Compact Microstrip Patch Antenna Design for 5G Communications

~Presented by~

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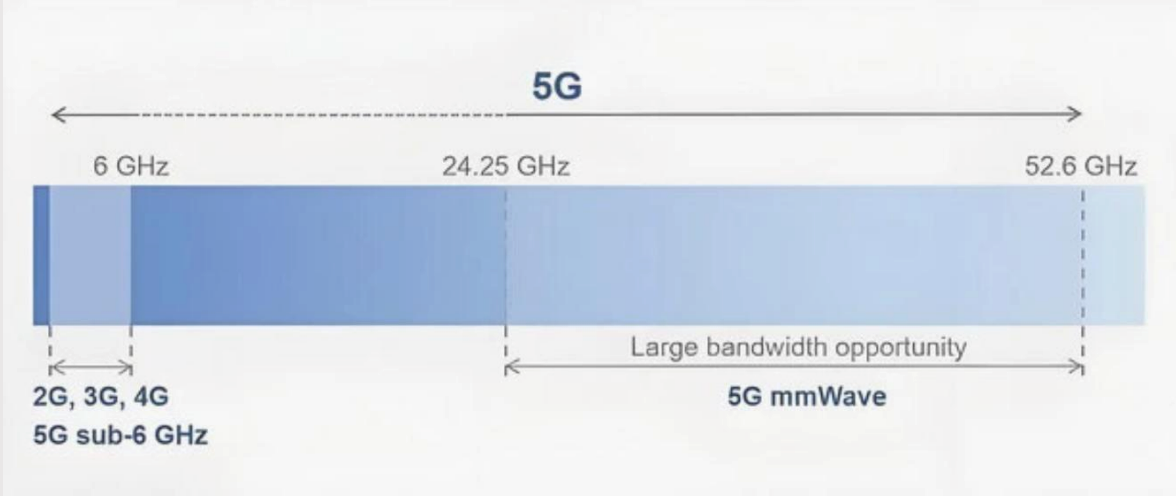
Exploring 5G in Sub-6 GHz

❑ 5G Sub-6 GHz

- ***Frequency Range:*** Below 6 GHz
- ***Coverage Area:*** Wider area; can cover several km
- ***Penetration & Propagation:*** Can penetrate walls and buildings effectively
- ***Deployment:*** Urban, Sub-urban and rural areas



Focus and Purpose

- **Sub-6 GHz** supports reliable 5G for **mobile broadband**, **IoT**, and **wide-area coverage**, ensuring strong connectivity in diverse environments
- With **wider coverage per cell**, Sub-6 GHz **lowers infrastructure costs**, making large-scale **5G deployment more affordable**
- Most modern devices support Sub-6 GHz, enabling **widespread 5G adoption** and **seamless connectivity** across various devices
- **Microstrip antennas** are widely utilized due to their **ease of integration** with **circuitry**, **low cost**, **lightweight design**, and **conformability**

Proposed Antenna Design

- Initial design was for a conventional circular microstrip patch antenna (MPA)
- Modifications in dimension values were made, but the intended outcome was not achieved
- As a result, the patch shape was modified from circular to elliptical
- Formulas used for the elliptical patch are similar to those for the circular MPA

Initial Prototype

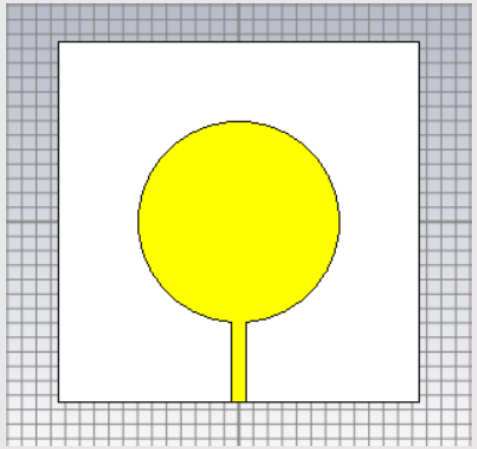


Fig: Front view of the initial proposed antenna

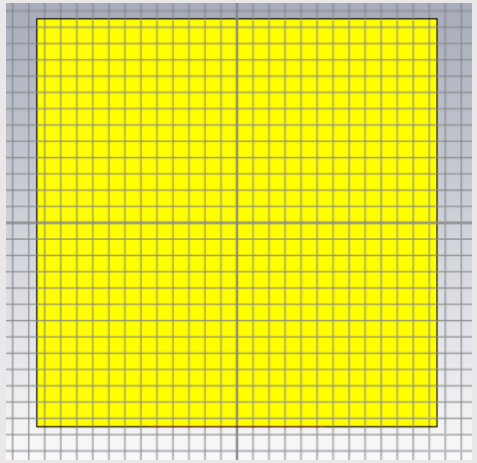


Fig: Rear-view of the Initial antenna

- As mentioned earlier this is the Initial Prototype of the Circular Microstrip Patch Antenna

