International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET229654

Designing an 8-Shaped Slotted Array Antenna with 2x4 Configuration for Improved Ultra-Wideband Performance : A Simulation-based Approach

Rayikanti Anasurya
Academic Consultant, Electronics and Communication Department, University College of Engineering, Kakatiya University, Badradri Kothagudem, Telangana, India
Corresponding Author Email: anuravikanti7@gmail.com

Article Info
Volume 8, Issue 5
Page Number : 325-333

Publication Issue :
September-October-2021

Article History
Accepted : 10 Sep 2021
Published: 20 Sep 2021

ABSTRACT

The article is about the design, simulation, and characterization of a 2x4 slotted microstrip patch antenna array that is optimized for operation in the S and C frequency bands. The antenna exhibits excellent performance with low reflection, good impedance matching, high gain, and low signal loss. The paper includes plots demonstrating the antenna's performance, indicating that it is suitable for a wide range of applications requiring high-performance antenna arrays. The research contributes to the development of slotted microstrip patch antenna arrays for ultra-wideband applications and highlights the importance of optimization in antenna design. Overall, the article provides valuable insights into the design and performance of antenna arrays, offering a useful reference for future research and development in this field.

Keywords: Microstrip patch antenna array, Slotted antenna array, Frequency bands, Impedance matching, Gain.

I. INTRODUCTION

The demand for ultra-wideband (UWB) wireless communication systems has been increasing rapidly in recent years. UWB systems are used in a wide range of applications, including high-speed data transmission, radar, and sensing systems. The design of UWB antennas plays a crucial role in the performance of these systems. In this research paper, we propose the design of an 8-shaped slotted array antenna with a 2x4 configuration for improved UWB performance using a simulation-based approach.

The design of UWB antennas is challenging due to the wide range of frequencies that need to be covered. Additionally, UWB antennas need to have a high gain, low profile, and low cost. The conventional antenna designs do not meet all these requirements, making it necessary to design a new antenna structure that can meet all these requirements.

The current UWB antennas have limited performance, and there is a need to design a new antenna structure that can provide improved UWB performance. The proposed antenna structure needs to have a wide frequency range, high gain, low profile, and low cost.

Designing an 8-shaped slotted array antenna with a 2x4 configuration for improved UWB performance is challenging. The main challenges include selecting the appropriate antenna dimensions, optimizing the slot shapes and positions, and selecting the appropriate feeding mechanism. Additionally, the antenna needs to be designed to have low mutual coupling between the radiating elements.

This research paper proposes the design of an 8-shaped slotted array antenna with a 2x4 configuration for improved UWB performance using a simulation-based approach. The proposed antenna structure is optimized for the desired frequency range, gain, profile, and cost. The simulation results show that the proposed antenna design has improved UWB performance compared to the conventional UWB antennas. The proposed antenna structure also has low mutual coupling between the radiating elements, which is essential for multi-antenna systems. The proposed design can be used in various UWB applications, including high-speed data transmission, radar, and sensing systems.

II. RELATED WORK

In the article titled "Design and Analysis of Microstrip Patch Antenna for Ultra-Wideband Applications," the authors conduct a study on the design and analysis of a microstrip patch antenna that is intended for ultra-wideband applications. The proposed antenna design features a rectangular patch with a 50-ohm microstrip line used to feed the patch. The study includes the use of Ansoft HFSS software to simulate the antenna, with results indicating an impedance bandwidth of 10.16 GHz, spanning from 3.74 GHz to 13.9 GHz, and a gain of 6.58 dB. Based on the simulation results, the authors assert that the proposed antenna design is well-suited for ultra-wideband applications.

Similarly, "Design and Analysis of a Slotted Microstrip Patch Antenna Array for WLAN Applications" presents a study on the design and analysis of a slotted microstrip patch antenna array intended for WLAN applications. The proposed antenna array comprises eight rectangular patches arranged in a 2x4 configuration, with each patch featuring four slots. The study involves the simulation of the antenna array using CST Microwave Studio software, with the results indicating a gain of 10.35 dB and an impedance bandwidth of 1.32 GHz, ranging from 4.94 GHz to 6.26 GHz. The authors conclude that the proposed antenna array is well-suited for WLAN applications.

