IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 8.021 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 4, April 2025

DOI: 10.17148/IJIREEICE.2025.134109

DESIGN OF A MINIATURIZED ULTRA WIDE BAND MIMO ANTENNA WITH MULTI-BAND CHARACTERISTICS

Sri. A. Rajasekhar[1], K. Jahnavi[2], K. Pratheesh[3], CH.V. Sujith[4], I. Kranthi babu[5]

Assistant Professor, Department of Electronics & Communication Engineering, N.B.K.R Institute of Science and Technology[1]

Student, Department of Electronics & Communication Engineering, N.B.K.R Institute of Science and Technology[2-5]

Abstract: An ultra-wideband (UWB) multiple-input multiple- output (MIMO) antenna having double band-notched attributes is expected for FR4 substrate (1.6 mm). The antenna is composed of a better ground plane and dual microstrip feeding lines with a minimized dimension. By properly choosing the shape of the patch and the required output is expected. Measurement and simulation are utilized to concentrate on the antenna execution as far as isolation between the two input ports, envelope correlation coefficient, impedance matching, efficiency, radiation pattern and peak gain. CST Studio Suite is used to design the proposed antenna. UWB-MIMO is Better adapted for radar, tracking, monitoring systems of communications equipment, and infrastructure applications.

Keywords: UWB MIMO, Hexagon patch, EM Energy, Communication Technology, WLAN, C-Band, X-Band, Antenna.

I. INTRODUCTION

The use of wireless devices is the latest trend in communication technology, and there is a constant demand for compactness or miniaturization of wireless electronic devices, as well as an increase in speed and data rate for these devices. In this regard, UWB MIMO antenna systems are being considered for better performance, and they present antenna engineers with many design challenges. This project has given us the opportunity to explore the world of telecommunication. Ultrawide band antennas will have multi frequencies which can be used in different systems at the same time. Using MIMO gives us faster speeds, increased capacity, and robustness. With these advantages, MIMO technology has been introduced to portable terminals such as laptops, mobile phones, USB dongles and others to realize high-speed data transmission. The demand for higher data rates over longer distances has been one of the primary motivations behind the development of MIMO antenna.

We are using CST studio suite 2024 for the purpose of antenna designing and antenna simulation. We used CST Studio Suite software to design and simulate our antenna structure. Instead of using other types of substrates we are using FR4 substrate since it is readily available and is not as costly as other substrates. In this software we are checking the radiation pattern, the S-parameters and the diversity gain of the antenna and implementing a multiple input and multiple outputs (MIMO) structure to radiate in the WIMAX and WLAN bands CST Studio Suite is a hopped-up 3D EM examination software package for conniving, looking over the graphs and advancing electromagnetic constituents. Magnetic solvers for solicitations across the EM spectrum are comprised within a non-multiuser interface in CST Studio Suite.

II. LITERATURE REVIEW

[1]. Tiwari, R.N.; Singh, P.; Kanaujia, B.K.; Srivastava, K. "Neutralization technique based two and four port high isolation MIMO antennas for UWB communication".

MIMO antennas with 2 and 4 ports for UWB use. Used a neutralization line to reduce mutual coupling (which means better signal quality and less interference between ports). Achieved high isolation between antenna elements very important for MIMO performance. The antennas operate over a wide frequency range: 3.52 GHz to 10.08 GHz.Physical size of the antenna is 48 × 34 × 1.6 mm³.The gain ranged between 0.95 to 2.91 db.

[2]. Tiwari, R.N.; Singh, P.; Kanaujia, B.K.

"A compact UWB MIMO antenna with neutralization line for WLAN/ISM/mobile applications".

A compact UWB MIMO antenna (small size but high performance). Incorporated a neutralization line to improve isolation between antenna elements. Designed specifically to work for WLAN, ISM, and mobile applications — so it's

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 8.021 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 4, April 2025
DOI: 10.17148/IJIREEICE.2025.134109

practical for real-world wireless use. The design supports Ultra-Wideband (UWB) frequencies, allowing high-speed data transmission and better system capacity. They achieved good performance in terms of return loss, gain, isolation, and efficiency.

[3]. Barani, I.R.R.; Wong, K.L.; Zhang, Y.X.; Li, W.Y.
“Low-profile wideband conjoined open-slot antennas fed by grounded coplanar waveguides for 4 × 4 5G MIMO operation”.

