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Design of a High Gain Dual Band Patch Antenna with T Slot Ground Structure for Millimeter Wave Communication Applications

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This paper introduces a novel design approach for achieving high gain, dual-band operation, and enhanced bandwidth in a microstrip patch antenna tailored for 5G applications. The antenna operates at the millimeter-wave bands of 28 GHz and 38 GHz, crucial frequencies for the next-generation 5G wireless communication systems. The proposed design employs two inverted T-shaped slots on the patch to enable dual-band functionality. Simultaneously, a very high gain is attained by strategically inserting two inverted T-shaped slots on the radiating element of the patch. To further improve the antenna's bandwidth, a ground slot structure with three different types of slots U-shaped, L-shaped, and T-shaped are compared on the ground plane. The best bandwidth enhancement is achieved by T shape Slot on both bands. The substrate chosen for the antenna fabrication is Rogers RT Duroid 5880, characterized by a thickness of 0.501mm, a low loss tangent of 0.0009, and a relative permittivity constant of 2.2. The simulations are conducted using Ansys HFSS software proposed antenna design, demonstrate impressive performance metrics. Maximum gains of 17 dB at 28 GHz and 38 GHz are achieved form T shape slot ground configuration, the U-shaped slot configuration yields a maximum gain of 15 dB, and the L-shaped slot configuration achieves 7.8 db. Furthermore, the impedance bandwidth response at the respective resonating frequencies extends to 1 and 2 GHz below the -10dB line, showcasing the antenna's excellent bandwidth characteristics. In terms of form factor, the proposed antenna is compact, measuring 16.2 x 12.8 x 0.501 mm. This compact size, coupled with the high gain and wide bandwidth at both operating bands, making the antenna well-suited for integration into 5G applications.

Keywords: 28/38GHz band; Microstrip-Patch; 5G; Dual-band; High Gain; slots, and Bandwidth.

Introduction:

This paper delves into the detailed design and optimization strategies employed to realize these impressive performance metrics, contributing to the advancement of antenna technologies for the rapidly evolving landscape of 5G communication systems. The rapid changes in the wireless communication have presented service providers with a myriad of challenges, prompting continuous enhancements to meet the escalating demands of uses. As wireless technology evolves across generations, services like Internet connectivity and the Internet of Things (IoT) increasingly demand greater bandwidth, rapid connectivity, and heightened security for seamless and efficient communication. The shift from 4G to 5G marked a pivotal transition from analog to digital systems, introducing diverse applications such as television/video streaming and global roaming, reliant on broad bandwidth capabilities. The subsequent evolution to 4G brought improved features, including enhanced video calls, mobile TV, and video broadcasting services [1]. The growing need for superior wireless performance has led to the emergence of 5G technology, designed to address technological demands that earlier generations struggled to accommodate. 5G technology is poised to drive advancements such as robotization, remote healthcare, and seamless integration of IoT devices [2].

The microstrip patch antenna stands out as a promising solution within the spectrum of antenna technologies for 5G applications due to its compactness, conformability, lightweight nature, and cost-effectiveness. However, traditional forms of microstrip patch antennas often faces limitations, including low gain, narrow bandwidth, and low efficiency [3]. The literature documents a wealth of experimentation, with researchers employing various strategies to enhance the performance of microstrip patch antennas [4] [5]. Researchers have explored the implementation of arrays [6] [7] [8] [9], and focused on single elements with diverse configurations tailored for specific applications [10] [11] [12] [13]. For instance, in 2019, Pon Bharathi proposed a compact microstrip patch antenna using Defected Ground Structure (DGS) for 5G applications, achieving a broadband of 6GHz; however, the gain was minimal at the resonating frequency [14]. Another study utilized H-slotted DGS to develop a dual microstrip patch for 5G [15].

Recent investigations have compared different substrate materials including FR4 and Rogers in a multiband two-slot rectangular patch antenna for 5G applications [16]. Additionally, researchers presented a coplanar waveguide for 5G applications, utilizing an elliptical shape for its advantageous wide bandwidth properties, achieving impressive results with a bandwidth of 4.78 GHz at the lower end and 4.16 GHz within the band [17]. Further innovations included a novel design of a compact patch antenna operating at 38/60GHz, where matching impedance of 2GHz and 3.2GHz within specific bands [18]. While these advancements represent significant strides in designing antennas for the millimeter-wave band, the specific demands of 5G systems applications necessitate directional antennas with wideband capabilities and high gains for optimal high data rate transmission [15].

This paper contributes to the significantly evolving landscape of 5G-compatible antennas by proposing a compact microstrip patch antenna operating in a dual-band configuration. The primary focus of this design is to optimize bandwidth and gain, key factors in ensuring the antenna's efficacy within the 5G spectrum. The choice of a rectangular shape is deliberate based on fabrication simplicity in comparison to alternative forms proposed in previous research [19]. In line with the emphasis on achieving larger bandwidth, the microstrip feedline method is chosen for its capability to outperform other feeding techniques [20]. The relentless evolution of wireless communication technologies, particularly with the advent of 5G, has ushered in a myriad of challenges and opportunities. As the demand for seamless and efficient communication escalates, there is a pressing need for antenna designs that can meet the stringent requirements of next-generation wireless communication systems. This paper introduces a ground breaking approach to address this demand through the design and optimization of a high-gain dual-band patch antenna specifically tailored for 5G applications. The antenna's operational frequencies at the millimeter-wave bands of 28 GHz and 38 GHz are strategically chosen to align with the critical requirements of 5G wireless communication systems. A key feature of the proposed design is the incorporation of two inverted T-shaped slots on the patch, enabling dual-band functionality.