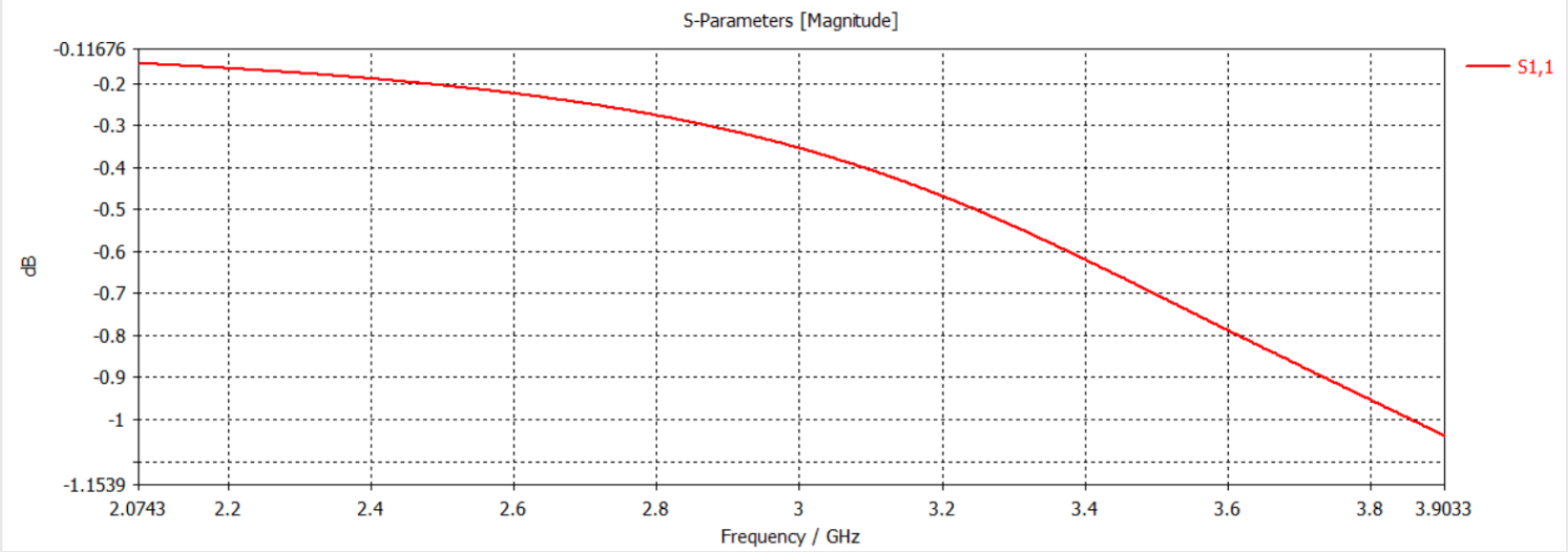


Fig: Return Loss Graph of the initial prototype

Intermediate Prototype

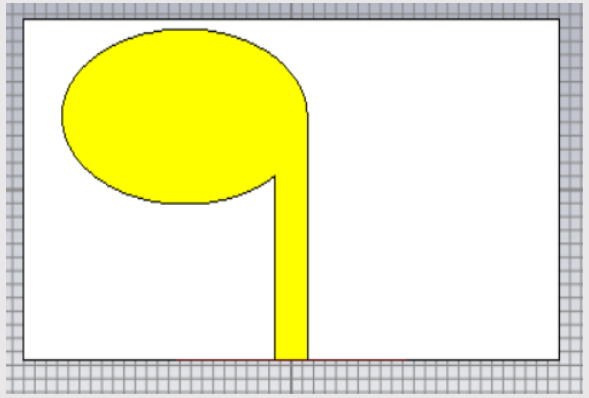


Fig: Front View of Elliptical Antenna

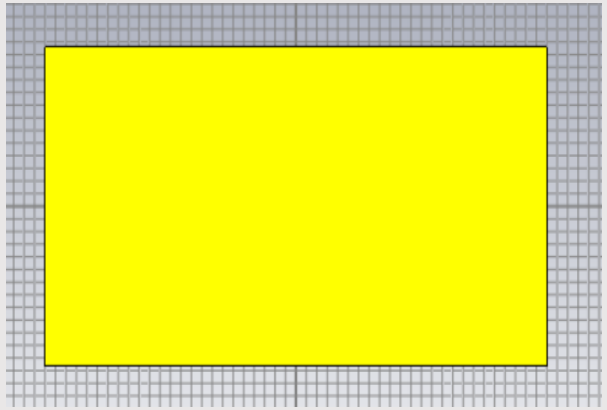


Fig: Rear-view of Elliptical Antenna

- This is the intermediate design- a flipped P antenna with a full ground

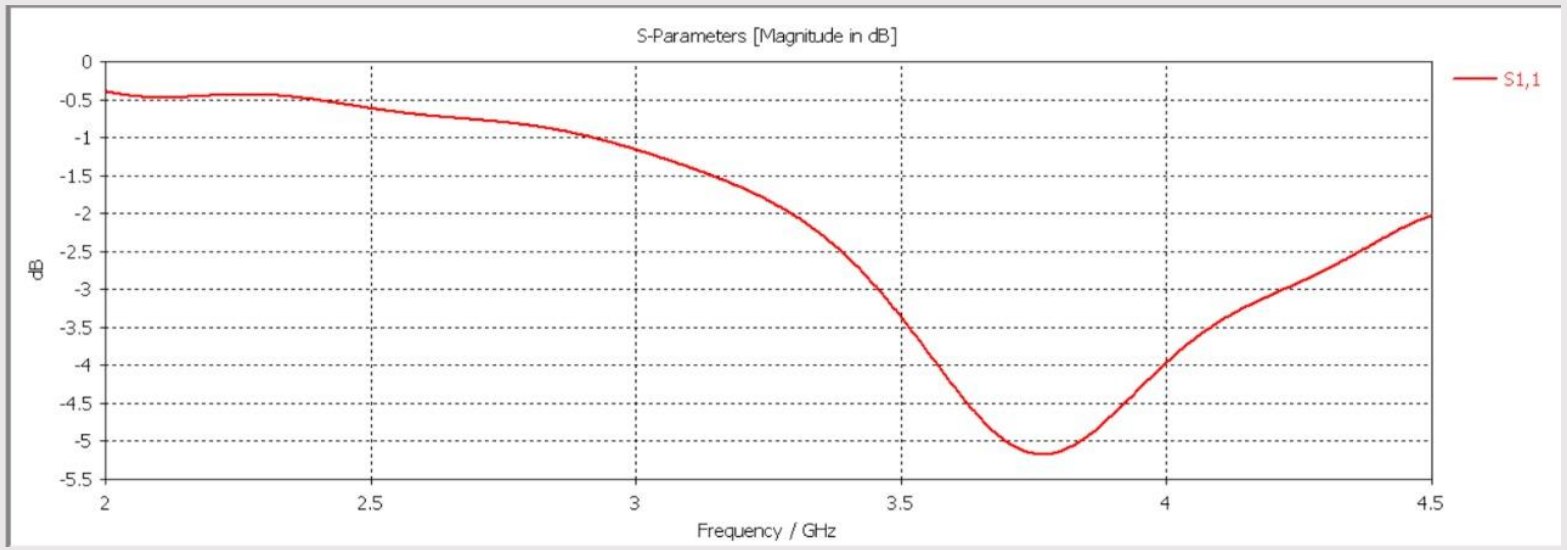
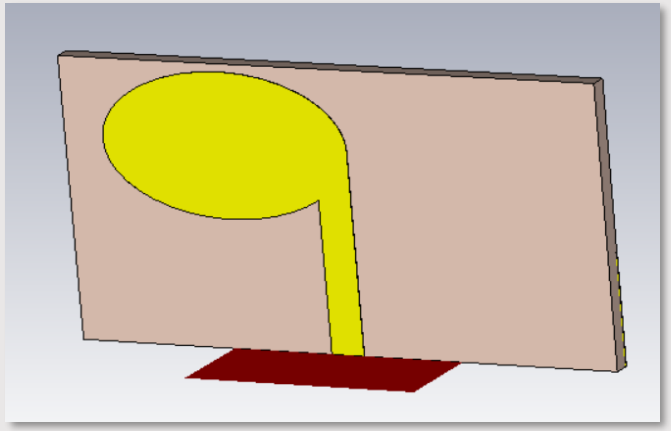


Fig: Return Loss Graph of the intermediate prototype

A Glimpse of the final Antenna Design and it's Scope

- **Proposed:** A Flipped-P Shaped Elliptical Microstrip Patch Antenna
- **Discussion:** Regarding the five primary characteristics of antennae and a comparative analysis using various dielectric materials
- **Scope:** high speed lower 5G/Wi-Fi communication, short range radar system, digital TV and radio broadcasting applications



