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Design and Development of Dual Band Antenna for Wireless Communication

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Abstract: There has been a significant amount of research conducted in recent times with the purpose of constructing and optimizing dual-band microstrip patch antennas, particularly for applications that include wireless communication technologies such as Wi-Fi and 5G. With the growing demand for high-speed wireless connectivity, antennas now play a critical role in electronic devices. A dual-band antenna, capable of resonating at two distinct frequencies, is the focus of this study. In this research work, a dual-band antenna is designed with a unique geometry optimized for compactness and performance. This antenna is configured to operate at two specific resonance frequencies, 2.4 GHz and 3.5 GHz. The design and simulation were carried out using the High Frequency Structure Simulator (HFSS) Student R2 version. The return losses at 2.4 GHz and 3.5 GHz are -27.1633 dB and -28.5333 dB, respectively, ensuring excellent impedance matching. The proposed antenna achieves a maximum gain of 4.7 dB, with the magnetic field oriented in the YZ plane and the electric field confined to the XZ plane, peaking in the Z direction. This design demonstrates its suitability for high-speed dual-band wireless communication applications.

Keywords: Micro strip Patch Antenna, Dual-band Antenna, Return loss, Magnetic field.

I. INTRODUCTION

Antennas are fundamental components of any wireless communication system, serving as the vital interface between electromagnetic waves propagating through space and the electrical signals processed by electronic devices. Their primary role is to efficiently transmit and receive electromagnetic waves, enabling seamless communication across various applications. Over the years, significant advancements in antenna design have been achieved to meet the evolving demands of modern communication systems. Among these developments, dual-band antennas have emerged as a critical solution, offering the ability to operate at multiple frequencies within a single compact structure.

Dual-band antennas are specifically designed to support communication at two distinct frequency bands, making them indispensable in applications requiring flexibility and high data rates, such as Wi-Fi systems, 5G networks, and IoT (Internet of Things) devices. By operating at multiple frequencies, these antennas enable compatibility with diverse wireless standards, reducing the need for multiple antennas and enhancing system efficiency. Typically, a dual-band antenna consists of a radiating element that is carefully engineered to resonate at the desired frequencies, supported by a dielectric substrate and grounded to a conductive plane. The substrate material and structural design play a significant role in determining the antenna's performance, influencing its impedance matching, radiation pattern, and gain.

The motivation behind designing dual-band antennas stems from the increasing demand for high-speed and reliable wireless connectivity. For instance, the 2.4 GHz band is widely used for Wi-Fi and IoT applications, while the 3.5 GHz band is a key frequency for emerging 5G networks. Combining these frequencies within a single antenna offers the advantage of compactness and compatibility, catering to the needs of modern compact electronic devices.

Despite their numerous advantages, dual-band antennas present certain design challenges, such as ensuring optimal impedance matching and minimizing interference between the two bands. Achieving high gain and efficient radiation patterns at both frequencies requires precise optimization of the antenna’s geometry and materials. Simulation tools, such as the High-Frequency Structure Simulator (HFSS), play an essential role in addressing these challenges. HFSS enables engineers to model and analyse the electromagnetic behaviour of dual-band antennas with high precision, facilitating the optimization of critical parameters such as patch shape, substrate material, and overall dimensions.

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This project focuses on the design and development of a dual-band antenna operating at 2.4 GHz and 3.5 GHz, leveraging advanced simulation techniques to achieve superior performance. The goal is to create a compact, high-efficiency antenna that meets the growing demands of wireless communication systems while addressing the challenges of dual-frequency operation.

II. METHODS AND MATERIALS

- Step 1: Size of the Width: for designing this proposed antenna, the primary step is to determine the width of the patch. This value is determined by this following equation: ……..…..(1)

Where, W =patch width, ε*r*= substrate's relative permittivity, fr = desired resonant frequency, c = speed of light.

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

- Step 2: Effective dielectric constant, εreff: This content Is determined by using this equation below:

$$_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Where, h = width of the dielectric substrate ..……..… (2)

- Step 3: Estimation of Effective length, **L**eff : This parameter Is determined by using this equation below: ……...…(3)

$$L_{eff} = \frac{c}{2fr\sqrt{\epsilon_{reff}}}$$

- Step 4: Estimation of the extent in length, ΔL : As there is an impact of the fringing field is available throughout the patch, it seems bigger comparatively than its initial size. So, for finding the extended length of the proposed antenna, this following equation is used: …………(4)

- Step 5: Estimation of Actual Length of the Patch(L). This parameter is determined by using this following equation:

$L = L\text{eff} - 2\Delta L$ …………. (5)

Step 6: Estimation of Ground Dimension (Wg, Lg):

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

Wg = 6h + W ……….(6)
Lg = 6h + L ……….(7)

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MATERIAL USED:

SOFTWARE TOOL:

HFSS STUDENT VERSION REVISION 2

HARDWARE MATERIAL:

- FR4 SUBSTRATE
- COPPER
- CONNECTING WIRE
- ROUTER

HARDWARE AND SOFTWARE IMPLEMENTATION:

Software implementation:

Software implementation for the design of a microstrip patch antenna using the HFSS (High-Frequency Structure Simulator) tool as shown in "Fig 1" involves creating a detailed 3D model of the antenna.

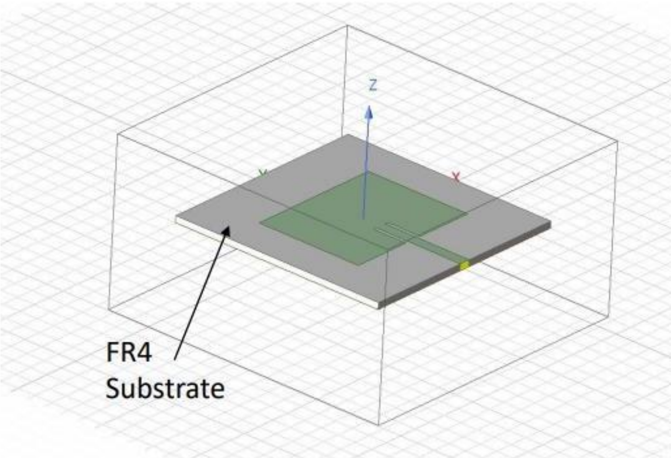

Fig: 1 - HFSS Software Design

HARDWARE IMPLEMENTATION:

The manufacturing of a Microstrip Patch Antenna for S-band applications at 2.4 GHz involves several key hardware components. The antenna primarily consists of an FR4 substrate, chosen for its favourable dielectric properties and cost-effectiveness. The copper patch, which acts as the radiating element, is precisely etched onto the substrate to achieve the desired resonant frequency and radiation characteristics. Additionally, a ground plane made of copper is placed on the opposite side of the substrate to enhance the antenna's performance. cost-effectiveness. The copper patch, which acts as the radiating element, is precisely etched onto the substrate to achieve the desired resonant frequency and radiation characteristics. Additionally, a ground plane made of copper is placed on the opposite side of the substrate to enhance the antenna's performance as shown in the "Fig 2".

We have developed a microstrip patch antenna and integrated it as an application for a Wi-Fi router, as depicted in "Fig 3". This antenna design is an innovative solution that combines simplicity, efficiency, and compactness, making it highly suitable for modern wireless communication systems. The microstrip patch antenna consists of a radiating patch made of copper, positioned on a dielectric substrate, with a copper ground plane underneath. This configuration ensures excellent electromagnetic performance while maintaining a lightweight and cost-effective structure.

The developed antenna is connected to the router's circuit board, where it acts as the main transceiver for wireless communication. By leveraging the design advantages of microstrip technology, this antenna enables the Wi-Fi router to achieve improved performance in terms of signal strength, bandwidth, and range.

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The compact size and low profile of the microstrip patch antenna make it an ideal choice for integration into compact networking devices without compromising aesthetics or functionality.

This application demonstrates the potential of microstrip patch antennas in enhancing the efficiency and reliability of Wi-Fi routers, ensuring high-speed data transmission and seamless connectivity. Furthermore, the scalable design of the antenna allows for customization to meet specific frequency requirements, such as 2.4 GHz or 5 GHz, commonly used in Wi-Fi networks. This development not only addresses the increasing demand for high-performance wireless devices but also highlights the versatility of microstrip patch antennas in various communication applications, including domestic, industrial, and IoT (Internet of Things) environments.

