International Journal of Inventive Engineering and Sciences (IJIES)
ISSN: 2319-9598 (Online), Volume-12 Issue-2, February 2025

A Novel Miniaturized Hexagonal-Shaped Patch Antenna for Microwave 5G Communications

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Abstract: ***The creation of a hexagon-shaped patch antenna for Sub-6GHz 5G communications is presented in this study. For 5G wireless applications, the suggested antenna can resonate at the center frequency of 6 GHz. The proposed antenna features a hexagonal design, multiple radiating slots with partial ground and is fed with a microstrip feedline. It measures 17.5 × 22.2 × 1.6 mm³ and operates on the N102 band at 6 GHz. Return loss, VSWR, peak gain, and impedance bandwidth are all elements of the performance of the proposed antenna. The proposed antenna employs slots that cover the frequency range of 5.92 GHz to 6.35 GHz. At a resonant frequency of 6.1 GHz, the suggested antenna's reflection coefficient (S_{11}) is 44.6 dB, with a peak gain of roughly 3.2 dB. Thus, the suggested antenna can be used for 5G wireless applications operating at 6 GHz.***

Keywords: ***Patch Antenna, Inset Feed, ISM Band, Dual Band.***

I. INTRODUCTION

5G technology is going to be recognised as the norm for mobile communication networks shortly. An increase in users causes a lack of bandwidth. Increased bandwidth is required for accommodating large end users, which enhances the system's overall data rates. End users can communicate faster and more sensibly because to the high data rate [1]. Many industries, including realistic Ultra High Definition, Artificial Intelligence, Blockchain, and Internet of Things services like Smart Cities, Smart Transportation, and Smart Grids, will be greatly enhanced by the significant rise in mobile data in 5G. Its frequency provides high quality from sub-6 GHz to millimetre waves. The 5G frequency spectrum offers enhanced coverage, decreased fading, and better data rates. Antennas designed for 5G operation perform significantly better in the sub-6 GHz frequency range, raising the standard for communication systems generally [2].

Considering the specifications for 5G, antennas that are cheap.

Manuscript received on 27 January 2024 | First Revised Manuscript received on 14 February 2024 | Second Revised Manuscript received on 25 January 2025 | Manuscript Accepted on 15 February 2025 | Manuscript published on 28 February 2025.

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Easy to manufacture in large quantities, conformable to a planar surface, lightweight, low-profile, and conformable in size must be used. The ideal choice to fulfil all the aforementioned requirements is a microstrip patch antenna [3]. Excellent option for 5G communication systems due to its inherent advantages is a microstrip patch antenna. The ability to reduce an antenna's physical dimensions without noticeably affecting performance has attracted a lot of interest to antenna miniaturisation techniques in recent years [4].

The literature lists several methods for achieving antenna miniaturization, including slots, fractals, loops, Transmission Lines (TLs), Defected Ground Structures (DGS), Composite Left-Right Left-Handed (CLRH), etc., despite the fact that this is a difficult and intimidating task [5]. For Sub-6GHz 5G applications, a number of size-reduced antennas have already been designed [6]. For instance, studies is being done on an extremely small microstrip antenna for sub-6 GHz 5G wireless applications [7]. The size is decreased by combining an L-shaped patch radiator with a defective ground plane that has two symmetrical stubs. The overall size of the antenna is reduced to 30 x 20 mm. The combination of T-shaped elements, passive elements, tapering, and meandering techniques is introduced by [8] for miniaturisation. With an overall size of 50 × 19.75 mm, the suggested antenna offers better impedance matching across all frequencies and covers all sub-6 GHz bands. The design and implementation of a wideband rose-shaped patch antenna for Sub-6 GHz wireless applications [9]. The antenna design covers the frequency range (2.7-5.74 GHz) is made from the Rogers RT5880 substrate material, which has a low volume of 20 × 35 mm and a bandwidth of 3.04 GHz.