Additionally, the antenna achieves a very high gain by strategically inserting two inverted T-shaped slots on the radiating element of the patch. To further enhance the antenna's performance, a ground slot structure with three different types of slots (U-shaped, L-shaped, and T-shaped) is explored on the ground plane. Notably, the T-shaped slot configuration proves to be the most effective in maximizing the antenna's bandwidth. The choice of substrate for antenna fabrication, namely Rogers RT Duroid 5880, further contributes to the antenna's impressive performance metrics. With a thickness of 0.71 mm, a low loss tangent of 0.0009, and a relative permittivity constant of 2.2, this substrate enhances the overall efficiency of the antenna design [15]. The simulations conducted using Ansys HFSS software showcase remarkable achievements in terms of gain and bandwidth.

In particular, the proposed antenna design attains maximum gains of 17 dB at 28 GHz and 38 GHz with the T-shaped slot ground configuration, 15 dB with the U-shaped slot configuration, and 7.8 dB with the L-shaped slot configuration. Furthermore, the impedance bandwidth response at the respective resonating frequencies extends to 1 and 2 GHz below the 10dB line, underscoring the antenna's excellent bandwidth characteristics. With a compact form factor measuring 16.2 x 12.8 x 0.501 mm, the proposed antenna not only achieves high gain and wide bandwidth at both operating bands but also demonstrates suitability for seamless integration into diverse 5G applications.

OBJECTIVE:

This study aims to design and evaluate a high gain dual-band patch antenna with a T slot ground structure for millimeter wave communication applications. Specifically, the objective is to investigate the effectiveness of incorporating T-shaped slots on the microstrip patch antenna to achieve dual-band operation and enhance antenna gain. The research also aims to compare various ground slot configurations to optimize antenna performance. Simulation using Ansys HFSS software is conducted to analyze the antenna's impedance bandwidth, gain, and overall suitability for 5G operations. The goal is to provide a compact, high-performance antenna solution that meets the demands of next-generation wireless communication systems.

MATERIAL AND METHOD:

The substrate chosen for fabricating the antenna is Rogers RT Duroid 5880. This substrate is characterized by: Thickness: 0.501 mm, Low loss tangent: 0.0009 and Relative permittivity constant: 2.2

PATCH DESIGN:

The microstrip patch antenna is designed to operate at the millimeter-wave bands of 28 GHz and 38 GHz, targeting 5G applications. Two inverted T-shaped slots are strategically integrated into the patch to enable dual-band functionality. To enhance gain, two additional inverted T-shaped slots are inserted on the radiating element of the patch.

GROUND SLOT STRUCTURE:

A ground slot structure is implemented on the ground plane to further improve the antenna's bandwidth. Three types of slots are compared: U-shaped, L-shaped, and T-shaped. The T-shaped slot configuration demonstrates the best bandwidth enhancement at both operating bands.

SIMULATION:

Simulations are conducted using Ansys HFSS software to evaluate the performance of the proposed antenna design. Key parameters analyzed include:

Gain: Maximum gains of 17 dB at 28 GHz and 38 GHz are achieved with the T-shaped slot ground configuration. The U-shaped slot configuration yields a maximum gain of 15 dB, while the L-shaped slot configuration achieves 7.8 dB.

Bandwidth: The impedance bandwidth response at the resonating frequencies extends to 1 and 2 GHz below the -10 dB line, demonstrating excellent bandwidth characteristics.

Form Factor: The proposed antenna has a compact size, measuring 16.2 x 12.8 x 0.501 mm**.** Design and Analysis of Slot-Modified Antennas for Enhanced Bandwidth.

