SHRI RAMDEOBABA COLLEGE OF ENGINEERING AND MANAGEMENT, NAGPUR
DEPARTMENT OF ELECTRONICS & COMPUTER SCIENCE ENGINEERING

Session: 2024-25

Project Evaluation

Project1(ECSP310) VI sem B.Tech (ECS)

Optimization of Antenna Design Using Machine Learning Algorithms

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Project Guide -
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OBJECTIVES

PART - 1

- Design a simple microstrip patch antenna using EM Simulator.
- Optimize the antenna for frequency, bandwidth, gain and return loss by using various variation

PART - 2

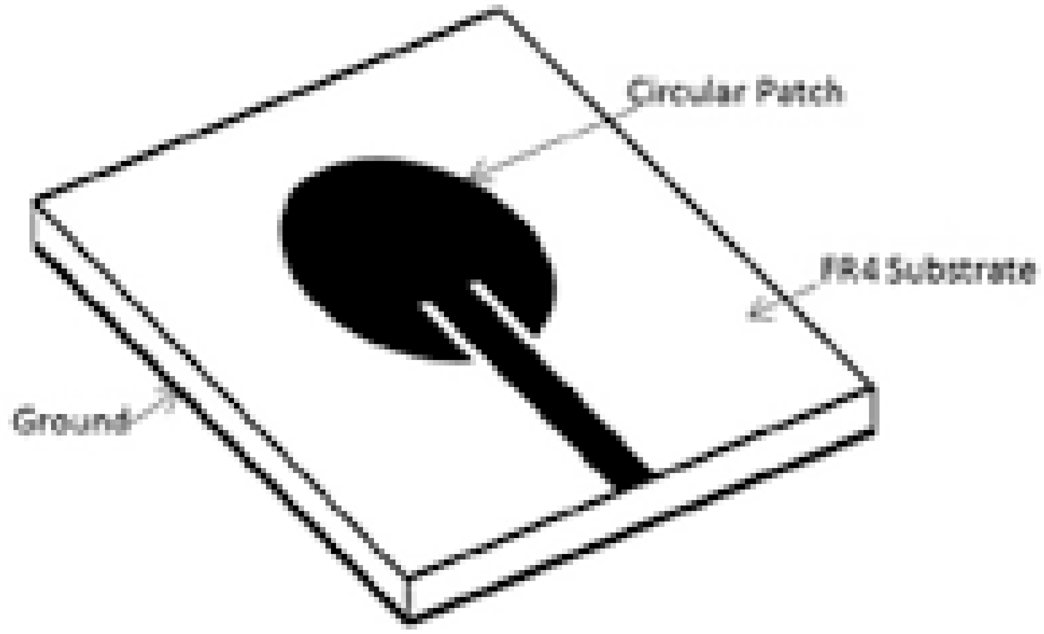
- Generate the dataset for antenna performance parameters to facilitate ML Model training.
- Analyze different machine learning (ML) models to incorporate for antenna design.
- Implement the generated data set on machine learning algorithms to optimize antenna performance and improve key parameters.
- Investigate the predicted output with the results obtained from the EM simulator.

Introduction

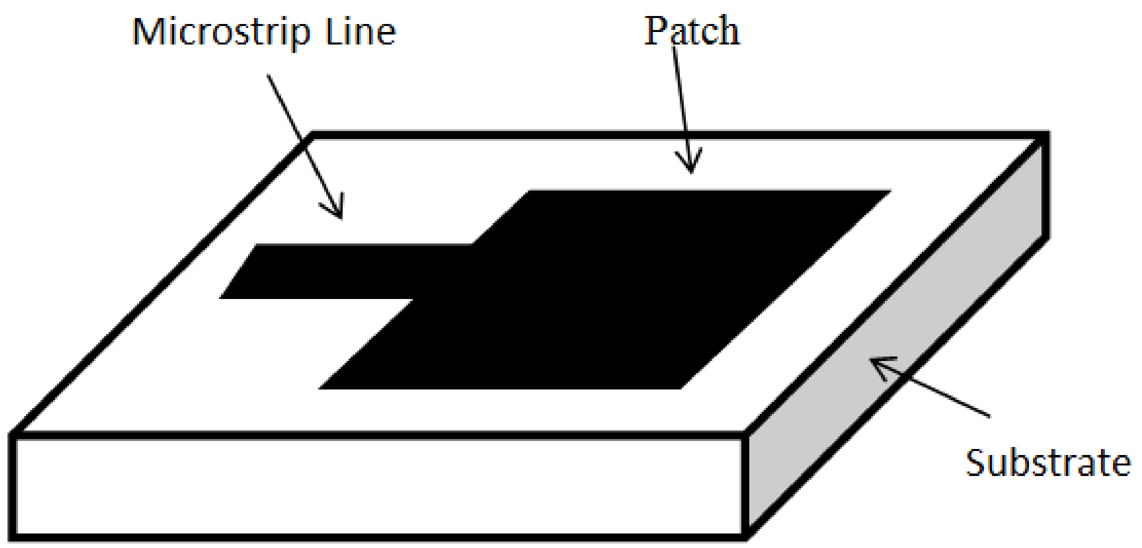
An antenna is a device used to transmit and receive electromagnetic waves, such as radio waves, microwaves, and even visible light in some advanced applications. It acts as a transducer, converting electrical signals into electromagnetic waves for transmission and vice versa for reception
Antenna act as a Transducer.

Microstrip Patch Antenna Overview

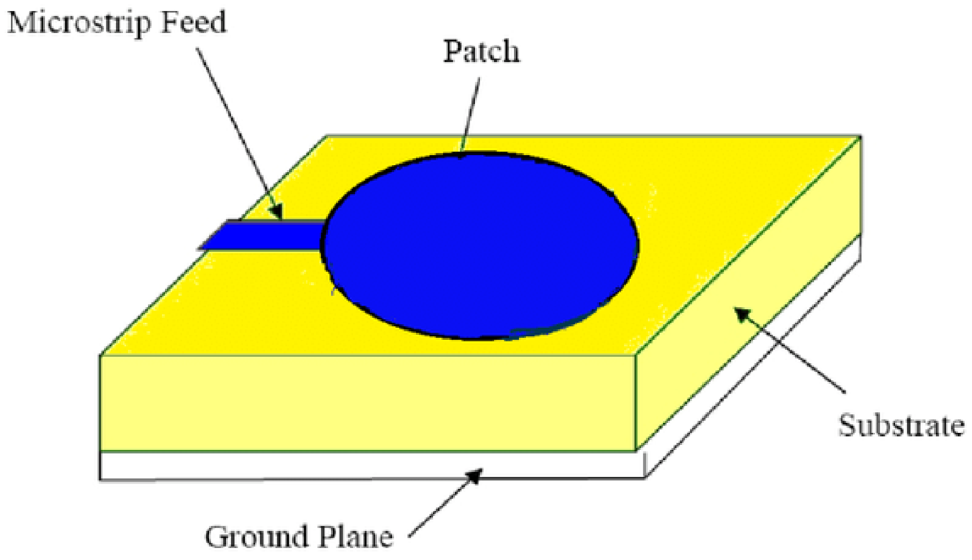
- **Patch:** Radiating element that emits electromagnetic waves.
- **Substrate:** Dielectric material supporting the patch and feed l
- **Ground Plane:** Conductive layer below the substrate for signal reflection and stability.