The design of a simple planar antenna for sub-6 GHz uses in 5G mobile terminals is described. The proposed antenna is comprised of one multi-branch driven strip and three parasitic grounded strips, and it has a simple layout that doesn't require lumped parts or a three-dimensional structure [10]. The 0.7-0.96 GHz and 1.6-5.5 GHz frequencies are covered by the -6dB impedance bandwidth, which has a compact design of 40 x 15 mm. With help of metamaterial ground plane, the dimensions of a compact TSRMPA are 30.2 x 36.4 mm. The modified rectangular patch with metamaterial ground plane resonated at three bands 3.27, 3.78, and 3.92 GHz [11]. A miniature printed monopole patch antenna with finite ground is used for demonstrating long-term Sub-6 GHz 5G wireless communications [12]. The size of the this antenna desires to measure 30 mm x 34 mm. The optimisation of the partial ground plane and stubs allows for accurate impedance matching over a wide range (3-7 GHz). For a 5G application, a microstrip patch with a T-shaped rectangular antenna patch operates at 3.6 GHz resonant frequencies from 2.9 to 4.4 GHz, respectively [13].

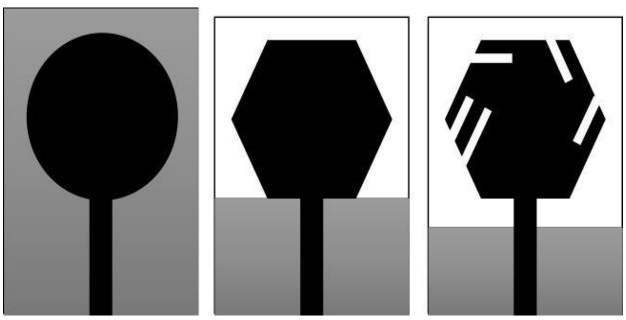
This paper demonstrates the analysis of a hexagonal-shaped antenna for Sub-6GHz 5G communications. The miniaturization of the proposed antenna has been achieved through the combination of its hexagonal-shaped and multiple radiating slots [14]. The overall volume of the designed antenna is approximately 17.5 22.2 1.6 mm^3. The designed antenna has a bandwidth of 1.1 GHz (from 5.4 GHz to 6.5 GHz), which is quite significant and makes it appropriate design. With proper design, the resultant peak gain values are nearly 3.2 dB [15]. Peak gain values are nearly 3.2 dB when properly designed. Furthermore, essential parameters such as VSWR, surface current density, and radiation patterns are computed and compared. The paper is organised as follows: The hexagonal patch antenna is designed and analysed in Section 2. Section 3 contains the outcomes of the investigation. Section 4 contains the paper's conclusion [16].

II. ANTENNA DESIGN & METHODOLOGY

Using the basic design equation for a patch antenna with a full ground, the designed antenna's initial design is calculated.

$$f_r = \frac{c}{4\,\pi r\sqrt{\varepsilon_{eff}}}$$

Where *"r"* is the circular patch's diameter, *"d"* is the light's velocity, and *"ε_{eff}"* is the equivalent dielectric constant [14]. With a dielectric constant of 4.4, the designated antenna has been constructed on a FR-4 substrate. As a result, the diameter of the circular patch is fixed at 15.9 mm for f_r = 6 GHz. To accomplish the innovation, the circular patch is changed to hexagonal shape, and to minimize the size of the antenna, different size slots are cut on hexagonal shape, and the ground plane is also reduced partially. The resulting antenna design operates at 6 GHz in a narrow band. The development of the proposed antenna is shown in Figure 1. CST simulation software is used to analyse the simulation of the proposed antenna design.

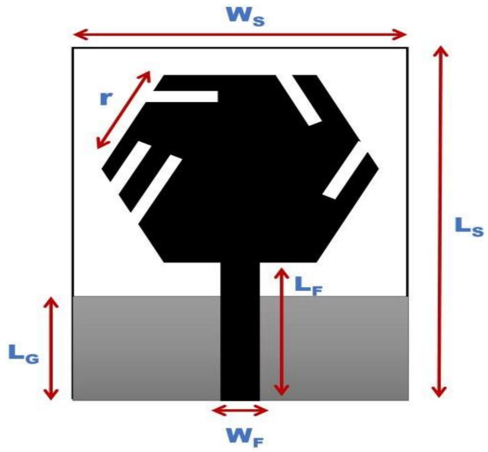


[Fig.1: Design and Evolutions of the Proposed Antenna]

Overall, the substrate measures 22.2 mm in length and 17.5 mm in width. Above the ground plane, the substrate layer is 1.6 mm thick in height. The antenna's feed arrangement is 2.4 mm in width by 8.5 mm in length. Figure 2 depicts the geometrical arrangements of the proposed antenna. Table 1 contains the structural characteristics of the proposed antenna.

