ANTENNA FOR UNMANNED VEHICULAR COMMUNICATION FOR 6G

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BONAFIDE CERTIFICATE

Certified that this project report entitled "**ANTENNA FOR UNMANNED VEHICULAR COMMUNICATION FOR 6G**" is a Bonafide work of **ARVINDHAN K [22BEC1026], SYED NABIEL HASAAN M [22BEC1063], DEEPTA V M [22BEC1086], MRITHYUM JAI M P [22BEC1132], YASHWANTH B [22BEC1218**] who carried out the Project work under my supervision and guidance for **BECE305L – Antenna and Microwave Engineering**.

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ABSTRACT

The rapid evolution of communication networks from 5G to 6G has catalyzed the demand for high-performance antennas in unmanned vehicular applications, promising ultra-reliable, low-latency, and high-capacity communications. This project explores the design and implementation of an antenna tailored for unmanned vehicular communication in 6G networks, focusing on achieving efficient, high-frequency operation essential for 6G's projected spectrum, which extends into the terahertz range. By utilizing advanced materials and miniaturized design approaches, this antenna aims to provide reliable communication even in high-mobility conditions, enabling real-time data transmission and processing critical to autonomous driving.

Key design objectives include broad bandwidth, omnidirectional coverage, and high radiation efficiency to ensure consistent connectivity regardless of vehicular speed or orientation. The antenna design is further optimized for interference mitigation, given the crowded electromagnetic environment typical of 6G applications. Simulation results and performance analysis demonstrate that the proposed antenna meets the rigorous demands of 6G vehicular communication, with potential applications extending to drones, autonomous delivery robots, and other unmanned systems. This project contributes to the development of robust, efficient communication systems for the next generation of vehicular technology, paving the way for fully autonomous, interconnected transportation networks.

ACKNOWLEDGEMENT

We extend our heartfelt gratitude to Dr. Usha Kiran ma'am for their invaluable guidance, unwavering support, and mentorship throughout the duration of this mini group project. Their expertise and encouragement have been instrumental in shaping the project's direction and ensuring its successful execution.

We would also like to acknowledge the exceptional contributions of our dedicated team members, whose collaborative efforts, diverse skills, and commitment have significantly enriched the project's outcomes.

Furthermore, we express our appreciation to the technical staff and laboratory personnel for their indispensable assistance in providing the necessary resources, equipment, and infrastructure essential for the practical implementation of the project.

Lastly, we are thankful to the academic institution for fostering an environment that encourages experiential learning, innovation, and the practical application of theoretical knowledge.

The successful completion of this project has been made possible through the collective support, guidance, and contributions of all those mentioned above, and for that, we are truly grateful.

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NAME WITH SIGNATURE NAME WITH SIGNATURE

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1 INTRODUCTION

1.1 OBJECTIVES AND GOALS

- **Enhanced Antenna Performance**: Achieve a high-gain, low-loss antenna design suitable for 6G communication.

- **Improved Mutual Coupling Reduction**: Minimize signal interference to enhance detection accuracy and reliability in vehicular applications.

- **Efficient Signal Matching**: Achieve optimal impedance matching to reduce power loss and improve signal strength.

- **Compatibility with Autonomous Systems**: Make the design robust for 6G-enabled autonomous vehicle radars.

1.2 APPLICATIONS

- The tooth-shaped patch antenna design is particularly applicable in:

- **Autonomous Vehicle RADAR Systems**: Useful for functions such as lane-change assistance, automatic braking, and pedestrian detection.

- **Vehicular Networking**: Enables vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, enhancing traffic safety and efficiency.

- **Short and Long-Range Radar**: Effective for short-range radar (SRR) and long-range radar (LRR) in automotive settings, facilitating precise object detection and situational awareness.

