International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

High Isolation Wideband MIMO Antenna without Decoupling Technique for IoT Applications

[1]Ashwini Kumar, [2]Ved Prakash*, [3]Suresh ChandraPadhy, [4]Amit Asthana, [5]Manik Chandra Pandey
[1]Department of Electronics and Communication Engineering, Poornima University, Jaipur, Rajasthan, India, Pin-303905
ashwiniarya15@gmail.com
ORCID- 0000-0002-7760-6030
[2]Department of Electronics and Communication, Amity School of Engineering and Technology, Amity University Haryana
vedprakash1986@gmail.com
ORCID- 0000-0001-8300-2340
*Corresponding Author
[3]Poornima University, Jaipur
sureshpadhy66@gmail.com
[4]FOET, Department of Computer Science, SGT University Gurugram Haryana, India Pin -122506.
amitasthana_feat@sgtuniversity.org
[5]Assistant Professor
DIT Dehradun
manikcp20@gmail.com

Abstract— This paper presents a method a high isolation wideband MIMO antenna without using any decoupling technique. This is achieved by transforming a strip line to a 1 ×2 MIMO antenna using Hilbert transform and Defected Ground structure is used in the antenna to resonate the antenna in for IOT and 5G sub-6 GHz bands. The proposed antenna has a size of 50 × 49.8 × 1.6 mm ^{3} and operates in the frequency band of 4.6 GHz to 5.94 GHz. The antenna simulated in ANSYS HFSS showed that its parameters Envelope correlation coefficient (ECC), Total Active Reflection Coefficient (TARC), Diversity gain (DG) and Channel Capacity Loss (CCL) are less than 0.04, -25 dB, 9.98 to 10 dB and less than 0.4 bits/s/Hz respectively. The radiation pattern of the antenna in both E-plane and H-plane has been simulated which the uniform distribution of power in the space.

Keywords- Hilbert Transform, Envelope correlation coefficient (EC-C), Total Active Reflection Coefficient (TAR-C), MIMO, CCL.

I. Introduction

In recent years, mobile communication's remarkable progress has significantly influenced economic and social development. Consequently, 5G technology has emerged as the bedrock for the future generation, around 2020, offering both evolutionary and revolutionary services. With its promise of ultra-high data rates, low latency, connection density, area traffic, spectral efficiency, increased capacity, and exceptional quality of service, 5G represents a groundbreaking advancement in technology [1], [2].

Notably, 5G technology presents fresh opportunities to overcome conventional development obstacles, unveiling a treasure trove of possibilities. Its support for the Internet of Things (IoT) positions 5G as a transformative force in crucial sectors like education, industry, healthcare, and other social domains [3] . The immense potential of 5G lies in its ability to create an extensive IoT ecosystem, seamlessly connecting countless devices. This huge network of the devices is prone to interference, multipath fading, and radiation losses. which can be overcome by using Multiple Input and Multiple output (MIMO) antenna system [4].

The main parameters on which the performance of a MIMO antenna is judged are Envelope correlation coefficient (EC-C), channel capacity, diversity gain and each should be in the specified ranges of less than 0.5, 0.4 bits/s/Hz and 10db respectively [5]. Fabricating an antenna with optimal values of these parameters is very difficult & the severity of the complexity increases as the frequency increases.

However, a myriad number of MIMO Antenna designs like slotted based antenna, fractal loaded, flexible antenna, 5G base station antenna, flexible antenna, EBG structure antenna have been implemented to improve these parameters [6], [7] , [8], [9],[10][11] . A better isolated antenna and high gain wideband MIMO antenna for communication system has been designed & fabricated and the antenna requires design of complete meta surface [12]. To improve further the MIMO antenna parameters and their size, defected ground structure has also been implemented along with a mention antenna design technique. A planar compact grounded coplanar waveguide (GCPW)-fed 4-element multiple-input multiple-output (MIMO) antenna with a defected ground structure (DGS) is designed for 5G communication resonating between 25.30 GHz to 42 GHz with maximum gain of 12 dBi [13]. A microstrip antenna, with DGS with triangular strip has been designed having a gain of 6.5 db [14]. In some other works, isolation enhancement has also been done by using 1 X 3 array element [15].