Proposed flipped P-shaped elliptical MPA

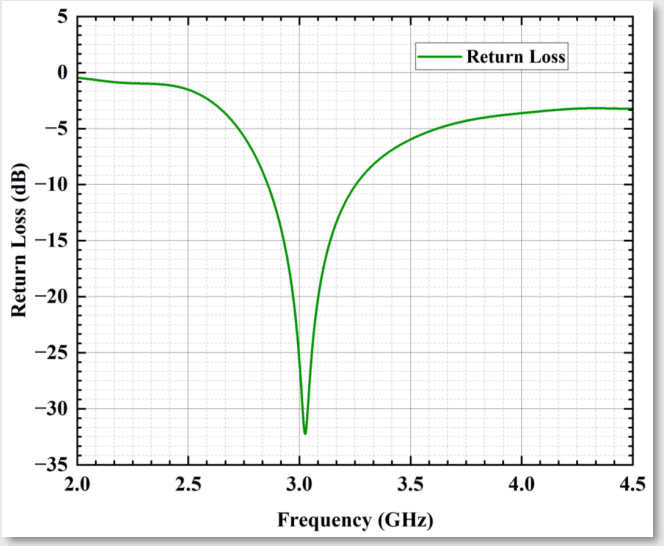
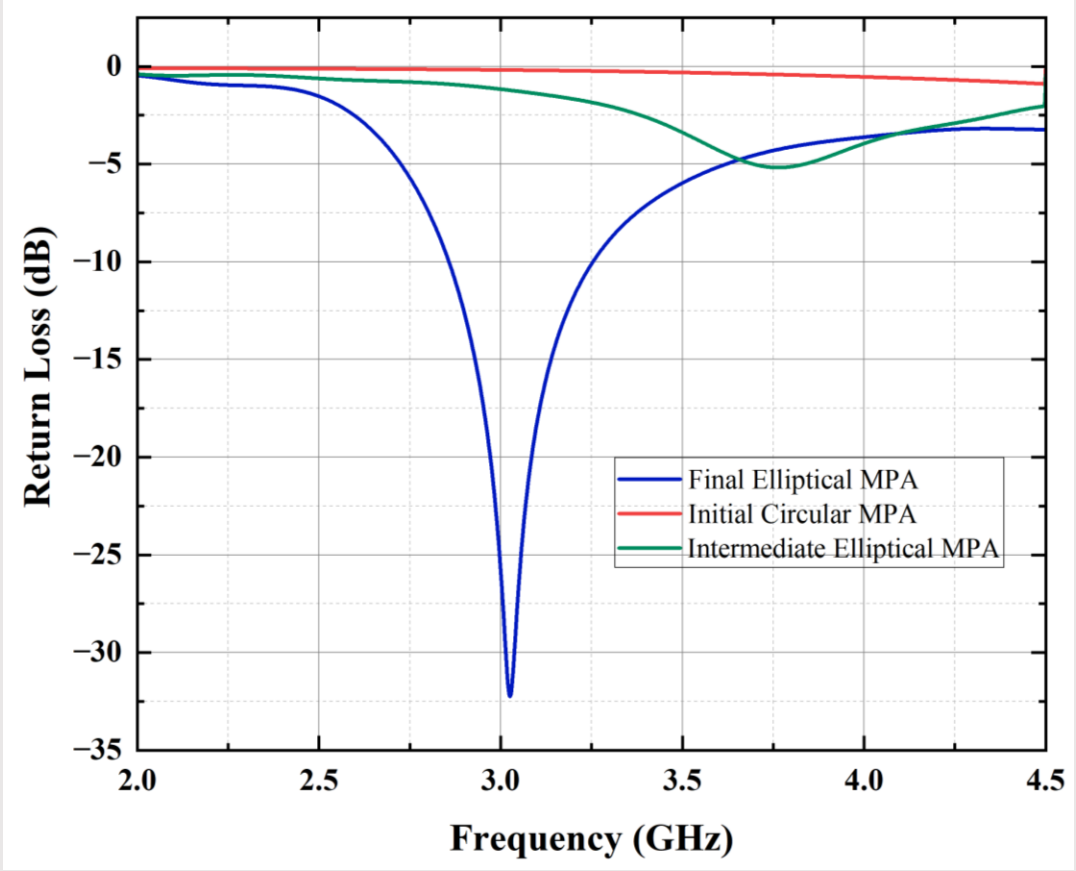


Fig: Return Loss Graph of the final prototype

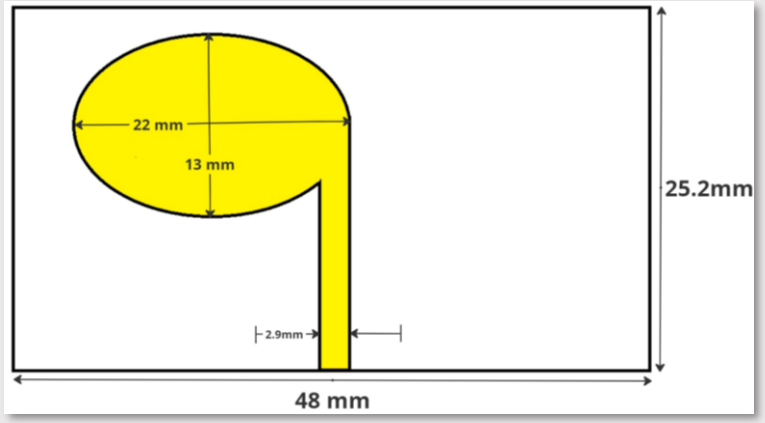
Comparison of S11 parameters of all designs

- Graph shows how the S11 parameters of the individual models differ from each other
- Initial Circular Antenna had no resonating frequency around 2-4.5 GHz
- The intermediate Elliptical Antenna with full ground however had a resonating frequency around 3.7 GHz but not desirable enough
- Then the final Elliptical Antenna with partial ground was suggested which had both desirable S11 parameter and a resonant frequency within the range

