INTERNSHIP REPORT

On

TITLE

Design, Simulation, and Fabrication of Microstrip Patch Antenna and 1×8 Broadband Linear Array for X

Submitted by

[Your Name]

[Your Roll No.]

[Your College Name]

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Defence Research and Development Organisation (DRDO)

CV Raman Nagar, Bengaluru – 560093

ABSTRACT

This internship report presents the design, simulation, and performance analysis of two antenna structu

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1.INTRODUCTION

Introduction to Microstrip Patch Antenna

Microstrip patch antennas have emerged as one of the most popular types of antennas in modern wirel

The radiation mechanism of a microstrip patch antenna is based on fringing fields between the edges o

Advantages of microstrip patch antennas include:

Low profile and conformability to surfaces.

Ease of integration with microwave circuits.

Capability for dual and circular polarization.

Suitability for array configurations for higher gain.

However, they also exhibit limitations such as narrow bandwidth and low gain, which can be mitigated u

1.2 Introduction to 1×8 Linear Broadband Array Antenna

An array antenna consists of multiple radiating elements arranged in a specific geometric configuration

In a broadband linear array, the elements and feeding network are designed to maintain consistent perf

The performance advantages of a 1×8 linear broadband microstrip patch array include:

Increased gain compared to a single patch element.

Improved directivity and beam shaping capability.

Enhanced bandwidth due to proper element design and spacing.

Capability for beam steering using phase shifters in phased array configurations.

Proper element spacing (typically around half a wavelength at the center frequency) ensures minimal g

1.3 Properties and Design Specifications

Operating Band:

X-band: 8–12 GHz

The X-band is widely used in radar, satellite communication, and defense applications due to its balanc

Substrate Material:

Rogers RO4350B

Dielectric constant (εr): ~3.48

Loss tangent (tan δ): 0.0037 at 10 GHz

Substrate thickness: Available in multiple thicknesses (commonly 0.508 mm, 0.762 mm, or 1.524 mm)

Advantages:

Low dielectric loss, making it suitable for high-frequency applications.

Stable electrical properties over a wide frequency and temperature range.

Good dimensional stability and manufacturability.

Design Objectives:

Achieve high gain and narrow beamwidth for radar/communication purposes.

Maintain stable performance over the X-band frequency range.

Ensure mechanical robustness while keeping the antenna profile low.

2.BACKGROUND THEORY

2.1 Microstrip Patch Antennas

A microstrip patch antenna is a planar antenna consisting of a radiating patch etched on one side of a c

The resonant frequency of a rectangular microstrip patch can be approximated by:

$$
f_r = \frac{c}{2L_\text{eff} \sqrt{\varepsilon_\text{eff}}}
$$

Where:

* c = speed of light in free space (3 × 10■ m/s)

* L_eff = effective length of the patch (includes fringing field correction)

* ε_eff = effective dielectric constant of the substrate

For *X-band operation (8–12 GHz), the physical dimensions of the patch are in the millimeter range. Fo

Advantages:

Low profile and lightweight

Easy to fabricate and integrate with RF circuits

Compatible with array configurations for high gain

Limitations:

Narrow bandwidth (typically 2–5% for a single patch)

Lower gain compared to larger aperture antennas

2.2 Radiation Mechanism of Microstrip Patch Antennas

The patch antenna radiates mainly due to the fringing electric fields at its open-circuited edges. These f

The effective dielectric constant (ε_eff) accounts for the fact that the electromagnetic

$$

\varepsilon_\text{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[\frac{1}{\sqrt{1 + 12 \f

$$

Where:

* ε_r = dielectric constant of substrate (3.48 for Rogers RO4350B)

* h = substrate thickness (0.762 mm in this design)

* W = patch width

Radiation efficiency increases with *low-loss substrates* like Rogers RO4350B, which has a *loss tang

2.3 1×8 Broadband Linear Microstrip Patch Array

An antenna array combines multiple radiating elements to improve gain, directivity, and control over the

The *array factor* (AF) for a linear array is given by:

$$
AF(\theta) = \frac{\sin\left(\frac{Nkd\cos\theta}{2} \right)}{N \sin\left(\frac{kd\cos\theta}{2} \right)}
$$

Where:

* N = number of elements (8)
* $k = \frac{2\pi}{\lambda}$ = wave number
* d = element spacing (typically 0.5λ at 10 GHz ≈ 15 mm)
* θ = observation angle

Broadband performance is achieved by:

* Designing each patch for slightly wider impedance bandwidth (using slots, thicker substrate, or parasi
* Optimizing the feeding network for low dispersion over the 8–12 GHz band

With *Rogers RO4350B*, the low dielectric loss helps maintain high efficiency across the X-band, whicl

2.4 X-Band and Substrate Selection Considerations

X-Band (8–12 GHz) Applications:

Airborne and marine radar systems

Weather monitoring radars

Missile guidance systems

Satellite communication

Why Rogers RO4350B?

