EE 305 Project 24: Microstrip Patch Antenna

Designed in Ansys HFSS, radiating at 3 GHz.

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Group 20

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What is an Antenna?

Antennas are key components of any wireless system.

Antenna is one type of transducer that converts the electrical energy into the electromagnetic energy in form of electromagnetic waves.
Antennas are required by any radio receiver or transmitter to couple its electrical connection to the electromagnetic field.

Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency range.

An antenna must be tuned to the same frequency band that the radio system to which it is connected operates in, otherwise reception and/or transmission will be impaired.

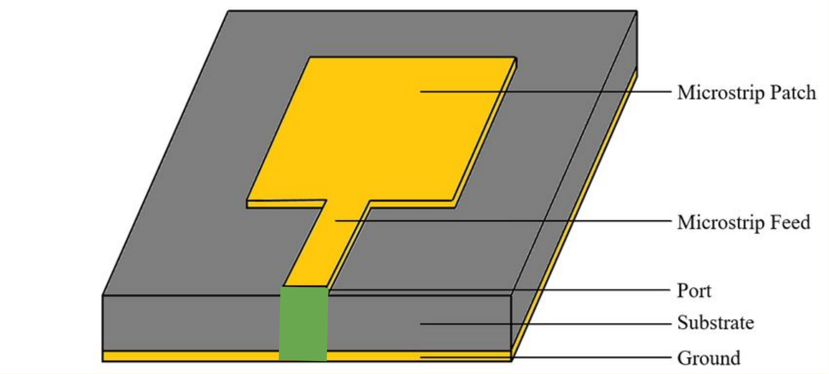
What is a Microstrip Patch Antenna?

In its most basic form a Microstrip patch antenna consists of a **radiating patch** on one side of **a dielectric substrate** which has **a ground plane** on the other side.

It was invented by Bob Munson in 1972.

Structure of

Microstrip Patch Antenna



- Patch
- Microstrip Line Feed
- Dielectric Substrate
- Ground Plane
- Port

Applications

- ✓ Used in mobile satellite communication system.
- ✓ Used in aircraft, spacecraft & missiles
- ✓ Direct broadcast television (DBS).
- ✓ GPS system.
- ✓ Telemetry & telemedicine
- ✓ Radar application

Basic Principles of Operation

The patch acts approximately as a resonant cavity (short circuit walls on top and bottom, open-circuit walls on the sides).

In a cavity, only certain modes are allowed to exist, at different resonant frequencies.

If the antenna is excited at a resonant frequency, a strong field is set up inside the cavity, and a s strong current on the (bottom) surface of the patch. This produces radiation (a good antenna)

Feed Techniques

- **Micro strip Line Feed:** In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.
- **Coaxial Feed**: The center of the coaxial connector is soldered to the patch.
- **Aperture Coupled Feed** : In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane
- **Proximity Coupled Feed:**This type of feed technique is also called as the electromagnetic coupling scheme.

Advantages

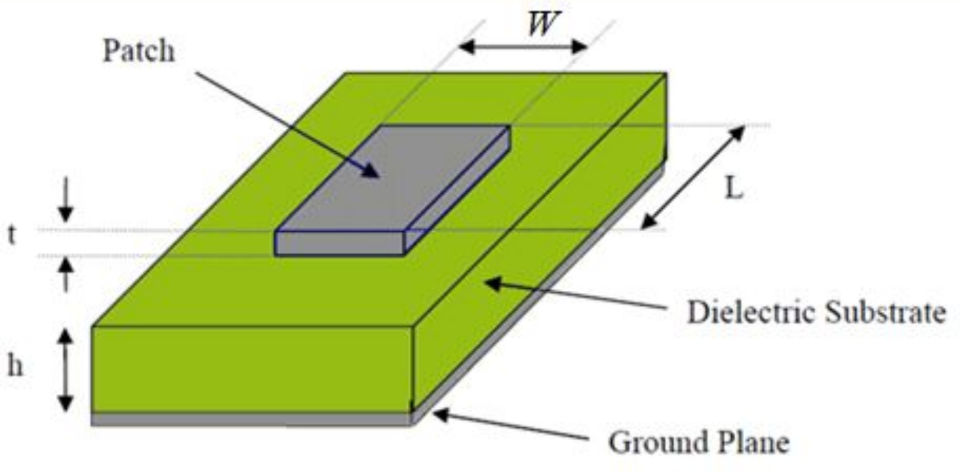
- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal to host surface.
- Low fabrication cost, hence can be manufactured in large quantities.
- Supports both, linear as well as circular polarization.
- Can be easily integrated with microwave integrated circuits (MICs).
- Capable of dual and triple frequency operations.
- Mechanically robust when mounted on rigid surfaces.

Disadvantages

- Narrow bandwidth
- Low efficiency
- Low Gain
- Extraneous radiation from feeds and junctions
- Poor end fire radiator except tapered slot antennas
- Low power handling capacity.
- Surface wave excitation

Parameters of

Micro-Strip Patch Antenna



- L = Length of the micro strip patch element
- W = Width of the micro strip patch element
- t = Thickness of patch
- h = Height of the dielectric substrate

Modelling in Ansys HFSS

The following materials are chosen for the Antenna design:

- **Ground:** Copper Sheet
- **Substrate:** FR4-Epoxy
- **Patch and Feed:** Copper Sheet
- **Radiating Boundary:** Vacuum

Parameters

- Ground:

  Copper Sheet of thickness 35 µm

  Dimensions= 33mm x 40mm

- Substrate:

  FR4-Epoxy Layer of relative permittivity of 4.4

  Thickness = 1.6mm

  Dimensions= 33mm x 40mm

- Patch:

  Copper Sheet of thickness 35 µm

  Dimensions= 23.4mm x 30.4mm (L x W)

- Feed:

  Copper Sheet of thickness 35 µm

  Dimensions= 4.8mm x 0.75mm (L x W)

Calculation of Parameters

- Patch:

  Width of patch = 30.4 mm

  Length of the patch = 23.4mm

  Effective Relative Permittivity = 4.03

  Effective Length(L_eff) = 24.9mm

  Variation in Length (ΔL) = 0.75mm

Width of patch (W) = $\frac{c}{2f}\sqrt{\frac{2}{\epsilon_r+1}}$

Length of patch (L) = $L_{eff} - 2\Delta L$

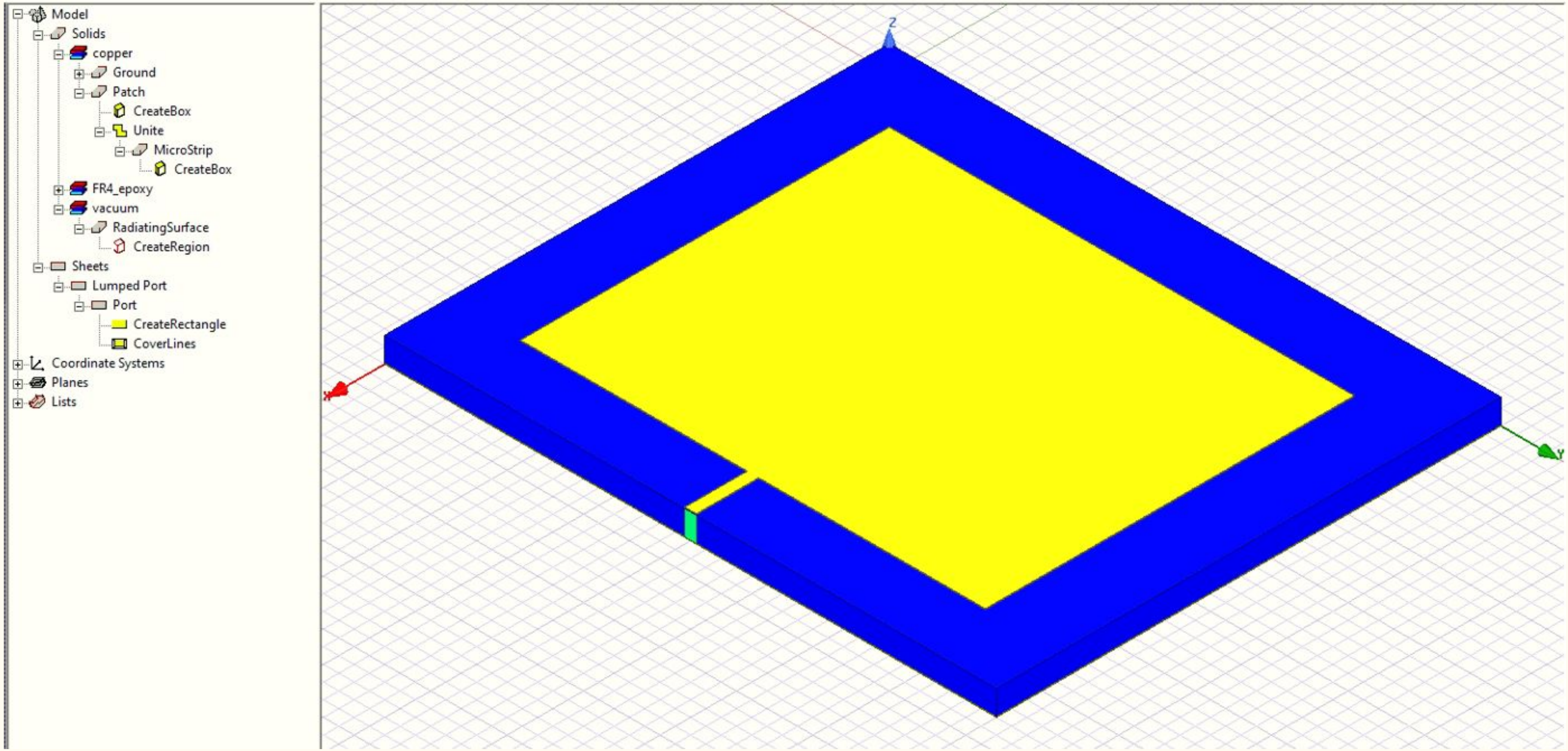
$$L_{eff} = \frac{c}{2f\sqrt{\epsilon_{reff}}}$$

