Design and analysis of radomes

for Microstrip Patch Antenna at 6 GHz

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INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

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Abstract

This report presents a comprehensive study on microstrip patch antennas as well as Radomes focusing on their fundamental principles, key design parameters, computer-aided design (CAD) modeling, and electromagnetic performance analysis.
The antenna was designed to operate at 6 GHz, with calculations performed to determine the optimal patch width and length using empirical formulas. The physical geometry was modeled using Autodesk Fusion 360, where a precise 3D representation of the antenna structure—including the patch, ground plane, and substrate—was created for export into simulation tools.
The electromagnetic behavior of the antenna with and without radome was then simulated using ANSYS HFSS, a high-frequency solver that provides accurate insights into return loss (S11), gain, and radiation pattern. The simulation validated the design, showing a strong resonance at 6 GHz with efficient radiation characteristics. This multidisciplinary approach demonstrates the full pipeline of patch antenna development—from analytical design and CAD modeling to high-fidelity simulation—highlighting its viability in high-frequency wireless applications

Acknowledgements

I would like to express my sincere gratitude to the organizers of the Kritikka Summer Program 6.0 for providing this enriching opportunity to explore the frontiers of astronomy and astrophysics. The program has been instrumental in broadening my understanding of research methodologies and contemporary developments in the field.

I extend my heartfelt thanks to my Mentor Mr. Arjun Ghosh for his valuable insights, guidance, and constant encouragement throughout the program. I am especially thankful to the coordinators for their dedicated efforts in making the sessions engaging and intellectually stimulating.

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1. Introduction

Antennas are essential components in radio frequency systems, functioning as transducers that convert electrical signals into electromagnetic waves and vice versa. In radio astronomy, where the detection of extremely weak and distant cosmic signals is required, the application of rigorous antenna theory is critical to system performance. Antenna behavior is governed by Maxwell's equations, with radiation characteristics derived using vector potentials and field integrals.

Core parameters such as radiation pattern, gain, directivity, impedance, beam - width, bandwidth, and polarization are central to evaluating an antenna's suitability for high-sensitivity applications as explained by Balanis (2005). Efficient reception of astrophysical signals necessitates maximizing effective aperture, minimizing return losses, and carefully analyzing the impact of mutual coupling in array configurations. Furthermore, design considerations must account for the frequency-dependent nature of cosmic sources, demanding wideband or frequency-tunable antenna structures. Thus, antenna theory provides a robust theoretical and computational foundation for developing and optimizing antennas in advanced radio astronomical instrumentation.
In this report our focus is on design and analysis of a 6GHz Rectangular Microstrip Patch Antenna and a flat radome.

1.1 Microstrip Patch Antenna

Microstrip antennas became very popular in the 1970s primarily for spaceborne applications. Today they are used for government and commercial applications. These antennas consist of a metallic patch on a grounded substrate. The metallic patch can take many different configurations, However, the rectangular and circular patches, are the most popular because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. The microstrip antennas are low profile, comformable to planar and non-planar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and very versatile in terms of resonant frequency, polarization, pattern, and impedance. These antennas can be mounted on the surface of high-performance aircraft, spacecraft, satellites, missiles, cars, and even mobile devices.

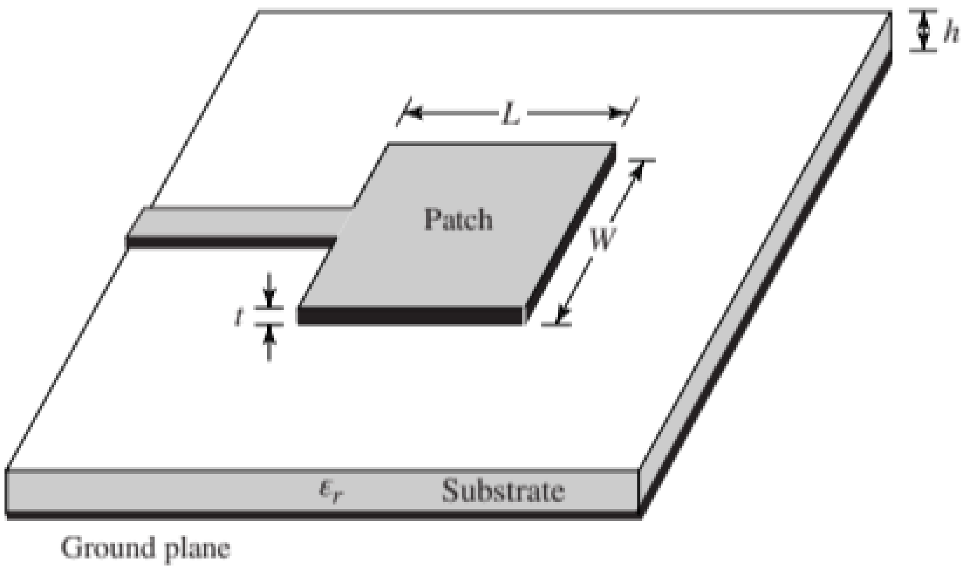

Figure 1.1: *Microstrip Patch Antenna (rectangular)*
Source: Antenna Theory by Constantine A Balanis

1.2 Rectangular Patch Antenna

Rectangular Patch Antennamajorly comprises of a patch, substrate and ground plane. The function of each part are as follows:

1. Patch Antenna: It is typically made of a conductive material, such as copper or gold. the patch aids in transmission
2. Substrate: The substrate is typically made of low-loss materials with a high dielectric constant. It is responsible for providing mechanical support and act as a medium of Electromagnetic wave propogation
3. Transmission Line: Responsible for delivering radio frequency (RF) energy to the radiating patch
4. Ground Plane: The ground plane is a conductive surface (usually a metal plate) that provides a stable reference point for the antenna's signal and also prevents the formation of backlobes

1.3 Design Parameters For Antenna

1.3.1 Initial Parameters

These are the parameters that are defined before starting the calculations. They are based on the desired application, operating frequency, and available materials

The Initial Parameter for this antenna are:

Operating frequency (f_0) : 6 GHz
Substrate Material: FR 4
Substrate Dielectric Constant (ϵ_r) : 4.4
Substrate Height: 1.6 mm

1.3.2 Calculated Parameters

Width(W) of the Patch:

$$W = \frac{c}{2f_0\sqrt{\frac{\epsilon_r+1}{2}}}$$

$$\implies W = \frac{299792458}{2 \times 6 \times 10^9\sqrt{\frac{4.4+1}{2}}} = 15.215\ mm$$

Effective dielectric Constant

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + 12(\frac{h}{W})}}\right]$$

$$\implies \epsilon_{eff} = 3.830$$

Length of the Patch:

$$L = \frac{c}{2f_0\sqrt{\epsilon_{eff}}} - 0.824\left(\frac{(\epsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\epsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)}\right)$$

$$\implies L = 11.329\ mm$$

Input impedance:

$$Z_{in} = 90\left(\frac{\epsilon_r^2}{\epsilon_r - 1}\right)\left(\frac{L}{W}\right)^2 \quad Z_{in} = 284.130\ \Omega$$

Transmission Line Width(W_0):

$$W_0 = 2.377\ mm$$

Inset spacing

$$S = \frac{1}{2}W_0 = 1.685\ mm$$

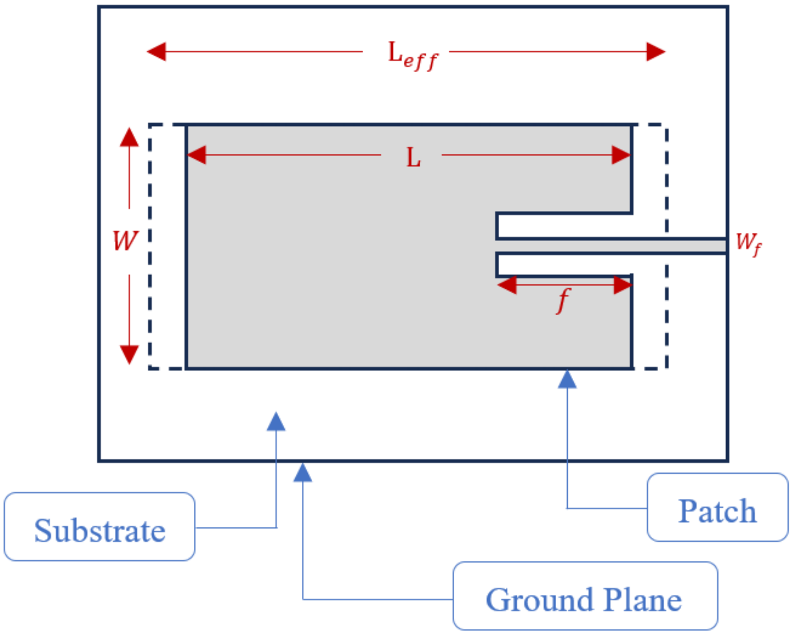

Figure 1.2: Parameters of Patch Antenna
Source: ee.iitb.ac.in

Table 1.1: Calculated parameters for Patch Antenna at 6 GHz for FR4 Substrate of height 1.6mm

Parameter	Value
Width of Patch, W (mm)	15.215
Length of Patch, L (mm)	11.329
Approximate Feed Location from edge, f (mm)	3.614
Width of Feed Line, W_f (mm)	2.377
Effective Permittivity, ε_e	3.830
Fringing Length, ΔL (mm)	0.723
Effective Length, L_{eff} (mm)	12.774
Edge Impedance (Ω)	284.130

1.4 Radome

A radome (radar dome) is an electromagnetically transparent protective shield that encloses mmWave Radar sensors and the antenna. It protects the mmWave antenna and electronics from external environment effects such as rain, sunlight, wind providing structural weatherproof enclosure. The radome minimally attenuates the electromagnetic signal transmitted or received by the antenna and as such should effectively be transparent to radio waves (Kumar, Mohammed, Peake, 2021).
In some cases, a radome could be constructed as a lens that alters the beam characteristics intentionally. Such a radome or lens needs to be designed using electro-magnetic simulation tools in conjunction with the antenna and desired field of view in consideration.
Based on the needs of specific end equipment, radomes can be constructed in several shapes such as planar, spherical, and geodesic where the shape will have some influence on the radiation pattern or field of view and maximum achievable distance by radar sensor. The radome material choice, such as fiberglass, PTFE-coated fabric, and polycarbonate, is generally dependent on the targeted application environmental use.

