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A Noval High Gain Compact Antenna for 5G Wireless Communication

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***Abstract*—** In this paper, a novel micro strip patch antenna, which contains the integration of triangular and inverted T-shaped slots on the radiating patch, for attaining high gain properties bandwidth while maintaining a well-matched impedance, is proposed. The novel approach involves precisely designed two symmetric triangular slots on both sides of the patch, each covering an area of $0.1mm^2$, four distinct extrusions along the patch edges, with an area of $0.06\,mm^2$ for each extension, and two inverted T-shaped slots, measuring $1.18mm$ in length and $0.2mm$ in width, are precisely positioned at a separation distance of $0.2mm$. It is revealed from the simulations that the proposed design of slotted antenna has an impressive 1.93GHz impedance bandwidth at center frequency of 28GHz with a return loss of -47.55dB. The antenna achieved a higher gain of 8.1dB. The radiation pattern exhibits a peak at 0 degrees, low side lobe levels at -14dB, and minimal back lobe radiation, with a half-power beam width spanning 75.5 degrees, contributing to its versatility. The antenna boasts an exceptional radiation efficiency of 90%, reflecting a well-matched impedance and impressive performance characteristics. This innovative micro strip patch antenna design represents a significant advancement in the field, offering enhanced gain, bandwidth, and overall performance for 5G wireless communication systems.

***Keywords*—** Micro strip patch antenna, Gain, Radiation Efficiency, Main lobe, Side lobe levels.

I. Introduction

In this rapidly evolving landscape, the role of Micro strip Patch antennas have gained paramount significance. These antennas serve as essential components that bridge the gap between the digital world and physical transmission, enabling the exchange of signals that drive 5G communication. Their compactness, cost-effectiveness, and ease of integration align perfectly with the demands of the 5G era, where the deployment of numerous small cells and diverse frequency bands is essential [1].

A single micro strip patch antenna boasts numerous advantages, including its compact size, lightweight nature, mechanical robustness when mounted on rigid surfaces, and its capability to support both linear and circular polarization, as well as dual operating frequencies [2]. However, these merits coexist with several limitations, including low directivity, modest gain, a narrow impedance bandwidth, and limited radiation efficiency. Nevertheless, these constraints can be effectively addressed through the application of various techniques to enhance the single-element micro strip antenna. By methodically designing and modifying the characteristics of this antenna, its overall performance can be significantly improved. This includes enhancements in terms of Signal to Noise Ratio (SNR), directivity, gain, bandwidth, impedance matching, total antenna efficiency, polarization diversity, and other performance parameters that are typically challenging to optimize with individual patch elements [3].

Several approaches address these constraints, including adopting micro strip patch array configurations, utilizing low dielectric substrates, increasing dielectric substrate thickness, incorporating slots into the antenna's geometry, stacking the antenna, implementing multiple resonators, and enhancing impedance matching [4]. Moreover, fundamental parameters like the patch's length, width, thickness, and feeding network configuration are crucial factors influencing the micro strip antenna's overall performance. By strategically addressing these aspects, micro strip patch antennas can overcome their limitations and achieve improved gain, bandwidth, and efficiency, thus elevating their effectiveness in various communication applications [5].

The micro strip antenna is a promising candidate for fulfilling the communication needs of 5G antennas due to its compact form, flexibility, lightweight nature, and cost-effectiveness. Nevertheless, conventional micro strip patch antennas exhibit inherent limitations, including lesser gain, restricted impedance bandwidth, and low antenna efficiency [6]. Extensive literature reveals that numerous researchers have explored diverse methodologies to enhance patch antenna performance [7]. Some have employed array configurations in their studies [8] [9], while others have investigated various single-element configurations tailored to specific applications [10]. For instance, D. W. Astute, et al. proposed a compact micro strip antenna utilizing Defected Ground Structures (DGS) for 5G communication in [11]. Although this design achieved a broad 6GHz bandwidth, the gain remained relatively modest at the resonant frequency. Recently, a comparative analysis of FR4 and Rogers substrates was conducted to explore a two-slot rectangular multiband micro strip antenna for 5G applications [12]. In another study, Murkowski fractal shapes was employed to develop a micro strip antenna for 5G applications [13]. Additionally, [14] introduced a co-planar waveguide antenna for 5G communication, featuring an elliptical shape to achieve a wide bandwidth. This design attained a substantial bandwidth of $4.79GHz$ at the lower end and $4.17GHz$ within the frequency spectrum. Furthermore, an innovative compact patch antenna design, operating at 38/60GHz, was presented in [15], achieving impedance matching at 2GHz and 3.2GHz for each band.

