

Optimized Rectangular Microstrip Patch Antenna for Wireless Communications

L. Sarika^{1,*}, J. Pavani², K. Priyanka², B. Anjali, G. Naga Srivani²

Abstract

The design is for a microstrip patch antenna that is rectangular. The wireless local area network (WLAN) resonance frequency of the suggested antenna is 2.4 GHz. The antenna's frequency selection has made it ideal for use in wireless local area networks, or WLANs. The antenna design is optimised using the optometric feature of the High Frequency Structure Simulator software (HFSS) to increase the accuracy and efficiency of the suggested antenna. HFSS software is used to simulate and apply the microstrip line model approach. Equations for designing a rectangular patch are presented and verified by accurately generated outcomes. With a 5 dB gain, the antenna also shows a good radiation pattern. The suggested antenna's small size, affordability, and high performance make it a viable option for WLAN applications. Microstrip patch antennas' small size, simplicity of construction, and adaptability have made them indispensable parts of contemporary wireless communication systems. The optimisation of rectangular microstrip patch antennas to improve their performance metrics, such as gain, bandwidth, and radiation efficiency, is examined in this study. Antenna properties are significantly improved by using sophisticated design techniques such parasitic element integration, patch geometry modification, and substrate material selection. The impact of optimisation on wireless communication applications, including satellite systems, mobile networks, and the Internet of Things, is highlighted in the study along with simulation findings and practical considerations.

Keywords: Microstrip patch antenna, HFSS, return loss, VSWR, gain, bandwidth

INTRODUCTION

Because of their small size, low profile, simplicity in production, and adaptability, microstrip patch antennas are now essential parts of contemporary wireless communication systems. These antennas are extensively used in many different applications, such as radar systems, satellite communication, and

*Author for Correspondence

L. Sarika

E-mail: sarikamaha@gvpcew.ac.in

¹Assistant Professor, Department of Electronics and Communication Engineering, Gayatri Vidya Parishad College of Engineering for Women, Visakhapatnam, Andhra Pradesh, India

²Student, Department of Electronics and Communication Engineering, Gayatri Vidya Parishad College of Engineering for Women, Visakhapatnam, Andhra Pradesh, India

Received Date: December 21, 2024

Accepted Date: January 13, 2025

Published Date: February 08, 2025

Citation: L. Sarika, J. Pavani, K. Priyanka, B. Anjali, G. Naga Srivani. Optimized Rectangular Microstrip Patch Antenna for Wireless Communications. Journal of Telecommunication, Switching Systems and Networks. 2025; 12(1): 37–47p.

Wireless Local Area Networks (WLANs). Microstrip patch antennas are designed and analysed by taking advantage of the electromagnetic properties of a metallic patch that is printed on a dielectric substrate. A metallic radiating patch is usually positioned on one side of a dielectric substrate and supported by a conductive ground plane on the other side of a microstrip patch antenna. A key factor in influencing the antenna's performance characteristics is the dielectric material's thickness and permittivity. The antenna's resonance frequency, bandwidth, and radiation pattern are determined by the patch's size and form. One of the key advantages of microstrip patch antennas is their ability to be easily integrated into the design of various electronic devices and

communication systems. The advent of simulation tools like the High-Frequency Structure Simulator (HFSS) has further facilitated the design process, allowing engineers to analyse and optimize antenna performance without the need for extensive prototyping. Microstrip patch antennas are particularly well-suited for applications where size constraints are critical, making them a popular choice for portable and compact communication devices. As the demand for high-performance wireless communication continues to grow, the ongoing research and development in microstrip patch antenna technology aim to enhance their efficiency, bandwidth, and adaptability to diverse communication scenarios.

Because they enable seamless communication and fast data transfer in a variety of settings, wireless local area networks, or WLANs, have become an essential component of our everyday life. Antenna system design and optimisation are essential as the need for small and effective wireless communication systems grows. One of the key components in WLAN applications is the microstrip patch antenna, known for its compact size, low profile, and ease of integration into planar structures. This work uses the High-Frequency Structural Simulator (HFSS) to simulate and build an antenna with a rectangular microstrip patch for WLAN purposes. The antenna's performance metrics, including return loss, gain, and 3D polar plot, will be thoroughly investigated, and analysed to ensure optimal functionality in WLAN environments. The rectangular microstrip patch antenna, which is the focus of this design, is made up of a rectangular patch with dimensions of (L1) and (W2). The proposed antenna works on the Wireless Local Area Network (WLAN) frequency of 2.4 GHz which is based on IEEE 802.11b for WLAN applications.

