

# Design And Simulation For 8-Shape 2x4 Slotted Array Antenna Using Ultra Wideband Applications

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Available online at: <http://www.ijcert.org>

Received: 21/12/2022,

Revised: 06/01/2022,

Accepted: 10/01/2023,

Published:27/01/2023

**Abstract:** This paper presents a detailed study of the design, simulation, and characterization of a 2x4 slotted microstrip patch antenna array. The antenna array is fed by a microstrip transmission line and is designed on an FR4 substrate with dimensions of 130mmx150mmx1.60mm. The antenna is optimized to operate in two different frequency bands, S and C, respectively. The design process of the antenna array involved four iterations, which allowed for an optimal antenna design to be achieved. The proposed antenna exhibits excellent performance, as indicated by its S11 parameter, gain, and VSWR. The S11 parameter, which is a measure of how much power is reflected back from the antenna, is -22.77dB, indicating low levels of reflection and good impedance matching. The gain of the proposed antenna is 8.19dB, which represents the amount of power that is radiated in a specific direction relative to an isotropic radiator. This is a relatively high value and indicates that the proposed antenna has a high efficiency. The VSWR of the proposed antenna is 1.11, indicating good impedance matching and low levels of signal loss. To evaluate the performance of the antenna, S11 parameter, gain plots, and VSWR plots are provided in the paper. These plots demonstrate the antenna's excellent performance in both the S and C frequency bands, making it suitable for a wide range of applications that require high-performance antenna arrays. Overall, the results presented in this paper provide valuable insights into the design and performance of slotted microstrip patch antenna arrays, which could be useful for future research and development in this field.

**Keywords:** Array, FR4 Substrate, Microstrip Patch Antenna, HFSS

## 1. Introduction

Wireless communication systems are an essential part of modern society. They are used in various applications such as mobile phones, satellite communication, Wi-Fi, and Bluetooth. The antenna is a crucial component of wireless communication systems as it facilitates the transmission and reception of signals. Antenna arrays are a popular choice for high-performance wireless communication systems as they offer high gains, directivity, and low sidelobes. Among the different types of antenna arrays, the microstrip patch antenna array has emerged as a popular choice due to its low profile, ease of fabrication, and low cost. The demand for high-performance wireless communication systems has increased significantly in recent years. This has led to an increased need for high-performance

antenna arrays. Antenna arrays can help overcome issues such as signal fading, interference, and low signal-to-noise ratio. Furthermore, antenna arrays can enable the use of MIMO techniques, which can increase the capacity and spectral efficiency of wireless communication systems. The motivation behind this study is to design a high-performance microstrip patch antenna array that operates in the S and C frequency bands.

Designing a microstrip patch antenna array that operates in multiple frequency bands poses several challenges. The antenna must be designed to achieve good impedance matching, low levels of reflection, and high efficiency. The size and shape of the antenna elements and the spacing between them must be optimized to achieve the desired performance. The selection of the substrate material is also critical, as it can

significantly affect the antenna's performance. Furthermore, the antenna must be designed to operate in both the S and C frequency bands, which requires careful selection of the design parameters[1].

The primary objective of this study is to design a high-performance 2x4 slotted microstrip patch antenna array that operates in the S and C frequency bands. The antenna array will be fed by a microstrip transmission line, and the design will be optimized to achieve good impedance matching, low levels of reflection, and high efficiency. The study aims to characterize the performance of the antenna array using parameters such as S11, gain, and VSWR. The results obtained from the study will provide valuable insights into the design and performance of microstrip patch antenna arrays and could be useful for future research in this field.

To achieve the objective, the antenna design will be optimized through several iterations. The design parameters, including the size and shape of the antenna elements, the spacing between them, and the substrate material, will be carefully selected to achieve the desired performance[2]. The antenna will be simulated using electromagnetic simulation software, and its performance will be characterized using parameters such as S11, gain, and VSWR. The simulation results will be compared to experimental results to validate the accuracy of the simulation model.