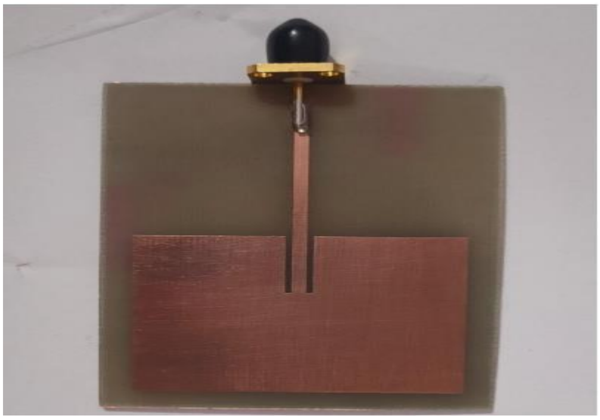

Fig: 2 Microstrip Patch Antenna

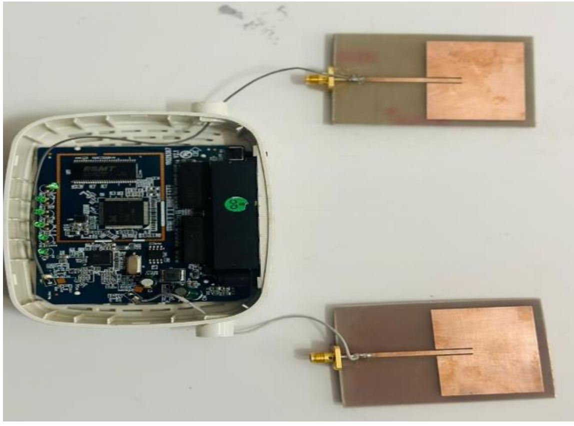

Fig:3 Hardware implementation on router

DIMENSION DETAILS:

SI. No	Parameters	Dimensions in mm
1	Substrate Length	60
2	Substrate Width	60
3	Substrate Height	1.6
4	Ground Plate Length	60
5	Ground Plate Width	60
6	Patch Length	34
7	Patch Width	24
8	Feed Line (Cut) Height	9.5
9	Feed Line (Cut) Width	5
10	Feed Line (Insect Line) Length	3
11	Port Height	1.6
12	Port Width	3

TABLE: 1

TABLE 1 gives the dimension details of the microstrip dual band.

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III. RESULT

S-Parameter Analysis:

Using the HFSS tool, S-parameter analysis evaluates the microstrip patch antenna's performance. The S11 parameter, shown in "Fig 4" represents return loss and reflection coefficient, indicating impedance matching. A low S11 value at the operating frequency (e.g., 2.4 GHz) signifies good matching, ensuring efficient power transfer and minimal signal loss.

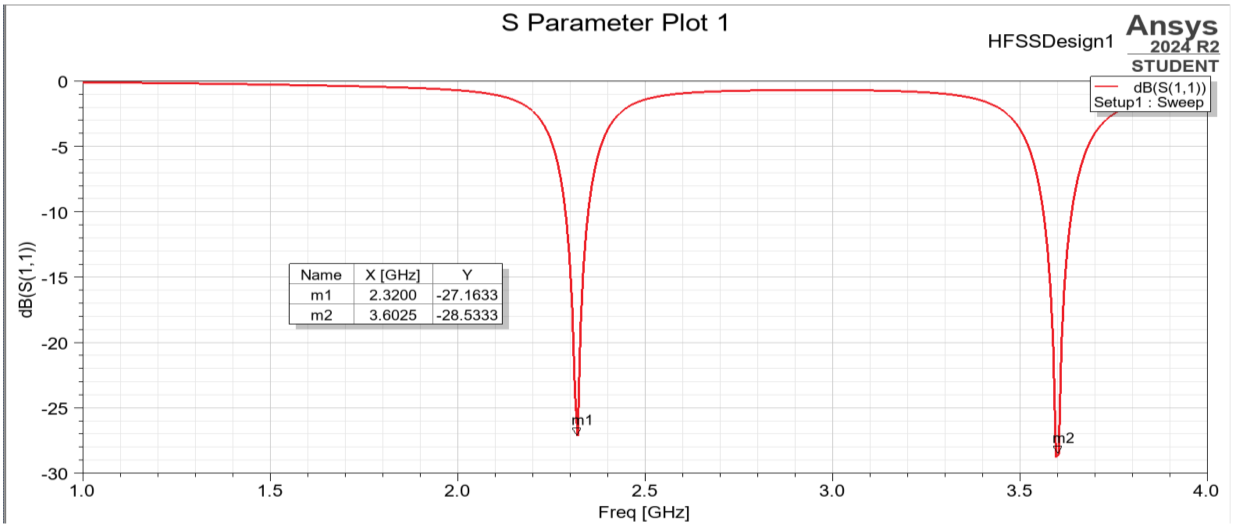

Fig:4 S Parameter

VSWR Plot:

VSWR, derived from S11 analysis, measures power transmission efficiency. As shown in "Fig 5" a VSWR close to 1:1 indicates minimal reflection and optimal impedance matching. Lower VSWR values signify better antenna performance and efficient operation at the target frequency.

