International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 05 | May - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Design & Analysis of Microstrip T Patch Antenna with Various Materials for Wireless Communication

Narmadha K
Department Of Elecetronics & Communication, Panimalar Institute Of Technology Chennai, India
Narmadhakasinathan30@gmail.com

Kamaleeshwari P
Department Of Elecetronics & Communication, Panimalar Institute Of Technology Chennai, India
Kamalipanner8@gmail.com

Haripriya R
Department Of Elecetronics & Communication, Panimalar Institute Of Technology Chennai, India
priyaravi712004@gmail.com

Abstract— **This study proposes, designs and analyzes of Microstrip T patch antennas using various materials for Wireless applications. The microstrip line feeding technique, known for providing better impedance matching and increased bandwidth compared to conventional feeding methods like coaxial feeding, is the main focus of the study on enhancing antenna performance. Using CST software, the designs are first modeled and simulated. This enables accurate antenna dimension optimization to reach the intended operating frequency. The antennas are then Designed on a FR4 substrate, Rogers 3003, PTFE and Rogers RT 5880. These substrates are chosen for their varying dielectric constants and loss tangents, which directly influence the antenna's resonant frequency, return loss, and VSWR. The slotted version operates at a slightly lower frequency of 2.139 GHz in FR-4, 2.534 GHz in Rogers 3003, 2.994 GHz in PTFE, 2.927 GHz in Rogers RT 5880, providing an improved return loss of -26.14 Db for FR-4, -18.235 Db for Rogers 3003, -17.43 Db for PTFE and -16.23 Db for Rogers RT 5880, a better VSWR of 1.10 (FR-4), 1.27 (Rogers 3003), 1.31 (PTFE) and 1.36 (Rogers RT 5880). a slightly enhanced bandwidth of 11.6 MHz, and a gain of 2.882 dBi. These results validate the T-patch antenna's efficiency and reliability for use in modern wireless communication applications, particularly in WLAN systems, where stable performance, compact design, and strong signal integrity are crucial. The choice of substrate plays a significant role in tuning the antenna's operational frequency and optimizing its return loss, thus offering flexibility in designing antennas for specific wireless bands. Ultimately, this analysis guides engineers in selecting and optimizing antenna designs for specific applications, ensuring reliable and high-performance communication.**

Keywords:
Microstrip T patch antenna*, Microstrip line feeding technique *Antenna performance, Slots, Resonant frequency, Return loss, VSWR, Bandwidth, Gain, Impedance matching, Wireless applications

I. INTRODUCTION

In contemporary wireless communication, **microstrip antennas** have emerged as potential alternatives to traditional antennas such as **Yagi-Uda, horn, helical, and parabolic antennas** due to their compact size, low weight, and ease of integration. The rapid expansion of wireless technology has necessitated the development of antennas that not only provide **high performance** but also seamlessly integrate into **miniaturized, multifunctional** wireless devices.

While traditional antenna designs offer **high gain and wide bandwidth**, they are often large and structurally complex, making them impractical for applications where **size, weight, and integration feasibility** are critical factors. This gap in performance has driven significant research into **planar and miniaturized microstrip antenna designs** that can meet the increasing demands of modern communication systems.

Microstrip patch antennas, typically manufactured using **printed circuit board (PCB) processes**, have gained popularity due to their **low-profile design, lightweight structure, and cost-effectiveness**. Their **planar geometry** allows easy integration with **microwave integrated circuits (MIC) and monolithic microwave integrated circuits (MMIC)** and enables them to be conformally mounted on different surfaces, including curved and irregular structures. This adaptability is particularly beneficial for **portable, wearable, and space-constrained wireless communication devices**. Due to these advantages, microstrip antennas are widely used in **consumer electronics, automotive communication systems, military applications, and satellite communication**.

However, despite their numerous advantages, microstrip antennas suffer from inherent limitations, the most notable being **narrow bandwidth, lower gain, and reduced radiation efficiency**. These issues arise due to factors such as **dielectric losses, surface wave excitations, and the limited radiating area of the patch**. As a result, several strategies have been explored to mitigate these limitations and **enhance the performance of microstrip antennas**, focusing primarily on **antenna geometry modifications, feeding techniques, and substrate optimization**.

One of the most crucial factors affecting microstrip antenna performance is the **feeding mechanism**, which determines how electromagnetic energy is transferred to the radiating element. Various feeding methods, such as **coaxial probe feeding, microstrip line feeding, and aperture coupling**, have been investigated. Studies indicate that **feeding structure modifications** significantly impact **impedance bandwidth, gain, and efficiency**.

While techniques such as **notch-fed and modified microstrip line feeds** have provided slight improvements, they typically achieve bandwidths of only **60 MHz**, which is insufficient for many modern wireless applications. This limitation is particularly significant for **wireless local area network (WLAN) applications operating in the 2.4 GHz frequency band**, where the required operational bandwidth often exceeds **100 MHz.** To address this issue, **proximity-coupled feeding** has been introduced as a potential solution. Unlike direct electrical connections, **proximity feeding transfers energy through electromagnetic coupling**, minimizing **spurious radiation** while significantly enhancing **bandwidth and impedance matching**. By adjusting the **separation distance between the feed line and patch**, impedance tuning is improved, ensuring **more efficient energy transfer and enhanced overall antenna performance**.