In this paper, a MIMO antenna resonating in the frequency range 4.6 GHz to 5.94 GHz has been designed which is useful for the public safety band and 5G sub-6GHz band applications. The paper is organized into four sections namely section II is describes the design and simulations of the proposed antenna while the Section III is dedicated to result and discussion and finally the paper concluded in Section IV.

II. Proposed Antenna

The base structure of the antenna is a strip line. The antenna is then modified to a Fractal Hilbert curve antenna followed by its defected ground structure. Finally, the antenna is then transformed into a Multiple Input and Multiple Output antenna. The figure 1 shows the transformation of strip line into a MIMO antenna with DGS [16]. All dimensional details of the proposed antenna is also shown in figure 1. Figure 2 shows the reflections coefficient (S_{11}) of the antenna at different design stages.

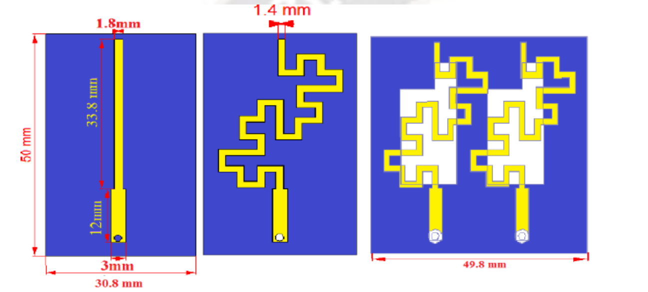

Figure 1: a) Stripline b) Stripline Hilbert curve c) 1x2 Stripline Hilbert curve with DGS (SH-DGS) MIMO Antenna

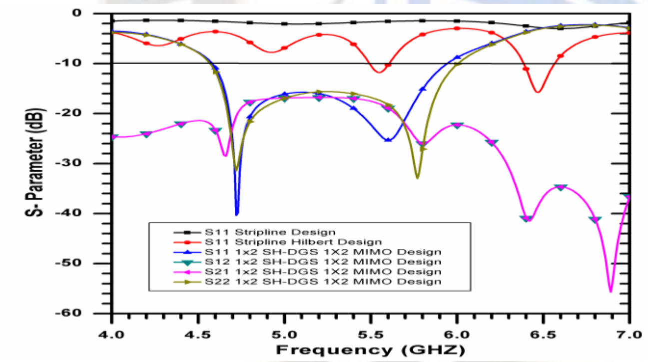

Figure 2: S_{11} of SH-DGS 1x2 MIMO antenna

III. Result and Discussions

S – Parameters: The Figure 2 showcases the simulated S-parameters of the proposed design at different stages. It can be seen from the figure 2 that the reflection coefficient (S_{11}) at initial design stage (stripline design) is above -10 dB line that means it's not matched and signal is received by radiating element but as it is converted into Hilbert curve shape the antenna shows multi resonance in its response and in final stage the design is transformed into a SH-DGS 1x2 MIMO structure which operates in the frequency range from 4.6 GHz to 5.94 GHz. The isolation of the simulated antenna are also sufficient to use it in the frequency range as shown in figure 2. The inter element isolation of more than 15dB is achieved here without use of any specific decoupling technique which is a novel aspect of the proposed structure.

Envelope correlation coefficient (EC-C): This factor assesses the similarity between the radiation patterns of two parent antennas and plays a crucial role in determining the correlation between the signal envelopes received by these antennas. Its value should be low for a low mutual coupling between the two antenna elements and has acceptable value of less than 0.5. It can be calculated using S-parameters as given below in equation (1):

$$EC-C = \frac{|S_{mm}^{*}S_{mn} + S_{nm}^{*}S_{nn}|^2}{(1-|S_{mm}|^2 - |S_{nm}|^2)(1-|S_{nm}|^2 - |S_{mn}|^2)} \quad (1)$$