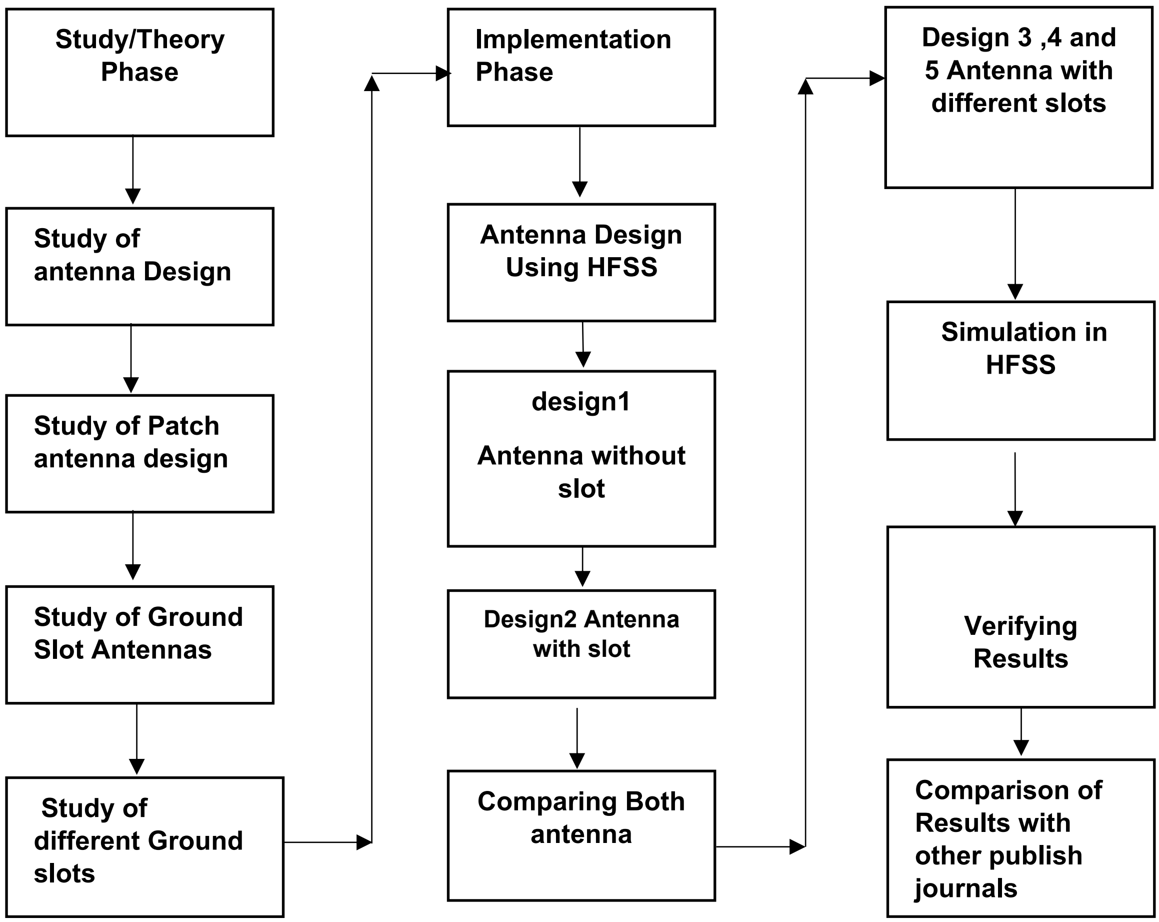

Figure 1: Methodology of antenna design

ANTENNA DESIGN AND DIMENSIONS:

To accommodate the millimeter-wave dual-band requirements at 28 GHz and 38 GHz, each antenna is designed to fully cover the entire frequency spectrum of both bands.

PROPOSED ANTENNA GEOMETRY:

The structure of the antenna is represented in Figure 1, showcasing its initial geometry. A feedline having dimensions of (FW x FL) was used to feed the antenna, which is fabricated on a Rogers RT 5880 substrate with a thickness of 0.7 mm. Based on the simplified formulation that has been described, a design procedure was outlined which lead to practical designs of rectangular microstrip antennas. The procedure assume that the specified information include the dielectric constant of the substrate (E r), the resonant frequency (fr), and the height of the substrate h. The comprehensive arrangement of the slot antenna can be witnessed in Figure 2. As demonstrated the two inverted T shape plane was firstly etched in a rectangular slot (16 mm x2 mm) to function as the main radiator of the dual-band antenna. Then an open section of 0.69 mm x 0.69 mm on the thin strip was cut which is etched alongside the PCB around the feed line.

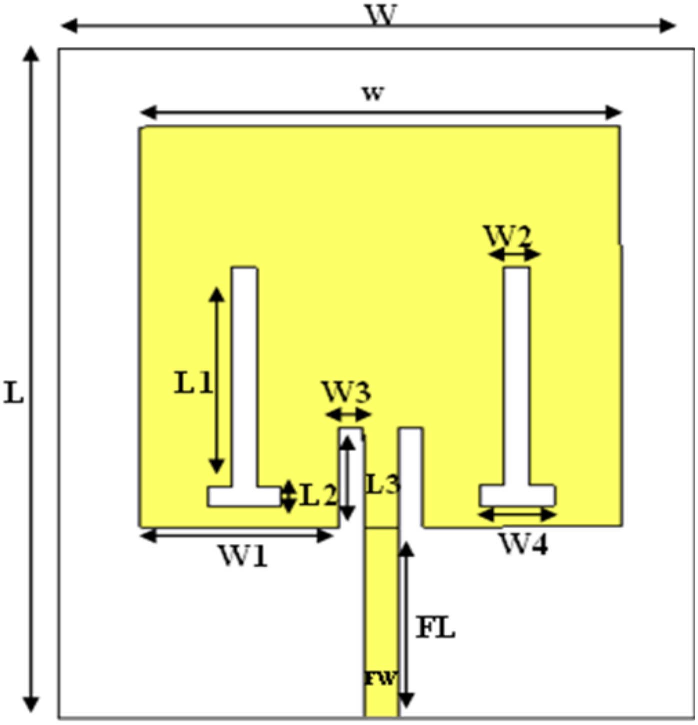

Figure 2: Proposed antenna.

ANTENNA DIMENSIONS AND CONFIGURATION:

The proposed antenna measures 16.2 x 12.8 x 0.501 mm. The configuration includes two inverted T-shaped slots on the patch and a T-shaped slot on the ground plane. The compact size and specific slot configurations help in achieving the desired performance metrics while maintaining a small form factor suitable for integration into 5G devices. To Achieve high gain and wide band a T Slot was etched on the ground plane with overall dimensions of (W x Lt) (12.8 x 17.2) and just 0.8 mm thickness of the T line etched inside the Ground plane. Upper part of the T shape has dimensions of (WxWt1) (12.8 x 0.5) and lower Part has dimensions of (Lt x Wt2) (17.2x 0.8). Results suggested that this design provided high gain wide band for proposed antenna. The feed-line involved vertical sections of 50- ohm micro-strip of size 6.57 mm x 0.8 mm separated by a length L 0.6 mm respectively. The slot parameters (L, L1, and L2) and the separation distances between them are accomplished by HFSS Electronic desktop version 2022.

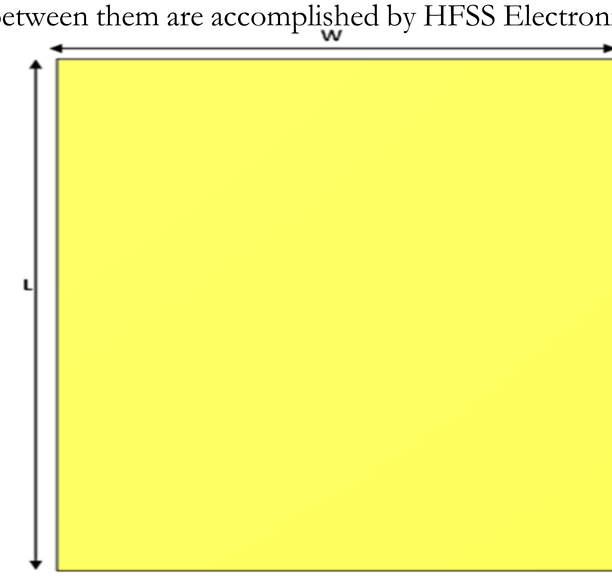

Figure 3: Proposed Ground Structure of antenna.

