ISSN: 2093-5374 / E-ISSN: 2093-5382

Development and Implementation of Wideband Elliptical Ring Microstrip Antennas for 5G and X-Band Use

Dr. Ranya M. Dawood[1*], Dr. Raed M. Shaaban[2], Dr. Ra'ed Malallah[3], and Zeki A. Ahmed[4]

[1*]Department of Physics, College of Science, University of Basrah, Basrah, 61004, Iraq.
ranya.mouslem@uobasrah.edu.iq, https://orcid.org/0009-0001-0486-0521

[2]Department of Physics, College of Science, University of Basrah, Basrah, 61004, Iraq.
read.shaaban@uobasrah.edu.iq, https://orcid.org/0000-0001-6250-9935

[3]School of Electrical and Electronic Engineering, University College Dublin, Ireland.
raed.malallah@mu.ie, r.malallah73@gmail.com, https://orcid.org/0000-0003-1268-780X

[4]Iraq University College, Basrah, 61004, Iraq.
zeki.ahmed@uobasrah.edu.iq, https://orcid.org/0000-0002-1065-0328

Received: October 23, 2024; Revised: December 10, 2024; Accepted: January 13, 2025; Published: March 31, 2025

Abstract

This study introduces an innovative design of a microstrip antenna with an elliptical ring patch, specifically designed for usage in the 5G and X-band frequencies. The antenna consists of four pairs of elliptical rings of different diameters, with each pair consisting of two elliptical rings that are perpendicular to each other. The design was modeled with the help of the Ansoft High Frequency Structure Simulator (HFSS). Analysed metrics included density of electric surface current, return loss, VSWR, bandwidth, and patterns of radiation. The antenna being suggested demonstrates dual-band capabilities, with the ability to resonate at two distinct frequencies. The modelling findings show that there are resonance peaks at 4.3 GHz and 10.39 GHz, with bandwidths of 2.726 GHz and 1.60 GHz, respectively. The measurement findings indicate resonance frequencies of 4.49 GHz and 9.71 GHz, with corresponding bandwidths of 2.998 GHz and 2.542 GHz, respectively. This antenna design is appropriate for a variety of 5G and X-band frequency bands and applications.

Keywords: Microstrip, Band Width, Dual-Band, 5g, X-Band.

1 Introduction

Wireless communication is essential in modern society, encompassing a variety of applications such as remotely automated and robot-controlled machines, the Internet of Things (IoT) and it's a wide range of applications, reliable and efficient remote communication, intelligent grid systems for energy distribution and transmission, smart home HDTV, and digital financial systems. These technologies significantly enhance human life (Bahmanzadeh & Mohajeri, 2021; Agarwal et al., 2021; Yi et al., 2023). The fifth generation (5G) network aims to exponentially increase communication capacity by utilizing the millimeter wave band, supporting data speeds up to 100 times higher than those of fourth-generation networks (Nasimuddin, 2007; Saleh et al., 2023; Prabha & Gayathri, 2014).

Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications (JoWUA), volume: 16, number: 1 (March), pp. 121-133. DOI: *10.58346/JOWUA.2025.I1.007*

*Corresponding author: Department of Physics, College of Science, University of Basrah, Basrah, 61004, Iraq.

The International Telecommunication Union (ITU) has described the 5G communication spectrum as consisting of two parts: the sub-6 GHz spectrum, often known as the 5G mid-band, and the millimeter-wave (mmWave) spectrum. The Federal Communications Commission (FCC) has proposed particular frequency bands within the (mm Wave) spectrum, including 24 GHz, 28 GHz, 37–39 GHz, and 60 GHz, to be used for 5G connectivity (Maity & Nayak, 2021; Hossain et al., 2023). Nevertheless, these proposed spectra have intrinsic obstacles and constraints that might affect the performance of the network (Ai et al., 2020; Shum, 2024). In order to tackle these problems, The International Telecommunication Union (ITU) has designated the 5G mid-band specifically for broadband wireless communication systems. This allocation allows for wider coverage and less propagation losses (Muralidharan, 2024).

To meet 5G requirements, antennas must be compact (low profile) low-cost, easy to install, lightweight and adaptable to non-planar and planar surfaces and (Miranda & De Mendonca, 2021; Salih & Nangir, 2024). Microstrip patch antennas (MPAs) are capable of meeting these requirements, despite their narrow bandwidth (Singh, & Paras, 2021; Srinivasan et al., 2024). Microstrip Patch Antennas (MPAs) generally consist of three main components: a conductive ground plane, a dielectric layer situated above the ground plane, and radiating elements placed on the opposite side of the dielectric layer (Wa’il et al., 2019; Malallah et al., 2020).

Designing an antenna with multiple functionalities in a single structure presents a significant challenge for antenna designers (Kim, 2020; Hossain, et al., 2023; Preethi et al., 2023). The growing demand for versatile antennas in wireless communication has spurred extensive research in this field. Traditionally, wireless systems were designed to cater to a broad range of applications, offering enhanced performance and more stable connections (Maseleno, 2019; Shokri et al., 2014).

This article proposes, simulates, and fabricates a novel design antenna with a microstrip patch (MPA) for dual-band applications, based on an elliptical ring patch design (Mathur & Arrawatia, 2020; Tumah et al., 2022). This compact structure provides significantly improved performance compared to traditional elliptical MPAs while maintaining a smaller effective patch area. The dual-band capabilities of the proposed antenna's design render it appropriate for use various applications, including 5G and X-band, such as mobile communications, industrial applications, satellite communications, radar systems, military and defense, and remote sensing and earth observation (Yi et al, 2023).