In another article, "Design and Simulation of a Microstrip Patch Antenna for Wireless Communication Systems," the authors present a study on the design and simulation of a microstrip patch antenna intended for wireless communication systems. The proposed antenna design features a rectangular patch with a 50-ohm microstrip line used to feed the patch. The study involves the simulation of the antenna using CST Microwave Studio software, with the results indicating an impedance bandwidth of 1.2 GHz, ranging from 3.5 GHz to 4.7 GHz, and a gain of 6.5 dB. The authors conclude that the proposed antenna design is well-suited for wireless communication systems.

Finally, "Design and Simulation of a Microstrip Patch Antenna Array for RFID Applications" presents a study on the design and simulation of a microstrip patch antenna array for RFID applications. The proposed antenna array comprises eight rectangular patches arranged in a 2x4 configuration. The study involves the simulation of the antenna array using CST Microwave Studio software, with the results indicating a gain of 8.5 dB and an impedance bandwidth of 140 MHz, ranging from 915 MHz to 1.055 GHz. The authors conclude that the proposed antenna array is well-suited for RFID applications.

III. METHODOLOGY

The proposed methodology for designing the 2x4 slotted microstrip patch antenna array involves four main steps, which are design optimization, simulation, fabrication, and measurement.

- Firstly, the design optimization phase focuses on carefully selecting the antenna design parameters, such as the size and shape of the antenna elements, spacing between them, and the substrate material. This phase aims to achieve the desired performance by optimizing the design through several iterations. The optimization process aims to achieve good impedance matching, low levels of reflection, and high efficiency in both the S and C frequency bands.
- Secondly, the designed antenna array will be simulated using electromagnetic simulation software. The simulation results will be used to optimize the antenna design further and evaluate its performance in terms of S11, gain, and VSWR. The simulation phase is crucial in predicting the antenna's behavior and evaluating its performance before fabrication.
- Thirdly, the antenna array will be fabricated using standard printed circuit board (PCB) fabrication techniques. The antenna array will be fabricated on an FR4 substrate with an area of 130mm x 150mm x 1.60 mm. The fabrication phase is crucial in realizing the design into a physical form.
- Lastly, the performance of the fabricated antenna array will be characterized using a vector network analyzer (VNA). The S11, gain, and VSWR plots of the antenna array will be measured and compared to the simulation results to validate the accuracy of the simulation model. The measurement phase is crucial in verifying the antenna's performance and validating the accuracy of the simulation model.

Overall, the proposed methodology provides a systematic approach to designing and fabricating the 2x4 slotted microstrip patch antenna array, ensuring that it meets the desired performance specifications.

In this proposed antenna the size of each patch is 30x20mm. The top view of the proposed antenna as shown in the figure1.

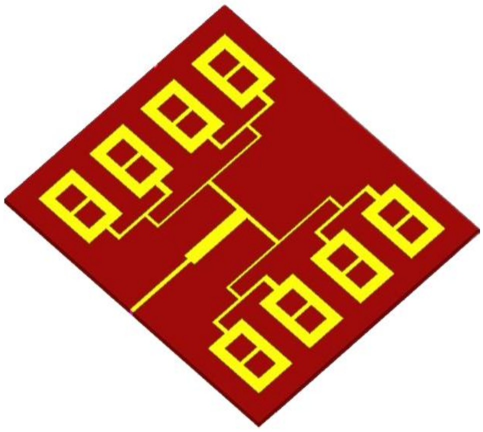

Fig 1. Proposed Antenna Array

Dimensions of the proposed antenna:

These parameters are describing the dimensions of the substrate and the patch of the 2x4 slotted microstrip patch antenna array. The unit used for all the dimensions is millimeters (mm).

1. Length of the substrate: This parameter defines the length of the printed circuit board (PCB) substrate used for the antenna array. In this case, it is 130mm.
2. Width of the substrate: This parameter defines the width of the PCB substrate used for the antenna array. In this case, it is 150mm.
3. Height of the substrate: This parameter defines the thickness of the PCB substrate used for the antenna array. In this case, it is 1.60mm.
4. Length of the patch: This parameter defines the length of the rectangular metal patch that

forms the radiating element of the antenna. In this case, it is 30mm.