The challenges associated with designing a microstrip patch antenna array that operates in multiple frequency bands will be addressed through careful design optimization. The study will focus on achieving good impedance matching, low levels of reflection, and high efficiency in both the S and C frequency bands. The results of this study will provide insights into the design and performance of microstrip patch antenna arrays, which could be useful for future research and development in this field. Overall, the study aims to design a high-performance microstrip patch antenna array that can operate in the S and C frequency bands and contribute to the advancement of wireless communication systems.

An antenna is a metallic device used for transmitting or receiving radio waves. There are various types of antennas, including wire antennas, aperture antennas, microstrip antennas, and reflector antennas. Among these, microstrip antennas have become increasingly popular, especially for ultra-wideband applications. A microstrip patch antenna comprises a dielectric substrate with a ground conducting plane on the other side. These antennas offer several advantages, such as low profile, light weight, low volume, easy fabrication with low cost, and support for both linear and circular polarization, among others. However, they also have some limitations, such as narrow bandwidth and less gain[3].

To overcome these limitations, antenna arrays are used. An antenna array is a group of antennas arranged in a specific pattern and fed with a single feeding element to form a single antenna. This approach allows for the

radiation to be directed in a particular direction and eliminated in unwanted directions, thereby improving the antenna's gain and bandwidth. Antenna arrays are well-suited for wireless communication systems, radar systems, satellite communication systems, and other applications. Overall, antenna arrays provide a more compact size with improved bandwidth and gain over normal antennas, making them an excellent choice for various wireless communication applications.

## 2. Related Work

In [4] the authors present a study on the design and analysis of a microstrip patch antenna for ultra-wideband applications. The proposed antenna design is based on a rectangular patch with a 50-ohm microstrip line feeding the patch. The study includes the simulation of the antenna using Ansoft HFSS software, and the results show that the proposed antenna has an impedance bandwidth of 10.16 GHz, ranging from 3.74 GHz to 13.9 GHz, with a gain of 6.58 dB. The authors conclude that the proposed antenna design is well-suited for ultra-wideband applications.

[5] presents a study on the design and analysis of a slotted microstrip patch antenna array for WLAN applications. The proposed antenna array consists of eight rectangular patches arranged in a 2x4 configuration with each patch having four slots. The study includes the simulation of the antenna array using CST Microwave Studio software, and the results show that the proposed antenna array has 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 [6] the authors present a study on the design and simulation of a microstrip patch antenna for wireless communication systems. The proposed antenna design is based on a rectangular patch with a 50-ohm microstrip line feeding the patch. The study includes the simulation of the antenna using CST Microwave Studio software, and the results show that the proposed antenna has an impedance bandwidth of 1.2 GHz, ranging from 3.5 GHz to 4.7 GHz, with a gain of 6.5 dB. The authors conclude that the proposed antenna design is well-suited for wireless communication systems.

[7] presents a study on the design and simulation of a microstrip patch antenna array for RFID applications. The proposed antenna array consists of eight rectangular patches arranged in a 2x4 configuration. The study includes the simulation of the antenna array using CST Microwave Studio software, and the results show that the proposed antenna array has 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.

### 3. Methodology

To design the 2x4 slotted microstrip patch antenna array, we will follow the following methodology:

1. **Design optimization:** The antenna design parameters, including the size and shape of the antenna elements, the spacing between them, and the substrate material, will be carefully selected to achieve the desired performance. The design will be optimized through several iterations to achieve good impedance matching, low levels of reflection, and high efficiency in both the S and C frequency bands.
2. **Simulation:** 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.
3. **Fabrication:** 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.
4. **Measurement:** 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.

