Participation for Student Design Contest MAPCON 2024 Hyderabad

---

Visvesvaraya National Institute of Technology, Nagpur

Team:

1. Rajas Tatwawadi
2. Mithilesh Mahure
3. Jude Melath
4. Gautam Gupta

Under the guidance of **DR. Arvind Kumar** (Prof Dept of ECE VNIT)

Title:

Design and Implementation of a 4 × 4 Sequentially Rotated Circularly Polarized Microstrip Patch Antenna Array with Meta-surface Loading for Wideband Operation at 8.25 GHz.

Introduction:

- This proposal presents the design of a **Right-Hand Circularly Polarized (RHCP) microstrip patch antenna array** operating at a centre frequency of **8.25 GHz**.
- The design addresses the challenge of achieving wideband performance, high gain, and optimal circular polarization by incorporating **sequentially rotated elements** and **meta-surface loading**.
- The antenna demonstrates significant improvements in **bandwidth**, **axial ratio**, and **radiation characteristics** compared to conventional designs, making it suitable for applications such as satellite communications, radar systems, and wireless communications in the 8 GHz band.

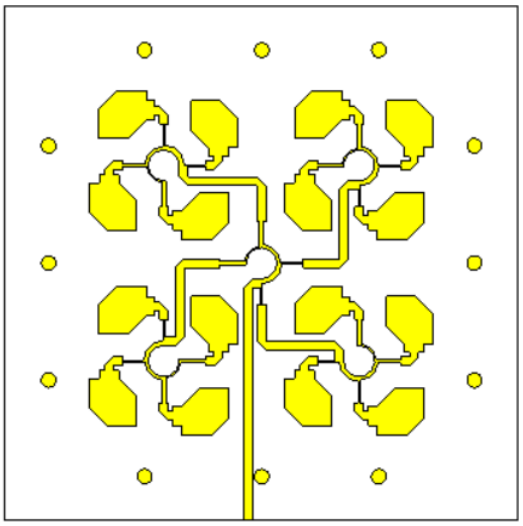
Objectives:

1. **Center Frequency**: The antenna is designed to operate at a center frequency of **8.25 GHz**.
2. **Bandwidth**: Achieve a bandwidth greater than **600 MHz** around the center frequency with a return loss better than 10 dB across the band.
3. **Axial Ratio**: Maintain an axial ratio of **less than 3 dB** throughout the bandwidth, ensuring efficient circular polarization.
4. **Gain**: Achieve a gain of **12 dBi or higher** throughout the operating bandwidth.
5. **Return Loss**: Ensure return loss is better than **10 dB** across the entire bandwidth.
6. **Polarization**: Ensure **Right-Hand Circular Polarization (RHCP)** for the antenna.
7. **Judgment Criteria**: The design will be evaluated based on the achieved bandwidth, VSWR, gain, beamwidth, and sidelobe levels.

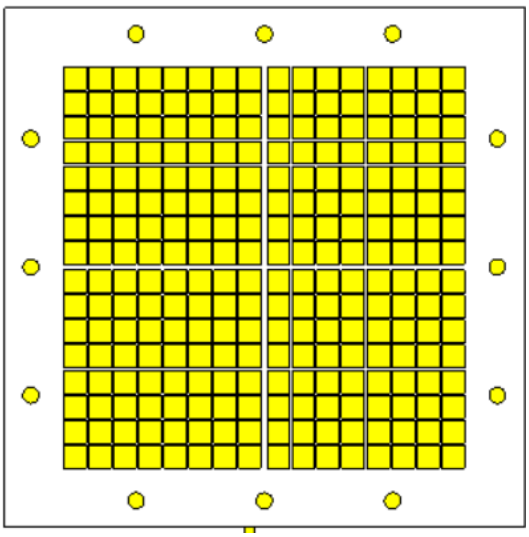
Design Overview:

The proposed antenna array consists of a **4 × 4 sequentially rotated patch configuration** with a **meta-surface-loaded structure** to enhance performance metrics. The key elements of the design are outlined below:

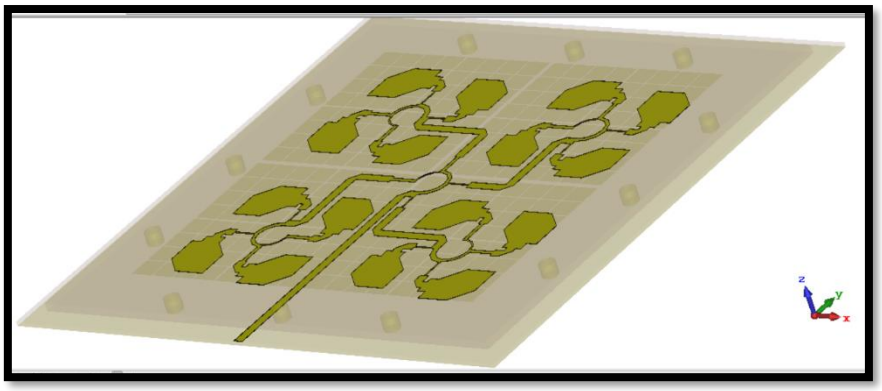
- **Sequential Rotation**: The individual patches in the array are sequentially rotated by **90°** to improve axial ratio bandwidth and achieve consistent circular polarization across the operating band. This technique minimizes axial ratio degradation and enhances circular polarization purity.
- **Dual-Layer Substrate**: The antenna utilizes **two dielectric substrates** to achieve optimal performance:
    - The **bottom substrate** houses the **sequentially rotated feed network**, designed to distribute power evenly to the patches while maintaining phase differences to support circular polarization.
    - The **top substrate** contains **metasurface cells**, which act as passive structures to control the electromagnetic wave propagation, thus broadening the bandwidth and improving gain.
- **Metasurface Loading**: The incorporation of a metasurface on the top layer enhances the bandwidth and reduces surface wave losses, leading to improved radiation efficiency and gain. The metasurface cells are carefully designed and placed to complement the behavior of the radiating elements below.



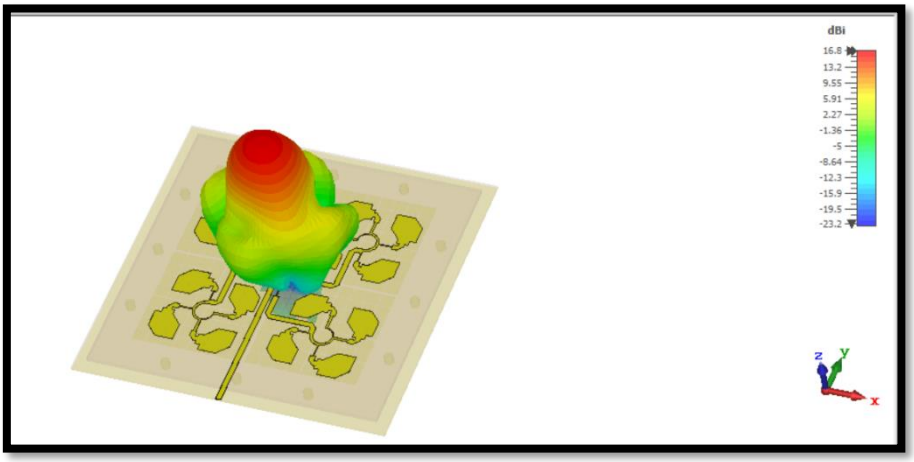
4x4 Sequentially Rotated Circularly Polarised Structure