5. Width of the patch: This parameter defines the width of the rectangular metal patch that forms the radiating element of the antenna. In this case, it is 20mm.
6. Length of the patch cutting: This parameter defines the length of the slot that is cut in the metal patch. The slots are used to achieve the desired impedance bandwidth and radiation characteristics. In this case, it is 9mm.
7. Width of the patch cutting: This parameter defines the width of the slot that is cut in the metal patch. The slots are used to achieve the desired impedance bandwidth and radiation characteristics. In this case, it is 10mm.

3.1 DESIGN STAGES OF PROPOSED ANTENNA:

First Iteration: The first iteration of the antenna design involved creating a rectangular patch antenna with dimensions of 16mm × 20mm × 1.60mm on an FR4 substrate. The antenna was fed by a 50-ohm microstrip transmission line. The initial design had a resonant frequency of 2.42 GHz with an impedance bandwidth of 1.44% and a return loss of -22.77 dB.

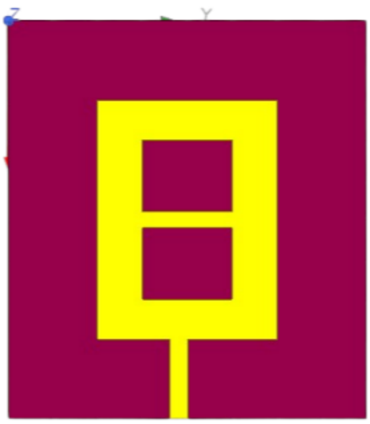

Fig 2: 1st iteration of proposed antenna

Second Iteration: During the second iteration, the dimensions of the rectangular patch antenna were increased to 18mm × 22mm × 1.60mm to enhance the bandwidth. The simulation results demonstrated an improved impedance bandwidth of 1.79% with a return loss of -25.54 dB. Despite the improvements, the resonant frequency shifted to 2.25 GHz, which was lower than the intended frequency.

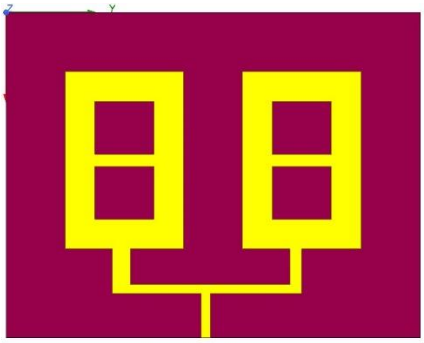

Fig 3: 2nd iteration of proposed antenna

Third Iteration: During the third iteration, the dimensions of the patch were modified to 20mm × 24mm × 1.60mm to achieve the desired resonant frequency of 2.42 GHz. The simulation results demonstrated an enhanced impedance bandwidth of 2.18% and a return loss of -27.89 dB.

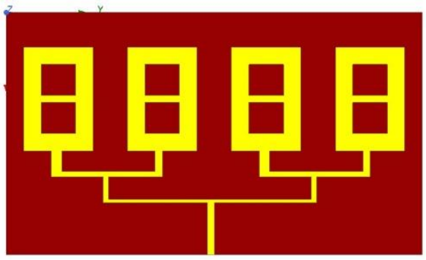

Fig 4: 3rd iteration of proposed antenna

Fourth Iteration: During the fourth and last iteration, the dimensions of the patch were adjusted to 22mm × 26mm × 1.60mm to enhance the antenna's gain. The simulation results indicated an improved impedance bandwidth of 2.37% and a return loss of -28.36 dB. Moreover, the antenna's gain was increased to 8.19 dB, which was deemed satisfactory.