A low-profile, wideband MIMO antenna system using conjoined open-slot antennas. The antenna is fed by grounded coplanar waveguides (GCPW), which helps achieve compact size and efficient performance. Designed for 4 × 4 MIMO operation, meaning it supports 4 transmitting and 4 receiving antennas — ideal for 5G applications. The antenna is optimized to be compact and suitable for integration in modern mobile devices. Achieved wide bandwidth, low mutual coupling, and high isolation, which are critical for 5G MIMO performance.

III. METHODOLOGY

A detailed study of existing UWB MIMO antenna designs was carried out to establish design goals focused on miniaturization, wide bandwidth (2.3–12.4 GHz), and high isolation. FR-4 was selected as the substrate for its affordability and suitable electrical properties ($\varepsilon r = 4.3$, loss tangent = 0.02) with a thickness of 1.6 mm.

An initial microstrip patch antenna was modeled using simulation tools like HFSS or CST, incorporating an octagonal radiator and partial ground to enhance bandwidth and reduce reflections. A compact two-element MIMO configuration was developed with techniques like orthogonal element placement and isolation slots to minimize mutual coupling. Simulations analyzed S-parameters, gain, efficiency, radiation patterns, and ECC across 1–15 GHz.

After optimization, the design was fabricated using PCB technology and tested using a Vector Network Analyzer (VNA). The measured results closely matched simulations, confirming multiband UWB performance, effective radiation, and strong isolation between antenna elements.

IV. ANTENNA DESIGN

This chapter presents the finite element analysis of a two-element MIMO antenna system. The proposed MIMO antenna has compact dimensions of 19 mm × 38 mm and operates over a wide frequency range from 2.39 GHz to 12.4 GHz, effectively covering almost the entire ultra-wideband (UWB) spectrum.

The configuration of the proposed antenna is illustrated in Fig. 4.1. The antenna is designed on an FR-4 substrate, which has a thickness of 1.6 mm, a relative permittivity of 4.3, and a loss tangent of 0.02. FR-4 was selected for its cost-effectiveness and easy availability, making it a practical choice without significantly compromising performance when compared to other substrate materials. The detailed dimensions of the antenna design are provided in Table 3.1. The antenna layout is developed on a rectangular substrate measuring 19 × 38 mm^2.

The design features a ground plane along the bottom edge and incorporates two microstrip feed lines at the base of the dielectric substrate. To achieve ultra-wideband performance, a large rectangular slot is etched into the ground plane. The radiator features an octagonal geometry, which enhances isolation between radiating elements compared to many other configurations. A 50-ohm feed line is used to excite the antenna, resulting in improved parametric performance.

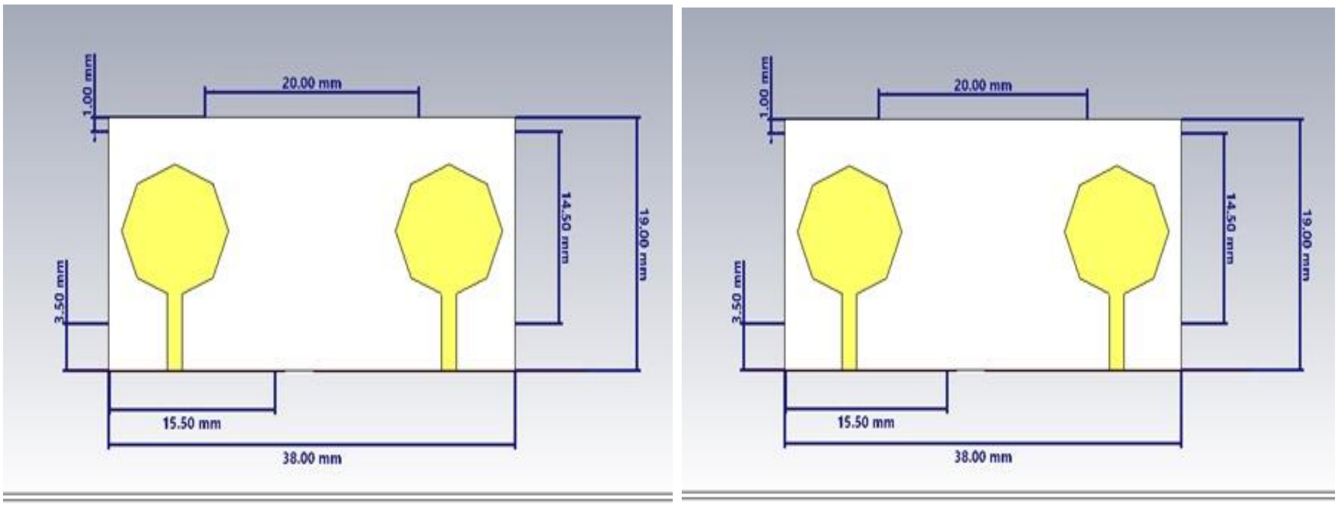
Figure 3.1 shows the custom-designed antenna model. The first view displays the front of the antenna with the feed positioned on top of the substrate, while the second view shows the back, highlighting the ground structure.

ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 8.021 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 4, April 2025

DOI: 10.17148/IJIREEICE.2025.134109



(a) **(b)**

Fig 3.1: Proposed antenna (a) Front view (b) Back view

V. CST MICROWAVE STUDIO

CST MICROWAVE STUDIO is a full-featured software package for Electromagnetic analysis and design in the highfrequency range. It simplifies the process of inputting the structure by providing a powerful solid 3D modelling front end. Strong graphic feedback simplifies the dentition of your device even further. After the component has been modelled, a fullyautomatic meshing procedure is applied before a simulation engine is started.

CST MICROWAVE STUDIO is part of the CST DESIGN STUDIO suite and offers a number of different solvers for different types of application. Since no method works equally well in all application domains, the software contains four different simulation Techniques (transient solver, frequency domain solver, integral equation solver, Eigen mode solver) to best fit their applications. The most flexible tool is the transient solver, which can obtain the entire broadband frequency behavior of the simulated device from only one calculation run (in contrast to the frequency step approach of many other simulators). It is based on the Finite Integration Technique (FIT)introduced in electrodynamics more than three decades ago. This solver is efficient for most kinds of high frequency applications such as connectors, transmission lines, filters, antennas and more

VI. SIMULATION WORKFLOW

After starting CST DESIGN ENVIRONMENT, choose to create a new CST MICROWAVE STUDIO project. You will be asked to select a template for a structure which is closest to your device of interest, but you can also start from scratch opening an empty project. An interesting feature of the on-line help system is the Quick Start Guide, an electronic assistant that will guide you through your simulation. You can open this assistant by selecting Help quick start guide if it does not show up automatically. If you are unsure of how to access a certain operation, click on the corresponding line.

The quick start guide will neither run an animation showing the location of the related menu entry or open the corresponding help page. As shown in the quick start-dialog box which should now be positioned in the upper right corner of the main view, the following steps must be accomplished for a successful simulation. CST STUDIO SUITE and its various products are employed for the design and optimization purposes of devices operating in wide range of frequencies.

It is used in several applications such as Microwave and RF applications, low frequency applications, PCBs and packages, cable harnesses and for calculation of temperature and mechanical stress. An overview of this tool is given, and its method of proceedings are shown. Microstrip antennas find growing applications in numerous fields due to their reduced interference and cost effectiveness. The four most popular feed techniques used are the microstrip line, coaxial probe, aperture coupling and proximity coupling were reviewed.

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 8.021 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 4, April 2025

DOI: 10.17148/IJIREEICE.2025.134109

VII. SIMULATION RESULT

1.1:S-PARAMETERS

The modelled S-parameters shown in Fig. 1.1 confirm that the antenna supports UWB operation with multiple resonant bands at 2.6 GHz, 3.6 GHz, 6.8 GHz, and 10.5 GHz. It offers an impedance bandwidth (S_{22} < -10 dB) from 2.3 GHz to beyond 12 GHz. The S_{11} plot shows deep notches, especially at 10.60 GHz (-43.83 dB), indicating strong impedance matching and minimal reflection. Meanwhile, consistently low S_{21} values (below -10 dB) suggest limited signal transmission, highlighting the antenna's potential use as a band stop or notch filter to suppress interference, particularly in the WLAN band**.**

