Journal of Nano- and Electronic Physics
Vol. **17** No 5, 05031(5pp) (2025)

Журнал нано- та електронної фізики
Том **17** № 5, 05031(5cc) (2025)

OPEN ACCESS

REGULAR ARTICLE

Self-Isolated Dual-Band MIMO Antenna for Improved Diversity in ISM Band and Wireless Applications

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(Received 15 August 2025; revised manuscript received 19 October 2025; published online 30 October 2025)

In this article, a self-isolated dual-band MIMO antenna for improved diversity in ISM and wireless applications is proposed. An orthogonally structured dual-port MIMO antenna, incorporating a meander line patch, is introduced. The antenna is constructed on an FR4 substrate with overall dimensions of $0.272\lambda \times 0.56\lambda \times 0.0128\lambda$ at 2.4 GHz. It resonates at dual bands, 2.40 GHz and 3.73 GHz, catering to ISM and C-band applications. The orthogonal orientation enhances isolation between the antenna elements, achieving a self-isolation level of < -18 dB. To evaluate the antenna's diversity capabilities, MIMO performance parameters such as diversity gain (DG) and envelope correlation coefficient (ECC) were calculated. The simulated results demonstrate excellent diversity performance, with an ECC of 0.01 and a DG of 9.989. Additionally, the antenna achieves an efficiency of over 85 %, with gains of 3.4 dBi for the ISM band and 4.1 dBi for the 5G C-band. With its compact dimensions, dual-band functionality, high isolation, and superior performance metrics, the proposed MIMO antenna stands out as a promising solution for next-generation dual-band wireless communication systems, particularly for ISM and 5G applications. Moreover, the measured and simulated radiation patterns exhibit stable directional patterns in the *E*-plane and consistent omnidirectional coverage in the *H*-plane, underscoring its reliability for real-world applications.

Keywords: MIMO, Diversity parameters, ISM, Self-isolation.

DOI: 10.21272/jnep.17(5).05031

PACS numbers: 73.61.Jc, 71.20.Mq, 88.40.jj, 88.40hj

1. INTRODUCTION

In wireless communications, spectrum is a finite and valuable resource, making high data rate transmission increasingly expensive. To address this challenge, MIMO (Multiple-Input Multiple-Output) technology, which employs multiple antennas at both the transmitter and receiver, has gained significant traction over the past decade [1]. However, achieving effective decoupling between closely spaced antennas in MIMO systems remains a critical challenge. While compact single-band WLAN antennas have been extensively studied [2], the rapid expansion of wireless services has driven the urgent need for multiband antennas. For example, the IEEE 802.11ax wireless local area network (WLAN) standard operates in both the 2.4 GHz and 5 GHz frequency bands. As a result, dual-band antennas capable of simultaneously covering these distinct bands are highly desirable. However, achieving high isolation between multiband antenna elements is crucial for ensuring optimal performance in MIMO WLAN systems [3]. Decoupling techniques for MIMO antennas can be broadly categorized into external and internal approaches. External decoupling techniques involve incorporating additional structures to mitigate mutual coupling. These include methods such as neutralization lines (NL), grounding branch structures, parasitic decoupling elements (PDE), defective ground structures (DGS), and metamaterial-based solutions. Internal decoupling techniques, on the other hand, leverage polarization diversity, utilizing orthogonal or multi-polarization configurations to achieve isolation [4-6]. Additionally, isolation can be improved by introducing parasitic structures or modifying the ground plane [7]. Neutralization lines also serve as an effective method for reducing mutual coupling between antenna elements [8Aiming for high isolation with a compact size, this paper presents a co-polarized dual-port patch antenna featuring an effective decoupling structure. By incorporating chip capacitors and metallic vias along the centre line of the microstrip antenna, an LC series band-stop filter structure is achieved [9]. A self-isolated MIMO antenna ensures high isolation by strategically placing its elements, eliminating the need for additional decoupling structures. This compact four-element design achieves excellent isolation, with an Envelope Correlation Coefficient (ECC) of less than 0.004, while delivering good radiation performance. The proposed approach simplifies the antenna structure while maintaining efficiency, making it ideal for space-constrained applications [10]. To achieve resonance at 2.45 GHz, a pair of horizontal stubs is utilized, while a vertical stub is introduced to cover the frequency band at 3.5 GHz [11]. A rectangular-shaped monopole is further modified with various slits to realize triband behaviour, resonating around 2.44 GHz, 3.5 GHz, and