Slotted microstrip patch antennas offer numerous advantages over their traditional counterparts without slots. These benefits encompass an array of performance enhancements that contribute to the antenna's versatility and effectiveness. The inclusion of slots brings about a series of advantages, including the expansion of the antenna's impedance bandwidth, enabling it to function efficiently over a broader spectrum of frequencies [16]. Additionally, slots have the capability to manipulate the field pattern of the antenna, resulting in elevated gain and directivity in specific directions. By strategically designing slots with distinct orientations, these antennas offer diverse polarization options, rendering them adaptable for a variety of communication scenarios. Furthermore, skillful slot design can reduce cross-polarization, optimizing the purity of desired polarization and minimizing interference. The implementation of slots also allows for fine-tuning the antenna's resonance frequency, enabling adjustments to align with desired operating frequencies. This design approach not only enhances performance but also supports size reduction, catering to applications constrained by space limitations [17].

In this paper, a novel slotted micro strip patch antenna is designed that demonstrates substantial advancements in terms of gain, bandwidth, and overall performance, catering to the demands of future wireless communication systems, particularly for 5G and beyond. In particular, a compact patch, which contains the impact of integration of triangular and inverted T-shaped slots on the radiating patch, for attaining high gain properties bandwidth while maintaining a well-matched impedance, is proposed.

II. Literature Review

An in-depth comprehension and comprehensive literature review on the the available knowledge concerning to microstrip patch antennas for achieving high gain, bandwidth and antenna efficiency for 5G applications, has been conducted in this section. Relevant research papers are chosen and thoroughly examined. The analysis of the associated literature study involves three main viewing fields, which contains; the structure of the antenna, techniques for enhancing the gain of antenna, and the microstrip antenna operation in 5G communication band around 28GHz.

The microstrip antenna is a promising candidate for fulfilling the communication needs of 5G antennas due to its compact form, flexibility, lightweight nature, and cost-effectiveness. Nevertheless, conventional microstrip patch antennas exhibit inherent limitations, including lesser gain, restricted impedance bandwidth, and low antenna efficiency [18].

In [19] K.A.fante and M.T.Gemeda proposed a broad band micro strip patch antenna resonating at 28 GHz. Featuring Rogers RT/Duroid5880 as dielectric substrate and a height of 0.354mm. The performance for the most part was focusing on the dimensions of an antenna achieving gain of 7.554 dBi and bandwidth of 1.062 GHz. The said antenna was mainly delineate for 5G Wireless communication.

Some have employed array configurations in their studies [20]. Also In [21] D. Mungur and S. Duraikanan introduced the MSPA for 5G application having a bandwidth of 582 MHz and an utmost gain of 6.92 dBi. The main aim behind the design was to operate for multipoint distribution services. The substrate Rogers RT/Duroid 5880 was used as a dielectric medium having a thickness of 0.254mm. Meanwhile others have investigated various single-element configurations tailored to specific applications [22]. For instance, D. W. Astuti, et al. proposed a compact micro strip antenna utilizing Defected Ground Structures (DGS) for 5G communication in [23].

Subsequently in [24] M.T. Gemeda put forwarded the MSPA design resonating at 28 GHz. FR-4 dielectric substrate with a height of 0.244 mm was used to resonate an antenna for the said frequency. An antenna was designed to achieve the peak gain of 7.587 dBi and a bandwidth of 1.046 GHz and they were considered better result as compared to previously mentioned in literature. The said antenna was featuring a single band communication over the 5G channel.