(Shaaban et al., 2024) and colleagues shows the design of a novel circularly polarized microstrip phased array antenna for 5G communication applications (Wang et al., 2023; Soh & Keljovic, 2024). This paper discusses how the phased array attains the high performance that would meet the requirements of beam steering, bandwidth, and circular polarization that are required in 5G hence meeting its high data rate and low latency (Alnedawe et al., 2023; Koteshwaramma et al., 2022) [7] [19]. The design achieves high gain, and low levels of cross-pol, thus making the antenna appropriate for present day communication systems, especially where density is high such as in urban areas.This work follows the advanced studies made in Raed (Ghazi, 2019) on slot-integrated patches to enhance the efficiency and performance of microstrip antennas(Fareed et al., 2020) in terms of beam steering, wide bandwidth, and circular polarization, which are crucial for 5G's high data rate and low latency demands. The design optimizes antenna parameters to enhance gain and reduce cross-polarization, making it highly suitable for modern communication networks, particularly in dense urban environments (Madhusudhana Rao et al., 2021).

This research is an extension to Raed (Ghazi, 2019) which explores innovative slot-integrated patch designs aimed at improving the efficiency and performance of microstrip antennas. The study focuses on the major problems such as increase of bandwidth for the ever-deteriorating channel and improvement of the radiation efficiency that is integral in most modern wireless communication systems. Introducing new slot configurations, the authors show significant enhancements of the antenna characteristics to be highly suitable for 5G, IoT, as well as for the more sophisticated radar applications.

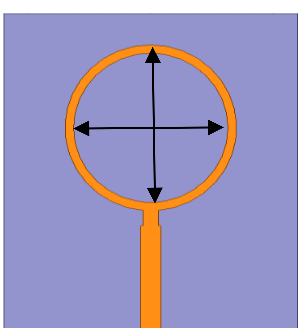
Mode Division Multiplexing (MDM) in Free Space Optical (FSO) systems has shown promise in enhancing data transmission capacity and resilience under varying conditions. Using Laguerre-Gaussian (LG) modes, an 8-channel MDM-FSO system at 1550 nm achieved 40 Gbps over 3000 meters in clear weather and reliable performance at 650 meters in heavy rain. Improved Bit Error Rate (BER) and favorable eye diagram results validate its suitability for 5G, IoT, and other advanced communication systems, addressing the need for efficient, weather-resilient technologies (Al-Dawoodi et al., 2019; Almusawi et al., 2024).

The integration of advanced communication technologies, such as 5G and X-band systems, demands efficient and adaptable solutions to enhance performance in diverse environments. Autonomous vehicles (AVs), reliant on robust wireless communication, require antennas capable of supporting dual-band functionality for seamless data transmission and control. Studies show that optimizing antenna designs, such as elliptical ring microstrip antennas, can significantly enhance communication reliability in urban traffic systems by minimizing delays and improving connectivity, especially in scenarios involving mixed AV behaviors. This underscores the critical role of antenna innovation in advancing 5G and X-band applications for intelligent transportation systems (Albdairi & Almusawi, 2024; Kasabegoudar et al., 2007).

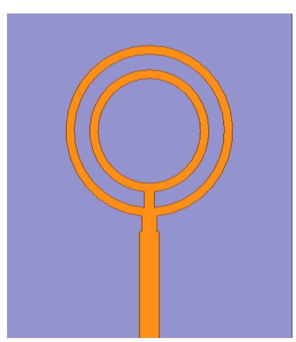
2 Antenna Design

The choice of radiating patch shape significantly impacts antenna performance by affecting the surface currents distributions, the frequency operation range that may be accommodated (bandwidth), the optimisation of impedance to ensure efficient power transfer, and the pattern in which electromagnetic radiation is emitted (Yi et al., 2023). Various patch antenna designs are explored to enhance these performance metrics. This article presents efficient and simple design to achieve dual-band and wide-bandwidth results.

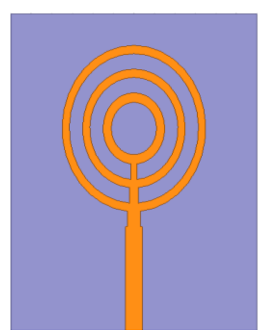
The proposed antenna design utilizes a simple elliptical ring patch (ERPA), as illustrated in Figure 1(a). Additional ERPAs are incorporated within the primary patch, with direct feeding from a strip line in the configurations illustrated in Figure 1(c) and Figure 1(b). In Figure 1(d), an ERPA with a smaller diameter is added inside the patch with indirect feeding. Finally, in Figure 1(e), the same patch from Figure 1(d) is rotated by 90 degrees, resulting in a perpendicular configuration with four ERPAs. The layout was modeled with the help of the Ansoft High Frequency Structure Simulator (HFSS).



a



b



c

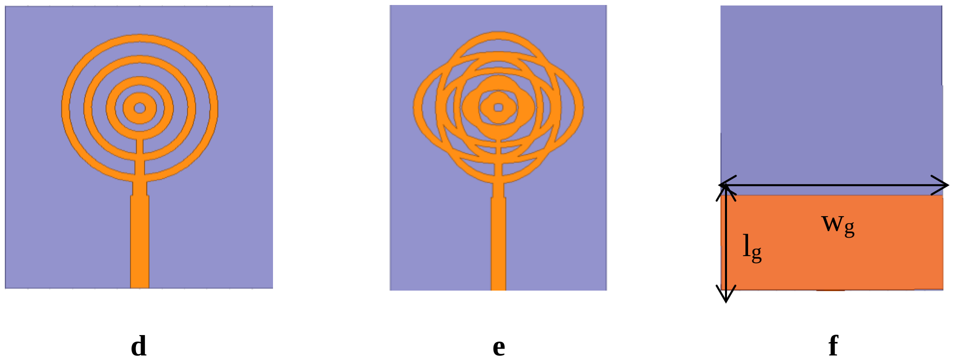


Figure 1: Stages in the Development of the Proposed Design of the Antenna

The antenna design illustrated in Figure 1(e) was chosen as the most favourable design based on its calculated results for return loss and radiation pattern, which will be investigated in the proceeding section. HFSS software was utilised for the optimisation of the antenna size and conduct parameter tests in order to attain optimal performance, as shown in Figure 2. The ideal configuration was constructed using a cost-efficient FR4_epoxy sublayer with A dielectric coefficient of $\varepsilon\_r = 4.4$. The dielectric substrate is 36.0 x 24.0 × 1.6 mm³.