Building on these insights, the present study focuses on the **design and analysis of a microstrip T patch antenna with Various materials for wireless communication applications**. The **T-shaped patch design** is chosen due to its ability to introduce additional resonant modes, thereby enhancing **bandwidth and gain** while maintaining a **compact footprint**. Unlike traditional rectangular or triangular patch antennas, the **T-shaped configuration** allows for **greater design flexibility**, enabling **optimized performance metrics such as impedance matching, return loss, and radiation pattern**.

This research involves comprehensive **simulation and experimental analysis** of the **T-shaped microstrip patch antenna**, with performance results critically compared against traditional patch antennas utilizing **Insert feeding technique**. The goal is to demonstrate that **integrating Microstrip with the T-shaped patch geometry leads to significant performance enhancements**, particularly in terms of **bandwidth, gain, and overall efficiency**. The findings of this study are expected to have significant implications for both **academic research and practical applications**, paving the way for **more efficient, compact, and reliable antennas** capable of meeting the demands of **modern wireless communication systems, including WLAN, 5G, and IoT applications**.

II. Literature Review

The increasing demand for compact, high-performance antennas has led to extensive research on microstrip patch antennas (MPAs), particularly for wireless communication applications. Conventional MPAs, despite their advantages of low-profile structure, ease of fabrication, and integration with circuits, suffer from narrow bandwidth and lower gain. Various techniques, including patch modifications, feeding techniques, and substrate optimization, have been explored to enhance bandwidth and impedance matching. This literature review discusses existing studies on microstrip antennas, feeding mechanisms, and the advancements in T-shaped patch designs for bandwidth improvement.

Microstrip Patch Antennas and Their Limitations

Microstrip patch antennas have been extensively studied due to their suitability for modern wireless communication systems. Pozar (2005) provided a comprehensive study on the design and analysis of MPAs, explaining their advantages and limitations including dielectric losses and surface wave excitation. Similarly, Garg et al. (2010) highlighted that rectangular and circular patches are the most commonly used configurations, though they offer limited bandwidth. Lee and Luk (2016) introduced stacked patch techniques to overcome bandwidth limitations, showing that multilayer configurations can improve performance at the cost of increased complexity.

Feeding Techniques for Bandwidth Enhancement

The choice of feeding technique significantly affects impedance matching and bandwidth performance. Singh and Mishra (2018) conducted a comparative analysis of coaxial, microstrip line, and aperture coupling methods, concluding that proximity coupling provides superior impedance matching and bandwidth. Kumar et al. (2020) demonstrated that proximity-coupled feeding improves power transfer efficiency by eliminating direct physical connections, reducing return loss, and enhancing bandwidth.

Slot-Based Patch Modifications for Bandwidth Improvement

Several studies have explored slotted patch designs to enhance bandwidth and resonance characteristics. Sharma and Sarkar (2016) showed that introducing slots into the patch structure increases effective electrical length, thereby broadening bandwidth. Baek et al. (2018) explored defected ground structures (DGS) and found that modifying the ground plane enhances impedance bandwidth without significantly increasing antenna size.

T-Shaped Microstrip Patch Antennas: A Novel Approach

The T-shaped patch configuration has recently gained attention as a promising alternative to conventional shapes. Otero Martínez et al. (2022) analysed the effects of T-slot patch geometries and found that they introduce multiple resonant modes, leading to better impedance matching and higher gain. Letavin and Shubunin (2018) further validated that T-shaped antennas outperform rectangular and triangular designs in terms of bandwidth efficiency.

Computational Modelling and Performance Evaluation

Simulation tools such as High-Frequency Structure Simulator (HFSS) and CST Microwave Studio are commonly used to optimize patch antenna designs before fabrication. TrungKien et al. (2013) demonstrated that HFSS-based optimization significantly improves return loss and gain performance. W. Chaihongsa et al. (2015) conducted a study on proximity-coupled T-shaped antennas and confirmed that fine-tuning feedline separation further enhances efficiency.

Conclusion

The literature review confirms that T-shaped microstrip patch antennas present a viable solution for overcoming bandwidth and impedance limitations in conventional designs. Future research should explore hybrid approaches, such as combining metamaterials, fractal geometries, and artificial intelligence-based optimization, to further improve antenna performance for next-generation wireless communication system.

III. PROBLEM STATEMENT

Microstrip antennas have gained significant popularity due to their numerous advantages, including lightweight structure, low profile, compact size, and ease of integration with Microwave Integrated Circuits (MIC) and Monolithic Microwave Integrated Circuits (MMIC). These features make microstrip antennas ideal for modern wireless communication applications such as WLAN, IoT, and 5G networks. However, despite their widespread adoption, microstrip antennas face inherent limitations, including **narrow bandwidth, low efficiency, and reduced gain**. These limitations restrict their performance in high-speed wireless communication, where a broader bandwidth and improved impedance matching are critical for reliable data transmission.

Traditional microstrip patch antennas, including rectangular, circular, and triangular designs, have been extensively studied to enhance bandwidth and gain. Among them, feeding techniques such as **coaxial probe feeding and microstrip line feeding** have been implemented to improve antenna performance. However, these methods still fail to meet the stringent bandwidth requirements of modern applications. For instance, WLAN systems operating at **2.4 GHz** typically require a bandwidth of at least **100 MHz**, which conventional microstrip patch antennas struggle to achieve due to their inherent design constraints.