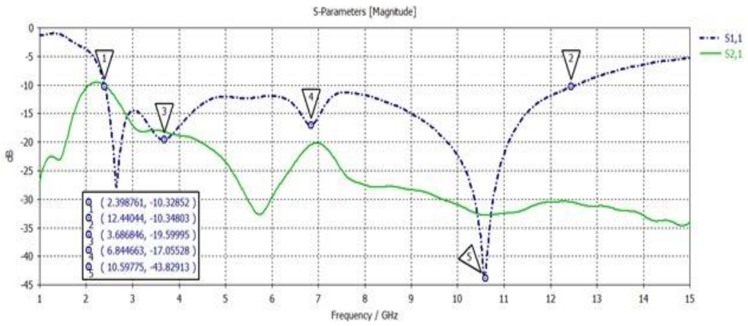
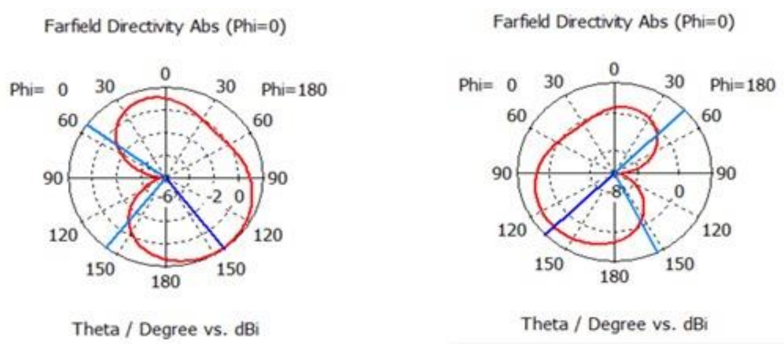


Fig 1.1: S-Parameter of the proposed antenna

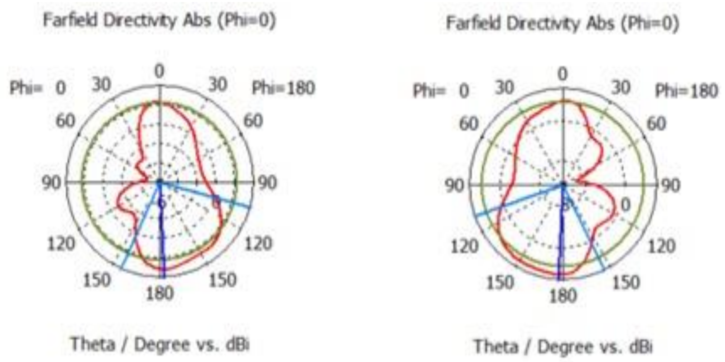
1.2 RADIATION PERFORMANCE

The Fig. 1.2 depicts the radiation pattern of the presented antenna work in the report. The 2D-polar radiation patterns of the proposed microstrip antenna at the center frequency are portrayed when the ports are invigorated independently. The radiation pattern of the produced antenna is displayed at 2.6 GHz and 10.6 GHz. The radiation patterns are plotted for both the port, port 1 and port 2.



(a) **(b)**

Fig 1.2.1: a). Radiation pattern for port 1 at 2.6 GHz
b). Radiation pattern for port 2 at 2.6 GHz



(a) **(b)**

Fig 1.2.2: a). Radiation pattern for port 1 at 10.6 GHz
b). Radiation pattern for port 2 at 10.6 GHz

DOI: 10.17148/IJIREEICE.2025.134109

1.3 ANTENNA GAIN

In the Fig 1.3, the curve of gain vs frequency is shown. Within the desired frequency range, the antenna has a favourable gain value. By utilizing the proposed method, the gain is diminished emphatically in the notch band while great radiation execution is accomplished over the other frequency e value of gain of the proposed antenna is of 4 db.