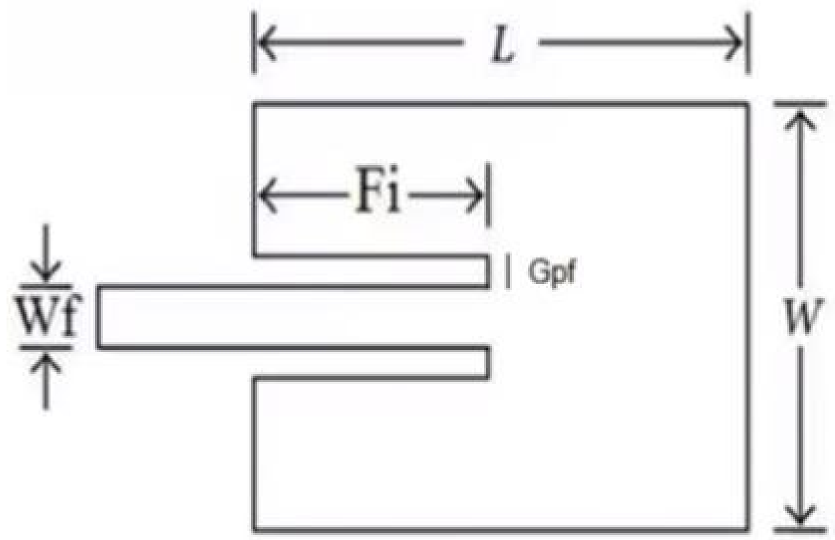
Types of Patches-



Rectangular patch



Circular patch



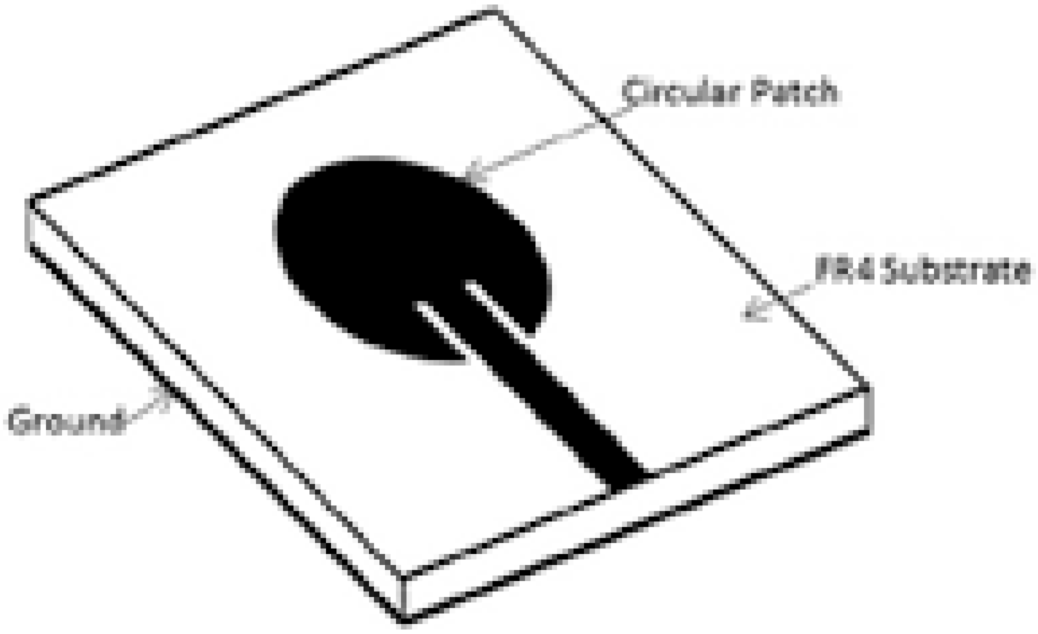
Square Patch

Key parameters of antennas:

- **Radiation Pattern:** Graphical representation of antenna radiation in space.
- **Bandwidth:** Frequency range over which the antenna operates effectively.
- **Gain:** Measure of how much power is directed in a specific direction.
- **Efficiency:** Ratio of radiated power to input power, indicating performance.

Circular Patch

- **Compact Size:** Requires less space, ideal for miniaturized devices.
- **Omni-directional Radiation Pattern:** Provides uniform coverage in all directions.
- **Higher Bandwidth:** Offers better bandwidth than a rectangular patch.
- **Easy Integration:** Seamlessly fits into wireless communication systems.



Design Specifications

Target Frequency: 2.45 GHz

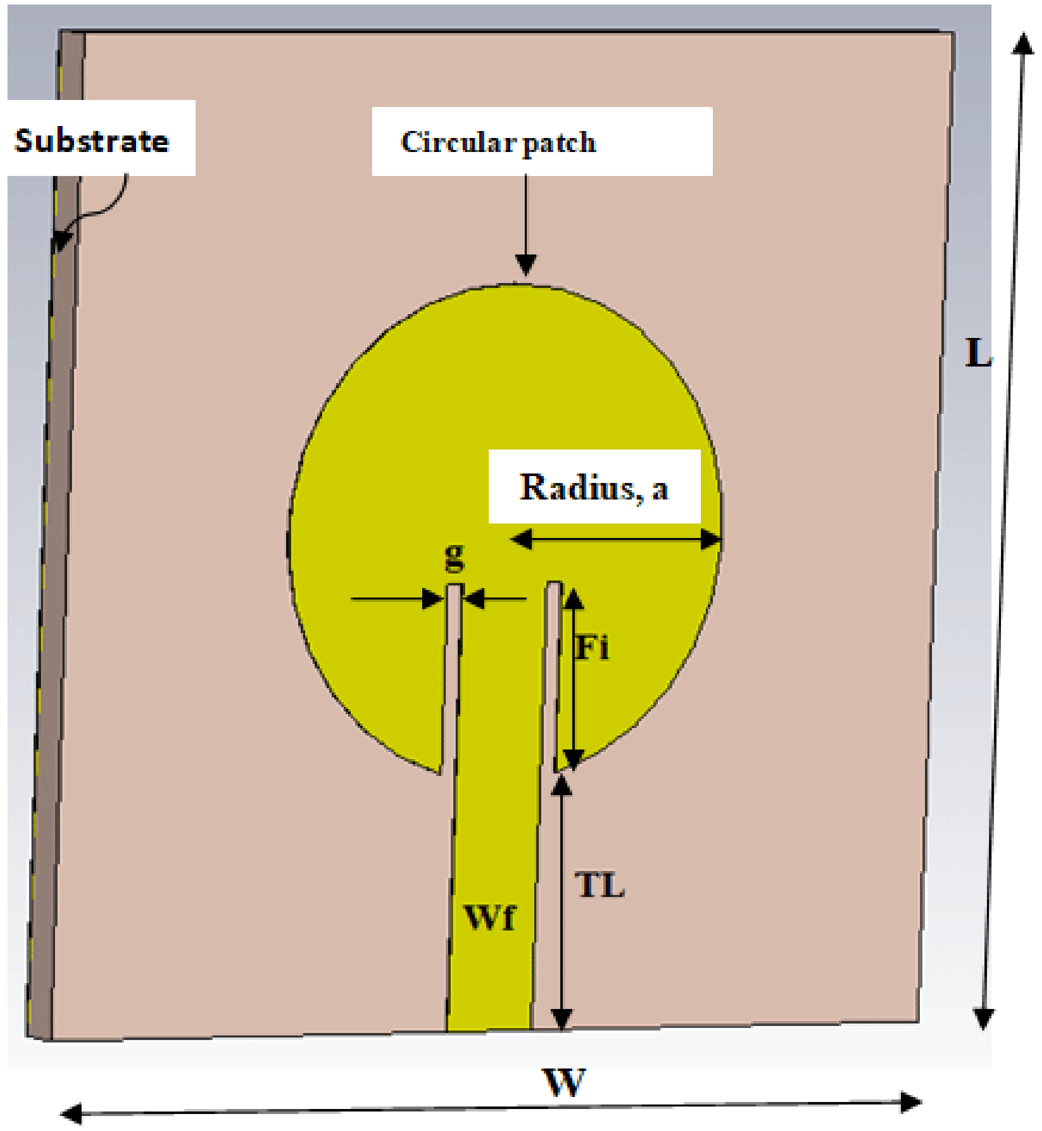
- Selected for Wi-Fi and ISM band applications
- Ensures compatibility with standard wireless communication systems

Substrate Material: FR4 Epoxy

- Low cost and ease of fabrication
- Provides stable mechanical and electrical properties
- Suitable for high-frequency applications

Dielectric Constant (εr): 4.4

- Determines the size and resonant frequency of the patch
- Higher dielectric constant results in a smaller antenna size



DESIGN EQUATIONS

Radius of the Patch (a)

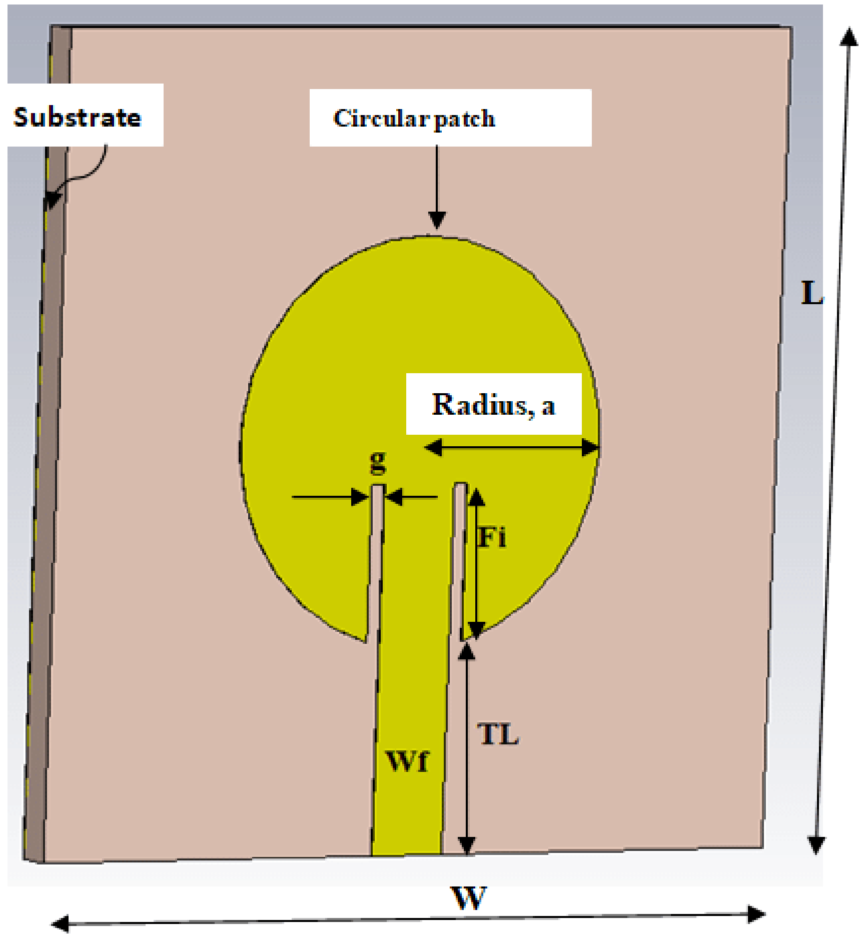
$$a = \frac{F}{\left\{1+\frac{2h}{\pi\epsilon_r F}\left[ln\left(\frac{\pi F}{2h}+1.7726\right)\right]\right\}^{\frac{1}{2}}}$$

