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BACHELOR OF TECHNOLOGY IN ELECTRONICS AND COMMUNICATION ENGINEERING

ECD 3201 ANTENNAS AND WAVE PROPAGATION

PROJECT TITLE

DESIGN AND SIMULATION OF 1X4 MICROSTRIP PATCH ARRAY ANTENNA WITH BEAM STEERING

A PROJECT REPORT

Under the Guidance of

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ABSTRACT

This project focuses on the design and simulation of a 1×4 microstrip patch antenna array using **CST Studio Suite**. A linear array comprising four identical rectangular patch elements was constructed and optimized to resonate at the desired frequency. The antenna's performance was evaluated through S-parameter analysis, confirming good impedance matching and acceptable inter-element isolation. Beam steering was implemented by applying progressive phase shifts of 0°, 30°, 45°, 60°, and 90° to the excitation ports. The resulting far-field radiation patterns demonstrated clear directional beam steering without mechanical movement. The simulation results validate the effectiveness of electronic phase control in guiding the main beam, making this design suitable for applications in smart antennas, radar systems, and next-generation wireless communication.

INTRODUCTION

Microstrip patch antennas have gained significant popularity in modern wireless communication systems due to their low profile, ease of fabrication, and compatibility with integrated circuits. However, a single patch antenna has limitations in terms of gain and beam direction control. To overcome these limitations, antenna arrays are used to enhance performance parameters such as directivity, gain, and beam steering capabilities.

Beam steering is a crucial technique in antenna array systems, enabling dynamic control of the radiation direction without physically moving the antenna. This is particularly valuable in applications such as radar, satellite communication, wireless networks, and smart antenna systems. Among the various beam steering methods, **electronic beam steering using phase shifting** is widely adopted due to its speed and precision.

In this project, a **1×4 linear microstrip patch antenna array** was designed and simulated using **CST Studio Suite**. The array was configured to operate at a desired frequency band, and its performance was analyzed through S-parameter evaluation and far-field radiation pattern visualization. Beam steering was achieved by introducing progressive phase shifts (0°, 30°, 45°, 60°, 90°) across the four antenna elements, demonstrating how the main lobe direction of the radiation pattern can be electronically controlled.This work highlights the effectiveness of phased antenna arrays and forms a foundation for more complex designs in adaptive and reconfigurable antenna systems.

ANTENNA DESIGN

In this project, a **1×4 linear microstrip patch antenna array** was designed and simulated using **CST Studio Suite**. The design was aimed at exploring the effect of progressive phase shifts on the far-field radiation pattern, enabling electronic beam steering. A feed network was not included; instead, each patch element was individually excited using discrete ports with manually applied phase shifts.

Single Patch Element Design

The process began with the design of a single **rectangular microstrip patch antenna**, resonant at **2.4 GHz**

Array Formation

- The single patch was duplicated to form a **1×4 linear array** along the x-axis.
- Elements were spaced at approximately **λ/2** to minimize mutual coupling and prevent grating lobes.

Excitation and Phase Control

- Each patch was excited individually using a **discrete port** in CST.
- Beam steering was implemented by applying **progressive phase shifts** across the elements: **0°, 30°, 45°, 60°, 90°**
- This allowed for electronic control of the main lobe direction in the far-field without mechanical movement.

