# Design of Beam-Scanning Antenna Array for 6 GHz Applications

## Introduction

In the field of high-frequency wireless communication, the 6 GHz spectrum offers significant potential for applications ranging from 5G networks to satellite communication and radar systems. However, as systems operate at increasingly higher frequencies, they face challenges such as atmospheric losses, interference, and the need for precise directional control to optimize communication. To address these challenges, beam-scanning antenna arrays have emerged as a powerful technology, providing dynamic, adaptive control over signal directionality.

Antenna arrays operating at 6 GHz are commonly used in advanced communication systems, particularly in wireless networks, satellite communications, and radar systems. However, at these high frequencies, performance can be significantly impacted by atmospheric loss, interference, and multipath effects. A carefully designed beam-scanning antenna array can help overcome these challenges by focusing energy in specific directions, thus enhancing signal strength, reducing atmospheric absorption and minimizing interference.

This proposal presents a beam-scanning antenna array optimized for 6 GHz frequency applications to address challenges posed by atmospheric attenuation and interference. Mutual coupling in an antenna array can lead to several undesirable effects that degrade the array's performance, impacting its efficiency, beamforming capability, and overall functionality.

## Objectives

- To design beam scanning antenna system that dynamically directs antenna beams with a steering accuracy of ±1° across a 120° scan range, reducing signal attenuation by 15% and enhancing signal-to-noise ratio by at least 10 dB.
- To maintain interference levels at or below -20 dB within a 6 GHz operating frequency, ensuring cross-talk reduction by at least 25% compared to conventional arrays
- To fabricate and test the designed antennas using vector network analyzer.

## Methodology

### 1. Microstrip Patch Antenna Design:

The design of a microstrip patch antenna begins with selecting the operating frequency and calculating the required physical dimensions. For 6 GHz, the following calculations are performed:

Resonant Frequency: $f0 = 6$ GHz

Wavelength: $\lambda = c/f0 = 5$ cm

Patch Length (L): 2.5 cm

Patch Width (W): 1.4 cm.

Microstrip patch antennas are designed to operate efficiently at the resonant frequency, 6 GHz in this case. The primary design considerations include ensuring resonance at the target frequency and achieving optimal dimensions to maximize gain and minimize losses. The length (L) and width (W) of the patch are derived based on the wavelength and substrate properties.

For this design, the antenna dimensions are calculated to enhance the directive gain and bandwidth. The patch is fabricated on an FR4 substrate, chosen for its affordable cost and moderate dielectric constant ($\varepsilon r = 4.4$). By achieving a half-wavelength resonance, this design aims to support the beam-scanning requirements of the array with minimized losses.

### 2. Array Configuration

The proposed beam-scanning array employs a 1x2 configuration. This array geometry allows uni-dimensional beam steering, which is essential for applications in urban environments with high device density. The inter-element spacing is set to $\lambda/2$ to avoid grating lobes while ensuring minimal mutual coupling between adjacent elements. This configuration enables optimal array gain and a narrow beamwidth, essential for precise beam steering.

### 3. Beamforming Network

Active Phase Shifting: Active phase shifters (using PIN diodes or Varactor diodes) are used at each antenna element to adjust the phase and achieve continuous beam scanning.

$\Delta\phi = 2\pi d \sin\theta / \lambda$

where ,d is the distance between elements and θ is the beam steering angle.

### 4. Simulation and Testing

Simulations are conducted in HFSS tool to model radiation patterns, impedance, and coupling.

## Expected Outcome

1. Beam-scanning antenna array to demonstrate precise beam control with an accuracy of ±1°, effectively steering beams within a 120° range. A 15% reduction in signal attenuation and a 10 dB improvement in signal-to-noise ratio, ensuring clearer and stronger signal reception
2. Beam forming network to maintain interference levels at or below -20 dB within a 6 GHz operating frequency, ensuring cross-talk reduction by at least 25% compared to conventional arrays.

## Gantt Chart

| | DATES | | | |
|---|---|---|---|---|
| Phases | 1/11/2024 | 20/11/2024 | 25/11/2024 | 05/12/2024 |
| Design and Simulation using HFSS | | | | |
| Feedback and Fine Tuning | | | | |
| Fabrication and Testing | | | | |

## References

1. O. Barrou, A. El Amri, and A. Reha, "Microstrip Patch Antenna Array and its Applications: A Survey," IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), vol. 15, no. 1, pp. 26-38, Jan.–Feb. 2020.

2. S. I. Abd Elrahman, A. M. Elkhawaga, A. H. Hussein, and A. E. A. Shaalan, "Linear Antenna Array Sectorized Beam Scanning Approaches Using Element Position Perturbation in the Azimuth Plane," Sensors, vol. 23, no. 14, p. 6557, July 2023.

3. S. I. Siddiqui, S. Bashir, A. Khan, S. Ghafoor, and I. Aziz, "A dual-band high-gain beam steering antenna array for 5G sub-6 GHz base station," Scientific Reports, vol. 14, no. 26517, pp. 1-14, 2024,

4. Rajesh Nema, Anzar Khan, "Analysis of Five Different Dielectric Substrates on Microstrip Patch Antenna," International Journal of Computer Applications, vol. 55, no. 14, pp. 40-47, Oct. 2012.

5. J. Sun and Y. Cheng, "Blindness-free beam scanning antenna with array of array architecture: principle, design, and experiment," Science China Information Sciences, vol. 67, no. 3, pp. 132301:1–132301:16, Mar. 2024.