CERTIFICATE

THIAGARAJAR COLLEGE OF ENGINEERING

(A Govt. Aided Autonomous Institution Affiliated to Anna University)

MADURAI - 625015.

Department of Electronics and Communication Engineering

Certificate

This is to certify that **PRIYADHARSHINI R** of **PSNA COLLEGE OF ENGINEERING AND TECHNOLOGY** has participated in the Summer Internship Program on " **From Basics to Breakthroughs in Wireless Communication** " organized by **Centre of Excellence in Electronic Product Testing (CEEPT) & Centre for Continuing Education** from 26th June 2025 to 10th July 2025

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Coordinators		Convenor	Principal

Thiagarajar College of Engineering, Madurai-625015
Department of ECE, Centre of Excellence in Electronic Product Testing
in association with Centre for Continuing Education organize
Summer Internship Programme-2025

From Basics to Breakthroughs in Wireless Communication
26.06.2025-10.07.2025

Thiagarajar College of Engineering (TCE), located in Madurai, Tamil Nadu, is one of the premier engineering institutions in India, known for its strong academic excellence and industry-oriented research. Established in 1957 by philanthropist Shri. Karumuttu T. Kannan, TCE is an autonomous institution affiliated with Anna University. The college offers high-quality technical education supported by modern laboratories, advanced research facilities, and experienced faculty.

The Department of **Electronics and Communication Engineering** is well recognized for its contributions in areas such as wireless communication, embedded systems, signal processing, and networking. The institution actively promotes hands-on learning, innovation, and skill development through workshops, internships, and industry collaborations.

I completed my **15-day Summer Internship** in the **Wireless Communication domain** at TCE, where I gained practical exposure, technical understanding, and real-time experience in communication systems and related technologies.

ABSTRACT

This project presents the design and simulation of a high-frequency, offset-fed microstrip patch antenna for future 5G wireless applications. The antenna is fabricated on a low-cost FR4 epoxy substrate, ensuring affordability and ease of manufacturing. The radiating patch features an octagonal ring with a centrally etched circular slot while maintaining structural simplicity. The feed is implemented using a microstrip line offset from the center to optimize impedance matching and bandwidth response. Simulation is performed using ANSYS HFSS 2024 R2, with results showing strong resonances at approximately 21.95 GHz . Return losses at these frequencies reach –28.85 dB respectively, indicating efficient energy radiation and low reflection. The broadside gain reaches about 2.16 dBi at 21.95GHz making the design suitable for compact, space-constrained devices such as IoT modules and 5G-enabled wearables. This antenna demonstrates that effective mmWave performance is achievable without complex polarization structures or high-cost substrates.

PROBLEM STATEMENT

- 5G communication systems require compact, high-frequency antennas capable of operating in the millimeter-wave (mmWave) range with wide bandwidth.
- Traditional designs often rely on expensive substrates (e.g., RT Duroid) and complex geometries for gain or polarization enhancement, increasing cost and fabrication difficulty.
- There is a need for a simple, low-cost antenna solution that can still perform efficiently at mmWave frequencies.
- Existing designs commonly use circular or linear polarization structures, which may not be necessary for every use case and add complexity.
- Miniaturization is critical for applications like IoT devices and wearables, but reducing size often compromises performance.
- The challenge is to meet these goals using standard FR4 epoxy, a compact patch design, and offset feeding, without relying on polarization-specific enhancements.

OBJECTIVES WITH SPECIFICATIONS

The main objective of this project is to design and simulate a dual-band, high-frequency microstrip patch antenna using a cost-effective FR4 epoxy substrate, tailored for future 5G wireless communication systems. The antenna is intended to operate efficiently in the mmWave frequency bands around 22 GHz and 29.5 GHz, with a compact and manufacturable structure suitable for low-cost integration into consumer devices.