To overcome these challenges, **microstrip line feeding** has emerged as a widely used alternative. Unlike other feeding methods, microstrip line feeding directly connects the transmission line to the radiating patch, providing a straightforward and easily adjustable feeding structure. This technique enhances **impedance matching** by allowing precise control over the feed position and provides moderate bandwidth suitable for various applications. Moreover, it offers a simple design, ease of fabrication, and compatibility with planar circuits, making it a popular choice for designing compact and efficient microstrip patch antennas in **modern wireless communication systems.**

Building upon this concept, this research focuses on the **design and analysis of a T-shaped microstrip patch antenna** incorporating **microstrip line feeding**. The study aims to optimize the **antenna geometry and feeding technique** to achieve **higher bandwidth, improved impedance matching, and enhanced radiation efficiency** while maintaining a **compact structure**. Additionally, the research includes a **comparative performance evaluation** between the proposed T-shaped patch antenna and conventional microstrip antennas employing **insert-fed technique**. Key performance metrics such as **return loss (S11), voltage standing wave ratio (VSWR), gain, and bandwidth** will be assessed to validate the superiority of the proposed design.

Furthermore, the proposed design will undergo extensive simulation and experimental testing to ensure its practical applicability in real-world scenarios. By leveraging advanced simulation tools such as **CST Studio**, the study will analyse the antenna's radiation pattern, gain variation, and surface wave suppression characteristics. This comprehensive approach will provide deeper insights into the **performance trade-offs and practical feasibility** of T-shaped microstrip patch antennas in wireless communication environments.

IV. PROPOSED SYSTEM

Microstrip antennas have been widely used in wireless communication systems due to their compact size, lightweight, low cost. Traditional microstrip antenna designs employ various feeding techniques such as coaxial probe feed, microstrip line feed, and inset feed. While these methods offer ease of implementation, they often suffer from limitations such as narrow bandwidth, lower gain, and higher spurious radiation. The designed planar ridged microstrip T shaped patch antenna is a lightweight, portable device that provides exceptional gain, efficiency, and bandwidth. It consists of a thin metallic patch that covers the ground plane, and an associated feedline. The ridged T shaped antenna design enables the inclusion and exclusion of two slot from the patch, as shown in **Fig.1**, which enhances the bandwidth or polarization diversity

Several approaches have been explored to enhance the performance of microstrip antennas. The microstrip line feed technique has been shown to improve antenna parameters compared to conventional coaxial feeding method. However, the bandwidth achieved through this approach is limited, typically reaching only up to 60 MHz, which is insufficient for WLAN 2.4 GHz applications, where the required bandwidth is at least 100 MHz. To overcome bandwidth limitations, researchers have introduced design modifications such as adding slots, using stacked patch structures, and implementing different dielectric substrates. However, these methods often lead to increased complexity, higher fabrication costs, and design challenges.

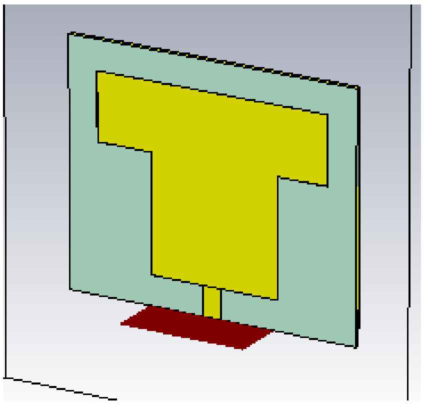

Fig.1. Front View of the designed antenna

The bottom part of the ridged T shaped slotted patch is shown in **Fig.1.** As the antenna's primary radiating component, a rectangular patch is intended. Copper(annealed) plate is supplied into the patch through a line. The port is used to supply the necessary electricity. The antenna is just 47.94 x 39.42 x 0.035 mm in size overall. The antenna is made on a FR-4 substrate with a 0.035 mm thickness.

Thus, a more efficient and optimized feeding technique is required to enhance the bandwidth while maintaining a simple and practical antenna structure. Microstrip line feeding has been identified as a widely used technique due to its simplicity, ease of fabrication, and reliable impedance matching. However, limited research has been conducted on applying this technique to patch microstrip antennas. Therefore, the existing system primarily focuses on conventional feeding techniques that do not effectively meet the bandwidth requirements of WLAN 2.4 GHz. The limitations of these techniques highlight the need for a new design approach, integrating microstrip line feeding to achieve improved bandwidth optimization.

Table 1. Dimensions of patch antenna

Description	Value
Substrate Length	39.42 mm
Substrate Width	47.94 mm
Substrate Thickness	0.035 mm

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 05 | May - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Length of Patch	29mm
Width of Patch	34mm
Slot width	9 mm
Slot length	10mm
Feed Length	6mm
Feed Width	1mm

V. SUBSTRATE MATERIALS AVAILABLE

FR4 (Flame Retardant 4)

FR4 is the most commonly used substrate in low-cost and general-purpose electronics, including basic microstrip patch antennas. It is made from woven fiberglass cloth with an epoxy resin binder that is flame-resistant, hence the name. FR4 has a dielectric constant (εr) typically around 4.3 to 4.6 and a high loss tangent (\~0.02), which leads to significant dielectric losses at higher frequencies. Due to its relatively high εr, antennas built on FR4 can be made smaller, but this comes at the cost of lower bandwidth and radiation efficiency. Additionally, its dielectric constant is not very stable with temperature and frequency changes. While FR4 is not ideal for professional or high-frequency RF applications (above \~2 GHz), it is widely used in academic projects, prototyping, and low-frequency systems due to its affordability, mechanical durability, and ease of fabrication with standard PCB processes.