The Figure 3 represents that the overall size of the ground plane (16.2 x 12.8) which is equlavent equivalent to the overall size of patch as ground covers complete back side of PCB.

T SHAPE SLOT IN GROUND PLANE :

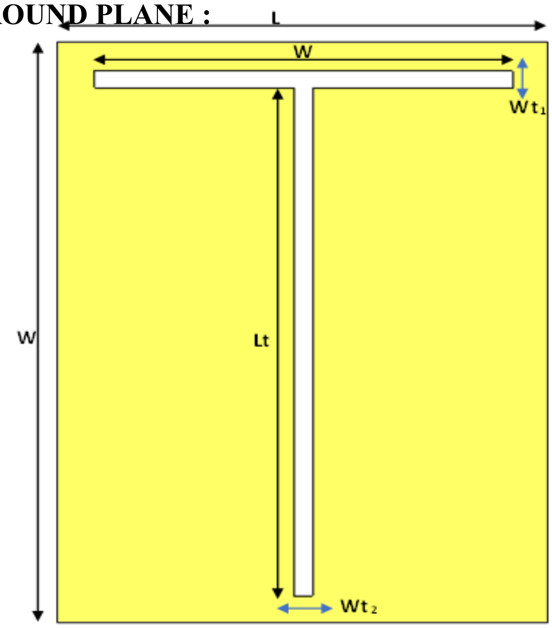

Figure 4: Proposed T shape slot Structure of ground.

To Achieve high gain and wide band a T Slot was etched on the ground plane with overall dimensions of (W x Lt) (12.8 x 17.2) and just 0.8 mm thickness of the T line etched inside the Ground plane as shown in figure 4. Upper part of the T shape has dimensions of (WxWt1) (12.8 x 0.5) and lower Part has dimensions of (Lt x Wt2) (17.2x 0.8). Results suggested that this design provided high gain wide band for proposed antenna.

U SHAPE SLOT IN GROUND PLANE:

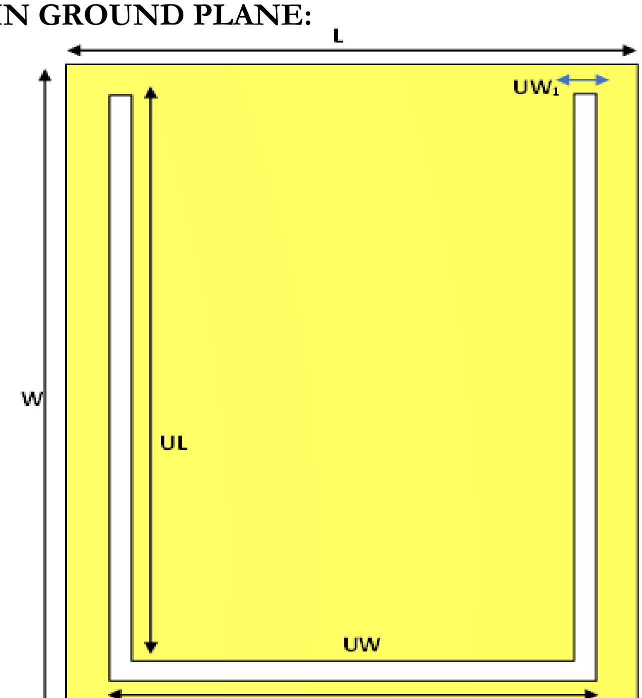

Figure 5: Proposed U shape slot Structure of ground.

To Achieve high gain and wide band a U Slot was etched on the ground plane with overall dimensions of (Uv x UL) (11 x 15) and just 0.5 mm thickness of the U line etched inside the Ground plane as shown in figure 5. Upper part of the U shape has dimensions of (ULxUW1)

(15 x 0.5) and lower Part has dimensions of (UW x UW2) (11x 0.5). Results suggested that this design did not achieve high gain wide band for proposed antenna

L SHAPE SLOT IN GROUND PLANE:

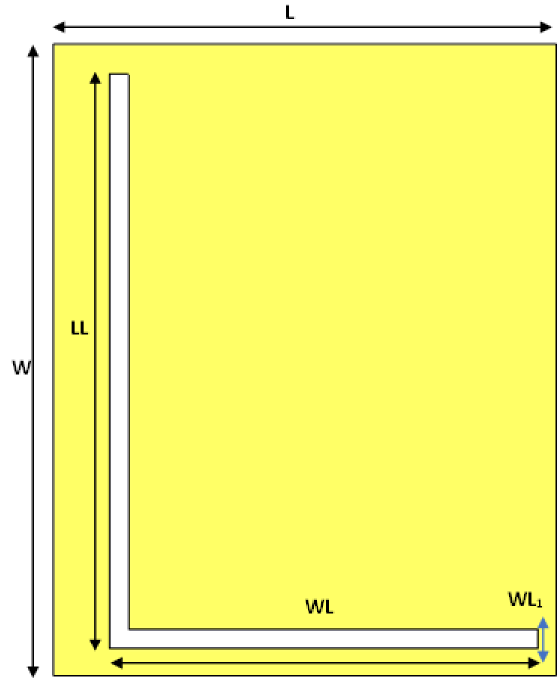

Figure 6: Proposed L shape slot Structure of ground.