In recent years, wireless communication has grown at an unparalleled rate, which has increased demand for small and effective antenna designs. The rectangular microstrip patch antenna's low profile, lightweight design, and simplicity of integration with printed circuit boards (PCBs) make it a popular option for wireless systems. However, bandwidth, gain, and efficiency, all crucial factors for contemporary communication standards, are frequently restricted in conventional systems. Rectangular microstrip patch antenna optimisation is necessary to satisfy the changing needs of wireless applications. To ensure compatibility with high-speed data transmission, reliable connectivity, and low energy consumption, this study focusses on important optimisation strategies that improve antenna performance.

LITERATURE SURVEY

Rectangular microstrip patch antennas have emerged as key components in wireless communication systems, particularly for WLAN applications operating at the popular 2.4 GHz frequency. The literature review provides insights into the historical development of microstrip patch antennas and recent advancements, emphasizing their relevance in the context of modern communication technologies. The evolution of microstrip patch antennas can be traced back to the mid-20th century, with notable contributions from researchers like Ernst Duda. While the early 1914 monopole antenna laid the groundwork, microstrip patch antennas gained prominence due to their simplicity and efficiency. The ease of construction and favourable power transfer characteristics made them attractive, leading to increased adoption during critical periods such as the First World War [1–6].

Recent years have witnessed a surge in interest regarding the use of rectangular microstrip patch antennas tailored for 2.4 GHz, a frequency range pivotal to WLAN applications, including Wi-Fi networks. Researchers have explored various design parameters to optimize the performance of these antennas in the context of wireless communication. A significant study explored the integration of microstrip patch antennas with dipole antennas for 1 GHz applications, highlighting their combined effectiveness in enhancing performance. While not directly at the 2.4 GHz frequency, this study underscores the adaptability of microstrip patch antennas to function in conjunction with dipole antennas. The microstrip patch antenna demonstrated a gain of approximately 6 dB at 1 GHz, showcasing its potential utility in wireless communication systems [7–9].

Addressing challenges associated with ground plane resistance, electromagnetic compatibility, and proximity to metallic objects is crucial for optimizing the effectiveness of rectangular microstrip patch antennas at 2.4 GHz. Researchers have explored innovative solutions, such as microstrip-to-microstrip dual dipole converters and patch dipole antennas, to overall performance of microstrip patch antennas in WLAN applications. The methodology for designing and optimizing rectangular microstrip patch antennas at 2.4 GHz involves a comprehensive approach. Parameters such as substrate material, patch dimensions, and ground plane configuration are meticulously analysed and adjusted using simulation tools like the High-Frequency Structure Simulator (HFSS). This iterative process enables engineers to fine-tune the antenna design to meet WLAN requirements, including efficient power transfer, appropriate gain, and a well-defined radiation pattern [8–11].

PROPOSED SYSTEM

Designing and evaluating a 2.4 GHz rectangular microstrip patch antenna (MPA) for use in wireless applications is the aim of this research. The antenna will be implemented on an FR-4 epoxy substrate with a thickness of 1.6 mm and a relative permittivity of 4.4, which is widely used due to its cost-effectiveness and reliability. A key focus of this research is to evaluate critical performance metrics, including return loss, which indicates how efficiently the antenna transmits power and minimizes reflection. Another essential parameter under investigation is the Voltage Standing Wave Ratio (VSWR), which reflects the impedance matching and overall efficiency of the antenna system. Additionally, the radiation patterns in both 2D and 3D will be analysed to understand the antenna's emission behaviour in different directions, providing insights into the strength and orientation of the radiated signals. The study will also measure the antenna's gain, a crucial indicator of its ability to transmit and receive signals effectively, and its potential performance in wireless communication systems like WLAN.

Design Methodology

A microstrip patch antenna, installed at ground level, consists of a metal patch with a dielectric material in between. These antennas offer highly flexible designs and can be easily manufactured on a PCB. The thickness of the ground plane or the patch is not relevant in this situation. These types of antennas employ high frequencies. The operating frequency of the antenna can be found using the following formula:

$$f_c = \frac{c}{2L\sqrt{\epsilon_r}}$$

Putting all the values we will get 2.4 GHz.

Width of the patch can be found using the following equation:

$$w = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}}$$

Effective dielectric constant:

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}}$$

Length correction in the patch due to fringing effect:

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)}$$

Effective length of patch will be calculated as:

$$R_{in}(y = y_0) = R_{in}(y = 0) \cos^2\left(\frac{\pi}{L}y_0\right)$$

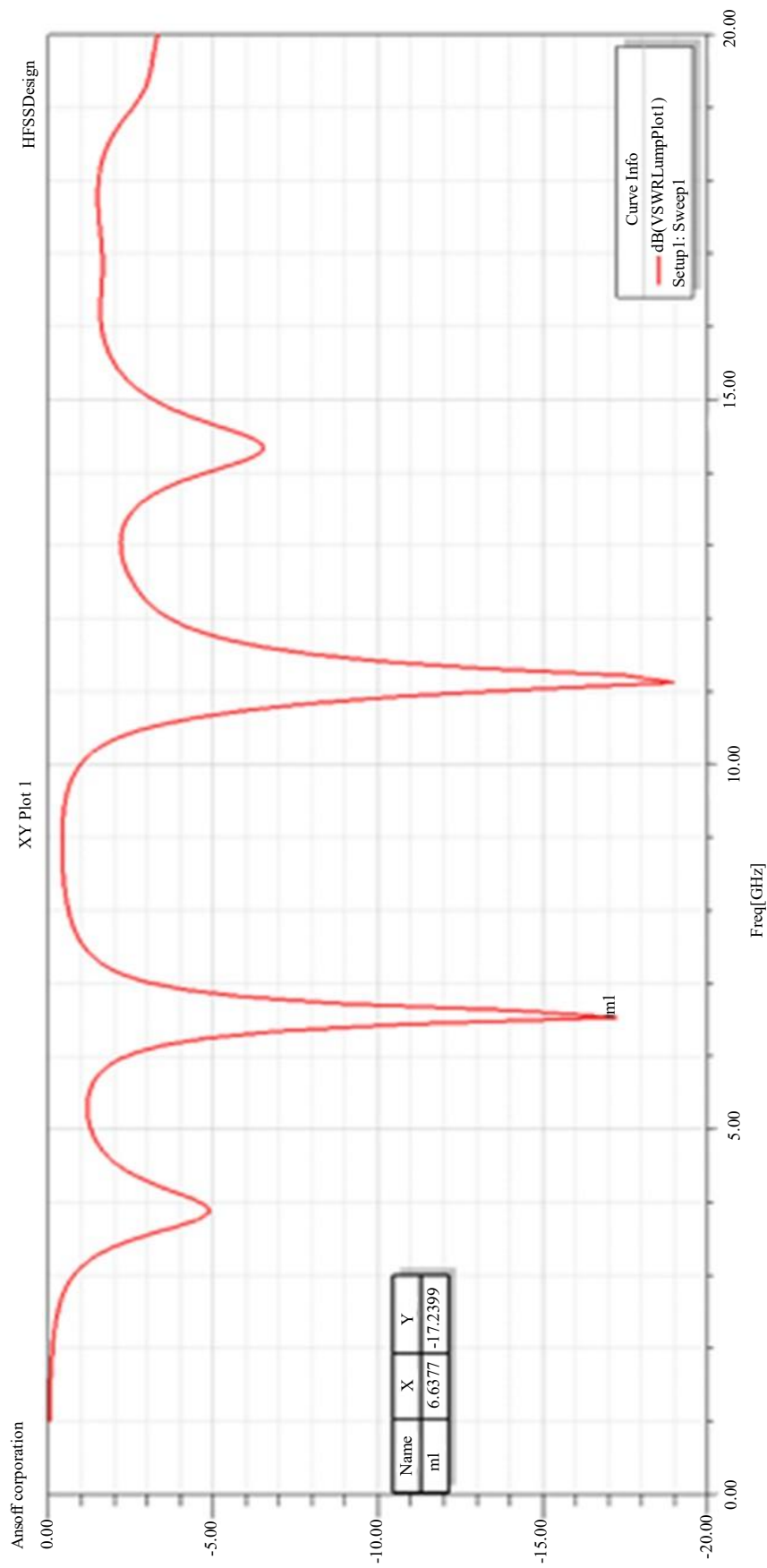


Figure 1. VSWR Plot.

Feed point position or the inset length calculation:

$$R_{in}(y = y_0) = R_{in}(y = 0) \cos^2\left(\frac{\pi}{L}y_0\right)$$

We know that Impedance when $y=y_0$ will be 50Ω but we also must calculate the impedance at the boundary of the patch, which was calculated using the equation below:

$$z_{in} = \frac{1}{Y_{in}} = R_{in} = \frac{1}{2G_1}$$

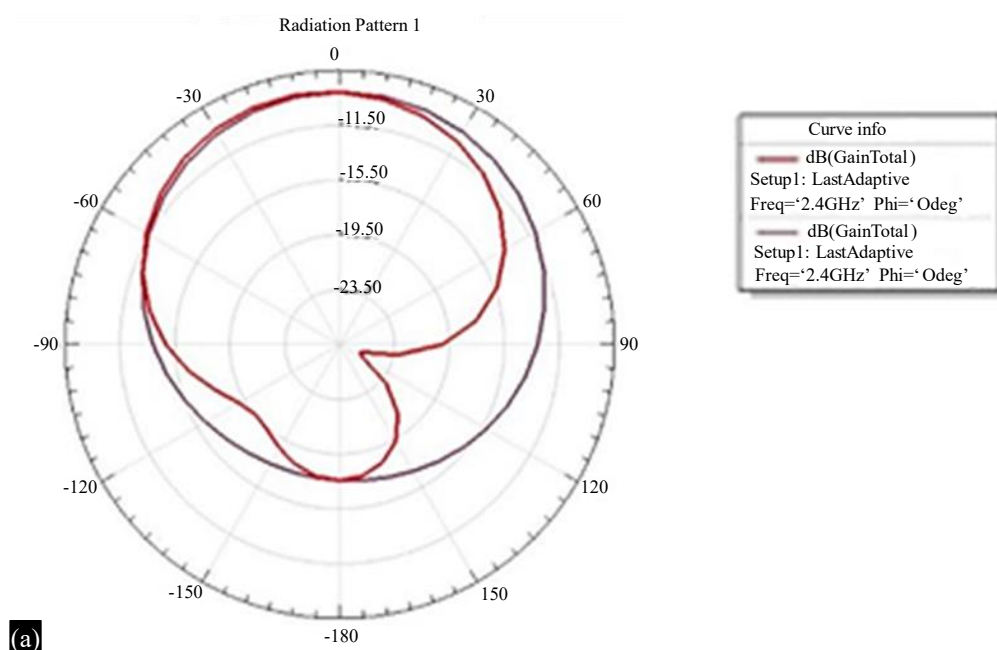
$$G_1 = \begin{cases} \frac{1}{90} \left(\frac{w}{\lambda_0}\right)^2 & \text{when } w \ll \lambda_0 \\ \frac{1}{120} \left(\frac{w}{\lambda_0}\right)^2 & \text{when } w \gg \lambda_0 \end{cases}$$

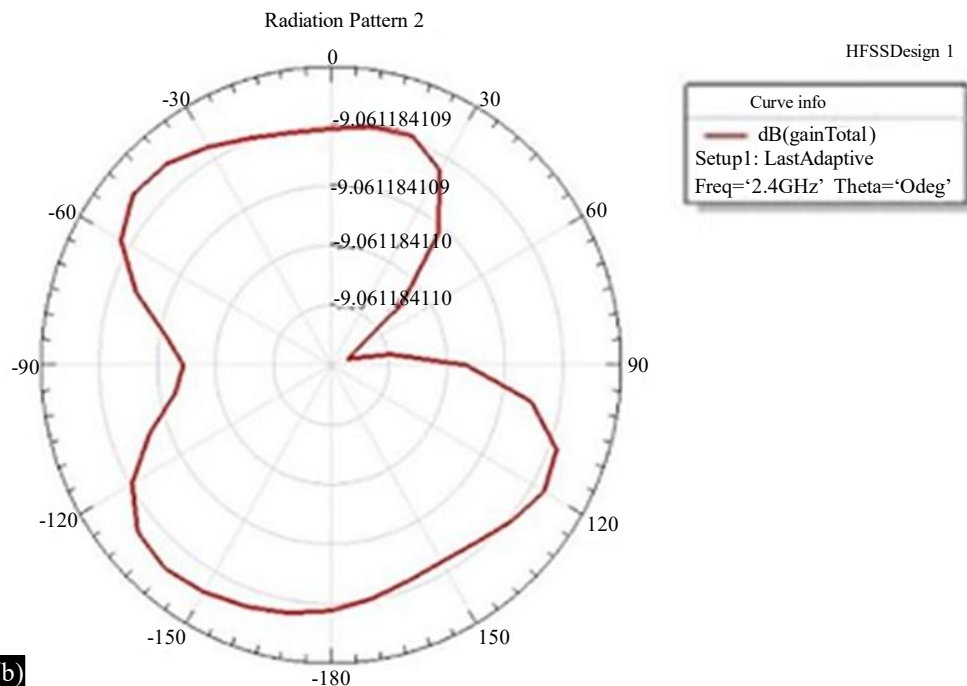
SIMULATION

In this study, we placed special emphasis on the length and positioning of the microstrip transmission line, which plays a crucial role in delivering power from the source to the antenna. The transmission line's length has been precisely determined to guarantee that there is little interference with the antenna's natural radiation pattern. This precise adjustment prevents the transmission line from disrupting the antenna's inherent radiation characteristics.

These design considerations form the foundation of our optimization strategy for the microstrip patch antenna. By meticulously determining the antenna's dimensions and transmission line specifications, we have aligned the design with the target operational frequency while achieving the desired radiation pattern. This approach offers an innovative contribution to enhancing antenna performance in wireless communication systems.

All simulation results are presented in the figures provided such as VSWR Plot shown in Figure 1. Far field radiation plot is shown in Figure 2 while its gain is shown in Figure 3. 3D Polar plot is shown in Figure 4 and axial ratio is shown in Figure 5 and for XY plot 4 VSWR is compared in Figure 6.





(b)

Figure 2. (a and b) Far field radiation.