1.4.1 Importance of Radome and Its Theory

Why are Radomes Required?

In advanced antenna systems—particularly in applications such as radio astronomy, deep-space communications, and high-sensitivity signal detection—the use of radomes is essential to ensure mechanical protection, environmental isolation, and electromagnetic transparency. A radome (radar + dome) is a structural enclosure that surrounds an antenna without significantly affecting its electromagnetic performance. Its purpose is to protect the antenna from environmental factors such as wind, rain, dust, and thermal gradients, while maintaining RF transparency within the operational frequency band.

In cryogenically-cooled antenna systems, such as those used in low-noise radio astronomical receivers, radomes become even more critical. These systems employ cryocoolers to reduce thermal noise in the low-noise amplifiers (LNAs) or receiver front-ends, often operating at temperatures as low as 4 K. However, the use of cryocoolers introduces a strong need for thermal insulation and environmental isolation, as even minor temperature fluctuations can degrade system performance. A radome serves as a thermal and mechanical barrier that helps maintain the internal stability of the system while still allowing the antenna to function electromagnetically. (M. A. McCulloch, et al. 2016)

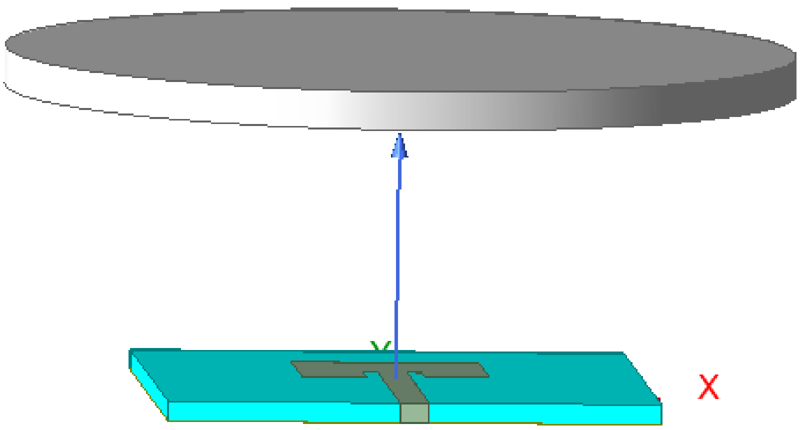

Figure 1.3: Isometric View of Radome and Antenna

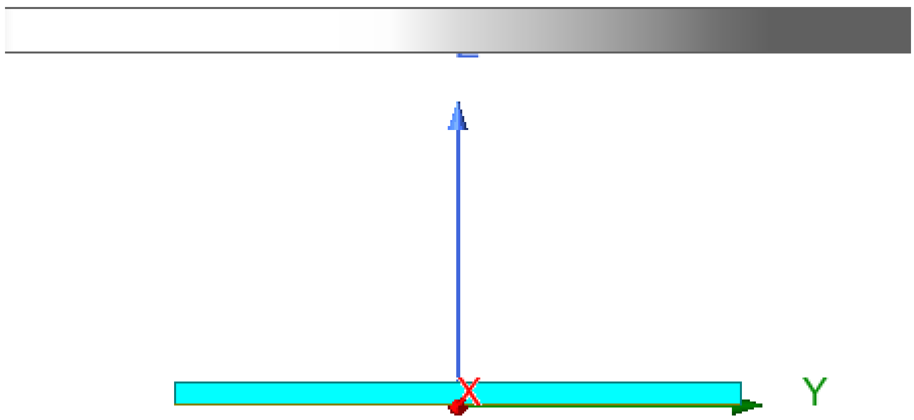

Figure 1.4: Side View of Radome and Antenna

Moreover, a radome enables physical integration of the cryogenic hardware without direct exposure to the external environment. In many systems, the cryostat and waveguide components may be co-located with the antenna, and the radome allows for a sealed volume where vacuum insulation and thermal shielding are feasible. In such configurations, it is essential to minimize reflections and dielectric losses introduced by the radome material—making material selection (e.g., PTFE, low-loss composites, or foam dielectrics) a critical design consideration.

Reflections due to Radome Wall

The dielectric constant (ϵ_r) and loss tangent (tan δ) are parameters Which influence how electromagnetic waves interact with materials, affecting signal transmission, reflection, and absorption. The dielectric constant impacts the speed of wave propagation, while the loss tangent quantifies how much electromagnetic energy is dissipated as heat.

Impedance mismatch at radome boundaries, caused by transitions between materials with different dielectric constants, results in partial reflection and transmission of electromagnetic waves. This phenomenon is described using reflection (Γ) and transmission (τ) coefficients, with equations derived from the electric field interactions at the material interfaces. Such mismatches lead to multiple internal reflections, impacting signal quality.

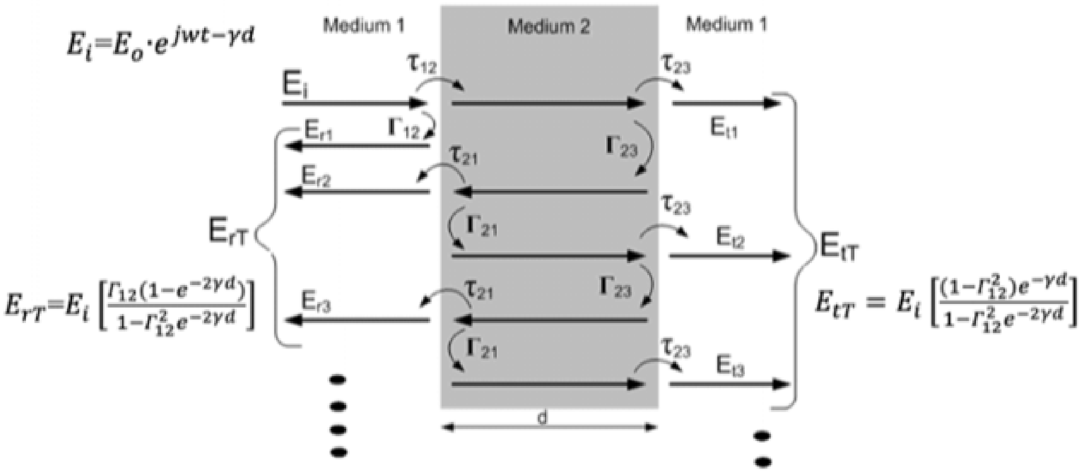

Figure 1.5: Multiple Reflections at Boundaries of Dielectric Mediums
Source: Texas Instruments mmWave Radar Radome Design Guide

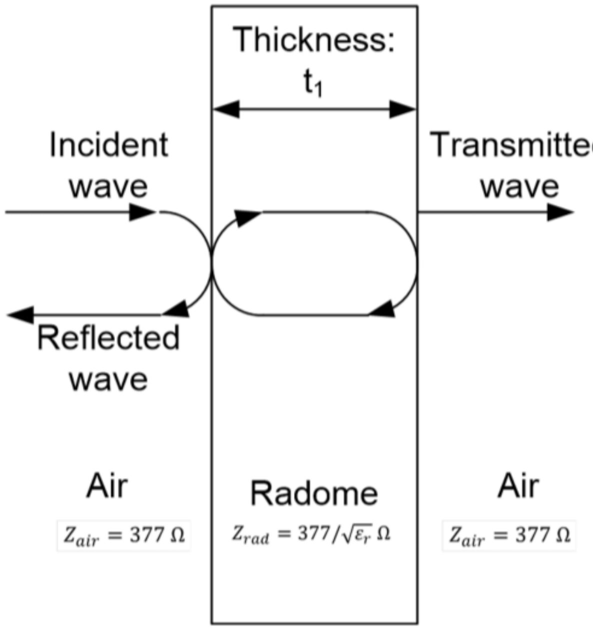

Figure 1.6: *Reflections at Radome Boundaries (assumption is that radome has a solid single wall)*
Source: Texas Instruments mmWave Radar Radome Design Guide

1.5 Flat Radome

Flat radomes are a specific class of antenna enclosures designed to provide a planar, protective interface between the antenna aperture and the external environment. Unlike curved or geodesic radomes, flat radomes offer structural simplicity and are often favored in compact or embedded antenna configurations, including planar phased arrays, low-profile radio astronomy feeds, or cryogenically cooled systems requiring thermal and environmental sealing without introducing complex geometries (Kumar, Mohammed, Peake, 2021).

From an electromagnetic perspective, flat radomes must meet stringent criteria: they must be RF-transparent, non-reflective, and minimally lossy across the antenna's operating frequency band. The presence of a flat dielectric slab in front of an antenna introduces potential challenges such as impedance mismatch, multiple internal reflections, and frequency-dependent transmission losses. These effects can cause beam distortion, gain reduction, and standing wave formation, especially in high-frequency or wideband systems. Therefore, the thickness and dielectric constant of the radome material are carefully chosen—often as a fraction of the wavelength—to act as a matching layer or, in some cases, a quarter-wave transformer to mitigate reflections.