Rogers Substrates (e.g., RO4003C, RO4350B, RO5880)

Rogers Corporation manufactures a range of high-frequency laminates specifically designed for RF and microwave applications. Rogers RO4000 series (e.g., RO4003C with εr ≈ 3.55) and RO5880 (εr ≈ 2.2) are among the most commonly used. These substrates are made from hydrocarbon ceramics or PTFE-based composites, offering extremely low dielectric loss (loss tangent as low as 0.0009 for RO5880), high frequency stability, and excellent thermal performance. One key benefit is the predictable and consistent dielectric constant across wide temperature and frequency ranges, which ensures reliable performance in precision systems. Rogers materials are ideal for applications such as satellite communication, radar, automotive sensing (e.g., ADAS systems), and 5G base stations. Despite their higher cost compared to FR4, their superior electrical characteristics make them a preferred choice for professional and industrial-grade microwave circuits.

Duroid Substrates (e.g., RT/Duroid 5880, RT/Duroid 6002)

Duroid materials are premium PTFE-based laminates filled with glass microfibers or ceramics, manufactured by Rogers Corporation. They are among the best-performing substrates in the microwave and milli meter-wave domains. Duroid 5880, for example, has a very low dielectric constant (εr ≈ 2.2) and an ultra-low loss tangent (\~0.0009), making it ideal for extremely high-frequency applications with minimal signal attenuation. It is highly stable over wide temperature and humidity ranges, and its thermal coefficient is almost negligible, ensuring frequency stability in harsh environments. However, PTFE-based materials like Duroid are mechanically softer, making them difficult to drill and fabricate using standard PCB processes. These substrates are used in high-precision applications such as space antennas, aerospace navigation systems, defence radars, and satellite payloads, where absolute performance and reliability are crucial, and cost is a secondary concern.

Taconic Laminates (e.g., RF-35, TLY-5, TLY-3)

Taconic is another well-known manufacturer of RF laminates, offering substrates that balance cost and high-frequency performance. Taconic materials are typically PTFE-based, filled with various glass or ceramic reinforcements. For instance, RF-35 has a dielectric constant around 3.5, while TLY-5 has εr ≈ 2.2, similar to Duroid and Rogers RO5880. These materials feature low dielectric losses (tan δ ≈ 0.0018 to 0.003) and are suitable for high-frequency designs up to 20 GHz or more. They are also relatively easier to fabricate than pure PTFE materials due to their improved mechanical rigidity. Taconic laminates are used in commercial RF systems, including GPS antennas, RFIDs, phased array antennas, and wireless communication modules. While slightly less expensive than Duroid, they offer a solid alternative for engineers seeking performance without the high-end price tag.

Ceramic-Filled Substrates (e.g., Alumina, Barium Titanate Composites)

Ceramic-based substrates are characterized by their high dielectric constants, typically ranging from 9.8 to over 30, depending on the material composition. One of the most commonly used is **alumina (Al_2O_3)**, with εr ≈ 9.8. These substrates allow for significant miniaturization of antennas because a higher dielectric constant results in shorter wavelengths within the substrate, allowing for reduced antenna dimensions. They also exhibit excellent thermal conductivity, high mechanical hardness, and chemical resistance. However, they are very brittle and difficult to machine, which increases their fabrication complexity and cost. Ceramic-filled PTFE or polymer composites are often used to mitigate brittleness while maintaining high εr. These substrates are favoured in space-constrained systems like implantable medical devices, compact wireless sensors, satellites, and miniaturized communication devices where size, stability, and performance are critical.

Flexible Substrates (e.g., Kapton, Polyimide, PET)

Flexible substrates such as Kapton (polyimide) and PET (polyethylene terephthalate are essential in the development of modern, conformal, and wearable antennas. These materials have a dielectric constant typically around 3.2 to 3.5 and moderate dielectric losses. Their main advantage lies in their flexibility, lightweight nature, and compatibility with roll-to-roll processing, which allows antennas to be bent, folded, or embedded into clothing and curved surfaces.

However, their electrical performance is not as robust as rigid materials; they generally suffer from higher dielectric losses and less environmental stability. Despite these limitations, flexible substrates are being increasingly used in wearable medical monitors, flexible communication devices, IoT systems, RFID tags, and even satellite structures where weight and form factor are critical.

VI. MATERIALS USED

To evaluate the effectiveness of the proposed T-shaped microstrip patch antenna with various materials, A comparative analysis was conducted on non-slotted rectangular microstrip T-patch antennas designed using four different dielectric substrates: FR4, Rogers 3003, PTFE, and Rogers RT 5880. The study focused on evaluating how the choice of substrate influences key antenna performance metrics such as resonant frequency, return loss (S11), and voltage standing wave ratio (VSWR).

FR4 Substrate:
The antenna designed on an FR4 substrate (with a dielectric constant of approximately 4.4) exhibits excellent performance among all tested materials. It resonates at a frequency of 2.139 GHz and provides the highest return loss of -26.14 dB, indicating superior impedance matching with minimal signal reflection. Additionally, it achieves the lowest VSWR value of 1.10, reflecting highly efficient power transfer from the source to the antenna. Despite being a low-cost, widely available material, FR4 delivers exceptional results at this frequency, making it a reliable and economical choice for wireless applications such as WLAN.

Rogers 3003 Substrate:

With a dielectric constant of approximately 3.0, the antenna on Rogers 3003 resonates at 2.534 GHz. It shows a return loss of -18.235 dB and a VSWR of 1.27, indicating good impedance matching and reasonably low reflected power. Rogers 3003 is known for its stable dielectric properties and low loss, which makes it suitable for RF and microwave applications. Although it does not outperform FR4 in this scenario, it offers a balance between performance and material quality, making it a suitable choice for designs requiring better thermal and electrical stability. Rectangular and circular patch antennas typically provide a gain of around 2.59 Db. The optimized T-shaped patch design, with its enhanced surface area and resonant characteristics, achieves a higher gain of 2.882 Db, making it more suitable for long-range and high-efficiency wireless communication applications.