RESULT ANALYSIS

Return Loss

The loss of signal strength caused by discontinuity in an optical fibre or transmission line is known as return loss. This discontinuity may be caused by a device that has been added to the line or by a mismatch with the terminating load. Decibels (dB) are typically used to express it as a ratio. The circular patch antenna shows a resonance peak at 11.1509 and gives return loss value equal to -17 dB.

Radiation Pattern

The radiation pattern remains uniform when one parameter is constant and another varies. However, null points are observed at 0 and 90° .

Bandwidth

The range of frequencies across which an antenna's performance, regarding certain features, complies to a stated standard is known as its bandwidth. The bandwidth and the percentage of bandwidth for a circular Microstrip patch antenna are determined as:

$$\text{Bandwidth: } f_h - f_l = 0.28 \text{ GHz}$$

$$\text{Percentage of bandwidth: } \{(f_h - f_l) \times 100\} / f_c = 2.517\%$$

Where,

$$f_h = 6.705,$$

$$f_l = 6.425, \text{ and}$$

$$f_c = 11.1206.$$

Gain

An antenna's gain is calculated by dividing the radiation strength in each direction by the radiation intensity that would result from radiating all of the power evenly in each direction. Since all of the power supplied to it is radiated equally well in all directions, it has a gain of unity ($g=1$ or $G=0$ dB) in all directions. The gain value of the rectangular patch antenna is -5.3987 dB.

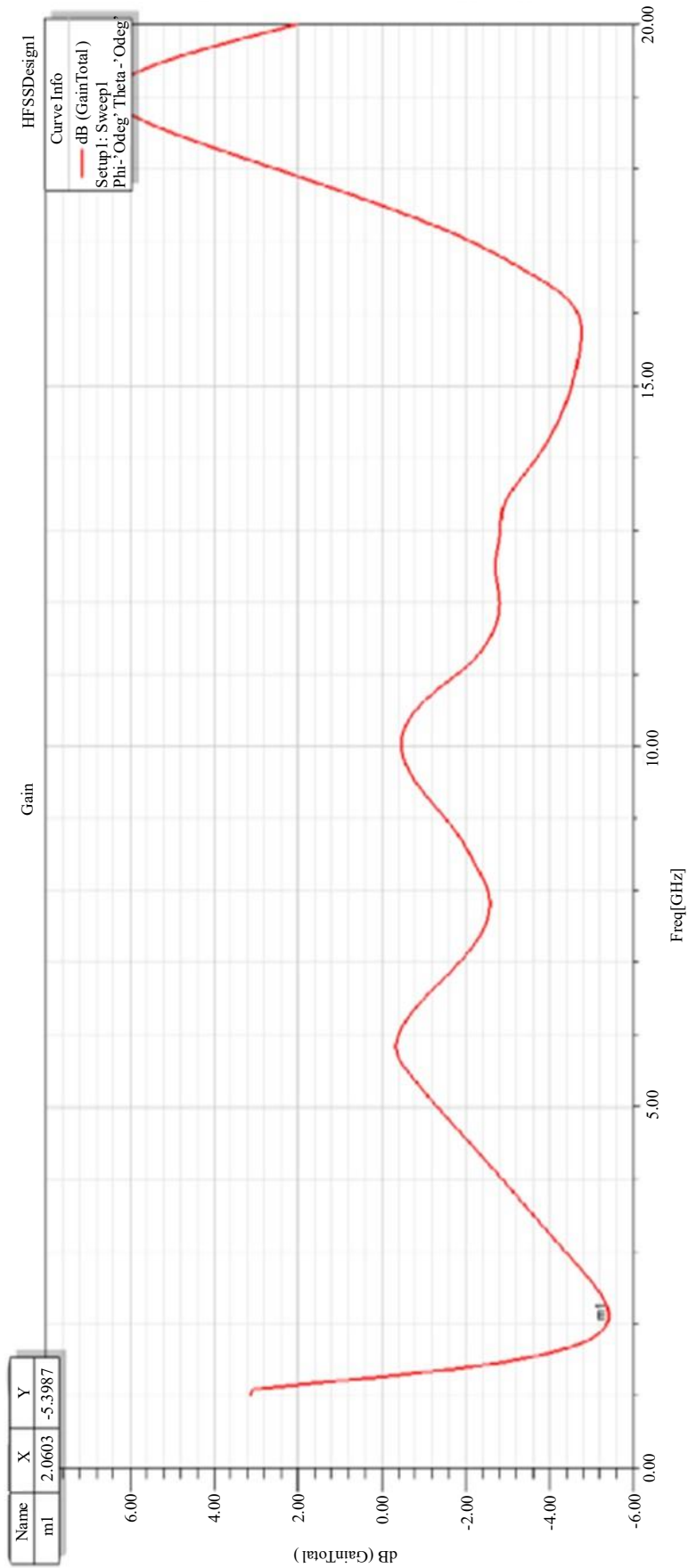


Figure 3. Gain.