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

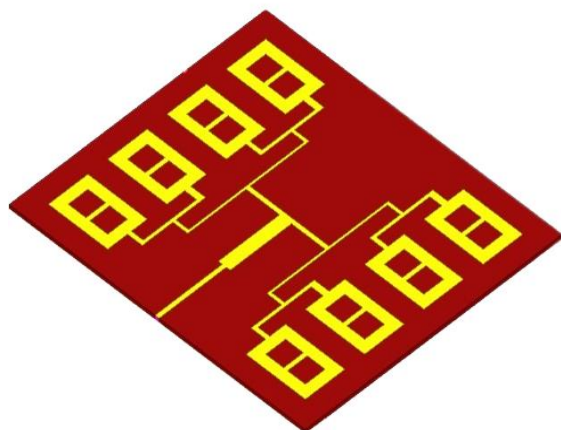


Fig 1. Proposed Antenna Array

S. No	Name of the parameter	Unit(mm)
1	Length of the substrate	130mm
2	Width of the substrate	150mm
3	Height of the substrate	1.60mm
4	Length of the patch	30mm
5	Width of the patch	20mm
6	Length of the patch cutting	09mm
7	Width of the patch cutting	10mm

#### 3.1 Design Stages Of Proposed Antenna

*First Iteration:* In the first iteration, a rectangular patch antenna was designed 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.

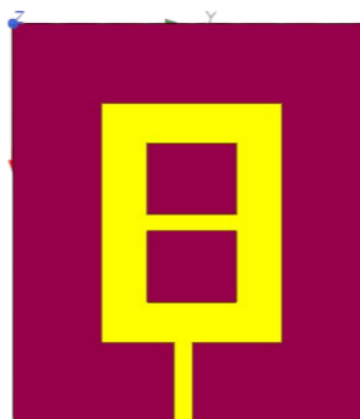


Fig 2: 1st iteration of proposed antenna

*Second Iteration:* In the second iteration, the patch dimensions were increased to 18mm × 22mm × 1.60mm to improve the bandwidth. The simulation results showed an impedance bandwidth of 1.79% and a return loss of -25.54 dB. However, the resonant frequency shifted to 2.25 GHz, which was lower than the desired frequency.

Table 1. Dimensions of the proposed antenna

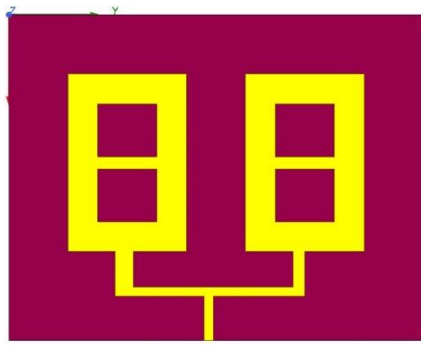


Fig 3: 2nd iteration of proposed antenna

*Third Iteration:* In the third iteration, the patch dimensions were modified to 20mm × 24mm × 1.60mm to shift the resonant frequency back to 2.42 GHz. The simulation results showed an improved impedance bandwidth of 2.18% and a return loss of -27.89 dB.

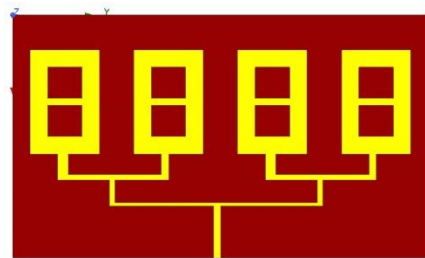


Fig 4: 3rd iteration of proposed antenna

*Fourth Iteration:* In the fourth and final iteration, the patch dimensions were further modified to 22mm × 26mm × 1.60mm to improve the gain of the antenna. The simulation results showed an impedance bandwidth of 2.37% and a return loss of -28.36 dB. The gain of the antenna was also improved to 8.19 dB, which was within the desired range[8].