Table 1: Parameters of the Proposed Antenna

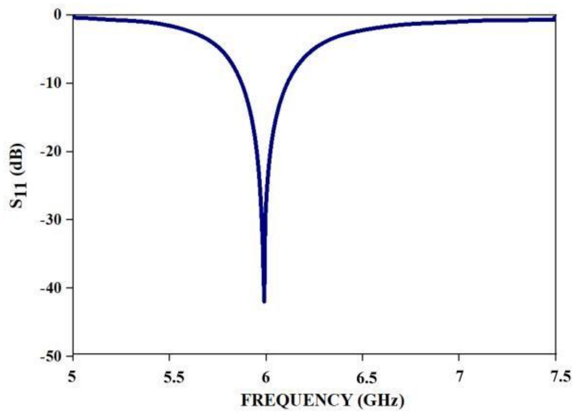
Parameter	Size (mm)	Parameter	Size (mm)
WS	17.5	L_G	4.3
LS	22.2	W_F	2.4
r	6.6	L_F	11.5



[Fig.2: Total Geometry and Structure of the Designed Antenna]

III. RESULTS & ANALYSIS

The bandwidth, radiation characteristics, and antenna-normalized gain have all been part of the antenna's performance. Figure 3 shows the total calculated and actual reflection coefficients of the proposed antenna. The antenna provides the reflection coefficients (S_{11}) around -46 dB at 5.9 GHz. This hexagonal-shaped antenna's observed impedance bandwidth in the simulation is around 500 MHz (5.6 - 6.1 GHz) at 5.9 GHz centre frequency. The required frequency is perceived as a suitable impedance bandwidth. The feeding losses may be the cause of the minor variation in the reflection coefficient that can be observed in the results. However, the proposed antenna's achieved bandwidth is sufficient for the targeted applications.



[Fig.3: Reflection Coefficient Plot of the Suggested Antenna]

Figure 4 displays the designed antenna's current flowing at a resonance frequency of 5.9 GHz. It proved that by etching several slots on the hexagonal patch, the current flow maintains its path inside the antenna surface and improves radiation performance. This demonstrates that at 5.9 GHz, the current is largely distributed at the outer region

Retrieval Number: 100.1/ijies.B108811020224
DOI: 10.35940/ijies.B1088.12020225
Journal Website: www.ijies.org

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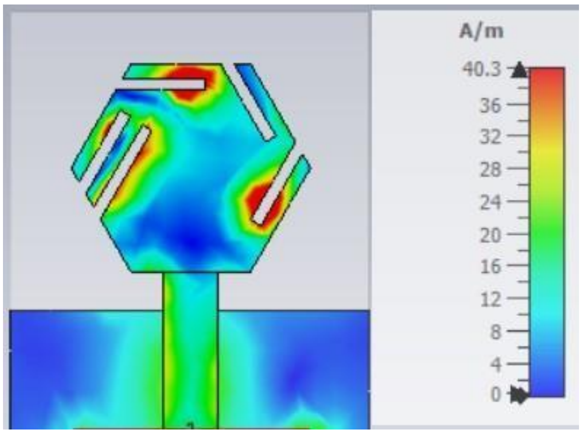
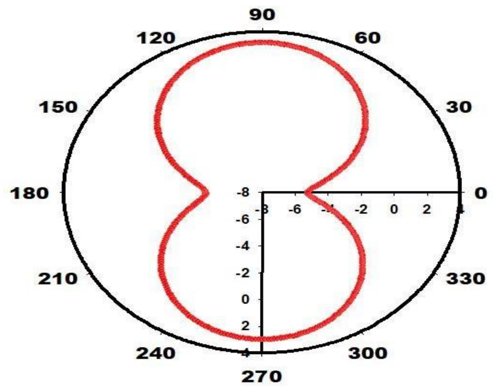
of the various slots. These findings clearly demonstrate that combination slots extend the overall electrical length while disturbing the flow of current. As a result, the antenna's resonance frequency is reduced without a change in patch size.

The suggested antenna is developed and evaluated based on this antenna performance.