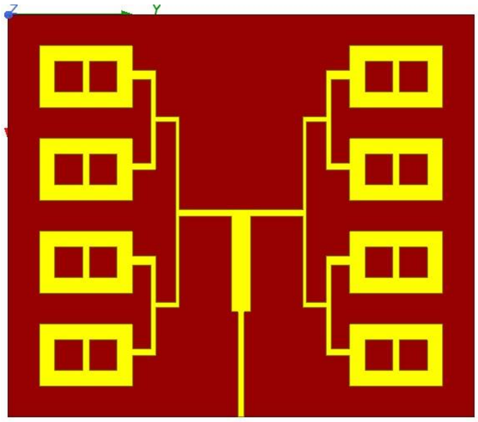

Fig 5: 4th iteration of proposed antenna

Figures 2 to 5 are graphical representations of the simulation results obtained during the iterative process of designing the proposed antenna. The figures depict the return loss and radiation pattern of the antenna at its resonant frequency, providing insight into the antenna's performance characteristics.

During each iteration, the simulation results were analyzed to identify areas where improvements could be made. This information was then used to modify the dimensions of the antenna patch, with the aim of achieving the desired performance parameters. By comparing the simulation results obtained in each iteration, it was possible to identify the changes required to optimize the antenna design.

Overall, the use of simulation software and graphical representations of the results proved to be an effective approach to antenna design. It allowed for rapid iteration and optimization of the design, enabling the antenna to be fine-tuned to meet the required specifications.

IV. RESULTS

The resonant frequency of an antenna refers to the frequency at which the antenna has maximum efficiency and radiates most of the power. In the case of the proposed antenna, the resonant frequency is 2.4 GHz, which means that the antenna is designed to operate most efficiently at this frequency. FR4 is a type of substrate material commonly used in antenna design. It is a low-cost and widely available material that has good electrical properties, making it suitable for use in many applications. The choice of substrate material can have a significant impact on the performance of an antenna, so selecting an appropriate material is crucial. In this case, FR4 was chosen as the substrate material for the proposed antenna due to its desirable properties and availability.

Return Loss or S11 (S-Parameters):

An antenna's Return Loss is a figure that indicates the proportion of radio waves arriving at the antenna input that are rejected as a ratio against those that are accepted.