In [25] another study, Minkowski fractal shapes were employed to develop a micro strip antenna for 5G applications (Fatah & Mohamed, 2021). Additionally, [26] introduced a co-planar waveguide antenna for 5G communication, featuring an elliptical shape to achieve a wide bandwidth. This design attained a substantial bandwidth of $4.79GHz$ at the lower end and $4.17GHz$ within the frequency spectrum. Furthermore, an innovative compact patch antenna design, operating at 38/60GHz, was presented in [27], achieving impedance matching at 2GHz and 3.2GHz for each band.

In [28], Yassine Jandi et al has presented a closely packed dual bands microstrip antenna for 5G devices. The proposed dimensions of the device are $19mm$ x $19mm$ x $7.787mm$ including the ground plane, substrate and patch. The frequencies for which the antenna set of are 10.15 GHz and 28 GHz. The antenna Gain provided by this design is 5.51dB at 10.15 GHz and 8.03dB at 28 GHz. The substrate material employed in the antenna is Rogers RT5880 with a thickness of $0.787mm$. The bandwidth of the proposed design at center frequency of 10.15GHz is 278MHz at return loss S_{11} of -26.9dBs with total efficiency of 60% having directivity of 7.75dB and 1.01GHz at return loss S_{11} of -24dB with total efficiency of 58% having a directivity of 7.38dB at center frequency of 28GHz respectively.

The design of a rectangular microstrip array for 5G wireless communication is studied in [29] by Saeed Ur Rahman et al. The dimensions of the single patch is $3.05mm$ with a width of $4.23mm$ respectively. Rogers RT5880 is used as dielectric in the antenna with height of substrate of 0.762 mm and dielectric value of 2.2. The distance between the two patches is 0.63λ. The return loss S_{11} parameter is below -10dB with bandwidth size of 1.2GHz and Gain of 7.86dB, the patch is resonated from 26.5GHz to 28.79GHz with impedance bandwidth size of 8.28%. For the Array design, the S_{11} parameter is also below -10dB with impedance bandwidth of 9.0GHz from 25GHz to 34GHz and the Gain observed is 10.7dB. Due to this technique of using the array, the impedance bandwidth, Antenna Gain as well as the overall performance is improved.

In [30], Shivangi Verma presents a small microstrip antenna for 5G communication. The proposed dimension of the patch are $20mm$ x $20mm$ x $1.6mm$ including the ground plane. The resonant frequency is 10.15GHz with return loss of -18.27dB with an impedance bandwidth of 0.4GHz. The Gain of the antenna is 4.45dB. The design is a low profile and can easily fitted in devices where space is a vital problem

Low Ching Yu et al presented in [31], in which they proposed three contrasting variations of microstrip array antennas to study their radiation pattern with resonant point at 28 GHz for 5G communication. The proposed antenna designs are excited through inset feed line technique. The Rogers RT5880 substrate is employed in the antenna with dielectric constant value of $\varepsilon_r = 2.2$ with thickness of $0.254mm$. The dimensions of the patches in all three designs is $4.24\ mm$ x $3.27\ mm$. The distance between the patches is $5.36mm$ or $\lambda/2$. The patch is fed by a feedline of 50Ω line. After simulation all three antennas gives us a bandwidth of 1.40GHz. Antenna 1 gives a Gain of 8.64dB, the second antenna exhibit a gain of 7.47dB and antenna 3 gives a gain of 7.46dB. The difference in gain is because Antenna 1 has feeding on same side that provides it with constructive interference on the radiation patterns while second and third antennas are obverse feeding structures so the radiation pattern interfere destructively.