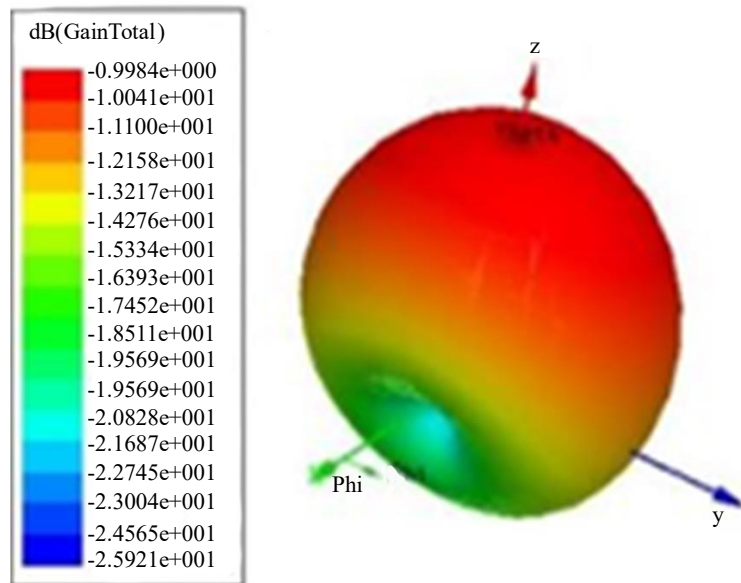


Figure 4. 3D polar plot.

Table 1. Parameters observed and their value.

S. No.	Parameters	Value
1.	Return Loss	-17 dB
2.	Bandwidth	0.28 GHz
3.	Bandwidth %	2.517%
4.	Gain	-5.3987
5.	VSWR	1.9590
6.	Operating Frequency	2.4 GHz

VSWR

Although it is not exactly an antenna characteristic, the standing wave ratio (SWR), also called the voltage standing wave ratio (VSWR), is used to characterise how well an antenna performs when connected to a transmission line. It is discovered that the suggested model's VSWR is almost 1.9590.

All the results value are presented in tabulated form in Table 1.

CONCLUSION

A rectangular microstrip patch antenna operating at UWB frequencies was successfully conceived and simulated. It is evident from looking at the return loss, or VSWR, that this antenna operates within the intended UWB frequency range. This study used the Advanced development System and the Ansoft High Frequency Structure Simulator to develop our UWB rectangular antenna in detail. As the view develops, we might broaden our investigation to examine how different slot antennas impact the bandwidth and resonance frequency. Additionally, microstrip antennas are employed in mobile communication, RFID (radio frequency identification), and healthcare.

Wi-Fi and Bluetooth services will benefit from the antenna's 10 dB operational bandwidth, which falls between 80 and 280 MHz. At 11.1206 GHz, the antenna's return loss is -17 dB. HFSS software simulates this designed antenna. By using microstrip line technology, a sufficient bandwidth was obtained for this antenna, allowing for the achievement of the target frequency of 2.4 GHz and a VSWR value of 1.9590. The microstrip antenna's design maximises coverage of WLANs. The suggested antenna is highly appealing for both present and future WLAN applications because it is extremely small, simple to construct, and fed by a 50 microstrip line.

