Journal of Information Systems Engineering and Management
2025, 10(42s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Enhancement of Bandwidth in 5G Applications using Micro Strip Patch Antenna

Kolli.Venkatrao* G. Merlin Sheeba[2]
*Research Scholar, School of Electrical and Electronics Engineering, Sathyabama Institute of Science and Technology, Chennai.Assistant Professor Department of ECE, SRKR Engineering College
[2]Professor, Department of ECE, Jerusalem College of Engineering, Chennai.
kolli.venkata436@gmail.com , drmerlinsheebag@gmail.com

ARTICLE INFO

Received: 30 Dec 2024

Revised: 12 Feb 2025

Accepted: 26 Feb 2025

ABSTRACT

The transition from 4G to 5G introduces numerous challenges such as spectrum sharing to antenna design, supports large bandwidths and seamless operations. A 5G-compatible antenna requires a simple design/geometry, an efficient feed system, and suitability for mass manufacturing. This paper presents the design of an antenna operating at the 28 GHz band. To optimize its performance, the initial design undergoes multiple modifications, particularly in the feed line along with radiating element i.e geometry of the patch. The antenna is analyzed at each stage based on key parameters such as gain and radiation pattern to evaluate its characteristics. Additionally, the impact of geometrical non-uniformities along the plane of the feed line on the antenna's gain, radiation pattern, and resonant properties is thoroughly analyzed. Simulations are conducted using HFSS, and the results are analyzed through the corresponding simulated plots. The measured results are good agreement with the simulation results. The overall size of the antenna is 18 mm X 18 mm X 0.508 mm and the substrate used is RO4003 with dielectric constant of 3.55.

Keywords: NR; 5G; MPA; VSWR and Tapering

INTRODUCTION

The introduction of 4G technology in 2009 brought a revolutionary change in wireless connectivity, delivering speeds that were reported to be 10 times faster than existing 3g networks. This advancement profoundly impacted commercial, satellite, and defence applications. In particular, the commercial market has benefitted significantly from technologies such as the Internet of Things (IoT) experiencing rapid growth. Additionally, the emergence of Industry 4.0 emphasized the need for high-speed connectivity coupled with excellent quality and robustness, driving the expansion of modern industrial environments, ease of use with the transition to 5g, and operating frequencies are notably higher than those of 4g systems. The 5g network operates within a typical frequency range of 28 GHz to 100 GHz, enabling data speeds of up to 10 GBPS. The 5g new radio, powered by 3gpp standards, is recognized for its smart, robust, and highly reliable nature. However, empirical data suggests a trade-off between data rate and coverage area, which are inherently conflicting parameters. 5G systems leverage enhanced mobile broadband (EMBB) technology to address this. To achieve high data rates over wide coverage areas. Applications such as autonomous vehicles, remote surgeries, and other time-sensitive operations fall under this category. Another essential aspect of 5G networks is ultra-reliable low low-latency communications, which ensures rapid data transfer in environments where multiple devices are connected.

Unlike traditional systems, this data transfer occurs irregularly, necessitating efficient handling by massive machine-type communication (MMTC) technologies. Reconfiguration of systems also plays a crucial role in adapting to such dynamic environments. Regarding The Content in this context, the design and development of advanced antenna systems are critical for enabling the extensive bandwidth capabilities required by 5G networks. Microstrip patch antennas have emerged as ideal candidates for such applications due to their low-profile planar structure, which makes them highly compatible with modern communication devices. Their adaptability for miniaturization, particularly in smartphones, is a significant advantage, as it allows for the compact integration of

Journal of Information Systems Engineering and Management
2025, 10(42s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/ **Research Article**

the entire circuit. Furthermore, patch antennas offer exceptional flexibility, as they can be designed in any desired shape or size to meet specific requirements, making them highly versatile for next-generation communication systems.

The manuscript is organized as follows: Section II provides a detailed literature survey, while Section III introduces the proposed antenna geometry. The simulation process, results, fabricated prototype is discussed along with measured results and comparisons. Finally, Section VI provides the overall conclusion with key findings.

