^2 - |S_{12}|^2]$$
$$MEG_2 = \frac{1}{2}[1 - |S_{21}|^2 - |S_{22}|^2]$$

Increasing the number of antennas in a MIMO system theoretically leads to increased channel capacity. However, due to correlation effects, a capacity loss may occur [19]. Figure 10 illustrates the Channel Capacity Loss, with observed CCL values below 0.4 bits/sec/Hz in operating frequencies.

$$CCL = -\log_2(\rho^R)$$
$$\rho^R = \begin{pmatrix} \rho_{11} & \rho_{12} \\ \rho_{21} & \rho_{22} \end{pmatrix}$$

where,

$$\rho_{11} = 1 - (|S_{11}|^2 - |S_{12}|^2), \quad \rho_{22} = 1 - (|S_{22}|^2 - |S_{21}|^2),$$
$$\rho_{12} = -(S_{11}^* S_{12} + S_{21}^* S_{22}), \quad \rho_{21} = -(S_{22}^* S_{21} + S_{12}^* S_{11}).$$

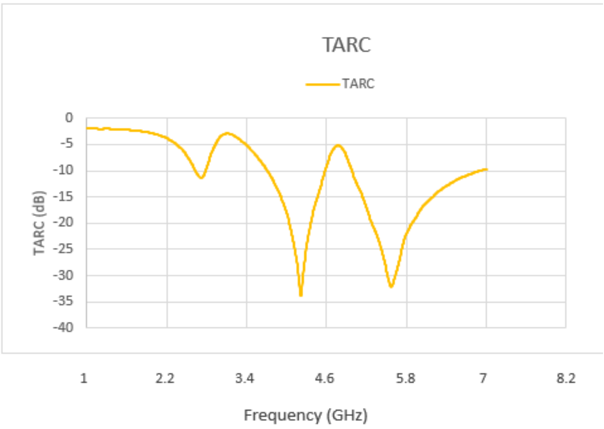


Figure 8:Total Active Reflection Coefficient of two element MIMO design.

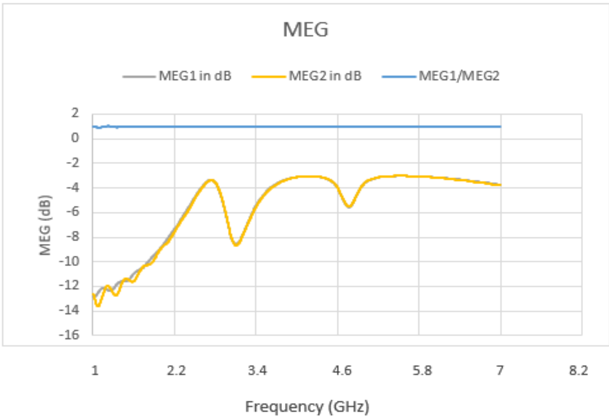


Figure 9: Mean Effective Gain of two element MIMO design.

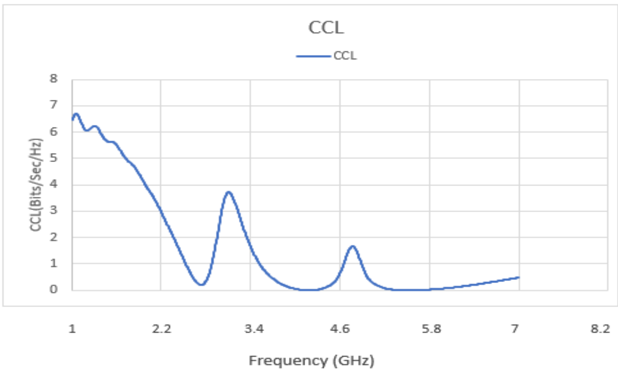


Figure 10 :Channel Capacity Loss between two elements in MIMO design.

V.CONCLUSION

This paper introduces a novel multiband decagon ring-based MIMO antenna system, for enhanced isolation. The antenna operates across three frequency bands,3.95–4.19GHz, and 5.2–5.55 GHz, covering WLAN, WiMAX, 5G applications. The antenna's orientation 3 results in high isolation values of -29.3 dB across operating frequencies. Simulated efficiency exceeds 70%.The paper investigates the diversity performance of the MIMO antenna, demonstrating measured ECC values below 0.001 and a DG of 10 dB across operating frequencies. Consequently, the proposed MIMO antenna offers a promising solution for various contemporary wireless applications.

REFERENCES

[1]. Yang, Y., Q. Chu, and C. Mao, "Multiband MIMO antenna for GSM, DCS, and LTE indoor applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 15, 1573–1576, 2016, doi: 10.1109/LAWP.2016.2517188.

[2]. Ramachandran, A., S. Mathew, V. Rajan, and V. Kesavath, "A compact triband quad-element MIMO antenna using SRR ring for high isolation," *IEEE Antennas and Wireless Propagation Letters*, Vol. 16, 1409–1412, 2017, doi: 10.1109/LAWP.2016.2640305.

[3]. Sanmugasundaram, R., S. Natarajan, and R. Rajkumar, "A compact MIMO antenna with electromagnetic bandgap structure for isolation enhancement," *Progress In Electromagnetics Research C*, Vol. 107, 233–244, 2021.

[4]. Liu, P., D. Sun, P. Wang, and P. Gao, "Design of a dual-band MIMO antenna with high isolation for WLAN applications," *Progress In Electromagnetics Research Letters*, Vol. 74, 23–30, 2018.