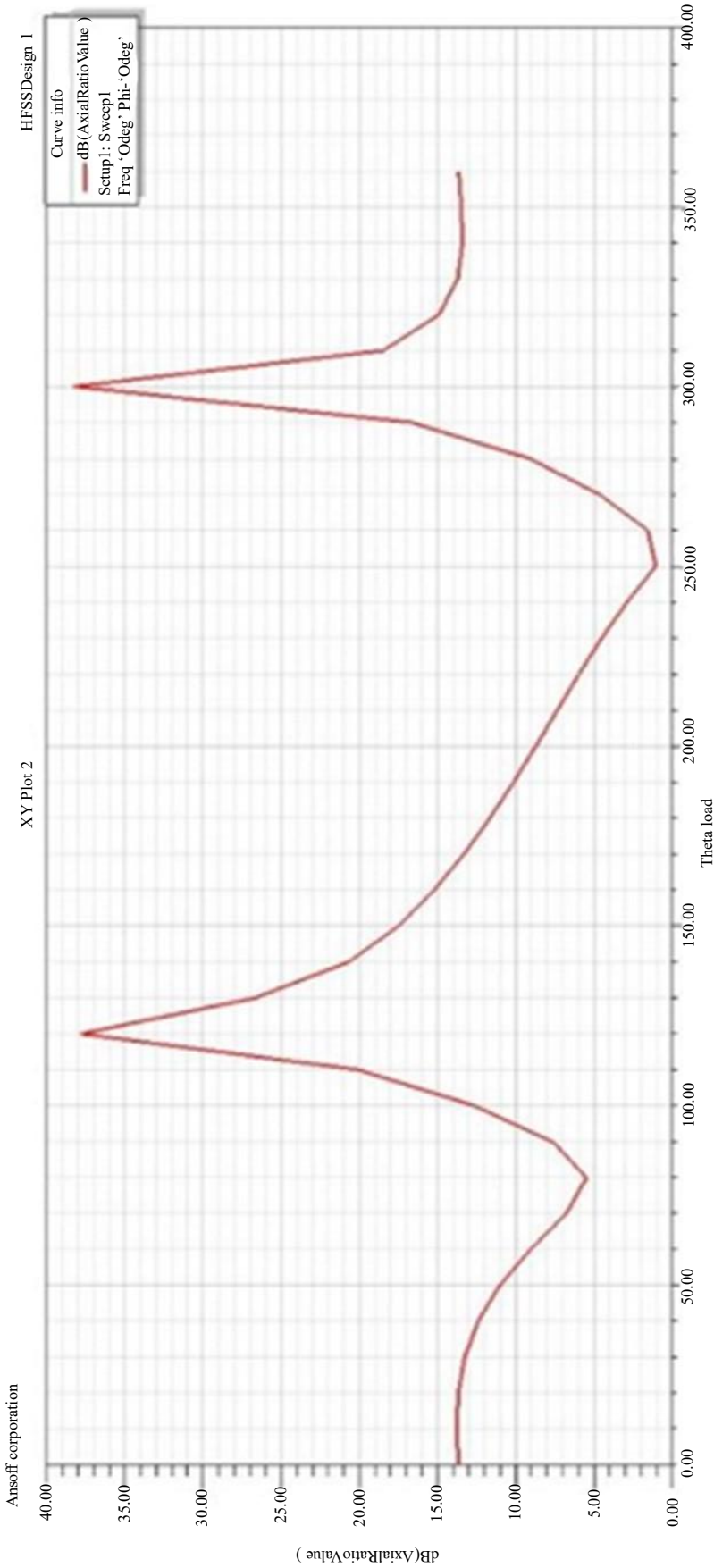


Figure 5. Axial ratio.