II.LITERATURE REVIEW

The evolution of wireless communication has led to the deployment of the fifth-generation (5G) network, characterized by ultra-high-speed data rates, massive connectivity, and low latency [4]. Features like compactness, high gain, and broad bandwidth are significant while designing antenna systems for 5G applications. MPAs have been the primary choice for antenna engineers for several commercial and IoT applications in general [1]. Though they are proven to be the most chosen in several commercial wireless applications, the scenario in 5G applications appears to be different as the MPA technology suffers narrow bandwidth, which could be a hindrance to the basic requirement of 5G bands. The bandwidth will be a big challenge, particularly in the sub-6 GHz and millimeter-wave ranges. However, techniques like innovation in designs that are capable of mitigating the bandwidths are often considered. These techniques can significantly change geometry, novel substrates, complex feeding methods, and artificial materials [6, 7].

Other techniques of enhancing the bandwidth include including slots of different shapes on radiating patches so that the current distribution can be controlled [18]. Similarly, fractal geometries increase the effective length of the patch [19], defected ground structures (DGS) improve impedance matching [12]. A wide variety of substrates are engineered to provide low permittivity, while in some cases, multiple substrates are stacked, whereas similarly electromagnetic bandgap (EBG) structures are proposed to mitigate the bandwidth [6].

Further, the feed mechanism has also been explored with several varieties of coupling the current to the surface of the patch while providing a substantial effect on the bandwidth. For instance, the proximity and aperture coupling can control the spurious radiation that results in impedance matching [14]. Corporate feeding networks have been introduced to handle the tapering phenomenon in arrays which can provide uniform power distribution [13]. Artificial magnetic materials with permittivity less than zero are often considered for BW mitigation [14]. One such example is a split-ring resonator (SRR) that can directly yield multi-resonant features [15].

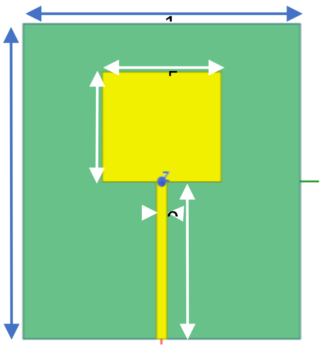
III.PROPOSED GEOMETRY

The proposed antenna design begins with a **rectangular patch geometry** that is **edge-fed**. The geometric details of the five types of proposed antennas are described sequentially as follows:

Geometry-1**:**
The initial antenna design consists of a rectangular patch on a RO4003 substrate with a square shape. The rectangular patch has specific dimensions of 5.5 mm × 4.17 mm, ensuring efficient radiation characteristics. A microstrip feed line, measuring 0.45 mm × 6 mm, connects to the patch and extends toward the substrate's edge, facilitating proper signal transmission. The substrate, chosen for its stable dielectric properties, has an 18 mm × 18 mm size with a 0.5 mm thickness, providing structural support and performance stability. This antenna configuration optimizes the impedance matching and radiation efficiency for high-frequency applications.

Journal of Information Systems Engineering and Management
2025, 10(42s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article



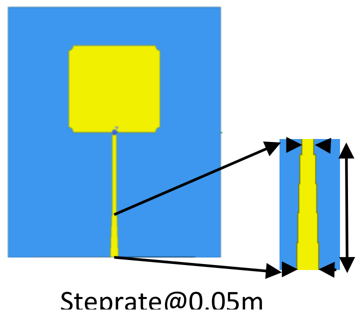


Fig.1 Basic Patch antenna   Fig.2 corner truncated patch antenna Fig.3 modified feed truncated antenna

Geometry-2:

Figure-2 is an improved version of Geometry-1 and is achieved by modifying the patch edges. In Geometry-2, the edges are trimmed to create a smooth and curved profile, where the curvature with a radius of 0.5 mm. This adjustment enhances the structural and electromagnetic (EM) properties of the patch without altering its core dimensions or overall structure. The remaining parameters of the antenna are retained as in the original design. This modification primarily aims to refine current distribution and radiation characteristics, contributing to improved antenna performance while maintaining the simplicity of the original geometry.