Gharbi and Hedi Ragad proposed three designs of patch array antennas in [32] for 5G applications. The antennas are fed by microstrip and coaxial lines. The designs discussed are 2x1, 2x2 and 4x1 array configurations. The substrate taken is Rogers RT5880 with height of 0.508 for all the designs. The dimensions of the patch in 2x1 is 3.7 x 3.4 mm, with the S_{11} parameter value of -39dB. The gain of the antenna is 9.7dB, the impedance bandwidth is 1.9 GHz. As for the 4 x 1 design the dimensions are 4.23 x 3.28 mm, the S_{11} parameter is -62dB with the bandwidth of 2.15GHz and gain of 13.2dB. And last the 2 x 2 antenna with dimensions $3.92mm$ x $3.36mm$, the return loss is -34dB with the gain 13.3dB and impedance bandwidth of 1.3GHz around the center frequency of 12GHz.

A novel design of 8x8 phased array is given in [33] by Muhammad Kamran Ishfaq et al. The dimensions of the patch is $3.539mm$ x $3.539\ mm$. The distance between the patches is $3.54mm$ or $\lambda/2$. The resonant frequency is 28GHz and the impedance bandwidth is 500MHz staring from 27.9GHz to 28.4 GHz. The gain of the antenna is 24.4dB.

Umair Rafique et al give a dual band microstrip array antenna design in [34]. In the paper an eight element microstrip array design is presented. The measurements of the patch is 16x16mm^2. The center frequency is 28GHz and 39.95GHz. The gains obtained through simulations are 15.6 dB for 28GHz and 10dB for 39.95GHz. The collective impedance bandwidth of the both the resonant points is 3.0GHz.

In [35] Qian Wang et al discusses their design of 5G MIMO conformal microstrip antenna. The author has designed an 8-cell series fed microstrip patch standing waves array antenna for Ka band i.e. 35GHz. The basic parameter of the patch is $2.45mm$x$3.32mm$. The dielectric in this antenna is Rogers RT5880 with dielectric value of $\varepsilon_r = 2.2$. The adjustment of spacing is realized by the deflection of major lobe and plane of the array, and the antenna synthesis makes use of the Taylor distribution. The S_{11} parameter of the antenna is -31.87dB and the relative bandwidth can be found to be 21.7%. The antenna is well match at 51.5Ω and the gain achieved is 13.36dB.

Zihao Chen and Yue Ping Zhang presented a design on array antenna design in [36]. They started with FR-4 being their substrate, the single patch has the parameters of $15mm$ x $15mm$ x $0.8mm$. The results through simulation gives a impedance bandwidth of 7.16GHz from 23.86GHz to 31.02GHz. The maximum gain of the design is 12.7dB at 29.2 GHz.

In [37], Yusnita Rahayu et al presented their design of a Rectangular Microstrip Antenna. They operated their antenna is 28GHz frequency range. Total of 56 radiation elements are combined to form a patch and in 2x2 configuration and a total of 112 rectangular radiating element pathes are used. The antenna is operated at a frequency spectrum from 27.5 to 29.5 GHz. This provides a bandwidth of 1.95 GHz (6.96%). The S_{11} parameter reaches up to -44.71dB at 28.5GHz. The gain of the proposed antenna is 18.5dB.

Mohamed Bakry El Mashade and E. A. Hegazy has presented a design of a rectangular array antenna [38]. In this article, the objective is to examine the design of a 28GHz microstrip patch array antenna consisting of four elements, intended for prospective 5G cellphone applications. The antenna under consideration is constructed on an FR-4 substrate, chosen for its ability to sustain excellent performance in gain and efficiency. Additionally, the results after simulation showed that the return loss response, the $S_{11} < -10dB$ in the range of 22GHz-34GHz. The single patch is very thin having dimension of $2.503mm$ x $3.215mm$. The return loss obtained is of -15.35dB at 27.901 GHz with a gain of 6.92 dB having a VSWR value of 1.787. The main purpose of this article is to improve the gain by the implementation of arrays. Initially, a 2x1 linear array antenna was designed and simulated, in the final stages a 4x1 linear antenna array was designed and analyzed which was to improve the gain and antenna efficiency to achieve an enhanced radiation pattern. For the 2x1 the gain achieved at 28GHz is 9.52 dB with S_{11} is up to -13.77dB. For the 4x1 array resonating at 27.53 having the S_{11} value of -21.44 dB, the gain achieved is 11.2dB.

