Technical Journal, University of Engineering and Technology (UET) Taxila, Pakistan Vol. 28 No. 4-2023
ISSN:1813-1786 (Print) 2313-7770 (Online)

Compact Printed MIMO Antenna for Future Generation N79, LTE-46/47, and X-Band Applications

M. Zahid[1], M. M. Taqdeer[2], U. Shahid[3], M. Samiullah[4], Y. Amin[5], N. Bhowmike [6]

[1,2,3,4,5]*Telecommunication. Engineering Department, University of Engineering. & Technology Taxila, Pakistan,*
[6] *Phillip M. Drayer Department of Electrical Engg. Lamar University, Beaumont, 77705, Texas, USA.*

[1]muhammad.zahid@uettaxila.edu.pk

Abstract- Compact printed multiple input multiple output (MIMO) antenna is reported for C-band (n79, LTE-46/47) applications. The presented two-element MIMO antenna has a size of 27×27 mm^2 and it is printed on a 0.8 mm thick, low-cost dielectric substrate (FR4). The rectangular patch consists of two parallel narrow slots on both sides of the patch. These parallel slots are used to enhance the impedance bandwidth of a proposed antenna. The antenna is fed via a 50Ω impedance feedline. The proposed antenna has partial ground that helps to get wider bandwidth. The antenna operates at a frequency of 4.42 GHz which is included in the future near radio (n79-band) 5G frequency band. Proposed antenna has a bandwidth of 2.45 GHz, and a peak gain of an antenna is 7.1 dB which is appropriate for portable C-band (n79, LTE-46/47) applications. Optimization using simulation and fabrication shows that the proposed MIMO antenna can provide requisite gain, reasonable bandwidth, and high radiation efficiency in resonant frequency bands.

Keywords- Compact MIMO, C-band, MIMO, n79, LTE-46/47.

I. INTRODUCTION

In recent years, antenna technology has played an important role in smartphone and 5G communication. All the modern advancements in 5G and 6G communication highly depend on antenna technology. Microstrip patch antennae become more popular due to their compact size and high reliability. Microstrip patch antennae are also useful in small-size devices like mobile phones and smartwatches due to their easy-to-install feature in such types of devices. In the wider field of antenna, MIMO (multiple input and multiple outputs) antenna becomes more effective as compared to other types of antennae. MIMO antennae have several advantages over traditional antennae such as higher data rate, enhanced gain, and coverage, increased spectral efficiency, and diversity gain [1]. Some promising frequency bands have been designed for modern wireless communication applications, such as 5G networks. Future communication was to take place in many configurations [2]. The emerging trend for huge MIMO applications and inner microcells is for mm-Wave [3]. Due to advancements in antenna technology, microstrip patch antennas provide polarization diversity that helps mitigate the effects of signal attenuation and polarization mismatch in wireless and WIFI communication systems [4]. In the paper, a compact two-element microstrip patch antenna is presented that is operated in C-band. Due to the given operating frequency, the presented antenna can be easily used in satellite communication, WIFI, and wireless communications [5]. C-band includes a frequency range between 4 to 8 GHz which is known for its ability to penetrate clouds and rain, also useful for long-distance communication [6]. The compact size of the antenna allows it to be integrated into limited-space devices such as mobile phones [7].