$$\epsilon_{reff} = \frac{e_r + 1}{2} + \frac{e_r - 1}{2}\left[1 + \frac{12h}{W}\right]^{\left(-\frac{1}{2}\right)}$$

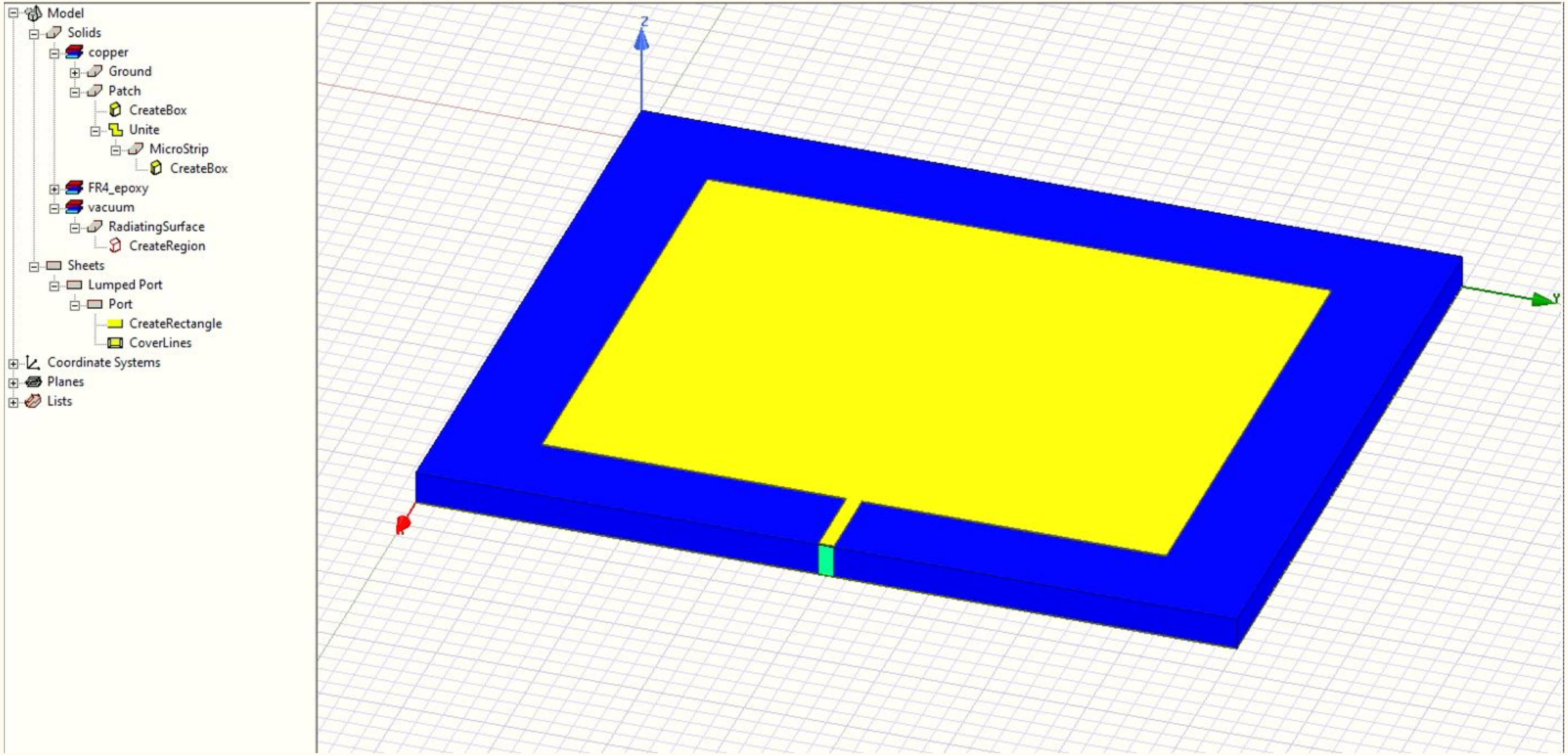
$$\Delta L = 0.412h\frac{(\epsilon_{\mathrm{reff}} + 0.3)(\frac{\mathrm{W}}{\mathrm{h}} + 0.264)}{(\epsilon_{\mathrm{reff}} - 0.258)(\frac{\mathrm{W}}{\mathrm{h}} + 0.8)}$$

where ‘h’ is the length of substrate.