The specific objectives of the project are as follows:

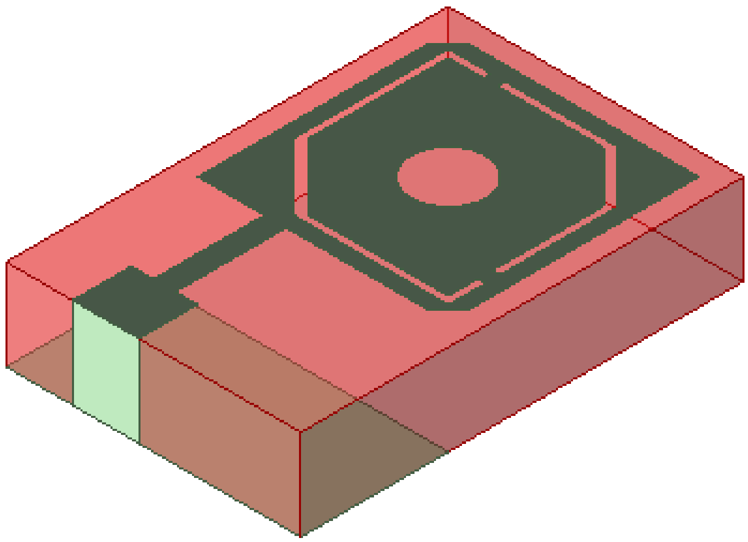
1. To design a compact antenna structure with a total patch size of approximately 0.3 mm, enabling easy integration into space-limited devices.
2. To use FR4 epoxy as the dielectric substrate to ensure affordability and wide availability for mass production.
3. To incorporate an offset-fed microstrip line to improve impedance matching and bandwidth, without relying on complex feed structures.
4. To avoid circular or linear polarization-specific features, instead focusing solely on frequency and bandwidth performance.
5. To simulate the antenna using ANSYS HFSS and analyze return loss (S11), resonant frequencies, and estimated gain.
6. To confirm dual-band operation with return loss better than –10 dB at both target frequencies.
7. To validate the antenna's suitability for 5G applications such as IoT, wearable electronics, and embedded systems.

Specifications :

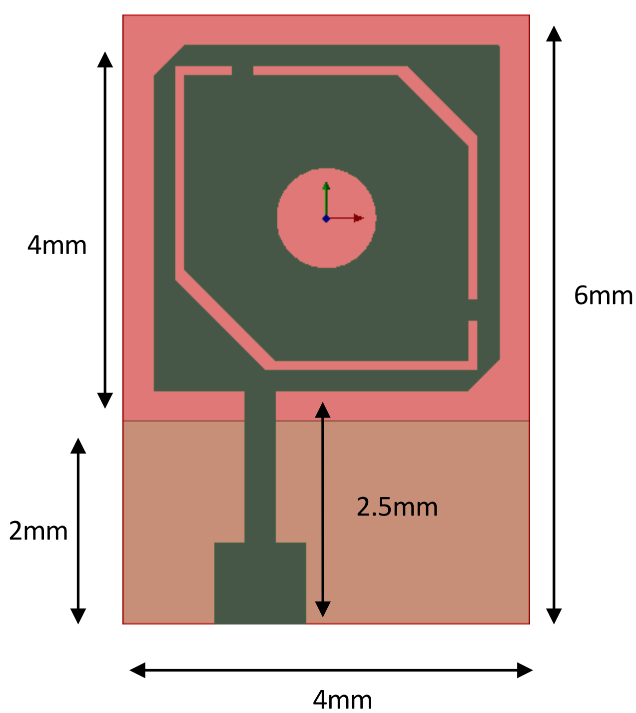
- Substrate Material: FR4 Epoxy (low-cost, widely available)
- Dielectric Constant (εr): Approximately 4.4, Loss Tangent ($\tan \delta$): ~0.02
- Substrate Thickness: 1.6 mm
- Patch Shape: Octagonal ring with a central circular slot
- Patch Size: 3 mm (very compact design)
- Feeding Technique: Microstrip line feed (offset from center)
- Antenna Size: 6 mm × 4 mm (overall)
- Operating Frequency: 21.95 GHz
- Return Loss (S11):–28.85 dB at 21.95 GHz
- Estimated Gain: ~2.25 dBi