1.5.1 Radome Parameters

Radome Wall Thickness

The wall thickness of the radome plays a key role in arriving at the optimum performance. Therefore it is essential to ensure that the radome wall thickness is an integral multiple of $frac\lambda_m 2//$ The thickness of radome can be calculated using the following equation:

$$t_{optimum=n\frac{\lambda_m}{2}}$$

$$\lambda_m = \frac{c}{f \times \sqrt{\epsilon_r}}$$

Where,

- $t_{optimum}$ = Optimum thickness of radome wall or target thickness to make the radome transparent
- n: 1,2,3...
- λ_m : Wavelength of the material
- c: speed of light
- f: mean carrier frequency used (for example, 62 GHz for a typical 60-64 GHz bandwidth)
- ϵ_r : relative permittivity

Optimal Distance Between Antenna and Radome

The optimal distance between the antenna and the internal surface of the radome helps to minimize the effects of reflections caused by the radome. These effects become minimal if the waves returned to the antenna are in phase with the transmitted waves

The equation for calculating the Optimal Distance is:

$$D = n\frac{\lambda}{2}$$

- n: 1,2,3...
- λ : Wavelength in air

1.5.2 Parameter Calculation

Thickness of The Radome

Using the Formula stated above we find the thickness of the radome to be

$$t_{optimum} = \frac{c}{f \times \sqrt{\epsilon_r} \times 2}$$

$$\implies t_{optimum} = \frac{299792458}{2 \times 6 \times 10^9 \times \sqrt{2.8}}$$

$$t_{optimum} = 14.94\ mm$$

Calculation of Optimal Distance

Using the formula:

$$D = \frac{\lambda}{2}$$

$$D = \frac{50}{2} = 25\ mm$$

1.5.3 Errors Induced by Radomes

Electrical distance traveled through the radome in boresight is equivalent to the thickness of the radome wall. However, this distance increases as angle of arrival increases and results in a higher angle estimation error.

The theory behind this phenomenon is such that if the radome wall thickness is designed to be $\lambda/2$ (half wavelength), then the round trip of the radar signal passing through the inner wall surface, then reflected back from the outer wall surface introduces a net 180° phase shift (180° -180° + 180°) emitted from the inner wall. Therefore, at boresight of the rectangular radome, the reflections at the inner wall will cancel since they are out of phase, resulting in low net reflections. However, when moving away from the boresight to higher grazing angles of arrival, the distance traveled by the mmWave signal is greater than "optimal thickness" or "half-wavelength".

This causes multiple reflections at the radome interface boundary resulting in ripples in the antenna radiation patterns and leading to nulls. These ripples and nulls can cause inconsistency in the detection of the objects at higher grazing angles resulting in angle estimation errors. This effect can be counteracted by tapering the radome wall towards the extents of the radar FoV, however, this will also compromise the strength of the radome.

2. Antenna: CAD & Analysis

2.1 CAD Modelling

The microstrip patch antenna was modeled using Autodesk Fusion 360, following a layered construction approach comprising the ground plane, dielectric substrate, radiating patch, and inset feed. The following steps outline the detailed CAD modeling procedure:

2.1.1 Making the Ground Plane

Step 1: Initiate a sketch and draw a 2-point rectangle measuring 40 mm × 40 mm on the XY-plane.

Step 2: Extrude the rectangle to a thickness of 0.0035 mm to represent the copper ground layer.

2.1.2 Making the Substrate

Step 1: On top of the ground plane, create a new sketch of the same 40 mm × 40 mm rectangle.

Step 2: Extrude the sketch to a height of 1.6 mm, corresponding to the dielectric substrate thickness (e.g., FR-4).

2.1.3 Making the Patch

Step 1: Create a new sketch on the top surface of the substrate. Draw a rectangle measuring 15.125 mm (width) × 11.329 mm (length) to represent the pat

Step 2: Extrude this sketch by 0.0035 mm, modeling the metallic patch layer.

2.1.4 Making the Inset and Transmission Line

Step 1: Sketch a rectangular cut-in (inset) on one of the shorter sides of the patch. The width of this inset is set to twice the transmission line width to accommodate the feed structure(H. Werfelli, et al., 2016).

Step 2: Extrude-cut this inset into the patch to a depth optimized for impedance matching.

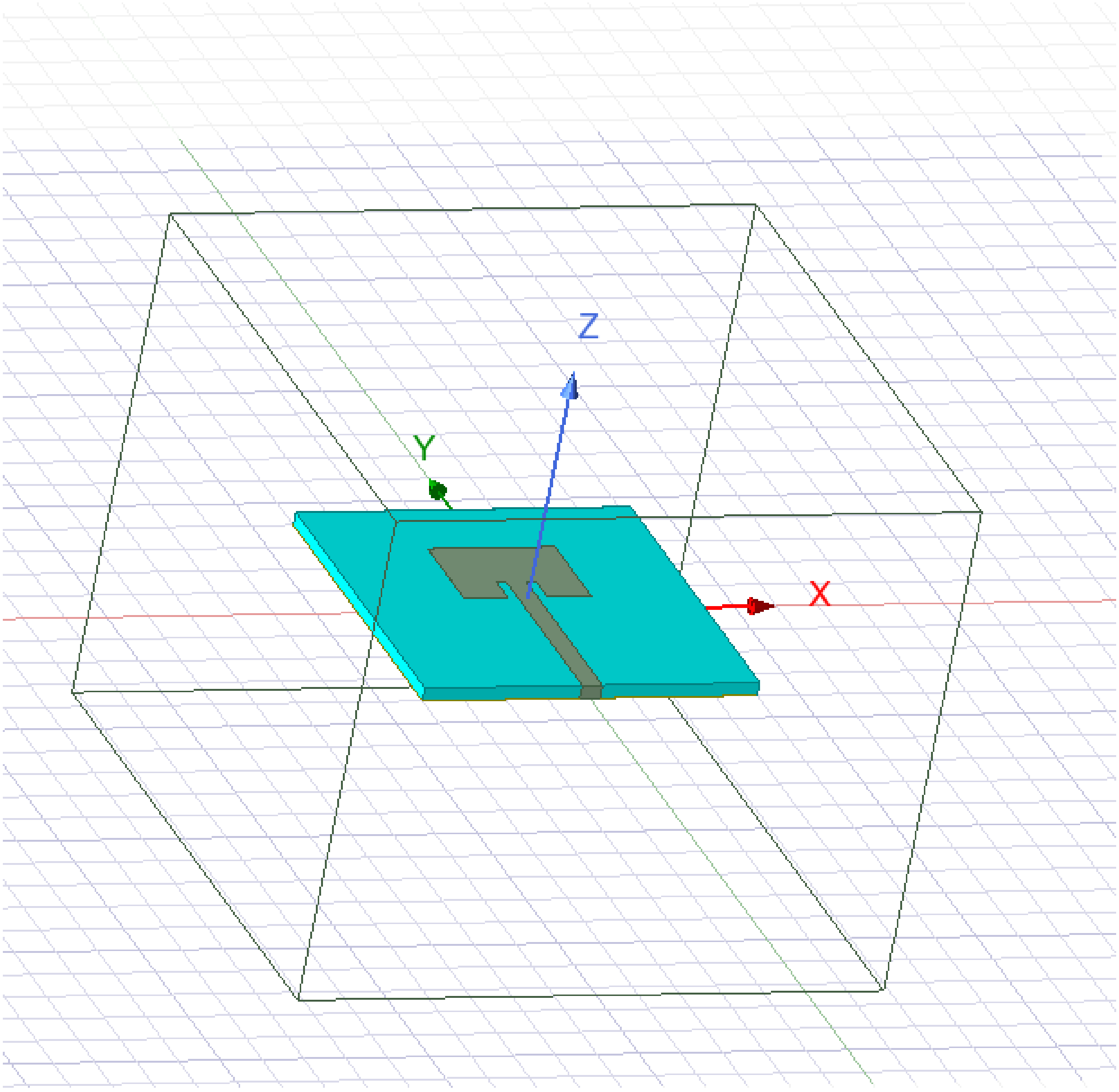

Figure 2.1: 3D Isometric View of Patch

Step 3: Draw the feed line with a width of 3.6 mm, aligned with the center of the inset, and extrude it to the same thickness (0.0035 mm) as the patch to complete the feed connection.

2.2 Simulation

To validate the antenna design and optimize its performance, a detailed electromagnetic simulation was conducted using ANSYS HFSS. The primary objective was to analyze the antenna's behavior at 6 GHz and perform a parametric sweep to determine the optimal inset depth for achieving the best impedance matching ($|S_{11}| \leq \breve{}10dB$).

A 3D model of the antenna, designed in Fusion 360, was imported into HFSS. The model included the ground plane, dielectric substrate, rectangular patch, and inset feed line Wave port excitation was applied at the end of the transmission line, and appropriate radiation boundaries were defined around the structure to ensure accurate field propagation. The solution frequency was set at 6 GHz.
To optimize the feed position, a parametric sweep was performed by varying the inset depth

2.2.1 Setting up the Simulator

Material Assignment

Step 1: Assign Copper as the material for both the patch and the ground plane, considering its high conductivity.

Step 2: Set the substrate material to FR4 Epoxy, with a relative permittivity (ϵ_r) of 4.4 and a loss tangent of 0.02.

Excitation Setup

Step 3: Create a rectangular interface connecting the feed line, substrate, and ground plane to serve as the excitation point.

Step 4: Assign a Lumped Port to this interface and set the impedance to 50Ω, representing a standard matched feed.

Boundary Conditions

Step 5: Construct a radiation box around the antenna, ensuring that all faces are placed approximately $\lambda/4$ (quarter-wavelength at 6 GHz) away from the nearest antenna surface.

Step 6: Assign:

- The patch and ground plane as Perfect Electric Conductor (PEC) boundaries.
- The outer surface of the radiation box as a Radiation boundary to allow wave propagation into free space.

Solution Setup

Step 7: Define the solution frequency as 6 GHz with a maximum of 20 adaptive passes for convergence

Step 8: Add a frequency sweep Set θ(theta) from 0° to 360° with a step size of 2°.from 1 GHz to 9 GHz, with a total of 401 frequency points, ensuring fine resolution in the return loss plot.