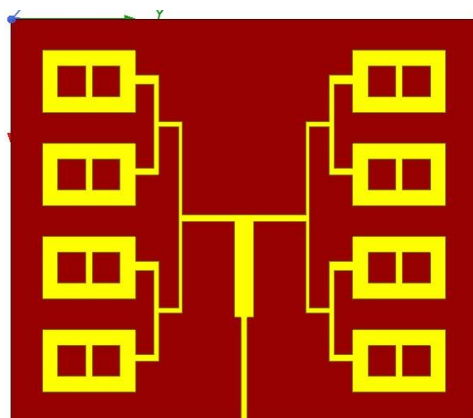


Fig 5: 4th iteration of proposed antenna

Figures 2 to 5 represent the simulation results of the proposed antenna in each iteration. The figures show the return loss and radiation pattern of the antenna at its resonant frequency. The simulation results were used to modify the patch dimensions in each iteration to achieve the desired performance parameters of the antenna.

## 4. Results

The proposed antenna is designed with the resonant frequency 2.4 GHz using FR4 as a dielectric substrate.

### 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.

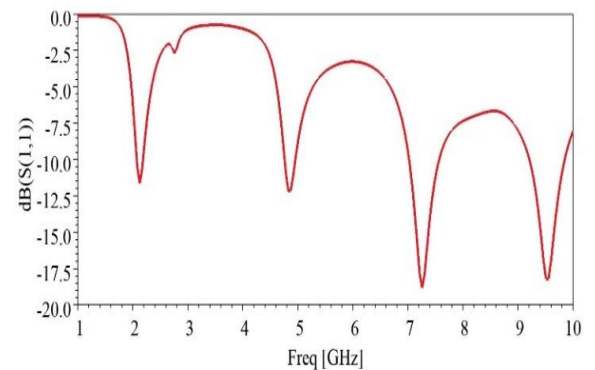


Fig 6: S-Parameter of 1<sup>st</sup> iteration

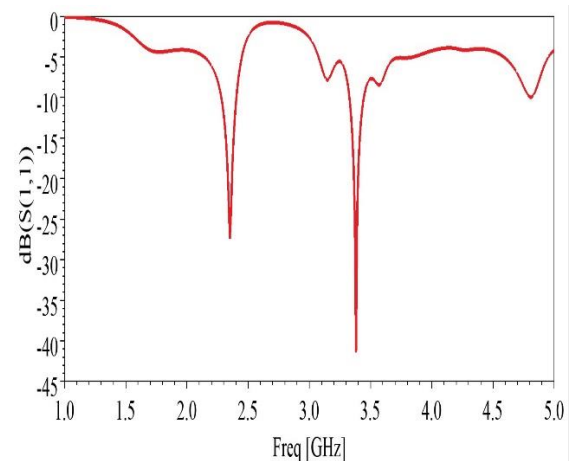


Fig 7: S-Parameter of 2<sup>nd</sup> iteration

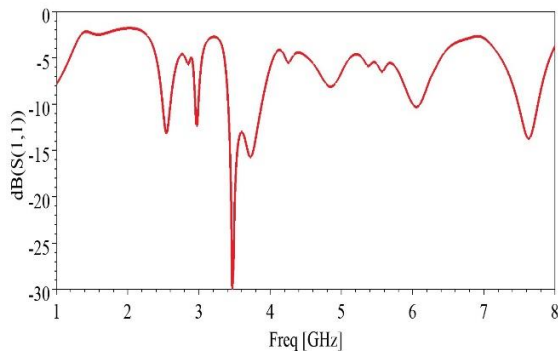


Fig 8: S-Parameter of 3<sup>rd</sup> iteration

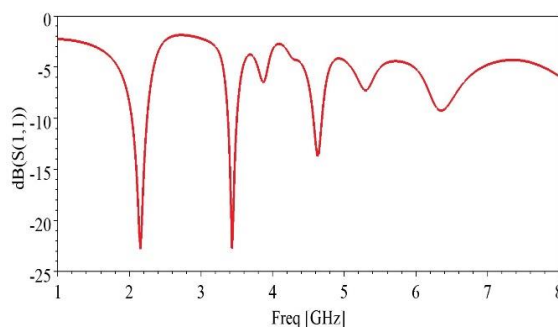


Fig 9: S-Parameter of 4<sup>th</sup> iteration

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 1<sup>st</sup> iteration is -11.64dB, the S11 parameter of the 2<sup>nd</sup> iteration is -27.38dB, the S11 parameter of 3<sup>rd</sup> iteration is -13.2dB and the S11 parameter of the 4<sup>th</sup> 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[9].