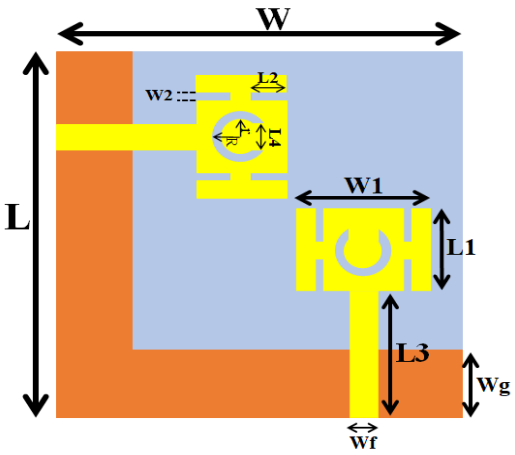
As wireless and Wi-Fi communication require higher gain and wide bandwidth and smart devices require less occupied space antenna [8]. The following key feature of the antenna makes it appropriate for the required application. So, the C-band frequency range has a nondegraded signal the antenna can be used in mountains and intense climate conditions [9]. It is an advanced universal wireless standard after 1G, 2G, 3G, and 4G. As in the Telecommunication industry, 5G is playing a vital role in advancement and technology building. 5G is a fundamental network in which the technologies are split into multiple domains called cells. All the domains within this network liaise by electromagnetic waves such as radio waves with a universal base station with the help of antennas. 5G networks help in many ways including wireless communication. Antennas are important components of the 5G domain subsystem that help in transferring and encountering electromagnetic waves [10]. 5G uses cutting-edge methods like

multiple-input multiple-output (MIMO) to boost capacity and expand coverage. These methods rely on groups of interconnected antennas that combine to produce and aim narrow beams of radio waves at users or locations [11-13].

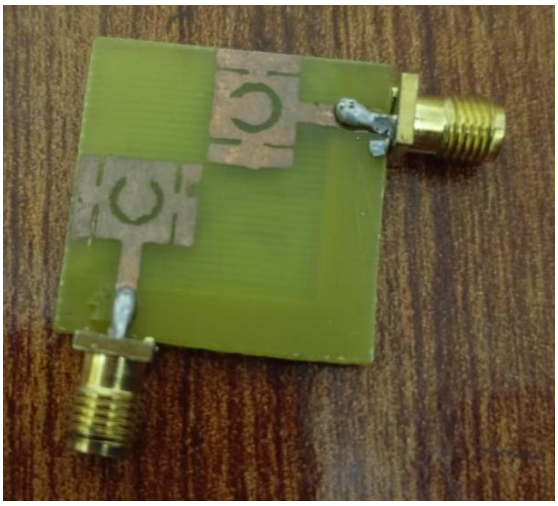
In this paper, first, we discuss the introduction of the antenna in section I. The introduction given in the paper contains the application of the C-band MIMO antennas. The design of an antenna is presented in section II and in section III, we discuss step-by-step design of the antenna as a parametric analysis. After that, we have a results and discussion section IV in which we discuss the performance of the antenna. In the next section, we compare our simulated results with fabricated results. In the end, we conclude that this antenna presents better than previous antenna, such as, efficiency, gain, and bandwidth.

II. Antenna Design

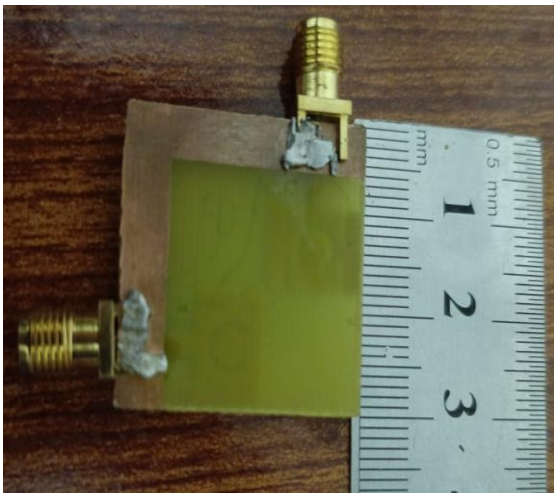
Compact MIMO antenna is printed at height of 0.8 mm on a dielectric FR4 substrate with a dielectric constant of 4.4. Because of its good electrical and mechanical qualities, ease of availability, and relatively inexpensive cost, the FR4 substrate is a popular choice for antenna design. The overall size of the substrate is 27×27 mm^2. The antenna consists of two patch elements with a common partial ground. Antenna element is fed from a 50Ω microstrip line to be operated for C-band applications [12]. The rectangular patch has a circular slot, and the end side of the patch contains two opposite stubs at both sides. Both the patch elements are perpendicular to achieve good isolation between two antenna elements and have a common partial ground to get wider bandwidth and high gain. The circular slot in the patch element is used for the directional radiation pattern that is required for long-distance communication. The dimensions of proposed MIMO antenna and a prototype are shown in Fig. 1. From Fig. 1 (a), yellow color is the radiator (patch), and the orange color shows the ground, as depicted in Fig. 1 (b) and Fig. 1 (c). Table I lists the MIMO antenna's final optimized dimensions.