The outer elliptical ring patch antenna (ERPA) has major and minor axes dimensions of rv1 = 7 mm and rh1 = 5.18 mm, respectively, with varying ERPA widths. The ground plane area is 11.83 × 24.0 mm². The best input impedance (50 ohms) for the proposed antenna was achieved using a tapered microstrip line, as seen in Figure 1(e). Table 1 lists the related parameters' dimensions of the optimized antenna design.

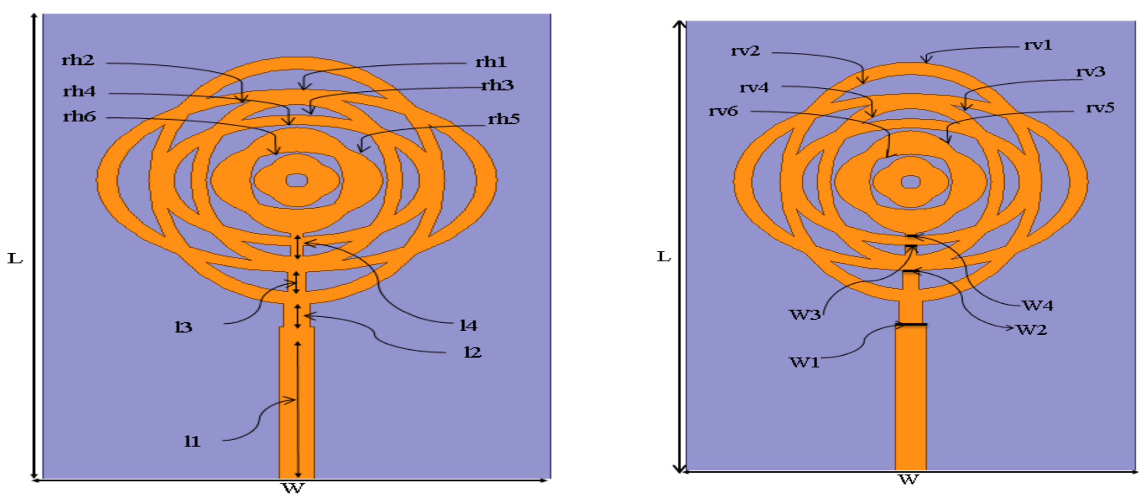
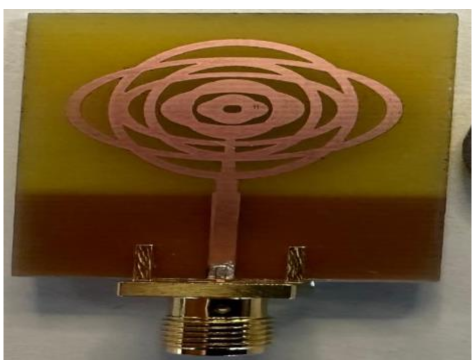


Figure 2: The Optimum Antenna Design Geometric Parameters

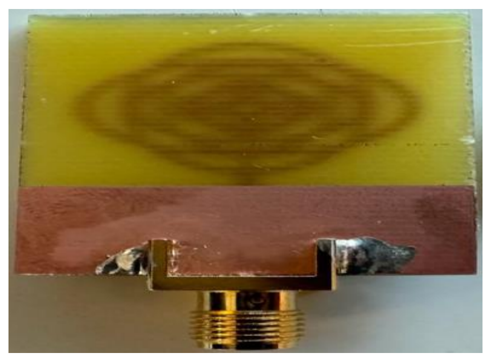
Table 1**:** The Optimum Antenna Design Parameters Dimensions

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
L	36	l_g	11.83
W	24	w_g	24
rv1	7	rh1	7
rv2	6.3	rh2	6.3
rv3	5	rh3	5
rv4	4.3	rv4	4.3
rvo	3	rho	3
rvi	2.2	rhi	2.2
rv	1.5	rh5	1.5
rv6	0.5	rh6	0.5
w1	1.6	l1	11.83
w2	1.2	l2	2
w3	0.8	l3	2.5
w4	0.6	l4	3.5

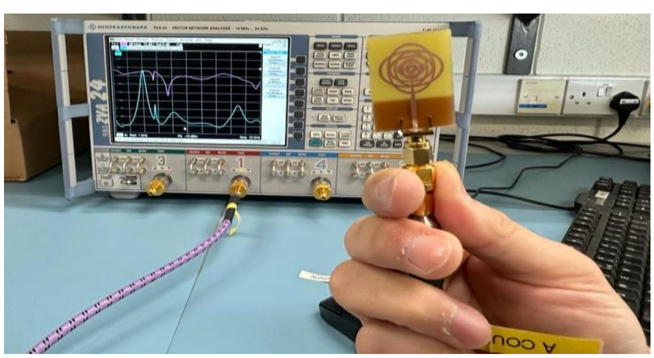
The constructed antenna is linked by means of a cable and positioned within a noise-free chamber for the purpose of measuring distant-field radiation. As seen in Figure 3, in order to assess the S11 (dB) and VSWR plots, the constructed prototype is linked to a vector network analyser (VNA).



a



b



c

Figure 3: (a) Top View (b) Bottom view, and (c) Measurement Setup of the Constructed Prototype

3 Results and Discussion

To save space and achieve dual-band functionality, the design in Figure 1(e) was simulated instead of using multiple antennas. This suggested antenna has been simulated, fabricated and designed to operate in the 5G and X-band frequencies. A compact microstrip patch antenna (MPA) design was achieved by introducing the elliptical ring patch antenna (ERPA), which includes three rings of different diameters, each pair perpendicular to the other, as illustrated in Figure 2. The surface currents achieve proper phase reversal when the diameters of the ERPA and the spacing between them are appropriately sized. To obtain the desired radiation patterns at relevant frequencies, the phase reversal in surface currents must be carefully selected. The performance of the fabricated antenna was enhanced as a result of the optimisation of the return loss of the simulated results. Embedding ERPA modifies the path of the surface current, leading to enhanced impedance alignment.

