Open Access | Rapid and quality publishing

International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 4 | Pages 1508-1512 | e-ISSN: 2347-470X

16-Elements Ring Shaped MIMO Antenna Design for 5G Wireless Communication

Megha Soni[1], Ajay Dadoriya[2] and Leeladhar Malviya[3]

[1]*Deaprtment of Electronics and Communication, Amity University Gwalior, soni_megha1987@yahoo.co.in*
[2]*Department of Electronics and Communication, Amity University Gwalior, akdadoria@gwa.amity.edu*
[3]*Department of Electronics and Telecommunication, Shri G.S. Institute of Technology and Science Indore, ldmalviya@gmail.com*

***Correspondence:** soni_megha1987@yahoo.co.in;

ABSTRACT- The most popular area of study in wireless communication is Fifth Generation (5G). In this paper, a 5G MIMO antenna with a wide bandwidth, large gain, and compact structure is designed. The suggested design has two input and two output ports, with eight octagonal randomly shaped patches designed with Rogers RT5880 substrate in a building from the front and stripped from the bottom sort of arrangement. On CST-Microwave Studio, the entire designing and simulation process is carried out. Several characteristic parameters have been determined in this research using CST software. Broadband from 32GHz to 35 GHz and -43.62 return losses achieved at 33.56 GHz frequency with the proposed design. More than 9.6 dBi gain is also achieved with the proposed antenna. The antenna is broadband, very compact, with high gain and efficiency.

Keywords: ECC, MIMO, Wireless communication, 5G.

ARTICLE INFORMATION

Author(s): Megha Soni, Ajay Dadoriya, and Leeladhar Malviya;
Received: 16/11/24; **Accepted:** 30/12/24; **Published:** 30/12/24;
E- ISSN: 2347-470X;
Paper Id: IJEER240437;
Citation: 10.37391/IJEER.120447
Webpage-link:
https://ijeer.forexjournal.co.in/archive/volume-12/ijeer-120447.html

Publisher's Note: FOREX Publication stays neutral with regard to Jurisdictional claims in Published maps and institutional affiliations.

1. INTRODUCTION

Internets of Things (IOT) and fifth-generation (5G) wireless network applications develop have greatly benefited people's well-being and the advancement of society. Long-term improvements in data speed and multi-network coexistence are required to fulfill the demands of various applications. Multiple-input multiple-output (MIMO) antenna is the prime component of transceivers. Enhancing spectral efficiency is necessary to allow multi-path transmission at limited power levels [1]. Stepped U-shaped slots and several vertical slots are used to create the wideband slot antenna [2]. Wide bandwidth, wide impedance matching, and high isolation remain some of the most difficult parameters to achieve. The design of four-element inverted L-monopole MIMO antennas with connected ground planes can be used to obtain bandwidth with wide impedance by adding an extra mode [3]. To improve inter-element isolation, cavity-backed MIMO slot antenna elements are separated by mushroom-shaped double-layer walls [4].

A loop-excited, two-element Yagi-based MIMO antenna with reduced overall size and enhanced bandwidth is demonstrated, when each side of the substrate has half of the driven loop element [5]. To enhance the wideband resonance, isolation, split ring resonator loading, and printed monopole, a ring-shaped ground is positioned adjacent to the wideband planar MIMO antenna. A wide impedance matching range of 2.2 GHz to 6.28 GHz is offered by the slotted ground plane [6]. Co-design without impedance confinement has been used on 50-Ω interfaces in place of developing the MIMO antenna and the radio-frequency amplifier independently. To achieve better wideband matching performance, this is carried out in an active MIMO array [7]. Having circular metallic unit cells as a single-layered artificial magnetic conductor eliminates coupling between the di-polarized antenna elements in a MIMO array and produces a low-profile in place of a standard ground plane [8].

The antenna's coverage is enhanced in a targeted direction by employing a process called beam forming. Beam formation, diversity, and spatial multiplexing are MIMO techniques frequently used in less frequency systems such as WLAN, IEEE802.11, and 3GPP LTE-4G standards. Feed networks emit very little radiation; they are preferable in 5-G patch array antennas over patches built on the same substrate. Ultimately, the fringing field that opposes microstrip lines cancels them out. [9-11].

By using an arbitrary-shaped patch placed in a tapered array, this suggested method achieves a wide bandwidth while also improving the antenna's gain. The substrate utilized is FR4, with dielectric constant of 4.3. With eight components per chain, the objective of this work is to construct a 5G MIMO antenna with extremely high gain. Over the complete bandwidth from 32GHz to 36GHz, the proposed antenna achieved return loss better than -44.352dB, VSWR less than 2:1, and gain greater than9.6dB.