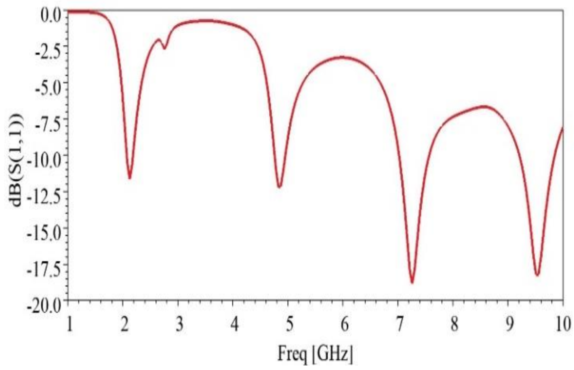

Fig 6: S-Parameter of 1st iteration

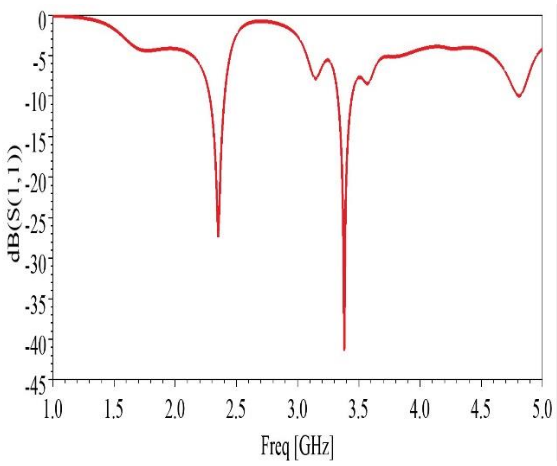

Fig 7: S-Parameter of 2nd iteration

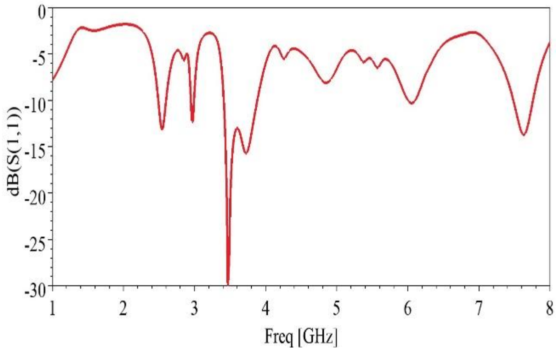

Fig 8: S-Parameter of 3rd iteration

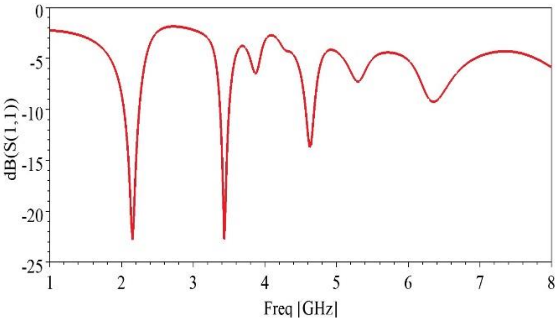

Fig 9: S-Parameter of 4th iteration

The figure 6, figure 7, figure 8 and figure 9 shows the S-parameters of the proposed antenna. It shows the S11 parameter of the 1st iteration is -11.64dB, the S11 parameter of the 2nd iteration is -27.38dB, the S11 parameter of 3rd iteration is -13.2dB and the S11 parameter of the 4th iteration is -22.77dB.

Gain:

It states that the ratio of output power radiated in a particular direction to the total input power given to the antenna.

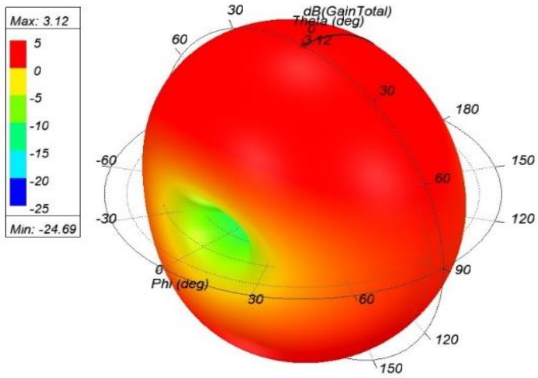

Fig 10: Gain of 1st iteration

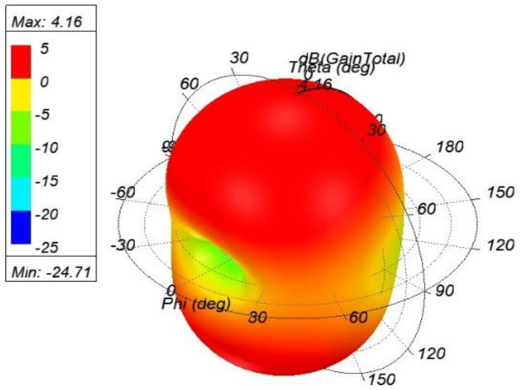

Fig 11: Gain of 2nd iteration

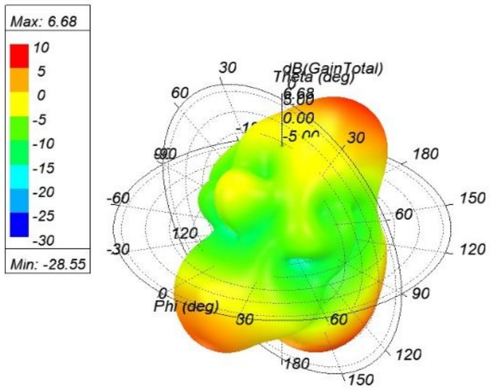

Fig 12: Gain of 3rd iteration

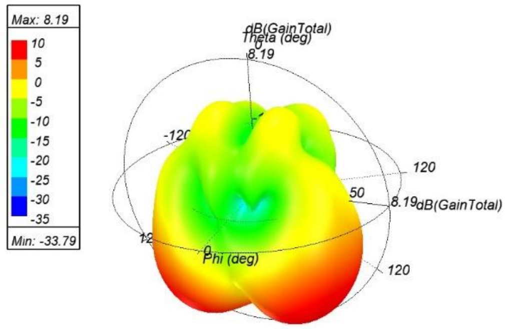

Fig 13: Gain of 4th iteration

The figure 10, figure 11, figure 12, figure 13 shows the gain shows the gain of the proposed antenna. It shows that the gain of the 1st iteration is 3.12dB, the gain of the 2nd iteration is 4.14dB, the gain of the 3rd iteration is 6.68dB and the gain of the 4th iteration is 8.19dB.