The new designed antenna was crafted and analysed using Ansoft HFSS on a budget-friendly FR4 sublayer with a dielectric coefficient of $\varepsilon_r = 4.4$. The substrate measures 36.0 × 24.0 × 1.6 mm and is coupled with a tapered strip line operating at 50 ohms, as illustrated in Figure 3. Table 1 depicts details of the dimensions of the proposed design of the antenna.

Figure 4 presents the calculated return loss of the designed antennas shown in Figure 1. This figure demonstrates that the optimum design provides the best reflection coefficient results. Consequently, the constructed antenna in Figure 1(e) is chosen as the best design. The optimum antenna exhibits dual-band performance at resonances of 4.3 GHz and 10.39 GHz.

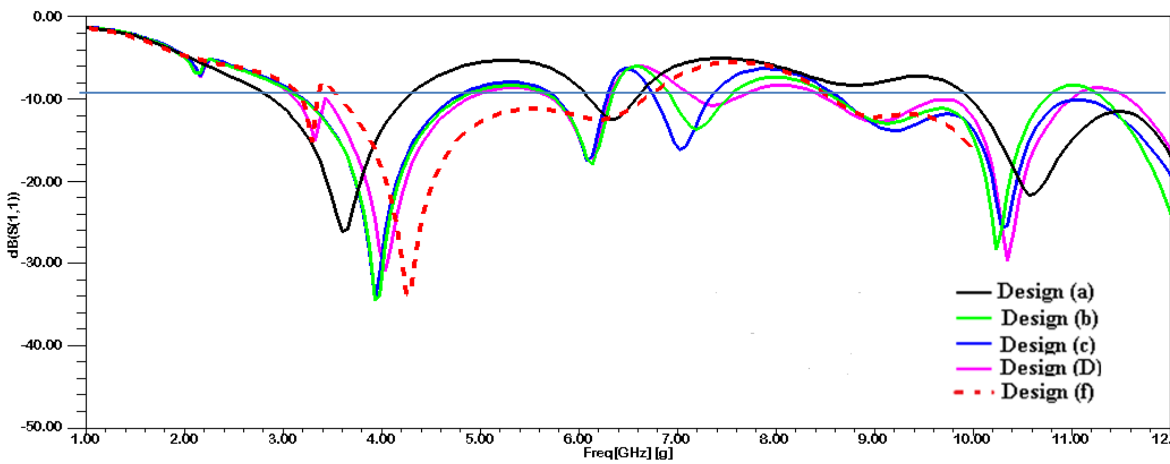


Figure 4: The Calculated Results of The Return Loss of The Constructed Antenna Seen in Figure 1

Figure 5 illustrates the calculated outcomes of the VSWR for the optimal antenna design. The figure shows a dual-band response with resonance frequencies at 4.3 GHz and 10.39 GHz, corresponding to VSWR values of 1.047 and 1.059, respectively. These dual bands fall within the 5G and X-band frequency ranges, making the proposed antenna suitable for the desired applications. These applications involve both satellite communications and swift wireless communications in the mid-band frequencies of 5G

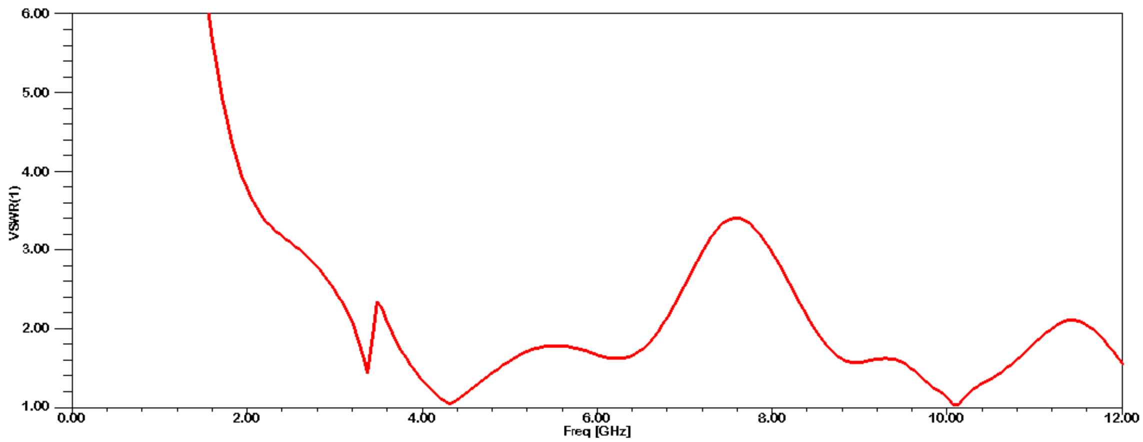


Figure 5: VSWR Simulation Finding of the Suggested Antenna (design e)

Figure 6 illustrates the strong correlation between the theoretical and experimental results for the return loss values of the fabricated antenna. The small variations observed can be due to the effects of soldering used in the SMA connector, which are not typically accounted for in simulations. The measured data reveal dual-band performance, with impedance bandwidths of 2.726 GHz (ranging from 3.948 to 6.674 GHz) and 1.600 GHz, corresponding to the characteristic frequencies of 4.49 GHz and 9.71 GHz, correspondingly.