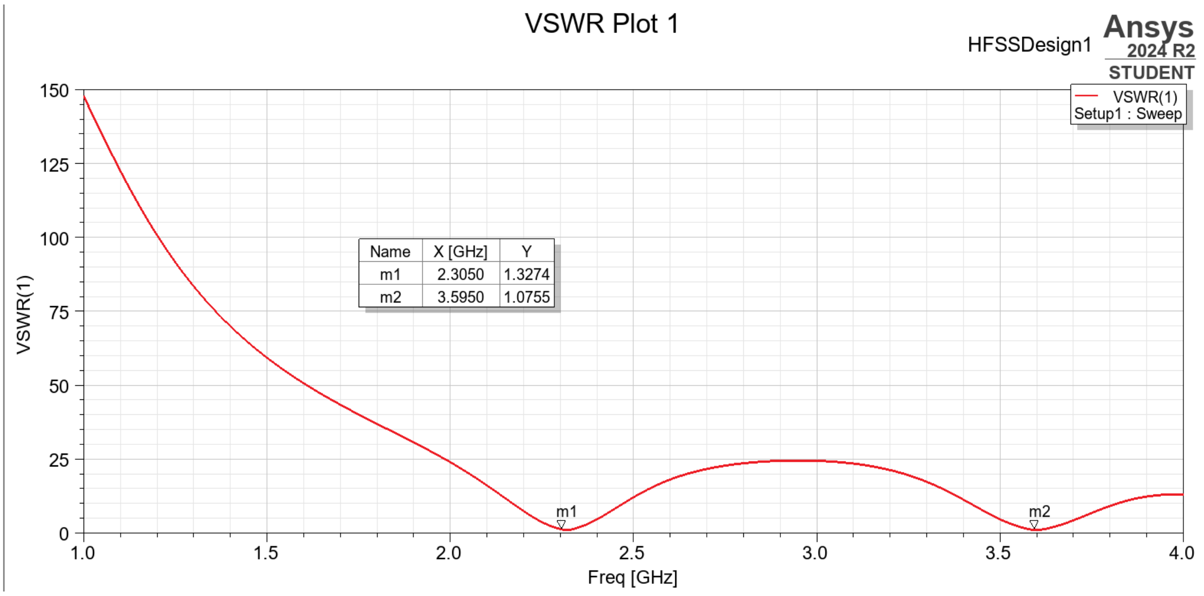

Fig:5 VSWR Plot

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Radiation Pattern:

The radiation pattern, analysed using HFSS and shown in "Fig 6" depicts energy distribution in space. It highlights directivity and beamwidth, ensuring effective power radiation in desired directions for optimal performance.

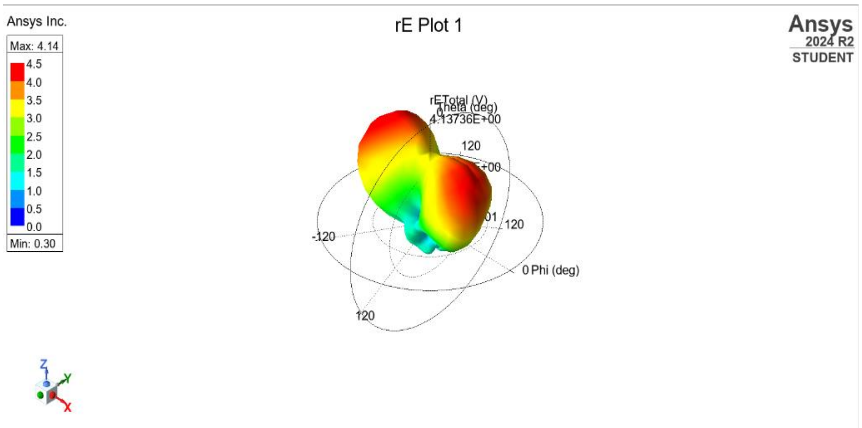

Fig:6 Radiation Pattern [3D]

Directivity Plot:

The directivity plot, based on S-parameters like S11 and S21, illustrates directional radiation characteristics. Shown in "Fig 7" it evaluates gain and efficiency, ensuring focused signal transmission and reliable antenna design.