EQ - 1

Where,

$$F = \frac{8.791 \times 10^9}{f_c\sqrt{\epsilon_r}}$$

- fc = Resonant frequency (GHz)
- ϵr = Relative permittivity of the substrate
- h = Thickness of the substrate



DESIGN EQUATIONS

Effective Dielectric Constant (ε_eff)

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-0.5}$$

Resonant Frequency Fc:

$$f_c = \frac{1.8412 \cdot c}{2\pi a\sqrt{\epsilon_{eff}}}$$

- fc = Resonant frequency (Hz)
- ϵr = Relative permittivity of the substrate
- h = Thickness of the substrate

Circular Microstrip Patch Antenna Calculator

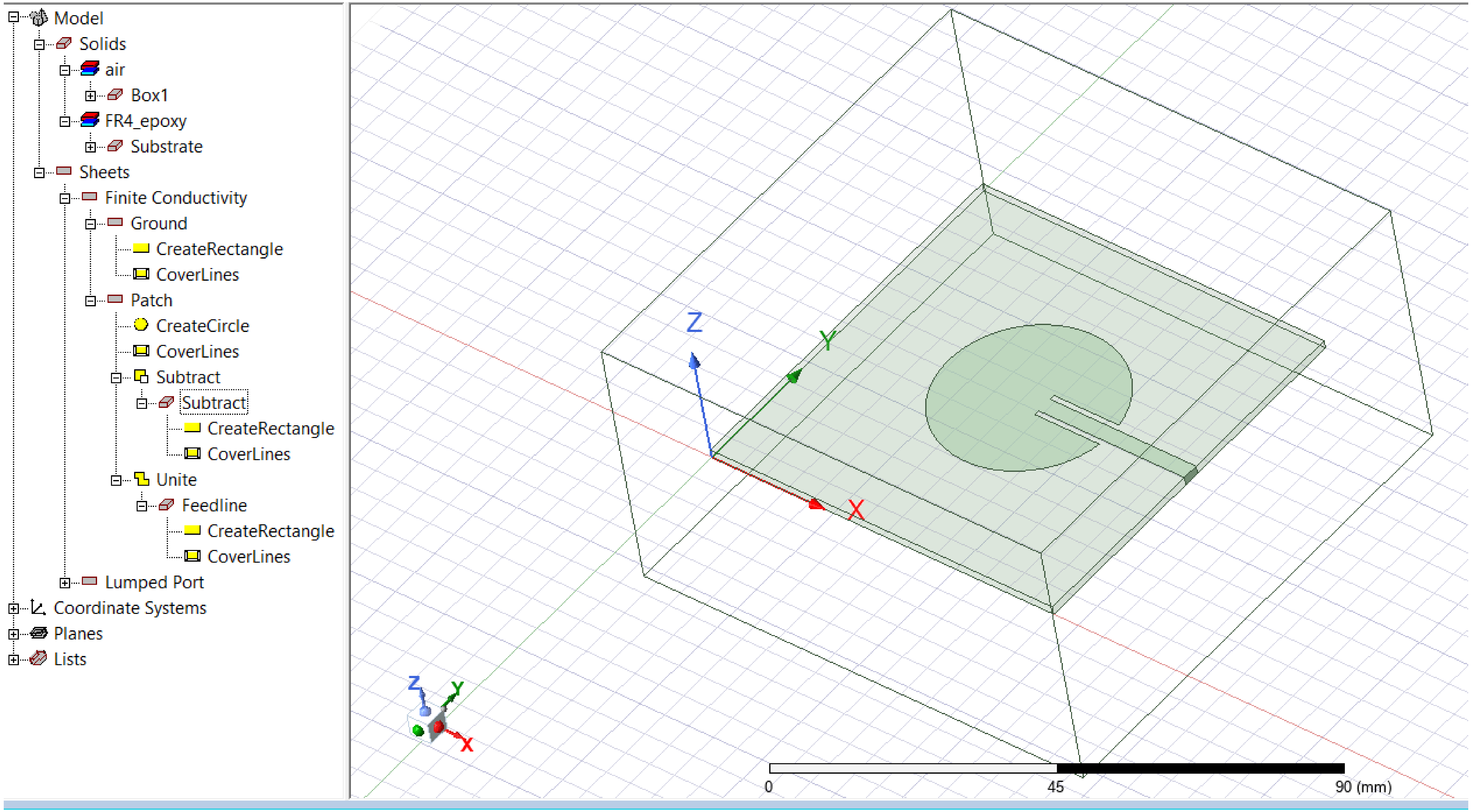
Input

Resonant Frequency	f_r	2.45	GHz
Substrate Relative Permittivity	ϵ_r	4.4	
Substrate Height	h	1.6	millimeter

Output

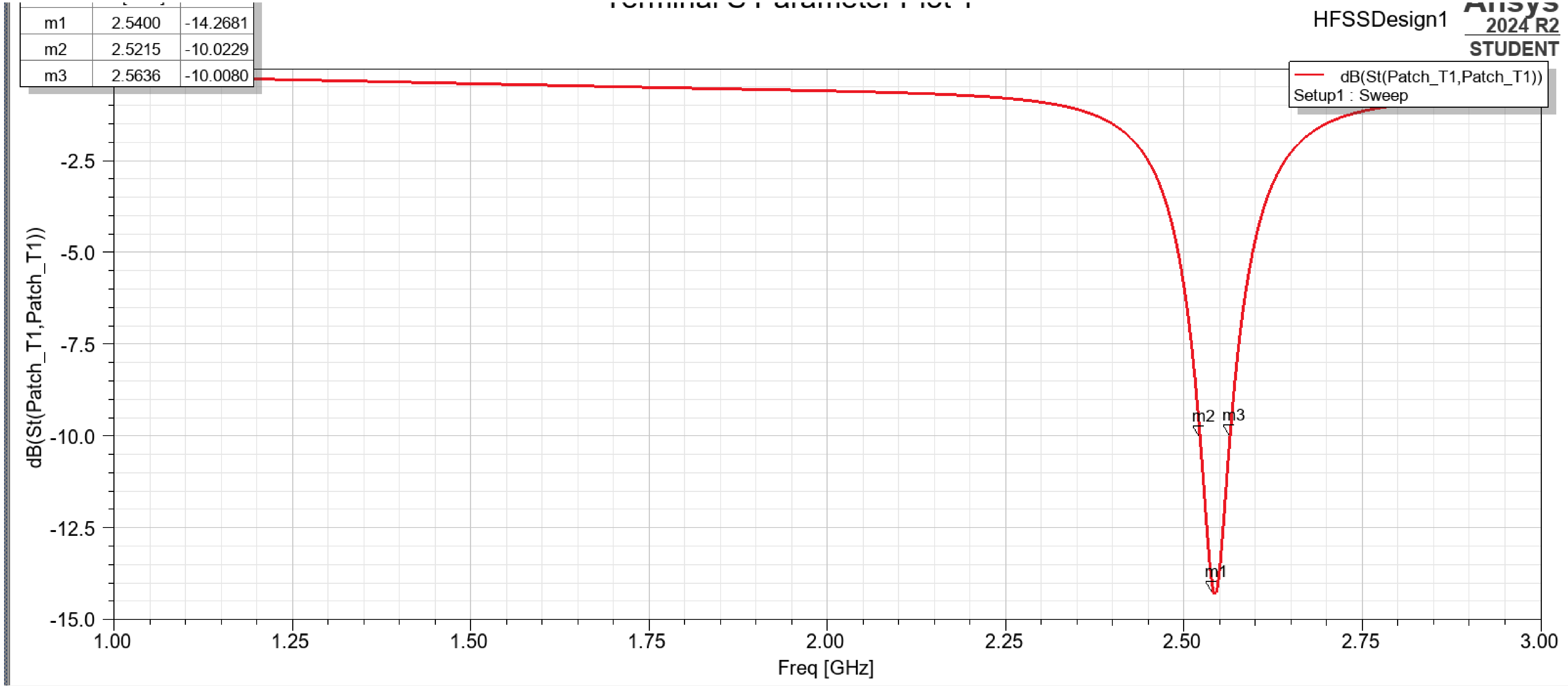
Patch Physical Radius a 16.59776 millimeter