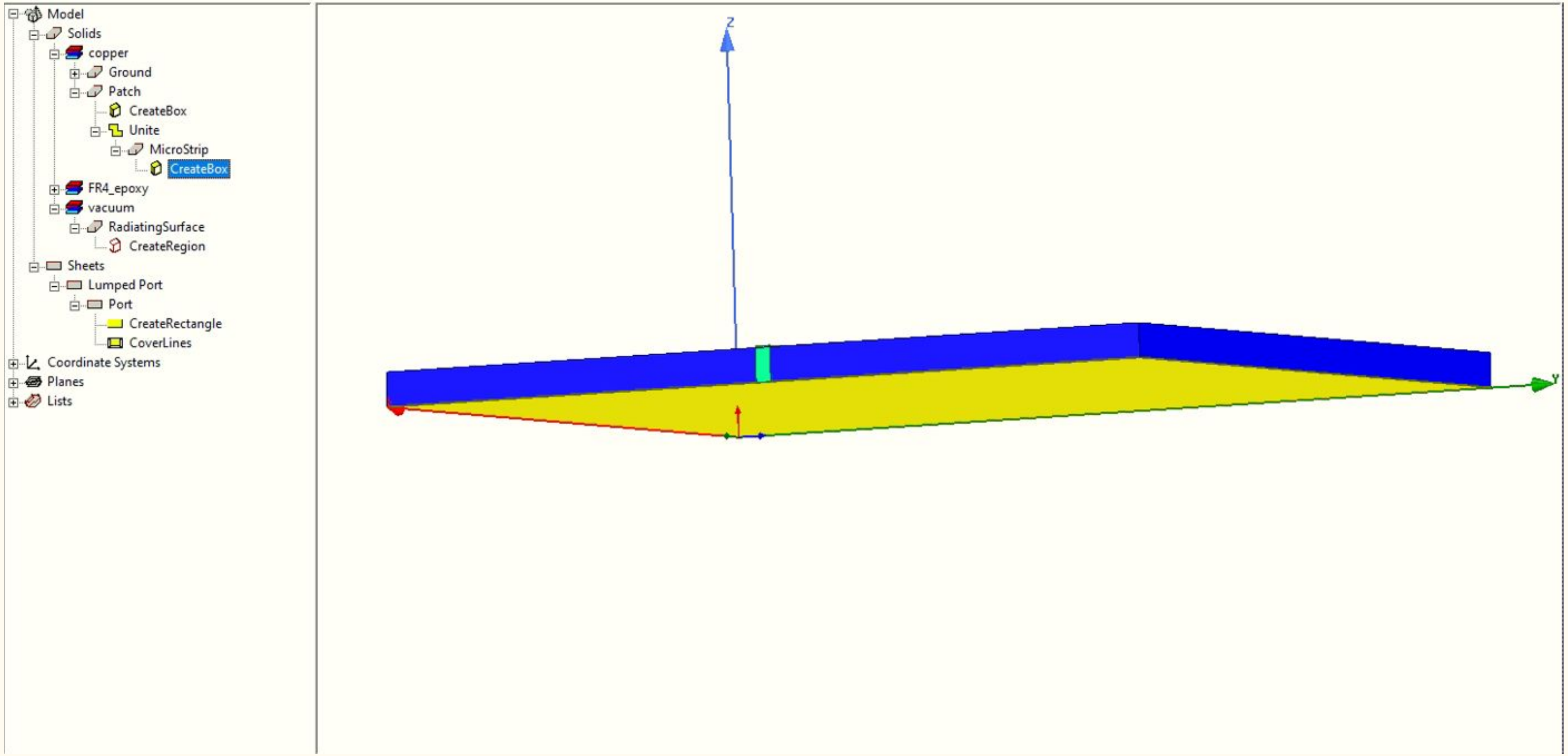
Antenna Diagram



Antenna Diagram



Antenna Diagram



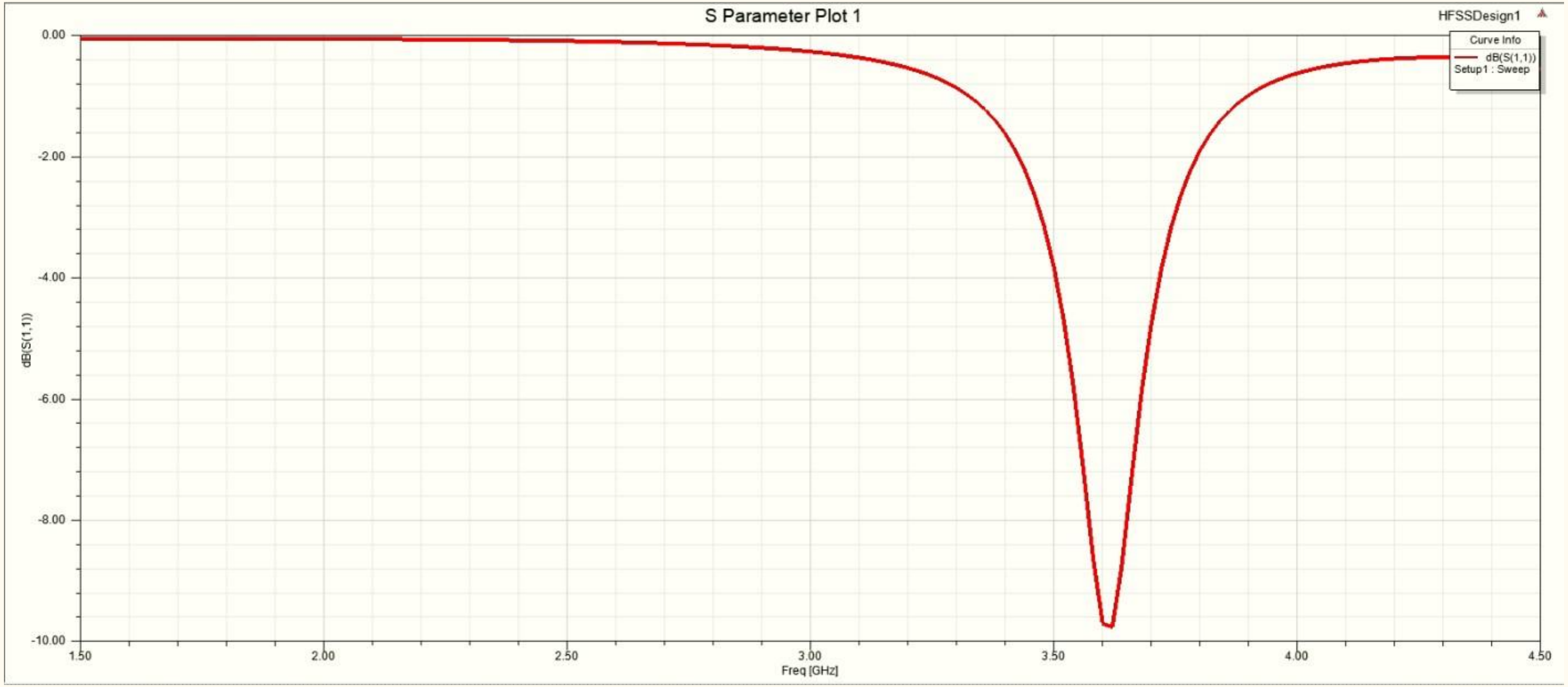
S(1,1)-Parameter Plots

S-Parameters are complex matrix that show Reflection/Transmission Characteristics (Amplitude/Phase) in frequency domain. The numbering conventions for the S-Parameters plots are such that the first number following S represents the ‘port’ where the signal emerges; The second number indicates the ‘port’ where the signal is applied.

Hence, S(1,1) indicates that the input and the output ports are the same.