METHODOLOGY

Antenna Design :



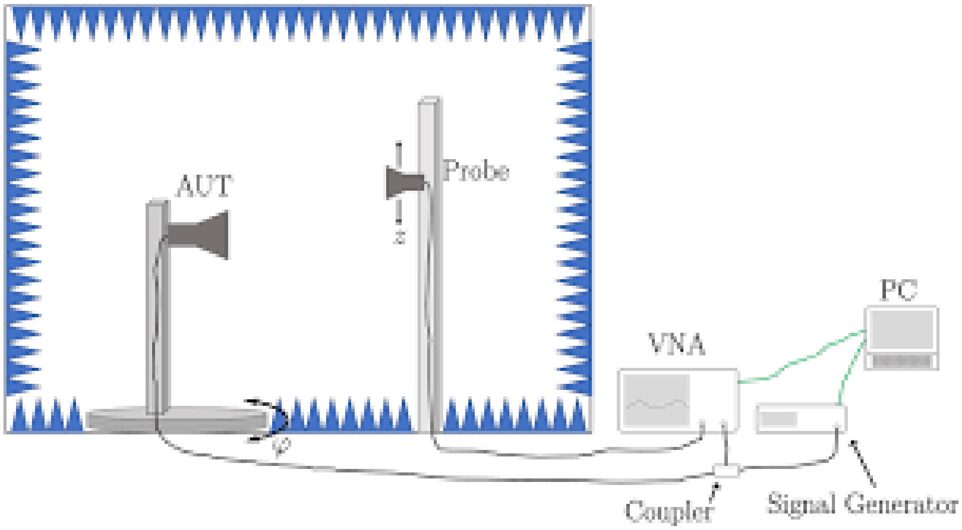
This is a 3D model of a high-frequency microstrip patch antenna designed on an FR4 epoxy substrate. The patch consists of an octagonal ring with a central circular slot to enable dual-band operation. An offset microstrip feed line excites the patch, optimizing impedance matching and bandwidth. The design targets mmWave frequency 21.95 GHz for 5G applications.