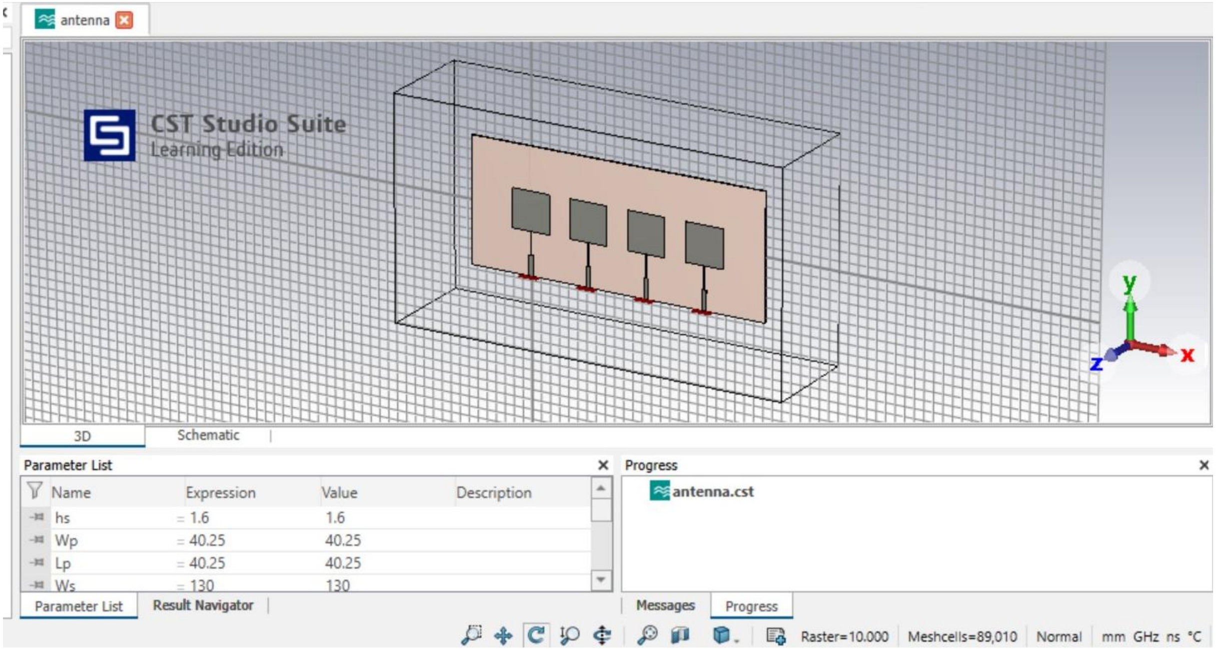
Simulation Setup in CST

- The 3D geometry was modeled in CST, with appropriate material assignments for the patch and substrate.