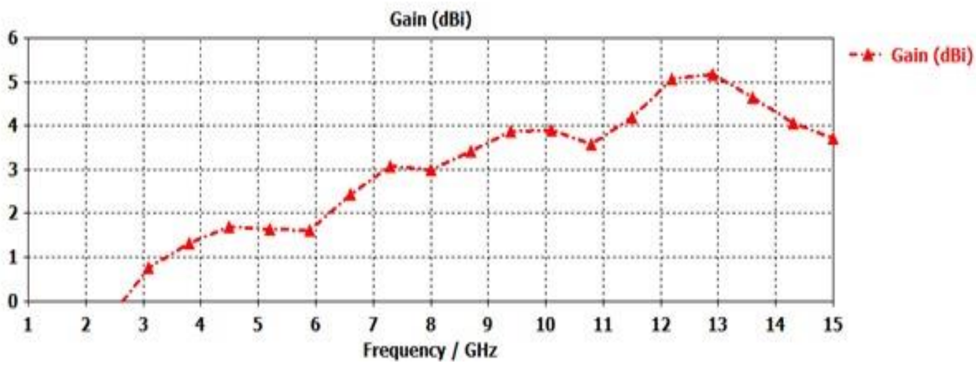


Fig 1.3: Gain of Proposed Antenna

1.4 ANTENNA DIRECTIVITY

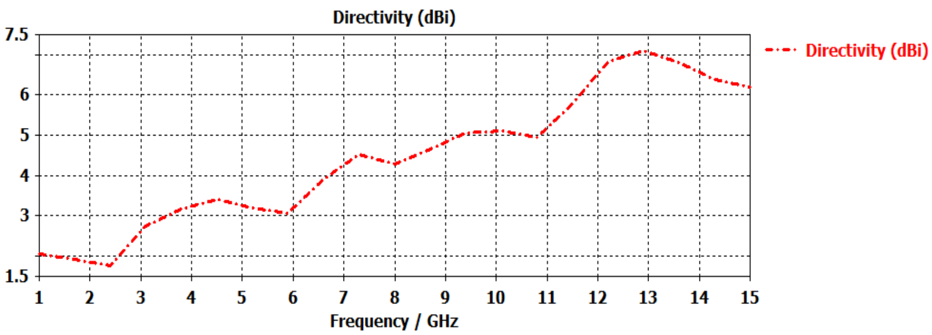


Fig 1.4: Directivity of Proposed Antenna

VIII. CONCLUSION

This report presented the work on the analysis and design of UWB MIMO antenna with optimal characteristics such as bandwidth, isolation, gain, ECC and Efficiency. An ultra-wideband (UWB) multiple-input multiple- output (MIMO) antenna having double band-notched attributes is expected for FR4 substrate (1.6 mm). The antenna's modelled S-parameter have a UWB frequency range with multi band such as 2.6 GHz, 3.6 GHz, 6.8 GHz and 10.5 GHz. It is exhibited that the antenna has an impedance bandwidth (for s22< -10 dB) from 2.3 GHz to more than 12 GHz. Multi band made to repress obstruction in the WLAN band. The ECC is underneath 0.002 all through UWB. Also, the antenna radiation efficiency on average is observed to be 70%. A diversity gain of near about 9.9 dB has been observed. The entirety of UWB antenna research is aimed at improving short-range wireless communication systems that require omni-directional patterns. However, there are other applications where no impediments exist, such as through-the-wall radar imaging. A directional antenna with high gain is necessary for this application. As a result, research work into high gain UWB directional antennas and antenna array may be carried out ahead.

REFERENCES

[1]. Malviya, L., Malik, J., Panigrahi, R. K., & Kartikeyan, M. V. (2015, December). Design of a compact MIMO antenna with polarization diversity technique for wireless communication. In *2015 International Conference on Microwave, Optical and Communication Engineering (ICMOCE)* (pp. 21-24). IEEE.

[2]. Wang, X., Feng, Z., & Luk, K. M. (2008). Pattern and polarization diversity antenna with high isolation for portable wireless devices. *IEEE Antennas and Wireless Propagation Letters*, *8*, 209-211.

[3]. Boukarkar, A., Lin, X. Q., Jiang, Y., Nie, L. Y., Mei, P., & Yu, Y. Q. (2017). A miniaturized extremely close-spaced

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 8.021 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 4, April 2025

DOI: 10.17148/IJIREEICE.2025.134109

four-element dual-band MIMO antenna system with polarization and pattern diversity. *IEEE Antennas and Wireless Propagation Letters*, *17*(1), 134-137.

[4]. Babu, K. V., & Anuradha, B. (2019). Analysis of multi-band circle MIMO antenna design for C-band applications. *Progress In Electromagnetics Research C*, *91*, 185-196.

[5]. Kumar, J. P., & Karunakar, G. (2018, December). Circular slotted ring shaped mimo antenna for ultra-wideband applications. In *2018 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)* (pp. 1-5). IEEE.

[6]. Sharawi, M. S., Ikram, M., & Shamim, A. (2017). A two concentric slot loop based connected array MIMO antenna system for 4G/5G terminals. *IEEE Transactions on antennas and propagation*, *65*(12), 6679-6686.

[7]. Nadeem, I., & Choi, D. Y. (2018). Study on mutual coupling reduction technique for MIMO antennas. *IEEE Access*, *7*, 563-586.

[8]. Punna, B., & Muthusamy, P. (2021). Printed MIMO/Diversity Antenna with Polarization Diversity. *Progress In Electromagnetics Research Letters*, *99*(00), 25-34.