To Achieve high gain and wide band a L Slot was etched on the ground plane with overall dimensions of (Ll x WL) (15 x 11) and just 0.5 mm thickness of the L line etched inside the Ground plane as shown in figure 6. Upper part of the L shape has dimensions of (LlxWL1) (15 x 0.5) and lower Part has dimensions of (WL x WL1) (11x 0.5). Results suggested that this design failed to achieve high gain wide band for proposed antenna. Table 1 provides the list of abbreviations used in this paper.

Table 1: List of Abbreviations

Definition	Abbreviations
Millimeter Wave Communication	MMW
RoHS compliant" and "Thermoset	RT Duroid
Giga hertz	GHz
Radio frequency	RF
dB	Decibel
Scattering Parameter	S11
Printed circuit board	PCB
High-Frequency Structure Simulator	HFSS
Fifth Generation	5G
Bandwidth	BW

RESULTS AND DISCUSSIONS:

S PARAMETERS AND BANDWIDTH OF THE ANTENNAS:

The designed inverted T slot Patch antenna is truly capable of working in the MMW Dual band 28/38 GHz with high gain. One of the standout features of this antenna is its impressive bandwidth performance, showcasing a substantial range of 1 GHz and 2 GHz at the respective frequency bands. The measured return loss values, showcased in the illustrative Figure 7 given below, demonstrate readings of -27 dB and -35 db. A distinctive aspect of our methodology is its strategic orientation toward enhancing bandwidth. Figure 2 visually encapsulates the efficacy of each design approach employed in our study. This graphical representation provides a profound visual insight into the achieved results, accentuating the success of our strategic approach in significantly augmenting the bandwidth capabilities of the proposed antenna as shown in figure 8.

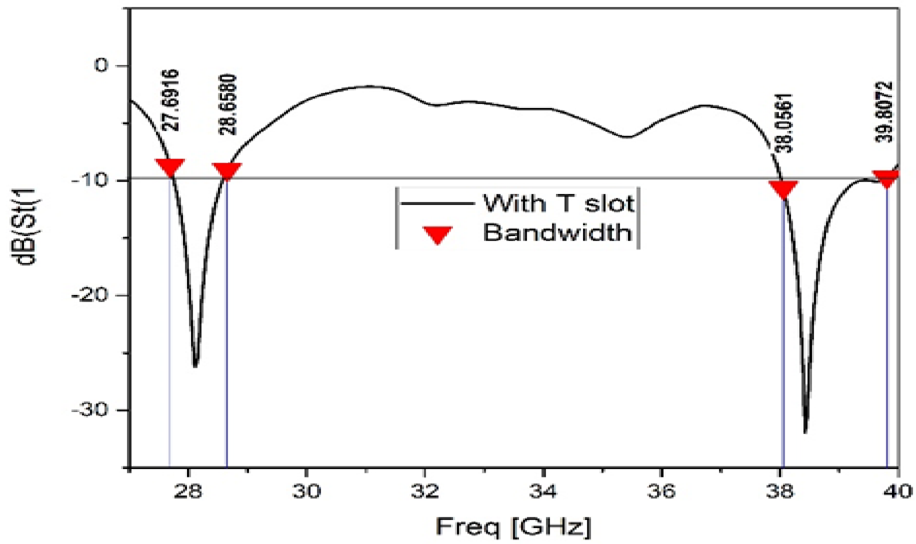

Figure 7: S11 and bandwidth of the T slot antennas

ANTENNA DESIGN CASES AND PERFORMANCE COMPARISON:

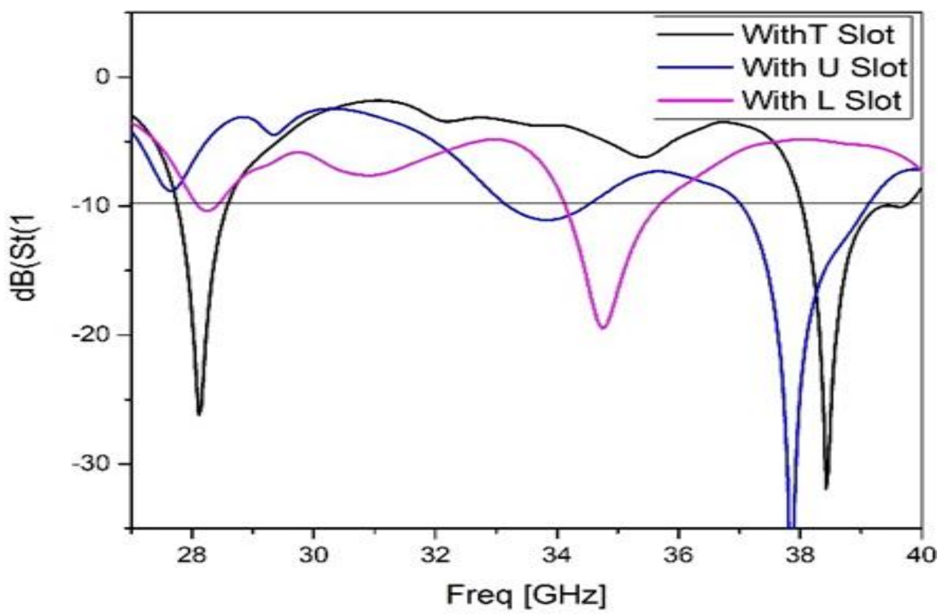

Figure 8: Antenna design cases and performance comparison with different ground slots

Table 2: Design and Analysis of Slot-Modified Antennas for Enhanced Bandwidth

S/N	Name	Band	Bandwidth
1	Antenna without Slot:	Dual band at 28 GHz and 38 GHz.	0.9 GHz (27.6 GHz to 28.5 GHz).
2	Antenna with T-shaped Slot:	Dual band at 28 GHz and 38 GHz.	1 GHz at 28 GHz and 2 GHz at 38 GHz.
3	Antenna with U-shaped Slot:		2 GHz at 38 GHz.
4	Antenna with L-shaped Slot:	35 GHz instead of 28 GHz and 38 GHz	

EXPLANATION:

ANTENNA WITHOUT SLOT:

Achieve dual-band operation with a decent bandwidth of 0.9 GHz, spanning from 27.6 GHz to 28.5 GHz. This design served as a baseline for performance evaluation.