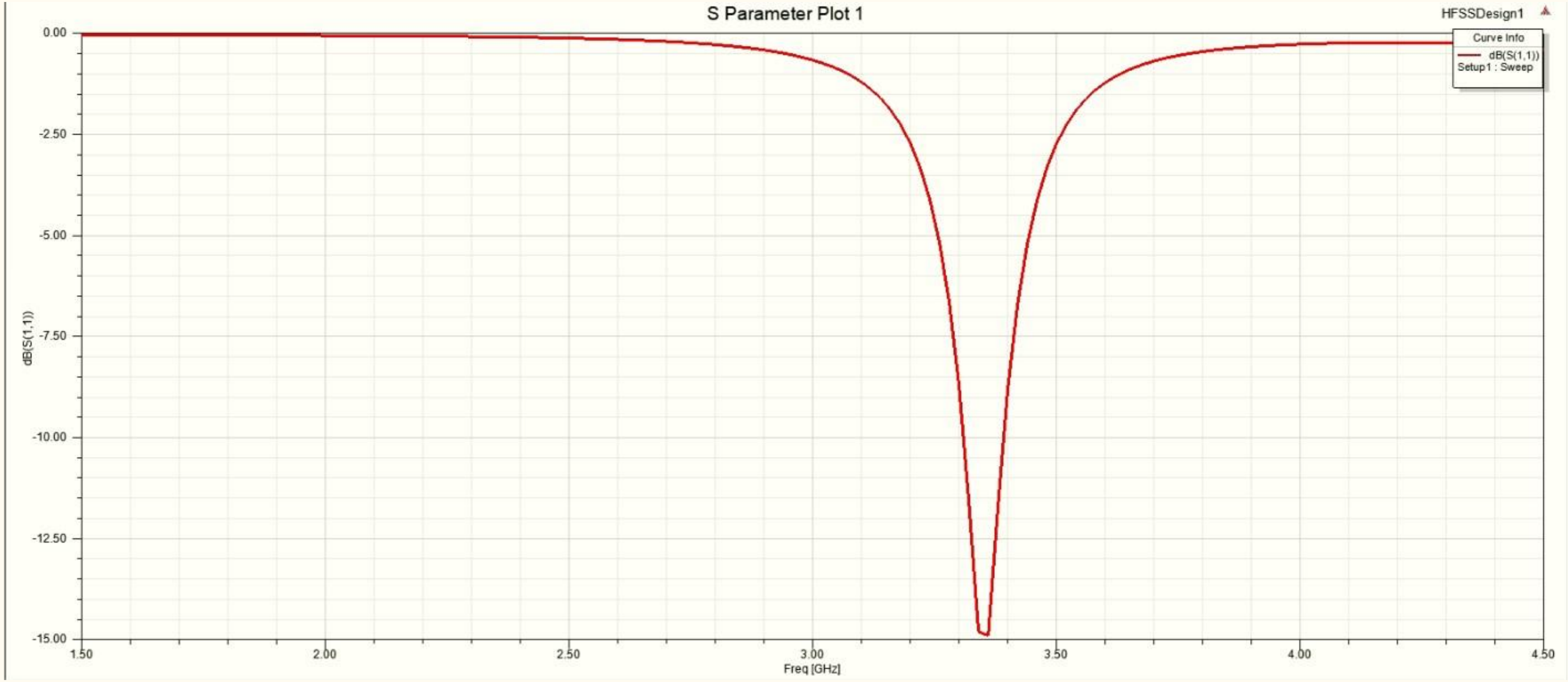
S-Parameter Plots

Patch Length = 19.4 mm



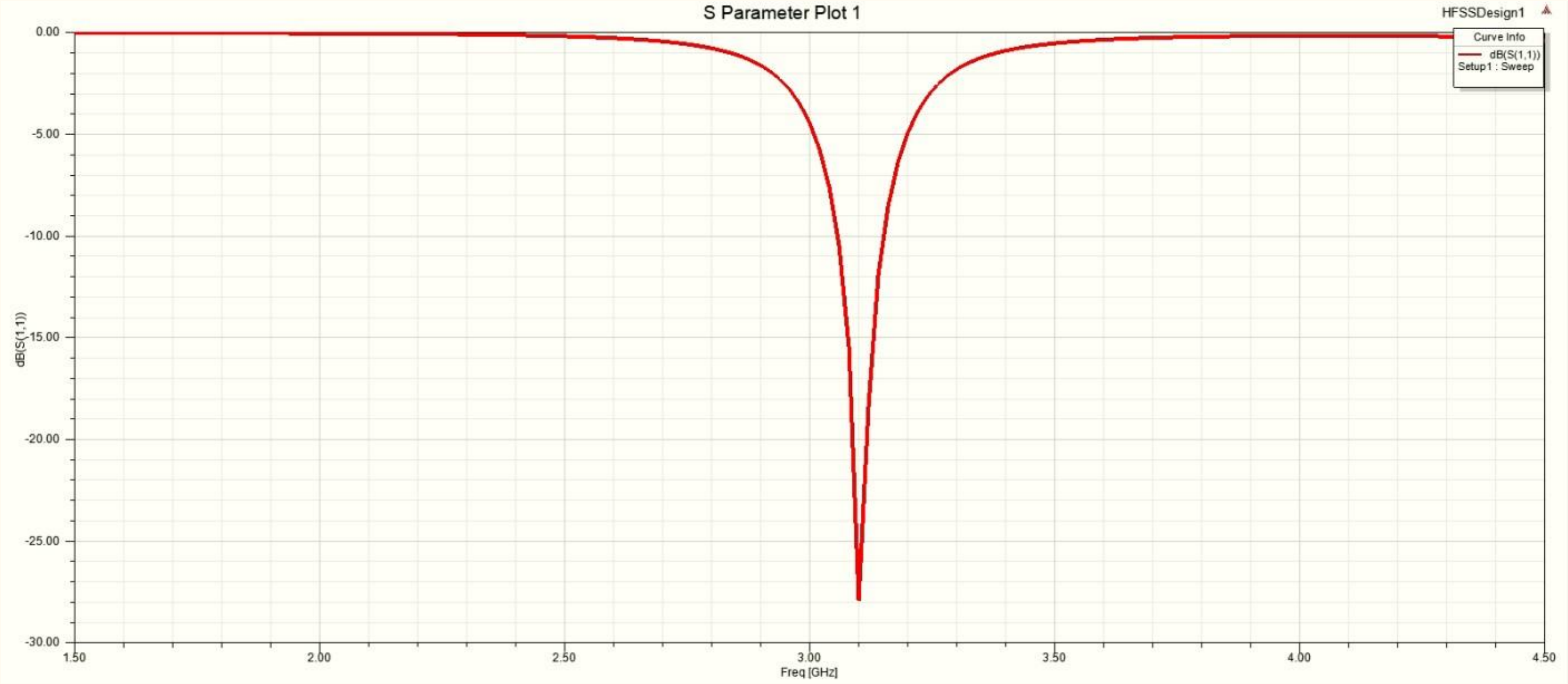
S-Parameter Plots

Patch Length = 21.4 mm



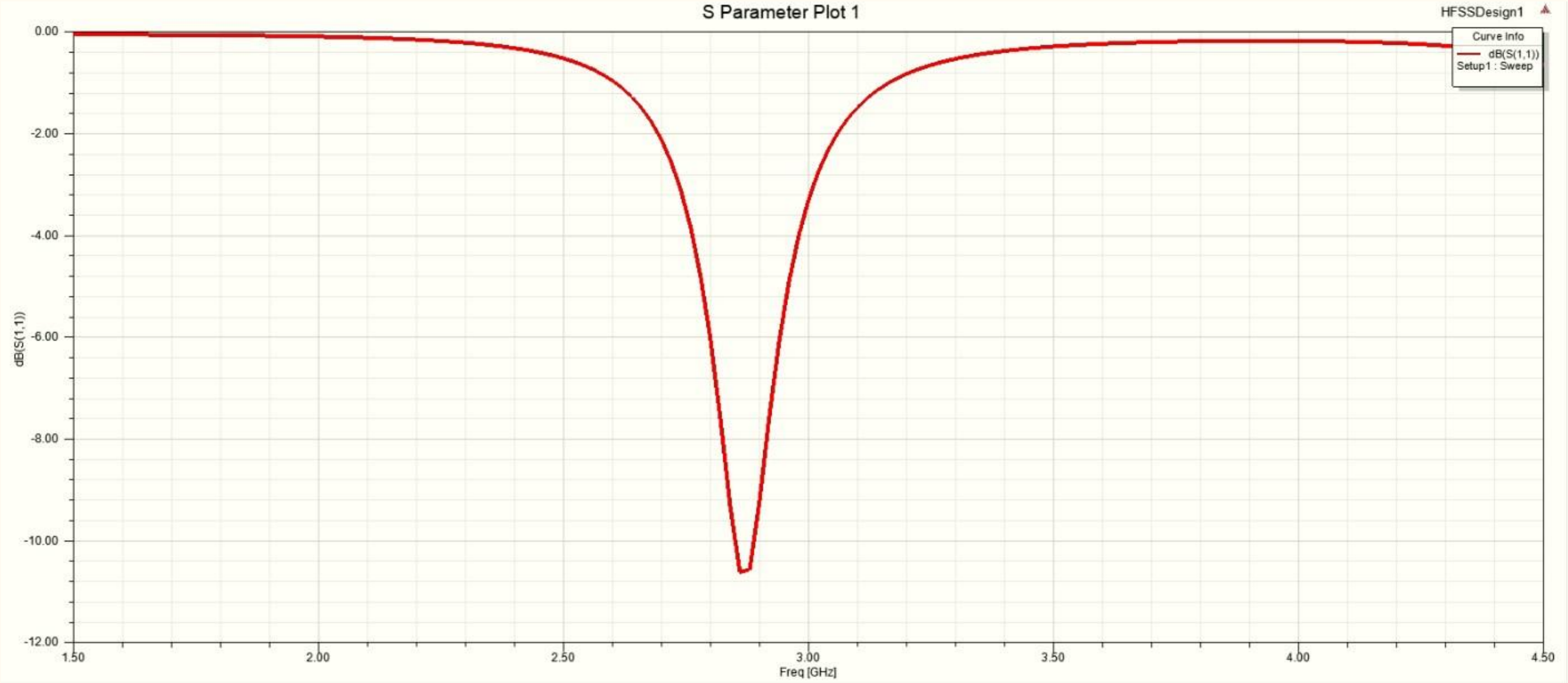
S-Parameter Plots

Patch Length = 23.4 mm



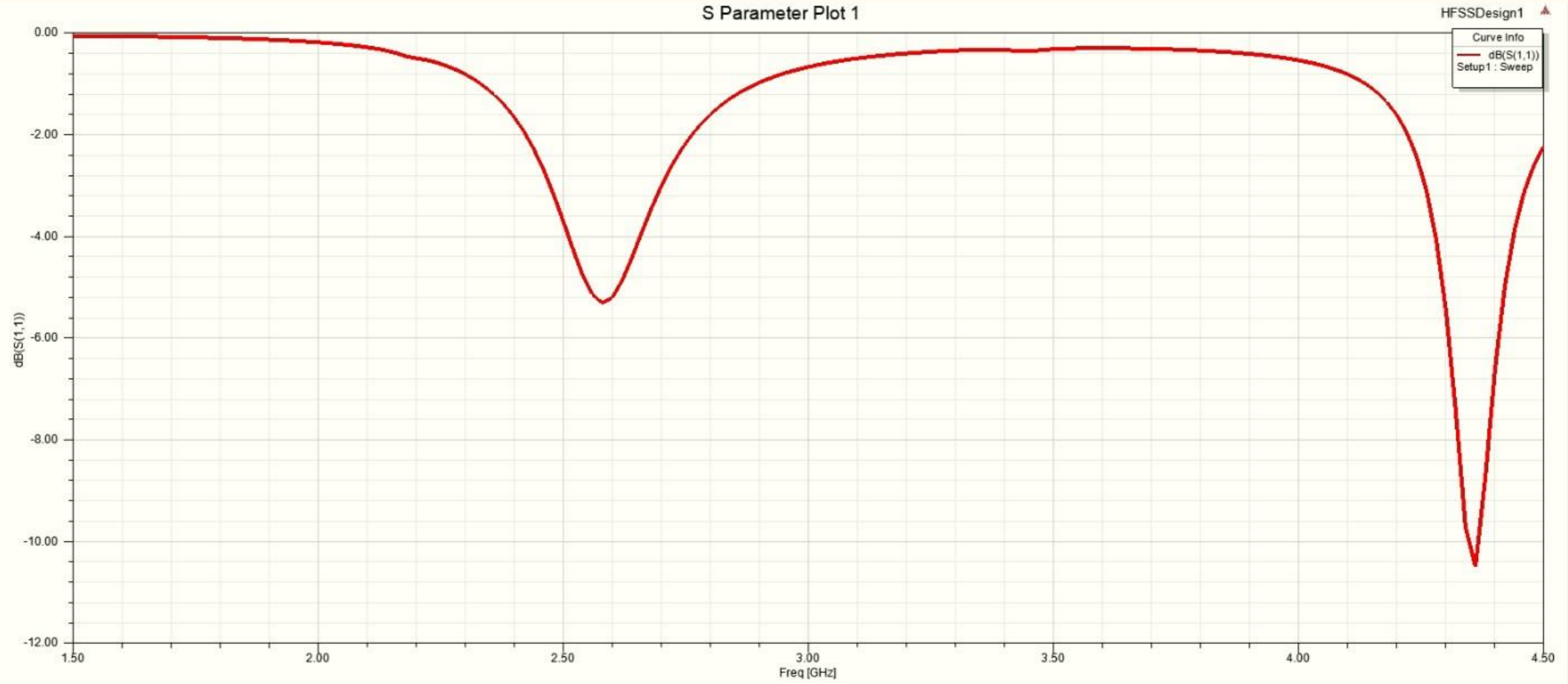
S-Parameter Plots

Patch Length = 25.4 mm



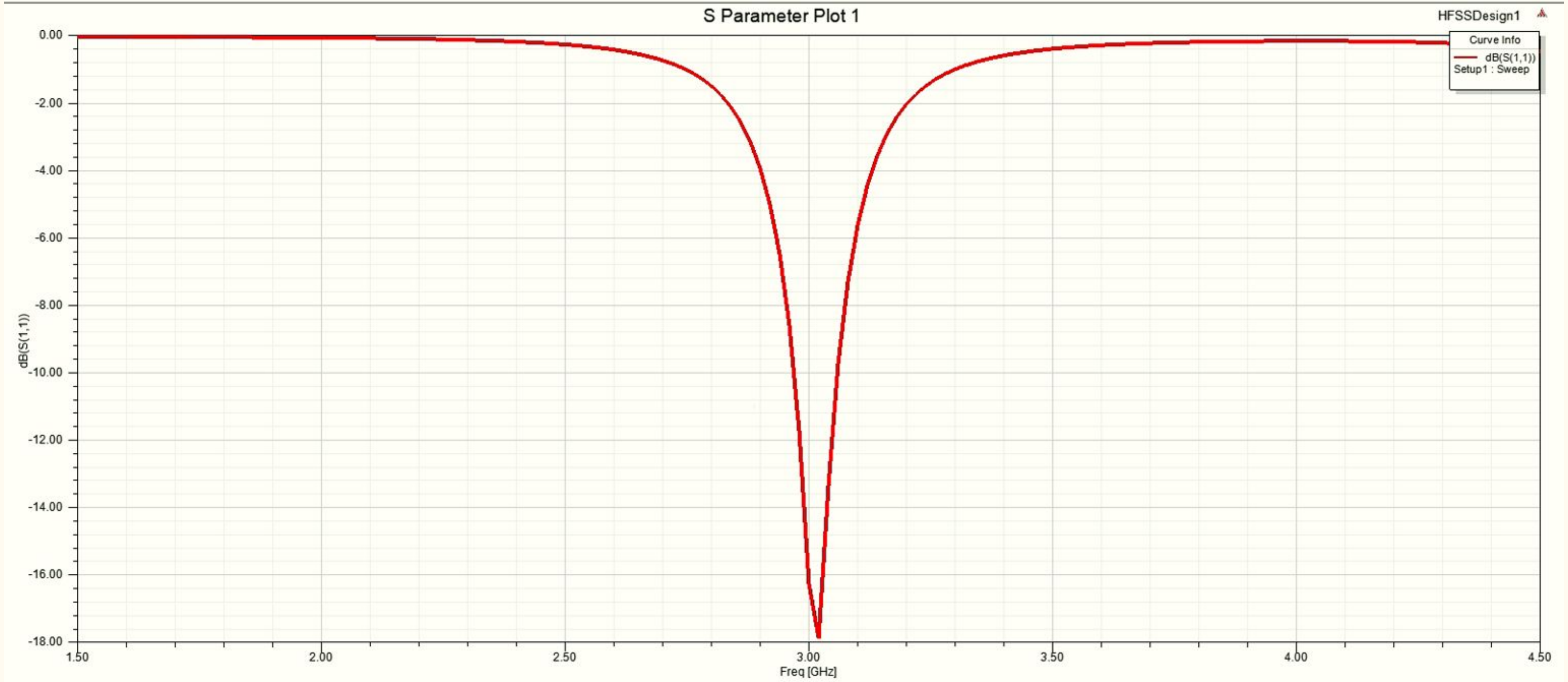
S-Parameter Plots

Patch Length = 27.4 mm



S-Parameter Plots

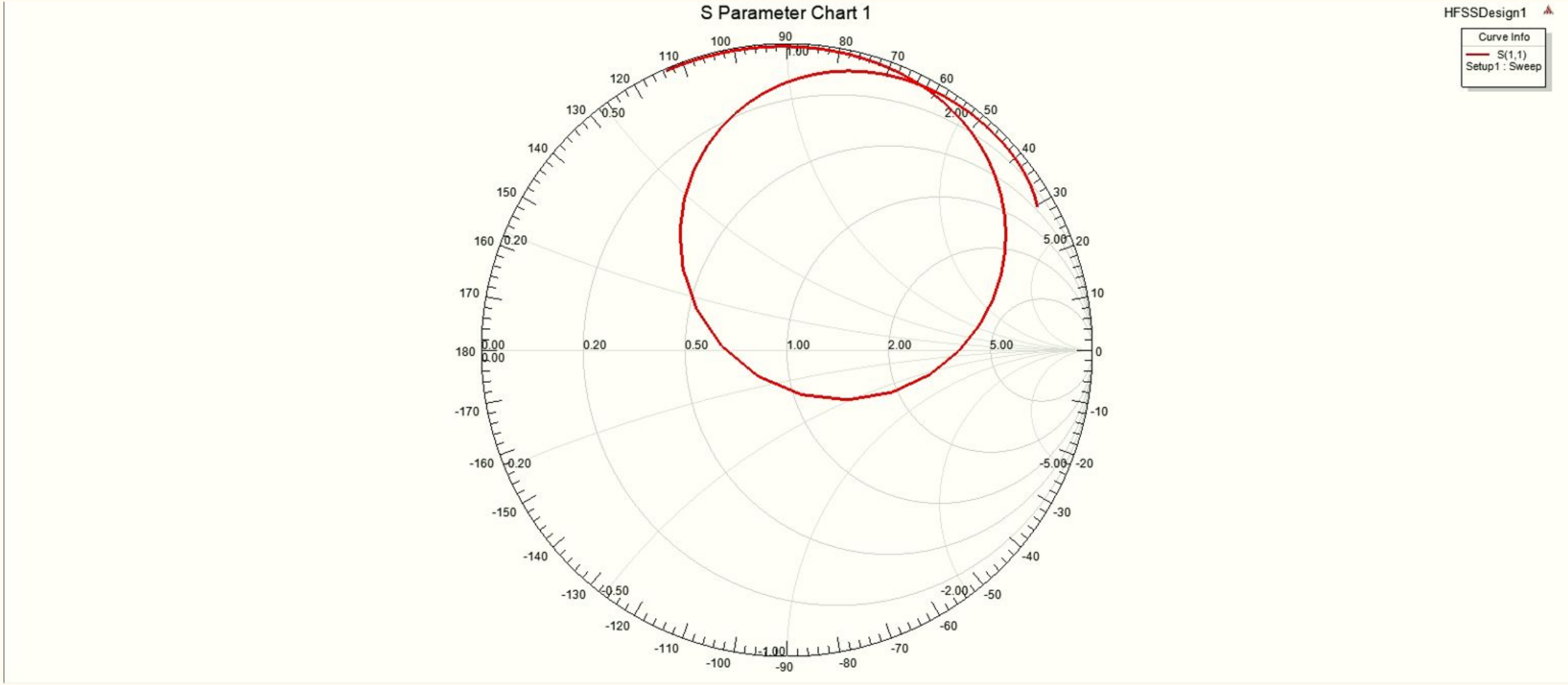
Patch Length = 24.12 mm **(Most optimized)**



Smith Chart

Smith Chart represents the plot of complex reflection coefficients overlaid with a normalized characteristic impedance (1 ohm) and/or admittance (1 mho/seimen) grid. It can be used to depict various parameters such as Reflection coefficients, Scattering parameters, Constant gain contours etc.

Smith Chart


S Parameter Chart 1
HFSSDesign1
Curve Info
S(1,1)
Setup1 : Sweep

3D Polar Plot

3D Polar Plot is used for visualizing functions defined on a disk. The data provided for the plot appears to be sampled on a spherical grid. Hence, in order to visualize the data, we intend to represent it as a surface to read it properly.

