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Course Name: Transmission lines, Waveguides and Antennas

Course Code: UE22EC351B

Design and Analysis of Antenna Array Using MATLAB Antenna Toolbox Project

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Introduction

This project involves the design and simulation of a linear dipole antenna array using MATLAB's Antenna Toolbox. The array comprises four dipole elements arranged in a Uniform Linear Array (ULA) configuration with half-wavelength spacing, operating at a frequency of 60 GHz. The objective is to analyze the array's radiation characteristics, including directivity, beamwidth, impedance behavior, S-parameters, and mutual coupling. Radiation patterns are examined in both azimuth and elevation planes, and key antenna performance metrics are extracted to assess suitability for high-frequency applications such as millimeter-wave (mmWave) communication.

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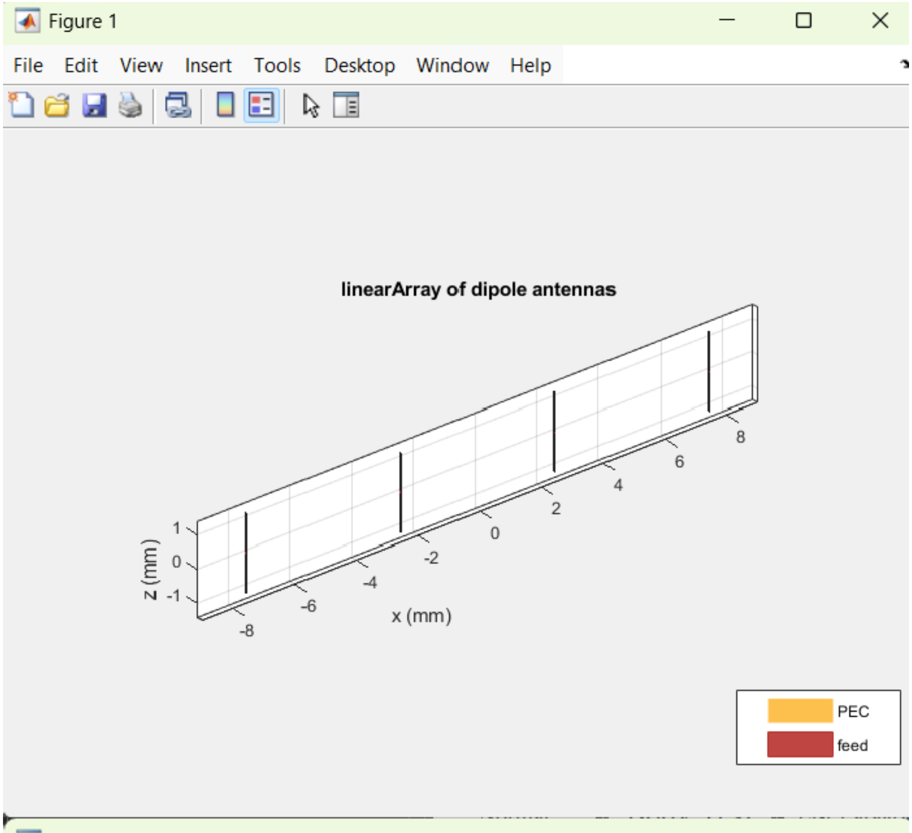
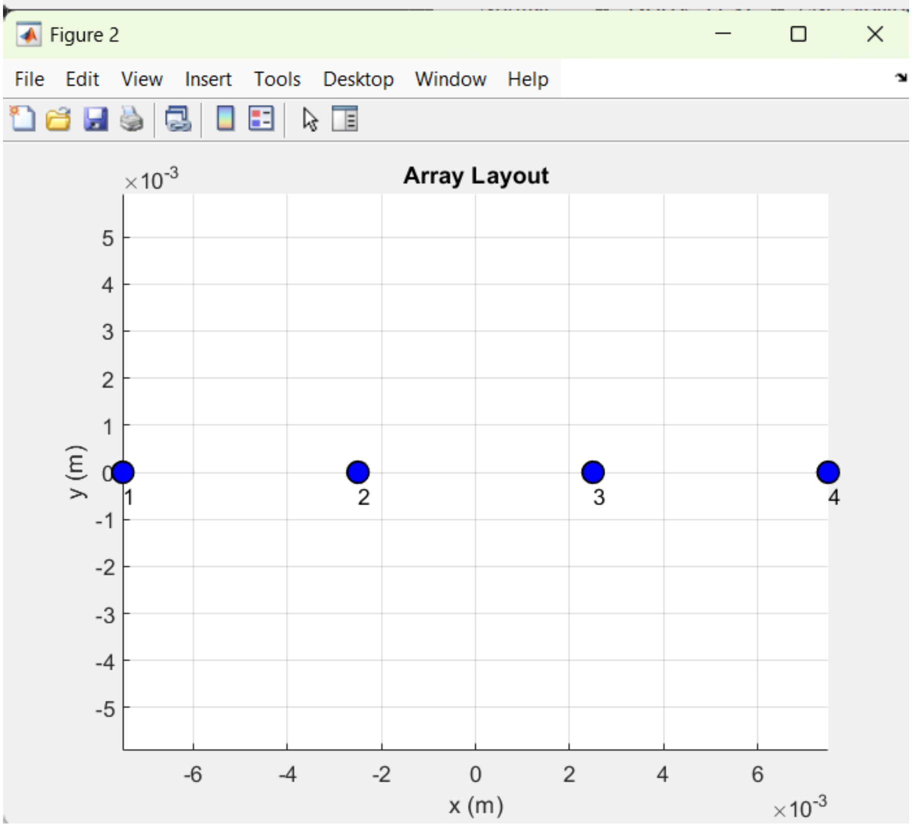
1. Antenna Array Design Parameters:

- **Element Type**: Uniform linear array (ULA) with dipole antenna elements
- Number of Elements: 6
- **Element Spacing**: 0.5 λ (half wavelength spacing)
- **Operating Frequency**: 1 GHz
- **Antenna Orientation**: Broadside configuration

Layout of linear dipole antenna array:



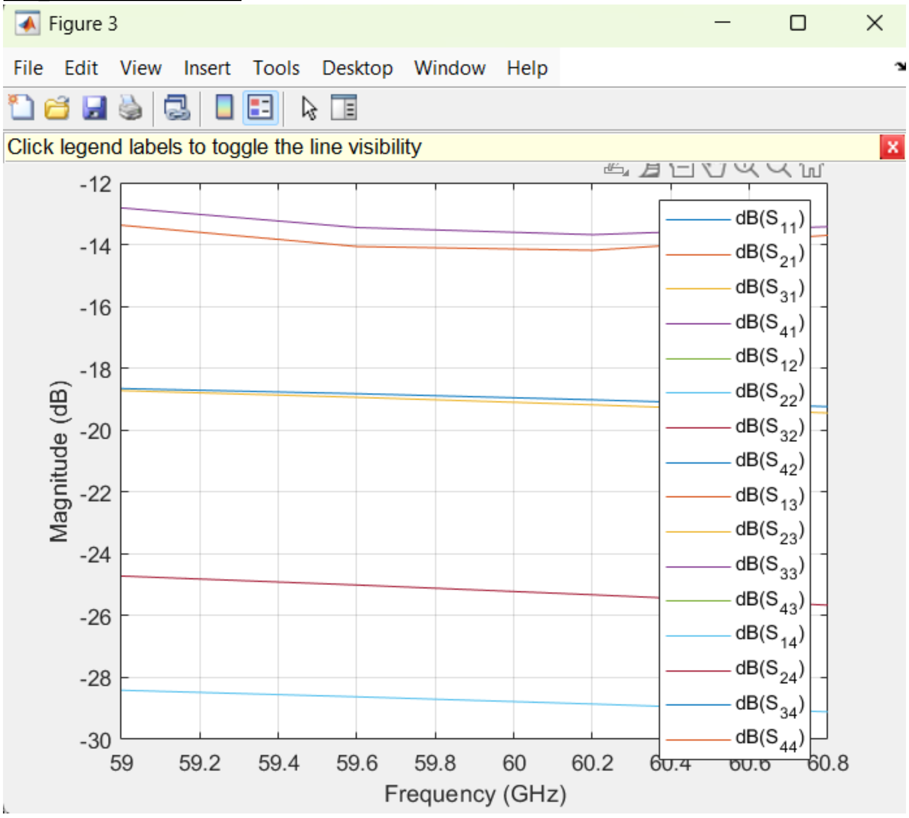


2. Performance Metrics Measured

Various performance metrics have been analyzed:

- **Directivity**:
  - 3D Pattern Max Value: **7.7 dBi**
  - Elevation Plane: ~5.98 dBi peak
  - Azimuth Plane: ~4.5 dBi peak
- **Half Power Beamwidth (HPBW)**:
  - **10°** in elevation plane
  - **50°** in azimuth plane
- **Front-to-Back Ratio**: 7.7 dB (elevation), 7.68 dB (azimuth)
- **Sidelobe Level (SLL)**:
  - As low as **0.00023 dB** in elevation (minimal interference)
- **Impedance Matching**:
  - Active impedance shows resistance around **80–95 ohms** and increasing reactance with frequency
  - S-parameter plots confirm reasonable isolation and matching
- **Correlation Coefficient**:
  - Between Element 1 & 3 is **< 0.02** , indicating low mutual coupling, which is ideal for MIMO configurations.

S parameter:



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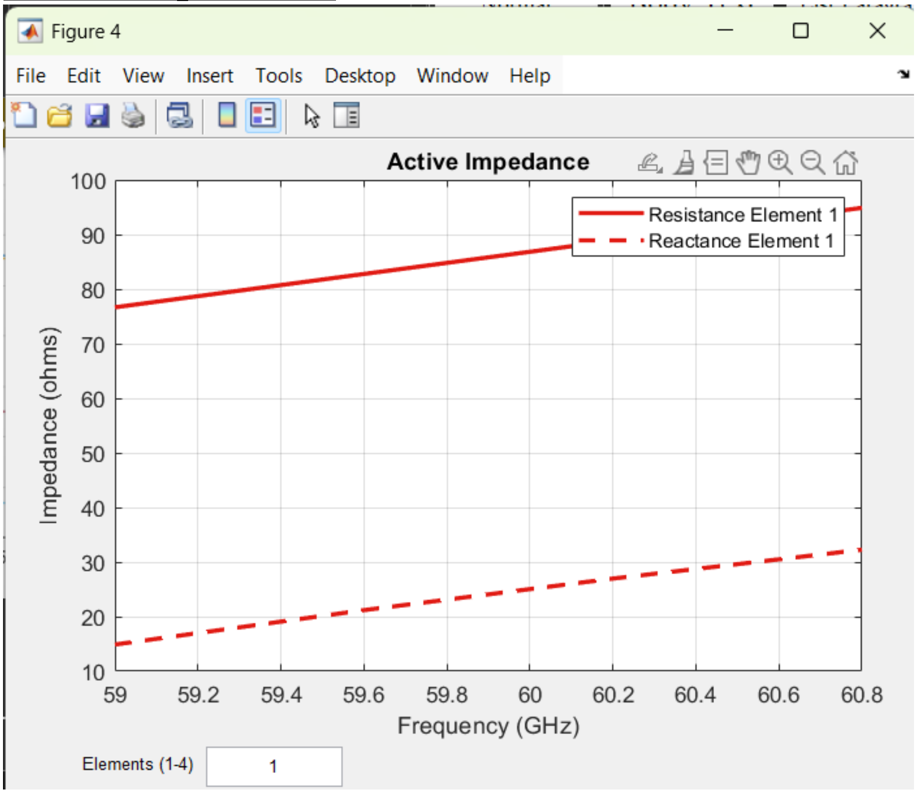
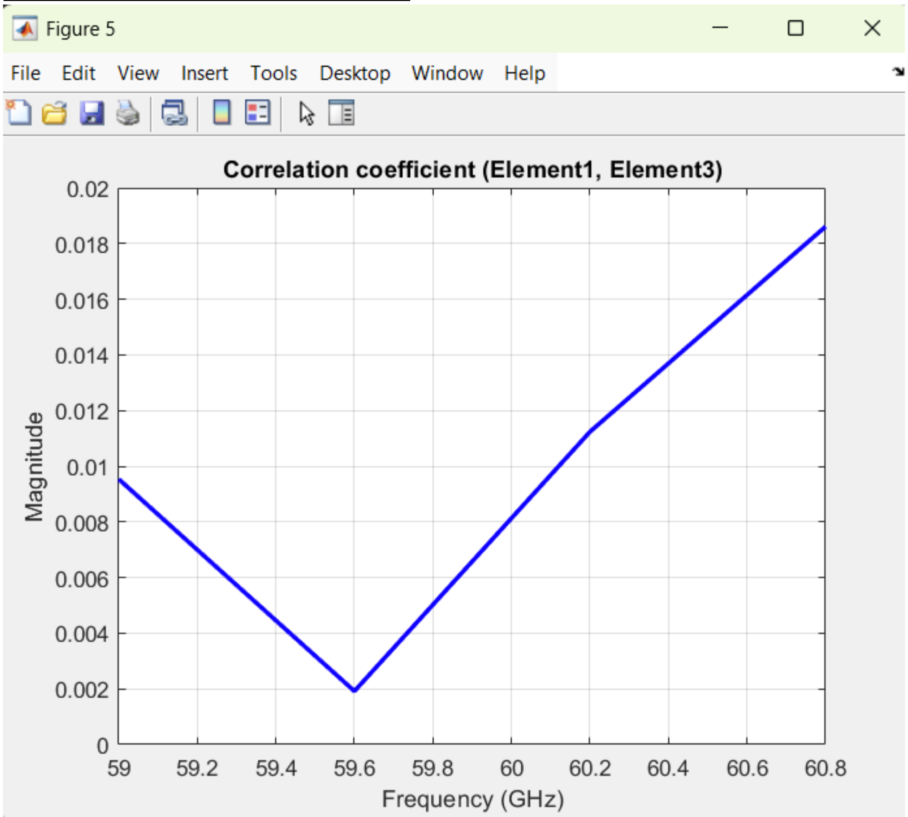
Active impedence:



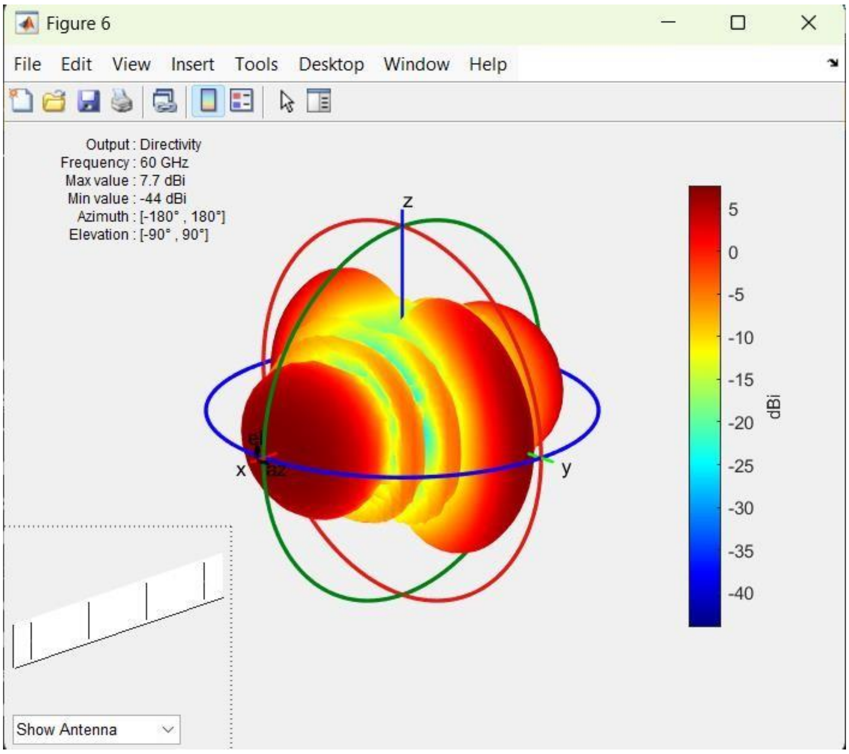
Correlation coefficient



3. Simulated Radiation Patterns:

- **3D Radiation Pattern** :
  - Highly directional radiation centered around the z-axis
  - Color intensity indicates higher directivity near the main lobe regions
  - Confirms strong broadside behavior, ideal for focused transmission
- **Elevation Radiation Pattern** :
  - Sharp main lobe centered at 90° with HPBW of **10°**
  - Well-suppressed sidelobes and minimal back radiation
- **Azimuth Radiation Pattern:**
  - Broader beam with HPBW of **50°**
  - Lower peak directivity compared to elevation but offers wide angular coverage