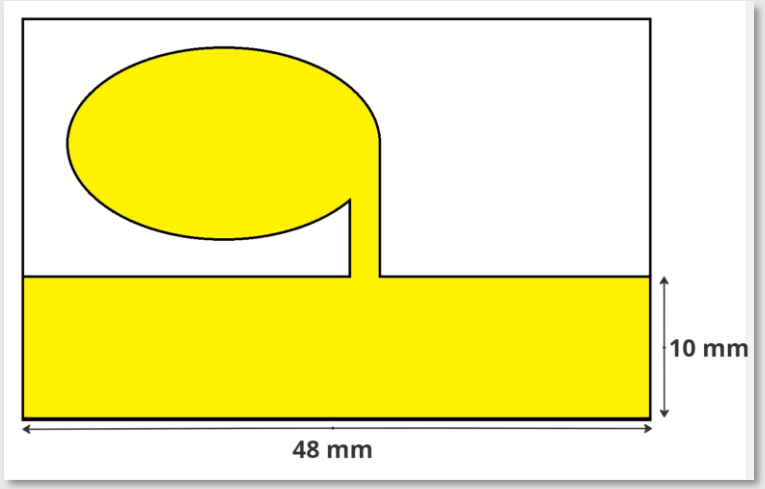


Antenna Dimensions and Specifications

Parameters	Optimized Value
Resonant Frequency, f_r (GHz)	3.025
Dielectric Constant, ε_r (FR- 4)	4.3
Substrate Height , h (mm)	1.6
Ellipse Major Axis, (mm)	22
Ellipse Minor Axis, (mm)	13
Substrate Length, L_s (mm)	25.2
Substrate Width, W_s (mm)	48
Feedline Width, (mm)	2.9
Feedline Length, (mm)	18
Ground length, (mm)	48
Ground Width, (mm)	10



Front view of the proposed antenna



Rear view of the proposed antenna with partial ground

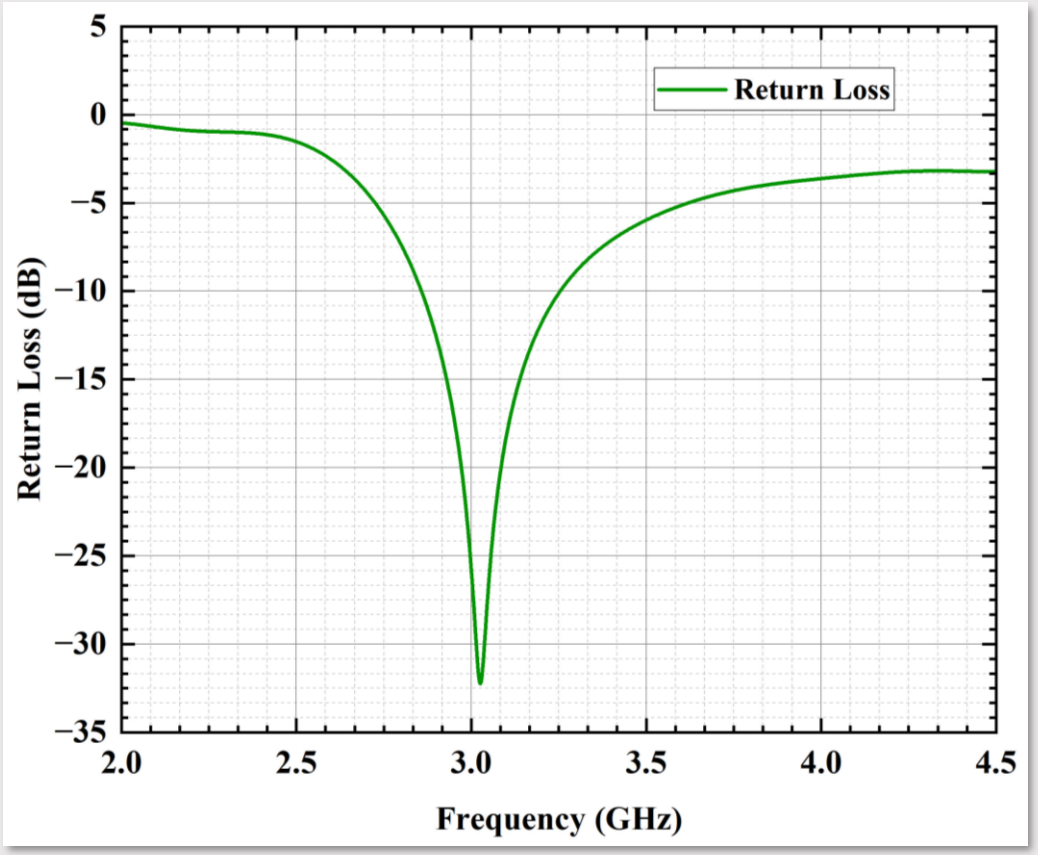
Results and Discussions

Return Loss or S_{11} parameter

- ***S_{11} Formula:***

  Return Loss$=-20log_{10}(\Gamma)$ dB

- ***EMPA Reflection Loss*: -32.27 dB** at **3.025 GHz**
- ***Reflection Meaning*:** High reflection with -32.27 dB, indicating efficient signal reflection.