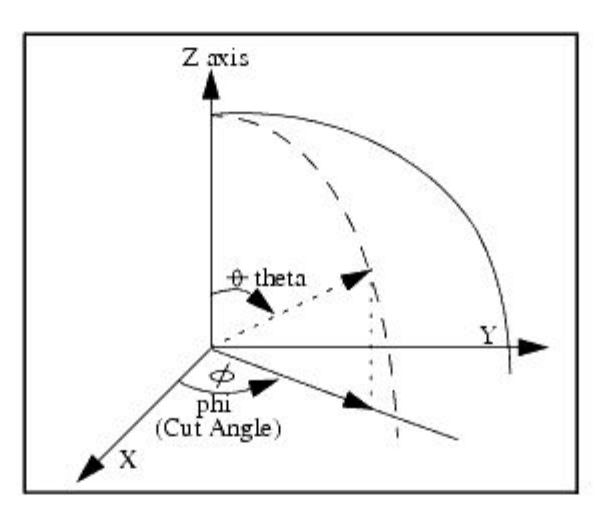
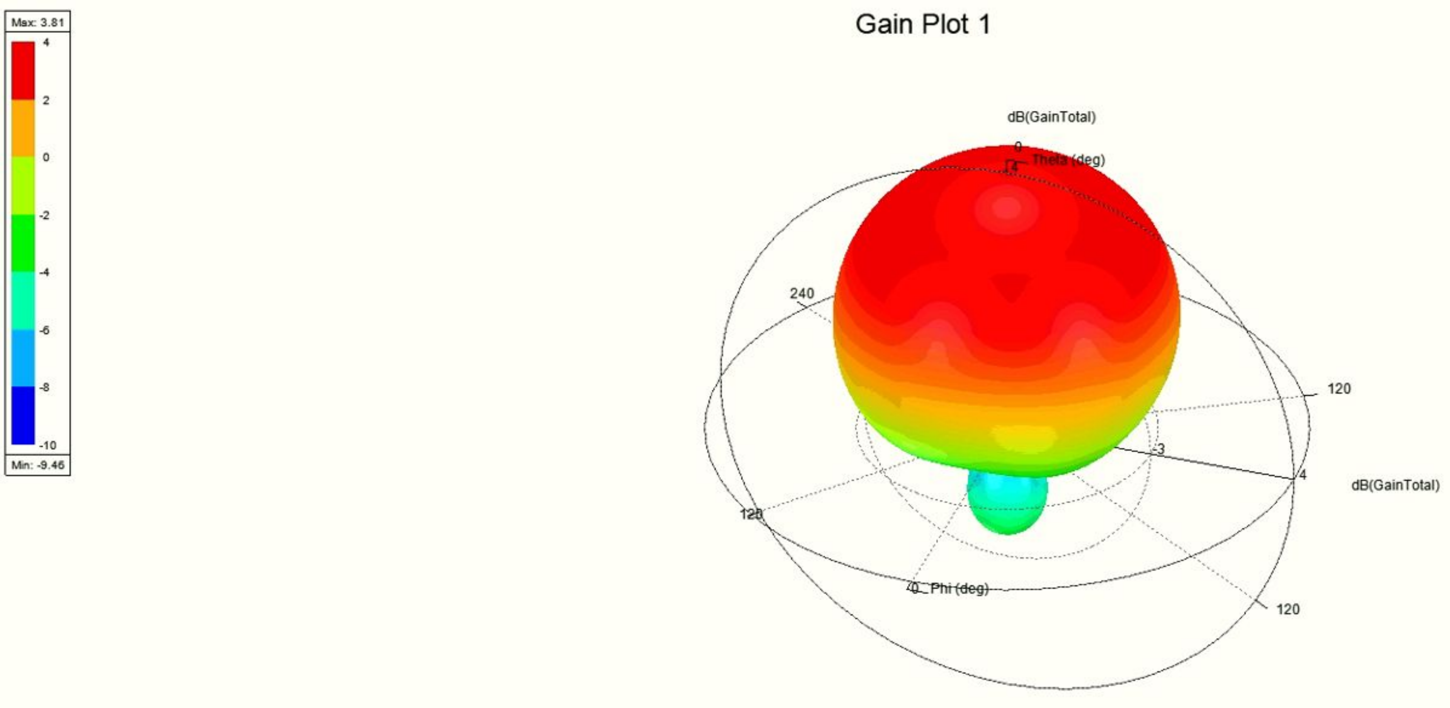