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Cite this article as: A.K. Maddirala et al., *J. Nano- Electron. Phys.* 17 No 5, 05031 (2025) https://doi.org/10.21272/jnep.17(5).05031

5.5 GHz [13]. This paper also presents a circular patch antenna with a meandered line, where the antenna elements are arranged orthogonally to achieve self-isolation. Additionally, diversity parameters are calculated to evaluate the performance of the design.

2. ANTENNA DESIGN METHODOLOGY

2.1 Single Antenna Design

The antenna's evolution, including the numerous phases that led to the suggested design, is seen in Fig. 1. The substrate that the single antenna is mounted on is 1.6 mm thick and total measurements of $0.272\lambda \times 0.272\lambda \times 0.0128\lambda$. A defective ground structure Initially, a circular patch with a radius of 6 mm is built, as shown in Ant-1 in Fig. 1(a), and a parametric analysis of the feed width is performed.

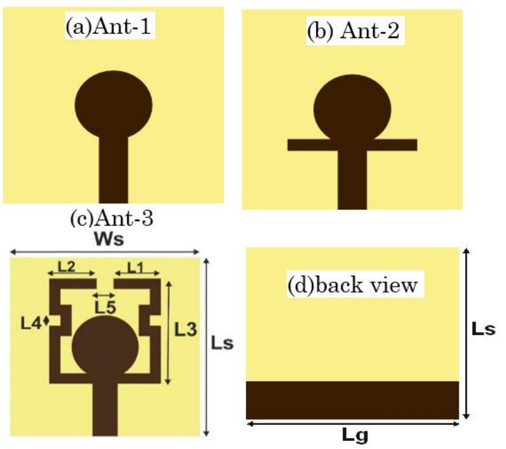

Fig. 1 – Evolution of single antenna with different stages (a) Ant-1 (b) Ant-2 (c) Ant-3 (d) back view

This configuration causes the antenna to resonate at 3.53 GHz. To further improve the bandwidth, a horizontal stub is introduced below the circular patch, as shown in Ant-2 in Fig. 1(b). This modification shifts the resonance to 3.71 GHz. Subsequently, two meander lines are connected to the horizontal stub, altering the current distribution on both sides of the lines, as depicted in Ant-3 in Fig. 1(c). As a result, the antenna achieves dual-band operation, resonating at 2.43 GHz in the ISM band and at 3.71 GHz in the C-band for 5G applications, with a reflection coefficient of – 22 dB.

Table 1 – Proposed antenna dimensions

Parameters	Value (mm)	Parameters	Value (mm)
Ws	34	*L5*	3
*L*1	8.5	*Ls*	34
*L*2	8.5	*Lg*	34
*L*3	20	*L*7	70
*L*4	2	*L*8	4.5
		*L*9	34

2.2 Dual Port Antenna Design

The recommended twin port mimo antenna, which is orthogonally orientated and created from a single antenna design, is shown in Fig. 2. To prevent isolation between antenna elements, the antenna elements are oriented orthogonally in this instance. The antenna's overall measurements are $0.272\lambda \times 0.56\lambda \times 0.0128\lambda$. The antenna elements are spaced 6 mm away from one another, which is less than the $\lambda/2$ space diversity. In the ISM band, which extends from 2.28 to 2.52 GHz, the suggested antenna reverberates at 2.40 GHz with a reflection coefficient of – 23 dB. Additionally, it resonates at 3.73 GHz with a bandwidth of 3.43 to 4.88 GHz.