Parametric Sweep

Step 9: Implement a parametric sweep over the Inset Depth, varying it linearly from 2 mm to 4 mm in steps of 0.4 mm.
This sweep is performed to determine the optimum inset depth for achieving the best impedance matching (minimized |S11|).

Far-Field Setup

Step 10: Configure a Far-Field Infinite Sphere to compute the radiation pattern.

- Set ϕ (phi) from 0° to 90° with a step size of 90°.
- Set θ (theta) from 0° to 360° with a step size of 2°.

2.2.2 Obtaining Results

The plots for the parametric sweep (S_{11} parameter), Gain Plot, 3D ploar plot of E and H field along with a 2D polar plot

2.3 Result and Analaysis

The simulation of the microstrip patch antenna was carried out in ANSYS HFSS to evaluate its electromagnetic performance and identify the optimal inset depth through a parametric sweep. This section presents and analyzes the key outcomes obtained from the simulation, including S-parameters (S11), gain plots, electric and magnetic field distributions, and radiation patterns. The parametric sweep over the inset depth, ranging from 2 mm to 4 mm, was used to observe the impact of feed position on input impedance and reflection characteristics. The value of inset depth that resulted in a minimum return loss ($|S_{11}| \leq \neg 10dB$) at 6 GHz was selected as the optimal configuration.

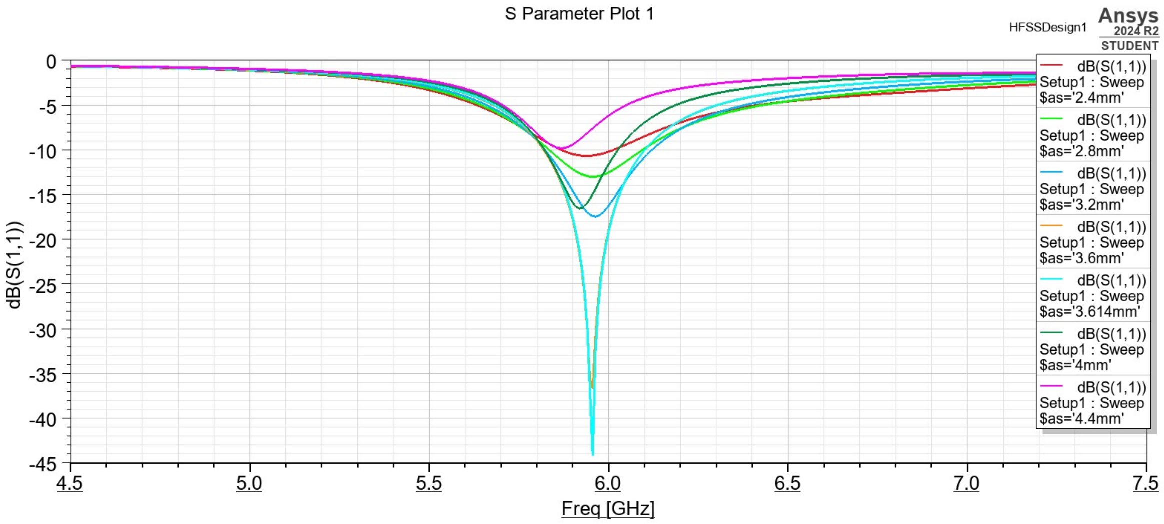

Figure 2.2: Parametric Sweep S_{11} plot for inset depth

From the following plot result we can conclude that the best results was obtained when the inset depth is 3.6 mm as per our calculations. The graph for inset depth 3.614 mm shows resonance around 6 GHz

2.3.1 S_{11} Plot of the antenna

The S11 plot shown below represents the reflection coefficient of the patch antenna across a frequency range of 1 GHz to 9 GHz. The S11 parameter indicates how much power is reflected back from the antenna input Key Observations:

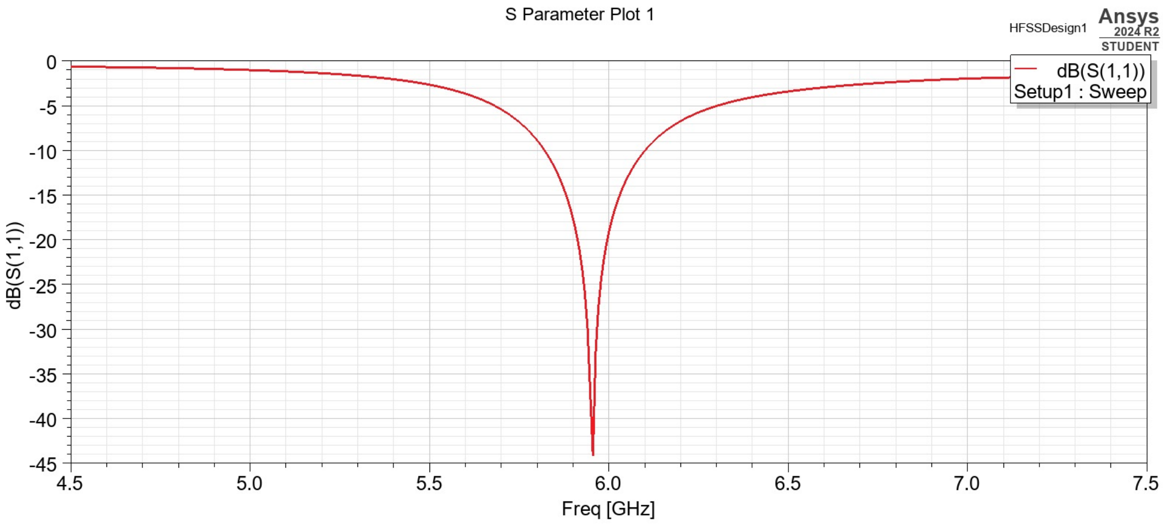

***Figure 2.3:** S_{11} Parameter Plot of Antenna*

- Resonant Frequency:
  The deepest point in the curve occurs at approximately 6.02 GHz, where the S11 value reaches close to –29 dB. This indicates excellent impedance matching at this frequency, confirming that the antenna resonates near the design target of 6 GHz.
- Resonant Frequency:
  The deepest point in the curve occurs at approximately 6.02 GHz, where the S11 value reaches close to –29 dB. This indicates impedance matching at this frequency, confirming that the antenna resonates near the design target of 6 GHz.
- Return Loss at Resonance:
  A return loss of –29 dB means that less than 0.1 % of the input power is reflected back, and over 99.9% is accepted by the antenna and radiated.
- Bandwidth:
  The –10 dB bandwidth (range of frequencies over which S11 remains below –10 dB) appears to span from approximately 5.8 GHz to 6.25 GHz

2.3.2 Polar Gain Plots

These polar plot illustrates the total gain distribution at phi = 0° (red curve) and phi = 90° (green curve), providing insight into the antenna's directional radiation in two orthogonal planes.

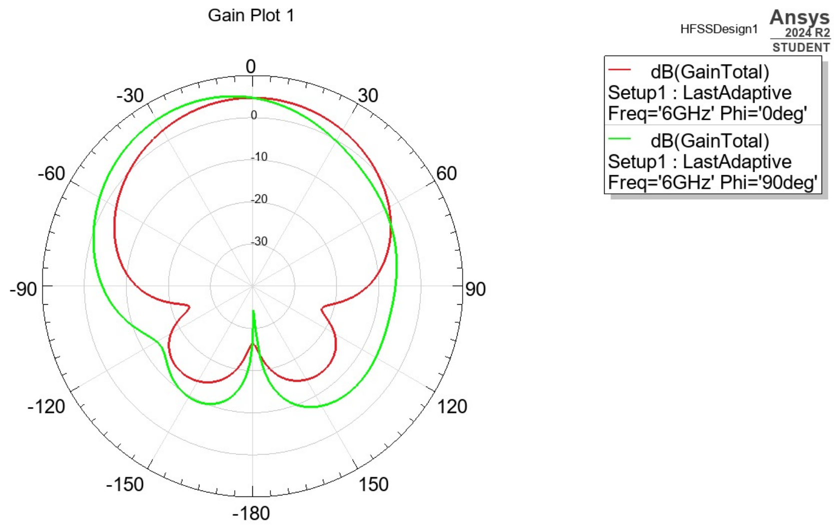

Figure 2.4: 2D Gain Polar Plot

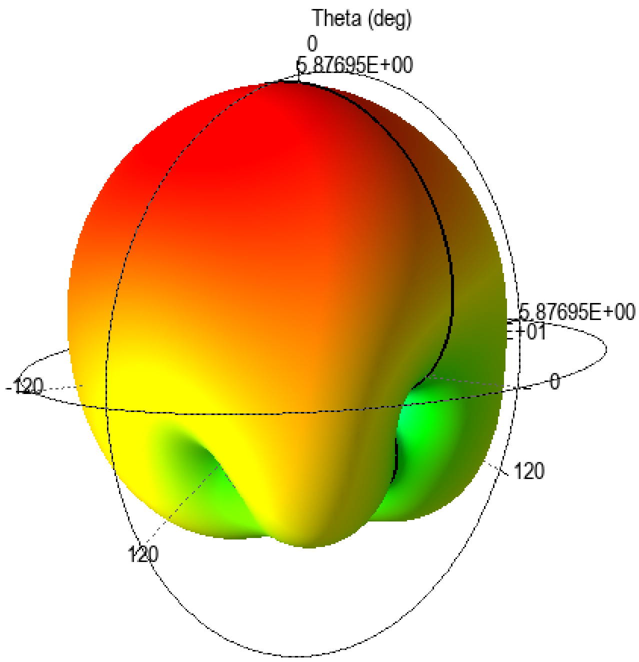

Figure 2.5: 3D Gain (Total) Polar Plot

Observations:

- The maximum gain occurs along the broadside direction (0°) with a peak value of approximately +3 dB, indicating effective forward radiation.
- The radiation pattern is directional with minimal back radiation, characteristic of a patch antenna.
- The patterns are mostly smooth and exhibit a typical butterfly-shaped lobe for patch antennas, confirming expected field behavior

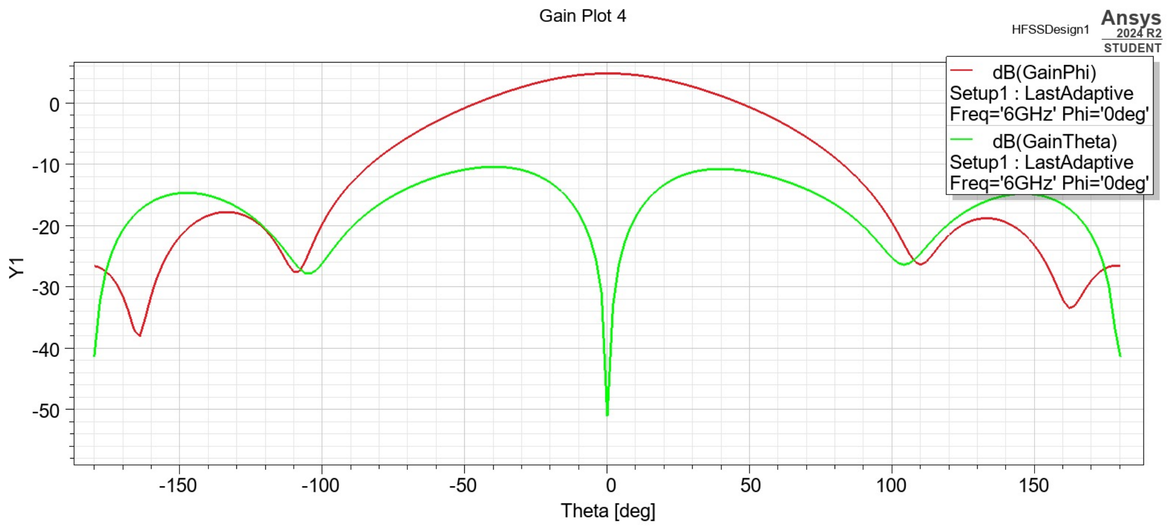

Figure 2.6: Gain Theta, Gain Phi E Plane Plot

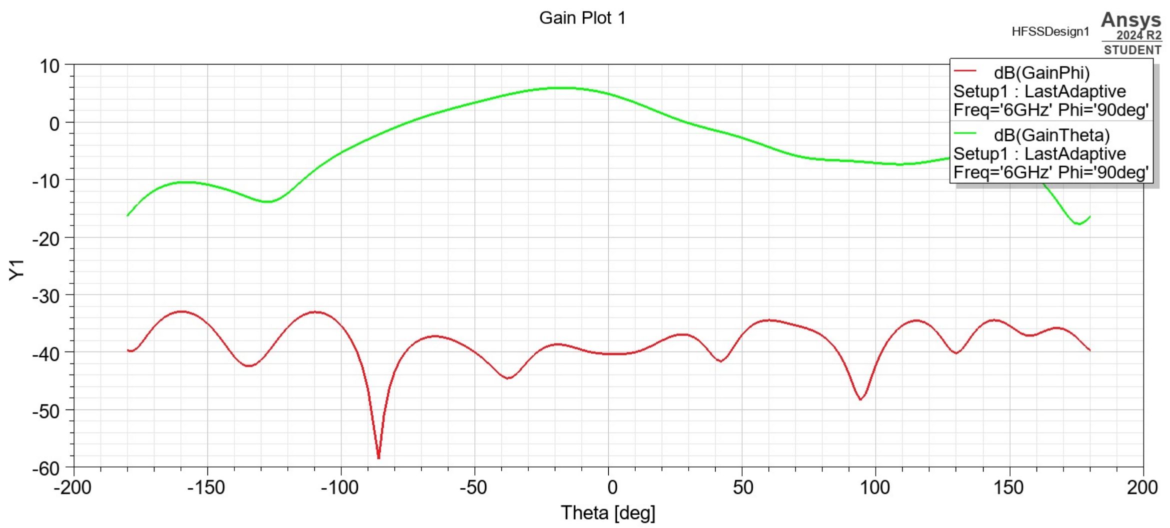

Figure 2.7: Gain Theta, Gain Phi H Plane Plot

- **Plane of Cut:** $\phi = 0^\circ$ — This is the *E-plane* (typically the electric field plane for linearly polarized antennas).

- **Frequency:** 6 GHz
- **Observation:**
  - The red curve represents **Gain(ϕ)**.
  - The green curve represents **Gain(θ)**.
  - The gain is plotted versus θ from -180° to 180°.
- **Behavior:**
  - Gain(θ) shows a dip near $\theta = 0^\circ$, possibly indicating a null in that direction.
  - Gain(ϕ) shows a maximum at $\theta = 0^\circ$, typical in directional antennas.
  - Multiple side lobes and nulls are visible in both curves, implying a complex radiation pattern.
  - Gain(ϕ) reaches nearly 7 dB, while Gain(θ) drops below -50 dB, indicating strong directivity along the ϕ direction.
- **Conclusion:** The antenna radiates more strongly along the ϕ direction in the E-plane. The θ component is suppressed, suggesting linear polarization with the electric field in the ϕ direction.

Figure 2.7: Gain Theta, Gain Phi H Plane Plot

- **Plane of Cut:** $\phi = 90^\circ$ — This is the *H-plane* (typically the magnetic field plane).
- **Frequency:** 6 GHz
- **Observation:**
  - Again, red = Gain(ϕ), green = Gain(θ).
  - Gain(θ) dominates the pattern here.
  - Maximum gain is around $\theta = 0^\circ$, approximately 3.8 dB.
  - The pattern is highly directive in the H-plane with symmetric fall-off beyond $\pm 60^\circ$.
  - Very low gain values (< 1 dB) beyond $\pm 60^\circ$, indicating a strong main lobe and weak side lobes.
- **Conclusion:** The antenna has a directive pattern in the H-plane, likely favoring broadside radiation. Gain(ϕ) is negligible in this plane, reinforcing linear polarization with the E-field along ϕ.

Overall Interpretation

- The antenna is linearly polarized, with the electric field aligned with the ϕ direction.
- It exhibits a directional radiation pattern, suitable for applications such as point-to-point communication or radar.
- Maximum gain is observed in the E-plane (around 7 dB), while the H-plane has a narrower beam with slightly lower gain (3.8 dB).

3. Radome: CAD & Analysis

3.1 Radome Design

In order to make the Radome we make a cylinder of $t_{optimuum}$ calculated and place it on top of Antenna at the calculated height
We assign the material of the Radome to be Acrylic and then simulate it to see changes in gain patterns
The material properties of Arcrylic are as follows: **Material Name:** PMMA

Properties of the Material

Name	Type	Value	Units
Relative Permittivity	Simple	2.8	—
Relative Permeability	Simple	1	—
Bulk Conductivity	Simple	1×10^{-16}	S/m
Dielectric Loss Tangent	Simple	0.001	—
Magnetic Loss Tangent	Simple	0	—
Magnetic Saturation	Simple	0	T
Lande G Factor	Simple	2	—
Delta H	Simple	0	A/m
Measured Frequency	Simple	6×10^{9}	Hz
Mass Density	Simple	1180	kg/m^3

Table 3.1: *Electrical, magnetic, and physical properties of PMMA (Polymethyl methacrylate).*
Source: Altuglas International / Arkema