(a) Simulated MIMO design



(b) Fabricated Top View



(c) Fabricated Rare View

Fig. 1 Perspective view of two element MIMO antenna design.

TABLE I. Values of Antenna Parameter.

Parameter	Value (mm)	Parameter	Value (mm)
W	27	L	27
Wf	1.53	Wg	4.9
W1	10.2	W2	0.6
R	2.3	R	1.55
L1	7	L2	2.75
L3	8	L4	2
Ws	22	Ls	14

III. Parametric Analysis

A. Step-01 Antenna:

In the first step, the antenna comprises of single rectangular patch with partial ground. A simple rectangular patch with two opposite slots that are added on left side of the rectangular patch where a slot is used to get the desired bandwidth. A 50-ohm impedance line is used to feed the antenna. Fig. 2(a) depicts the design of a single-element antenna.

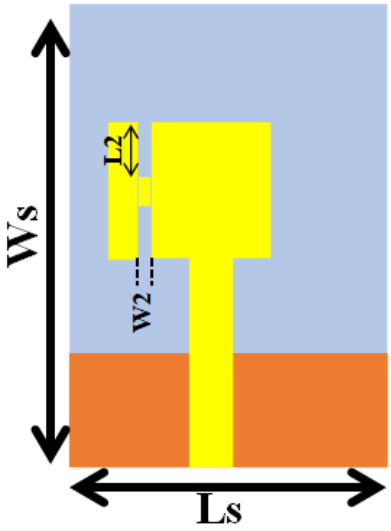
B. Step-02 Antenna:

In second step, the overall antenna is the same as in the previous setup, but it consists of two patches having the same dimension. The first simple MIMO antenna is indicated in Fig. 2(b) where results are discussed in the subsequent section.

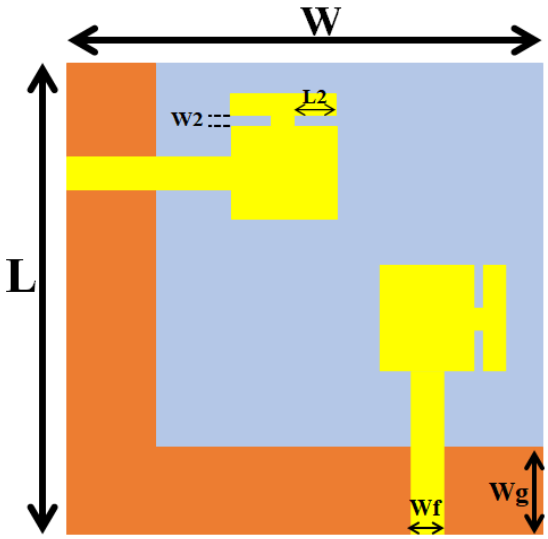
C. Step-03 Antenna:

In the next step, a rectangular stub is added on both sides of the antenna patch in the antenna element to get better antenna performance. This antenna has almost the same results as compared to a final antenna concerning bandwidth and return loss. The design of antenna is displayed in Fig. 2(c).