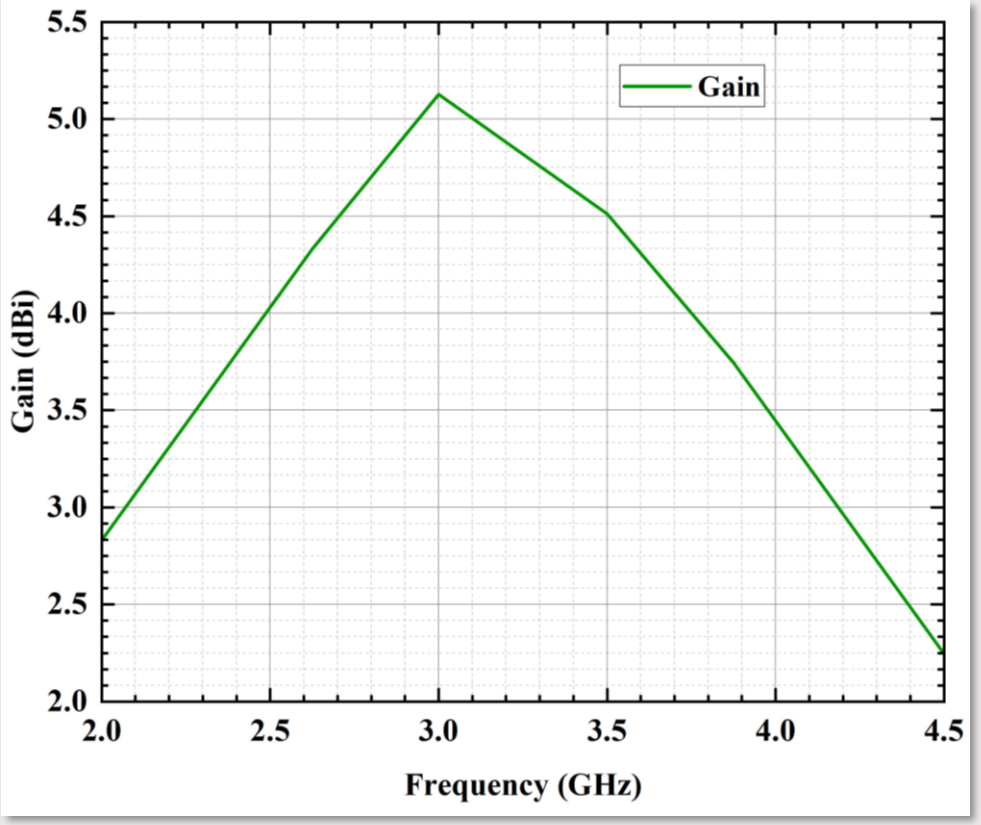


Return Loss vs. Frequency for proposed antenna

Results and Discussions

Bandwidth & Gain

- ***S11 Criterion:*** Bandwidth computed where S11 < -10 dB
- ***Antenna BW:*** **2.86 GHz** to **3.25 GHz**
- ***Figure :*** Shows **5.12 dBi** gain at 3.025 GHz
- ***Benefit:*** High gain for greater range and signal quality in a specific direction

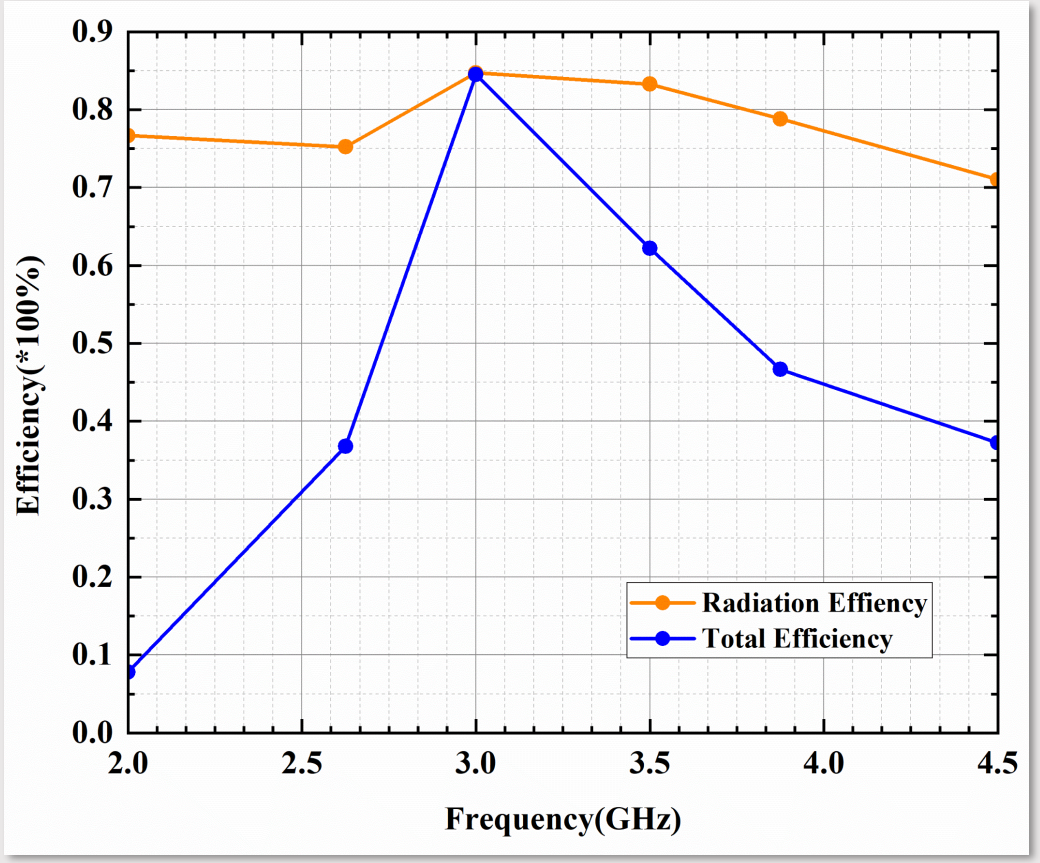


Peak Gain vs Frequency for proposed antenna

Results and Discussions

Efficiency

- ***Efficiency Figures***: Radiation and total efficiency at 84.72%.