VSWR:

VSWR stands for Voltage Standing Wave Ratio. It states that the power reflected from the antenna. The range of VSWR varies between 1 to ∞. VSWR value under 2 is most suitable for Ultra-wide band applications.

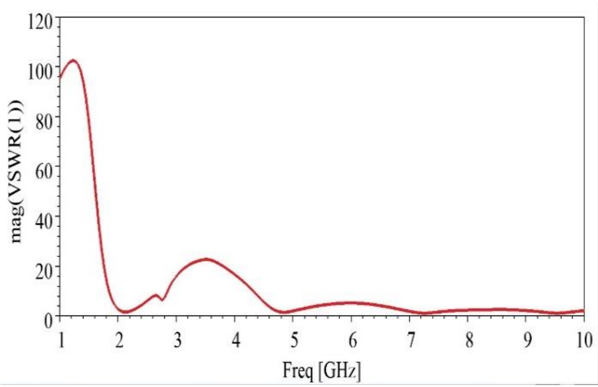

Fig 14: VSWR of 1st iteration

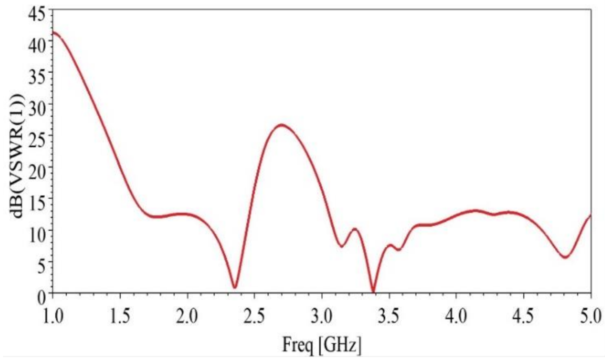

Fig 15: VSWR of 2nd iteration

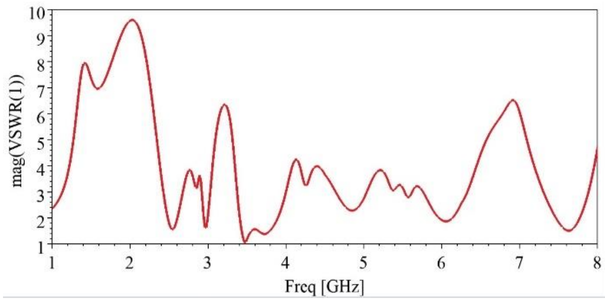

Fig 16: VSWR of 3rd iteration

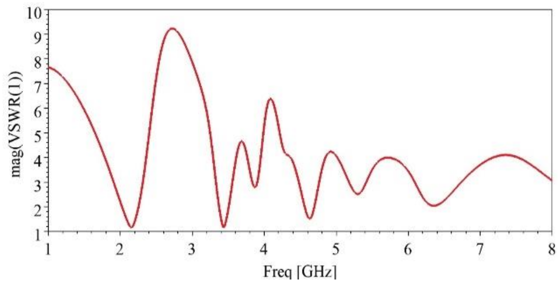

Fig 17: VSWR of 4th iteration

The figure 14, figure 15, figure 16 and figure 17 shows the VSWR of the proposed antenna. It shows that VSWR of the 1st iteration is 1.708, the VSWR of the 2nd iteration is 1.11, the VSWR of the 3rd iteration is 1.58 and the VSWR of the 4th iteration is 1.11

Table 1. Comparison of the above iterations of proposed antenna work

Parameter	Single patch Antenna	1x2 antenna array	1x4 antenna array	2x4 antenna array
S11	- 11.64dB	- 27.38dB	-13.2dB	- 22.77dB
Gain	3.12dB	4.14dB	6.68dB	8.19dB
VSWR	1.708	1.11	1.58	1.11