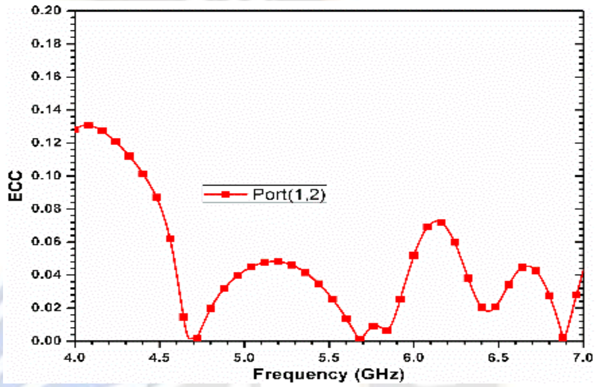

Figure 3: ECC of SH-DGS 1x2 MIMO antenna

EC-C for the SH-DGS 1x2 MIMO antenna is shown in figure 3 which is less than 0.01 which makes it suitable to use as MIMO antenna.

Diversity gain (D-G): Since, in wireless communication multiple antennas would be transmitting the signal, so the signal received by antenna quantifies the gain as diversity gain. This is in comparison to that of reception from single antenna. This methodology of signal transfer helps us to overcome fading, signal quality, burst errors etc. So, D-G is considered as a parameter for signal quality improvement accomplished through MIMO antenna and ideally has a typically around 10 dB, throughout the operating frequency range. It is calculated as in Equation (2) as presented below:

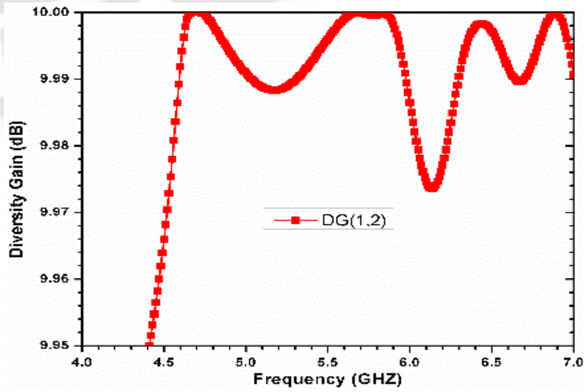

Figure 4: DG of SH-DGS 1x2 MIMO antenna

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

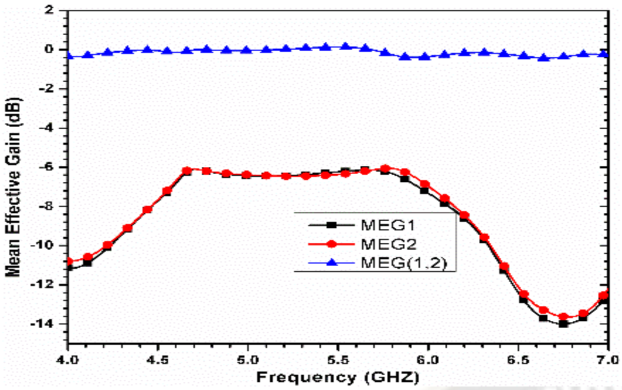

Figure 5: ME-G of SH-DGS 1x2 MIMO antenna

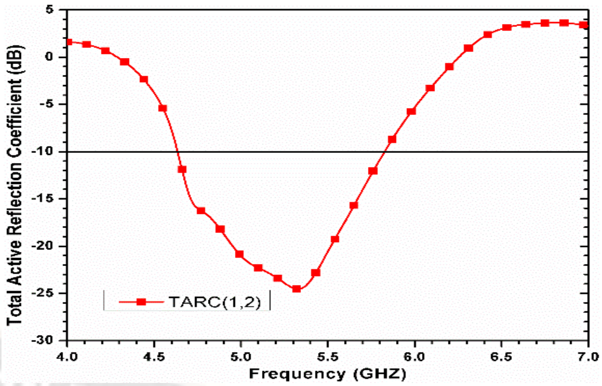

Figure 6: TAR-C of SH-DGS 1x2 MIMO antenna

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

D-G for the SH-DGS 1x2 MIMO antenna is shown in figure 4 and the value of D-G is greater than 9.8 dB for the operating frequency region.