In [39], Siti Nor Hafizah et al proposed an antenna array for 5G applications by using graphene as a substrate. The mentioned antenna is tested on three substrates i.e. Kapton, A4-paper and RT duroid having thickness 0.075mm, 0.05mm and 0.245mm, respectively. For Kapton the frequency range was

13.84–15.73 GHz with a bandwidth of 1.89GHz, for the A4 paper the frequency range was 14.14–16.26 GHz with a bandwidth of 2.12GHz and for the RT Duroid the frequency range was 14.05–15.79GHz with a bandwidth of 1.74GHz. The gain achieved for RT Duroid, A4 paper and Kapton substrates are $7.19dB$, $7.09dB$ and $7.62dB$ respectively. The radiation efficiency of the array is overall decent which is 92.27% for Kapton substrate, 93.14% for A4 paper substrate and 92.15% on RT Duroid substate respectively.

Beenish et al presented a novel 16-element microstrip patch antenna array in [40]. In the design, the radiating patches are attached in a planar configuration through high impedance microstrip lines. To simplify the design, a coaxial feed was employed instead of numerous microstrip feed lines, and efforts were made to minimize the substrate thickness. A substrate having dimensions $34.265mm$x$34.265mm$, $\varepsilon_r = 2.2$ and thickness of $0.25mm$ is used. The novel 16-elements microstrip array antenna resonated at 28 GHz with a gain of 14.82 dB having S_{11} value of -21.7 dB with impedance bandwidth of 112.6 MHz.

Hidayat Ullah and Farooq A. Tahir in their study has proposed a wire hexagon antenna array for 5G application [41]. The presented design has dimensions of $45 \times 20\ mm^2$. The impedance bandwidth of the designed antenna spectrum from 25.052GHz to 34.923GHz which is wide bandwidth of 9.871GHz and is suitable for broadband. The single element structure is simple and can be tuned in the chosen frequency millimeter band of 28GHz. Two hexagonal wire loops that are in the middle and are moved apart by a tiny gap. The array feeding system was specially designed which enabled it to radiate with a gain of 12.15dB. The proposed array is considered a strong candidate for the 5G communications primarily due to its compact dimensions, design, and wideband frequency response.

In [42], Osama Haraz et al discusses a design of 4-element dual band microstrip antenna array and analysis for 5G mobile networks. The proposed antenna possesses a compact form factor resonating at 28/38 GHz. To feed the designed antenna array, a Wilkinson power divider has been employed. Additionally, Electromagnetic Bandgap (EBG) structures have been integrated to further enhance the performance of the power divider. The antenna gain with a value of 10.58 dB at 28GHz band and 12.15 dB at 38 GHz band respectively.

III. DESIGN CONFIGURATION AND ANTENNA MODELLING OF PATCH

The proposed design is implemented for 28GHz center frequency on Rogers RT/duroid 5880, a substrate known for its high-frequency capabilities. The chosen substrate offers specific properties, including a density of Rho = 1050 [Kg/m³], a substrate height of 0.787mm, and a relative dielectric constant $\varepsilon_r = 2.2$.

In the initial phase, the standard formulas pertaining to a rectangular microstrip patch has been utilized in order to compute the parameters associated with the proposed microstrip antenna, as specified in equations 1 to 5. To calculate the dimensions (L_p for length, W_p for width) of the radiating patch using equations for resonance, based on the desired center frequency of 28GHz, equation (1) is used.

$$W_p = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (1)$$

Where

C is the speed of light approximately equals to $3 \times 10^8\ m/s$.
$\boldsymbol{\varepsilon_r}$ is the relative permittivity of the substrate.
$\mathbf{f_r}$ represents the resonant frequency.
Because the field extends beyond the interior of the substrate material, it is necessary to take into account the effective dielectric properties of the substrate. This is calculated by the equation (2).