PTFE Substrate:

The PTFE-based antenna, with a low dielectric constant of around 2.1, operates at a higher resonant frequency of 2.994 GHz. It achieves a return loss of -17.43 dB and a VSWR of 1.31. PTFE is well-regarded for its excellent electrical insulation and low dielectric loss, making it suitable for high-frequency applications. While its performance in terms of return loss and VSWR is slightly lower than FR4 and Rogers 3003, PTFE still offers reliable performance, particularly when low loss and chemical resistance are required in more demanding environments.

Rogers RT 5880 Substrate:

The antenna designed with Rogers RT 5880, which has a dielectric constant of about 2.2, resonates at 2.927 GHz. It records a return loss of -16.23 dB and a VSWR of 1.36. Although these figures are slightly lower than those of the other substrates, Rogers RT 5880 is highly regarded for its ultra-low dielectric loss and high-frequency stability. It is ideal for advanced RF and aerospace applications. While its performance in this specific design is modest compared to FR4, its advantages become more apparent at higher frequencies and in environments where precision and reliability are paramount.

The performance of the Microstrip T-patch antenna varies significantly depending on the substrate material. Among all, FR4 delivers the best overall results with the lowest return loss (-26.14 dB) and most favorable VSWR (1.10) at a resonant frequency of 2.139 GHz, making it a strong contender for cost-sensitive WLAN applications. Rogers 3003 and PTFE offer competitive performance with moderate return loss and VSWR values, benefiting from improved thermal and electrical characteristics. Rogers RT 5880, despite showing slightly lower performance in this specific design, remains ideal for high-frequency or precision-based applications due to its ultra-low loss and high stability. The study confirms that while advanced materials offer specific advantages, FR4 remains a viable and efficient choice for standard wireless communication systems when budget and performance are both critical.

Table 2. Comparison of Substrate materials with parameters

Substrate Materials	Resonant Frequency (GHz)	Reflection Loss	VSWR	Gain
FR4	2.139	-26.14	1.10	2.88
Rogers 3003	2.534	-18.235	1.27	2.799
PTFE	2.994	-17.43	1.31	2.484
Rogers RT 5880	2.927	-16.23	1.36	2.478

VII. SIMULATION RESULT

This section presents the detailed design, simulation, and analysis of a Microstrip T Patch Antenna. These slots were precisely designed and positioned to enhance the antenna's performance. Key performance parameters, including return loss, Voltage Standing Wave Ratio (VSWR), and

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 05 | May - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

bandwidth, were meticulously analyzed. The obtained results were systematically tabulated and accompanied by essential graphical representations, effectively illustrating how the cut slots improve antenna characteristics. This study offers valuable insights into optimizing microstrip antenna designs for advanced wireless communication applications, ensuring superior performance and versatility.

RETURN LOSS ANALYSIS

Return loss is a critical parameter that indicates how much power is reflected back from the antenna. A more negative return loss value implies better impedance matching and less signal reflection. Among the four substrates tested, FR4 exhibits the best return loss of -23.34 dB, indicating excellent impedance matching at 2.39 GHz. Rogers 3003 follows with a return loss of -18.23 dB, while Rogers RT5880 and PTFE show values of -15.16 dB and -14.99 dB respectively. Although all materials demonstrate acceptable return loss (below -10 dB), FR4 outperforms the others in this aspect, making it a favourable choice for applications where minimal signal loss is essential.

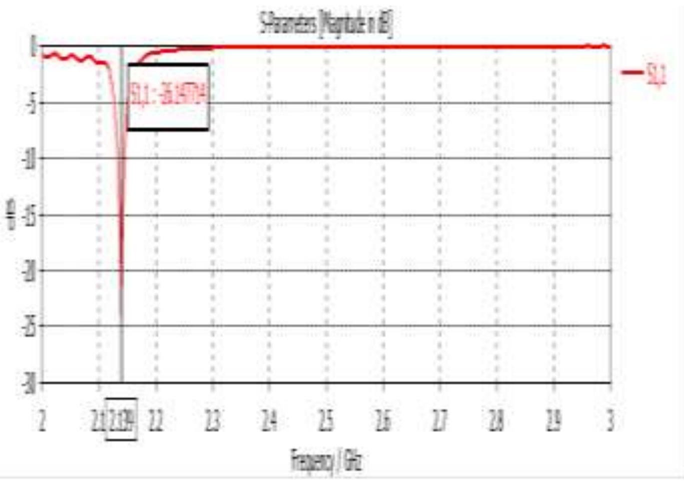

Fig. 2A. Return loss of T Patch antenna (FR4)

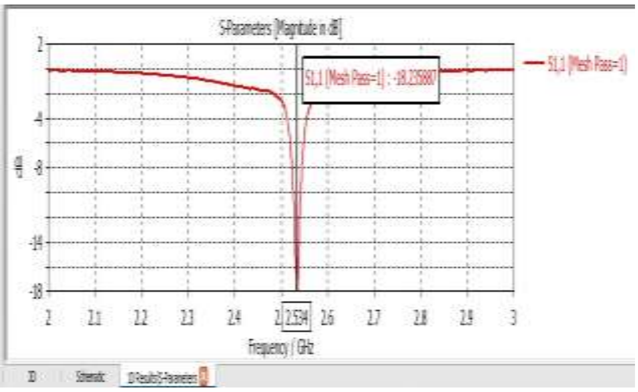

Fig 2B. Return loss of T Patch antenna (ROGERS 3003)