1.3 FEATURES

- **High Gain**: The design achieves a gain of approximately 9.4 dB, supporting strong signal transmission and reception.
- **Improved Return Loss**: A return loss of -37.94 dB indicates efficient impedance matching, minimizing signal reflections.
- **Compact and Robust**: Designed with compact dimensions using Duroid 5880, making it suitable for vehicular installations.
- **Optimized Mutual Coupling**: The shape modifications reduce unwanted electromagnetic coupling, ensuring more reliable data transmission in high-density areas.

2 DESIGN AND IMPLEMENTATION

2.1 BLOCK DIAGRAM

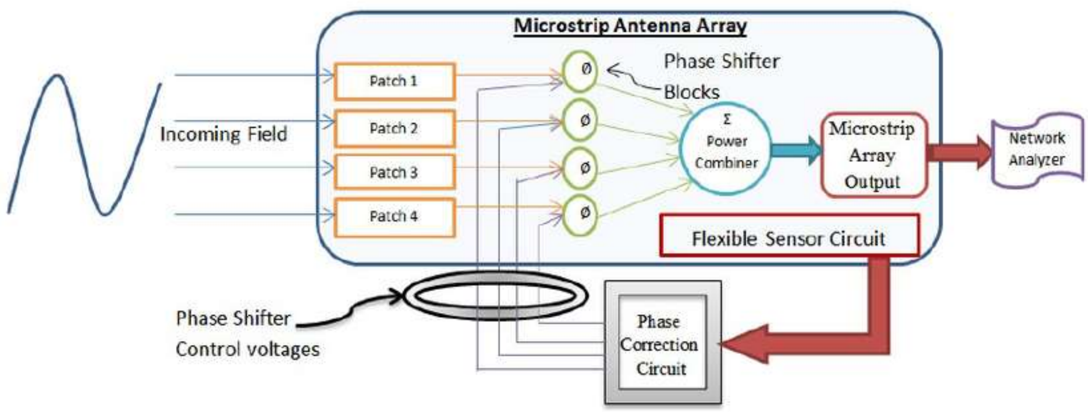
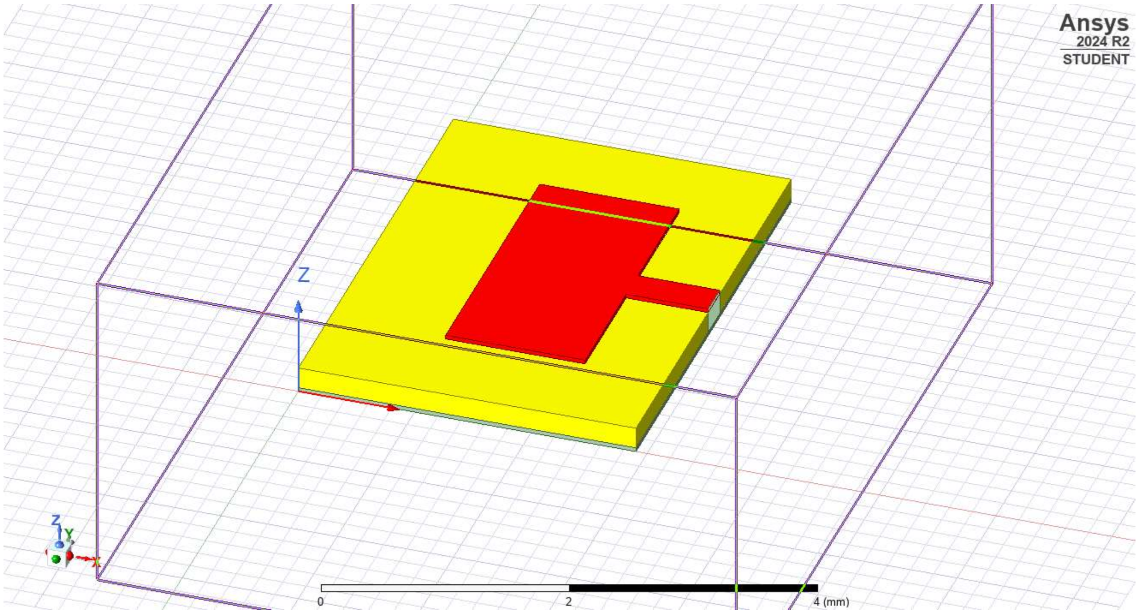