Geometry-3:

Figure-3 is derived from of Geometry-2, incorporating modifications to the feed line of the antenna. Unlike the uniform-width feed in the geometry 1 and 2 designs, this version introduces a nonlinear, non-uniform transition. From the substrate edge to 2 mm toward the radiating patch, the feed line width gradually narrows from 0.45 mm to 0.25 mm in four equal steps. This tapering is designed to improve impedance matching and optimize signal transmission, ensuring better antenna performance.

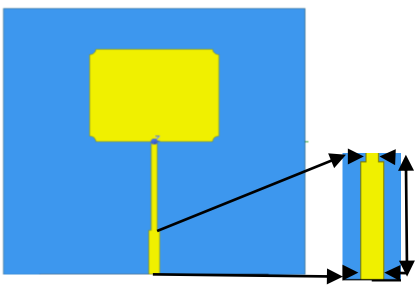


Fig.4 stepped line feed truncated patch antenna

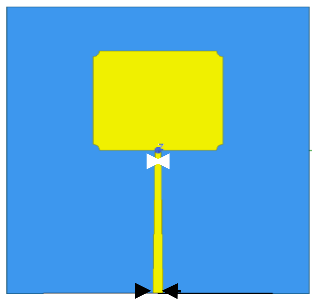


Fig.5 Proposed balun feed truncated patch antenna.

Geometry-4

Figure-4 introduces further refinements to the non-uniform feed line i.e from geometry-3 by modifying both the number of steps and the width transition. Unlike the gradual tapering in the previous design, the feed line now starts at 0.4 mm and abruptly decreases to 0.2 mm in a single step. This sudden transition occurs at a distance of approximately 2 mm from the substrate edge. The modification aims to enhance impedance matching and improve signal transmission efficiency.

Geometry-5

Figure-5 introduces further modified to the feed line design by extending the non-uniform stepped variation along its entire length compared with geometry-4. Unlike Geometry-4 the width of the feed is transitioned in a single step, this design implements multi-step variation throughout of the microstrip feed. By distributing the width variation more evenly, Geometry-5 aims to enhance impedance matching and optimize signal transmission.

Journal of Information Systems Engineering and Management
2025, 10(42s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

RESULTS & DISCUSSION

Geometry-1:

This section presents the simulation results for the designed geometry-1 by analyzing key radiation parameters such as reflection coefficients, VSWR, and 3D radiation patterns. The evaluation begins with Geometry-1, where the obtained simulation results are represented in the Figures 6(a) and 6(b).

As shown in Figure 6(a), the resonant frequency of Geometry-1 is 28 GHz, with a corresponding VSWR that remains consistently low across this frequency. The VSWR <2 indicates efficient impedance matching, ensuring minimal signal reflection and optimal power transfer.

By examining these parameters from the simulation, the results offer a clear understanding of how Geometry-1 behaves under operating frequency range. The low reflection coefficients and stable VSWR values confirm that the initial antenna design is well-tuned to resonate at 28 GHz, demonstrating strong radiation efficiency. Subsequent geometrical modifications are expected to further refine these characteristics for enhancing gain and radiation performance.

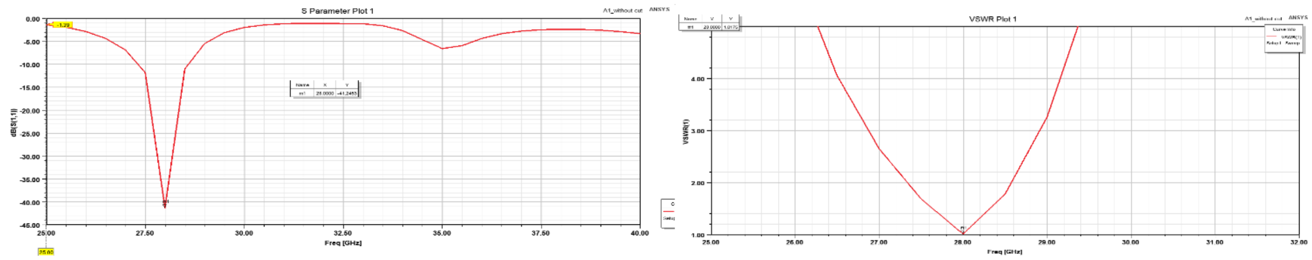


Fig.6: characteristics of Geometry-1 a) Reflection coefficient (b) VSWR

Geometry-2:

Based on the reflection coefficient and VSWR analysis, the resonant frequency is confirmed to be 28 GHz, indicating effective impedance matching. The radiation pattern closely resembles that of Geometry-1, maintaining similar directional characteristics like previous geometry. This consistency suggests that the antenna efficiently radiates at the intended frequency of operation i.e. 28 GHz. The stable VSWR further supports optimal power transfer for ensuring reliable performance.

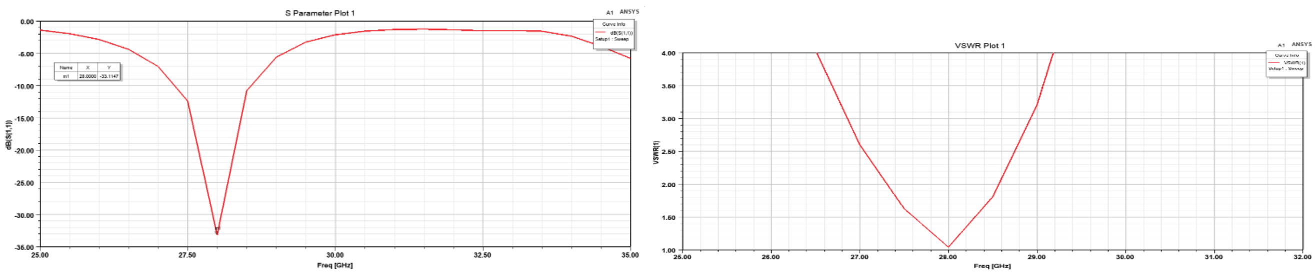


Fig.7: characteristics of geometry-2 a) S11 and (b) VSWR

Geometry-3:

The performance characteristics of Geometry-3 is analyzed through Figures 7(a) and 7(b) by incorporating radiation characteristics similar to Geometries 1 and 2. However, the variations occur in the magnitudes of S11 and VSWR, indicating changes in impedance matching. Despite these differences, the overall radiation pattern remains consistent at the 28 GHz frequency and maintaining two well-defined lobes separated from each other.

Journal of Information Systems Engineering and Management
2025, 10(42s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

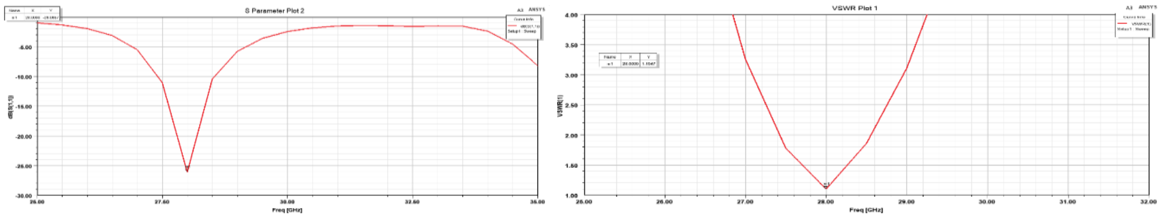


Fig.8: characteristics of geometry-3 a) S11 and (b) VSWR

Geometry-4 and Geometry-5:

The resonant characteristics of Geometries 4 and 5 are represented in Figures 9 and 10, exhibit a consistent resonant frequency and indicating a stable resonant behavior. However, the variations in magnitude are observed, likely resulting from differences in the feed line geometry modifications. These changes impact impedance matching and signal transmission and affecting overall antenna performance. Despite the magnitude differences, the fundamental frequency response remains unchanged, highlighting the role of feed structure modifications in fine-tuning antenna characteristics. This analysis provides insights into optimizing the feed design to achieve better impedance matching, reduced losses, and improved radiation efficiency for 28 GHz applications.