[9]. Ullah, U., & Koziel, S. (2019). A geometrically simple compact wideband circularly polarized antenna. *IEEE Antennas and Wireless Propagation Letters*, *18*(6), 1179-1183.

[10]. Chen, S. C., Wu, P. W., Hsu, C. I. G., & Sze, J. Y. (2017). Integrated MIMO slot antenna on laptop computer for eight-band LTE/WWAN operation. *IEEE Transactions on Antennas and Propagation*, *66*(1), 105-114.

[11]. Chattha, H. T. (2019). 4-port 2-element MIMO antenna for 5G portable applications. *IEEE Access*, *7*, 96516-96520.

[12]. Ullah, U., Al-Hasan, M., Koziel, S., & Mabrouk, I. B. (2020). Circular polarization diversity implementation for correlation reduction in wideband low- cost multiple-input-multiple-output antenna. *IEEE Access*, *8*, 95585-95593...

[13]. Li, H., Sun, S., Wang, B., & Wu, F. (2018). Design of compact single-layer textile MIMO antenna for wearable applications. *IEEE Transactions on Antennas and Propagation*, *66*(6), 3136-3141.

[14]. Dicandia, F. A., Genovesi, S., & Monorchio, A. (2017). Analysis of the performance enhancement of MIMO systems employing circular polarization. *IEEE Transactions on Antennas and Propagation*, *65*(9), 4824- 4835.

[15]. Ullah, U., Mabrouk, I. B., Koziel, S., & Al-Hasan, M. (2020). Implementation of Spatial/Polarization Diversity for Improved-Performance Circularly Polarized Multiple- Input- Multiple -Output Ultra-Wideband Antenna. *IEEE Access, 8, 64112-64119.doi:10.1109/access. 2020.2984697*.

[16]. Ahmed, F., Chowdhury, M. H. M., & Rahman, A. M. A. (2017, February). A multiband MIMO antenna for future generation handset applications. In *2017 International Conference on Electrical, Computer and Communication Engineering (ECCE)* (pp. 91-94). IEEE.

[17]. Wu, W., Zhi, R., Chen, Y., Li, H., Tan, Y., & Liu, G. (2019). A compact multiband MIMO antenna for IEEE 802.11 a/b/g/n applications. *Progress In Electromagnetics Research Letters*, *84*, 59-65.

[18]. Sandi, E., & Marani, T. (2020, July). Design of multiband MIMO antenna for 5G millimeterwave application. In *IOP Conference Series: Materials Science and Engineering* (Vol. 852, No. 1, p. 012154). IOP Publishing.

[19]. Sarade, S. S., & Ruikar, S. (2020). Development Of Multiband MIMO Antenna with Defective Ground Structure. *Procedia Computer Science*, *171*, 1829-1838.

[20]. Ullah, U., Mabrouk, I. B., & Koziel, S. (2020). Enhanced performance circularly polarized MIMO antenna with polarization/pattern diversity. *IEEE Access*, *8*, 11887-11895.

[21]. Srivastava, G., & Kanuijia, B. K. (2015). Compact dual band-notched UWB MIMO antenna with shared radiator. *Microwave and Optical Technology Letters, 57*(12), 2886-2891.

[22]. Latif, F., Tahir, F. A., Khan, M. U., & Sharawi, M. S. (2017). An ultra-wide band diversity antenna with band-rejection capability for imaging applications. *Microwave and Optical Technology Letters*, *59*(7), 1661-1668.

[23]. Zhu, J., Feng, B., Peng, B., Li, S., & Deng, L. (2016). Compact CPW UWB diversity slot antenna with dual band-notched characteristics. *Microwave and Optical Technology Letters*, *58*(4), 989-994.

[24]. Tang, T. C., & Lin, K. H. (2014). An ultrawideband MIMO antenna with dual band-notched function. *IEEE Antennas and wireless propagation letters*, *13*, 1076-1079.

[25]. Chacko, B. P., Augustin, G., & Denidni, T. A. (2013). Uniplanar polarisation diversity antenna for ultrawideband system.

[26]. Kang, L., Li, H., Wang, X., & Shi, X. (2015). Compact offset microstrip-fed MIMO antenna for band-notched UWB applications. *IEEE Antennas and Wireless Propagation Letters*, *14*, 1754-1757.

[27]. Liu, L., Cheung, S. W., & Yuk, T. I. (2013). Compact MIMO antenna for portable devices in UWB applications. *IEEE Transactions on antennas and propagation*, *61*(8), 4257-4264.