ANTENNA WITH T-SHAPED SLOT:

Demonstrated the most favorable outcomes, maintaining dual-band characteristics at 28 GHz and 38 GHz. Notably, it exceeded with an expanded bandwidth of 1 GHz at 28 GHz and 2 GHz at 38 GHz, showcasing superior overall performance compared to other designs.

ANTENNA WITH U-SHAPED SLOT:

While achieving a notable bandwidth of 2 GHz at 38 GHz, the introduction of the U-shaped slot resulted in the removal of the 28 GHz band, leading to a performance loss in terms of dual-band operation.

ANTENNA WITH L-SHAPED SLOT:

Yielded the least desirable performance, deviating from the intended dual-band operation. The resonance at 35 GHz instead of 28 GHz and 38 GHz indicates a significant compromise in the antenna's functionality. Design of a high gain dual band patch antenna with t slot ground structure for millimeter wave communication applications is presented in table 2. The baseline antenna without a slot achieved dual-band operation with a bandwidth of 0.9 GHz, covering 27.6 GHz to 28.5 GHz. In contrast, the antenna with a T-shaped slot demonstrated superior performance, maintaining dual-band characteristics at 28 GHz and 38 GHz, and boasting an expanded bandwidth of 1 GHz at 28 GHz and 2 GHz at 38 GHz. The U-shaped slot antenna, while achieving a notable 2 GHz bandwidth at 38 GHz, lost the 28 GHz band, thus compromising dual-band operation. The L-shaped slot antenna performed the worst, deviating from the intended dual-band operation with resonance at 35 GHz instead of 28 GHz and 38 GHz, significantly compromising its functionality. Figure 9 illustrates bandwidth comparison of base line and T slot Antenna.A comparison of all antennas with different ground planes is shown in Table 3.

Table 3: Comparison of All antennas with different Ground Planes

S/N	Proposed Antenna Design with different Ground Slots	Frequency	BW at 28	BW at 38
1	Without Slot	28/38 GHz	0.9 GHz	0.9
2	**T-shaped Slot**	**28/38 GHz**	**1 GHz**	**2**
3	U-shaped Slot	38 GHz	Single band	2
4	L-shaped Slot	35 GHz	Single band	Single band

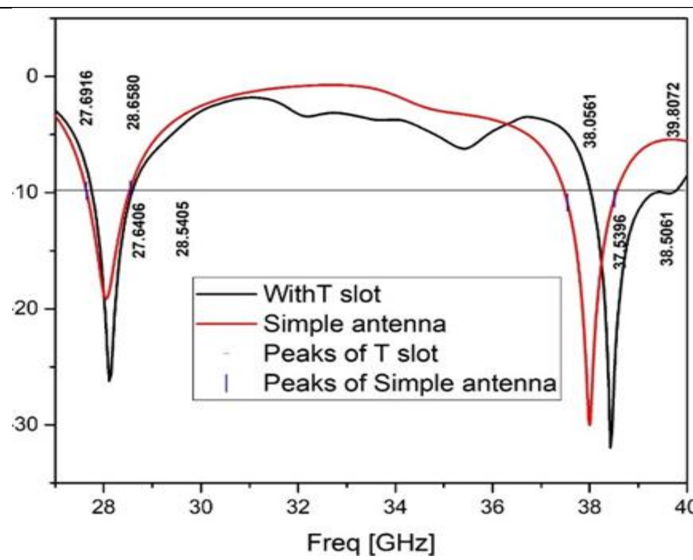

Figure 9: Bandwidth comparison of base line and T slot Antenna

The T-shaped slot antenna outperformed the baseline antenna in terms of bandwidth at both 28 GHz and 38 GHz. The increased bandwidth is indicative of the T-shaped slot's positive impact on the antenna's frequency response, allowing for more versatile and efficient operation across a broader range of frequencies. This improvement in bandwidth is a key advantage of the T-shaped slot design, contributing to the overall performance enhancement of the antenna in comparison to the baseline configuration. Voltage Standing Wave Ratio (VSWR) is a measure of how efficiently radio-frequency power is transmitted from the source, such as a transmitter, to the load, such as an antenna. It is expressed as the ratio of the maximum voltage to the minimum effective power transfer at the specified frequencies. Antennas match the impedance of the transmission line and effectively transfer power. A VSWR close to one (1) indicates minimal reflection and indicate better impedance matching. The VSWR values provide insights into how well the dimensionless quantity, and lower VSWR values. Figure 10 shows Voltage Standing Wave Ratio (VSWR) comparison with different Ground Planes.

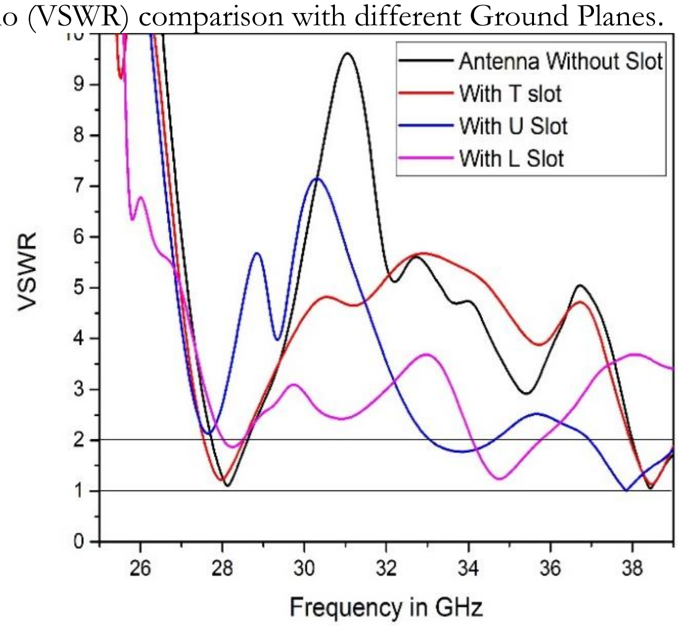

Figure 10: Voltage Standing Wave Ratio (VSWR) comparison with different Ground Planes