FINAL DESIGN ON HSFF



RESULT

- **Return Loss-**

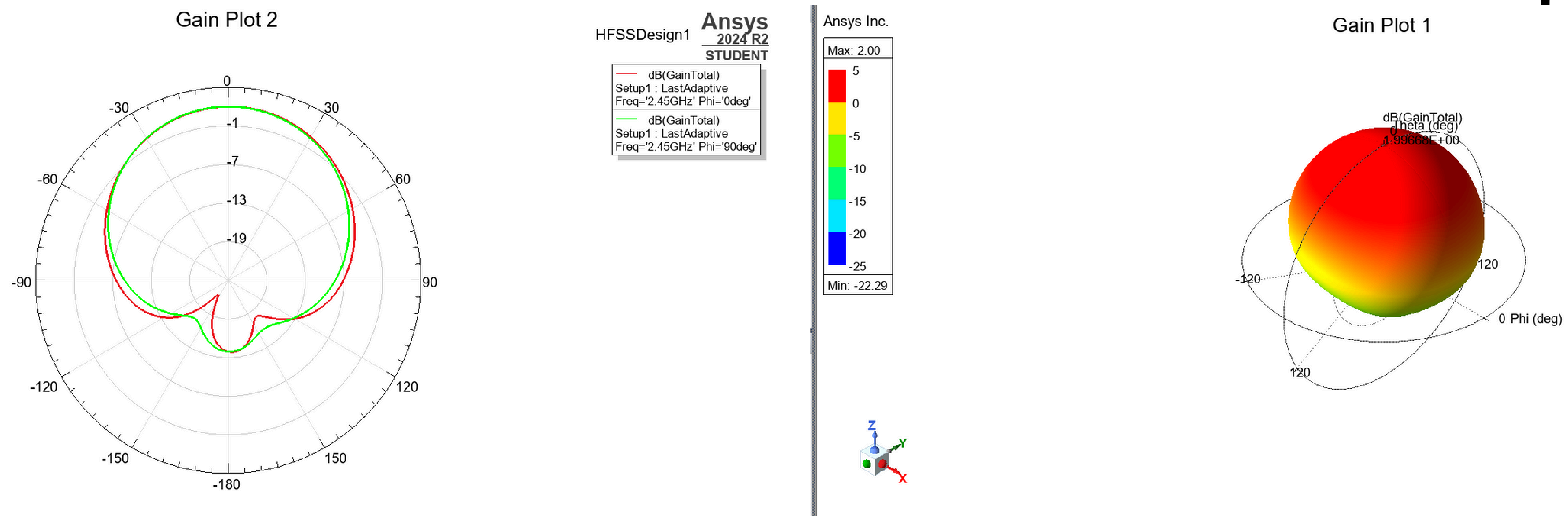


Observed Results:

The minimum return loss is -14.2681 dB (m1).

.**Bandwidth** = 2.5636 - 2.5215 = **42.1 MHz**

- Gain and Radiation Pattern -



DGS(Defected Ground Structure)

- DGS stands for Defected Ground Structure.
- It involves making intentional cuts, slots, or shapes in the ground plane of a microstrip or planar antenna
- These cuts change how signals flow in the ground part of the antenna.