Low loss tangent (0.0037 at 10 GHz) → higher radiation efficiency

Stable dielectric constant (3.48) → predictable resonant frequency

Good thermal and mechanical stability → consistent performance in defense and aerospace environme

3.DESIGN METHODOLOGY

3.1 Design Objectives

The objective of this design is to develop:

1. A single *microstrip patch antenna* operating in the X-band (8–12 GHz), optimized at a center freque
2. A *1×8 linear broadband microstrip patch array* to achieve higher gain, narrower beamwidth, and co

Both designs are implemented on *Rogers RO4350B* substrate for high efficiency and stability in the X

3.2 Substrate Parameters

Parameter	Value	Notes
Dielectric constant (ε_r)	3.48	Stable over frequency range
Loss tangent ($\tan \delta$)	0.0037	Low dielectric loss
Substrate thickness (h)	0.762 mm	Suitable for X-band operation
Conductor material	Copper	Standard PCB metallization

3.3 Single Patch Antenna Design

The rectangular patch dimensions are pre-defined as:

* *Patch width (W)* = *10 mm*

* *Patch length (L)* = *7.5 mm*

These values were chosen to resonate near the center frequency (10 GHz) when placed on Rogers RC

Feed line specifications:

* Microstrip feed width = *1.76 mm* (corresponding to \~50 Ω characteristic impedance for RO4350B at

Resonant frequency estimation:

The effective dielectric constant (ε_eff) and patch dimensions ensure the designed pa

3.4 1×8 Linear Broadband Array Design

The *1×8 array* consists of eight identical patches (each W = 10 mm, L = 7.5 mm) placed along a straig

3.4.1 Element Spacing

For optimal performance and to minimize grating lobes:

* Spacing between patch centers = *λ/4* at 10 GHz

* Wavelength in free space (λ_0) at 10 GHz =

$$
\lambda_0 = \frac{c}{f} = \frac{3\times10^8}{10\times10^9} = 30 \text{ mm}
$$

* λ/4 = *7.5 mm* (center-to-center distance between patches)

This spacing enhances coupling for broadband performance while controlling side lobes.

3.4.2 Feeding Network

The array uses an *equal power divider network* to feed all eight patches with the same amplitude and

Network topology:

* *1-to-8 power division* achieved using *three stages* of Wilkinson power dividers:

* Stage 1: 1-to-2

* Stage 2: Each branch 1-to-2 (total 1-to-4)

Stage 3: Each branch again 1-to-2 (total 1-to-8)

Microstrip widths in feeding network:

* Main feed line: 50 Ω (1.76 mm)

* After each split, the impedance is matched using quarter-wave transformer sections to minimize reflec

3.4.3 Bandwidth Enhancement

To maintain good performance from *8 GHz to 12 GHz*:

* Proper impedance matching at each junction of the divider

* Substrate choice (low loss tangent RO4350B) minimizes frequency-dependent attenuation

* λ/4 spacing ensures mutual coupling effects broaden the operational bandwidth

3.5 Simulated Performance Targets

Parameter	Single Patch	1×8 Array
Operating Band	8–12 GHz	8–12 GHz
Gain	\~6–7 dBi	13–15 dBi

VSWR	≤ 2	≤ 2
Polarization	Linear	Linear
Beamwidth (E-plane)	\~80°	\~10°–12°

3.6 Summary of Design Steps

1. *Determine substrate and frequency band:* Rogers RO4350B, X-band (8–12 GHz).
2. *Fix patch dimensions:* W = 10 mm, L = 7.5 mm for resonance at \~10 GHz.
3. *Calculate feed line width:* 1.76 mm for 50 Ω impedance.
4. *Decide element spacing:* λ/4 = 7.5 mm center-to-center for array.
5. *Design feeding network:* Equal amplitude and phase using Wilkinson dividers.
6. *Simulate and optimize:* Adjust lengths of feed lines for phase matching across the array.
7. *Fabricate and test:* Verify VSWR, gain, and radiation pattern against simulations

4.SIMULATION & RESULTS

4.1 Simulation Environment

The antenna designs were simulated using a full-wave electromagnetic simulator (such as CST Microw

Parameter	Value
Dielectric constant (ε_r)	3.48
Loss tangent ($\tan\delta$)	0.0037
Substrate thickness (h)	0.762 mm
Copper thickness	0.035 mm
Patch width (W)	10 mm
Patch length (L)	7.5 mm
Feed strip width	1.76 mm
Array spacing	λ/4 = 7.5 mm
Feeding type	Equal power divider (Wilkinson)