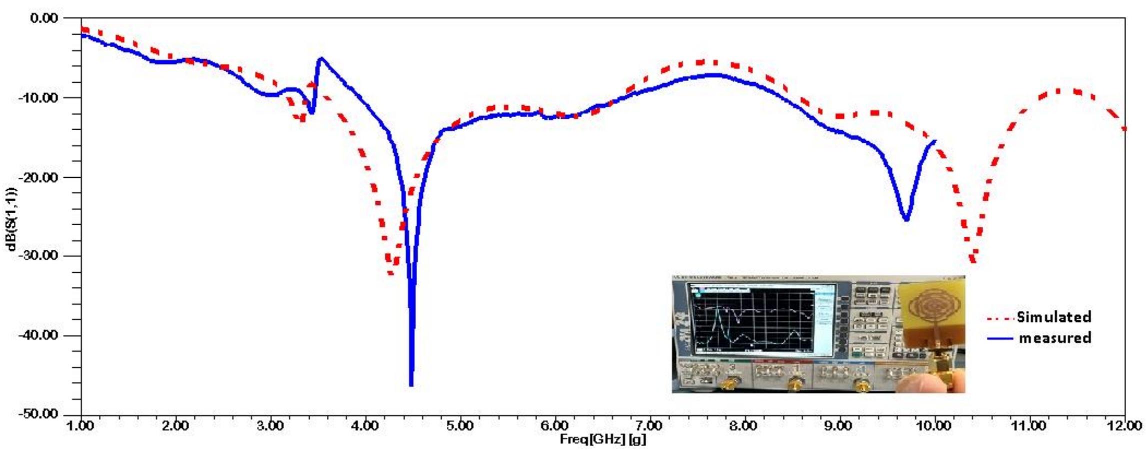
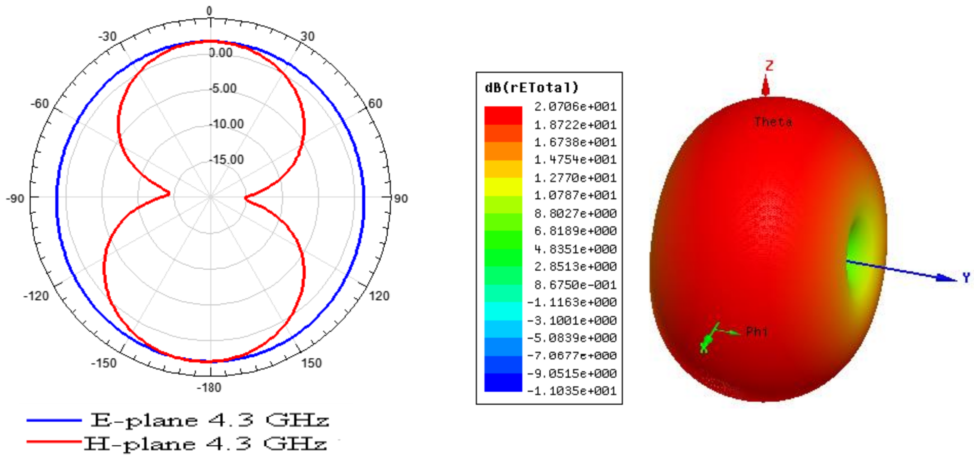
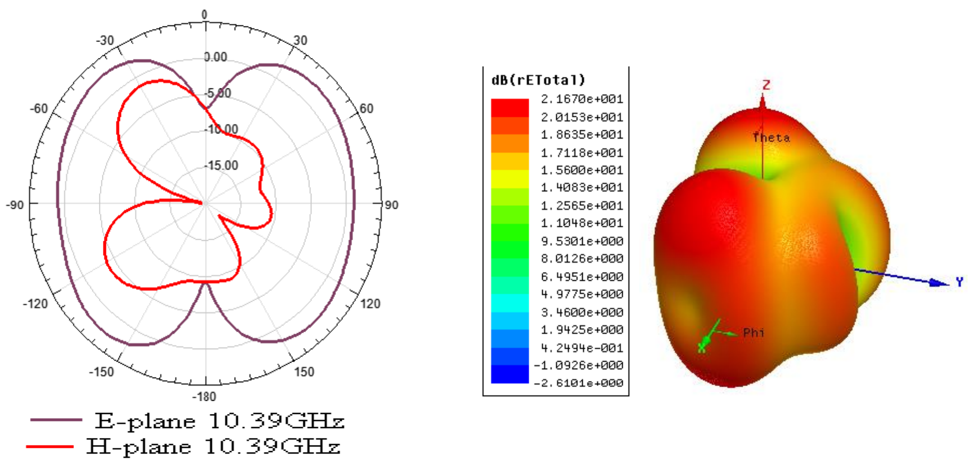


Figure 6: The Measured and Calculated of the Return Loss for the Recommended Antenna

Figure 7 displays the modelled radiation patterns of the optimal antenna design (design e) with resonances of 4.3 GHz and 10.39 GHz. These patterns are shown in both the H- and E-planes, as well as in three dimensions. The maximum radiation is observed in the broadside direction for all patterns. At 4.3 GHz, the E-plane pattern is omnidirectional, while the H-plane pattern is dumbbell-shaped, indicating an omnidirectional radiation coverage. At 10.39 GHz, the recommended antenna shows an E-Plane directional pattern and a H-Plane bi-directional pattern. The current density is unevenly distributed on the radiating patch, leading to electromagnetic interference at this frequency.



a

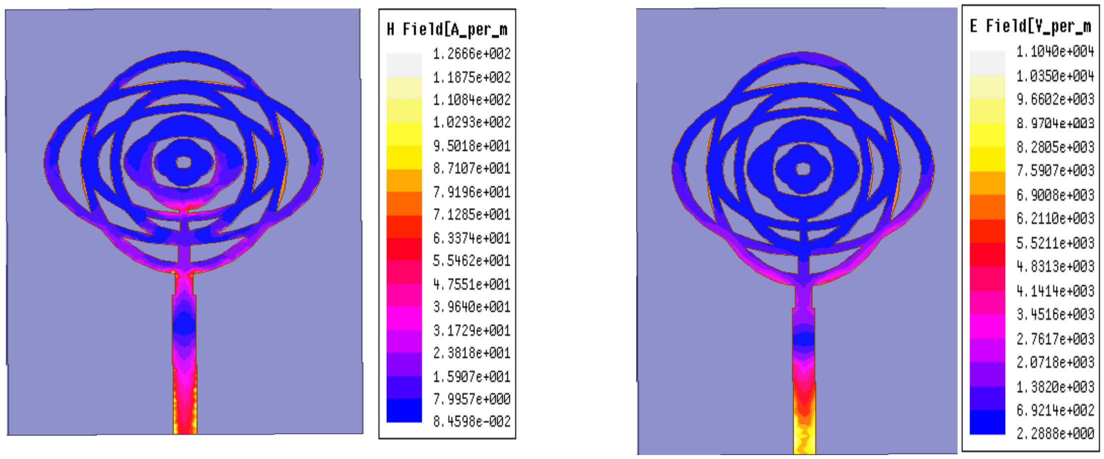


b

Figure 7: Simulated Results of Radiation Patterns of ERPA Antenna (e) in Two and Three Dimensions at (a) 4.3 GHz (b) 10.39GHz