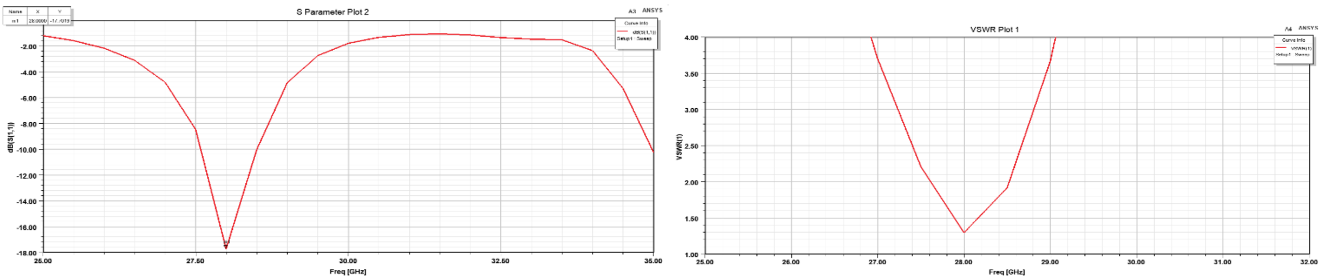


Fig.9: characteristics of geometry-4 a) S11 and (b) VSWR

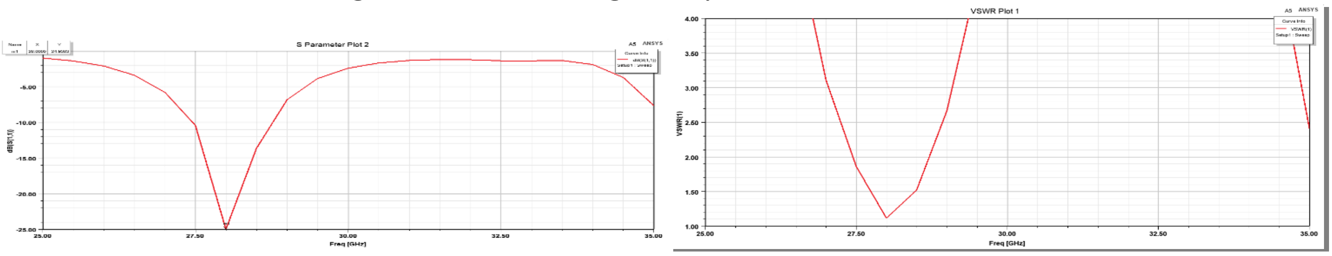


Fig.10: characteristics of geometry-5 a) S11 and (b) VSWR

The characteristics of all geometries are summarized in Table 1. The frequency response and 3D radiation pattern shape remain consistent across designs; no table variations occur in gain and return loss. These changes are mainly due to modifications in the geometries, particularly in the feed line and patch structure. It influences impedance matching and radiation efficiency. The observed variations highlight the impact of structural changes on antenna performance, guiding further optimizations. Understanding these effects is essential for improving gain, minimizing losses, and enhancing overall efficiency in 28 GHz wireless communication applications.

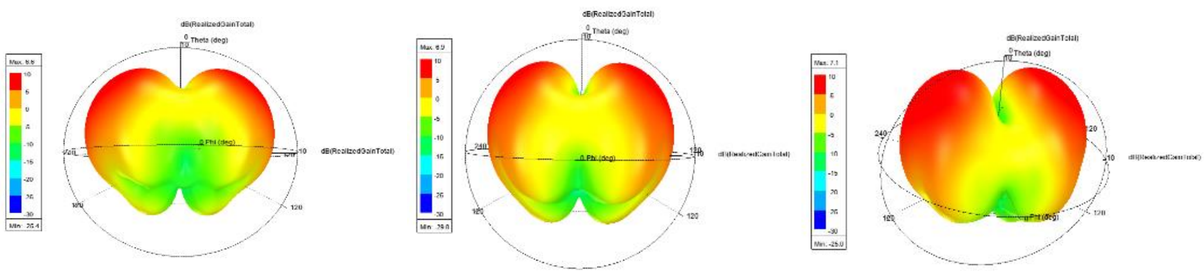


Fig.11: Radiation pattern at centre frequency (28 GHz).