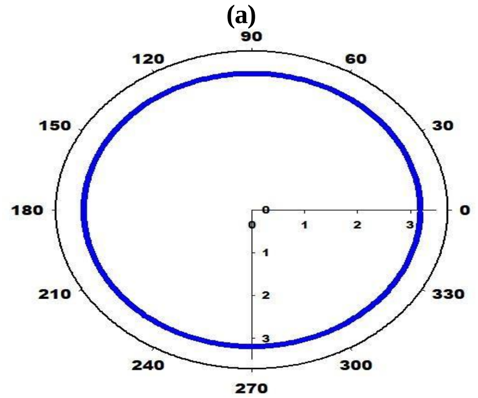


[Fig.4: Surface Current Density on Proposed Antenna at 5.9 GHz]

The suggested hexagonal patch antenna's radiation pattern is simulated at 5.9 GHz. Figure 5 a) and b) show that the optimum simulated radiation results are obtained at the centre frequency of 5.9 GHz in both the xy and xz planes. These plots show that the antenna exhibits a nearly bi-directional plot in the xy plane and an omnidirectional plot in the xz plane. The radiated fields in the yz-plane and xz-plane are standardized to the desired band at each frequencies.



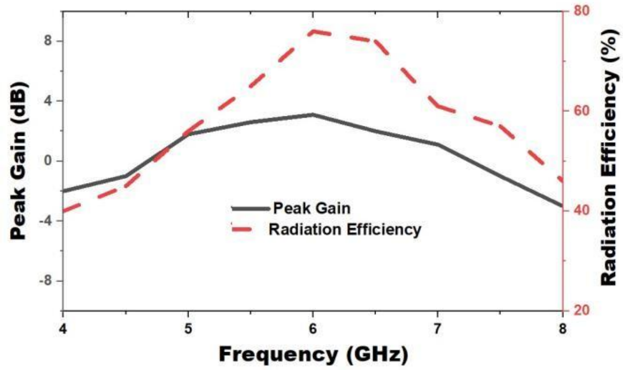
(a)



(b)

[Fig.5: The Compared Radiation Pattern of the Proposed Antenna at 5.9 GHz]

Figure 6 illustrates the suggested antenna's estimated radiation efficiency and maximum gain at different frequencies. Results demonstrate that the antenna operates at the working frequency more efficiently. The designed antenna obtained 76 % radiation efficiency and 3.1 dB gain at the required frequency of 5.9 GHz.



[Fig.6: Obtained Gain and Radiation Efficiency of the Intended Antenna]

Additionally, comparisons and analyses of this antenna's dimensions, normalised gain, bandwidth, and percentage of miniaturisation are accomplished. The designed antenna has a total size that is 56 % less than a conventional antenna and obtains a gain of 3.1 dB at 5.9 GHz, which makes it much more suited for 5G applications.

IV. CONCLUSION

In this paper, a basic, gain-enhanced, small hexagonal shaped microstrip antenna with various slots is examined. A hexagonal patch with several slots and a partial ground plane in the shape of a hexagon forms a component of the proposed antenna. Better gain and reflection coefficients at 5.9 GHz are provided by the suggested design. By employing multiple slot configurations, the recommended antenna reduces its size by approximately 56% when compared to a traditional antenna. Thus, the proposed antenna is beneficial for 5G applications functioning at sub-GHz frequencies.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it has been conducted without any external sway.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is contributed equally to all participating individuals.