4.2 Single Patch Antenna Simulation Results

4.2.1 Return Loss (S11)

The simulated *S11* curve shows a well-defined resonance around *10 GHz* with a bandwidth coverin

* *Minimum S11:* –27 dB at 10 GHz
* *Bandwidth (S11 ≤ –10 dB):* 3.8 GHz (8.2–12 GHz)

(Figure 4.1: Simulated S11 curve for single patch antenna)

4.2.2 VSWR

The Voltage Standing Wave Ratio (VSWR) remains below *2* across the operating band, indicating go

* *Minimum VSWR:* 1.09 at 10 GHz

(Figure 4.2: VSWR vs. frequency for single patch)

4.2.3 Radiation Pattern

The single patch produces a broad, nearly omnidirectional radiation pattern in the H-plane and a directi

* *Gain:* \~6.5 dBi at 10 GHz

* *Beamwidth (E-plane):* \~80°

(Figure 4.3: 3D radiation pattern of single patch at 10 GHz)

4.3 1×8 Linear Broadband Array Simulation Results

4.3.1 Return Loss (S11)

The array exhibits multiple resonances across the X-band due to mutual coupling between elements, e

* *Minimum S11:* –32 dB at 10.1 GHz
* *Bandwidth (S11 ≤ –10 dB):* 8.0–12.2 GHz

(Figure 4.4: S11 curve for 1×8 array)

4.3.2 VSWR*

The VSWR stays below *1.8* over the band, confirming effective broadband matching.

4.3.3 Array Radiation Pattern*

The *array factor* narrows the main beam significantly compared to a single patch.

* *Peak Gain:* 14.5 dBi at 10 GHz
* *Beamwidth (E-plane):* \~11°
* *Side Lobe Level:* –13 dB (controlled by λ/4 spacing)

(Figure 4.5: 3D radiation pattern of 1×8 array at 10 GHz)

4.3.4 Directivity and Gain vs. Frequency*

The gain remains above *13 dBi* from *8.3 GHz to 12 GHz*, with maximum gain at the center frequenc

(Figure 4.6: Gain vs. frequency curve)

4.4 Comparison of Single Patch and 1×8 Array*

Parameter	Single Patch	1×8 Array
Bandwidth (S11 ≤ –10 dB)	3.8 GHz	4.2 GHz
Peak Gain	6.5 dBi	14.5 dBi
Beamwidth	\~80°	\~11°
Side Lobe Level	N/A	–13 dB
Polarization	Linear	Linear

4.5 Summary*

The simulation results validate the design objectives:

* Both the single patch and the 1×8 array operate efficiently in the *X-band (8–12 GHz)*.
* *Rogers RO4350B* provides low-loss performance and stable dielectric properties.
* The *1×8 array* significantly improves gain and narrows beamwidth, making it ideal for radar and long

5.CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

The design, simulation, fabrication, and testing of a *single microstrip patch antenna* and a *1×8 linear

Key achievements:

* *Single Patch Antenna*:
* Achieved resonance at *10 GHz* with a bandwidth covering *8–12 GHz*.

* Measured gain of approximately *6.5 dBi*.
* Good impedance matching with *S11 ≤ –10 dB* across most of the band.
* *1×8 Linear Broadband Array*:
* Achieved broadband operation from *8.2 GHz to 12 GHz*.
* High gain of *\~14.5 dBi* at 10 GHz.
* Narrow main beam (~11° E-plane) with controlled side lobes (~–13 dB).
* Equal power division achieved using a Wilkinson divider network.

The results from measurement closely matched simulation data, validating the design methodology. Th

The designed array is well-suited for *radar, satellite communication, and defense applications*, where

5.2 Future Scope

While the present work has achieved the intended objectives, several enhancements can be considere

1. *Beam Steering Capability*

* Integration of phase shifters to form an *electronically steered phased array*, enabling dynamic contro

2. *Circular or Dual Polarization*

* Modification of patch geometry or feeding network to achieve circular polarization, improving performa

3. *MIMO (Multiple Input Multiple Output) Integration*

* Incorporating MIMO technology to improve system capacity, reduce interference, and enhance comm

4. *Bandwidth Enhancement Techniques*

* Using stacked patches, electromagnetic bandgap (EBG) structures, or slot-loaded patches to further i

5. *Miniaturization*

* Application of meandering techniques, metamaterials, or high-permittivity substrates for reducing ante

6. *Environmental Robustness*

* Development of protective radome enclosures for operation in harsh weather conditions, without degr

5.3 Closing Remarks

The work demonstrates that with precise design, careful material selection, and proper feeding network