Figure depicting the angles Phi ϕ and Theta θ

Far Field Plots: 3D Polar Plot

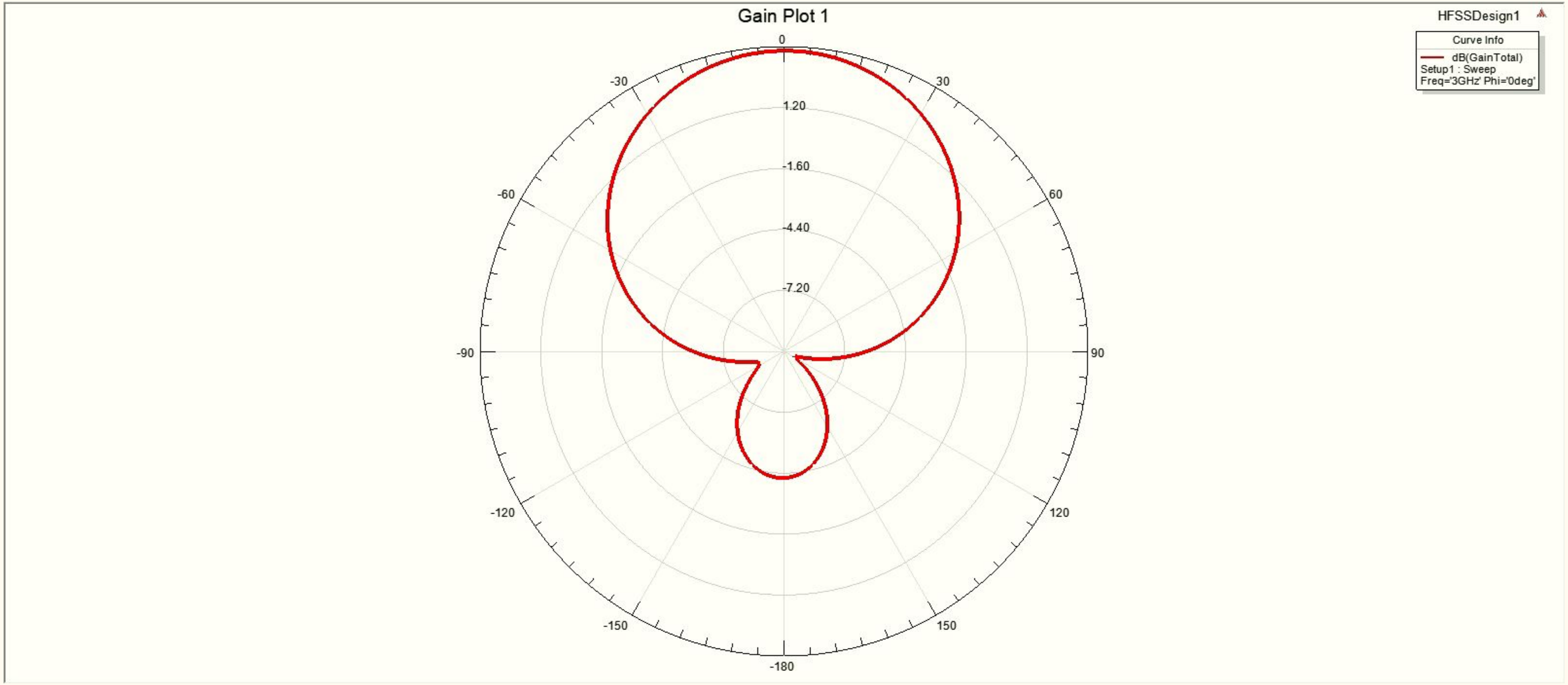


f = 3 GHz

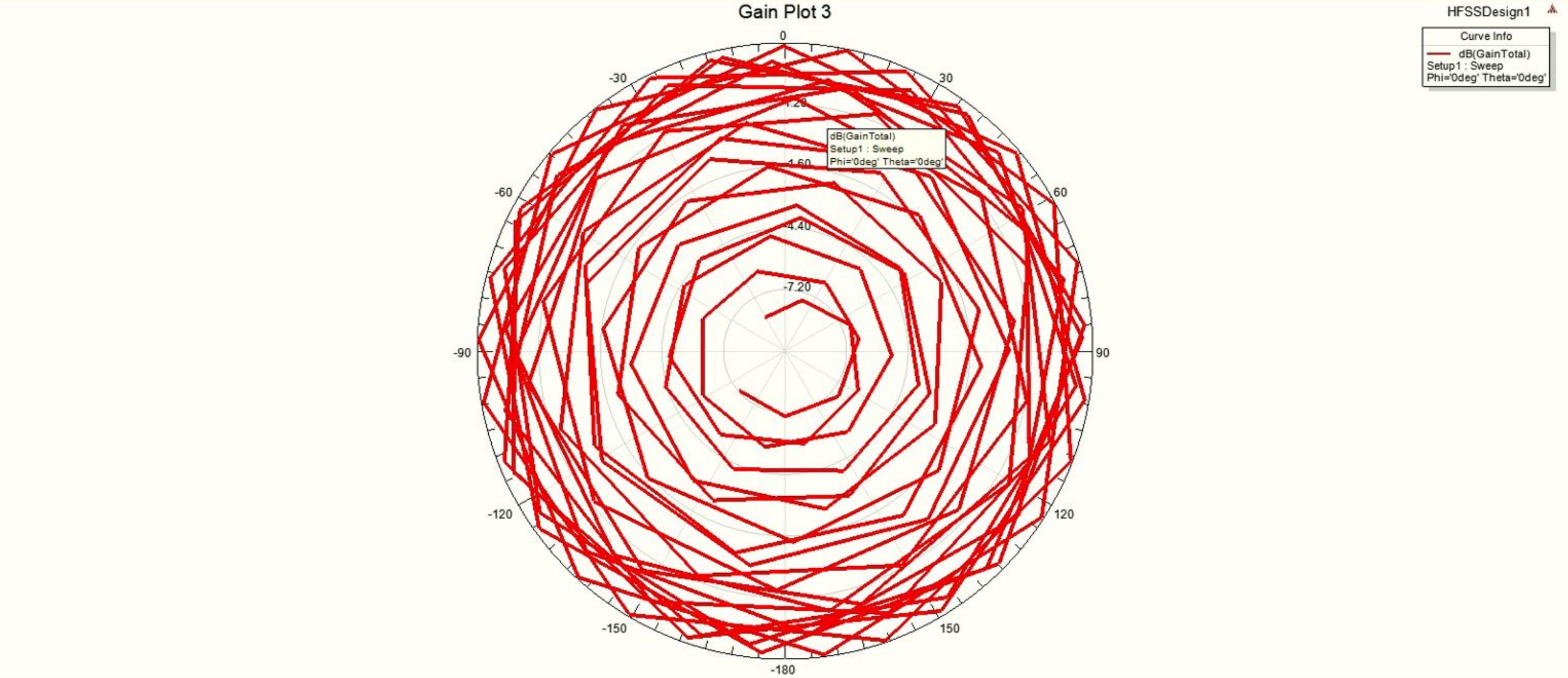
Radiation Plot

The energy radiated by an antenna is represented by the Radiation pattern of the antenna. Radiation Patterns are diagrammatically represented as the distribution of radiated energy into space, as a function of direction away from the said antenna.

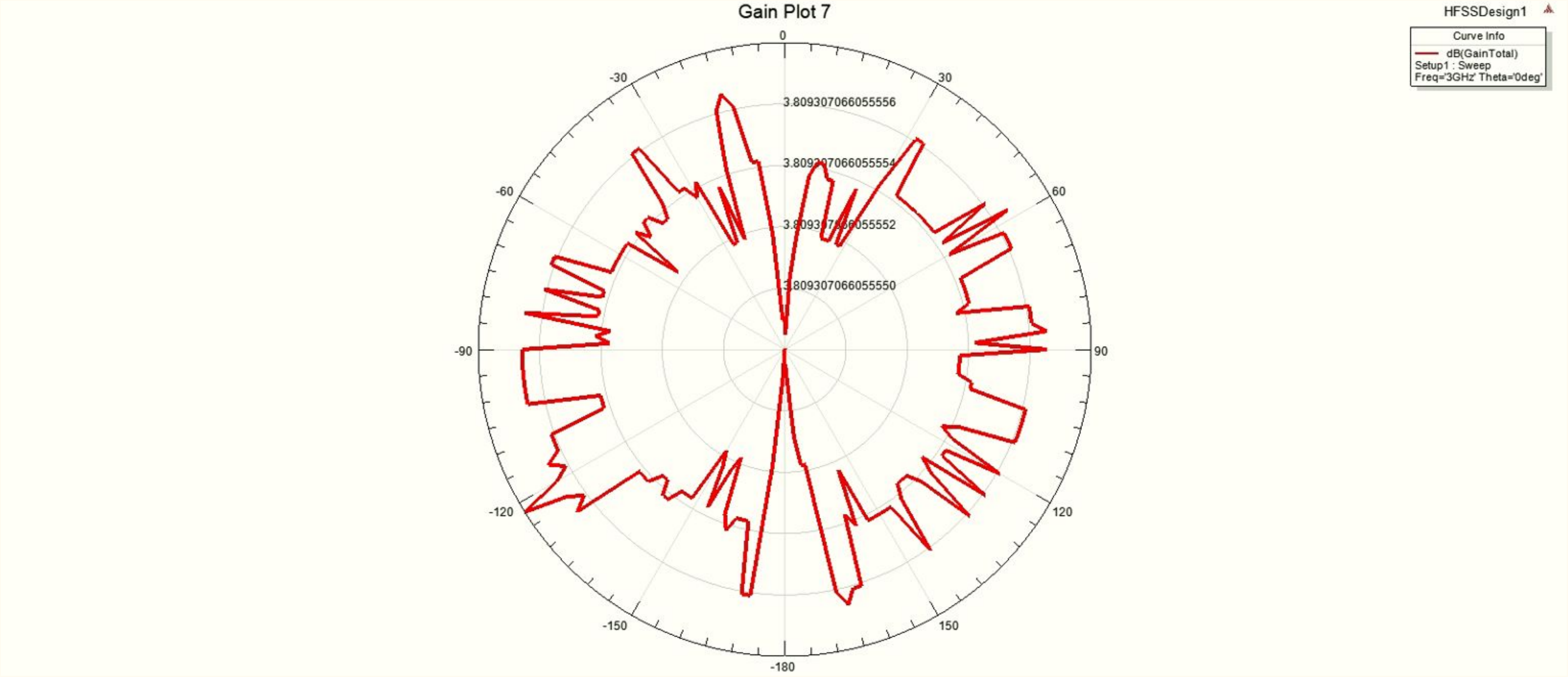
Far Field Plots: Radiation Plot - Theta Angle Sweep



Far Field Plots: Radiation Plot - Frequency Sweep



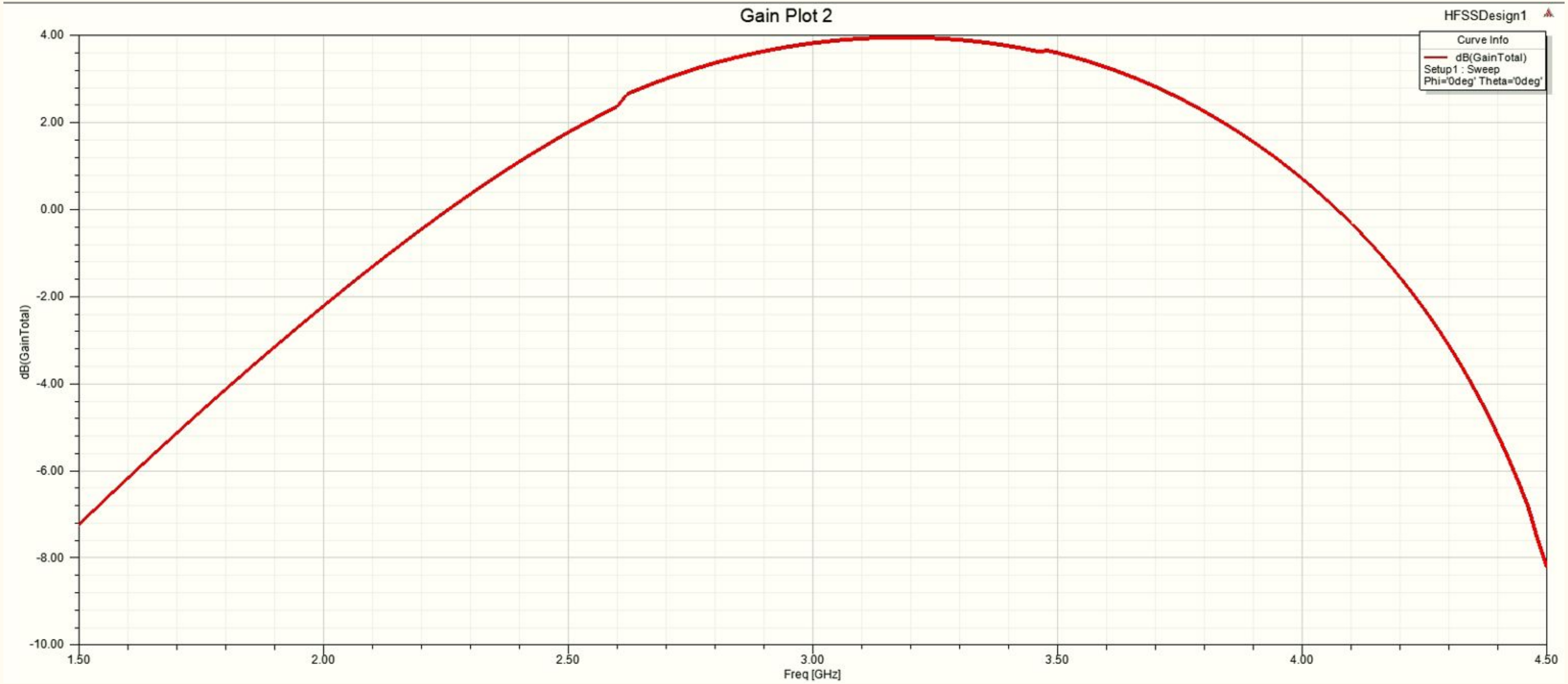
Far Field Plots: Radiation Plot - Phi Angle Sweep