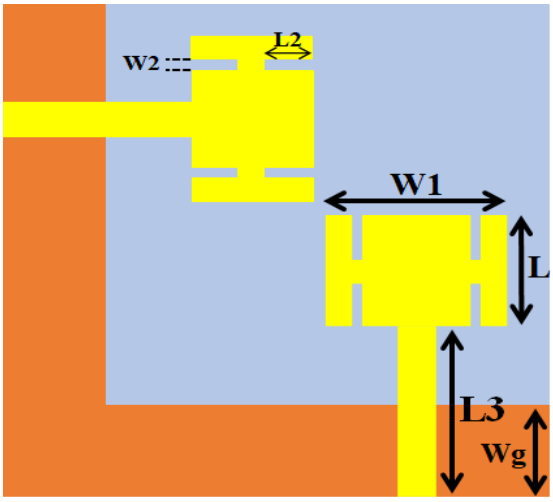
Final step (as shown in Fig. 1 (a)) has an additional band at 9.4 GHz which makes it useful for satellite and radar communication.



(a) Step-01



(b) Step-02



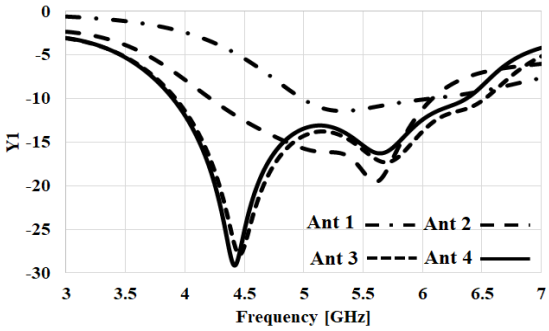
(c) Step-03

Fig. 2 Parametric Analysis of a proposed MIMO Antenna configuration.

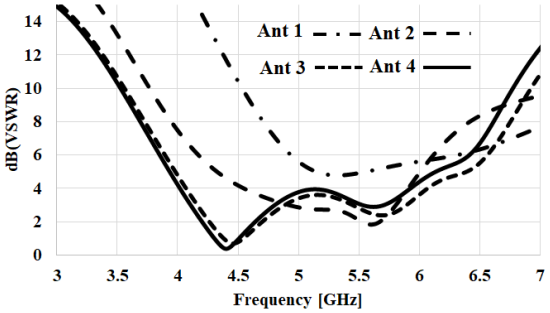
IV. Results and Discussion

D. S Parameters and VSWR

The S parameters graph shows that proposed antenna operates at C-Band frequency range, and proposed antenna operates at frequency of 4.42 GHz as shown in Fig. 3 (a). The S parameters show that as we change our antenna from step-01 to the final design results become better and more efficient. Proposed antenna has an overall bandwidth of 2.45 GHz. In addition, the proposed antenna outperforms the other three antennas with a return loss of -29.14 dB. Proposed compact MIMO antenna has low VSWR value, which is necessary for improved antenna performance. The antenna has a low value of VSWR which is about 0.38. The VSWR graph is shown in Fig. 3 (b). It indicates how much power is reflected in the antenna.