3.2 Parametric sweep of Radome to Antenna distance

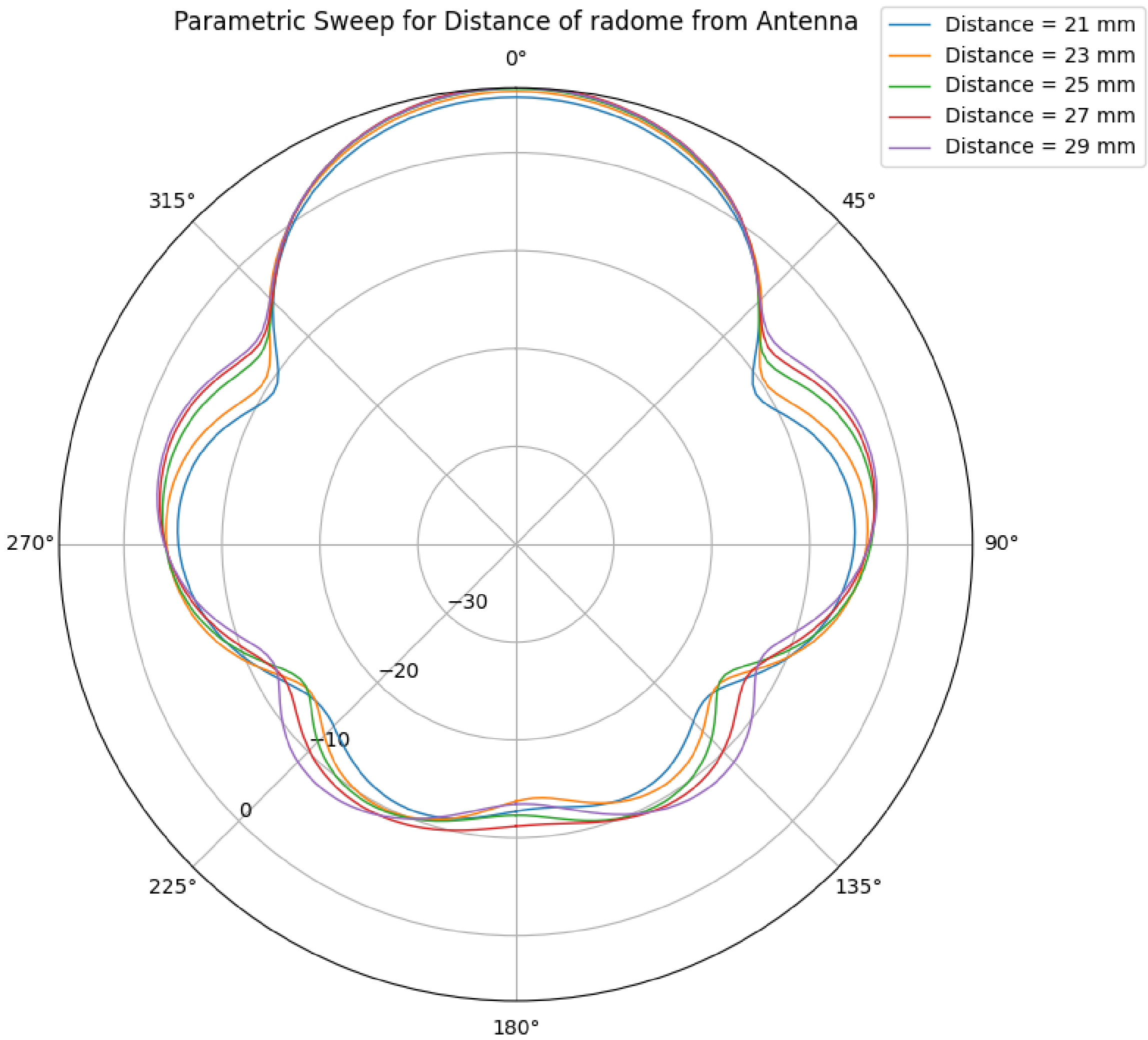

Figure 3.1: Parametric Sweep of Gain Plots for Distance between Radome and Antenna

The result of the parametric sweep suggest that Plot 6 or 25 mm is the optimal distance for antenna and radome which is also the result we obtained from theoretical calculation

3.3 Effect of Radome on Gain Plot

After placing the radome on top of the antenna at a distance of 25 mm from the antenna we plot the E and H plane with and without Radome for 3, 6 and 9 GHz

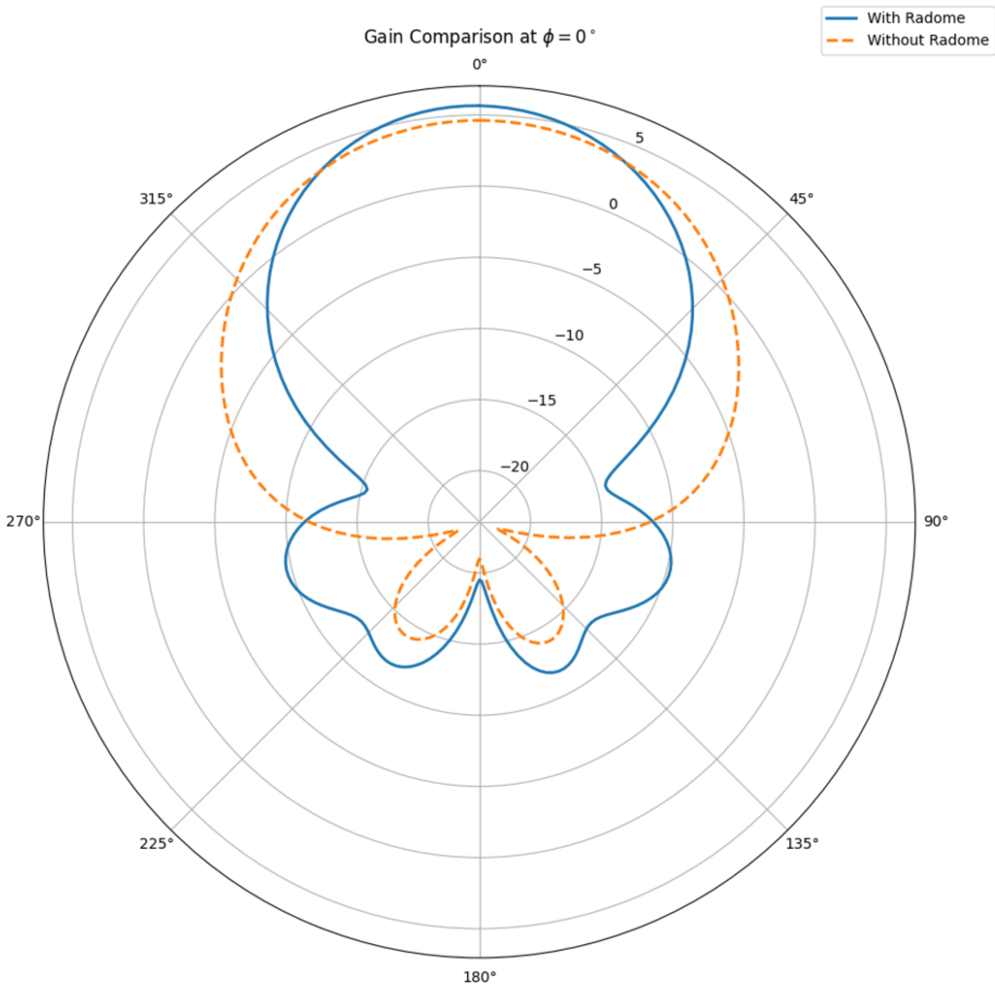

Figure 3.2: *Gain Total With and Without Radome (E Plane) at 6 GHz*

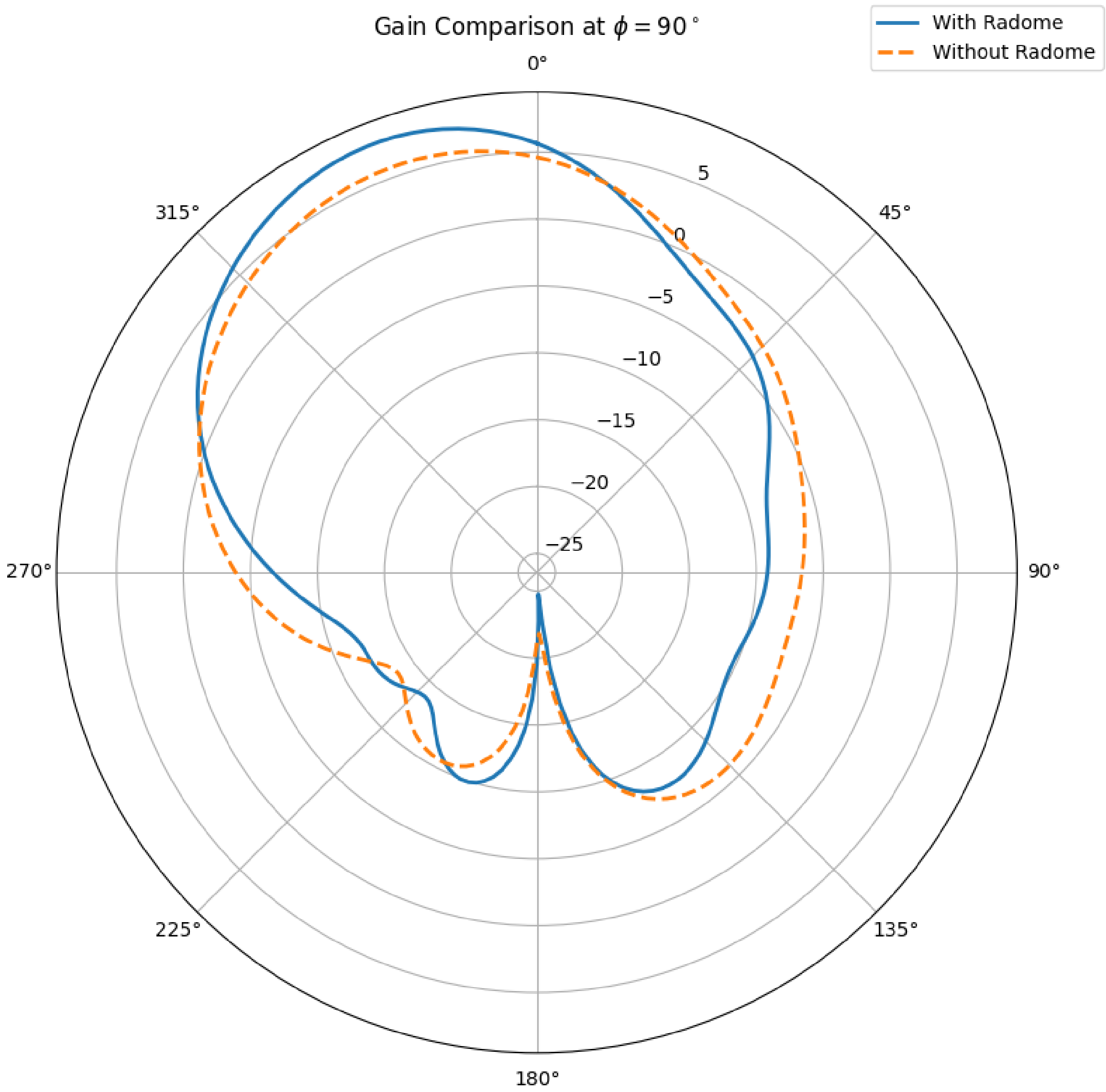

Figure 3.3: Gain Total With and Without Radome (H Plane) at 6 GHz

From these plots we see a similar gain but a significant increase in the back-lobe. This is due to the constructive interference caused by the dielectric medium of the Radome