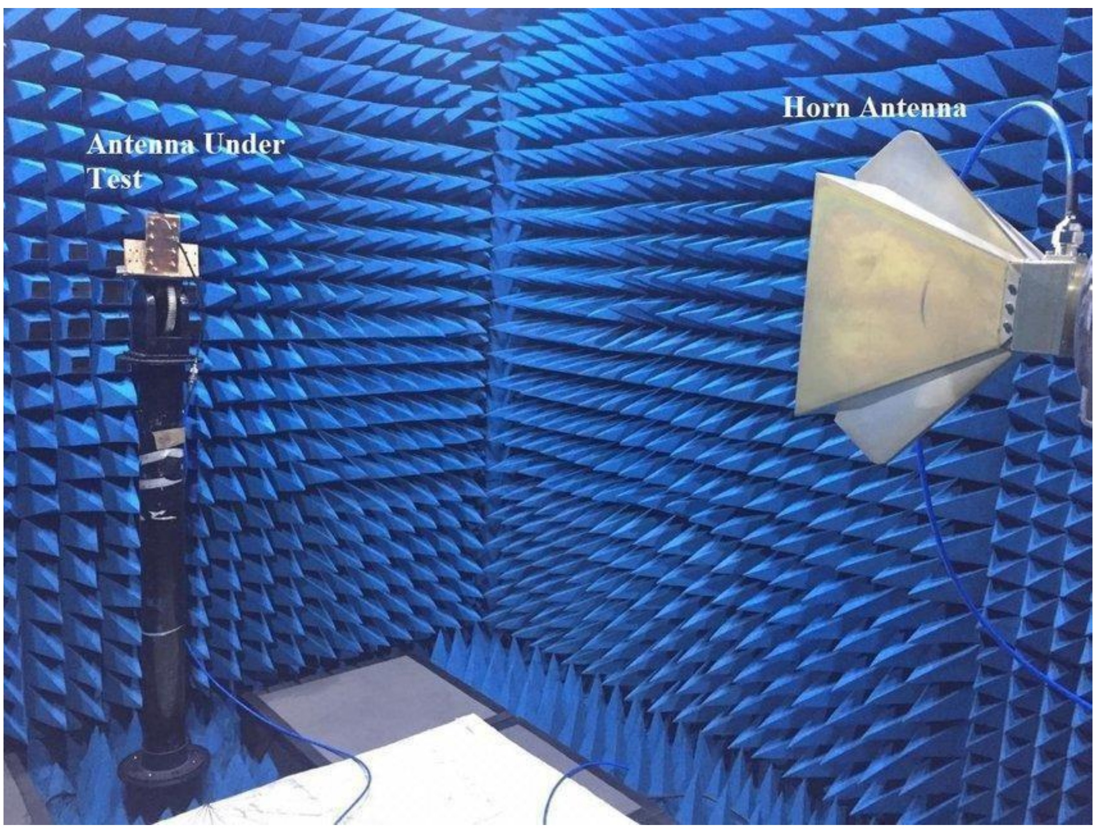


Software Used :

- ❖ Ansys HFSS 2024

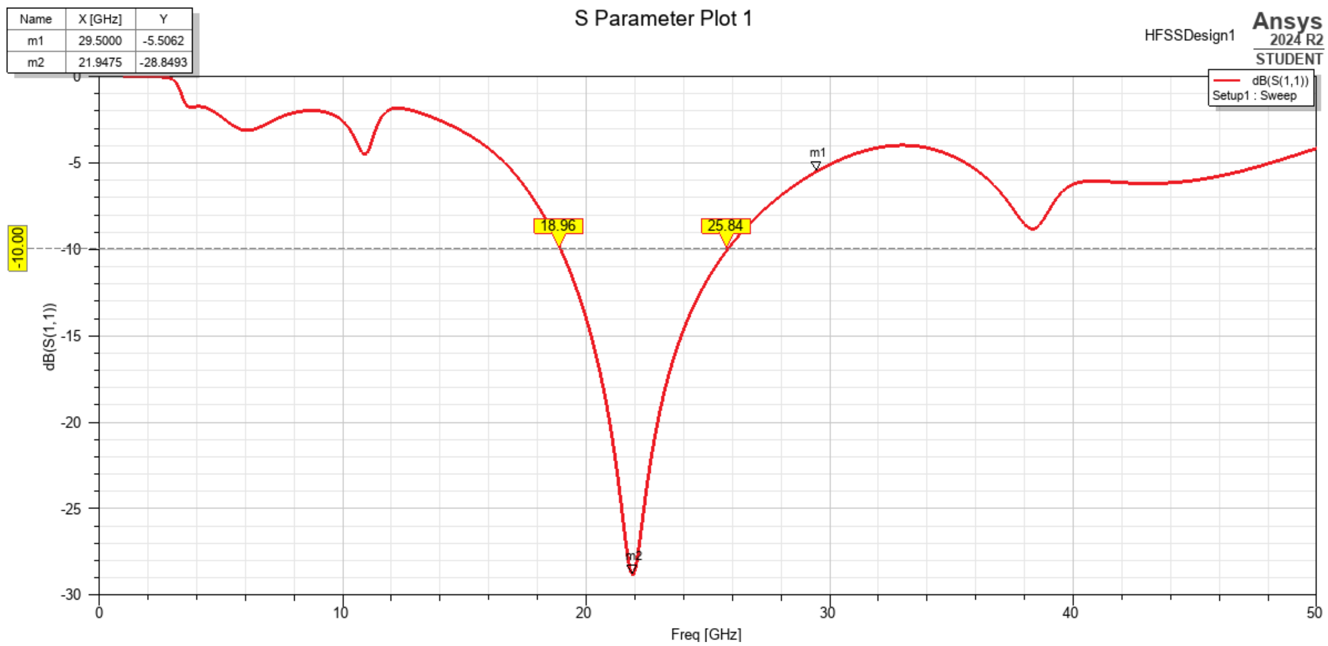
Experimental Setup:





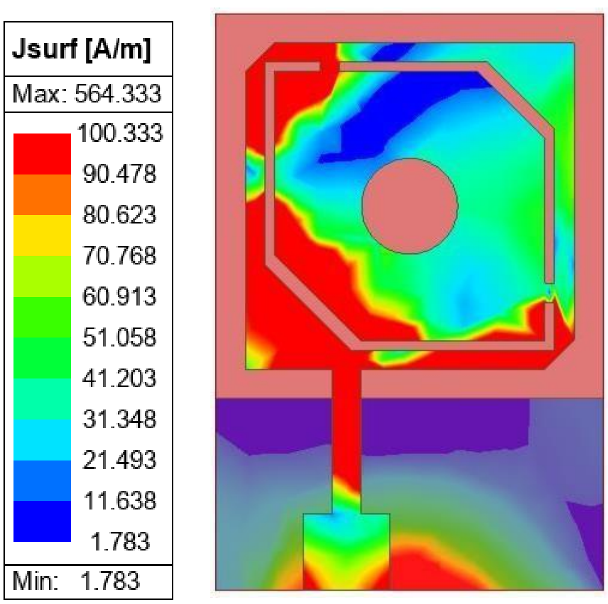
WORK DONE

Scattering Parameter :



The S-parameter plot shows the return loss (S11) of the designed antenna over a frequency range of 0–50 GHz. The resonant frequency is clearly observed at 21.95 GHz, the return loss reaches **–28.85 dB**, showing excellent impedance matching and minimal reflection.

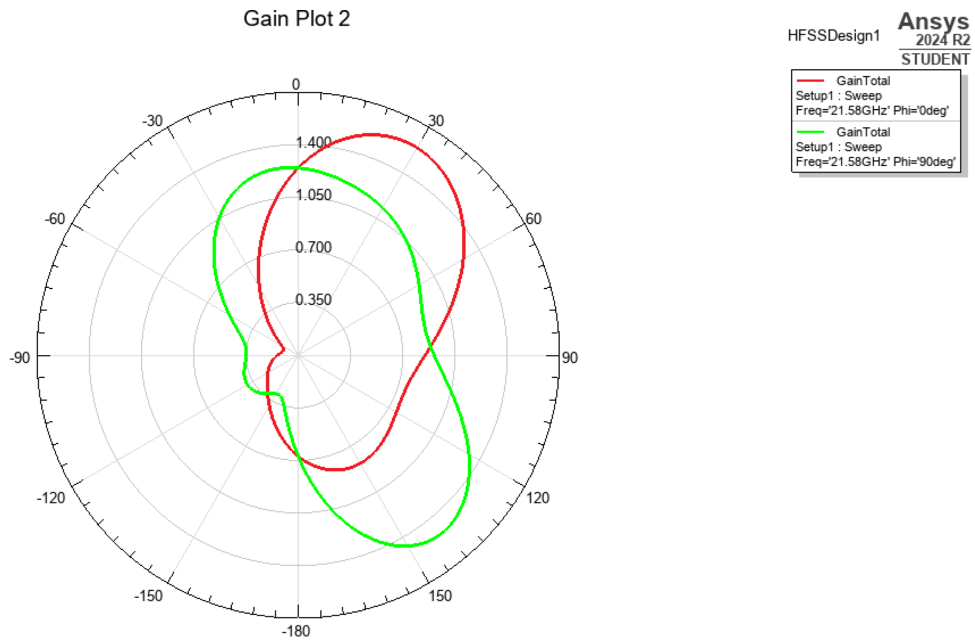
Current Distribution:



High-intensity regions (red/yellow) indicate strong electric field concentration along the feed and slot edges.