Table I *Design Parameters of proposed patch antenna at 77 GHz*

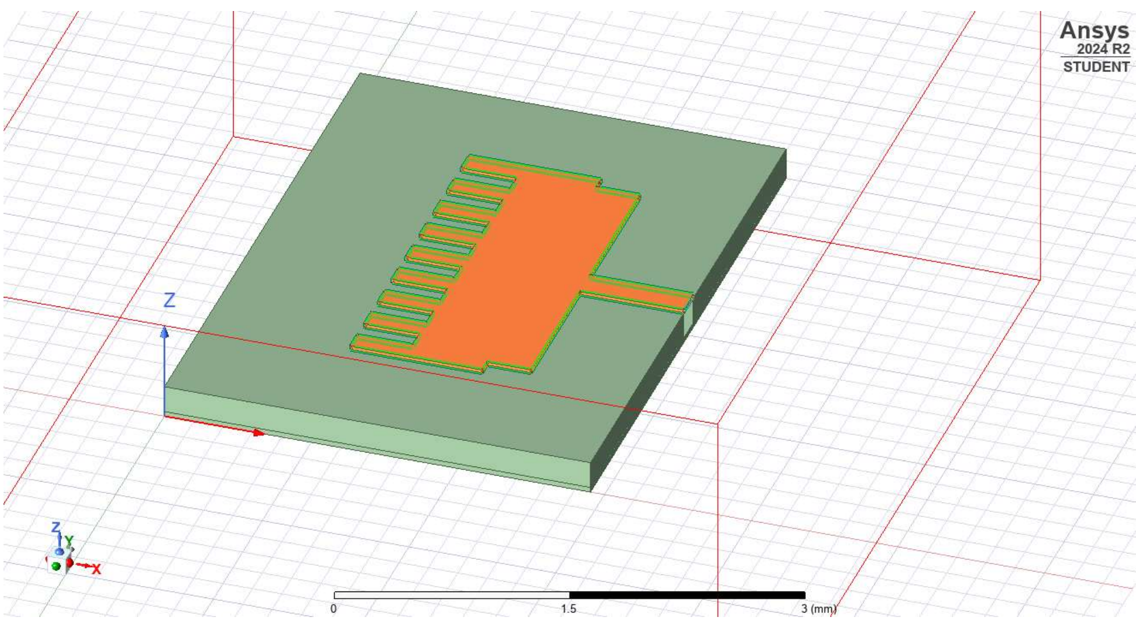
Antenna Parameters	Values
Center frequency	77 GHz
Patch Length =L	1.2 mm
Patch Width =W	2.43 mm
Substrate dimension	Length = 2.905 mm Width= 4 mm Height= 0.19 mm
Ground dimension	Length= 2.905 mm Width= 4 mm
Lf	0.555 mm
Wf	0.3 mm
Y0	0.25 mm
g	0.01 mm
le	0.4 mm
ld	0.3 mm
W_e	0.142 mm
W_d	0.1 mm