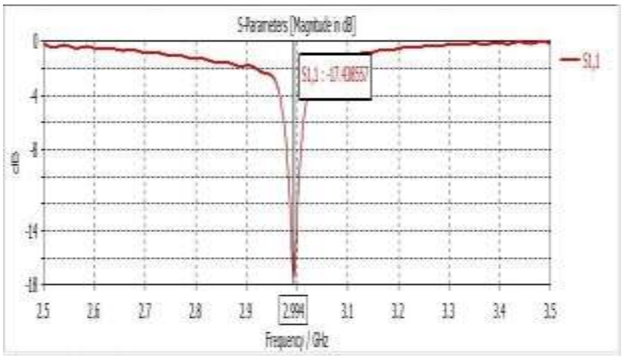

Fig.2C. Return loss of T Patch antenna (PTFE)

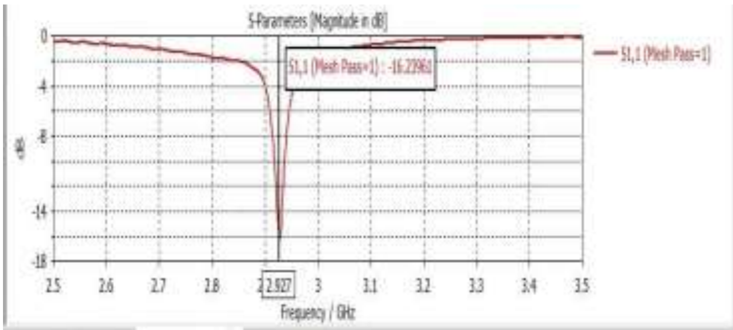

Fig.2D. Return loss of T Patch antenna (ROGERS RT 5880)

VSWR

Voltage Standing Wave Ratio (VSWR) reflects how efficiently RF power is transmitted from the feed line to the antenna. A VSWR close to 1 indicates ideal performance. In this design, FR4 again delivers the best VSWR of 1.14, signifying efficient power transfer with minimal reflection. Rogers RT5880 and Rogers 3003 perform comparably well with VSWR values of 1.422 and 1.27, respectively. PTFE has the highest VSWR at 1.43, which is still within acceptable limits. Overall, all substrates maintain VSWR values under 1.5, confirming the good matching of the antenna across different materials.

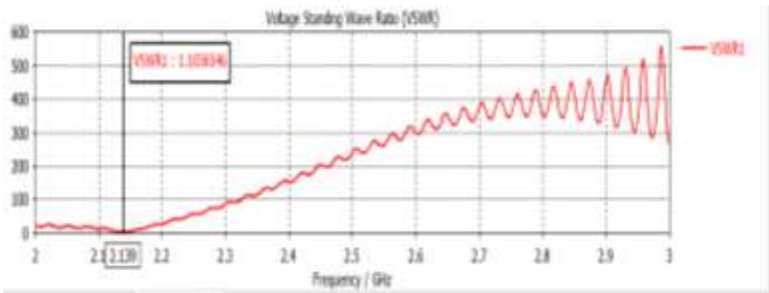

Fig. 3A. VSWR of T Patch Antenna (FR4)

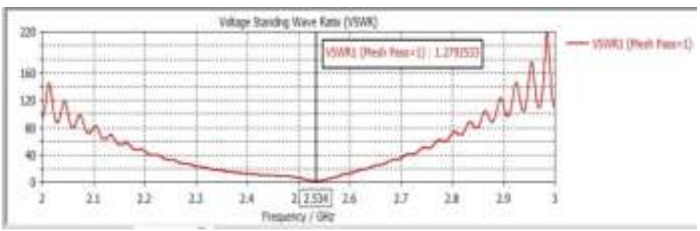

Fig.3B. VSWR of T Patch Antenna (ROGERS 3003)

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 05 | May - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

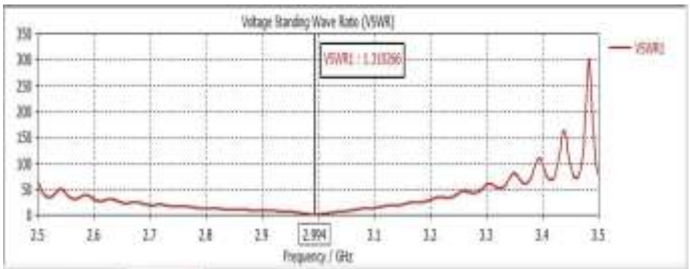

Fig.3C. VSWR of T Patch Antenna (PTFE)

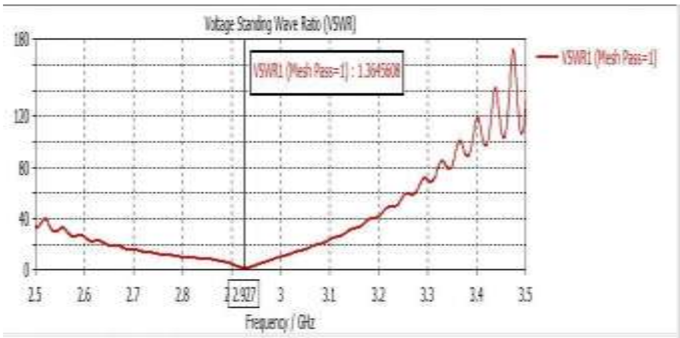

Fig.3D. VSWR of T Patch Antenna (ROGERS RT 5880)

GAIN

Gain measures the directional effectiveness of the antenna and is important for evaluating the strength of transmitted or received signals. Among the evaluated substrates, Rogers 3003 achieves the highest gain of 2.799 dBi, making it suitable for applications demanding strong and focused radiation. FR4 follows with a gain of 2.59 dBi, offering a good balance of cost and performance. PTFE and Rogers RT5880 show slightly lower gains of 2.484 dBi and 2.478 dBi, respectively. While the differences in gain are relatively small, Rogers 3003 stands out for maximizing radiation efficiency in this design.