3. RESULTS AND DISCUSSION

The simulation results shows that Ant-1 to Ant-3 is depicted in Fig 3. Initially, Ant-1 with a circular path, resonates at 3.54 GHz, achieving a bandwidth of 3.27-3.89 GHz and a reflection coefficient of – 23dB.

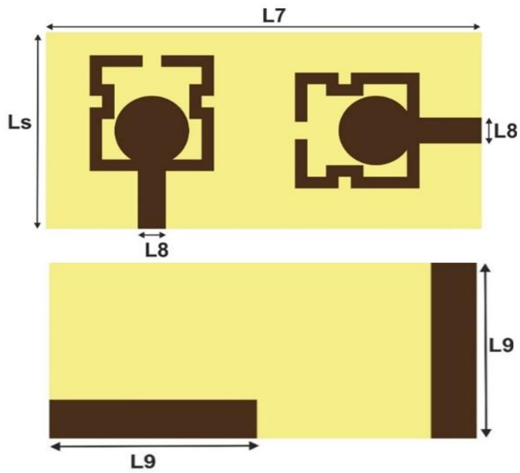

Fig. 2 – Proposed two element MIMO antenna front view and back view

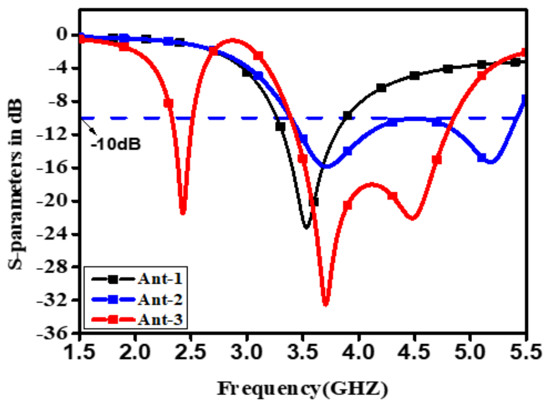

Fig. 3 – Simulation results of evolution of single antenna

Subsequently, Ant-2, is optimized to resonate at 3.71GHz offering an extended bandwidth of 3.39–5.41 GHz. The final optimized single antenna, Ant-3 achieves Dual-band operation in the ISM band, with a reflection coefficient of – 22 dB and a bandwidth of 2.33–2.51GHz, resonates at 2.43 GHz. The other band the reflection coefficient of -32dB and a broader bandwidth of 3.39–4.85 GHz, it resonates at 3.73 GHz in the C-band. The simulated S_{11} results of the recommended dual-port antenna design are illustrated in Fig. 4. In Fig. 5 The S_{11} and S_{22} characteristics suggest that the antenna resonates at 2.40 GHz with a bandwidth of 2.28–2.52 GHz in the ISM band. Additionally, the antenna resonates at 3.73 GHz, with a bandwidth of 3.73–4.88 GHz. Because the antenna elements are orientated orthogonally, the design achieves self-isolation. The S_{11} parameters between the antenna elements are observed to be less than – 18 dB, as shown in Fig. 5.