2. DESIGN OF 5G MIMO ANTENNA AND METHODS

In the designed MIMO antenna, a Rogers RT5880 substrate with a hexagonal-shaped patch of eight elements in each port as shown in *fig 1. (a)* .4.3 is the dielectric constant and the substrate thickness is 0.51for the antenna for 5G broadband applications. The antenna is simulated with CST-Microwave studio. With a thickness of 35 µm, the ground layer of copper is developed on a substrate of 26×12mm^2 as depicted in *fig 1. (b)*. the purpose of the building-type configurations is to enhance the beam directions and gain. *Fig.1* displays the proposed 5G MIMO-array antenna, and the computed parameters are displayed in *table I.*

Table I. Dimensions of the proposed antenna

Parameter	Dimension (in mm)
L1	26
L2	12
W1	0.92
W2	1.07
G1	1.00
G2	1.80
W3	4.00
W4	7.00
W5	1.00
Ts	0.51

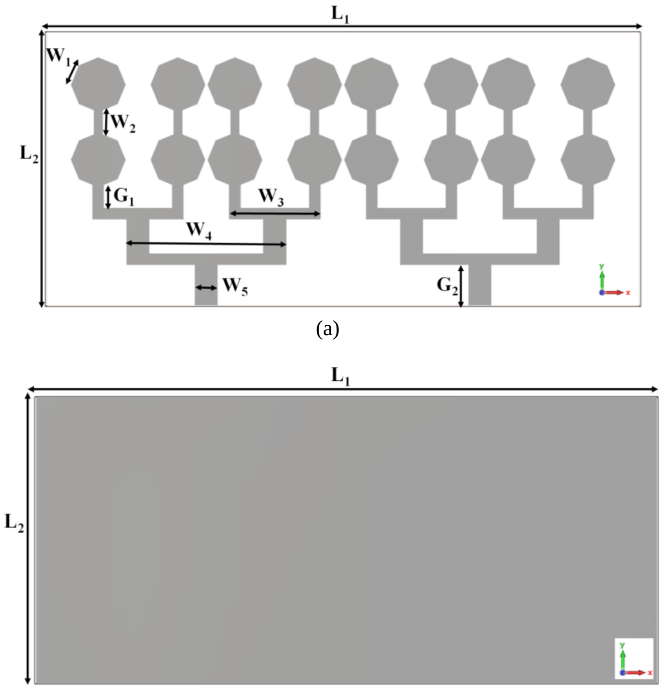


Fig.1. Designed MIMO antenna (a) Front View and (b) Back view

3. RETRIEVED RESULTS

3.1. Return Loss and VSWR

The outcomes of the suggested antenna are described in this section. CST MW Studio is used to optimize the significant parameters. At the 33.56 GHz resonating frequency, both ports receive a return loss of -43.62dB, and the VSWR is less than 2:1. The isolation is 13.5dB at the resonant frequency and exceeds 25dB throughout the whole band. *Figure 2* displays the isolation parameters, and the return loss for Ports 1 and 2, while *figure 3* shows the VSWR. For ease of analysis, only S_{11} and S_{12} are taken into consideration in this work based on the simulation results, which are S_{11}= S_{22} and S_{21}= S_{12}.