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} * \left[1 \Big/ \sqrt{1 + \frac{12H_s}{W_p}}\right] \qquad (2)$$

Where
$\boldsymbol{\varepsilon_{eff}}$ represents the effective dielectric permittivity.
$\mathbf{W_p}$ represents the width of the radiating patch.
$\mathbf{H_s}$ represents the thickness or height of the substrate.
$\boldsymbol{\varepsilon_r}$ represents dielectric constant of the substrate.
By considering the effects of fringing fields around the antenna, the actual length of the radiating patch is calculated by equation (3).

$$L_p = L_{eff} - 2\Delta L_p \qquad (3)$$

Where $L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}}$, and ΔL_p represents the extension of length due to fringing effect in the region surrounding the antenna and is given by equation (4)

$$\Delta L_p = 0.412H_s \frac{\left(\varepsilon_{eff} + 0.3\right)\left(\frac{W_p}{H_s} + 0.268\right)}{\left(\varepsilon_{eff} - 0.3\right)\left(\frac{W_p}{H_s} + 0.8\right)} \qquad (4)$$

The microstrip antenna is connected to a transmission line with a 50Ω impedance.

A. DESIGN OF A SLOTTED PATCH ANTENNA

The process of incorporating slots into a micro strip patch antenna encompasses the determination of both the slot's dimensions and its precise position on the patch. While Equation (5) offers an initial framework for slot design on the radiating patch, achieving greater design precision and optimizing slot placement is accomplished through iterative adjustments using CST software.

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_r - 1}} - \frac{L_p}{2} \quad (5)$$

Where L_{eff} represents the effective length of the slot while the width is calculated through iterative alterations using parametric sweep in CST software. The blueprint for the $28GHz$ microstrip antenna, employs an inset line feeding technique with a 50Ω impedance. Given the small dimensions of the antenna, it's essential to ensure efficient power transfer between the radiating patch and the feed line. Consequently, the inset type feeding technique is selected to maximize power transfer.

The design of slots on the proposed microstrip patch is revealed in Figure 1.

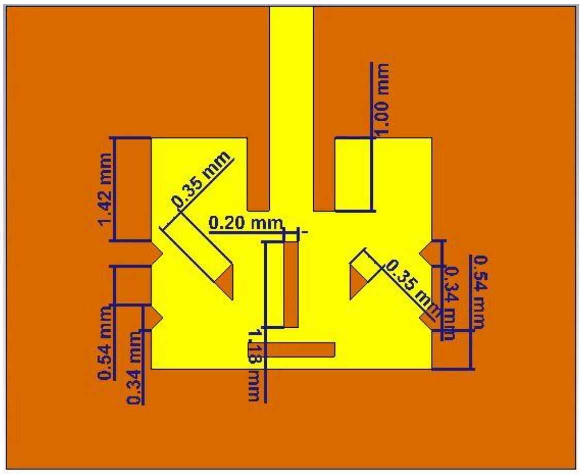

Figure 1: Proposed slotted patch antenna

The parameters used in the design of proposed miniaturized slotted microstrip antenna are listed in Table 1.

Table 1: Design specification of slotted patch antenna

Parameters	**Values (mm)**	**Description**
L_g	6.34	Length of the ground plane and substrate
W_g	7.78	Width of the ground plane and substrate
H_s	0.787	Height of the Substrate
L_p	3.17	Length of the Patch
W_p	3.83	Width of the Patch
L_f	1.8	Length of the microstrip feedline
ε_r	2.2	Value of Dielectric Constant
W_f	0.6	Width of the microstrip feedline
P_t	0.035	Thickness of the patch metal
G_t	0.035	Thickness of the ground plane metal
L_{ins}	1	Length of the Inset feed
W_{ins}	0.3	Width of the Inset feed
L_{slot1}	1.18	Length of upper slot
W_{slot1}	0.20	Width of upper slot
L_{slot2}	1.18	Length of lower slot
W_{slot2}	0.20	Width of lower slot
D_{slot}	0.20	Distance between the two T-Shaped slots
$L_{t.slot}$	0.34	Length of Triangular slots
$W_{t.slot}$	0.34	Width of Triangular slots
$D_{t.slot}$	0.20	Distance between the Triangular-Shaped slots