Journal of Information Systems Engineering and Management
2025, 10(42s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

TABLE I. CHARACTERISTICS OF ALL GEOMETRY

S.NO	***Description***	***Return Loss (dB)***	***Gain (dBi)***
1	Microstrip line (ML)	-24.69	6.6
2	ML with circular slot on the patch edges	-33.11	6.7
3	ML with a step rate of 0.05 mm from step size 0.45mm to 0.24 mm with circular slo s on the patch edges	-26.06	6.8
4	ML with single step i.e., from step size 0.45 to 0.24 mm with circular slot s on the patch edges	-17.70	7.0
5	ML with Balun (0.45mm to 0.24 mm) with circular slots on the patch edges	-24.93	6.9

MEASURED RESULTS

The fabricated prototype of BALUN feed patch antenna and the comparison result of simulation versus measured result is provided in figure 12. The provided figure 12(b) illustrates the return loss characteristics of the designed antenna across a frequency range of **25 GHz to 30 GHz.** Two curves are presented: the **red curve** for simulated results and the **blue curve** for measured results. From the figure 11(b), both the simulated and measured results show a significant dip in return loss at approximately **28 GHz**, indicating the resonance frequency of the antenna where maximum power is radiated, and reflected power is minimized. The simulated result (red curve) exhibits a return loss of approximately **-32 dB** at 28 GHz, which indicates excellent impedance matching and minimal power reflection. In contrast, the measured result (blue curve) achieves a return loss of around **-15 dB** at the same frequency. Although the measured return loss is higher than the simulated result, it still meets acceptable performance criteria, as a return loss below **-10 dB** is generally considered sufficient. The operational bandwidth of the antenna can be observed from the frequency range where the return loss remains below **-10 dB**. Both the simulated and measured results suggest a bandwidth of approximately **1 GHz**, centered around **28 GHz**, making the antenna suitable for millimetre-wave **5G applications**. However, there is a noticeable discrepancy between the simulated and measured results across the frequency range, with the measured return loss being higher than the simulated return loss. This deviation is common in practical scenarios and can be attributed to several factors, including fabrication inaccuracies, material losses, connector mismatches, or environmental effects during testing. Despite these variations, the measured results confirm that the antenna performs within acceptable limits. The figure 12 demonstrates the successful operation of the antenna at **28 GHz** with a reasonable bandwidth of **1 GHz**. The simulated return loss highlights excellent impedance matching, while the measured result, though slightly higher, validates the design's effectiveness for 5G millimetre-wave applications.

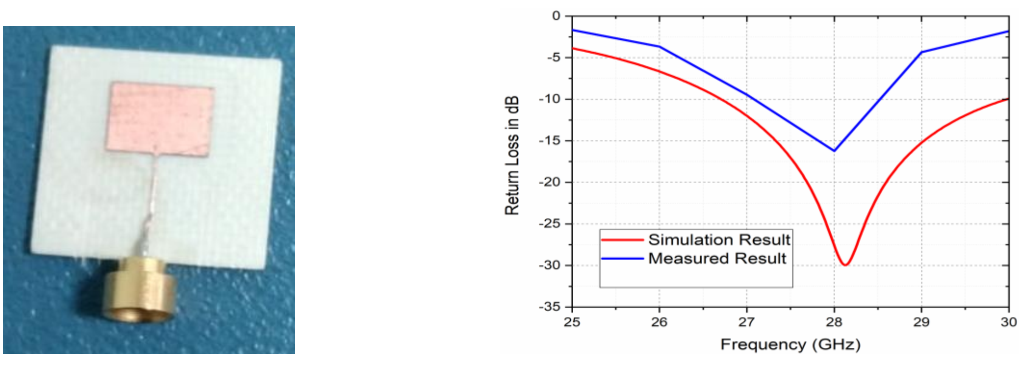


Fig.12: Proposed Balun feed truncated patch antenna (a) fabricated prototype (b) simulation and measured result comparison.