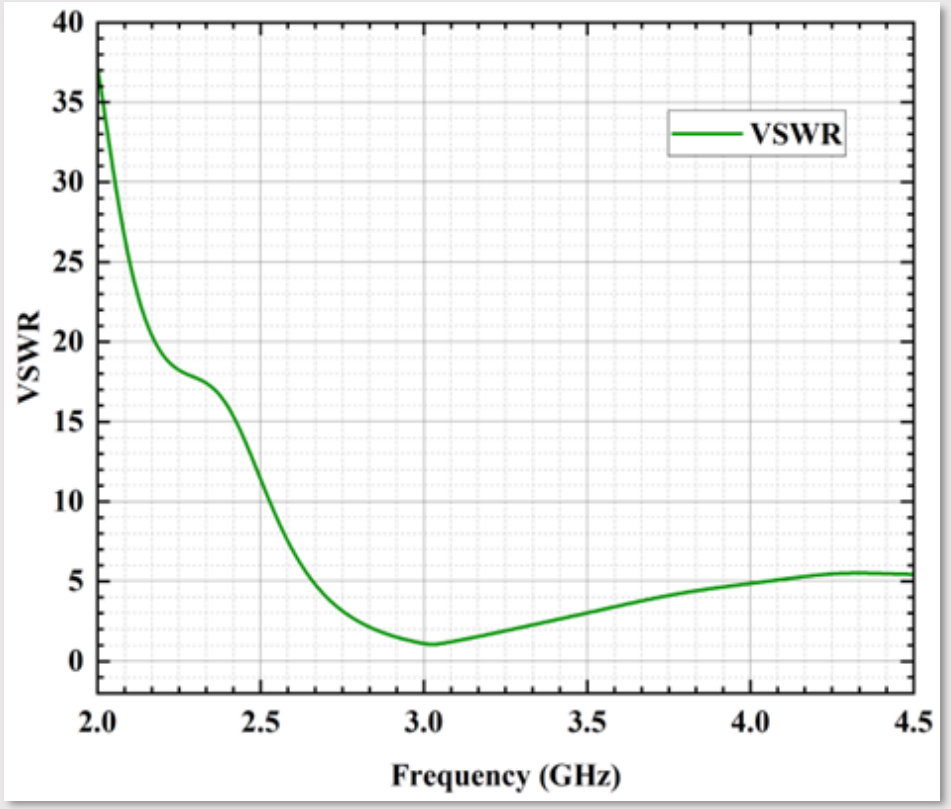


Efficiency vs Frequency for proposed antenna

Results and Discussions

VSWR

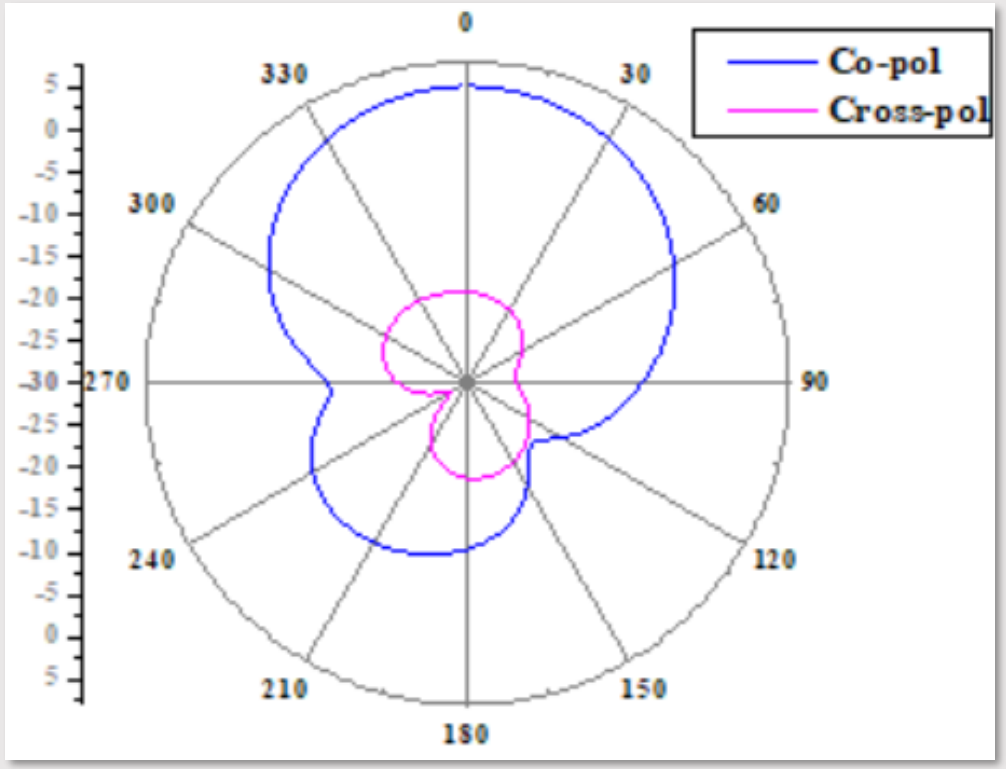
- ***Figure:*** Shows VSWR of 1.048 at 3.025 GHz.