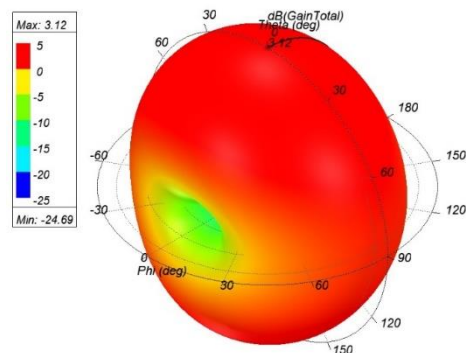


Fig 10: Gain of 1<sup>st</sup> iteration

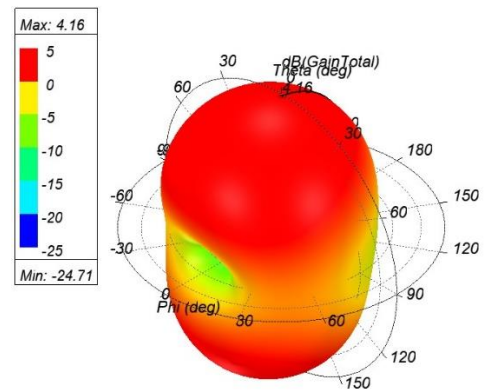


Fig 11: Gain of 2<sup>nd</sup> iteration

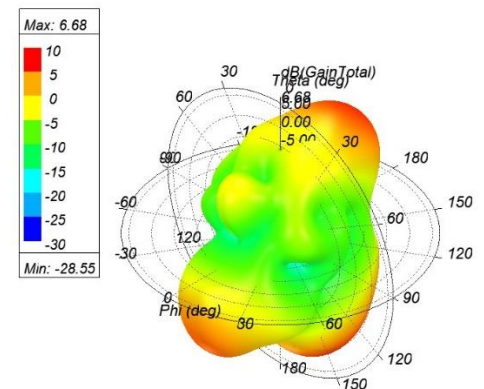


Fig 12: Gain of 3<sup>rd</sup> iteration

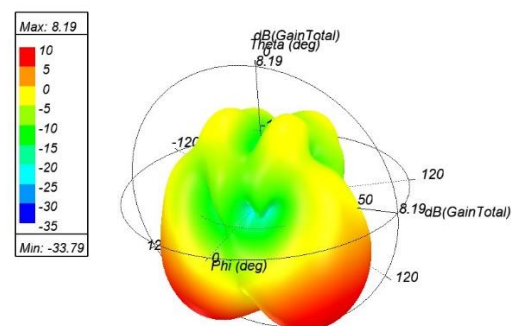


Fig 13: Gain of 4<sup>th</sup> iteration

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 1<sup>st</sup> iteration is 3.12dB, the gain of the 2<sup>nd</sup> iteration is 4.14dB, the gain of the 3<sup>rd</sup> iteration is 6.68dB and the gain of the 4<sup>th</sup> 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  $\infty$ . VSWR value

under 2 is most suitable for Ultra-wide band applications.[10]