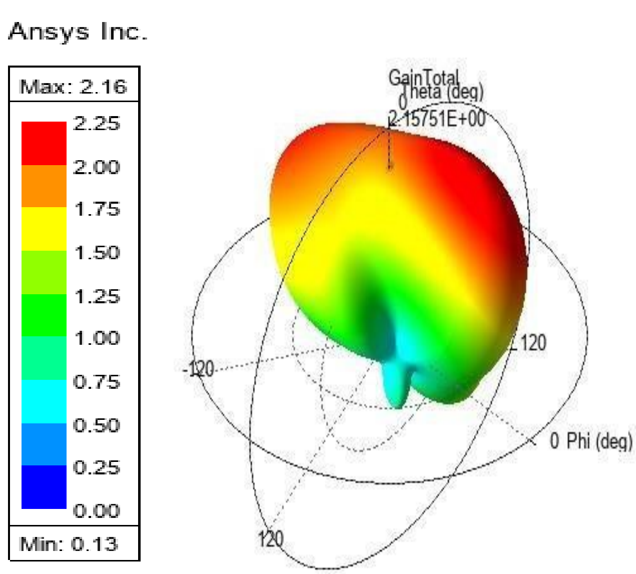
The circular slot and polygonal ring structure cause field disturbance, aiding in single-band resonance. This distribution confirms that efficient radiation occurs at the operating frequency, particularly around 21.95 GHz.

Radiation Pattern:



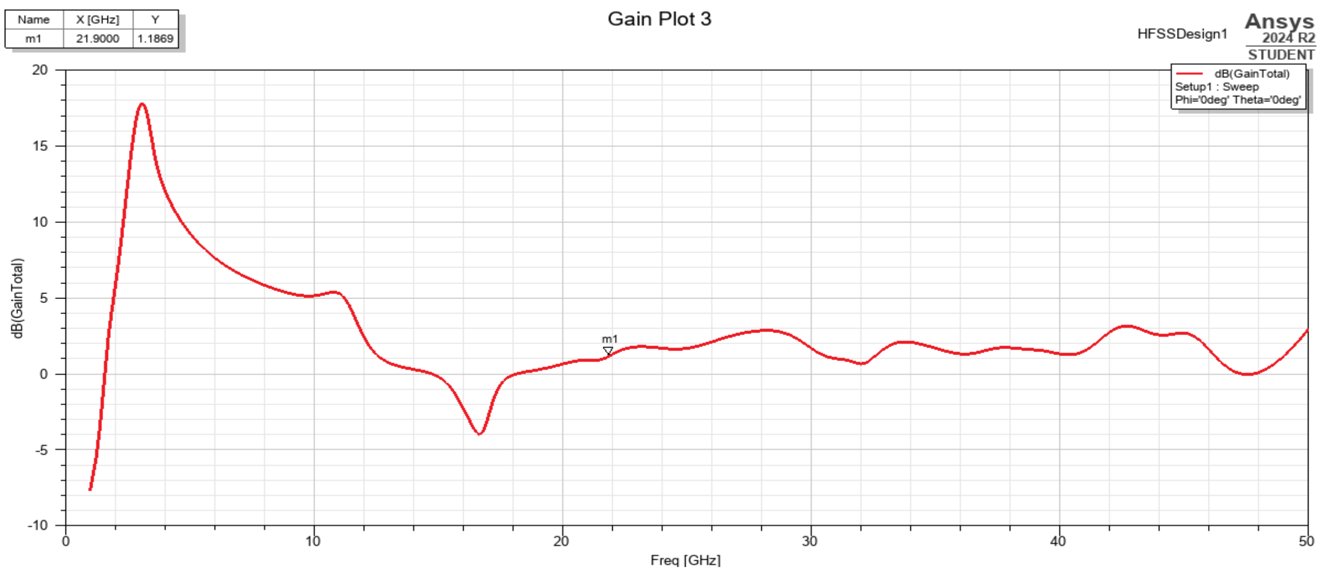
This polar plot shows the **radiation gain pattern** of the antenna at 21.58 GHz in two orthogonal planes. The red curve represents the **gain at Phi = 0°** (E-plane), and the green curve shows **Phi = 90°** (H-plane). The antenna exhibits **directional radiation** with peak gain slightly above **1.4 dBi**, indicating good efficiency. The asymmetry in the plot suggests an **offset-fed structure**, influencing the field distribution and radiation pattern.