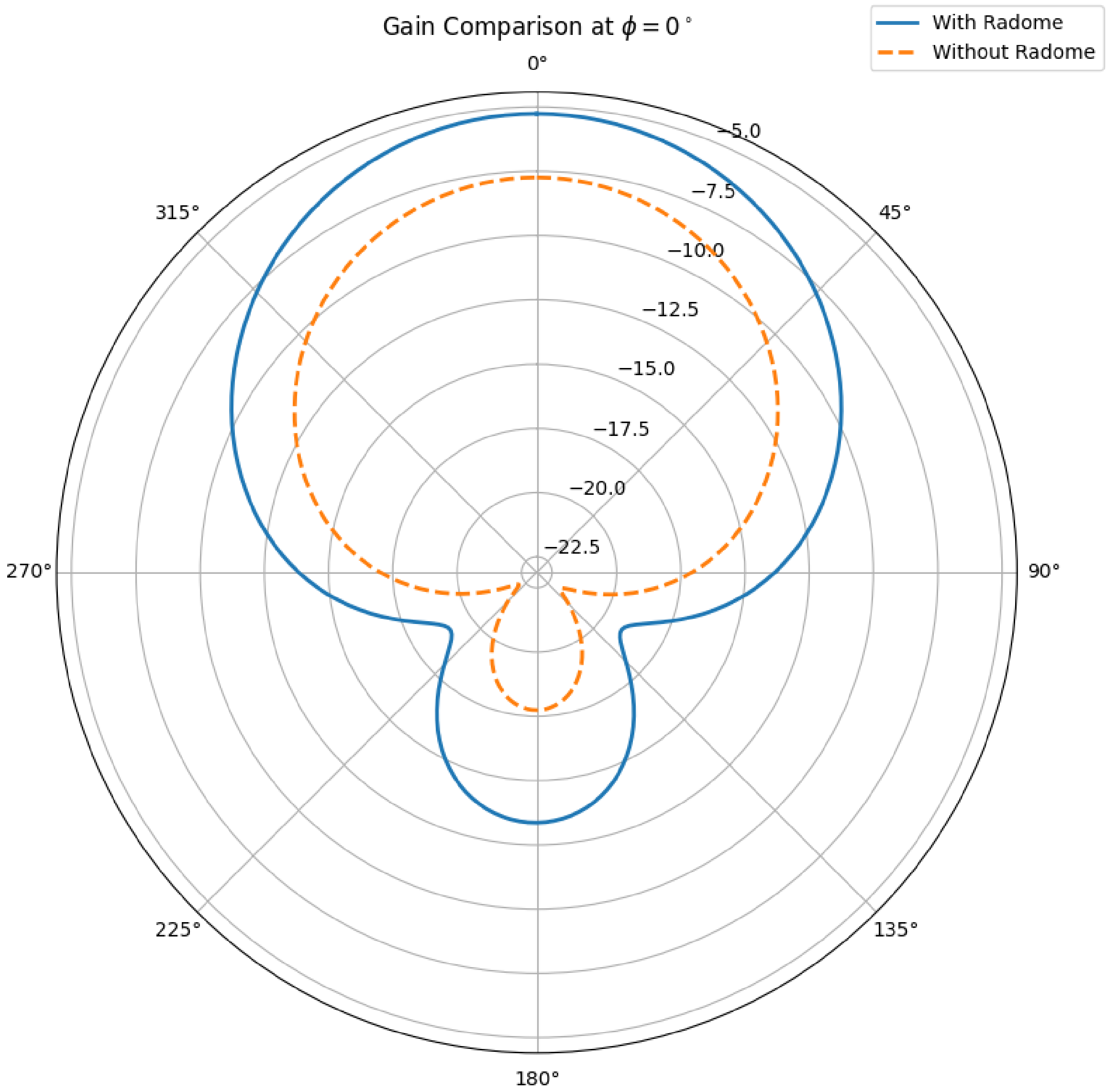

Figure 3.4: *Gain Total With and Without Radome (E Plane) at 3 GHz*

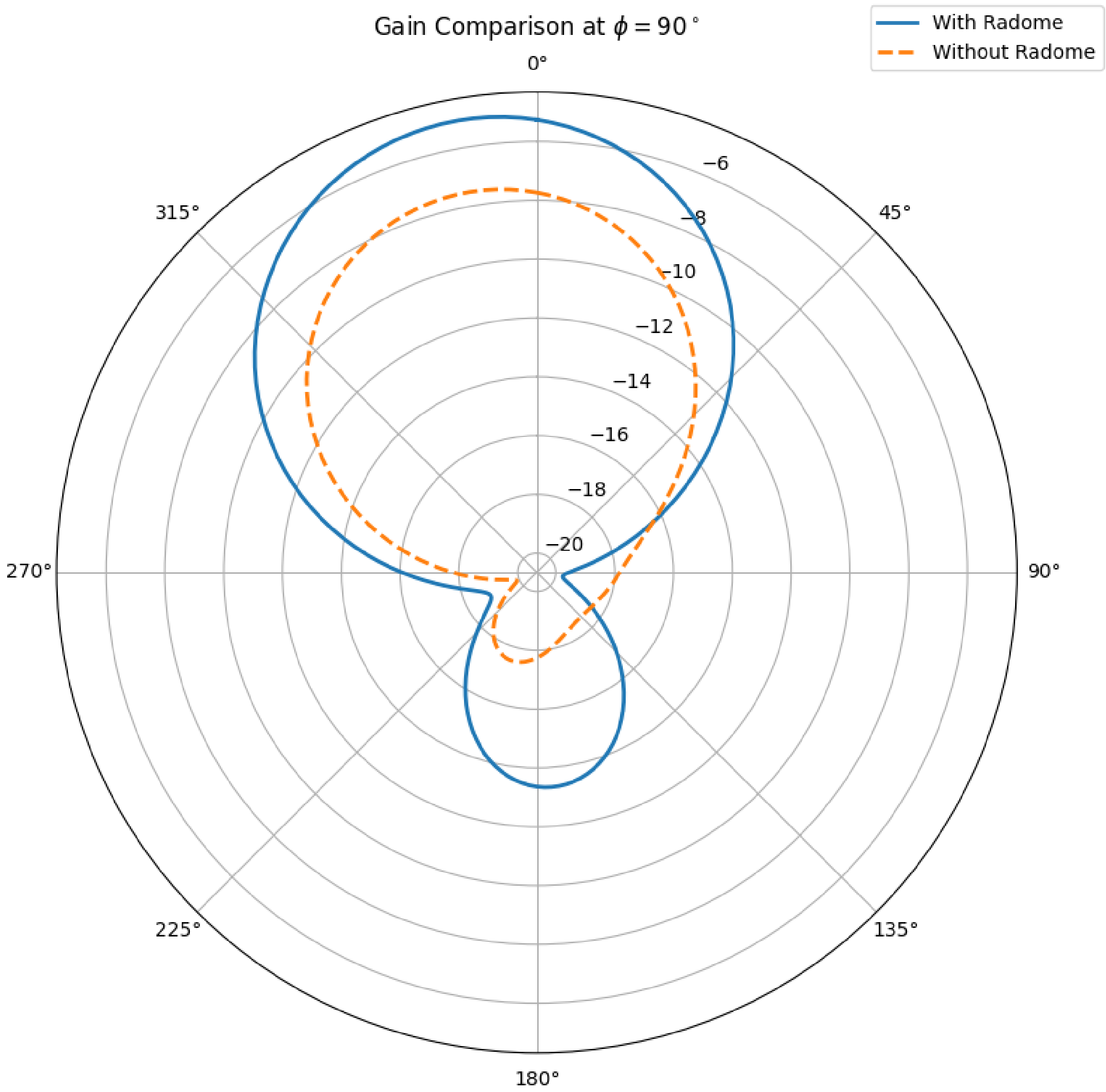

Figure 3.5: *Gain Total With and Without Radome (H Plane) at 3 GHz*

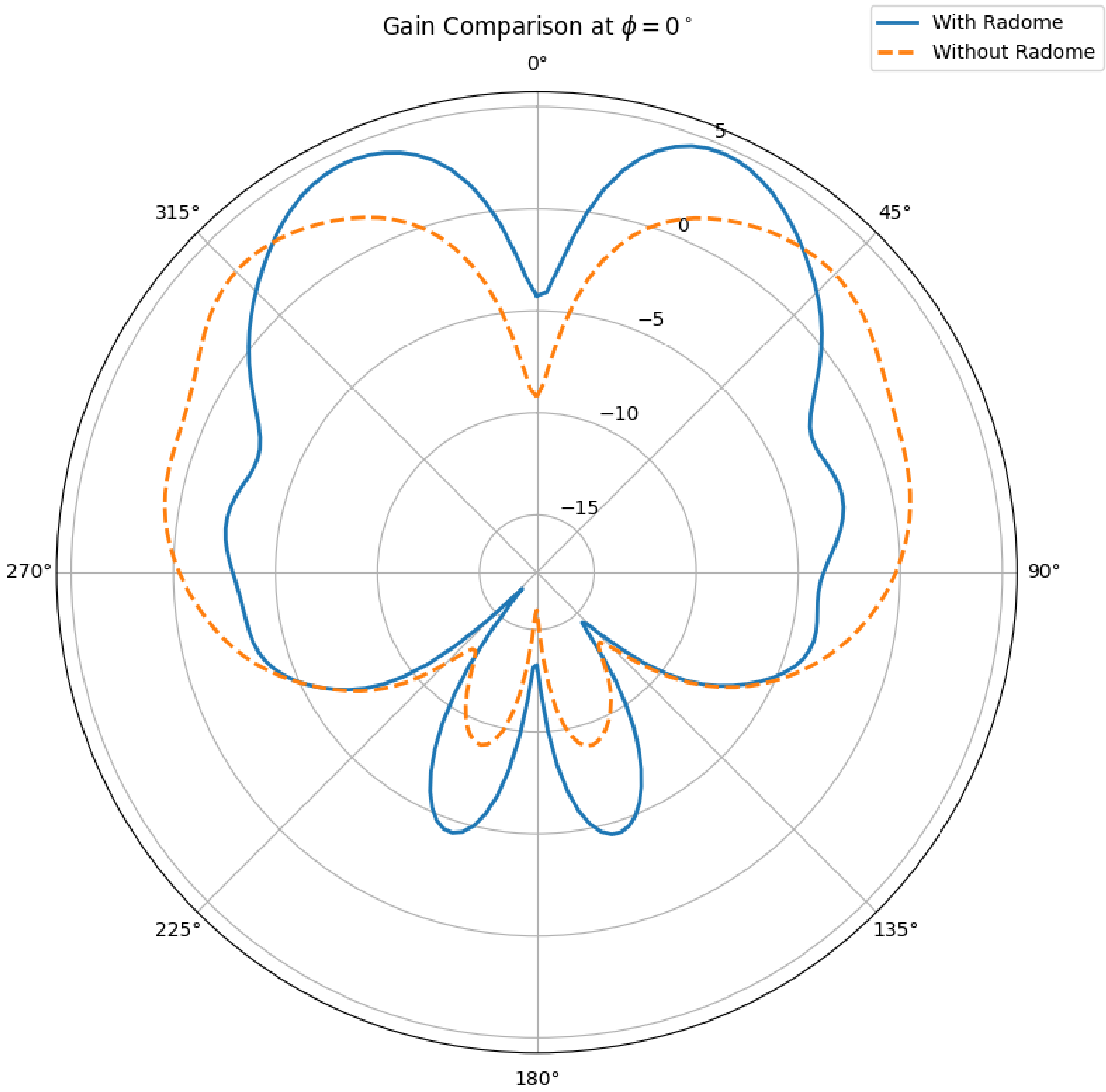

Figure 3.6: Gain Total With and Without Radome (E Plane) at 9 GHz

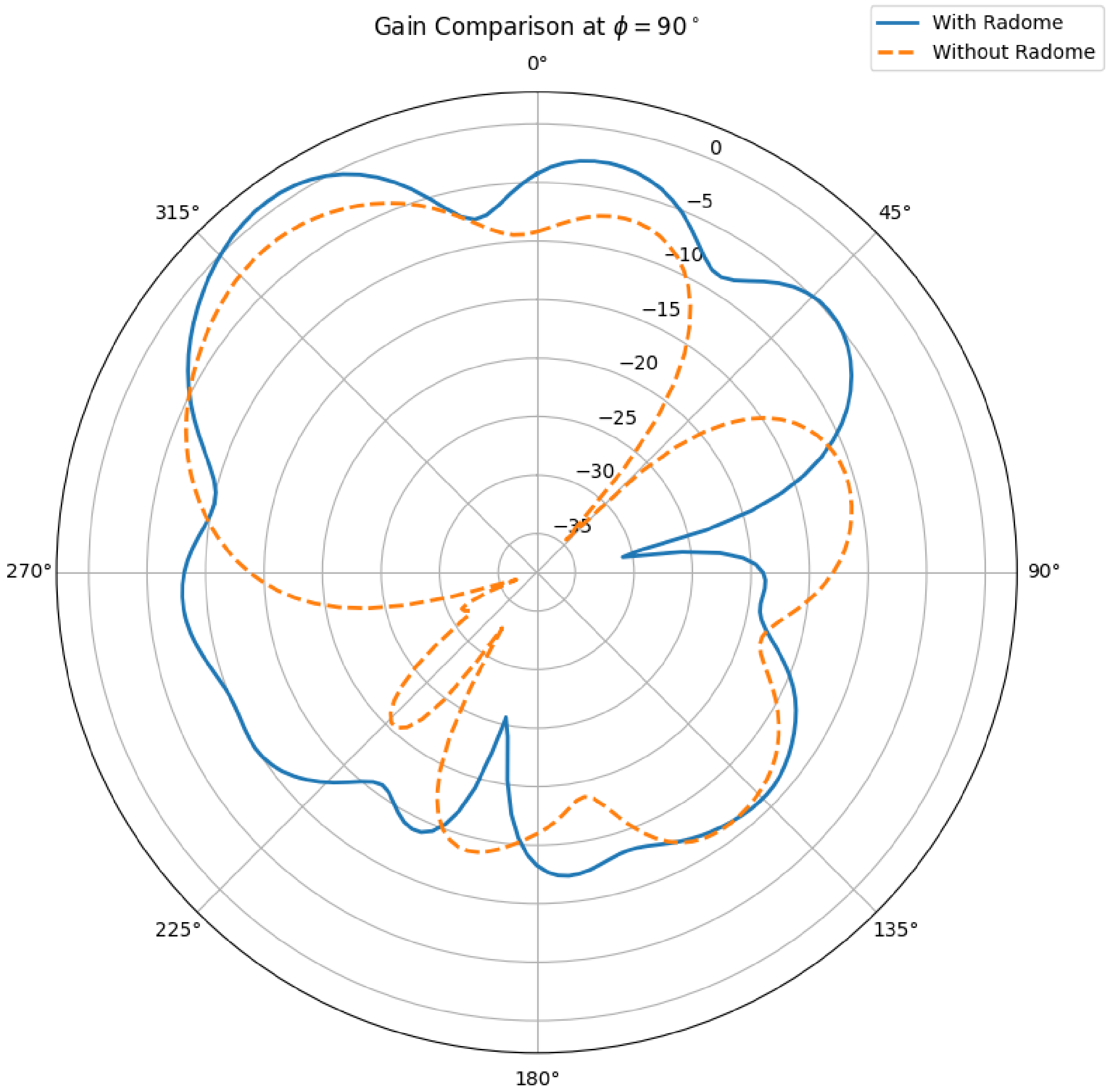

Figure 3.7: Gain Total With and Without Radome (H Plane) at 9 GHz

From these graphs a direct wave from the patch and the wave that refracts through, reflects from, and re-emerges at the radome's far face add in phase and the gain plots of 3 and 9 GHz show a deviated gain pattern thus also proving that our Antenna operates at a resonance frequency of 6 GHz

3.4 S_{11} Parameter

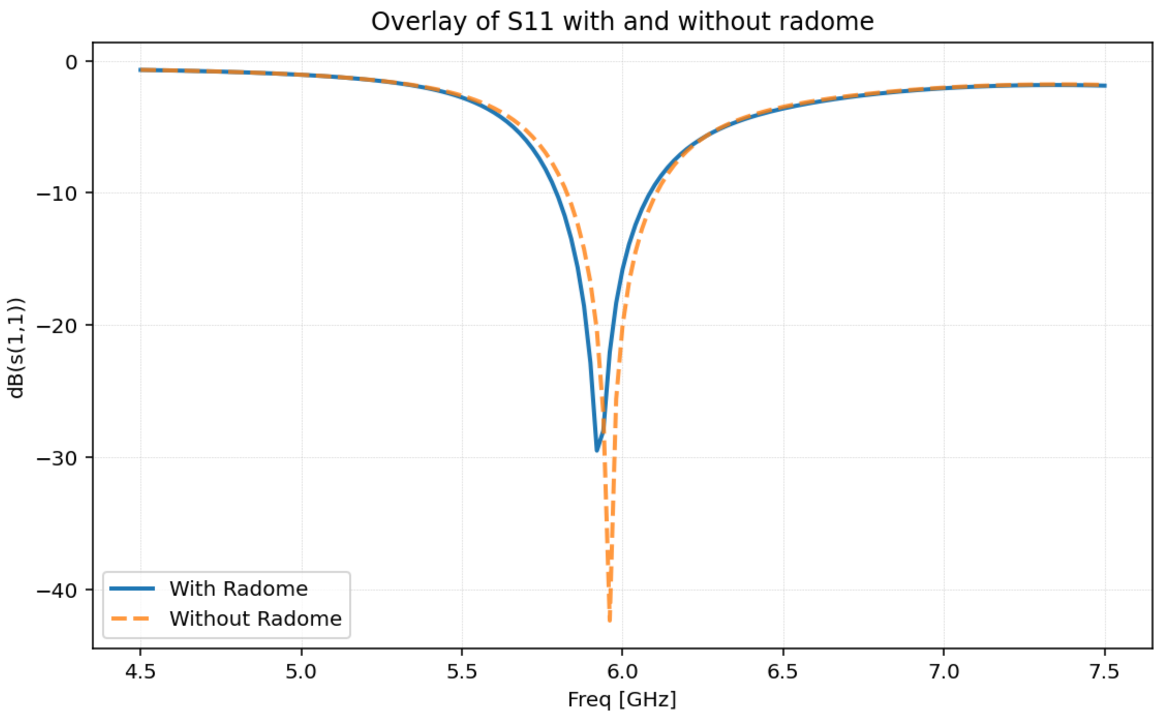

Figure 3.8: *S_{11} overlay plot*

The S_{11} overlay plot suggest the radome adds effective permittivity in front of the patch, increasing ϵ_{eff}, which lowers the gain.

Thus The patch becomes more sensitive to frequency changes.

Conclusion

In this study, we successfully designed and analyzed a Microstrip Patch Antenna operating at 6 GHz using CAD tools. The antenna's resonance was validated through the S parameter plot, which confirmed effective impedance matching near the desired frequency, indicating proper design and minimal reflection.

Following this, we generated gain plots to understand the radiation characteristics in both E-plane and H-plane. These patterns revealed a directive beam, suitable for point-to-point applications. To further optimize performance, a parametric sweep was conducted to fine-tune the inset width, ensuring optimal feed point matching and improved return loss.

Additionally, we designed and modeled a flat radome to evaluate its impact on antenna performance. The simulated gain plots with and without the radome demonstrated that the radome introduced minor variations but preserved the overall radiation behavior, thus validating its suitability for protective applications without compromising performance significantly.

This comprehensive design process—from initial modeling to parametric optimization and environmental simulation—illustrates the practical workflow involved in antenna development and highlights key considerations for real-world deployment of microstrip antennas at microwave frequencies.

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