Journal of Information Systems Engineering and Management
2025, 10(42s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/ **Research Article**

CONCLUSION

This study successfully simulated and analyzed the typical characteristics of 5G antennas. The frequency response, represented by S11 and VSWR, remained consistent across all designed geometries, as the resonating surface and dimensions were maintained unchanged. However, significant variations in gain, S11, and VSWR magnitudes were observed, as outlined in Table 1. The reduction in S11 was likely influenced by changes in the geometry, particularly in the feed line design. Future work could focus on developing a prototype and conducting experimental measurements for further validation.

REFERENCES

[1] Akpakwu, Godfrey Anuga, et al. “A survey on 5G networks for the Internet of Things: Communication technologies and challenges.” IEEE Access 6 (2017): 3619-3647.

[2] Govindarajulu, Sandhiya Reddy, Rimon Hokayem, and Elias A. Alwan. "A 60 GHz millimeter-wave antenna array for 3D antenna-in-package applications." *IEEE Access* 9 (2021): 143307-143314.

[3] Mavromoustakis, Constandinos X., George Mastorakis, and Jordi Mongay Batalla, eds. Internet of Things (IoT) in 5G mobile technologies. Vol. 8. Springer, 2016.

[4] Trzebiatowski, Kamil, et al. "Simple 60 GHz switched beam antenna for 5G millimeter-wave applications." *IEEE Antennas and Wireless Propagation Letters* 20.1 (2020): 38-42.

[5] Lak, A., et al. "Design and SAR assessment of three compact 5G antenna arrays." *Scientific reports* 11.1 (2021): 21265.

[6] Ali, Tanweer, Mohammad Saadh Aw, and Rajashekhar C. Biradar. “A Compact Bandwidth Enhanced Antenna Loaded with SRR For WLAN/WiMAX/Satellite Applications.” Advanced Electromagnetics 7, no. 4 (2018): 78-84.

[7] Saraereh, Omar A. "A novel broadband antenna design for 5G applications." *Computers, Materials & Continua* 67.1 (2021): 1121-1136.

[8] Ren, Wang, Li-Juan Zhang, and Shu-Wei Hu. "A novel ACPW-fed quad-band hybrid antenna for wireless applications." *International Journal of Microwave and Wireless Technologies* 10.4 (2018): 460-468.

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

[10] Garg, R., Bhartia, P., Bahl, I., & Ittipiboon, A. (2001). *Microstrip Antenna Design Handbook*. Boston, MA: Artech House.

[11] Yang, F., & Rahmat-Samii, Y. (2009). *Electromagnetic Band Gap Structures in Antenna Engineering*. Cambridge, UK: Cambridge University Press.

[12] Werner, D. H., & Ganguly, S. (2003). "An overview of fractal antenna engineering research." *IEEE Antennas and Propagation Magazine*, 45(1), 38-57. https://doi.org/10.1109/MAP.2003.1189656.

[13] Li, J., Zhang, L., & Wang, H. (2015). "A novel DGS-based wideband microstrip patch antenna." *Progress In Electromagnetics Research Letters*, 56, 37-44. https://doi.org/10.2528/PIERL15061206

[14] James, J. R., & Hall, P. S. (Eds.). (1989). *Handbook of Microstrip Antennas*. London, UK: Peter Peregrinus Ltd.

[15] Wong, K. L. (2004). *Compact and Broadband Microstrip Antennas*. Hoboken, NJ: Wiley.

[16] Veselago, V. G. (1968). "The electrodynamics of substances with simultaneously negative values of ε and μ." *Soviet Physics Uspekhi*, 10(4), 509-514. https://doi.org/10.1070/PU1968v010n04ABEH003699

[17] Pendry, J. B., Holden, A. J., Robbins, D. J., & Stewart, W. J. (1999). "Magnetism from conductors and enhanced nonlinear phenomena." *IEEE Transactions on Microwave Theory and Techniques*, 47(11), 2075-2084. https://doi.org/10.1109/22.798002

[18] Mahatthanajatuphat, C., Boonpoonga, W., & Krairiksh, M. (2010). "Bandwidth enhancement of microstrip patch antennas using parasitic elements." *Microwave and Optical Technology Letters*, 52(3), 610-616. https://doi.org/10.1002/mop.24965