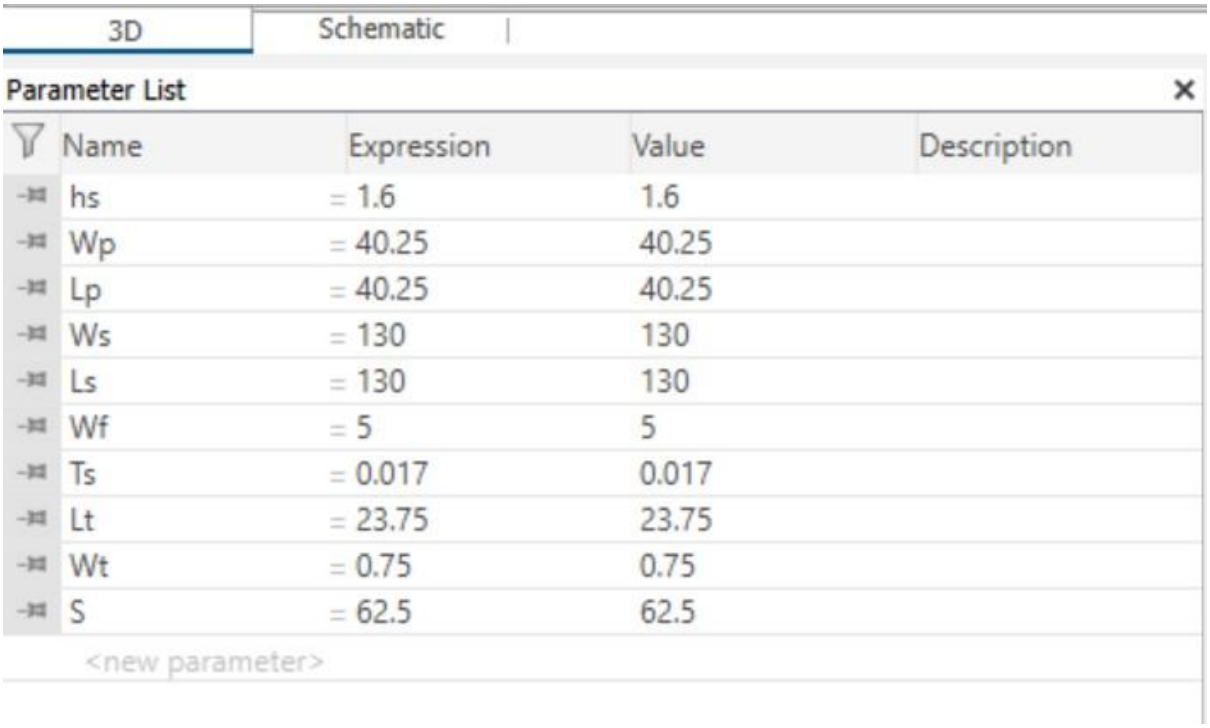
Simulations included: **S-parameters** to check matching and isolation, **Far-field analysis** to observe the impact of phase shifts on the radiation direction.