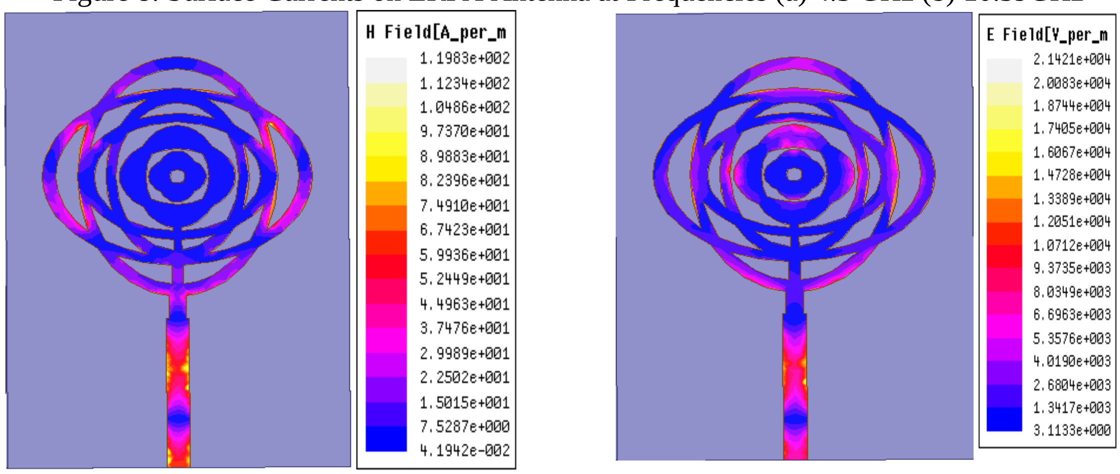
The layout patterns of surface currents for the fabricated antenna are illustrated in Figure 8. At 4.3 GHz (Figure 8a), surface current is predominantly induced along the lower edge of the ERPA and the tapered strip line. At 10.39 GHz (Figure 8b), the current is distributed across each elliptical ring of the antenna.

Figure 9(a) and 9(b) show the magnetic and electric field distributions on the ERPA at resonant frequencies of 4.3 GHz and 10.39 GHz. The variations in the electric and magnetic fields lead to surface currents as depicted in the figure. The fields validate the surface current distribution. where currents are in phase at certain edges of the ERPA, resulting in maximum radiation, and out of phase at other edges, leading to minimum radiation.



A

Figure 8: Surface Currents on ERPA Antenna at Frequencies (a) 4.3 GHz (b) 10.39GHz



b

Figure 9: E and H Fields on the Patch of ERPA Antenna at (a) 4.3 GHz, (b) 10.39GHz

4 Conclusions

This paper introduces the ERPA-loaded elliptical ring antenna, designed for 5G and X-band applications. With a compact volume of 36.0 × 24.0 × 1.6 mm³, the proposed antenna demonstrates simulation and measurement impedance bandwidths of 3.075 GHz and 2.542 GHz, and 2.745 GHz and 1.600 GHz, respectively, along with a directional radiation pattern. The elliptical ring patch design achieves dual-band performance with a return loss value below -10 dB. Experimental results confirm the dual-band feature and performance predicted by simulations. The proposed antenna is ideal for enhanced mobile broadband, the Internet of Things (IoT), virtual reality, and high-definition video streaming, satellite communications, radar systems, military and defense applications, and more.

References

[1] Agarwal, M., Dhanoa, J. K., & Khandelwal, M. K. (2021). Two-port hexagon shaped MIMO microstrip antenna for UWB applications integrated with double stop bands for WiMax and WLAN. *AEU-International Journal of Electronics and Communications*, *138*, 153885. https://doi.org/10.1016/j.aeue.2021.153885

[2] Ai, H., Wu, C., & Zhou, S. (2020, November). Design and simulation of rectangular microstrip patch antenna with 5Gmm-wave coaxial line back-feed and microstrip line side-feeds. In *2020 5th International Conference on Information Science, Computer Technology and Transportation (ISCTT)* (pp. 179-182). IEEE. https://doi.org/10.1109/ISCTT51595.2020.00039

[3] Albdairi, M., & Almusawi, A. (2024). Examining the Influence of Autonomous Vehicle Behaviors on Travel Times and Vehicle Arrivals: A Comparative Study Across Different Simulation Durations on the Kirkuk-Sulaymaniyah Highway. *International Journal of Automotive Science and Technology*, *8*(3), 341-353. https://doi.org/10.30939/ijastech.1480916

[4] Al-Dawoodi, A. R. A. S., Maraha, H. E. Y. A. M., Alshwani, S. A. R. A., Ghazi, A., Fakhrudeen, A. M., Aljunid, S., ... & Ameen, K. A. (2019). Investigation of 8 x 5 Gb/s mode division multiplexing-fso system under different weather condition. *Journal of Engineering Science and Technology*, *14*(2), 674-681.