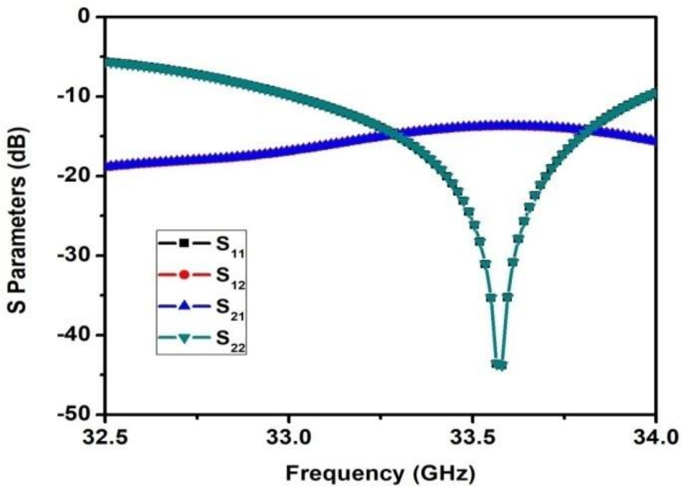


Fig. 2. S-Parameters for the proposed antenna

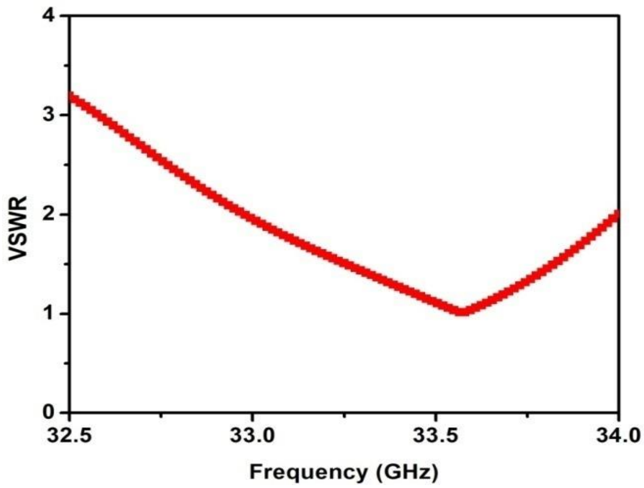


Fig. 3. VSWR with respect to frequency

3.2.Envelope correlation coefficient (ECC)

The Envelope Correlation Coefficient indicates the degree of independence between the radiation patterns of two antennas. Therefore, the correlation between two antennas would be 0 if one was fully horizontally polarized and the other was fully vertically polarized. The ECC of two antennas would likewise be zero if one exclusively emitted energy into the sky and the other solely emitted energy into the earth. As a result, the Envelope Correlation Coefficient considers the polarization, radiation pattern form, and even the relative phase of the fields for both antennas.

The antenna's understanding of the varying performance of the specified work is demonstrated by the envelope correlation coefficient, or ECC. The ECC result for the suggested design reveals that the ECC values are fewer than 10-35 throughout the total frequency range as shown in Fig 4. The S-parameter and the formula listed in Equation 1 below can be used to calculate the ECC.

FOREX Publication
Open Access | Rapid and quality publishing
International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 4 | Pages 1508-1512 | e-ISSN: 2347-470X

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

Where, the number of antennas is N, and the antenna elements are *m* and *n*.

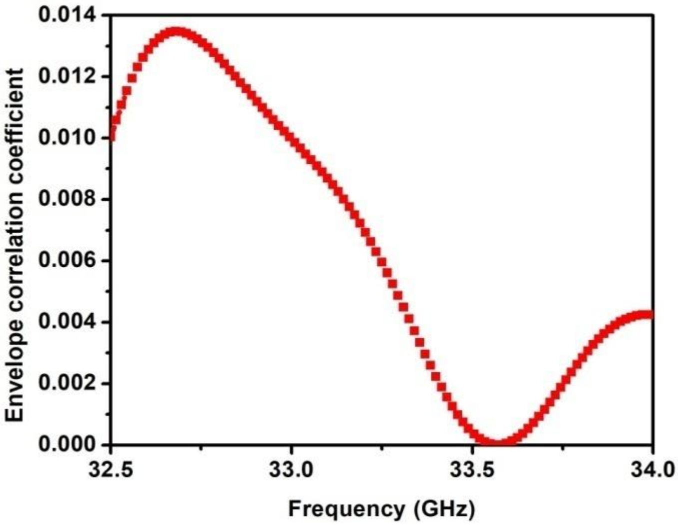


Fig. 4. The proposed MIMO antenna's ECC

3.3.Gain of Antenna

The gain of antenna calculates the antenna's proficiency to radiate in the prescribed direction. The gain values in the proposed simulation design of the MIMO-array antenna are displayed in *figure 5* and a very high gain is achieved in the proposed antenna.