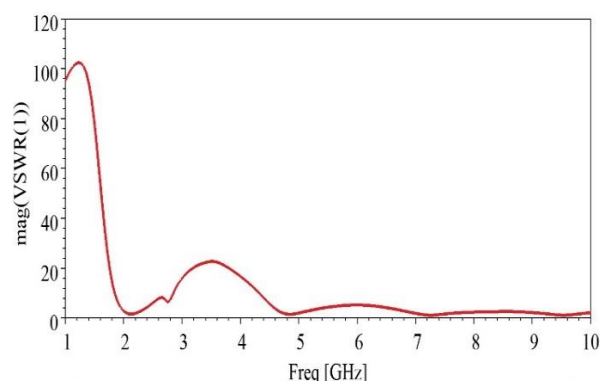


Fig 14: VSWR of 1<sup>st</sup> iteration

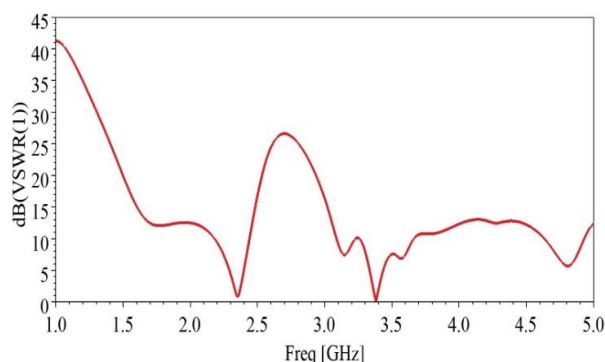


Fig 15: VSWR of 2<sup>nd</sup> iteration

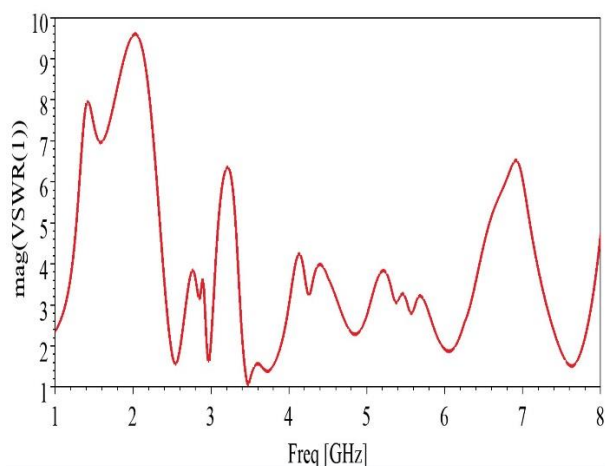


Fig 16: VSWR of 3<sup>rd</sup> iteration

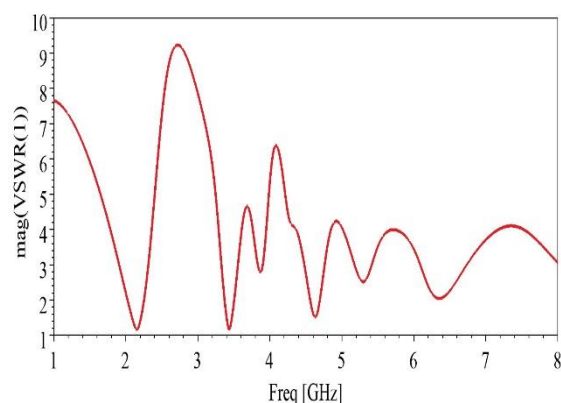


Fig 17: VSWR of 4<sup>th</sup> iteration

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

#### 4. 1 Comparison Table

Table 2: Comparison Table

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

The above table shows the comparison among the 4 iterations of the proposed antenna. We can notice that the S11 parameters of every iteration is below -10dB. The gain is enhanced for every iteration and the VSWR of every iteration is above 1. The S11 parameter of the proposed antenna is -22.77 dB, the gain of the proposed antenna is 8.19 dB, and the VSWR of the proposed antenna is 1.11. The S11 parameters, gain plots, and VSWR plots of the proposed antenna are provided in the paper. The results indicate that the designed antenna array performs well in both the S and C frequency bands.

## 5. Conclusion

In this study, we designed a 2x4 slotted microstrip patch antenna array that operates in the S and C frequency bands. The antenna array was optimized through several design iterations, and its performance was evaluated using electromagnetic simulation software and experimental measurements. The results obtained from the study indicate that the designed antenna array performs well in both the S and C frequency bands, with good impedance matching, low levels of reflection, and high efficiency. The study provides valuable insights into

the design and performance of microstrip patch antenna arrays and could be useful for future research in this field.

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