[5] Almusawi, A., Albdairi, M., & Qadri, S. S. S. M. (2024). Integrating Autonomous Vehicles (AVs) into Urban Traffic: Simulating Driving and Signal Control. *Applied Sciences*, *14*(19), 8851. https://doi.org/10.3390/app14198851

[6] Alnedawe, B. M., Ibraheem, W. E., & Al-Abbasi, Z. Q. (2023). Modelling and Compensation of SIC Imperfection in IRS-NOMA based 5G-System. *Journal of Internet Services and Information Security*, *13*(3), 31-40. https://doi.org/10.58346/JISIS.2023.I3.003

[7] Bahmanzadeh, F., & Mohajeri, F. (2021). Simulation and fabrication of a high-isolation very compact MIMO antenna for ultra-wide band applications with dual band-notched characteristics. *AEU-International Journal of Electronics and Communications*, *128*, 153505. https://doi.org/10.1016/j.aeue.2020.153505

[8] Chen, C. (2023). A Single-Layer Single-Patch Dual-Polarized High-Gain Cross-Shaped Microstrip Patch Antenna. *IEEE Antennas and Wireless Propagation Letters*, *22*(10), 2417-2421. https://doi.org/10.1109/LAWP.2023.3289861

[9] Chen, Q., Zhang, H., Zhang, X., Jin, M., & Wang, W. (2018, August). An X Band Dual-polarized Shared Aperture Antenna Using Waveguide and Microstrip Antennas. In *2018 IEEE Asia-Pacific Conference on Antennas and Propagation (APCAP)* (pp. 106-107). IEEE. https://doi.org/10.1109/APCAP.2018.8538018

[10] Fareed, A., Ghazi, A., Al-Dawoodi, A., Aljunid, S. A., Idrus, S. Z. S., Rashidi, C. B. M., ... & Fadhel, I. E. I. (2020, January). Comparison of Laguerre-Gaussian, Hermite–Gaussian and linearly polarized modes in SDM over FMF with electrical nonlinear equalizer. In *AIP Conference Proceedings* (Vol. 2203, No. 1). AIP Publishing.

[11] Ghazi, A., Aljunid, S. A., Noori, A., Idrus, S. Z. S., Rashidi, C. B. M., & Al-Dawoodi, A. (2019). Design & investigation of 10x10 gbit/s MDM over hybrid FSO link under different weather conditions and fiber to the home. *Bulletin of Electrical Engineering and Informatics*, *8*(1), 121-126. https://doi.org/10.11591/eei.v8i1.1398

[12] Hossain, Md. M., & Hossam-E-Haider, M. (2023). Design and optimization of x-band microstrip array antenna using both-sided microwave integrated circuit (Mic) for gain enhancement. *2023 International Conference on Information and Communication Technology for Sustainable Development (ICICT4SD)*, 398–401. https://doi.org/10.1109/ICICT4SD59951.2023.10303431

[13] Hozen, T., Saito, S., & Kimura, Y. (2021, January). Measurement of a microstrip antenna array fed by longitudinal slots on a narrow wall of the rectangular waveguide with standing-wave excitation for linear polarization perpendicular to the axis. In *2020 International Symposium on Antennas and Propagation (ISAP)* (pp. 433-434). IEEE. https://doi.org/10.23919/ISAP47053.2021.9391513

[14] Kasabegoudar, V. G., Upadhyay, D. S., & Vinoy, K. J. (2007). Design studies of ultra-wideband microstrip antennas with a small capacitive feed. *International Journal of Antennas and Propagation*, *2007*(1), 067503. https://doi.org/10.1155/2007/67503

[15] Kim, H. (2020). 5G core network security issues and attack classification from network protocol perspective. *Journal of Internet Services and Information Security*, *10*(2), 1-15.

[16] Koteshwaramma, K. C., Vijay, V., Bindusree, V., Kotamraju, S. I., Spandhana, Y., Reddy, B. V. D., Charan, A. S., Pittala, C. S., & Vallabhuni, R. R. (2022). ASIC Implementation of an Effective Reversible R2B FFT for 5G Technology Using Reversible Logic. *Journal of VLSI Circuits and Systems*, *4*(2), 5–13. https://doi.org/10.31838/jvcs/04.02.02

[17] Madhusudhana Rao, K., Kishore, M. N. D., Yogesh, M. P., Saheb, S. K. A., & Hemanth, K. (2021). Triple frequency microstrip patch antenna using ground slot technique. *National Journal of Antennas and Propagation*, *3*(2), 1–5.

[18] Maity, B., & Nayak, S. K. (2021, October). A high gain narrowband microstrip antenna array for wireless applications. In *2021 International Symposium on Antennas and Propagation (ISAP)* (pp. 1-2). IEEE. https://doi.org/10.23919/ISAP47258.2021.9614559

[19] Malallah, R. E., Shaaban, R. M., & Wa'il, A. (2020). A dual band star-shaped fractal slot antenna: Design and measurement. *AEU-International Journal of Electronics and Communications*, *127*, 153473. https://doi.org/10.1016/j.aeue.2020.153473

[20] Maseleno, A. (2019). Wideband Rectangular Patch Antenna with DGS For X Band Applications. *National Journal of Antennas and Propagation*, *1*(1), 25-28. https://doi.org/10.31838/NJAP/01.01.07

[21] Mathur, P., & Arrawatia, M. (2020, July). High gain series fed planar microstrip antenna array using printed l—probe feed. In *2020 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting* (pp. 589-590). IEEE. https://doi.org/10.1109/IEEECONF35879.2020.9329574

[22] Miranda, A. K., & de Mendonça, L. M. (2021, August). Analysis and Simulation of the Effects of Superstate Layer on the Performance of Microstrip Antennas. In *2021 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC)* (pp. 193-196). IEEE. https://doi.org/10.1109/APWC52648.2021.9539779

[23] Muralidharan, J. (2024). Advancements in 5G technology: Challenges and opportunities in communication networks. *Progress in Electronics and Communication Engineering*, *1*(1), 1–6. https://doi.org/10.31838/PECE/01.01.01

[24] Nasimuddin, N. (2007). Design of wideband circularly polarized stacked microstrip antennas with dielectric cover using single coaxial feed. *Microwave and Optical Technology Letters*, *49*(12), 3027-3033. https://doi.org/10.1002/mop.22937

[25] Prabha, I. M. T., & Gayathri, R. (2014). Isolation Enhancement in Microstrip Antenna Arrays. *International Journal of communication and computer Technologies*, *2*(2), 79-84. https://doi.org/10.31838/IJCCTS/02.02.02