The proposed antenna exhibits an overall geometrical dimension of $6.34mm$ x $7.78mm$ x $0.787mm$. An inset feed method has been employed, with feed lines measuring $1.8mm$ in length and $0.6mm$ in width. The inset cut has a width of $0.3mm$. To manage the electrical size of the antenna, two inverted T-shaped slots, each $1.18mm$ in length and $0.2mm$ in width, are incorporated. These slots are positioned at a distance of $0.2mm$ from each other. In the innovative design approach, two symmetrical extrusions were etched on either side of the upper slot, with each extrusion covering an area of $0.1mm^2$. Additionally, four extrusions were etched on the edges of the patch in the novel design approach, with two on each side, and each extrusion having an area of $0.06mm^2$. Through the utilization of a parametric sweep analysis in the CST Simulation tool, adjustments to the size, shape, and placement of these slots are made iteratively. This fine- tuning process precisely tailors the radiation pattern to meet specific performance criteria. This antenna configuration is well-suited for wireless communication systems in millimeter wave 5G applications around $28GHz$.

IV. RESULTS AND DISCUSSION

The proposed design of microstrip antenna represents a notable achievement in terms of high gain, enhanced bandwidth, and overall impressive performance. A unique and innovative approach has been employed to augment the antenna's gain, achieved through the strategic insertion of slots onto the patch. In this inventive design strategy, symmetrical extrusions have been meticulously incorporated on both sides of the upper slot, each covering an area of $0.1mm^2$. Additionally, four distinct extrusions have been carefully etched along the edges of the patch, with two on each side, and each of these extrusions occupies an area of $0.06mm^2$. As a complementary enhancement, two inverted T-shaped slots have been introduced, each with dimensions of $1.18mm$ in length and $0.2mm$ in width, positioned at a precise separation distance of $0.2mm$. The fabricated design of the proposed slotted patch is shown in Figure 2. Figure 3 displays the return loss S_{11} parameter in dB for the proposed antenna at $28GHz$. Additionally, Figures 4 and 5 present the far-field gain patterns.