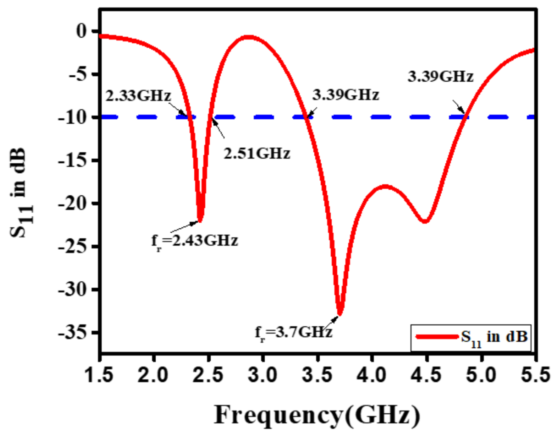

Fig. 4 – Simulation results of proposed antenna

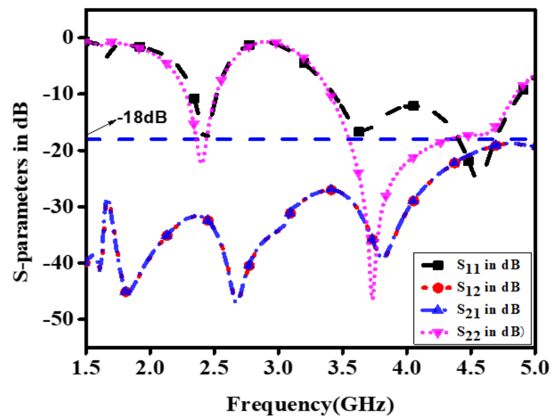

Fig. 5 – Simulation results of dual port antenna

The proposed antenna demonstrates excellent performance characteristics, making it highly suitable for wireless communication systems operating in the ISM and C-bands.

4. DIVERSITY PARAMETERS OF MIMO ANTENNA

4.1 Envelope Correlation Coefficient (ECC)

The Envelope Correlation Coefficient (ECC) Eq (1) is used to evaluate the mutual interaction between antennas in a MIMO radiator system [14]. The degree of correlation between the array's antennas is measured by this parameter. For MIMO antenna performance, an ECC value of less than 0.5 is generally considered acceptable. The ECC obtained from the S-parameter measurements is shown in Fig. 6.

$$ECC = \frac{|S_{11}^{*}S_{12}+S_{21}^{*}S_{22}^{2}|^{2}}{(1-|S_{11}^{2}|-|S_{21}^{2}|)(1-|S_{22}^{2}|-|S_{12}^{2}|)} \qquad (1)$$

4.2 Directive Gain (DG)

It refers to the ability of several antennas to improve the quality of the signal and reliability by exploiting multipath propagation. This leads to increased data rates and improved coverage in wireless networks. Enhancements in diversity gain are typically associated with reduced Envelope Correlation Coefficient (ECC) values. Specifically, higher diversity gain corresponds to lower ECC values. Figure. 6. shows a simulated diversity gain of 9.99 dB. To compute the diversity gain, use the method outlined in Eq (2) [15].

$$DG = 10 \times \sqrt{1 - ECC^2} \qquad (2)$$

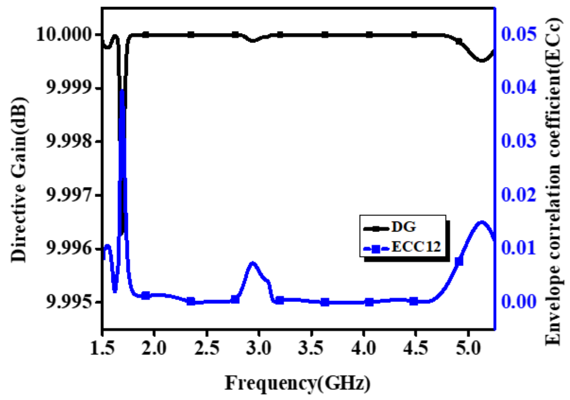

Fig. 6 – simulation results of ECC and DG

5. GAIN AND RADIATION PATTERN

5.1 Radiation Pattern

The radiation pattern of the dual-port MIMO antenna at the resonant frequencies of 2.40 GHz and Fig 7.