[26] Preethi, V., Swamalatha, P., Rajpoot, V., Krishna, R. V. V., & Kumar, S. (2023, June). Design and Implementation of Circular Microstrip Patch Array Antenna for 5G Communication Using Rogers RT5880. In *2023 International Conference on Advanced & Global Engineering Challenges (AGEC)* (pp. 32-37). IEEE. https://doi.org/10.1109/AGEC57922.2023.00018

[27] Saleh, S., Jamaluddin, M. H., Razzaz, F., Saeed, S. M., Timmons, N., & Morrison, J. (2023). Compactness and performance enhancement techniques of ultra-wideband tapered slot antenna: A comprehensive review. *Alexandria Engineering Journal*, *74*, 195-229. https://doi.org/10.1016/j.aej.2023.05.020

[28] Salih, A. A. K., & Nangir, M. (2024). Design and Analysis of Wireless Power Transmission (2X1) MIMO Antenna at 5G-Frequencies for Applications of Rectenna Circuits in Biomedical. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications*, *15*(3), 203-221. https://doi.org/10.58346/JOWUA.2024.I3.014

[29] Shaaban, R. M., Dawood, R. M., Mutashar, R. A., & Wa'il, A. (2024). Enhancing Microstrip Antenna Efficiency with Novel Slot-Integrated Patch Configurations. *Operational Research in Engineering Sciences: Theory and Applications*, *7*(1). https://oresta.org/menu-script/index.php/oresta/article/view/723

[30] Shokri, A. H., Jazari, B. M., & Rezaei, M. (2014). The effect of GPS1 antenna's phase center offset and satellite DOP2's on the exact positioning. *International Academic Journal of Science and Engineering*, *1*(1), 145–157.

[31] Shum, A. (2024). System Level Architectures and Optimization of Low Cost, High Dimensional Mimo Antennas For 5G Technologies. *National Journal of Antennas and Propagation*, *6*(1), 58-67. https://doi.org/10.31838/NJAP/06.01.08

[32] Singh, A. K. (2021). Dual-Beam Leaky-Wave Antenna (Lwa) Based on Microstrip. *National Journal of Antennas and Propagation*, *3*(1), 7-10. https://doi.org/10.31838/NJAP/03.01.02

[33] Soh, H., & Keljovic, N. (2024). Development of highly reconfigurable antennas for control of operating frequency, polarization, and radiation characteristics for 5G and 6G systems. *National Journal of Antennas and Propagation, 6*(1), 31–39.

[34] Srinivasan, G., Lavanya, M., Karupasamypandiyan, M., & Krishnaparamathma, M. (2024, March). Siting and Sizing of Capacitors in RPDF Considering Load Variations: A Profit-Based Evaluation. In *2024 Third International Conference on Intelligent Techniques in Control, Optimization and Signal Processing (INCOS)* (pp. 1-6). IEEE.

[35] Tomura, T., & Kimura, Y. (2023, October). Design of a Dual-Polarized Single-Layer Wideband Ring Microstrip Antenna Fed by Two L-probes. In *2023 IEEE International Symposium on Antennas and Propagation (ISAP)* (pp. 1-2). IEEE. https://doi.org/10.1109/ISAP57493.2023.10389123

[36] Wa'il, A., Shaaban, R. M., & Ahmed, Z. A. (2019, July). A modified E-shaped microstrip patch antenna for dual band in x-and ku-bands applications. In *Journal of Physics: Conference Series* (Vol. 1234, No. 1, p. 012028). IOP Publishing. https://doi.org/10.1088/1742-6596/1234/1/012028

[37] Wang, B., Zhao, Z., Sun, K., Du, C., Yang, X., & Yang, D. (2022). Wideband series-fed microstrip patch antenna array with flat gain based on magnetic current feeding technology. *IEEE Antennas and Wireless Propagation Letters*, *22*(4), 834-838. https://doi.org/10.1109/LAWP.2022.3226461

[38] Yi, L. Y., Wang, A. Z., Zhang, L., Fang, S., & Hui, C. T. (2023, August). A circularly polarized microstrip phased array antenna for 5G communication. In *2023 16th UK-Europe-China Workshop on Millimetre Waves and Terahertz Technologies (UCMMT)* (Vol. 1, pp. 1-3). IEEE. https://doi.org/10.1109/UCMMT58116.2023.10310309

Authors Biography

Dr. Ranya M. Dawood, a lecturer in Physics at the University of Basra, Iraq, specializes in electromagnetic field calculations for antenna systems, focusing on microstrip antennas and wireless communication. She earned her Ph.D. in Physics in 2014 and is proficient in advanced simulation tools like HFSS and CST. Dr. Dawood is committed to research, teaching, and mentoring, inspiring future physicists and engineers with her expertise and practical insights.

Dr. Raed M. Shaaban is a lecturer in the Department of Physics at the University of Basrah, Iraq. His fields of interest include antenna design, microwave engineering, and wireless communications. He earned his bachelor's degree in physics from the University of Basrah in 2009, followed by a Master's degree in 2012. Dr. Shaaban completed his Ph.D. in 2017, making significant contributions to the field of wireless communications.

Dr. Ra'ed Malallah graduated from the University of Basrah with a BSc in 1997 and an MSc in 2006, both in the field of Physics/Communication/Microwave. Since 2007, he has been serving as an Associate Professor in the Physics Department at the College of Science, University of Basrah. He earned his PhD in Electrical & Electronics Engineering from University College Dublin in 2017, specializing in Holography Storage and Self-Written Waveguide fields. Additional to his academic experience in lecturing, he has a strong research expertise in the multidisciplinary fields of Photonics, Optics, and Microwave applications (Modulations & Experiments).

Zeki A. Ahmed is a professor and the leader of the microwave group in the Department of Physics, College of Science at University of Basrah. He received the B.Ss. degree in physics and the M.Sc. and Ph.D. degrees in antennas from the same University in 1983 and 1996, respectively. His current research is concentrated on microstrip antennas, radiation and scattering problems of electromagnetic. Also, his work included research on health effects of microwave.