Maximum Efficiency Gain (ME-G): It gives details of efficiency and gain of the designed MIMO antenna. It is calculated on basis S-parameters of a particular port and has optimal value below 3 dB for two ports. Equation (3) and (4) are employed for the calculation of ME-G for a scenario of $m \times n$ MIMO antennas. Figure 5 shows the mean effective gain of proposed antenna which shows it optimally accepted values.

$$ME - Gm = 0.5 \times [1 - |S_{mm}|^2 - |S_{mn}|^2] \quad (3)$$

$$ME - Gn = 0.5 \times [1 - |S_{mn}|^2 - |S_{nn}|^2] \quad (4)$$

Total Active Reflection Coefficient (TAR-C): This parameter determines the overall reflection coefficient as the signal is being transmitted by multiple antennas and calculated by taking the square root of the ratio between the total power reflected from all ports and the total power incident to all ports. This calculation can be performed using the S-parameters and the equations (5) and (6) provided below: and ideally value as

$$TAR - C = \frac{\sqrt{\sum_{m=1}^{N} |Y_m|^2}}{\sqrt{\sum_{m=1}^{N} |X_m|^2}} \qquad (6)$$

$$TAR - C = \sqrt{\frac{|(S_{11} + S_{12}e^{j\theta}|^2 + |(S_{22} + S_{21}e^{j\theta}|^2}{2}} \qquad (7)$$

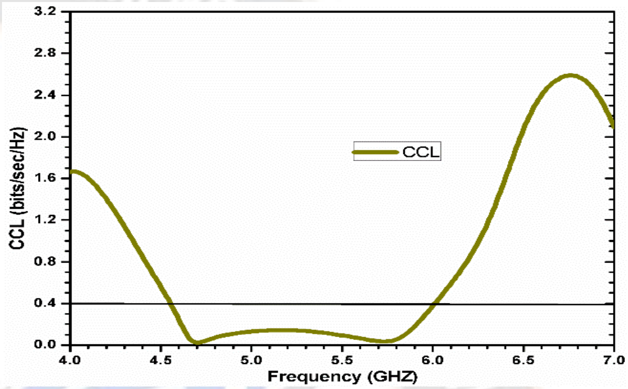

Figure 7: CC-L of SH-DGS 1x2 MIMO antenna

Figure 6 shows the TAR-C of the MIMO antenna and its value if well below the -10dB desired value for the desired frequency band.

Channel Capacity Loss (CC-L): This parameter takes account of the loss in the system performance with respect to the data rate per hertz. Ideally, a loss of 0.4 bits/s/Hz is acceptable The calculation of CC-L can be performed using equations (7-10) [17][18] based on the S-parameters.

$$CC - L \quad = -log_2|a^R| \qquad (7)$$

$$a^R = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \qquad (8)$$

$$a_{ii} = 1 - \left| \sum_{n=1}^{N} S_{in}^* S_{ni} \right| \text{for i, j} = 1, 2, 3 \text{ and } 4 \qquad (9)$$

$$a_{ij} = - \left| \sum_{n=1}^{N} S_{in}^* S_{nj} \right| \qquad (10)$$

The figure 7 shows the CC-L and it the value of the proposed SH-DGS 1x2 MIMO antenna is 0.01 bits/s/Hz.

Radiation Pattern: The simulated radiation characteristics of proposed MIMO antenna Co-Pol and Cross-Pol radiation patterns at phi 0 degree and 90 degree are shown in figures 8-11 for resonating frequency of 4.72 and 5.6 GHz. At the resonating frequency of 4.72 and 5.6 GHz, the radiation pattern exhibits bidirectional characteristics in the E-plane, while in the H-plane, the proposed antenna radiates nearly uniformly in all directions.