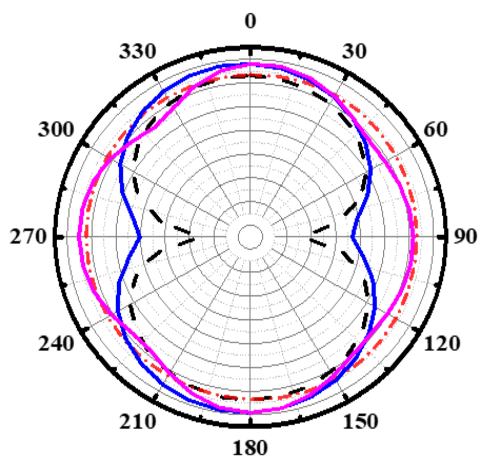

Fig. 7 – Radiation pattern of proposed antenna

3.73 GHz exhibits distinct directional characteristics, optimized for both ISM and 5G C-band applications. At 2.40 GHz, the antenna shows a near omnidirectional radiation pattern in the azimuth plane. At 3.73 GHz, the pattern becomes more directional, with a slight shift in the main lobe, providing improved coverage and isolation between the antenna elements. The antenna demonstrates consistent beamwidth and reduced sidelobe levels across both frequencies, enhancing signal integrity and diversity. These radiation patterns contribute to the antenna's effective performance in diverse communication environments.

5.2 Gain of Proposed Antenna

2-port MIMO antenna, which reaches a peak gain of 2.31dBi at 2.40GHz and 4,49dBi at 3. 73GHz.The antenna is suitable for ISM and 5g c-band communication. The Fig. 8. shows the peak gain of antenna.

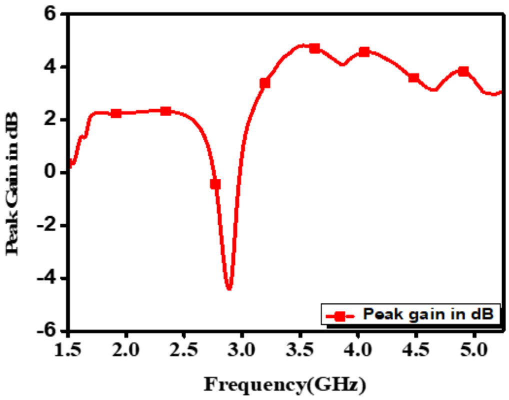

Fig. 8 – Peak gain of dual-port proposed antenna

6. EXPERIMENTAL RESULTS

Fig. 9. shows the fabricated proposed dual band antenna. The antenna resonated at dual bands at 2.40 GHz and 3.73 GHz.

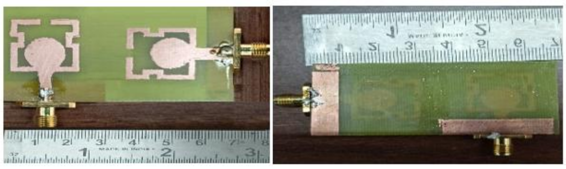

Fig. 9 – Fabricated proposed dual-band antenna front and back view

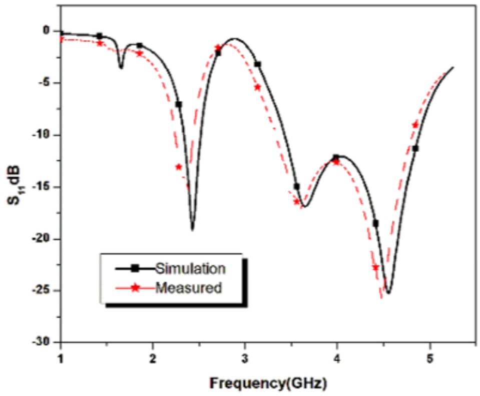

Fig. 10 – Sim vs measured results of proposed dual band antenna

The S_{11} results of measured antenna depicted in Fig. 10. which indicates that the antenna is resonated at dual band.

7. CONCLUSION

This work utilizes a two-element orthogonal dual-port MIMO antenna to enhance isolation and diversity performance in ISM and 5G C-band communication systems. The suggested 2-element MIMO antenna configuration shows significant improvements, with a S_{11} of – 32 dB and S_{12} less than – 18 dB. It indicates a significant diversity gain of 9.99 dB, with ECC values < 0.001 over the entire band. At 3.41 GHz, the antenna reaches a peak gain of 4.49 dBi at 3.73 GHz and 2.32 dBi at 2.40 GHz and is well-suited for ISM and 5G C-band applications.