2.2 HFSS SNAPSHOTS

MICROSTRIP PATCH ANTENNA



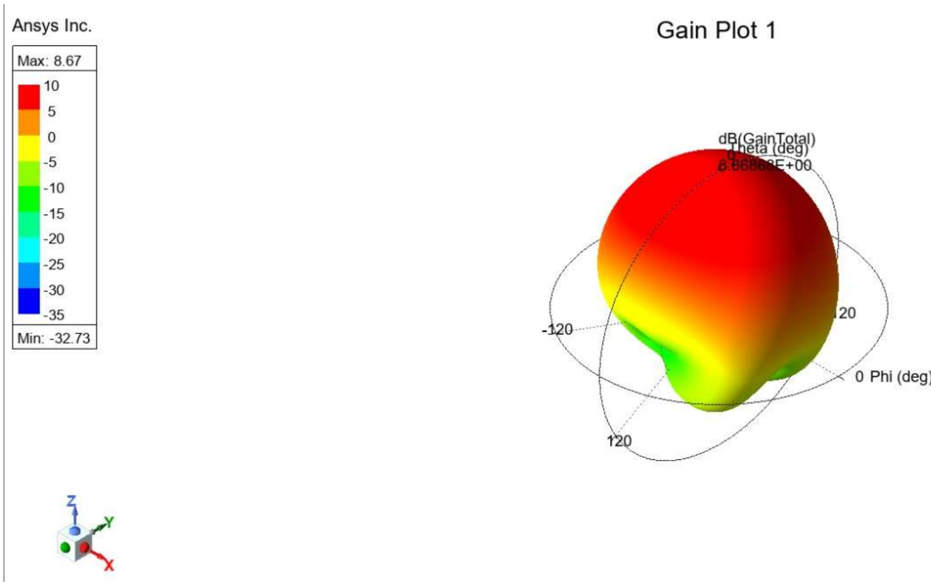
TOOTH-SHAPED PATCH ANTENNA

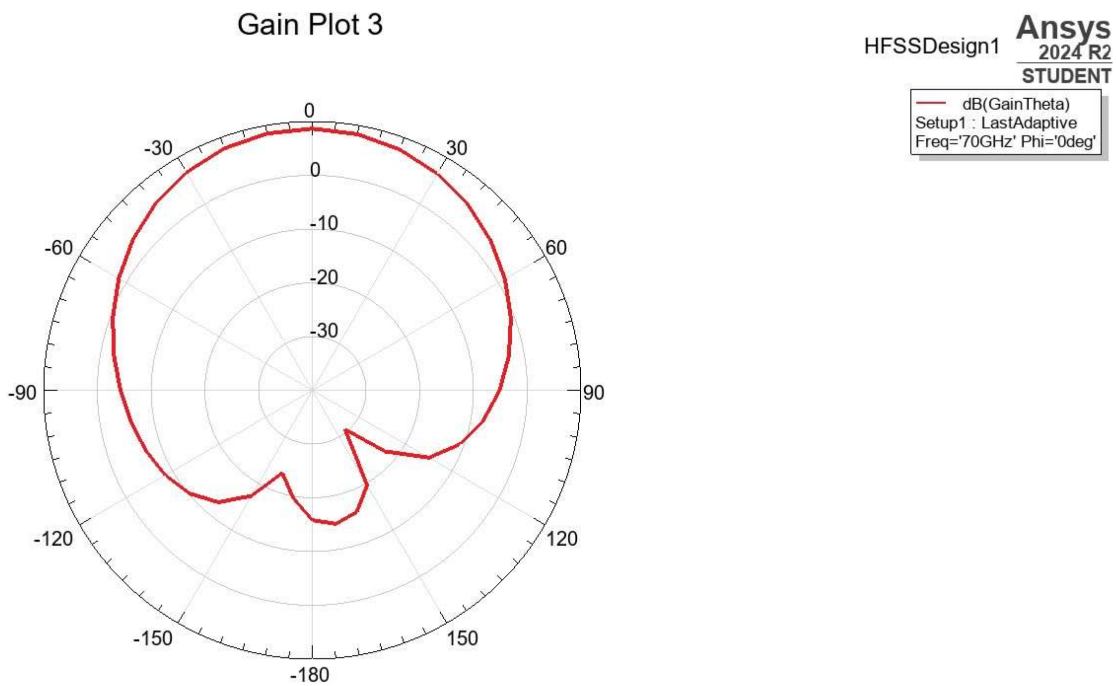


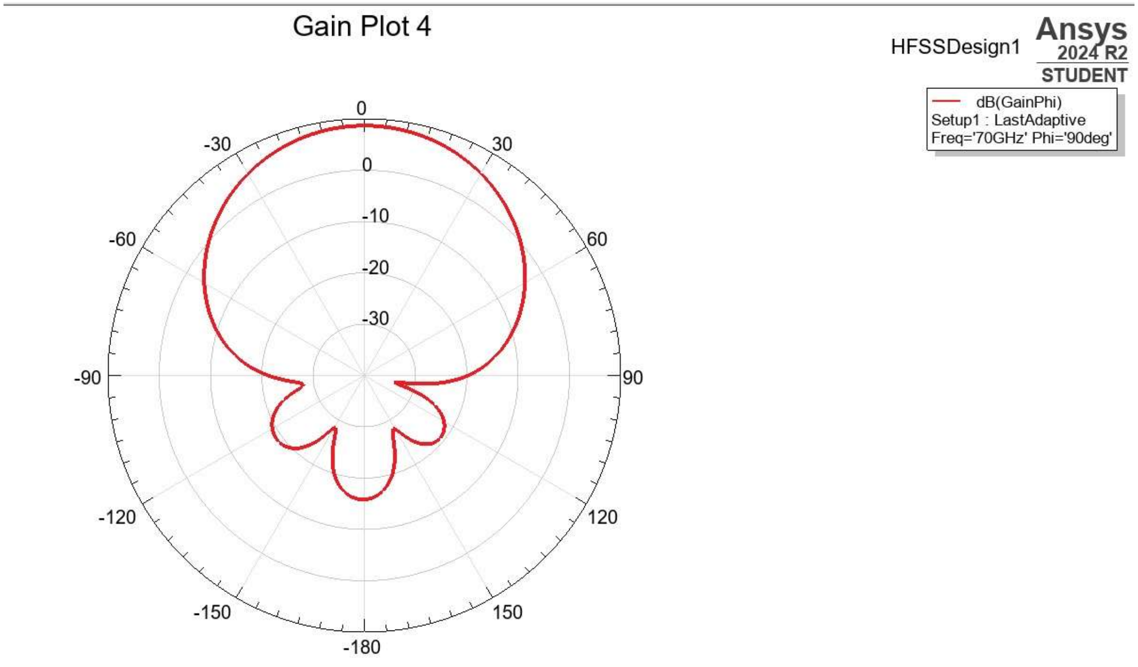
3 SOFTWARE ANALYSIS

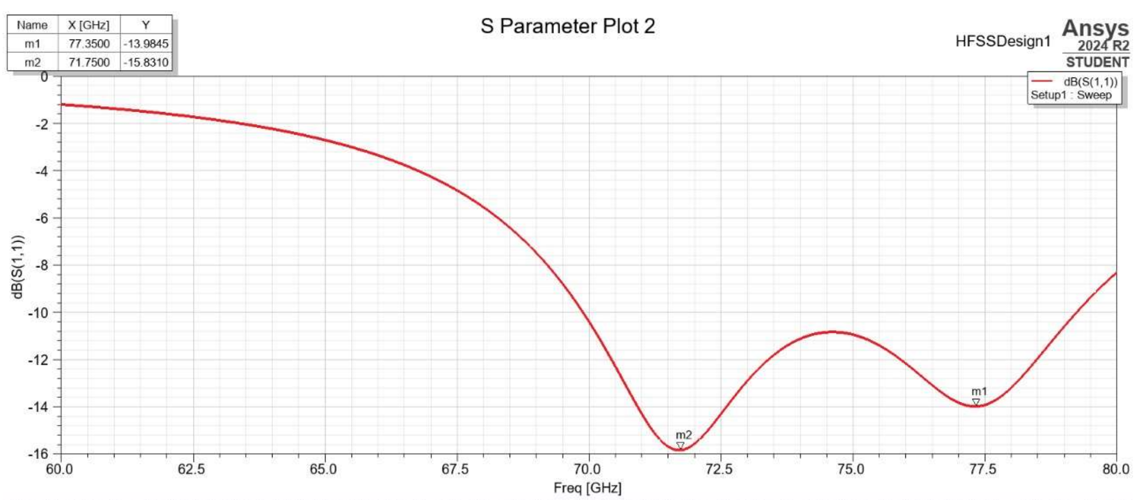
3.1 RESULTS SNAPSHOTS

MICROSTRIP PATCH ANTENNA

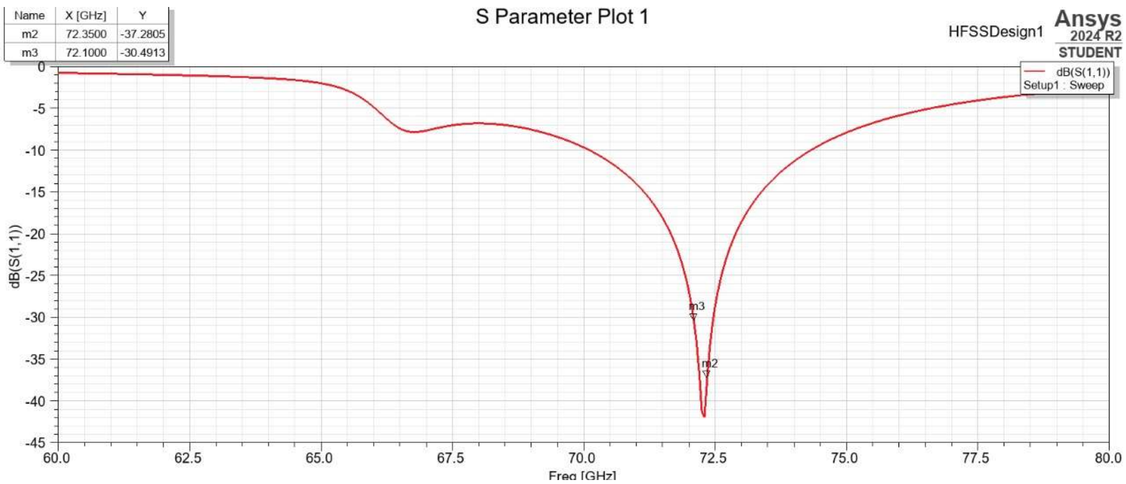


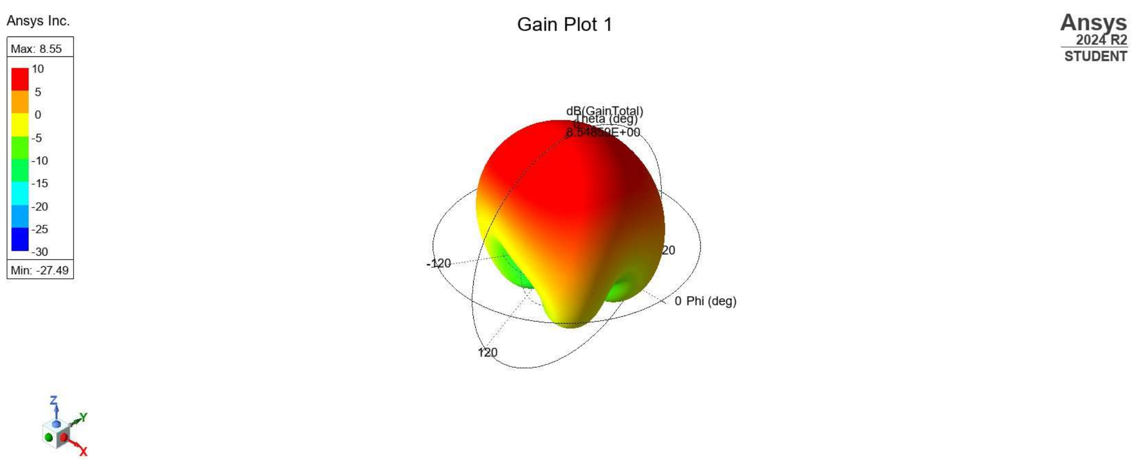