Parameter	**Value / Description**
Frequency (f_0)	2.4 GHz
Substrate Material	FR-4 ($\varepsilon r = 4.4$)
Substrate Thickness	1.6 mm
Number of Elements	4
Array Type	1×4 Linear
Element Spacing	$\lambda/2$ (≈ 62.5 mm)
Phase Shifts Applied	0°, 30°, 45°, 60°, 90°
Tool Used	CST Studio Suite

1X4 MICROSTRIP PATCH ARRAY ANTENNA DESIGN:



PARAMETERS:



Name	Expression	Value	Description
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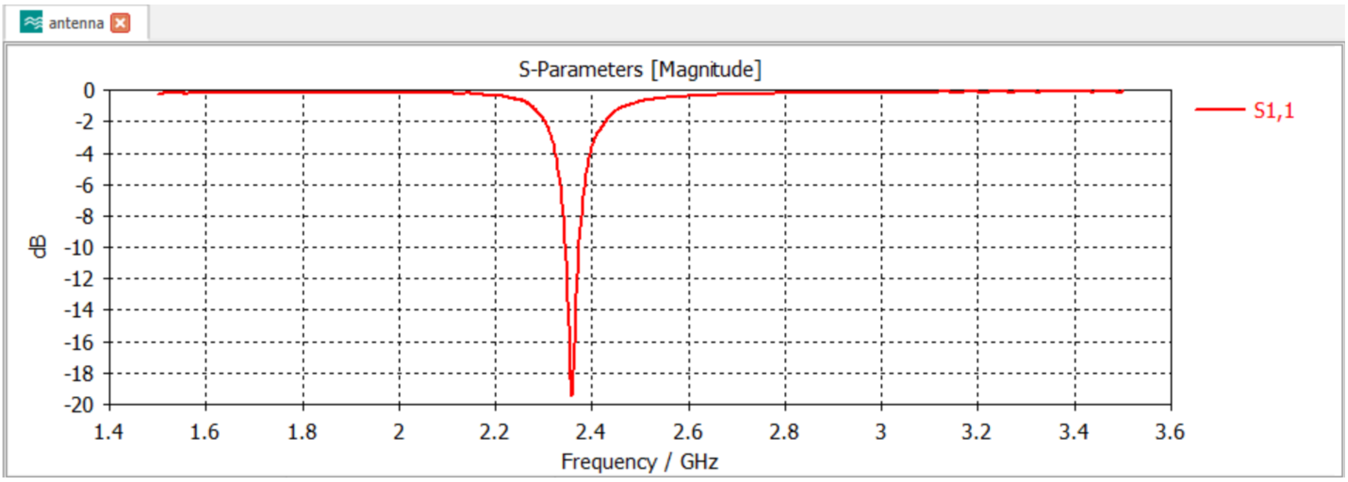
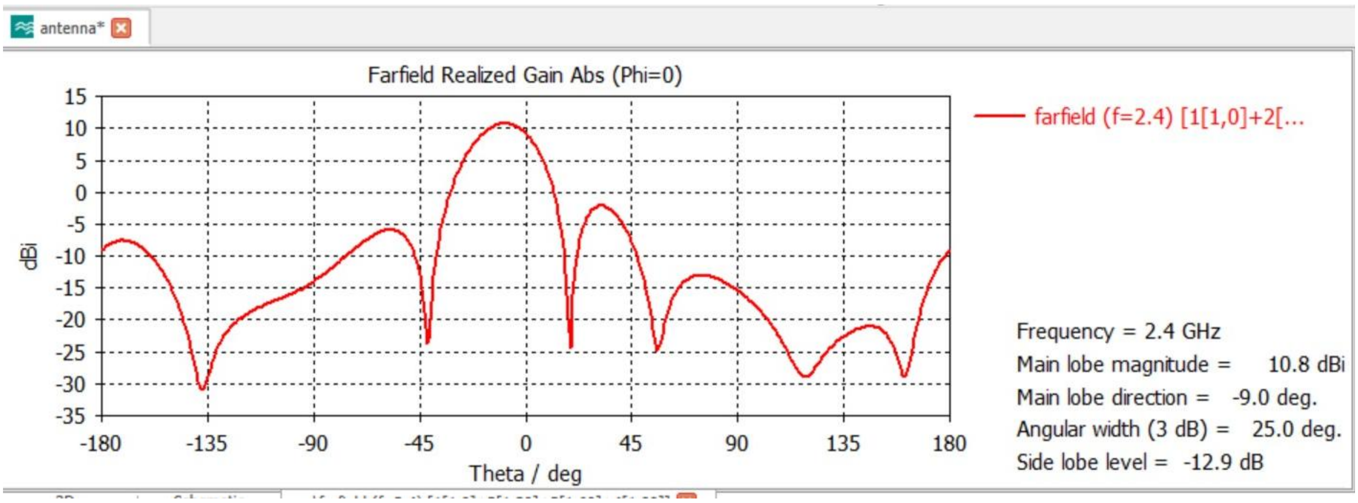
Wp	= 40.25	40.25	
Lp	= 40.25	40.25	
Ws	= 130	130	
Ls	= 130	130	
Wf	= 5	5	
Ts	= 0.017	0.017	
Lt	= 23.75	23.75	
Wt	= 0.75	0.75	
S	= 62.5	62.5	
<new parameter>			

S PARAMETERS GRAPH:

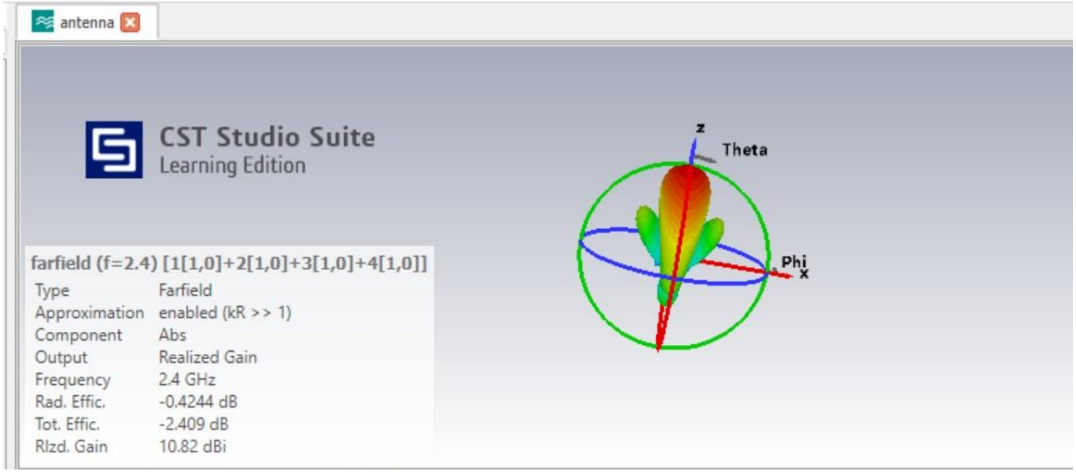


FARFIELD REALIZATION:



PHASE SHIFTING:

0 DEGREE:



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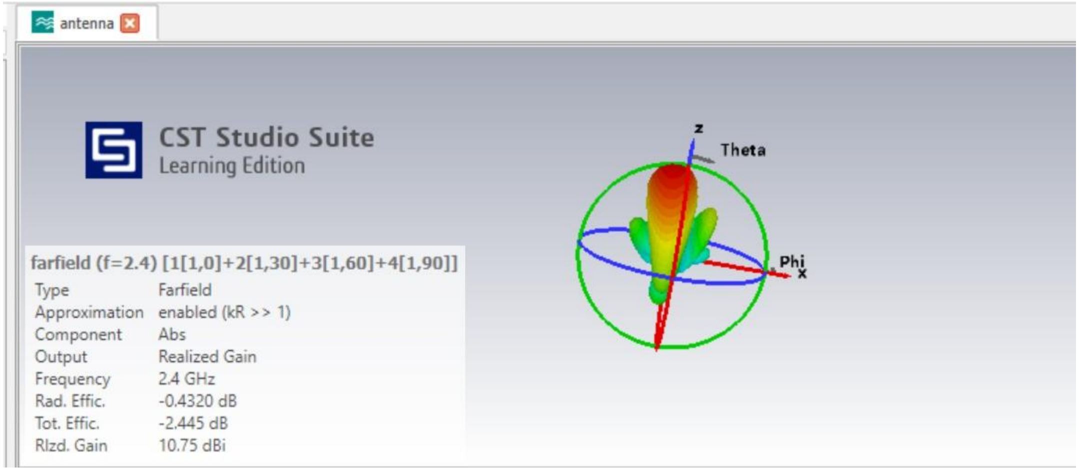

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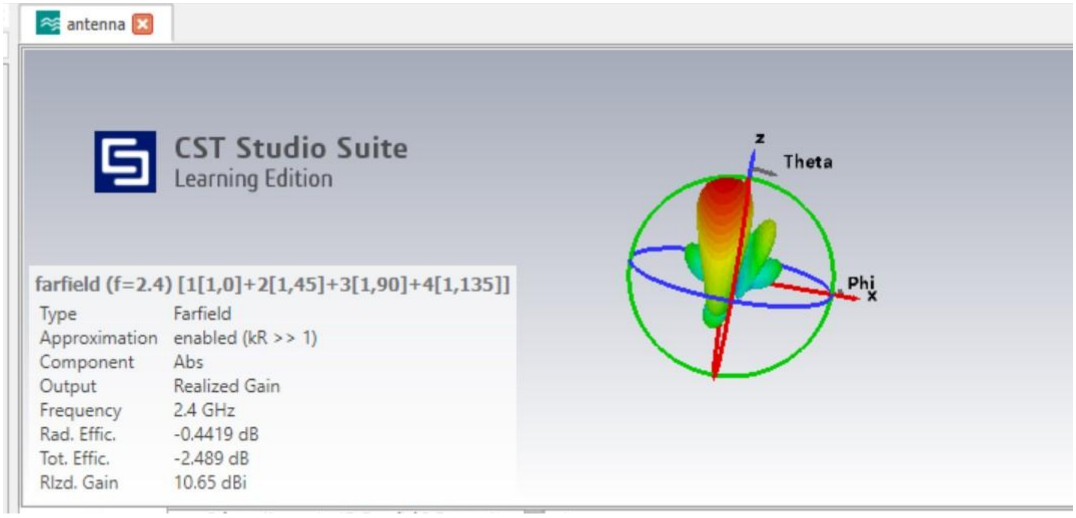