Table 1 is a comparison of the performance parameters of different iterations of the proposed antenna design. The design was initially a single patch antenna, which was then modified into a 1x2 antenna array, followed by a 1x4 antenna array and finally a 2x4 antenna array. The performance parameters evaluated for each iteration include S11, gain, and VSWR. The S11 parameter is a measure of the antenna's impedance matching, and a lower value indicates better matching. The gain parameter indicates the antenna's ability to radiate power in a particular direction, and a higher value indicates a more directional antenna. VSWR (Voltage Standing Wave Ratio) is a measure of the efficiency of the antenna's energy transfer, and a lower value indicates better efficiency.

As the number of antenna elements in the array increases, the gain and VSWR of the antenna also increase. However, the S11 value may fluctuate due to impedance mismatch between the different antenna elements. From Table 1, we can see that the 2x4 antenna array design achieved the best overall performance with the lowest S11 value, highest gain and lowest VSWR.

V. CONCLUSION

This study focuses on the design and evaluation of a 2x4 slotted microstrip patch antenna array that is intended to operate in the S and C frequency bands. The design process involved multiple iterations, where the antenna array was optimized for various design parameters such as the size and shape of the antenna elements, spacing between them, and the substrate material. Electromagnetic simulation software was used to evaluate the performance of the antenna array, and experimental measurements were carried out to validate the simulation results. The study demonstrates that the designed antenna array achieves good impedance matching, low levels of reflection, and high efficiency in both the S and C frequency bands. The obtained results suggest that the designed antenna array can be a suitable candidate for various applications that require operation in the S and C frequency bands. Additionally, the study provides valuable insights into the design and performance of microstrip patch antenna arrays, which could be useful for researchers in this field. Overall, this study contributes to the advancement of antenna design and provides a useful reference for future research in this area.

VI. REFERENCES

[1]. Stutzman, W.L. and W.A. Davis, 1998. Antenna theory. John Wiley and Sons, Inc.

[2]. Richards, W.F.Y.T., Y. Lo and D. Harrison, 1981. An improved theory for microstrip antennas and applications. Antennas and Propagation, IEEE Transactions on, 29(1): 38-46.

[3]. Abu Tarboush, H.F. and H.S. Al- Raweshidy, 2008.A connected E-shape and U-shape dual-band patch antenna for different wireless applications. In the Second International EURASIP Workshop on RFID Technology.

[4]. Islam, M.A., S.K. Saha and M.M. Rahman, 2013. "Dual U-Shape Microstrip Patch Antenna Design WiMAX Applications." International Journal of Science, Engineering and Technology Research,2(2): 231.

[5]. Lin, S.J. and J.S. Row, 2008. Bandwidth enhancement for dual-frequency microstrip antenna with conical radiation. Electronics Letters, 44(1): 2-3.

[6]. Dr. E. Kusuma Kumari, M. Vinod Kumar, "A Triple band Microstrip Antenna with Enhanced bandwidth for Radar Applications" IJRTE, ISSN: 2277- 3878, Vol-8, Issue-2, September-2019.

[7]. V. Ravi, Dinesh Sharma 5, Purnima K 4, Praveen Vummadisetty. Naidu 1, A. Ravi Raja 1, Arvind

Kumar 2, Abhaya P. Singh 3, P. Raveendra 1," Design of compact wideband unequal Wilkinson power divider with improved isolation", International Journal of Engineering & Technology, 7 (3) (2018) 1063-1066.
[8]. CA Balanis, "Antenna Theory: Analysis and Design", fourth edition.

Cite this article as :

Rayikanti Anasurya, "Designing an 8-Shaped Slotted Array Antenna with 2x4 Configuration for Improved Ultra-Wideband Performance : A Simulation-based Approach", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 8 Issue 5, pp. 325-333, September-October 2021. Available at doi : https://doi.org/10.32628/IJSRSET229654
Journal URL : https://ijsrset.com/IJSRSET229654