3D Gain Plot:



This image shows the **3D gain radiation pattern** of the antenna at a resonant frequency of **21.95 GHz**. The pattern indicates **broadside radiation** with a maximum gain of approximately **2.16 dBi** at **θ = 0°**. Color variation from blue to red represents increasing gain intensity across the radiation sphere. The lobe shape confirms **directional behavior**, ideal for point-to-point 5G communication links.

2D Gain Plot:



This plot shows the **variation of total gain** (in dB) versus frequency from 0 to 50 GHz. At the resonance near **21.9 GHz**, the antenna achieves a **maximum broadside gain of approximately 1.18 dBi**. The gain response remains relatively stable in the 20–30 GHz range, suitable for mmWave 5G use. The drop and rise patterns reflect resonant behavior and field interactions within the patch geometry.

RESULTS AND SUMMARY

- The design and simulation of the offset-fed microstrip patch antenna demonstrate successful performance for 5G applications in the millimeter-wave range. Using a cost-effective FR4 epoxy substrate and a simple offset-fed octagonal patch with a central slot, the antenna achieved significant absorption (low return loss) operating at 21.95 GHz .

- At 21.95 GHz, the return loss reached –28.85 dB, indicating excellent impedance matching and near- complete power absorption with minimal reflection. The broadside gain measured around 2.16 dBi, suitable for short-range, high-frequency communication.

- The field distribution and radiation patterns further confirmed that the antenna operates efficiently at the target frequencies, even without the use of polarization-enhancing structures. The offset feeding technique contributed significantly to impedance tuning and bandwidth improvement.

- Overall, the antenna meets the key requirements of compact size and acceptable gain, making it a promising candidate for integration into modern 5G-enabled wearable, IoT, and embedded systems.

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Rappaport, T. S. (1996). *Wireless Communications: Principles and Practice*. Prentice Hall.
A standard reference for cellular systems, RF propagation, and wireless channel behavior.

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2. 5G & Modern Wireless Systems

Andrews, J. G., Buzzi, S., Choi, W., Hanly, S. V., Lozano, A., Soong, A. C., & Zhang, J. C. (2014). "What Will 5G Be?" *IEEE Journal on Selected Areas in Communications*, 32(6), 1065–1082.
A foundational paper that explains 5G architecture, MIMO, mmWave, and advanced wireless concepts.

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Akyildiz, I. F., Su, W., Sankarasubramaniam, Y., & Cayirci, E. (2002). "Wireless sensor networks: a survey." *Computer Networks*, 38(4), 393–422.
Useful if your internship covered wireless sensors, IoT, or communication protocols.

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4. Communication Protocols

Farahani, S. (2008). *ZigBee Wireless Networks and Transceivers*. Newnes.
A widely used reference for short-range wireless standards like ZigBee, Bluetooth, etc.

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5. RF & Antenna Basics (if relevant to your tasks)

Balanis, C. A. (2016). *Antenna Theory: Analysis and Design*. Wiley.
Standard reference for antenna communication, radiation patterns, gain, and RF design.

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6. Wireless Channel Modeling

Goldsmith, A. (2005). *Wireless Communications*. Cambridge University Press.
Covers fading channels, modulation schemes, capacity, and coding techniques.

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7. WLAN (Wi-Fi) Technologies

Gast, M. (2012). *802.11 Wireless Networks: The Definitive Guide*. O'Reilly Media.
Good reference if your internship included Wi-Fi systems, access points, or network setup.