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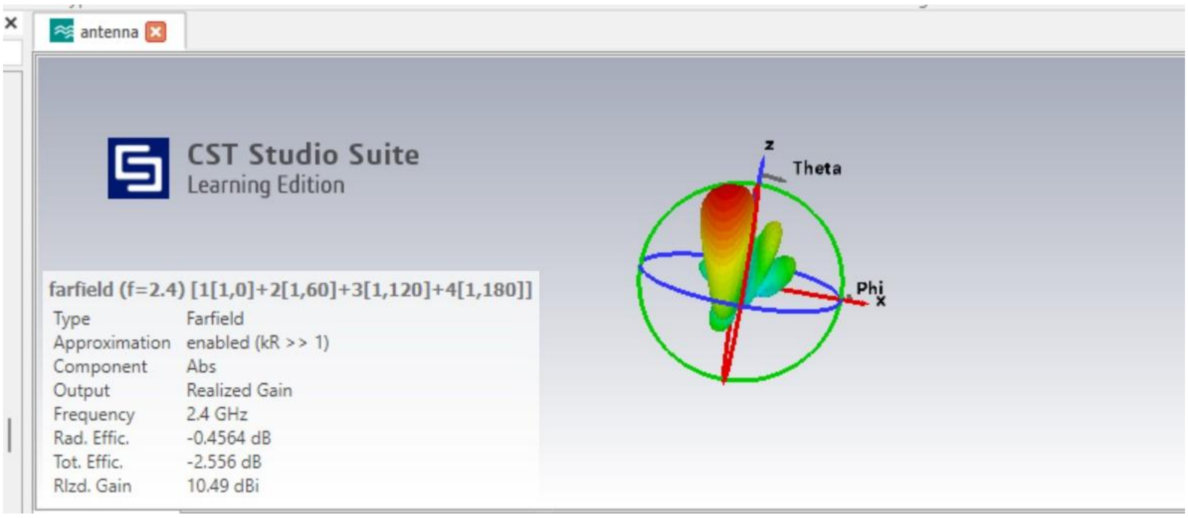
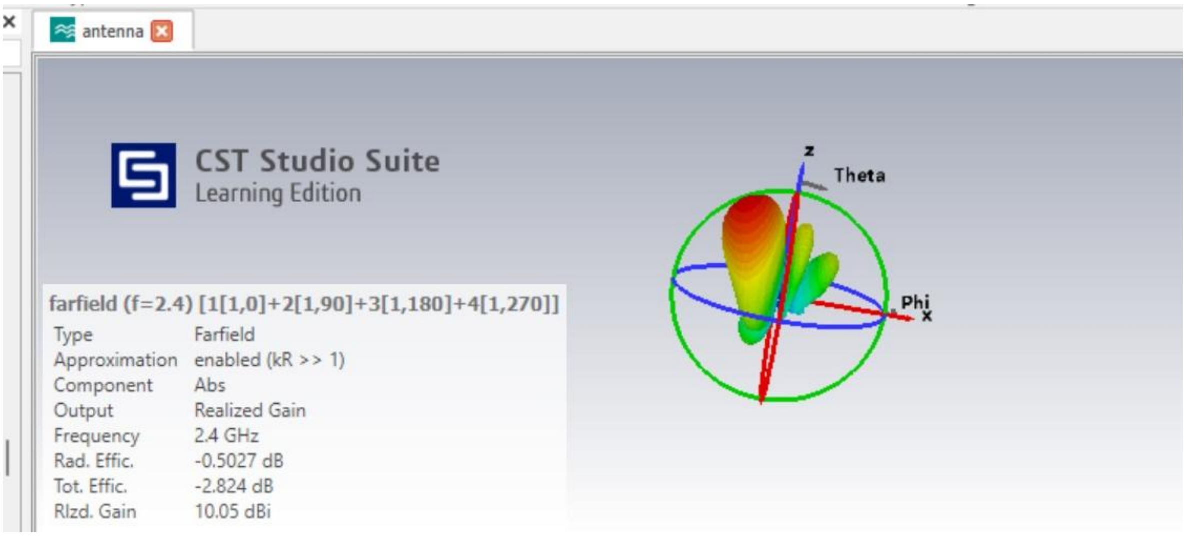