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REFERENCES

1. Dilsha M.D., Neenu Welson, 2015, Introduction to 5G Wireless Technology, International Journal of Engineering Research & Technology (IJERT), 2015 (Volume 4 – Issue 06). https://www.ijert.org/introduction-to-5g-wireless-technology
2. K. Jain, R. Acharya, S. Jakhar and T. Mishra, "Fifth Generation (5G) Wireless Technology "Revolution in Telecommunication"," 2018 Second International Conference on Inventive Communication and Computational Technologies (ICICCT), Coimbatore, India, 2018, pp. 1867-1872. DOI: https://doi.org/10.1109/ICICCT.2018.8473011
3. N. Sekeljic, Z. Yao and H. -H. Hsu, "5G Broadband Antenna for sub-6 GHz Wireless Applications," 2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, Atlanta, GA, USA, 2019, pp. 147-148. DOI: https://doi.org/10.1109/APUSNCURSINRSM.2019.8888509
4. C. Mohan & S. Esther Florence (2022) Miniaturised Triangular Microstrip Antenna with Metamaterial for Wireless Sensor Node Applications, IETE Journal of Research, 68:2, 1177-1182. DOI: https://doi.org/10.1080/03772063.2019.1643266
5. Khan, M.U., Sharawi, M.S. and Mittra, R. (2015), Microstrip patch antenna miniaturisation techniques: a review. IET Microw. Antennas Propag., 9: 913- 922. DOI: https://doi.org/10.1049/iet-map.2014.0602
6. M. Fallahpour and R. Zoughi, "Antenna Miniaturization Techniques: A Review of Topology- and Material-Based Methods," in IEEE Antennas and Propagation Magazine, vol. 60, no. 1, pp. 38-50, Feb. 2018. DOI: https://doi.org/10.1109/MAP.2017.2774138
7. P. Pradeep, J. S. Kottareddygari and C. Sekhar Paidimarry, "Design of a Novel Compact L-slotted Monopole Antenna for 5G Applications in sub-6 GHz Band," 2022 3rd International Conference on Electronics and Sustainable Communication Systems (ICESC), Coimbatore, India, 2022, pp. 394-397. DOI: http://dx.doi.org/10.1109/ICESC54411.2022.9885520
8. L. C. Paul, S. C. Das, M. N. Hossain and W. -S. Lee, "A Wideband Rose-shaped Patch Antenna with a Ground Slot for Sub-6 GHz Applications," 2021 IEEE Indian Conference on Antennas and Propagation (InCAP), Jaipur, Rajasthan, India, India, 2021, pp. 901-904. DOI: http://dx.doi.org/10.1109/InCAP52216.2021.9726293
9. M. Vinoth and R. Vallikannu, "A compact triple slotted Rectangular Microstrip Patch Antenna with Metamaterial ground for Sub-6 GHz/5G communication," 2020 Fifth International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN), Bangalore, India, 2020, pp. 34-38. DOI: https://doi.org/10.1109/ICRCICN50933.2020.9296184
10. U. Farooq et al., "A Compact Monopole Patch Antenna for Future Sub 6 GHz 5G Wireless Applications," 2020 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting, Montreal, QC, Canada, 2020, pp. 1715-1716. DOI: http://dx.doi.org/10.1109/IEEECONF35879.2020.9329624
11. Abdulbari, Ali Abdulateef et al. Design compact microstrap patch antenna with T-shaped 5G application. Bulletin of Electrical Engineering and Informatics, v. 10, n. 4, p. 2072-2078, 2021. DOI: https://doi.org/10.11591/eei.v10i4.2935
12. Marineni Vamsi , Yampati Venkata Rajesh , Vijay Kuruba , Ramella Eswara Sai Krishna, Dr. H.Umma Habiba, 2022, Design and Implementation of Antenna for Sub-6 GHz Applications in 5G Mobile Terminals, International Journal of Engineering Research & Technology (IJERT), Volume 11, Issue 05. https://www.ijert.org/design-and-implementation-of-antenna-for-sub-6-ghz-applications-in-5g-mobile-terminals-2
13. Kaur, G., Kaur, A., Toor, G. K., Dhaliwal, B. S., & Pattnaik, S. S. (2015). Antennas for biomedical applications. Biomedical Engineering Letters, 5(3), 203-212. DOI: http://dx.doi.org/10.1007/s13534-015-0193-z
14. A Technological Highlights of 5G Network Technology with their Research Challenges. (2019). In International Journal of Innovative Technology and Exploring Engineering (Vol. 8, Issue 10S, pp. 318–322). https://doi.org/10.35940/ijitee.j1057.08810s19
15. Selvi, S. A., Saravana, S., & Kanagavalli, G. (2019). Technical Advancement and Social Challenges Associated with Functional Capabilities of 5G Cellular Technologies. In International Journal of Engineering and Advanced Technology (Vol. 8, Issue 6s2, pp. 707–709). https://doi.org/10.35940/ijeat.f1260.0886s219
16. Ray, S., & Bhattacharyya, B. (2020). Diverse Cell Association Schemes for Fifth-Generation Wireless Networks. In International Journal of Recent Technology and Engineering (IJRTE) (Vol. 8, Issue 6, pp. 647–653). https://doi.org/10.35940/ijrte.f7215.038620