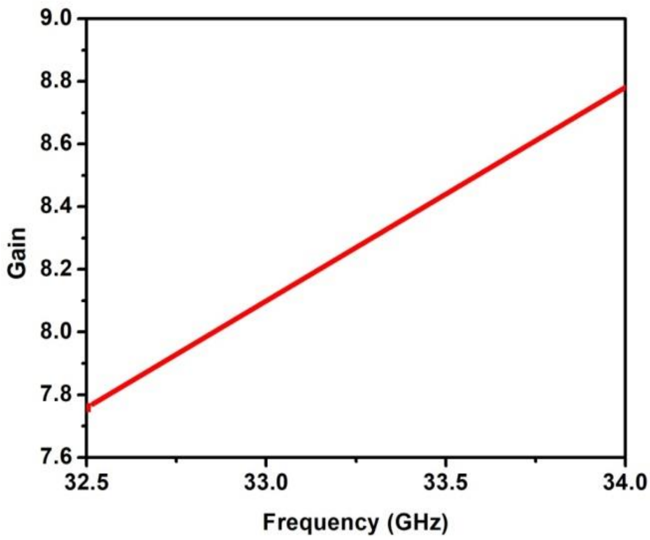


Fig.5. Gain of antenna with respect to frequency

3.4. Antenna Efficiency

Figure 6 shows the combined efficiency of the simulation radiation and the prescribed MIMO-array antenna. The graph indicates that the total efficiency is larger than 85% and the efficiency for radiation is better than 87% over the entire bandwidth.

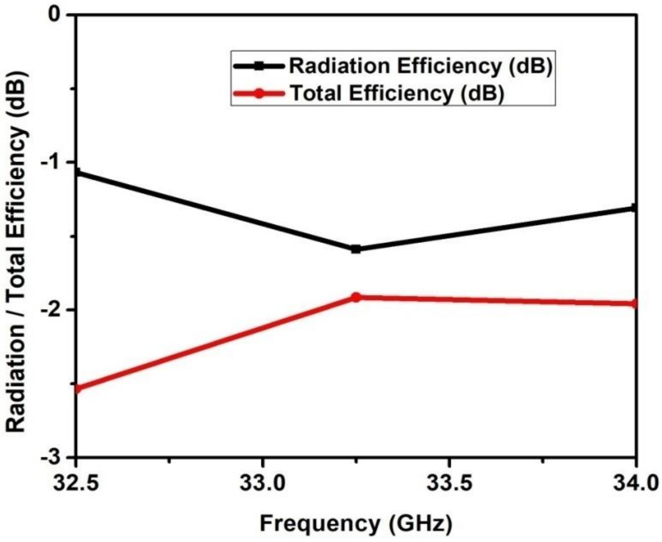


Fig.6. Efficiencies for the proposed MIMO-antenna

The presented design consists of 16 element arrays. The designed structure is the optimized one. The *fig. 7* compares the S_{11} parameter for 8 and 16 elements. As depicted from the figure when the number of elements is less the obtained bandwidth and the s_{11} parameter also has less value than the 16-element array.

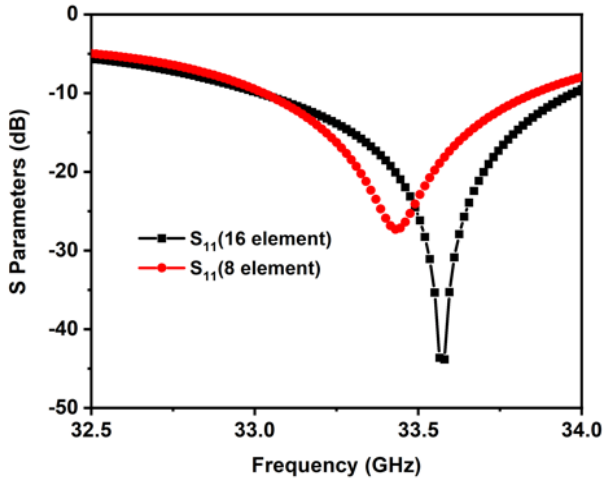
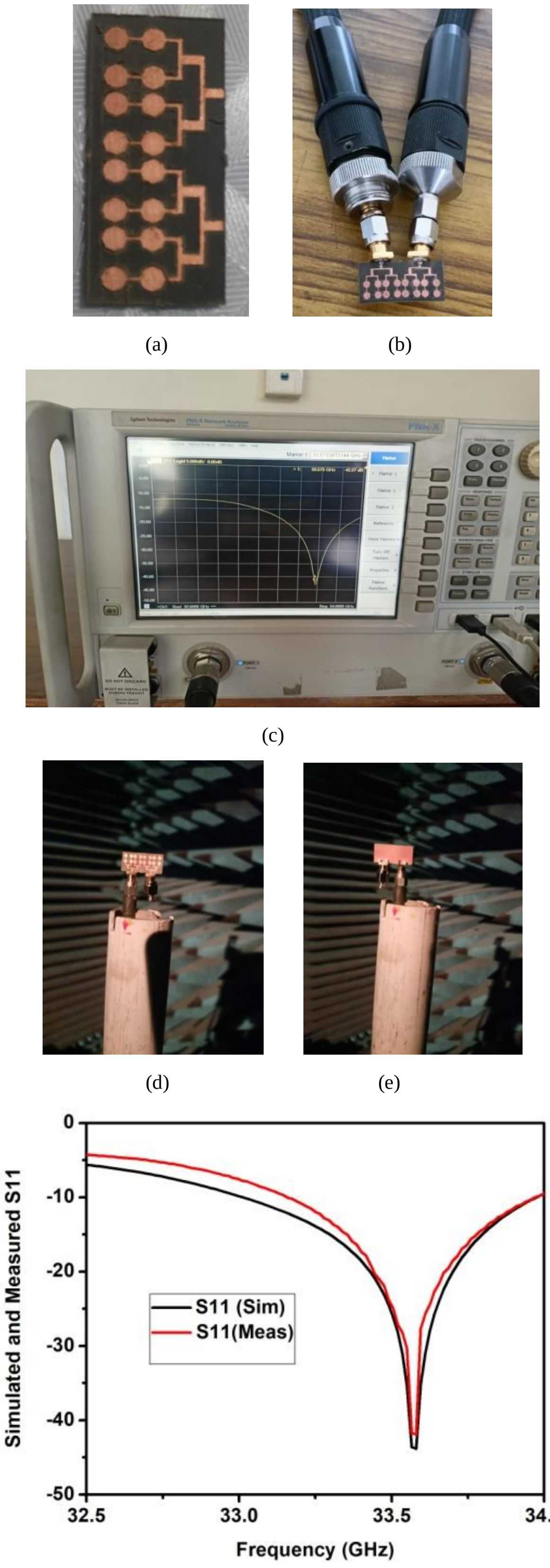