(a) Reflection Co-efficient of proposed MIMO

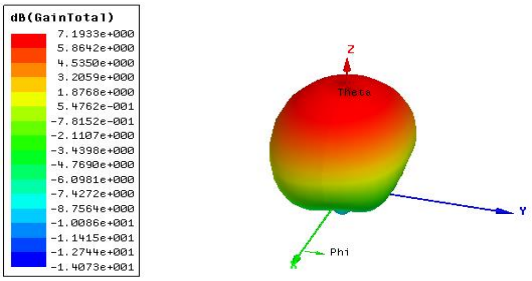


(b)VSWR of proposed MIMO

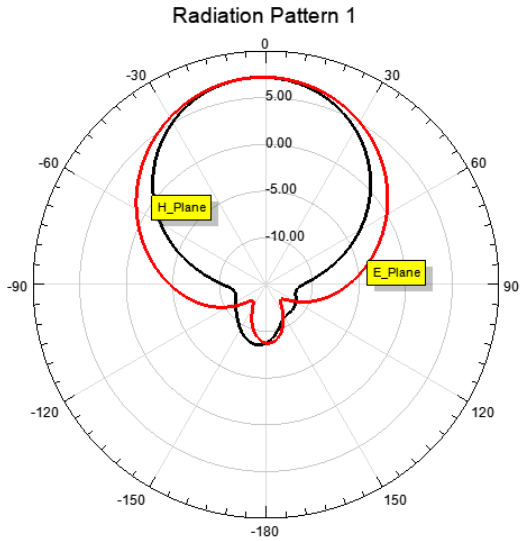
Fig. 3 S-parameters and VSWR of a proposed antenna in parametric analysis.

E. Gain

The proposed compact MIMO antenna has a peak gain of 7.19 dB at a frequency of 4.4 GHz. The antenna gain is a ratio of power received from an antenna in particular direction to power received from a reference antenna in the same direction. A higher antenna gain indicates that the antenna is more powerful at receiving signals in its direction. This is important in communication systems, such as Wi-Fi networks, where a higher gain helps to increase the range of the signal. In Fig. 4(a) and Fig. 4(b), the 3D gain and 2D E- & H-Planes of the proposed antenna are illustrated.



(a) 3D plot



(b) 2D radiation pattern

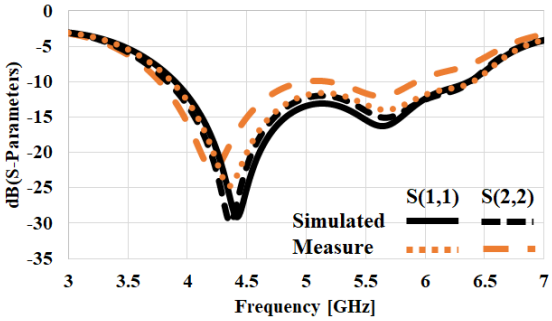
Fig. 4 The 2D and 3D radiation pattern of a proposed compact MIMO antenna at the resonance frequency of 4.4 GHz.

TABLE II. Comparison of proposed work with literature.

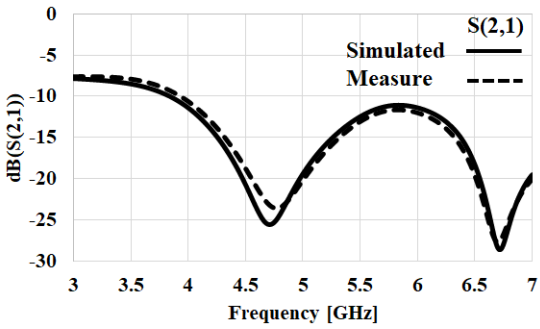
Ref. no.	Area (mm^2)	Ports	Bandwidth (MHz)	Gain (dBi)	Efficiency (%)	ECC (dB)
[9]	200 × 260	8	200	3.5	47 – 58	-----
[13]	30 × 30	2	1000	5.4	71	<0.02
[14]	50 × 60	4	3600	-----	-----	<0.04
[15]	38 × 38	4	700	4.4	-----	<0.025
[16]	35 × 50	2	2540	5.23	-----	<0.02
[17]	31.7 × 31.7	4	12000	2.0	60	<0.08
This work	27 × 27	2	2450	7.19	74	<0.015

F. Measured S-Parameters

The modeling and parametric analysis of the proposed antenna is simulated on HFSS 15. Fig. 5 (a) shows the S parameters graphs of simulated and measured results. We perceive that measured and simulated results closely resemble to each other, indicating a high standard of similarity between the two sets of information. We observe that in simulated results the overall antenna bandwidth is 2.45 GHz and in measured results, we have a bandwidth of almost 2.2 GHz in S (1,1) parameters. While in the next Fig. 5 (b), we have simulated and measured the results of S (2,1). The S (2,1) Graphs show that the antenna has good isolation between two elements in both simulation and measure. This shows that measured results have a good approximation of simulated results. The channel capacity loss (CCL) of a proposed two-port MIMO antenna design is shown in Fig. 6. CCL is less than 0.5 bits/s/Hz throughout desired band. The proposed design is further compared to the latest articles, and the proposed design shows a maximum bandwidth of 2450 MHz, which is good for the design purpose. From Table II, it is shown that proposed compact MIMO antenna has good bandwidth and gain in terms of antenna performance for their applications.