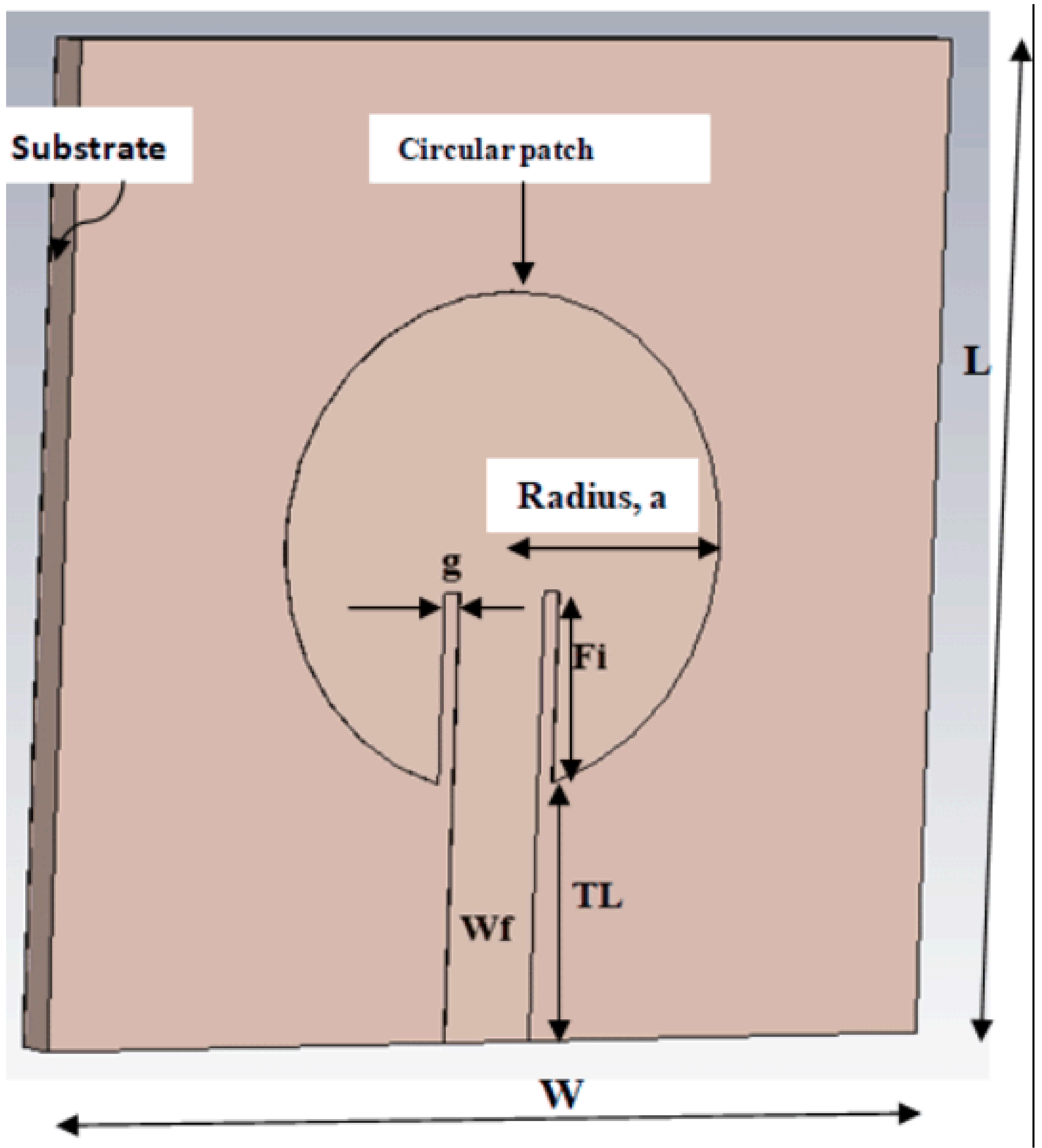
Advantages of DGS in Antenna Design

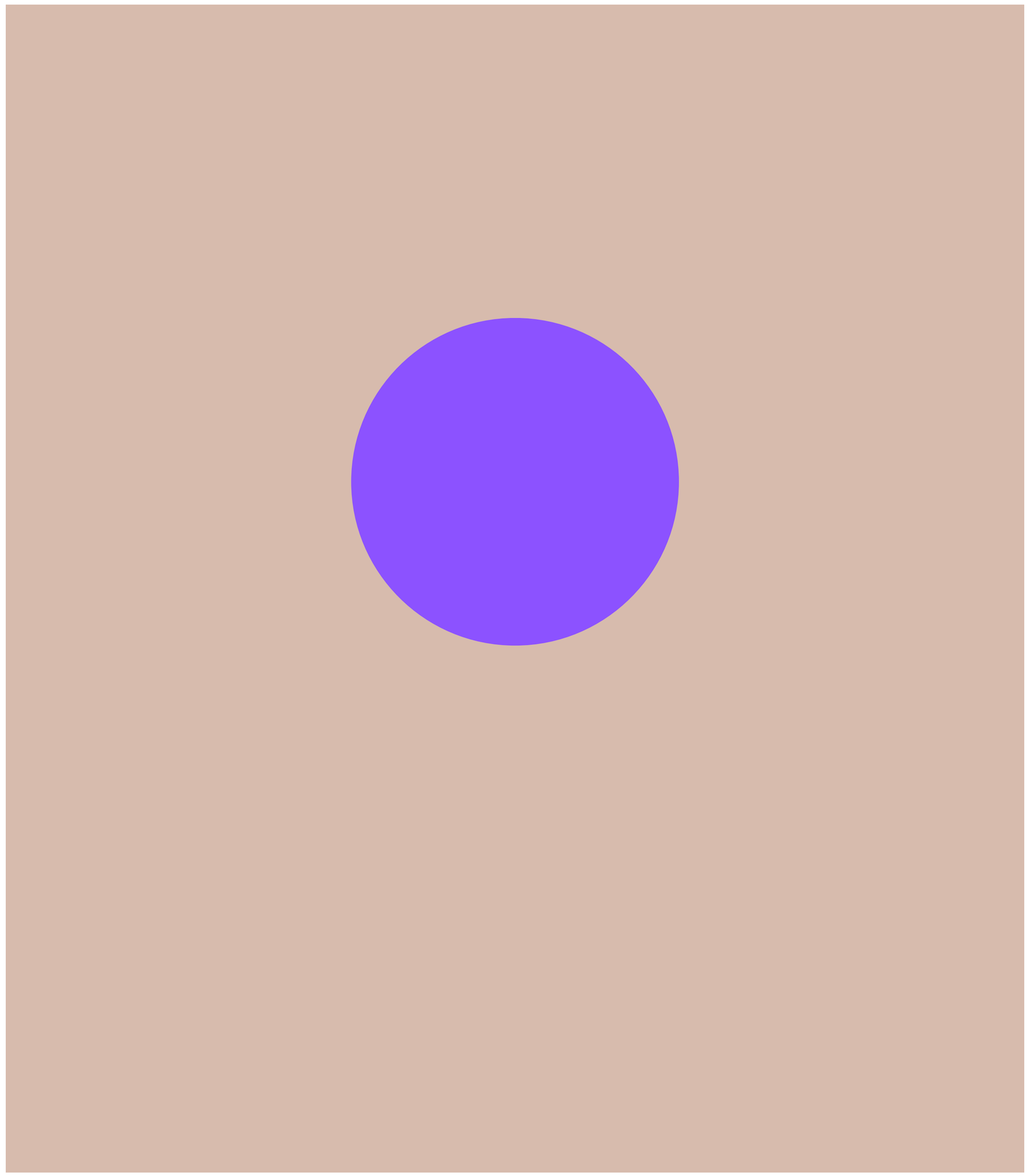
- Bandwidth Enhancement
- Size Reduction (Miniaturization)
- Gain Improvement
- Radiation Pattern Control
- Surface Wave Suppression

- **Types of DGS:**
- Dumbbell-shaped
- Circular, rectangular and Triangular slots
- Spiral shapes
- U-shaped or H-shaped defects

- **Working of DGS:**
- It modifies the effective inductance and capacitance of the structure.
- This introduces a stopband or slow-wave effect, depending on the pattern.
- These effects can be used to tailor the current distribution and radiation pattern of the antenna

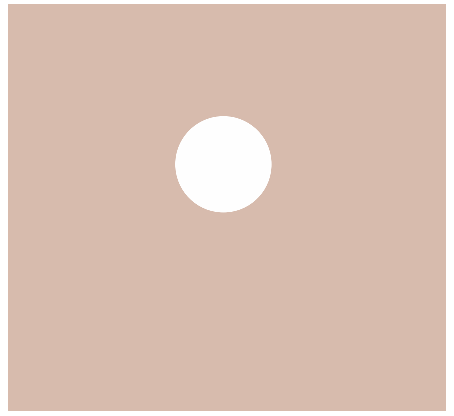
Circular DGS ground cut design





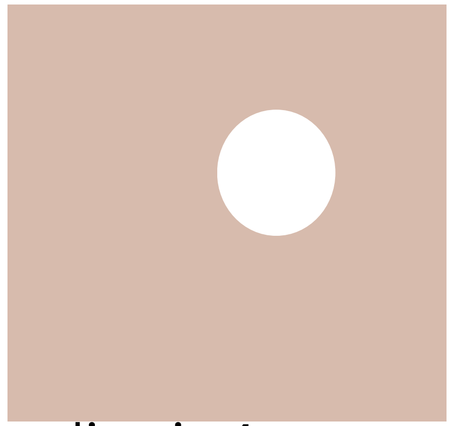
Circular DGS design

C1



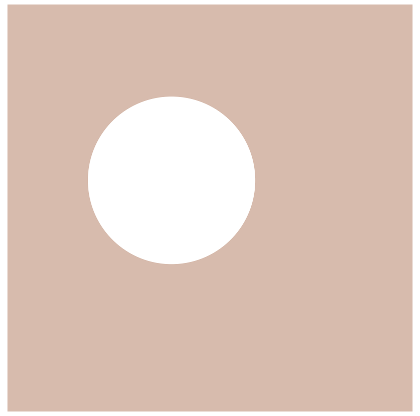
radius is 3mm and it is inside the patch slightly above the center

C2



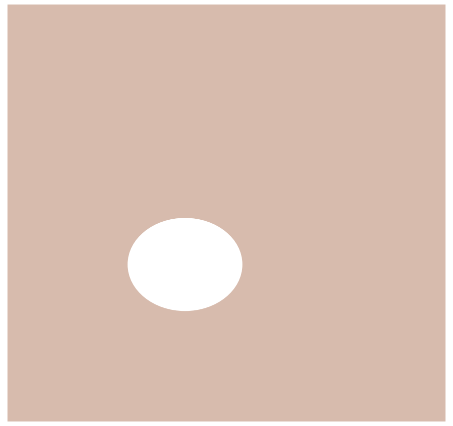
radius is 4mm and shifted from the top-left to the top-right.

C3



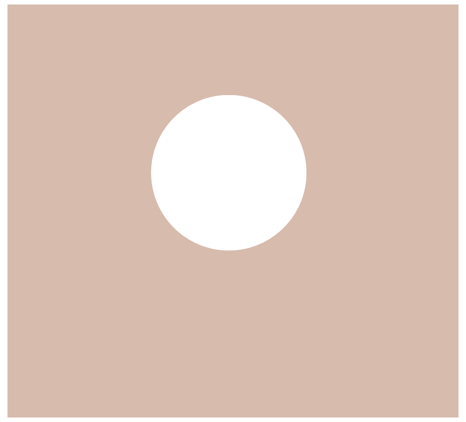
radius is 6mm and It is offset a short distance from the top and left edges.