Fig. 7. Comparison of S parameter for 8 and 16 elements

4. EXPERIMENTAL VALIDATION

The proposed structure is fabricated on Roger's 5880 substrate using PCB printing and etching. *Fig 8(a)* Shows the fabricated structure top view and the bottom side are a fully coated copper layer. *Fig 8(b)* Shows the antenna connected with connector on the two ports. *Fig 8(c)* Depicts the measured obtained results on the Vector network analyzer. *Fig 8(d)* and *8(e)* shows the front and the back side of the fabricated antenna placed inside the anechoic chamber. The measurement is done using a vector network analyzer. The comparison of S_{11} for simulated and the fabricated structure is shown in *figure 8 (f)*. Simulation and measurement results are in good agreement to each other.



(f)

Fig 8. Fabricated antenna (a) Prototype, (b) Antenna with connectors, (c) Measured results on VNA, (d) Antenna testing inside anechoic chamber visible top view, (e) Antenna testing inside anechoic chamber visible top view, (f) Simulated and measured S_{11} parameter

The available MIMO antennas are designed for a lower frequency range. A little research is done on 5G technology. The presented antenna is compared with little available literature. *Table II* presents a comparison between the prior papers and the proposed MIMO-array antenna. The results indicate that the suggested MIMO has a broad bandwidth, low size, good radiation efficiency, and very high gain when compared to the existing references.

Table II. Comparison with available references

Ref. No.	Frequency Band/ Bands (GHz)	No. of elements	Size (mm^2)	Gain (dBi)	Efficiency (%)
[13]	22.66-29.11	8	20 x 20	9.9	70
[14]	27-29	4	100 x 100	6	-
[15]	26-29.5	4	20 x 20	7.3	70
[16]	29	2	11 x 5.3	-	-
Proposed work	32-36	8	12 x 26	8.5	87

5. CONCLUSION

On Roger's 5880 substrate with 16 elements, an octagonal ring-shaped patch slot-based MIMO antenna has been designed to utilize a series-parallel configuration with a 2:1 VSWR band with a 33.56GHz frequency band. The antenna is fabricated, tested, and measured. The simulated and measured results are in good agreement with each other. This antenna is broadband in comparison to others. The proposed antenna is very compact, with high gain and efficiency. Important MIMO antenna characteristics and parameters have been discussed in this paper. According to the paper's data, the return loss is -43.62, more than 8.5dBi gain, and 87% efficiency is achieved.

REFERENCES

[1] Y. Li, C.-Y.-D. Sim, Y. Luo, and G. Yang, "High-isolation 3.5 GHz eight-antenna MIMO array using balanced open-slot antenna element for 5G smart phones," *IEEE Trans. Antennas Propag*., vol. 67, no. 6, pp. 3820-3830, Jun. 2019.