90 DEGREE:



SIMULATION RESULTS:

The simulation of the 1×4 microstrip patch antenna array was performed using CST Studio Suite to evaluate its performance in terms of impedance matching, radiation characteristics, and beam steering behavior.

1. S-Parameter Analysis

The **S-parameters** were obtained to examine the return loss (S11) and inter-element coupling (S12, S13, S14). The return loss for each element was observed to be below –10 dB at the resonant frequency of **2.4 GHz**, indicating good impedance matching. Additionally, the mutual coupling between adjacent elements was maintained at acceptable levels, confirming minimal interaction and good isolation among the elements.

2. Far-Field Radiation Pattern

The far-field radiation pattern was analyzed for each phase shift configuration. The beam direction was clearly observed to vary with the applied progressive phase shift, validating the concept of electronic beam steering.

- **At 0° phase shift:** The main lobe pointed perpendicular to the array, i.e., at **0°**, as expected for in-phase excitation.
- **At 30° phase shift:** The main lobe shifted toward **approximately 15°**.
- **At 45° phase shift:** The main beam steered to around **22°**.
- **At 60° phase shift:** A more significant beam tilt was observed, directing the beam at around **30°**.
- **At 90° phase shift:** The main beam showed maximum deviation, steering toward **45°** off boresight.

This demonstrated the array's ability to steer the beam across a desired angular range without any mechanical rotation.

3. Gain and Directivity

The antenna array showed enhanced gain compared to a single patch element due to the array factor. The main lobe gain increased with proper phase excitation, and the side lobe levels were maintained within tolerable limits.

4. **Summary of Observations**

Phase Shift	**Beam Direction**	**Return Loss (S11)**	**Observations**
0°	0°	< -10 dB	Broadside radiation, symmetrical pattern
30°	~15°	< -10 dB	Slight tilt in beam, good match
45°	~22°	< -10 dB	Clear beam steering
60°	~30°	< -10 dB	Enhanced directivity
90°	~45°	< -10 dB	Maximum beam deviation

The simulation results validate the performance of the 1×4 microstrip patch antenna array in terms of effective beam steering using progressive phase shifts. This proves the feasibility of using such an array in applications requiring electronically reconfigurable directional antennas.

CONCLUSION

In this project, a 1×4 linear microstrip patch antenna array was successfully designed and simulated using CST Studio Suite. The array was optimized to operate at a center frequency of 2.4 GHz, and each element was excited with individually applied progressive phase shifts to achieve electronic beam steering.

The simulation results demonstrated effective control over the radiation direction without any mechanical movement. The S-parameter analysis confirmed good impedance matching and acceptable inter-element isolation. Far-field radiation patterns clearly showed the beam steering behavior for different phase shift values (0°, 30°, 45°, 60°, 90°), validating the use of phase control for directing the antenna's main lobe.

This work proves the potential of phased array antennas in dynamic beam steering applications such as radar systems, smart antennas, and next-generation wireless communications. The methodology can be extended to more complex array configurations and frequency bands, paving the way for reconfigurable and adaptive antenna systems in real-world scenarios.

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3. “A Review on Beam Steering Techniques in Reconfigurable Microstrip Patch Antennas” (2020)