(a) Reflection co-efficient of MIMO



(b) Transmission co-efficient (Isolation) of MIMO

Fig. 5 Simulated and measured results of a proposed MIMO antenna design.

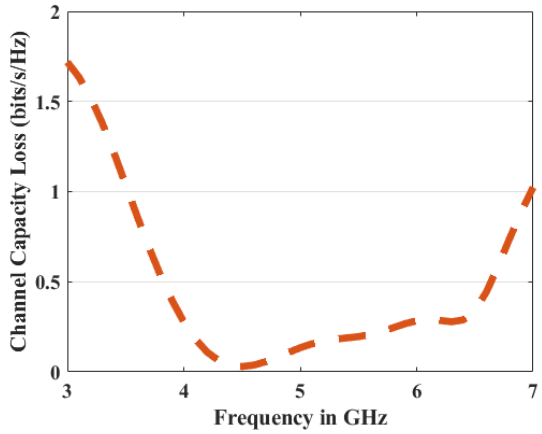


Fig. 6 The channel capacity loss of a proposed compact MIMO antenna.

V. CONCLUSION

This research paper presents a two-element patch antenna that is proposed for future-generation (n79, LTE-46/47) smartphones and other devices. The proposed compact MIMO antenna has higher gain of 7.19 dB which makes it suitable for long-range communication. Also, the antenna covers the C-band frequency range that is used for higher bandwidth and reduces interference. In parametric analysis, the antenna design is refined in three steps, gradually improving its performance. The final design of the antenna performs better concerning the required parameters. The antenna has an operating frequency of 4.42 GHz with 2.45 GHz bandwidth and 7.19 dB peak gain. The proposed antenna has a low value of VSWR which means a minimum amount of power is reflected to the transmission line and a higher proportion of transmitted power is effectively radiated by the antenna. In the end, the research paper shows that this antenna performs better than the previously designed antenna. In conclusion, the presented antenna is used for C-band (n79, LTE-46/47) applications.

REFERENCES

[1] J. -F. Lin, H. Deng and L. Zhu, "Design of Low-Profile Compact MIMO Antenna on a Single Radiating Patch Using Simple and Systematic Characteristic Modes Method," *in IEEE Transactions on Antennas and Propagation*, vol. 70, no. 3, pp. 1612-1622, March 2022.

[2] M. Shafi, A. F. Molisch, P. J. Smith, T. Haustein, P. Zhu, P. D. Silva, F. Tufvesson, A. Benjebbour, and G. Wunder, "5G: A Tutorial Overview of Standards, Trials, Challenges, Deployment, and Practice," in IEEE Journal on Selected Areas in Communications, vol. 35, no. 6, pp. 1201-1221, June 2017, doi: 10.1109/JSAC.2017.2692307.

[3] T. Li and Z. N. Chen, "Shared-Surface Dual-Band Antenna for 5G Applications," *in IEEE Transactions on Antennas and Propagation*, vol. 68, no. 2, pp. 1128-1133, Feb. 2020,

[4] I. T. McMichael, "A Mechanically Reconfigurable Patch Antenna With Polarization Diversity," *in IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 7, pp. 1186-1189, July 2018.

[5] Z. Zheng, J. Ntawangaheza and L. Sun, "Wideband MIMO Antenna System for Sub-6 GHz Cell Phone," *2021 International Conference on Electronics, Circuits and Information Engineering (ECIE)*, Zhengzhou, China, 2021, pp. 1-5.