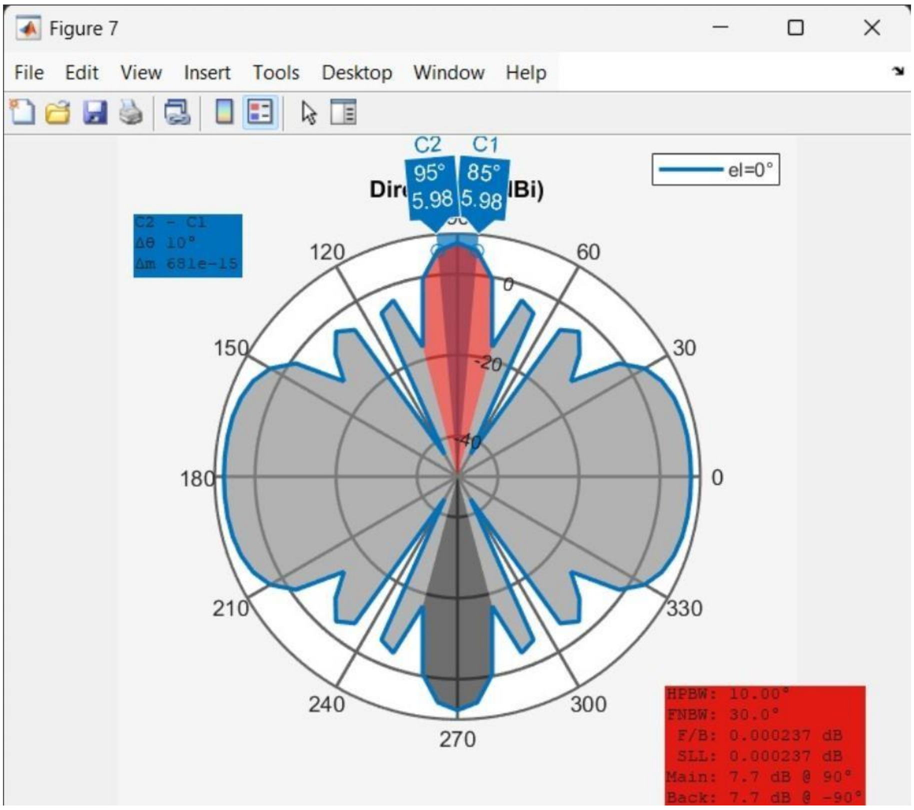
3D Radiation Pattern:



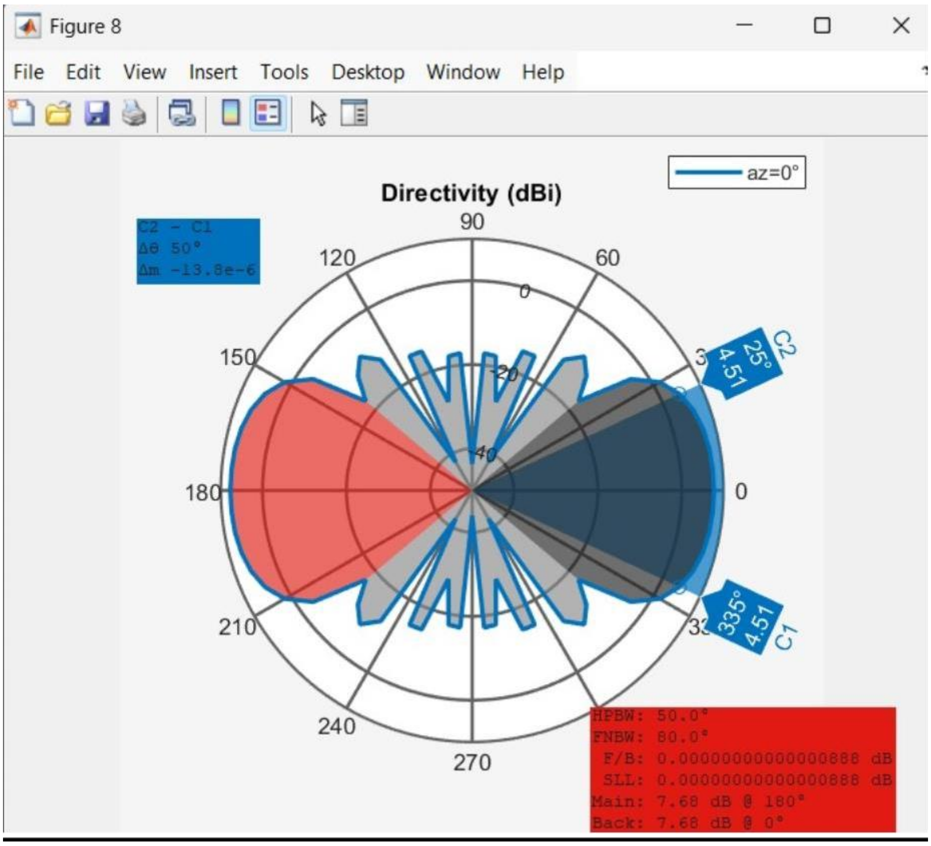
4. Radiation Pattern Plots in Different Planes:

- **Azimuth Plane (Az = 0°)**:
  - Broader pattern indicating wide horizontal coverage
  - Peak around ±25°–35° (Figure 8)
- **Elevation Plane (El = 0°)**:
  - Narrow, focused beam in the vertical direction (Figure 7)
  - Best suited for point-to-point communication at higher frequencies

Radiation pattern in elevation plane:



Radiation pattern in azimuthal plane:



5. Notable Features:

- **Main Lobe Direction**: Broadside (90° from array axis)
- **Sidelobe Level**: Extremely low (< 0.001 dB), ensuring minimal interference
- **Back Lobe**: Around -7.7 dB, indicating good front-to-back ratio
- **Grating Lobes**: Not observed due to half-wavelength spacing
- **Element Correlation**: Very low, making it suitable for MIMO/beamforming systems
- **Bandwidth**: Good performance across the 59–60.8 GHz range based on impedance and S-parameters

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<u>MATLAB Code</u>:

```
% Create a linearArray with dipole element.
% Generated by MATLAB(R) 24.2 and Antenna Toolbox 24.2
%Generated on:25-Mar-2025 10:55:58

%% Array Properties

SubObject = design(dipole, 60*1e9);
arrayObject = design(linearArray('Element', SubObject), 60*1e9, SubObject);
arrayObject.NumElements = 4;
arrayObject.ElementSpacing = 0.005;

%% Array Analysis
% Show for linearArray
figure;
show(arrayObject)
% Layout for linearArray
figure;
layout(arrayObject)
% S-parameter for linearArray
freqRange = (59:0.6:61)*1e9; refImpedance = 50;
figure;
rfplot(sparameters(arrayObject, freqRange, refImpedance));
% Impedance for linearArray
freqRange = (59:0.6:61)*1e9;
figure;
impedance(arrayObject, freqRange)
% Correlation for linearArray
freqRange = (59:0.6:61)*1e9; refImpedance = 50;elementNumbers = [1 3];
figure;
correlation(arrayObject, freqRange, elementNumbers(1), elementNumbers(2), refImpedance )
% Pattern for linearArray
plotFrequency = 60*1e9; termination = 50;
figure;
pattern(arrayObject, plotFrequency);
% Azimuth for linearArray
plotFrequency = 60*1e9; azRange = 0:5:360; termination = 50;
figure;
pattern(arrayObject, plotFrequency, azRange, 0);
% Elevation for linearArray
plotFrequency = 60*1e9; elRange = 0:5:360; termination = 50;
figure;
pattern(arrayObject, plotFrequency, 0, elRange);
```

Conclusion:

Therefore the simulated dipole antenna array demonstrates strong performance at 60 GHz, achieving a peak directivity of 7.7 dBi, a narrow beamwidth, and very low sidelobe and back lobe levels. The impedance plot and S- parameters confirm good matching and low reflections, while the low correlation coefficient indicates minimal mutual coupling between elements. These results highlight the array's suitability for directional and high- frequency systems such as 5G, radar, and beamforming. MATLAB's Antenna Toolbox effectively supports both design visualization and performance evaluation through scripting and simulation tools.