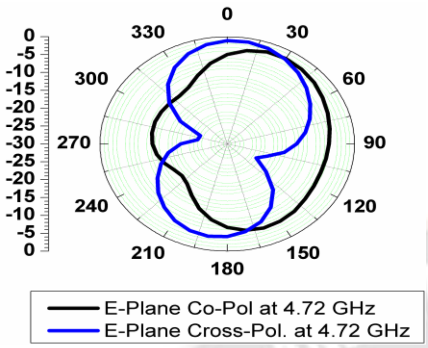

Figure 8: Radiation pattern in E-plane @4.72 GHz

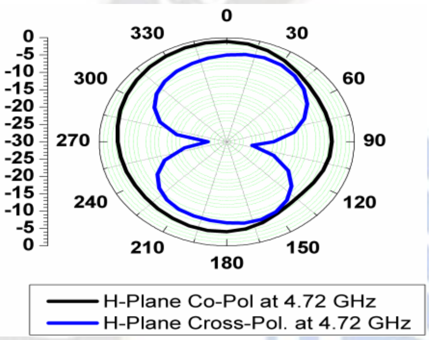

Figure 9: Radiation pattern in H-plane @4.72 GHz

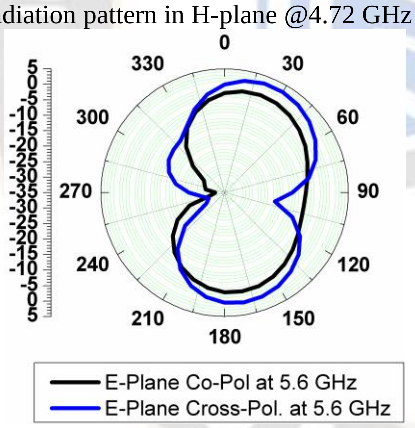

Figure 10: Radiation pattern in E-plane @ 5.6 GHz

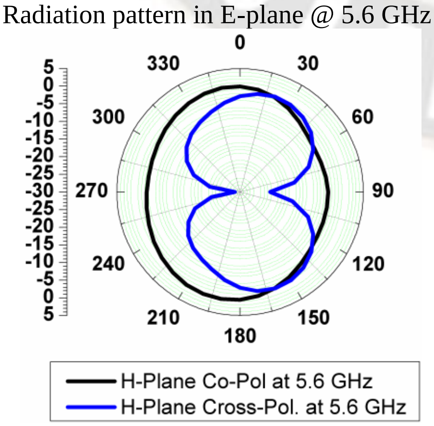

Figure 11: Radiation pattern in E-plane @ 5.6 GHz

IV. CONCLUSION

It can be concluded that the antenna resonates in the frequency range from 4.6 to 5.94 GHz making it suitable for public safety applications and 5G applications in sub 6 GHz band. The various parameters of the antenna shows that its parameters Envelope correlation coefficient (ECC), Total Active Reflection Coefficient (TARC), Diversity gain (DG) and Channel Capacity Loss (CCL) are less than 0.04, -25 dB, 9.98 to 10 dB and less than 0.4 bits/s/Hz respectively. Furthermore, the antenna can be fabricated compared with the simulated results. The research paves way for the inclusion of more antenna structures into it to enhance the antenna parameters. The use of defected ground structure method which is effective miniaturization could also be implemented for future work.

REFERENCES

[1] M. Shafi *et al.*, "5G: A tutorial overview of standards, trials, challenges, deployment, and practice," *IEEE J. Sel. Areas Commun.*, vol. 35, no. 6, pp. 1201–1221, 2017, doi: 10.1109/JSAC.2017.2692307.

[2] H. Tataria, M. Shafi, A. F. Molisch, M. Dohler, H. Sjoland, and F. Tufvesson, "6G Wireless Systems: Vision, Requirements, Challenges, Insights, and Opportunities," *Proc. IEEE*, vol. 109, no. 7, pp. 1166–1199, 2021, doi: 10.1109/JPROC.2021.3061701.

[3] X. Cheng, Z. Huang, and S. Chen, "Vehicular communication channel measurement, modelling, and application for beyond 5G and 6G," *IET Commun.*, vol. 14, no. 19, pp. 3303–3311, 2020, doi: 10.1049/iet-com.2020.0531.

[4] S. K. Ibrahim *et al.*, "Design, Challenges and Developments for 5G Massive MIMO Antenna Systems at Sub 6-GHz Band: A Review," *Nanomaterials*, vol. 13, no. 3, 2023, doi: 10.3390/nano13030520.

[5] S. Kumar, A. S. Dixit, R. R. Malekar, H. D. Raut, and L. K. Shevada, "Fifth generation antennas: A comprehensive review of design and performance enhancement techniques," *IEEE Access*, vol. 8, pp. 163568–163593, 2020, doi: 10.1109/ACCESS.2020.3020952.

[6] S. S. Al-Bawri *et al.*, "Broadband Sub-6GHz Slot-based MIMO Antenna for 5G NR Bands Mobile Applications," *J. Phys. Conf. Ser.*, vol. 1962, no. 1, 2021, doi: 10.1088/1742-6596/1962/1/012038.