[2] H.-T. Hu, F.-C. Chen and Q.-X. Chu, "A wideband u-shaped slot antenna and its application in MIMO terminals," *IEEE Antennas Wireless Propag. Lett*, vol. 15, pp. 508-511, Jul. 2015.

[3] D. Sarkar and K. V. Srivastava, "A compact four-element MIMO/diversity antenna with enhanced bandwidth," *IEEE Antennas Wireless Propag. Lett.* vol. 16, pp. 2469-2472, Jul. 2017.

[4] G. Zhai, Z. N. Chen, and X. Qing, "Enhanced isolation of a closely spaced four-element MIMO antenna system using metamaterial mushroom," *IEEE Trans. Antennas Propag*., vol. 63, no. 8, pp. 3362-3370, Aug. 2015.

[5] S. S. Jehangir and M. S. Sharawi, "A miniaturized UWB biplanarYagilike MIMO antenna system," *IEEE Antennas Wireless Propag. Lett*. vol. 16, pp. 2320-2323, Jun. 2017.

[6] R. Anitha, P. V. Vinesh, K. C. Prakash, P. Mohanan, and K. Vasudevan, "A compact quad element slotted ground wideband antenna for MIMO applications," *IEEE Trans. Antennas Propag*., vol. 64, no. 10, pp. 4550-4553, Oct. 2016.

[7] S. K. Dhar, M. S. Sharawi, O. Hammi, and F. M. Ghannouchi, "An active integrated ultra-wideband MIMO antenna," *IEEE Trans. Antennas Propag*., vol. 64, no. 4, pp. 1573-1578, Apr. 2016.

[8] H. Zhai, L. Xi, Y. Zang, and L. Li, "A low-profile dual-polarized high isolation MIMO antenna arrays for wideband base-station applications," *IEEE Trans. Antennas Propag*., vol. 63, no. 8, pp. 3362-3370, Aug. 2015.
[9] Malviya L., Panigrahi R.K., and Kartikeyan M.V., "A Multi-Standard, Wide Band 2x2 Compact MIMO Antenna with Ground Modification Techniques", *International Journal of Microwave and Optical Technology*, vol.11, 2016, pp. 259-266.
[10] Pant M, Malviya L, Choudhary V. "A 28 GHz Corporate Series-Fed Taper Antenna Array for Fifth-Generation Wireless Communication". In *Mobile Radio Communications and 5G Networks* 2021 (pp. 697-705). Springer, Singapore
[11] Malviya L., Panigrahi R.K., and Kartikeyan M.V., "Circularly Polarized 2 x 2 MIMO Antennas for WLAN Applications", *Progress in Electromagnetic Research C*, vol. 66, 2016, pp. 97-107.
[12] Malviya L, Parmar A, Solanki D, Gupta P & Malviya P. Highly isolated inset-feed 28 GHz MIMO-antenna array for 5G wireless application. In *Mobile Radio Communications and 5G Networks* 2021 (pp. 401-408). Springer, Singapore
[13] A. Pandey, A. K. Singh, V. Yadav, S. Singh and R. Singh, "An ultra-wideband (UWB) MIMO Antenna for 5G Applications," 2021 *6th International Conference on Communication and Electronics Systems (ICCES)*, 2021, pp.420-425, doi 10.1109/ICCES51350.2021.9488966.
[14] Y. Gillani, M. U. Khan, A. Ghalib, R. Hussain, M. S. Sharawi and R. Mittra, "Integrated 4-Element MIMO Antenna and mm-Wave Arrays for 5G Access Points," 2020 *IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting*, 2020, pp. 1361-1362, doi:10.1109/ IEEECONF35879.2020.9330044.
[15] A. M. Saleh, K. R. Mahmoud, M. M. Elmesalawy and I. I. Ibrahim, "MIMO Wideband Circularly Polarized Patch Antenna Array for 5G Millimeter-Wave Systems," 2021 *International Conference on Computer Communication and Informatics (ICCCI)*, 2021, pp 1-5, doi: 10.1109/ICCCI50826.2021.9402419.
[16] Ahmad, Ashfaq,Choi, Dong-you, Ullah, Sadiq, 2022, "A compact two elements MIMO antenna for 5G communication", JO - Scientific Reports, 3608, 12, 1, SN - 2045-2322, https://doi.org/10.1038/s41598-022-07579-5, 10.1038/s41598-022-07579-5