C4

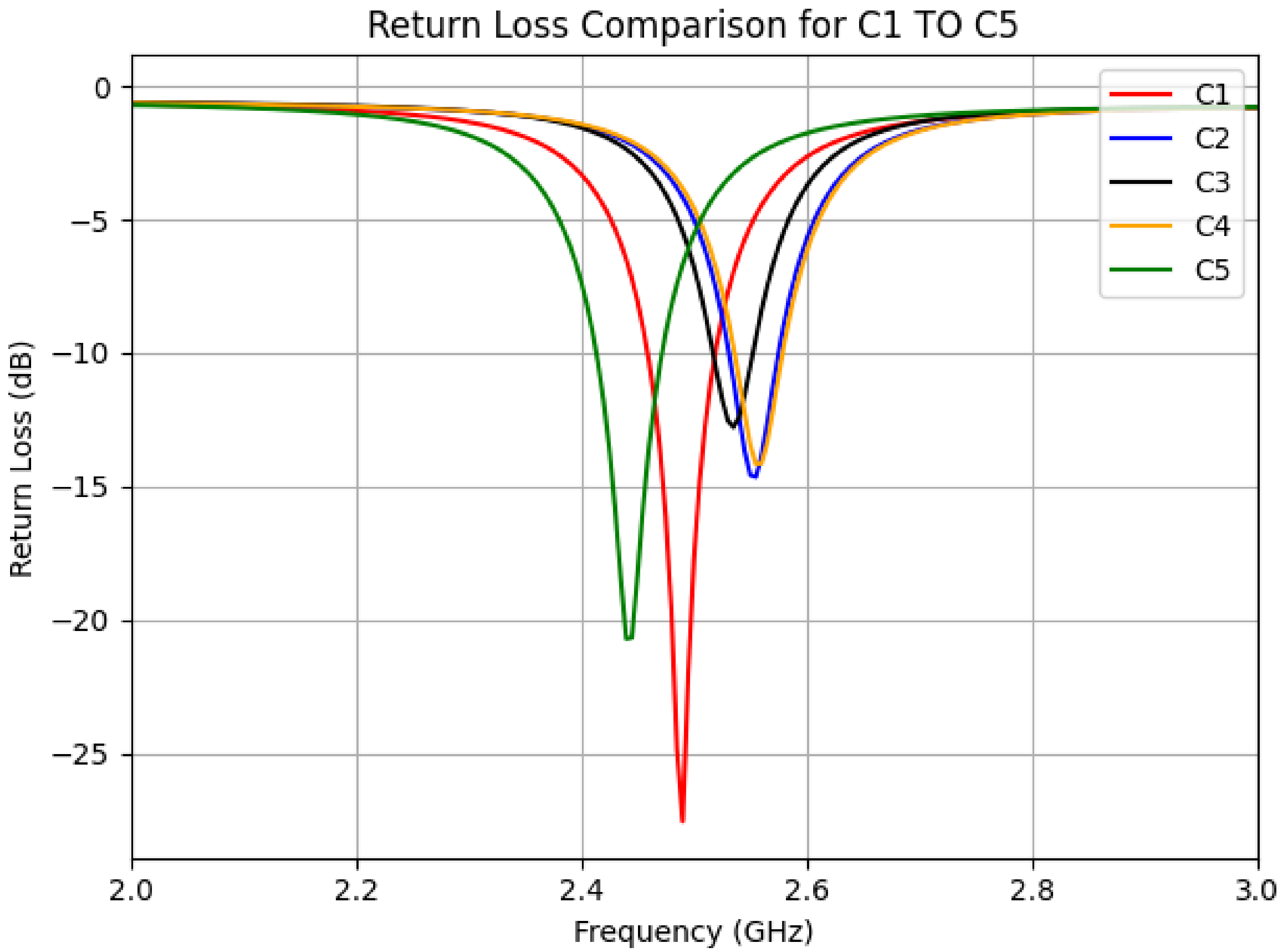


radius is 5mm and it is inside the patch in left corner

C5



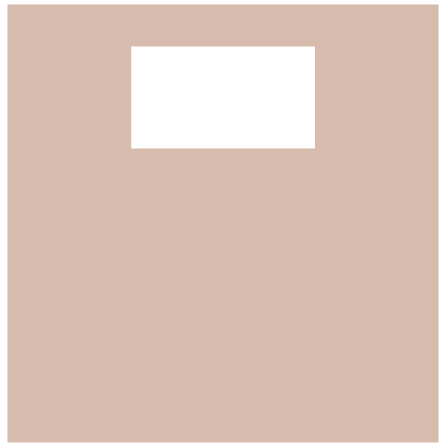
radius is 5mm and it is inside the patch slightly above the center



Variation	Gain	Return Loss	Frequency
C1	2.73db	-27.37db	2.49Ghz
C2	2.42db	-13.7db	2.52Ghz
C3	2.00db	-14.65db	2.55Ghz
C4	2.13db	-12.7db	2.53Ghz
C5	3db	-20.67db	2.44Ghz

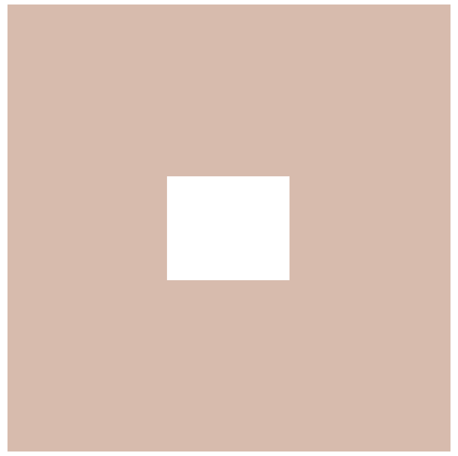
Rectangle DGS design

R1



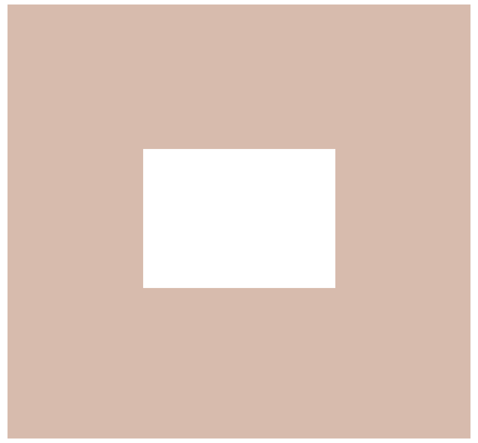
Rectangle with L:20 & W:10 cut from the ground within the patch radius

R2



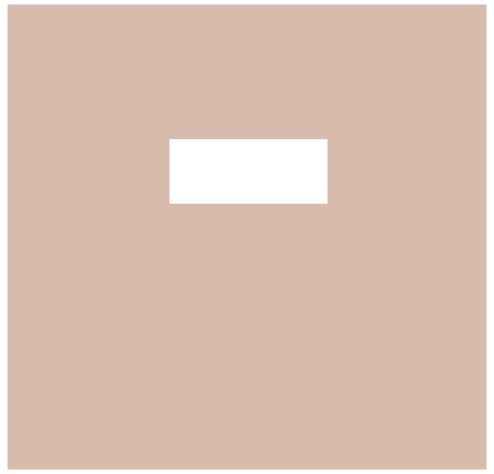
Rectangle with L:10 & W:12 cut from the ground within the patch radius

R3



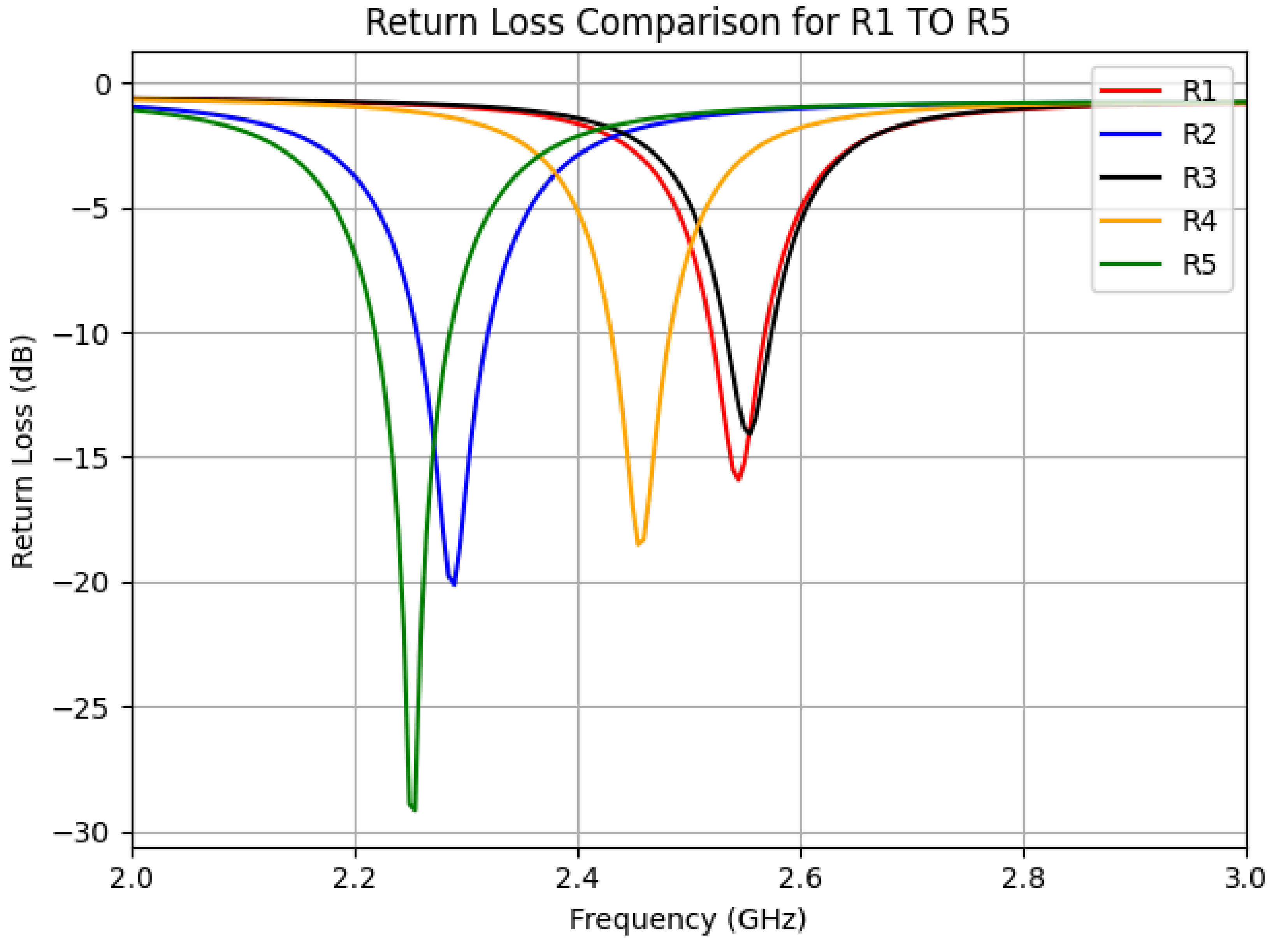
Rectangle with L:12 & W:15 cut from the ground within the patch radius