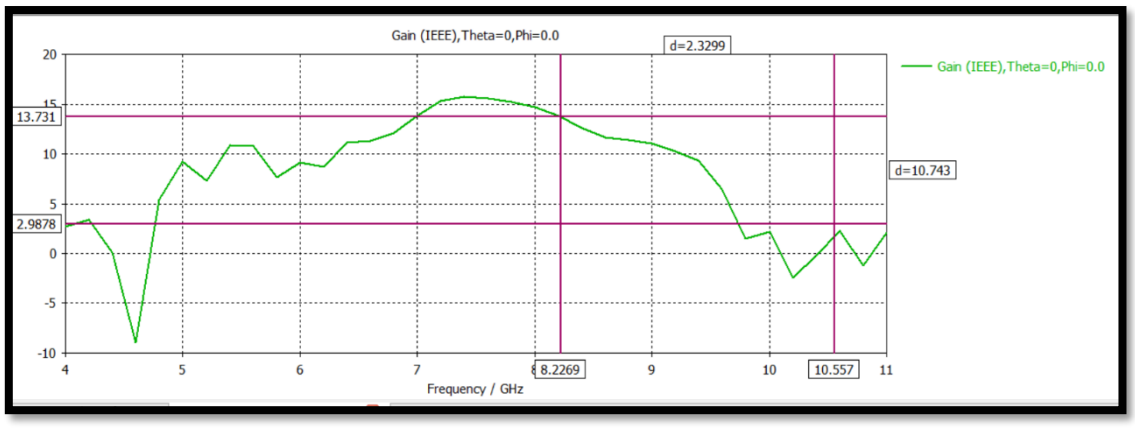
Meta-surface Loading



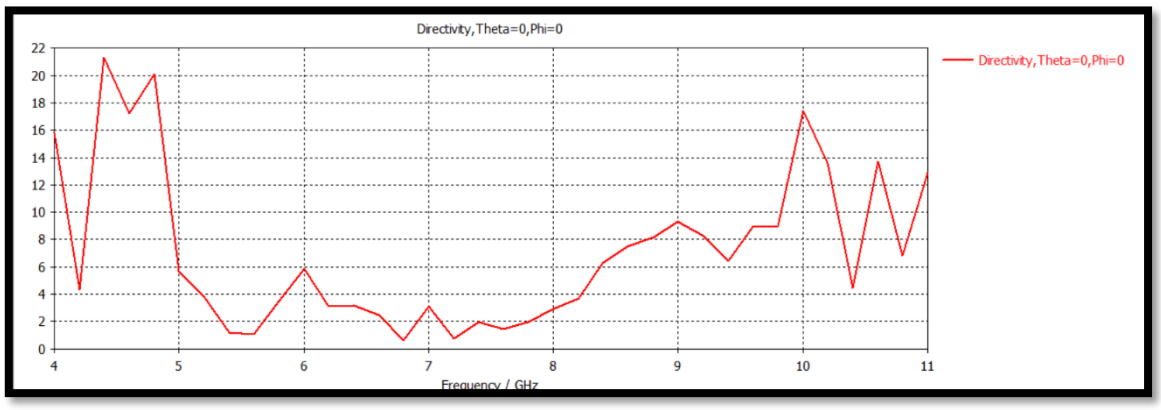
Diagonal View



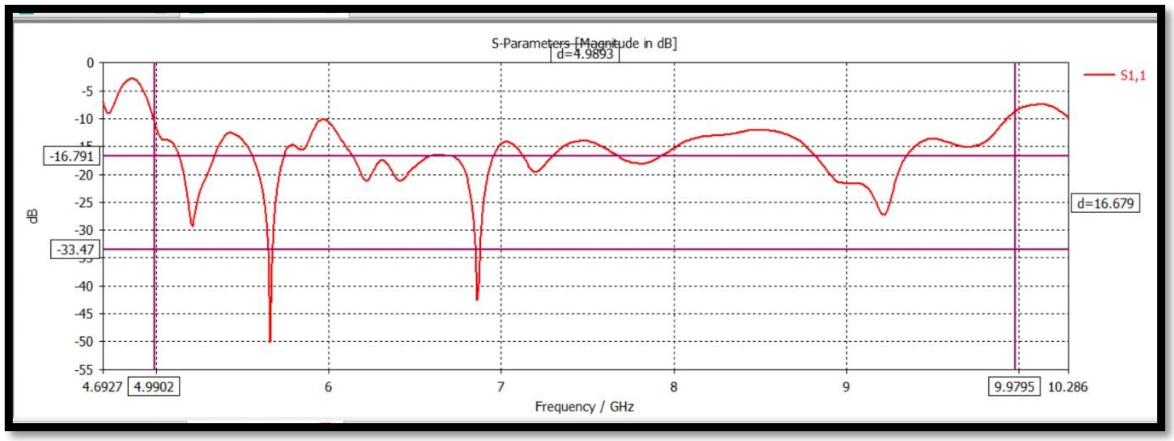
Radiation Pattern



Gain(IEEE), Theta=0, Phi=0



Directivity, Theta=0, Phi=0



S11 parameter

Key Features:

- **Enhanced Bandwidth**: The use of metasurface loading and dual substrates increases the bandwidth to more than **600 MHz** around the center frequency.
- **Improved Axial Ratio**: Sequential rotation of the patches ensures an axial ratio below **3 dB** throughout the band, resulting in high-quality circular polarization.
- **High Gain**: The array configuration and metasurface structure achieve a gain of **12 dBi or higher**, making the design suitable for long-range communication systems.
- **Low Return Loss**: The antenna exhibits a return loss better than **10 dB** across the operational bandwidth, ensuring efficient power transfer.
- **Reduced Sidelobes**: The use of sequential rotation and proper feed network design helps in reducing the sidelobe levels, leading to a cleaner radiation pattern.

Simulation and Testing:

The antenna design was simulated using full-wave electromagnetic simulation tools (CST Microwave Studio). The following parameters were evaluated:

- **Return Loss (S11)**: Measured across the frequency range to ensure a return loss better than 10 dB.
- **Axial Ratio**: Simulated and confirmed to be less than 3 dB across the band.
- **Gain**: Achieved gain of 12 dBi across the operating frequency range.
- **Radiation Pattern**: The radiation pattern was analyzed to ensure optimal beamwidth and minimal sidelobes.

Prototypes were fabricated, and tests were conducted in an anechoic chamber to validate the design against the simulation results. The prototypes went through return loss and radiation pattern measurements using a vector network analyzer (VNA) and anechoic chamber testing.

Conclusion:

The proposed design of a **4 × 4 circularly polarized microstrip patch antenna array with meta-surface loading** successfully meets the contest criteria, achieving wide bandwidth, high gain, and excellent circular polarization characteristics. The sequentially rotated feed and meta-surface integration are key innovations that distinguish this design, providing a robust solution for applications in satellite and radar communications.