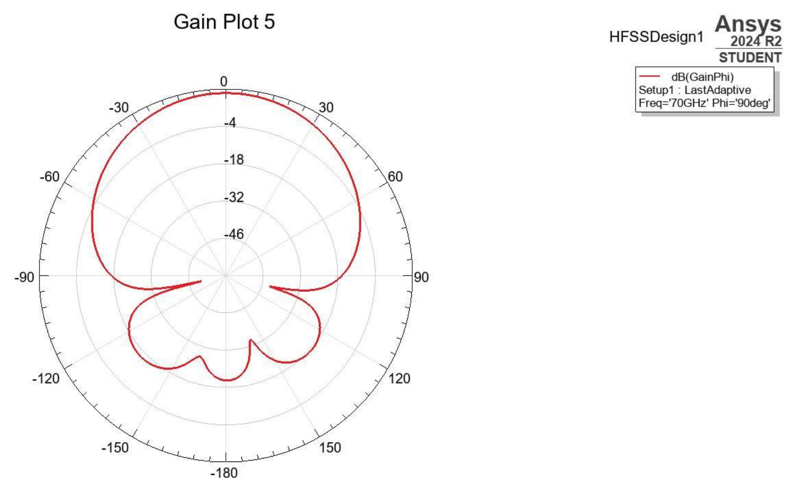

Gain Plot 4
HFSSDesign1
Ansys
2024 R2
STUDENT
dB(GainPhi)
Setup1 : LastAdaptive
Freq='70GHz' Phi='90deg'

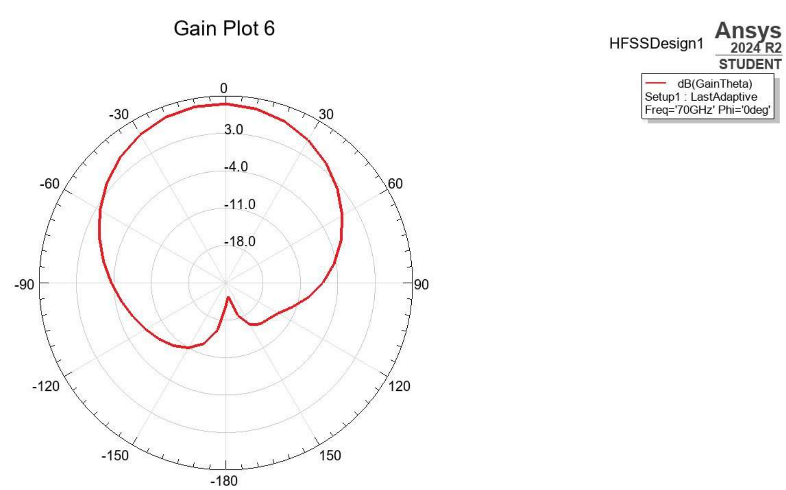

S Parameter Plot 2
HFSSDesign1
Ansys
2024 R2
STUDENT
dB(S(1,1))
Setup1 : Sweep
Name X [GHz] Y
m1 77.3500 -13.9845
m2 71.7500 -15.8310
dB(S(1,1))
Freq [GHz]

TOOTH-SHAPED PATCH ANTENNA






Gain Plot 5
HFSSDesign1
Ansys
2024 R2
STUDENT
dB(GainPhi)
Setup1 : LastAdaptive
Freq='70GHz' Phi='90deg'
0
30
60
90
120
150
-180
-150
-120
-90
-60
-30
-4
-18
-32
-46


Gain Plot 6
HFSSDesign1
Ansys
2024 R2
STUDENT
dB(GainTheta)
Setup1 : LastAdaptive
Freq='70GHz' Phi='0deg'
0
30
60
90
120
150
-180
-150
-120
-90
-60
-30
3.0
-4.0
-11.0
-18.0

4 CONCLUSION AND FUTURE WORK

4.1 RESULT, CONCLUSION AND INFERENCE

- **RESULT:**

The simulation results of the tooth-shaped patch antenna at 77 GHz demonstrate:

1. **High Gain**: The antenna achieves a gain of approximately 9.4 dB, showing a significant improvement over traditional patch design.

2. **Improved Return Loss**: A return loss of -37.94 dB indicates highly effective impedance matching, minimizing signal reflections and loss.