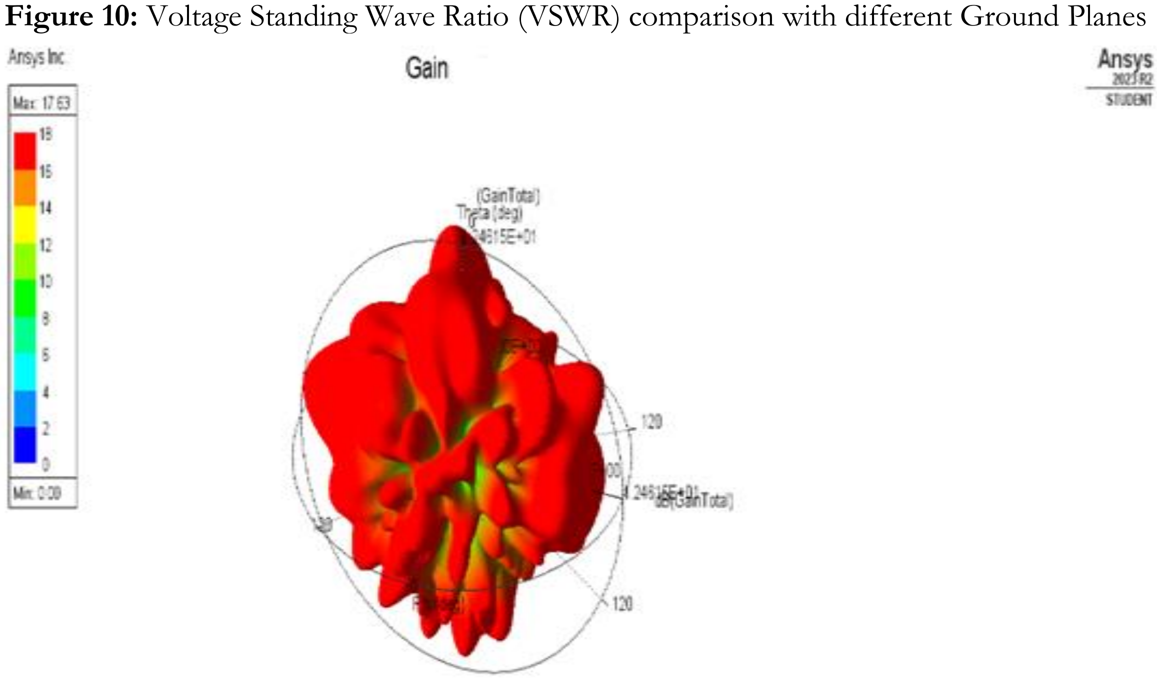

Figure 11: Gain of T slot AT 28 GHz

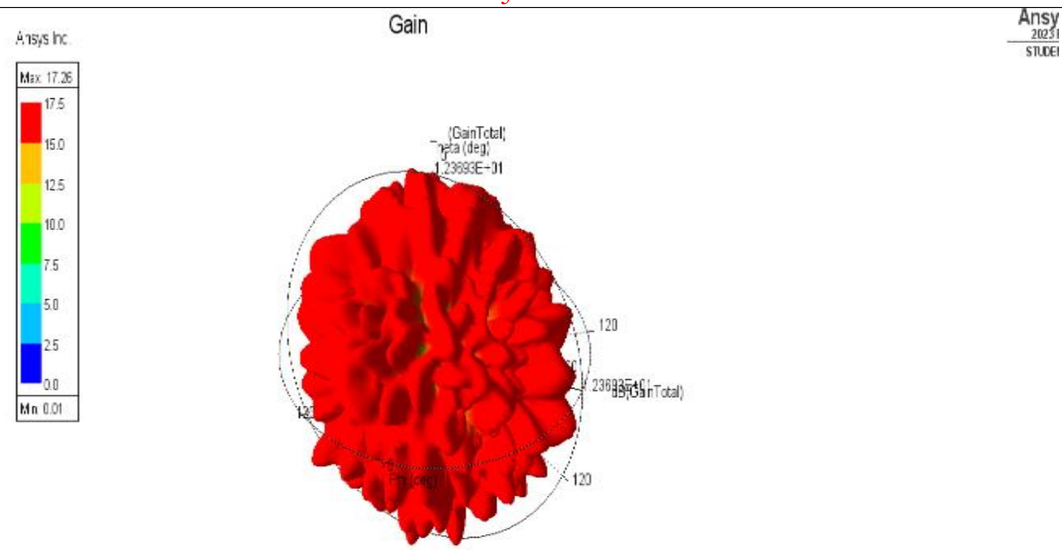

Figure 12: Radiation Pattern of T slot at 38 GHz

DISCUSSION

The designed antenna presents a high-performance solution tailored for 5G operations, featuring a dual-band configuration at the millimeter-wave bands of 28 GHz and 38 GHz. The innovative approach involved incorporating two inverted T-shaped slots on the microstrip patch antenna, contributing to the achievement of dual-band operation. Additionally, the insertion of these T-shaped slots on the radiating element enhanced the antenna's gain significantly. To further improve the bandwidth, various ground slots, including U-shape, L-shape, and T-shape, were compared, with the T-shaped slot demonstrating the most favorable results. The antenna was constructed on a substrate of Rogers RT Duroid 5880, with specific material properties. Ansys HFSS software was utilized for simulation, providing a comprehensive analysis of the antenna's performance. The proposed design achieves a maximum gain of 10 dB for a simple ground, 17 dB for a T-shaped slot at both 28 GHz and 38 GHz as shown in figure 11 and 12. The impedance bandwidth response met the criteria of 1 and 2 GHz at the respective resonating frequencies, showcasing the antenna's suitability for 5G applications. The compact form factor, with dimensions of 16 x 12 x 0.501 mm, made the antenna practical for integration into 5G devices. The T-shaped slot design outperformed in terms of both performance gain and increased bandwidth, making it a key element in achieving optimal antenna performance. In summary, the proposed antenna design successfully addresses the challenges of 5G communication, offering a dual-band, high-gain, and bandwidth-enhanced solution suitable for the demands of next-generation wireless

COMPARISON WITH OTHER WORKS

Table 4 presents a comparative analysis of our antenna's performance against data from various sources in the open literature. Our findings demonstrate favorable comparisons with the majority of the referenced data. This comparison suggests that the inclusion of cutting edges in the microstrip patch design contributes to the compactness of the proposed antenna while simultaneously enhancing its bandwidth and achieving a corresponding high gain. The observed consistency and superiority in performance metrics across various studies underscore the effectiveness of the cutting-edge approach in optimizing the antenna's compact form factor, bandwidth, and gain, positioning it competitively within the existing body of research in the field.

Table 4. Comparison of All antennas

Ref /N0	Frequency	Bandwidth GHz	Gain (dB)
2	28/38	1/0.5	5

6	28/38	5/10	8/6
8	28	5/8	4
9	38/60	2.0/3.2	5/4
13	28	1	6
14	2.4/5.8	4/2	3
Proposed	**28/38**	**1/2**	**17/15**

The proposed antenna design demonstrates significant improvements in both gain and bandwidth compared to the referenced antennas from the literature. The specific metrics compared and their relevance are as follows:

Frequency Bands: The proposed antenna operates at 28 GHz and 38 GHz, which are critical frequencies for 5G applications. This dual-band operation is essential for accommodating different communication channels and increasing the overall data throughput.

Bandwidth: The proposed design achieves bandwidths of 1 GHz at 28 GHz and 2 GHz at 38 GHz. Compared to other designs, such as Reference 6 which achieves 5 GHz bandwidth at 28 GHz but only 10 GHz at 38 GHz, the proposed antenna offers a more balanced and substantial bandwidth improvement at both operating frequencies. This ensures better performance in handling high data rates and reducing latency, which are crucial for 5G communication.