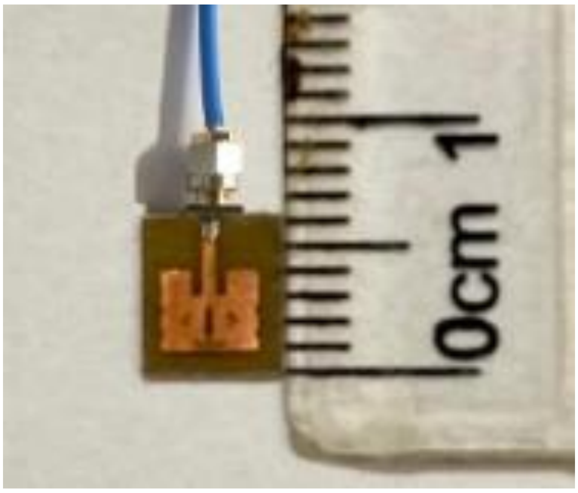

Figure 2: Fabricated design of proposed slotted patch antenna

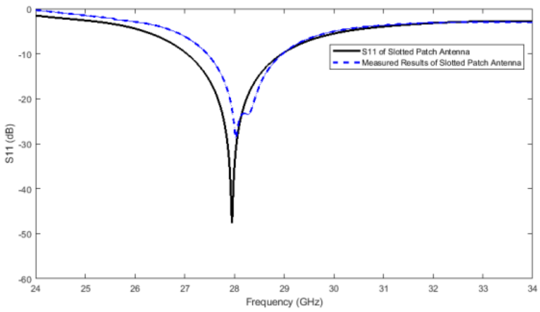

Figure 3: Frequency response (S_{11} Parameter) of slotted patch antenna

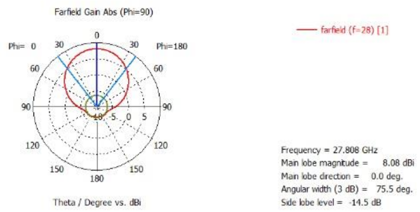

Figure 4: Far field pattern (Polar plot) of slotted patch antenna

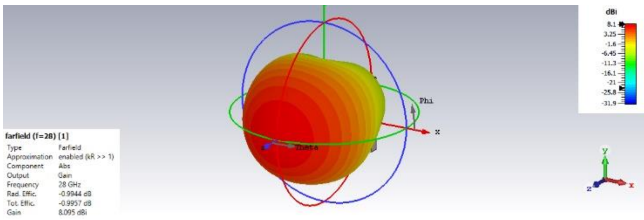

Figure 5: Far field pattern (3D plot) of slotted patch antenna

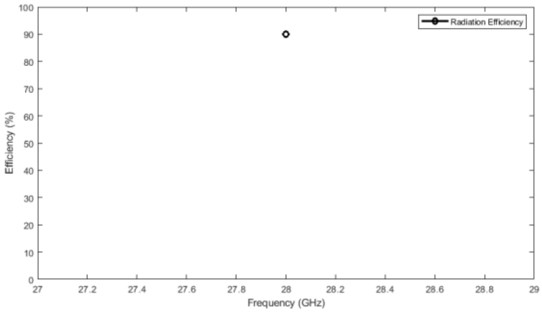

Figure 6: Radiation efficiency of slotted patch antenna

The reflection coefficient analysis of the proposed design reveals that the patch antenna resonates precisely at $28GHz$. Impressively, the antenna showcases a bandwidth of $2GHz$, exemplified by a return loss of $-47.55dB$, as visually depicted in Figure3. The primary objective of this approach was to significantly enhance the antenna's gain, and it succeeded with a remarkable 55% increment, resulting in a high and commendable gain of $8.1dB$. Notably, the radiation pattern exhibits its peak at 0 degrees, coupled with a low sidelobe level of $-14dB$ and very low back lobe radiation. The half-power beamwidth of antenna spans 75.5 degrees, contributing to its versatile performance. Furthermore, the antenna boasts an exceptional radiation efficiency of 90%, reflected in its overall efficiency, highlighting its well-matched impedance and remarkable performance attributes for 5G applications.

Table no: 2 Comparison of proposed design with previous published work.

References	Resonating Frequency(GHz)	Bandwidth (GHz)	Gain (dB)
[19]	28	1.062	7.554
[21]	28	0.585	6.69
[24]	28	1.046	7.5
[43]	28	0.847	6.63
[44]	28	1.1	6.72
[45]	28	1.33	7.6
This Work	28	1.93	8.15

CONCLUSION

A novel and inventive strategy has been employed to heighten the antenna's gain through the strategic introduction of slots onto the patch structure. Through a carefully crafted approach involving the strategic integration of triangular and T-shaped cuts, the antenna achieved impressive results. The exactly designed symmetric extrusions and the precisely positioned inverted T-shaped slots not only expanded the bandwidth but also significantly amplified the antenna's gain. This gain enhancement, a commendable $8.1dB$ gain, marked a significant achievement in the pursuit of high-performance antennas. The analysis of the antenna's reflection coefficient confirmed its precise resonance at the target frequency of 28GHz, with a remarkable bandwidth of 1.93GHz, as evidenced by a return loss of -47.55dB. Additionally, the radiation pattern analysis showcased not only the main radiation peak at 0 degrees but also noteworthy characteristics including low sidelobe levels at -14dB and minimal back lobe radiation. The broad half-power beamwidth of 75.5 degrees highlighted the antenna's versatility. Furthermore, the antenna's exceptional radiation efficiency of 90% was indicative of its overall efficiency, underscoring its well-matched impedance and impressive performance characteristics.

Its success in achieving high gain, extended bandwidth, and excellent radiation characteristics make it a valuable contribution to the field and a promising candidate for the evolving wireless 5G communication landscape.

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