3. **Enhanced Mutual Coupling Reduction**: Modifications in the patch geometry, specifically the insertion of slots, effectively reduce mutual coupling, thereby improving overall performance.

These results confirm the efficacy of the tooth-shaped design in providing stable and strong signal transmission, meeting the demanding requirements of autonomous vehicular systems.

- **CONCLUSION:**

The tooth-shaped patch antenna designed for 6G vehicular communication proves to be a viable solution for high-frequency autonomous vehicle applications. Key conclusions are:

- **Performance Improvement**: This design enhances critical parameters such as gain, return loss, and mutual coupling reduction.
- **Suitability for Autonomous Vehicles**: The antenna's characteristics align well with the needs of autonomous vehicle radar systems, particularly in terms of reliable, high-gain communication at millimetre-wave frequencies.

- **Validation of Design Choices**: The use of Rogers RO/Duroid 5880 substrate and optimized slot geometry supports the desired performance in 6G vehicular radar applications.

- **INFERENCE:**

From the results, we can infer that:

- **Reliability in High-Density Communication**: The improved gain and reduced mutual coupling make this antenna design resilient against interference, crucial for vehicular communication.
- **Potential for Future 6G Deployment**: This design is capable of meeting the requirements for high-speed, low-latency 6G networks in automotive radar applications.
- **Foundation for Further Development**: The positive outcomes from simulation indicate that with physical testing and possible array configurations, this design could serve as a foundational component in advanced radar systems for autonomous vehicles.

4.2 FUTURE WORK

- **Prototype Fabrication**: Develop a physical prototype for real-world testing to validate simulation results.
- **Extended Frequency Range**: Explore performance at slightly different frequencies within the 77-81 GHz range to assess adaptability across 6G applications.
- **Array Configuration**: Implement a phased array configuration to expand the antenna's field of view and further enhance gain.
- **Weather Resistance Testing**: Assess performance under various environmental conditions (e.g., rain, fog) to ensure robustness in all vehicular applications.

5 REFERENCES

(IN IEEE FORMAT)

[1] Hamieh, Ismail, "A 77 GHz Reconfigurable Micromachined Microstrip Antenna Array" (2012). Electronic Theses and Dissertations. Paper 128 [http://scholar.uwindsor.ca/etd].

[2] Rudolf Lachner, ’Development Status of Next Generation Automotive Radar in EU’, ITS Forum 2009, Tokyo, February 26th, 2009. (https://itsforum.gr.jp/Public/J3Schedule/P22/lachner090226.pdf: access date: June 5, 2021).

[3] Shinichi Honma and Naohisa Uehara, ‘Millimeter-Wave RADAR Technology for Automotive Application’, Technical reports, Mitsubishi Electric ADVANCE, June 2001, pp. 11~13.

6 PHOTOGRAPH OF PROJECT ALONG WITH TEAM MEMBERS

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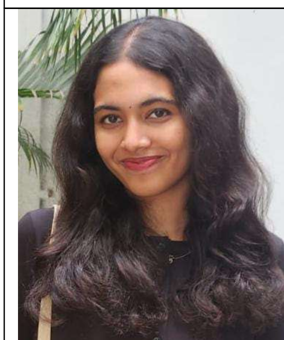	Name: Deepta V M Mobile Number: +91 73587 91314 E-mail: deepta.vaitha2022@vitstudent.ac.in Permanent Address: B22, AGS Colony, Beach Main Road, Kottivakkam, Chennai - 600041
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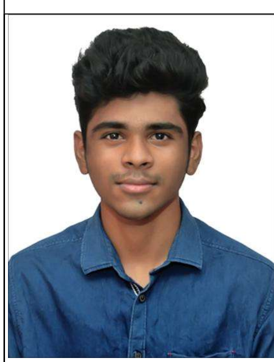	Name: Yashwanth B Mobile Number: +91 9176396794 E-mail: yashwanth.b2022@vitstudent.ac.in Permanent Address: No1- Gangai amman kovil street, Thiruvanmiyur,Chennai -600041