[7] T. Addepalli, M. S. Kumar, C. R. Jetti, N. K. Gollamudi, B. K. Kumar, and J. Kulkarni, "Fractal Loaded, Novel, and Compact Two- and Eight-Element High Diversity MIMO Antenna for 5G Sub-6 GHz (N77/N78 and N79) and WLAN Applications, Verified with TCM Analysis," *Electron.*, vol. 12, no. 4, 2023, doi: 10.3390/electronics12040952.

[8] D. M. John, S. Vincent, S. Pathan, P. Kumar, and T. Ali, "Flexible Antennas for a Sub-6 GHz 5G Band: A Comprehensive Review," *Sensors*, vol. 22, no. 19, 2022, doi: 10.3390/s22197615.

[9] R. Darwin and P. Sampath, "Sub-6 GHz band massive MIMO antenna system for variable deployment scenarios in 5G base stations," *Microsyst. Technol.*, vol.

28, no. 9, pp. 2047–2059, 2022, doi: 10.1007/s00542-022-05344-2.

[10] J. Ge and G. Wang, "CmWave to MmWave Reconfigurable Antenna for 5G Applications," *2020 IEEE Int. Symp. Antennas Propag. North Am. Radio Sci. Meet. IEEECONF 2020 - Proc.*, pp. 619–620, 2020, doi: 10.1109/IEEECONF35879.2020.9329483.

[11] N. Jaglan, P. Dalal, S. D. Gupta, and M. A. Abdalla, "Band notched uwb mimo/diversity antenna design with inductance boosted compact EBG structures," *Prog. Electromagn. Res. C*, vol. 105, no. July, pp. 185–202, 2020, doi: 10.2528/PIERC20072402.

[12] M. M. Hasan *et al.*, "Author Correction: Gain and isolation enhancement of a wideband MIMO antenna using metasurface for 5G sub-6 GHz communication systems (Scientific Reports, (2022), 12, 1, (9433), 10.1038/s41598-022-13522-5)," *Sci. Rep.*, vol. 13, no. 1, p. 41598, 2023, doi: 10.1038/s41598-023-29750-2.

[13] A. Kumar, A. Kumar, and A. Kumar, "Defected Ground Structure Based High Gain, Wideband and High Diversity Performance Quad-element MIMO Antenna Array for 5G Millimeter-wave Communication," *Prog. Electromagn. Res. B*, vol. 101, no. March, pp. 1–16, 2023, doi: 10.2528/pierb23030601.

[14] T. Olawoye and P. Kumar, "A High Gain Antenna with DGS for Sub-6 GHz 5G Communications," *Adv. Electromagn.*, vol. 11, no. 1, pp. 41–50, 2022, doi: 10.7716/aem.v11i1.1670.

[15] Z. Niu, H. Zhang, Q. Chen, and T. Zhong, "Isolation Enhancement for 1×3 Closely Spaced E-Plane Patch Antenna Array Using Defect Ground Structure and Metal-Vias," *IEEE Access*, vol. 7, no. 119375, pp. 119375–119383, 2019, doi: 10.1109/ACCESS.2019.2937385.

[16] A. Kumar and A. P. S. Pharwaha, "Development of a Modified Hilbert Curve Fractal Antenna for Multiband Applications," *IETE J. Res.*, vol. 68, no. 5, pp. 3597–3606, 2022, doi: 10.1080/03772063.2020.1772126.

[17] A. W. M. Saadh, P. Ramaswamy, and T. Ali, "A CPW fed two and four element antenna with reduced mutual coupling between the antenna elements for wireless applications," *Appl. Phys. A*, vol. 127, no. 2, p. 88, Feb. 2021, doi: 10.1007/s00339-020-04224-8.

[18] W. M. Abdulkawi, W. A. Malik, S. U. Rehman, A. Aziz, A. F. A. Sheta, and M. A. Alkanhal, "Design of a compact dual-band mimo antenna system with high-diversity gain performance in both frequency bands," *Micromachines*, vol. 12, no. 4, 2021, doi: 10.3390/mi12040383.