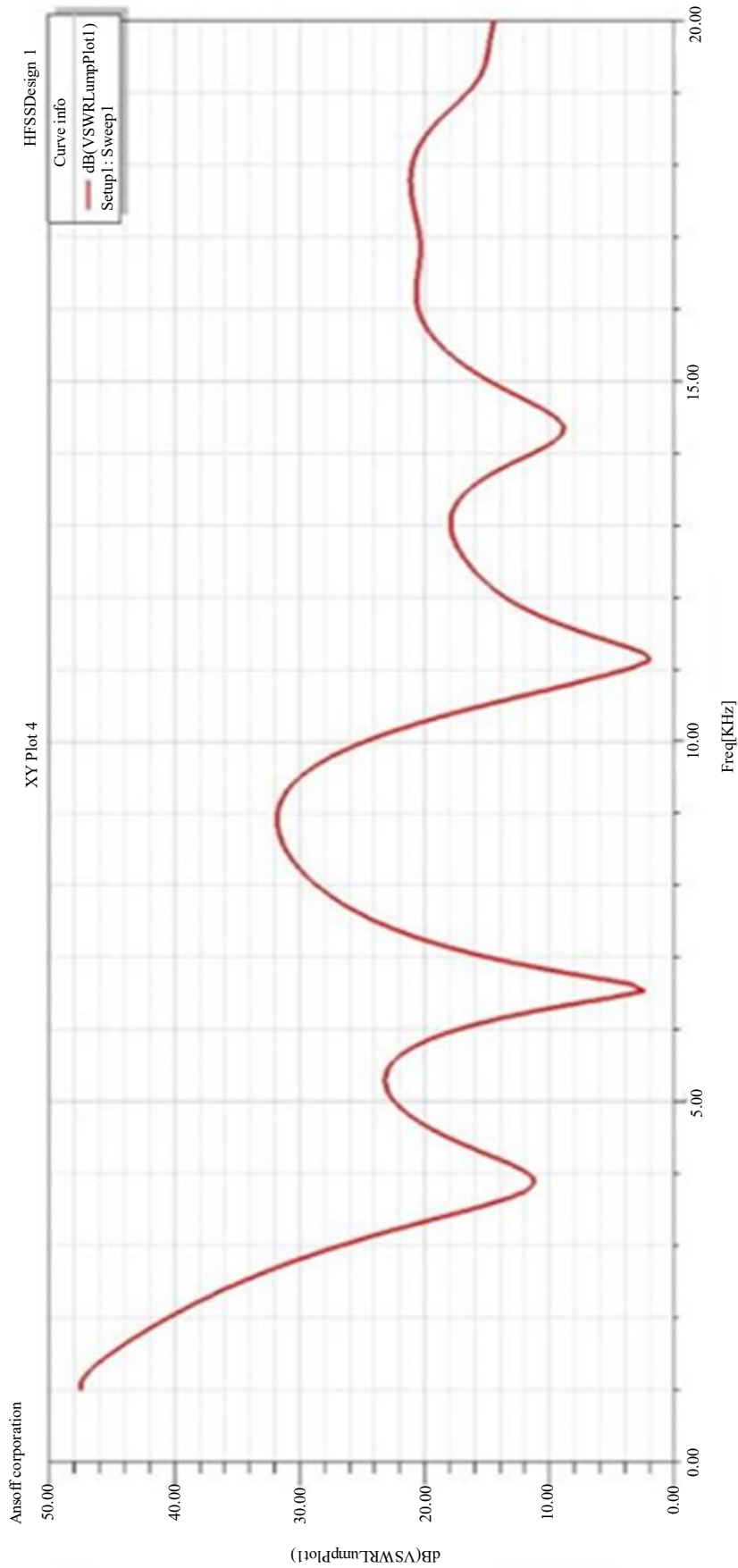


Figure 6. VSWR for XY Plot 4.

Future Scope

With the growing need for compact, efficient, and high-performance antennas in wireless networks, microstrip patch designs are increasingly being optimized for higher bandwidth, multi-frequency operation, and better radiation efficiency. Future advancements are likely to focus on integrating materials like metamaterials and flexible substrates to enhance performance, allowing these antennas to function effectively in devices with compact form factors. Additionally, as 5G and 6G networks expand, rectangular microstrip patch antennas will play a pivotal role in supporting higher data rates, low latency, and more efficient power usage. Their adaptability to various wireless applications, including IoT, wearable technology, and high-frequency satellite communication, underscores their relevance in next-generation wireless ecosystems, making them a key component in the future of telecommunications.

REFERENCES

1. Shera Prabjyot Singh, Ashish Singh, Deepak Upadhyay, Sunilkumar Pal, Mahesh Munde. Design and Fabrication of Microstrip Patch Antenna at 2.4 Ghz for WLAN Application using HFSS. IOSR Journal of Electronics and Communication Engineering (IOSR-JECE). Special Issue - AETM'16. 2016; 1–6.
2. Tanish Narang, Shubhangi Jain, Patel BD. Microstrip Patch Antenna- A Historical Perspective of the Development. Conference on Advances in Communication and Control Systems 2013 (CAC2S 2013). Atlantic Press; 2013; 445–449.
3. Ogunlade Michael Adegoke, Ismael Saad Eltoum. Analysis and Design of Rectangular Microstrip Patch Antenna AT 2.4Ghz WLAN Applications. International Journal of Engineering Research & Technology (IJERT). 2014 Aug; 3(8): 1239–1242. 10.17577/IJERTV3IS081043.
4. James JR, Hall PS. Handbook of microstrip antennas. IEE Electromagnetic Waves Series, Issue 28. Peter Peregrinus Ltd.; 1989. <https://doi.org/10.1049/PBEW028F>
5. Balanis CA. Antenna Theory-Analysis and Design. 2nd Edn. India: John Wiley and Sons; 2007; 728–730.
6. Girish Kumar, Ray KP. Broadband microstrip antennas. UK: Artech House; 2003.
7. Mailloux R, McIlvanna J, Kernweis N. Microstrip array technology. IEEE Trans Antennas Propag. 1981 Jan; 29(1): 25–37. doi: 10.1109/TAP.1981.1142525.
8. Ansoft Corporation. HFSS User's Guide, version 10 & 12. Pittsburgh, CA: Ansoft Corporation; 2005. [Online]. Available from <https://anlge.umd.edu/HFSSv10UserGuide.pdf>
9. Nandini Ammanagi, Rahul Khadilkar, Akash Harwani, Disha Budhlani, Disha Dembla. Comparison of the performance of Microstrip Antenna at 2.4GHz Using Different Substrate Materials. Int J Eng Adv Technol. 2014 Apr; 3(4): 73–75.
10. Siva Sundara Pandian S, Suriyakala CD. Novel Octagonal UWB Antenna for Cognitive Radio. IOSR Journal of Electronics and Communication Engineering (IOSR-JECE). 2012 Sep–Oct; 3(5): 21–26.
11. Al-Nuaimi MKT. On the miniaturization of microstrip line fed slot antenna using various slots. 2010 International Conference on Computer and Information Application, Tianjin, China. 2010; 390–393. doi: 10.1109/ICCIA.2010.6141618.