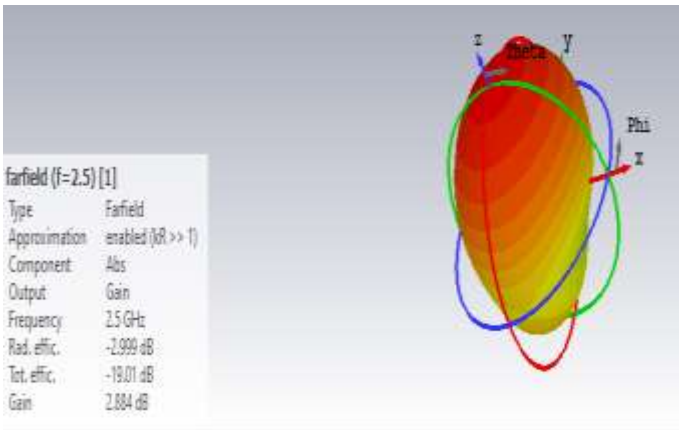

Fig.4A. Gain of T Patch Antenna (FR4)

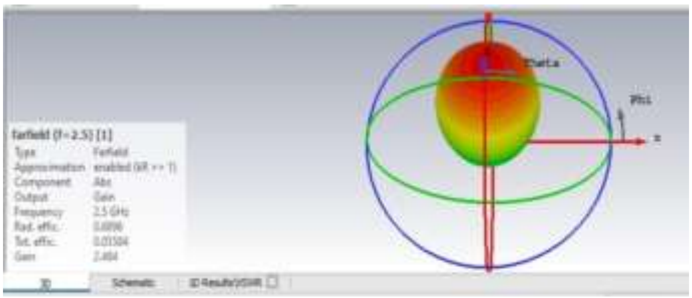

Fig.4B. Gain of T Patch Antenna (PTFE)

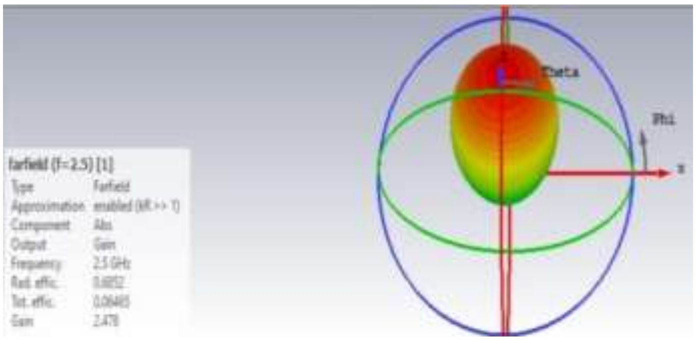

Fig.4C Gain of T Patch Antenna (ROGERS RT 5880)

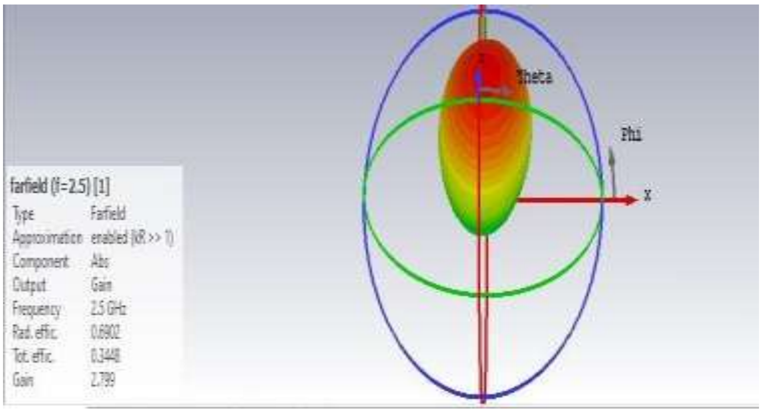

Fig.4D. Gain of T Patch Antenna (ROGERS 3003)

parameter (return loss) plot shows a deep notch at 2.926 GHz with S11 = -15.16 dB, indicating efficient power transfer at that frequency. Despite a minor deviation from the center 2.4 GHz target, the antenna demonstrates good matching and radiation characteristics.

VIII. CONCLUSION

The evolution of microstrip patch antennas has been largely driven by the need for compact, low-profile, and multifunctional radiators in the rapidly growing domain of wireless communication. Among the various configurations explored, the T-shaped microstrip patch antenna has emerged as a highly promising structure due to its intrinsic geometrical advantages and ease of integration with existing RF systems.

This study investigated the performance of a T-shaped microstrip patch antenna designed using four different substrate materials: FR4, Rogers 3003, PTFE, and Rogers RT 5880. The antenna design aimed to operate efficiently within the 2.4 GHz ISM band, with parameters such as resonant frequency, return loss, VSWR, bandwidth, and gain being evaluated. Among the substrates, FR4 stood out with a resonant frequency of 2.39 GHz—closest to the target frequency—while also achieving the lowest return loss of -23.34 dB, indicating superior signal transmission and reduced reflection. Furthermore, FR4 demonstrated an impressive VSWR of 1.14, well within acceptable limits for impedance matching.