Gain: The proposed antenna achieves an impressive gain of 17 dB at 28 GHz and 15 dB at 38 GHz. These values are significantly higher than those of other designs listed in the table 4. For instance, Reference 6 shows a gain of 8 dB at 28 GHz and 6 dB at 38 GHz, which are considerably lower. The higher gain of the proposed antenna indicates better signal strength and coverage, making it highly effective for millimeter-wave 5G applications.

Discussion

The inclusion of cutting edges in the microstrip patch design has played a pivotal role in achieving these performance metrics. The cutting edges help in:

Compactness: The innovative design approach contributes to the compact form factor of the antenna, measuring only 16.2 x 12.8 x 0.501 mm. This compactness is crucial for integrating the antenna into modern, space-constrained 5G devices.

Enhanced Bandwidth: The T-shaped slots on both the patch and the ground plane have been instrumental in enhancing the bandwidth. This design ensures efficient impedance matching over a wide frequency range, thus broadening the bandwidth.

High Gain: The strategic placement and configuration of the T-shaped slots on the patch element significantly improve the radiation efficiency, resulting in higher gain values. This superior gain is essential for achieving long-range communication and robust signal quality in 5G networks.

Conclusions

In conclusion, the current research showcases a microstrip patch antenna design optimized for 5G applications, incorporating innovative features such as cutting edges in the microstrip patch. The comprehensive evaluation of the proposed antenna's performance, reveals noteworthy advantages in terms of compactness, enhanced bandwidth, and high gain. The comparison with data from other works in the open literature consistently positions our antenna favorably, indicating the effectiveness of the cutting-edge approach in optimizing key performance parameters. Notably, the antenna featuring the T-shaped slot demonstrates impressive gains of 17 dB at 28 GHz and 15 dB at 38 GHz. This remarkable performance at both frequencies underscores the efficacy of the T-shaped slot design in achieving superior gain characteristics crucial for millimeter-wave 5G applications. The combination of compactness, widened bandwidth, and high gain the proposed antenna well-suited for the demands of next-generation wireless networks. In essence, the research contributes valuable insights to the field of antenna design for 5G, emphasizing the significance of incorporating cutting-edge techniques to achieve a compact form factor without compromising on performance. The consistent favorable comparison with existing literature underscores the robustness and competitiveness of the proposed antenna design. The success of this study opens avenues for further exploration and advancements in the realm of microstrip patch antennas for high-frequency applications.

Conflict of Interest

The author(s) declare that the publication of this article has no conflict of interest.

Author's Contribution

- **i)** Dr Raheela Manzoor, Engr usama and Engr Hamza did the critical review and wrote this manuscript.
- **ii)** Engr Usama saleem contributed to the key idea and the procedural approach of the research. Engr Hamza saleem designed the structure of the antenna and paper, further refine the manuscript.
- **iii)** The first author and second authors are indebted to Miss Noreen Nadeem and Dr Fareeda Behlil, SBK University Quetta, Pakistan for their support in guiding the manuscript and providing valuable suggestions/comments

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