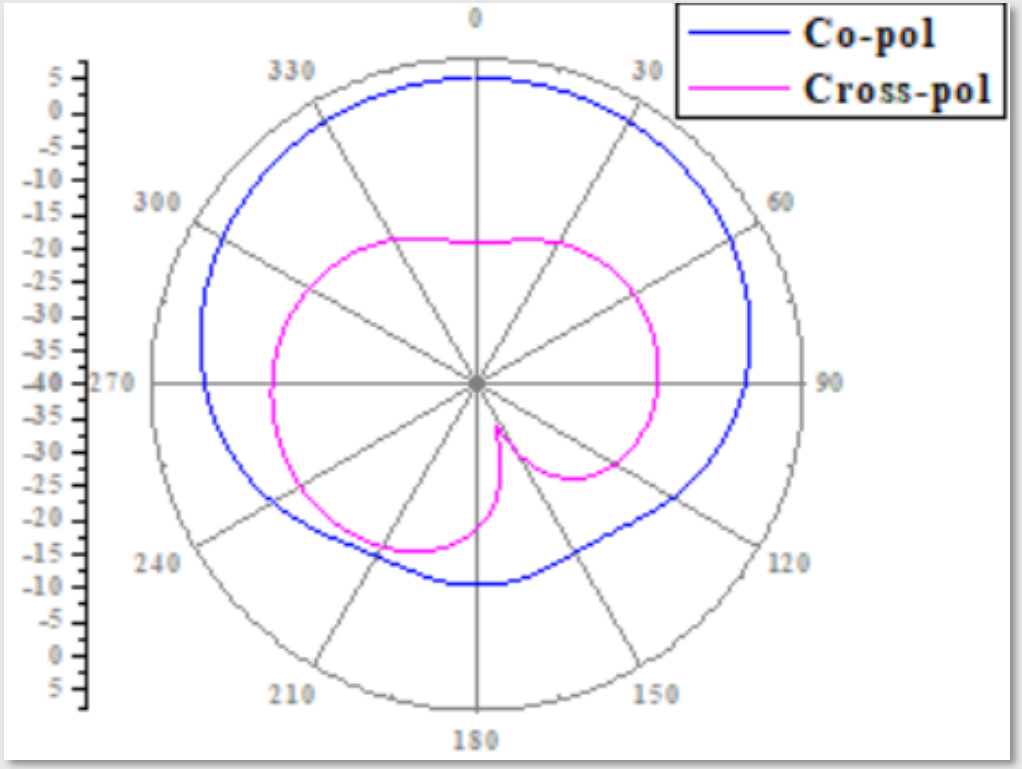
Voltage Standing Wave Ratio (VSWR)

Results and Discussions

Radiation Pattern



Normalized E-plane Radiation Pattern at 3.025GHz



Normalized H-plane Radiation Pattern at 3.025 GHz

Study of Recent 5G Antenna Designs

Ref.	Size of Antenna(mm^2)	Return Loss(dB)	Gain(dBi)
[1]	37.3×46.86	-47.47	3.271
[2]	35×31	-36.81	2.647
[3]	30×30	-16.32	6.46
[4]	29.5×42.5	-5.325	7.59
[5]	56×56	-24.51	6
Proposed	***25.2×48***	***-32.27***	***5.12***

Conclusion

- **Antenna Type:** Miniature flipped-P shaped elliptical microstrip patch antenna for 5G
- **Key Performance:**
  - ***Resonant Frequency:*** 3.025 GHz
  - ***Radiation Efficiency:*** 84.72%
  - ***VSWR:*** 1.048
  - ***Gain:*** 5.12 dBi
  - ***Return Loss:*** -32.27 dB
- **Applications:** High-speed lower 5G/Wi-Fi, short-range radar, digital TV/radio broadcasting
- **Future Improvements:**
  - Adding shaped slots (e.g., circle, rectangle) to the patch
  - Use of diverse methodologies and substrates for further enhancements
  - Fabrication for comparison of simulated and real results

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Reference

[1]Verma, Ramesh Kumar, and D. K. Srivastava. "Bandwidth enhancement of a slot loaded T-shape patch antenna." Journal of Computational Electronics 18 (2019): 205-210

[2]Paul, Liton Chandra, Md Tanvir Rahman Jim, Tithi Rani, Sarker Saleh Ahmed Ankan, Sajeeb Chandra Das, and Himel Kumar Saha. "A Π-shaped slotted patch antenna with a partial ground structure for lower 5G/WiFi/WiMAX applications." Heliyon 8, no. 10 (2022).

[3]Prashanth, Kolluri, Chintagumpula Jayakrishna Sai, B. L. Srihari, and Kumari Manisha. "Design of micro-strip patch antenna for C–band applications." In E3S Web of Conferences, vol. 391, p. 01066. EDP Sciences, 2023

[4]Hossain, I., T. Ahmed, and H. Kabir. "Design of Rectangular Microstrip Patch Antenna at 3.3 GHz Frequency for S-band Applications." Int. J. Eng., Manuf 12, no. 4 (2022): 46-52.

[5]Murugan, S. "Compact Square patch antenna for 5G Communication." In 2nd International Conference on Data, Engineering and Applications (IDEA), pp. 1-3. IEEE, 2020

Thank You