R4



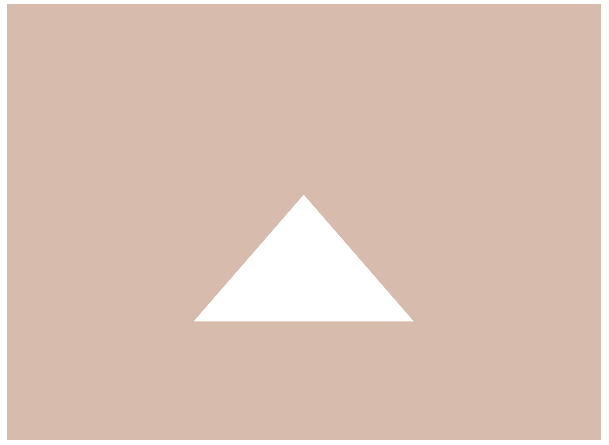
Rectangle with L:10 & W:5 cut from the ground within the patch radius

Variation	Return Loss	Gain	Frequency
R1	-16.49 db	2	2.54Ghz
R2	-20.10db	1.44	2.29Ghz
R3	-14.07db	1.85	2.55Ghz
R4	-18.49db	2.93	2.45Ghz
R5	-29.65db	1.05	2.25Ghz



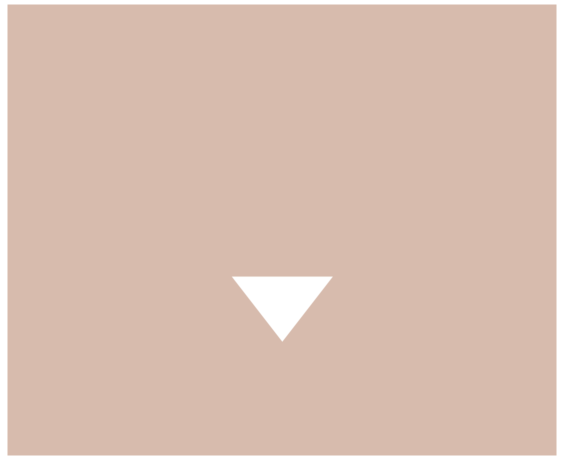
Triangular DGS design

T1



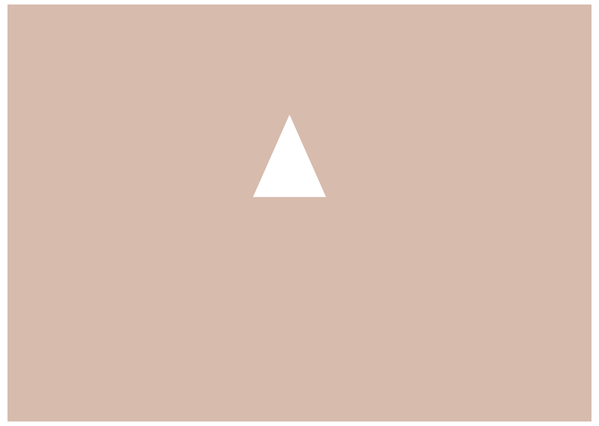
equilateral triangle cut from the ground within the patch radius

T2



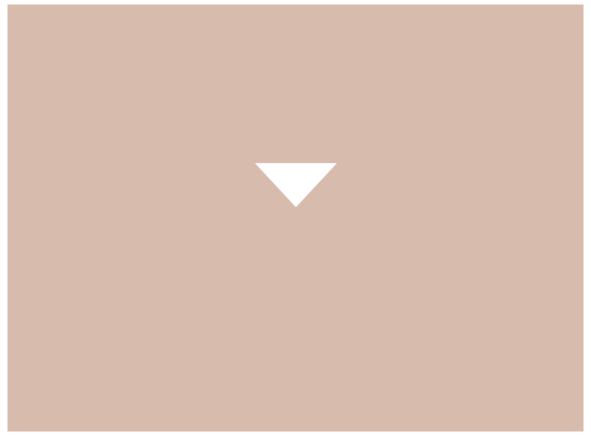
triangle cut from the ground within the patch radius on the feedline

T3



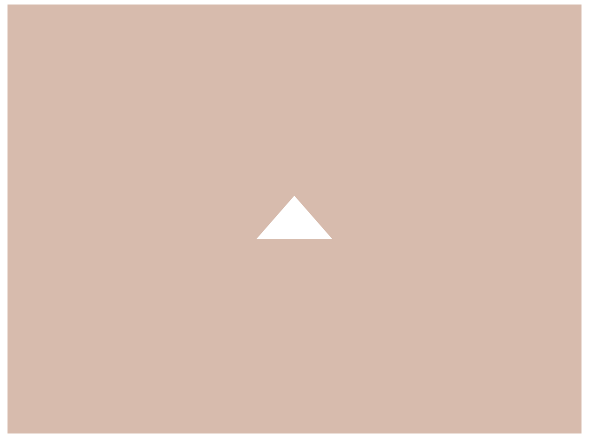
elongated triangle cut from the ground within the patch radius on the edges of the patch

T5



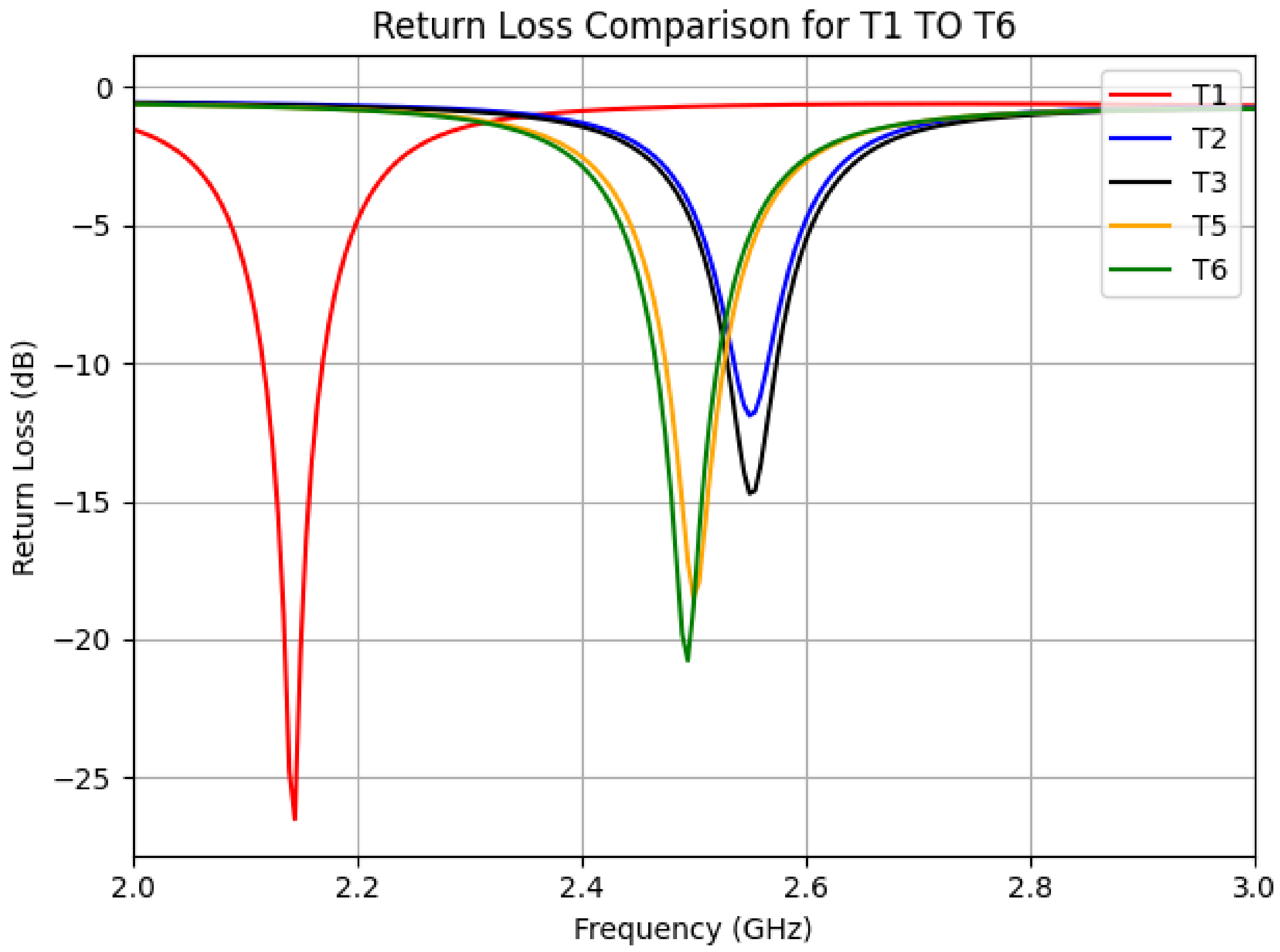
euilateral triangle cut from the ground within the patch radius at the centre pointing towards feedline