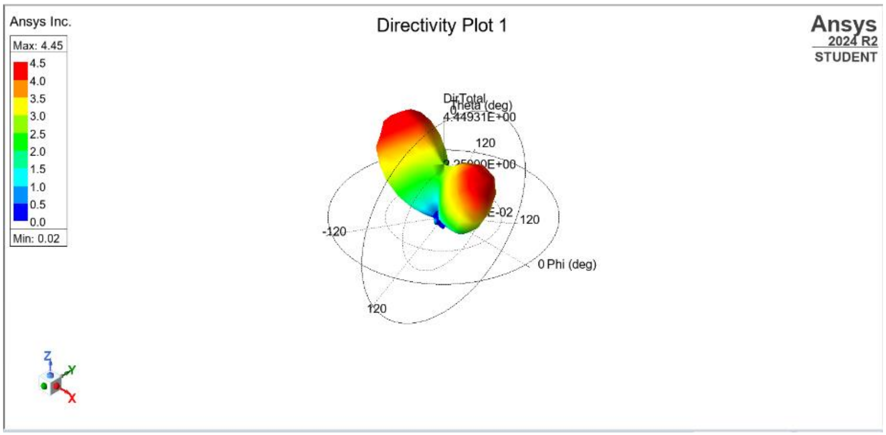

Fig:7 Directivity Plot

IV. CONCLUSION

In this study, a novel method for designing a dual-band microstrip patch antenna tailored for wireless communication applications has been presented. The approach involves optimizing the geometry and introducing specific design enhancements to achieve dual-band operation at 2.4 GHz and 3.5 GHz. The resulting antenna exhibits return losses of -27.1633 dB at 2.4 GHz and -28.5333 dB at 3.5 GHz, with VSWR values of 1.09 and 1.05, respectively, indicating excellent impedance matching and minimal signal reflection.

The proposed design is particularly advantageous for dual-band wireless communication due to several key attributes: its compact size, facilitating integration into modern devices; its straightforward fabrication process, ensuring cost-effective production; its enhanced gain of 4.7 dB, which improves signal strength and coverage; and its satisfactory radiation efficiency, ensuring effective transmission and reception across both frequency bands. Overall, the proposed antenna design offers a highly efficient and practical solution for dual-band wireless communication applications.

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REFERENCES

[1] S. T.-Van, J. M. Lee, Y. Yang, K.-Y. Lee, and K. C. Hwang, "A Sidelobe-Reduced, Four-Beam Array Antenna Fed by a Modified 4 * 4 Butler Matrix for 5G Applications", IEEE Transactions on Antenna and Propagation, 67(7), 4528-4536, 2018.

[2] A. Bansal, R. Gupta, "A Review on Microstrip Patch Antenna and Feeding Techniques", International Journal of Information Technology, 12(1), 149-152, 2020.

[3] R. M. González, R. Linares, L. M. Peralta, "Wideband Microstrip Antenna Design for 3G and LTE (4G) Mobile Phones", IEEE International Autumn Meeting on Power, Electronics and Computing, 1- 6, 2018.

[4] K. B. Babu, B. Anuradha, "Design and Performance Analysis of Triband Wang shaped MIMO Antenna", International Journal of Information Technology, 12(2), 556-559, 2020.

[5] L. Kong, X. Xu, "A Compact Dual-Band Dual-Polarized Microstrip Antenna Array for MIMO-SAR Applications", IEEE Transactions on Antenna and Propagation, 66(5), 2374-2381, 2018.

[6] J. -F. Lin, Q. -X. Chu, "Enhancing Bandwidth of CP Microstrip Antenna by Using Parasitic Patches in Annular Sector Shapes to Control Electric Field Components", IEEE Antennas and Wireless Propagation, 17(5), 924-927, 2018.

[7] Khiewlamyong, Arachaporn, C. Pirak, "Loop Antenna Design for Smart Energy Meter", International Conference on Circuits, System and Simulation, 7 , 2011.

[8] M. S. Islam, M. T. Islam, M. A. Ullah, G. K. Beng, N. Amin, N. Misran, "A Modified Meander Line Microstrip Patch Antenna with Enhanced Bandwidth for 2.4 GHz ISM-band Internet of Things (IoT) Applications", IEEE Access, 7, 127850-127861, 2019.

[9] A. Sarma, K. Sarmah, K. K. Sarma, "Low Return Loss Slotted Rectangular Microstrip Patch Antenna at 2.4 GHz", International Conference on Signal Processing and Integrated Networks, 35-39, 2015.

[10] A. Kumar, A. Kushwah, A. Anand, K. M. Patel, A. Kumar, "Design and Analysis of H shape Microstrip Patch Antenna", International Journal of Applied Science and Research Technology, 10(5), 2422-2425, 2022.