[6] S. Sambhav and J. Ghosh, "A Compact Polarization Insensitive FSS based Absorber for S-band & C-band Applications," *2021 IEEE Indian* Conference *on Antennas and Propagation (InCAP)*, Jaipur, Rajasthan, India, India, 2021, pp. 710-712.

[7] Z. Chen, W. Hu, Y. Gao, L. Wen, C. Li, Z. Hu, W. Jiang, and S. Gao, "Compact Wideband Circularly Polarized Loop Antenna Based on Dual Common and Differential Modes," in *IEEE Antennas and Wireless Propagation Letters*, vol. 21, no. 8, pp. 1567-1571, Aug. 2022.

[8] X. -T. Wu, W. -J. Lu, J. Xu, K. F. Tong and H. -B. Zhu, "Loop-Monopole Composite Antenna for Dual-Band Wireless Communications," *in IEEE Antennas and Wireless Propagation Letters*, vol. 14, pp. 293-296, 2015.

[9] Y. Li, W. -S. Chen, Y. -T. Liu and H. -T. Chen, "Printed MIMO antennas for 5G C-band for laptop computer applications," *2021 International Symposium on Antennas and Propagation (ISAP)*, Taipei, Taiwan, 2021, pp. 1-2, doi: 10.23919/ISAP47258.2021.9614449.

[10] J. Colaco and R. Lohani, "Design and Implementation of Microstrip Patch Antenna for 5G applications," 2020 5th International Conference on Communication and Electronics Systems (ICCES), Coimbatore, India, 2020, pp. 682-685, doi: 10.1109/ICCES48766.2020.9137921.

[11] Singh, Ghanshyam, et al. "Design and implementation of a compact tri-band four-port multiple-input-multiple-output antenna." *International Journal of RF and Microwave Computer-Aided Engineering* 32.8 (2022): e23218.

[12] J. Banerjee, S. Bhattacharya, A. Choudhury, A. Biswas, R. Paul, A. Dutta, R. Ghatak, "An Orthogonally Oriented Multiband MIMO Antenna for WLAN, C-Band, and X-Band Wireless Applications," 2020 IEEE Calcutta Conference (CALCON), Kolkata, India, 2020, pp. 328-332, doi: 10.1109/CALCON49167.2020.9106497.

[13] M. A. Arshad, M. Zahid, Y. Amin and S. S. Jaffer, "MIMO Antenna for C-band Applications," 2023 International Multi-disciplinary Conference in Emerging Research Trends (IMCERT), Karachi, Pakistan, 2023, pp. 1-5, doi: 10.1109/IMCERT57083.2023.10075193.

[14] P. Jain and S. Ghosh, "A Reconfigurable Four-Port MIMO Antenna for Sub-6 GHz Applications," 2022 IEEE Wireless Antenna and Microwave Symposium (WAMS), 2022, pp. 1-5, doi: 10.1109/WAMS54719.2022.9847798.

[15] T. Pan and Y. Sun, "A Dual-Band Compact Four-Element MIMO Antenna for Sub-6G Applications," 2021 International Conference on Microwave and Millimetre Wave Technology (ICMMT), 2021, pp. 1-3, doi: 10.1109/ICMMT52847.2021.9618065.

[16] Alsharari, M.; Lavadiya, S.; Aliqab, K.; Armghan, A.; Daher, M.G.; Patel, S.K. A Novel Design of Complementary Split Ring Resonator Metamaterial-Based Low-Profile MIMO Antenna with Defected Ground Structure for S/C/X/Ka Band Applications. *Micromachines* 2023, *14*, 1232.https://doi.org/10.3390/mi14061232.

[17] Mistri, R.K.; Mahto, S.K.; Singh, A.K.; Sinha, R.; Al-Gburi, A.J.A.; Alghamdi, T.A.H.; Alathbah, M. Quad Element MIMO Antenna for C, X, Ku, and Ka-Band Applications. Sensors 2023, 23, 8563. https://doi.org/10.3390/s23208563.