[5]. Bai, J., R. Zhi, W. Wu, M. Shangguan, B. Wei, and G. Liu, "A novel multiband MIMO antenna for TD-LTE and WLAN applications," *Progress In Electromagnetics Research Letters*, Vol. 74, 131–136, 2018.

[6]. Saleem, R., M. Bilal, H. T. Chattha, S. Ur Rehman, A. Mushtaq, and M. F. Shafique, "An FSS based multiband MIMO system incorporating 3D antennas for WLAN/WiMAX/5G cellular and 5G Wi-Fi applications," *IEEE Access*, Vol. 7, 144732–144740, 2019, doi: 10.1109/ACCESS.2019.2945810.

[7]. Anuar, S. U., M. H. Jamaluddin, J. Din, K. Kamardin, M. H. Dahri, and I. H. Idris, "Triple band MIMO dielectric resonator antenna for LTE applications," *AEU — International Journal of Electronics and Communications*, Vol. 118, 153172, ISSN 1434-8411, 2020, https://doi.org/10.1016/j.aeue.2020.153172.

[8]. Deng, J., J. Li, L. Zhao, and L. Guo, "A dual-band inverted-F MIMO antenna with enhanced isolation for WLAN applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 16, 2270–2273, 2017, doi: 10.1109/LAWP.2017.2713986.

[9]. Deng, J. Y., Z. J. Wang, J. Y. Li, and L. X. Guo, "A dual-band MIMO antenna decoupled by a meandering line resonator for WLAN applications," *Microw. Opt. Technol. Lett.*, Vol. 60, 759–765, 2018, https://doi.org/10.1002/mop.31049.

[10]. Rajeshkumar, V. and R. Rajkumar, "SRR loaded compact tri-band MIMO antenna for WLAN/WiMAX applications," *Progress In Electromagnetics Research Letters*, Vol. 95, 43–53, 2021.

[11]. Wu, W., R. Zhi, Y. Chen, H. Li, Y. Tan, and G. Liu, "A compact multiband MIMO antenna for IEEE 802.11 a/b/g/n applications," *Progress In Electromagnetics Research Letters*, Vol. 84, 59–65,2019.

[12]. Fang, Q., D. Mi, and Y.-Z. Yin, "A tri-band MIMO antenna for WLAN/WiMAX application," *Progress In Electromagnetics Research Letters*, Vol. 55, 75–80, 2015.

[13]. Babu, K. V. and B. Anuradha, "Analysis of multi-band circle MIMO antenna design for C-band applications," *Progress In Electromagnetics Research C*, Vol. 91, 185–196, 2019.

[14]. Nandi, S. and A. Mohan, "A compact dual-band MIMO slot antenna for WLAN applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 16, 2457–2460, 2017, doi: 10.1109/LAWP.2017.2723927.

[15]. Chaudhari, A. A. and R. K. Gupta, "A simple tri-band MIMO antenna using a single ground stub," *Progress In Electromagnetics Research C*, Vol. 86, 191–201, 2018.

[16]. Kommuri, R., "Isolation enhancement for dual-band MIMO antenna system using multiple slots loading technique," *Int. J. Commun. Syst.*, Vol. 33, e4470, 2020, https://doi.org/10.1002/dac.4470.

[17]. Mohammad Saadh, A. W., K. Ashwath, P. Ramaswamy, T. Ali, and J. Anguera, "A uniquely shaped MIMO antenna on FR4 material to enhance isolation and bandwidth for wireless applications," *AEU — International Journal of Electronics and Communications*, Vol. 123, 153316, ISSN 1434-8411, 2020, https://doi.org/10.1016/j.aeue.2020.153316.

[18]. Chouhan, S., D. K. Panda, V. S. Kushwah, and S. Singhal, "Spider-shaped fractal MIMO antenna for WLAN/WiMAX/Wi-Fi/Bluetooth/C-band applications," *AEU — International Journal of Electronics and Communications*, Vol. 110, 152871, ISSN 1434-8411, 2019, https://doi.org/10.1016/j.aeue.2019.152871.

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| Monthly Peer Reviewed & Referred Journal |

| Volume 7, Issue 3, March 2024 |

| DOI:10.15680/IJMRSET.2024.0703020 |

[19]. Ekrami, H. and S. Jam, "A compact triple-band dual-element MIMO antenna with high port-to- port isolation for wireless applications," *AEU — International Journal of Electronics and Commu- nications*, Vol. 96, 219–227, ISSN 1434-8411, 2018, https://doi.org/10.1016/j.aeue.2018.09.044.

[20]. Chen, X., G. Fu, S. Gong, Y. Yan, and W. Zhao, "Circularly polarized stacked annular-ring microstrip antenna with integrated feeding network for UHF RFID readers," *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, 542–545, 2010, doi: 10.1109/LAWP.2010.2051791.

[21]. Chae, S. H., S. Oh, and S. Park, "Analysis of mutual coupling, correlations, and TARC in WiBro MIMO array antenna," *IEEE Antennas and Wireless Propagation Letters*, Vol. 6, 122–125, 2007, doi: 10.1109/LAWP.2007.893109.

[22]. Thaysen, J. and K. B. Jakobsen, "Envelope correlation in (N, N) MIMO antenna array from scattering parameters," *Microw. Opt. Technol. Lett.*, Vol. 48, 832–834, 2006, https://doi.org/10.1002/mop.21490.

INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor
7.521

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

निस्केयर
NISCAIR

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY

| Mobile No: +91-6381907438 | Whatsapp: +91-6381907438 | ijmrset@gmail.com |

www.ijmrset.com