T6



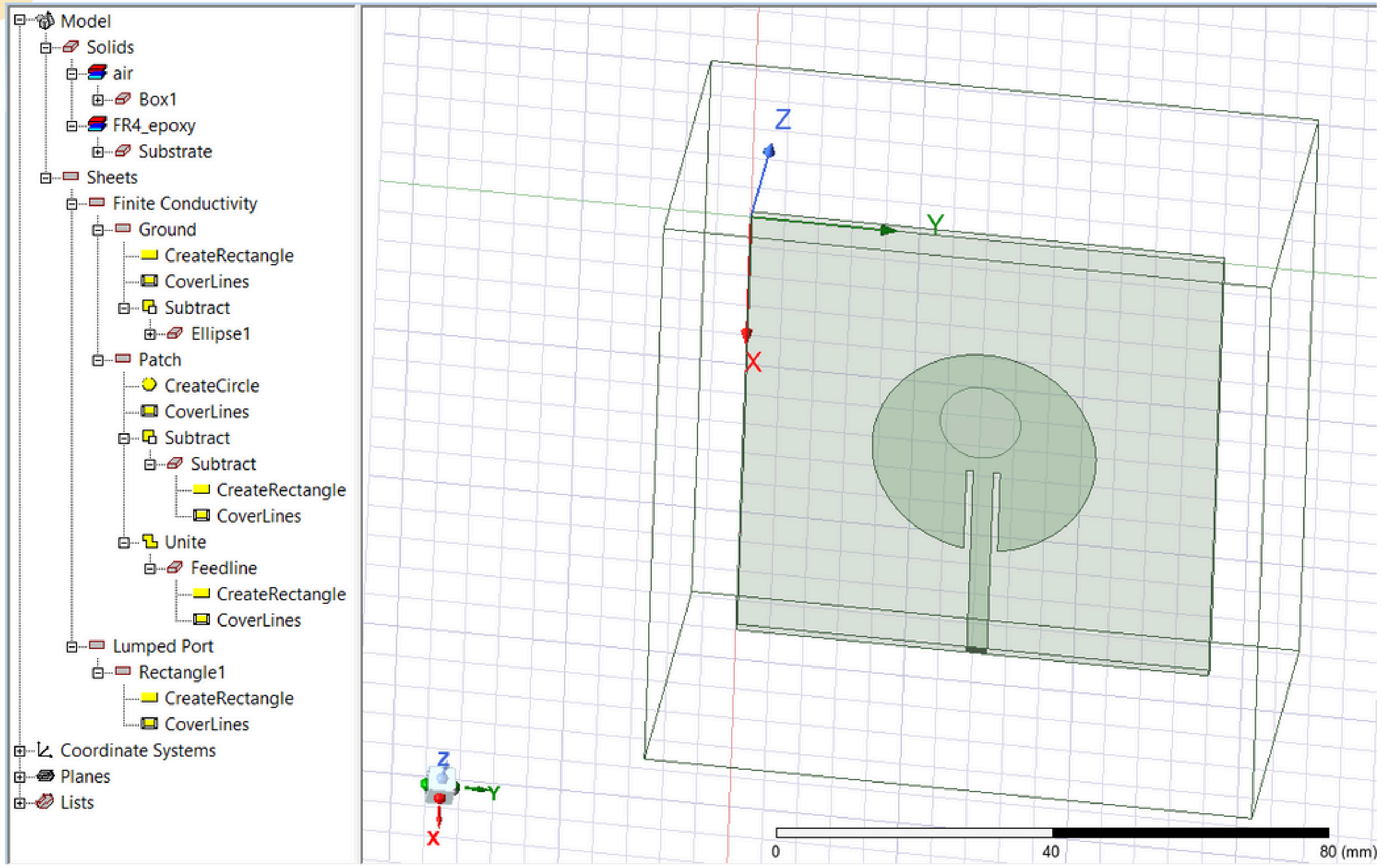
euilateral triangle cut from the ground within the patch radius at the centre pointing against feedline

Variation	**Return Loss**	**Gain**	**frequency**
T2	-11.90db	2	2.55 Ghz
T1	-26.48db	**2**	2.14Ghz
T3	-12.65db at	2.11	2.54 Ghz
T5	-18.49db at	2.65	2.5Ghz
T6	-20.75db at	2.62	2.49Ghz

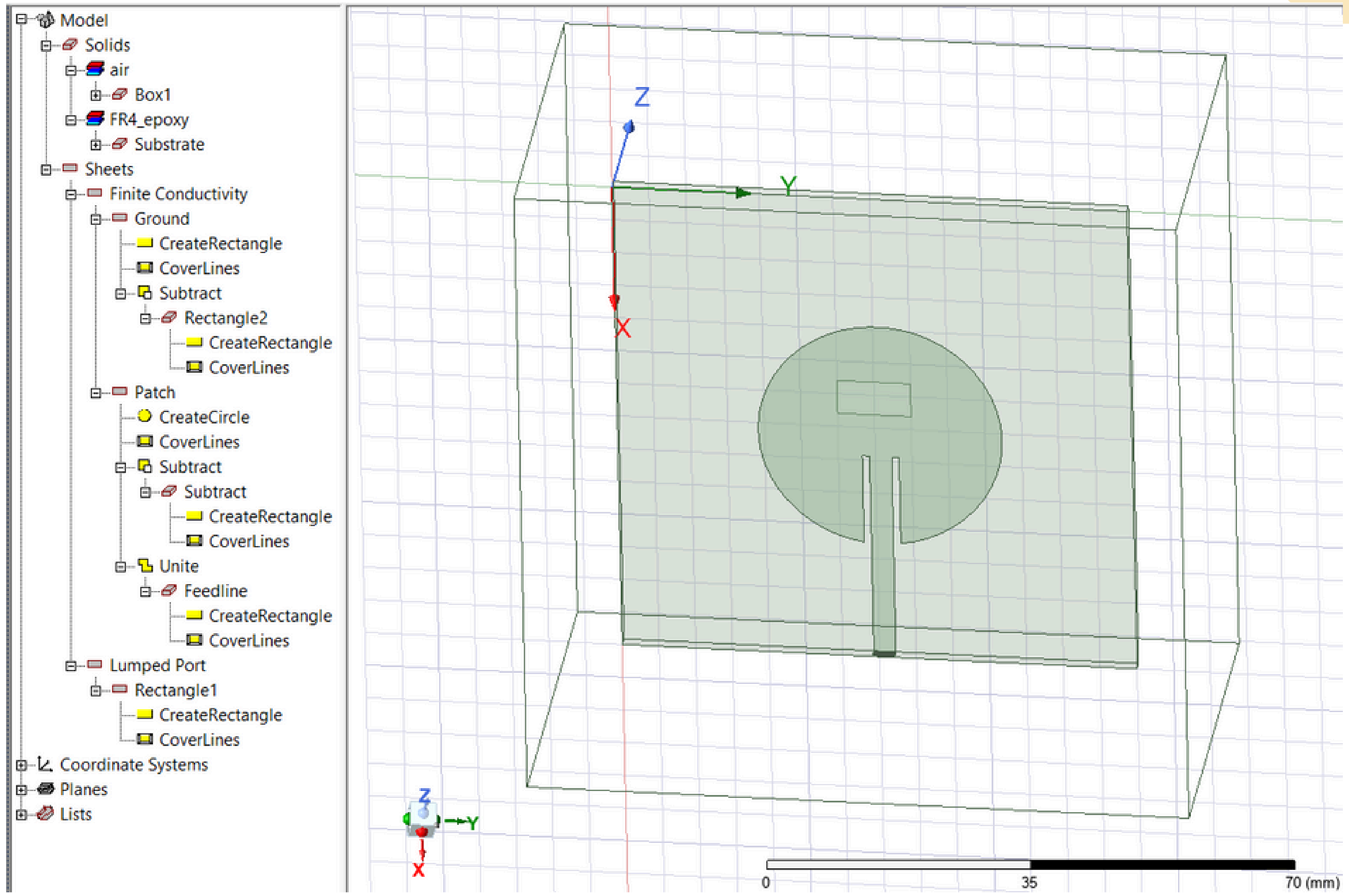


FINAL DESIGN

DESIGN 1



DESIGN 2



Results for Design 1:

Return loss = -20.67 dB

Frequency = 2.44 GHz

Bandwidth = 2.4717 - 2.4135 = 58.2 MHz

Gain = 3.00 dB

Results for design 2:

Return loss = -18.5 dB

Frequency = 2.45 GHz

Bandwidth = 2.4835 - 2.4307 = 52.8 MHz

Gain = 2.93 dB

CONCLUSION

- Designed and simulated a circular patch antenna at **2.45 GHz**
- Achieved good return loss, bandwidth, and gain by using DGS
- DGS leads to compact, high-performance antenna design.

FUTURE WORK

- Now we are ready for data set generation and apply this dataset on machine learning algorithms.

9. REFERENCES

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THANK YOU