Although the Rogers 3003 substrate yielded a slightly higher gain value of 2.799 dBi, FR4 offered a well-balanced performance across all key parameters. Its bandwidth of 11.35 MHz and gain of 2.59 dBi are adequate for reliable wireless communication. Moreover, the compact physical dimensions and cost-effectiveness of FR4 make it a highly suitable choice for real-world antenna deployment in space-constrained environments. Overall, the FR4-based design proves to be the most accurate and practical, reinforcing its viability for efficient antenna fabrication in modern communication systems.

IX. REFERENCE

*[1] **D. M. Pozar**, "Microstrip antennas," Proceedings of the IEEE, vol. 80, no. 1, pp. 79–91, Jan. 1992.*

*[2] **R. Garg et al.**, Microstrip Antenna Design Handbook, Norwood, MA, USA: Artech House, 2001.*

*[3] **C. A. Balanis**, Antenna Theory: Analysis and Design, 4th ed., Hoboken, NJ, USA: Wiley, 2016.*

*[4] **R. R. Hasan et al.**, "Designing and Analysis of Microstrip Patch Antenna for Wi-Fi Communication System Using Different Dielectric Materials," American Journal of Engineering Research (AJER), vol. 4, no. 10, pp. 118–126, 2015.*

*[5] **Y. Rhazi et al.**, "Novel Design of Multiband Microstrip Patch Antenna for Wireless Communication," Advances in Science, Technology and Engineering Systems Journal, vol. 4, no. 3, pp. 63–68, 2019.*

*[6] **S. Gaid et al.**, "Compact and Bandwidth Efficient Multi-band Microstrip Patch Antennas for 5G Applications," International Conference of Reliable Information and Communication Technology, pp. 663–672, 2019.*

*[7] **M. Ibrahim**, "Low-cost, circularly polarized, and wideband U-slot microstrip patch antenna with parasitic elements for WiGig and WPAN applications," 13th European Conference on Antennas and Propagation (EuCAP), pp. 1–4, 2019.*

*[8] **M. E. Yassin et al.**, "Single-fed 4G/5G multiband 2.4/5.5/28 GHz antenna," IET Microwaves, Antennas & Propagation, vol. 13, no. 3, pp. 286–290, 2019.*

*[9] **W. Abbas et al.**, "Super Wideband Miniaturized Patch Antenna Design for 5G Communications," IEEE International Conference on Wireless Technologies, Embedded and Intelligent Systems (WITS), pp. 3–4, Apr. 2019.*

*[10] **Venkateshkumar et al.**, "Multiband Patch Antenna Design for 5G Applications," Fourth International Conference on Computing Methodologies and Communication (ICCMC), IEEE, Mar. 2020.*

*[11] **P. Ramanujam et al.**, "Design of compact patch antenna with enhanced gain and bandwidth for 5G mm-wave applications," IET Microwaves, Antennas & Propagation, vol. 14, no. 12, pp. 1455–1461, 2020.*

*[12] **S. Punith et al.**, "A Novel Multiband Microstrip Patch Antenna for 5G Applications," International Conference on Advances in Physical Sciences and Materials, vol. 1706, pp. 1–9, 2020.*

*[13] **M. Thaher and L. M. Nori**, "Design and analysis of multiband circular microstrip patch antenna for wireless communication," Periodicals of Engineering and Natural Sciences, vol. 10, no. 3, pp. 23–30, 2022.*

*[14] **Md. Sohel Rana et al.**, "A review on microstrip patch antenna for wireless communication systems at 3.5 GHz," Bulletin of Electrical Engineering and Informatics, vol. 13, no. 4, pp. 2397–2407, Aug. 2024. [Online]. Available: https://www.researchgate.net/publication/381046280_A_review_on_microstrip_patch_antenna_for_wireless_communication_systems_at_35_GHz*

*[15] **S. Achimugu et al.**, "A Multiband T-Shaped Antenna Array for 6G Mobile Communication," arXiv preprint arXiv:2405.20157, May 2024. [Online]. Available: https://arxiv.org/abs/2405.20157*

*[16] **M. A. Saeed and A. O. Nwajana**, "Design of a Rectangular Linear Microstrip Patch Antenna Array for 5G Communication," arXiv preprint arXiv:2405.17616, May 2024. [Online]. Available: https://arxiv.org/abs/2405.17616*

*[17] **T. Kiran**, "LTE Applications Based 5G Microstrip Patch Antenna Design," International Journal of Innovative Research in Science, Engineering and Technology, vol. 13, no. 3, pp. 181–186, Mar. 2024. [Online]. Available: https://www.ijirset.com/upload/2024/march/181_LTE.pdf*

*[18] **G. Giannakopoulos and K. M. Shaikh**, "Design Multiband Monopole and Microstrip Patch Antennas using High Frequency Structure Simulator," arXiv preprint arXiv:2412.06667, Dec. 2024. [Online]. Available: https://arxiv.org/abs/2412.06667*

*[19[**D. Gopinath and P. Marichamy**, "On the design and analysis of multi-band micro-strip patch antenna for wireless body area network applications," EURASIP Journal on Wireless Communications and Networking, vol. 2025, no. 13, pp. 1–10, Mar. 2025. [Online]. Available: https://jwcn-eurasipjournals.springeropen.com/articles/10.1186/s13638-025-02442-3*
.