REFERENCES

1. W. Zhang, Y. Li, K. Wei, Z. Zhang, *IEEE Trans. Anten. Propag.* **71** No 7, 5749 (2023).
2. R. Lv, H. Zhao, X. Luo, D. Zhao, *IEICE Electron. Exp.* **21** No 18, 20240406 (2024).
3. M.A. Chung, M.Y. Chen, C.C. Hsu, C.W. Yang, C.W. Lin, Z.X. Zhang, *IEEE Access* **10**, 19875 (2022).
4. K. Du, Y. Wang, Y. Hu, *Appl. Sci.* **12** No 8, 3816 (2022).
5. P. Kumar, et al., *IEEE Trans. Circ. Syst. II: Exp. Briefs* **70** No 3, 949 (2023).
6. V.S.D. Rekha, P. Pardhasaradhi, B.T.P. Madhav, Y.U. Devi, *IEEE Access* **8**, 145871 (2020).
7. H.H. Tran, N. Nguyen-Trong, *IEEE Access* 9, 30011 (2021).
8. K.R. Jha, Z.P. Jibran, C. Singh, S.K. Sharma, *IEEE Open J. Anten. Propag.* **2**, 689 (2021).
9. K. Sharma, G.P. Pandey, *Prog. Electromagn. Res. C* **100**, 173 (2020)
10. F. Mohsenifard, A. Mahmoodzadeh, Z. Adelpour, *IEEE Access* **11**, 9483 (2022).
11. A.U. Fakhriddinovich, M.A. Sufian, W.A. Awan, N. Hussain, N. Kim, *IET Microwaves, Antennas & Propagation* **12**, 1559 (2023).
12. M. Hussain, W.A. Awan, M.S. Alzaidi, D.H. Elkamchouchi, *Heliyon* **9** No 7, e17404 (2023).
13. A.A. Al-Gburi, Z. Zakaria, M. Palandoken, I.M. Ibrahim, A.A. Althuwayb, S. Ahmad, S.S. Al-Bawri, *Comput. Mater. Contin* **73**, 2785 (2022).
14. T. Hemalatha, B. Roy, *J. Nano- Electron. Phys.* **16** No 4, 04010 (2024).
15. Indra Surjati, Syah Alam, et al., *J. Nano- Electron. Phys.* 16 No 2, 02009 (2024).

Самоізольована дводіапазонна MIMO-антена для покращеного рознесення у ISM-діапазоні та для бездротового застосування

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У цій статті пропонується самоізольована дводіапазонна MIMO-антена для покращеного рознесення в ISM-діапазоні та бездротових застосуваннях. Представлено ортогонально структуровану двопортову MIMO-антену, що включає патч меандрової лінії. Антена побудована на підкладці FR4 із загальними розмірами $0{,}272\lambda \times 0{,}56\lambda \times 0{,}0128\lambda$ на частоті 2,4 ГГц. Вона резонує в двох діапазонах, 2,40 ГГц та 3,73 ГГц, що відповідає вимогам ISM та C-діапазону. Ортогональна орієнтація покращує ізоляцію між елементами антени, досягаючи рівня самоізоляції < -18 дБ. Для оцінки можливостей рознесення антени було розраховано параметри продуктивності MIMO, такі як коефіцієнт рознесення (DG) та коефіцієнт кореляції обвідної (ECC). Результати моделювання демонструють відмінну продуктивність рознесення з ECC 0,01 та DG 9,989. Крім того, антена досягає ефективності понад 85 %, з коефіцієнтом підсилення 3,4 дБі для діапазону ISM та 4,1 дБі для діапазону C 5G. Завдяки компактним розмірам, дводіапазонній функціональності, високій ізоляції та чудовим показникам продуктивності, запропонована антена MIMO виділяється як перспективне рішення для дводіапазонних бездротових комунікаційних систем наступного покоління, особливо для застосувань ISM та 5G. Крім того, виміряні та змодельовані діаграми спрямованості демонструють стабільні діаграми спрямованості в площині *E* та стабільне всенаправлене покриття в площині *H*, що підкреслює її надійність для реальних застосувань.

Ключові слова: MIMO, Параметри рознесення, ISM, Самоізоляція.