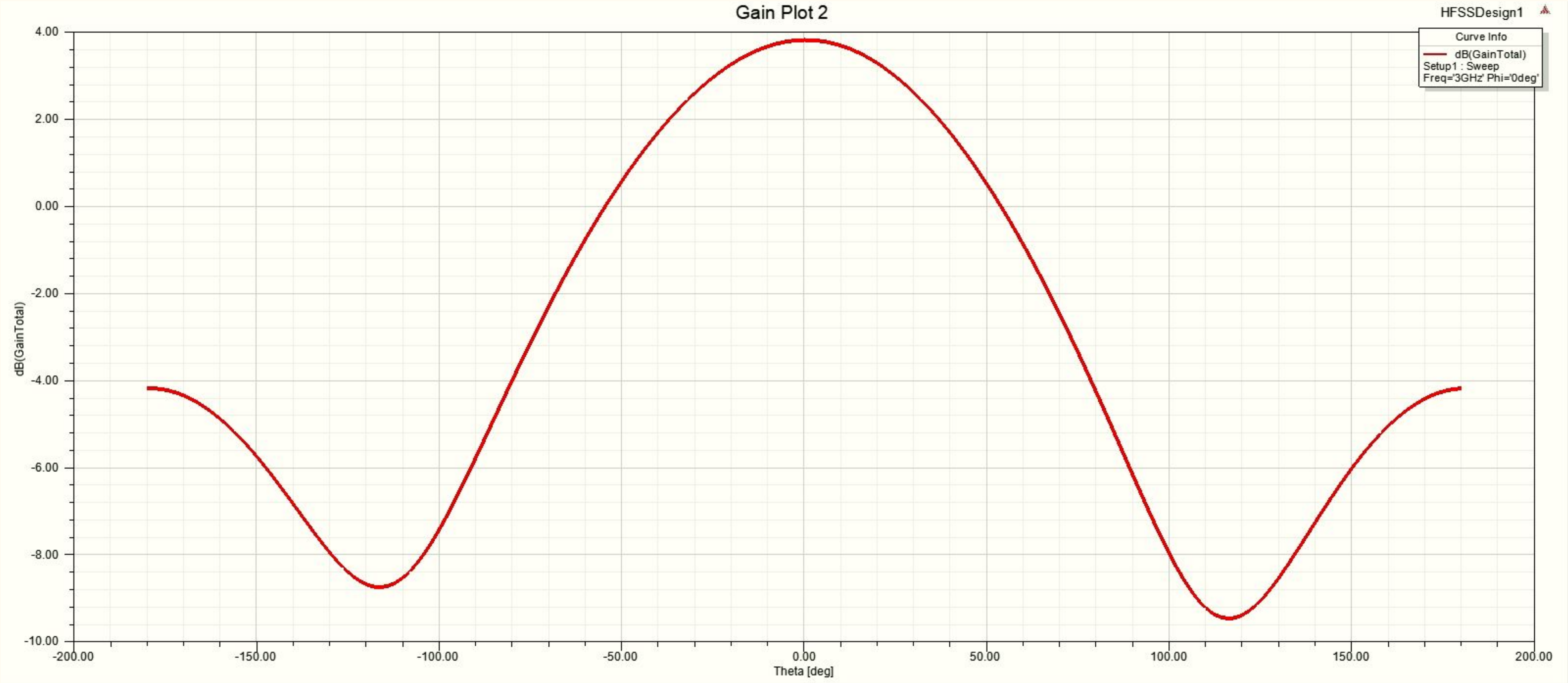
Total Gain

Antenna gain is defined as the maximum radiation intensity produced by the antenna compared to that given by a lossless isotropic radiator supplied with the same level of power. It is a key performance number which combines an antenna's directivity and electrical efficiency. In a transmitting antenna, the gain describes how well the antenna converts input power into radio waves headed in a specified direction. In a receiving antenna, the gain describes how well the antenna converts radio waves arriving from a specified direction into electrical power.

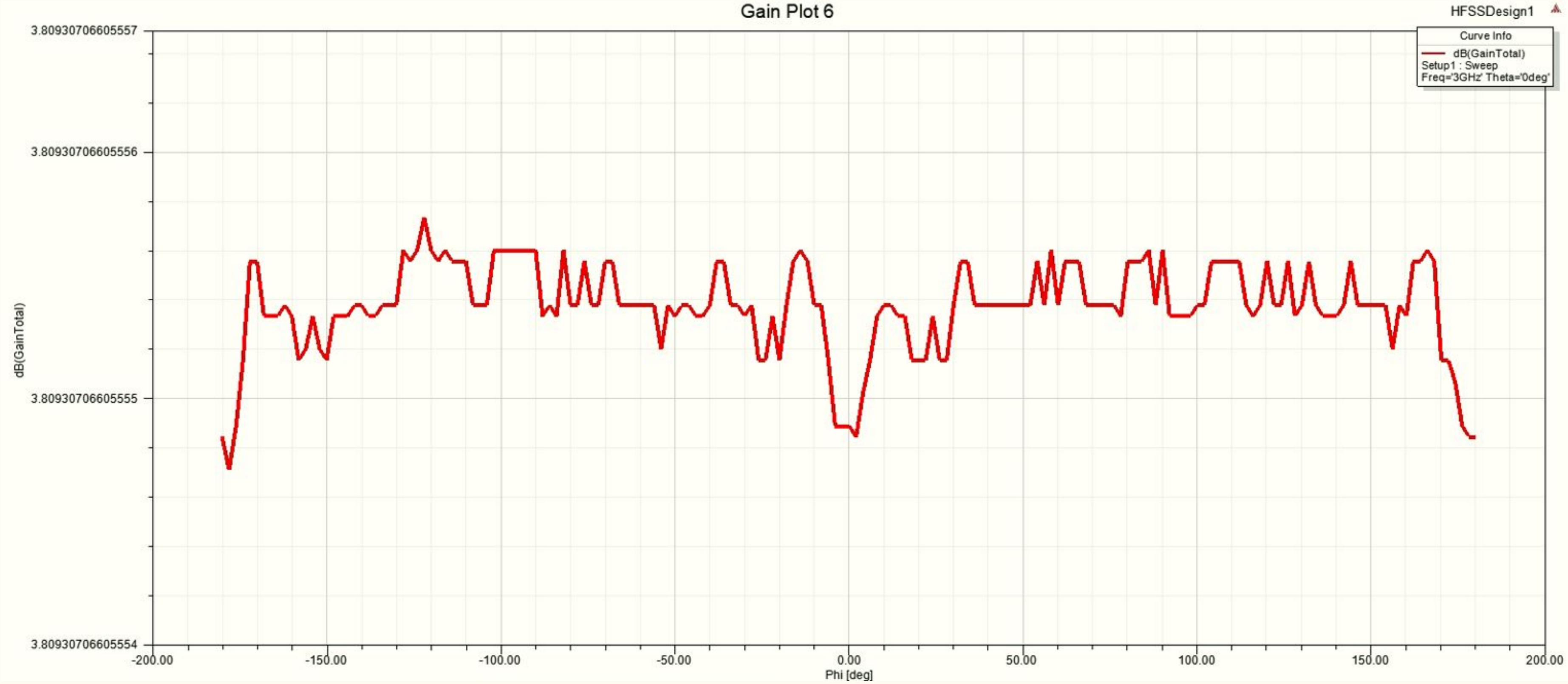
Far Field Plots: Total Gain Plot - Frequency Sweep



Far Field Plots: Total Gain Plot - Theta Angle Sweep



Far Field Plots: Total Gain Plot - Phi Angle Sweep



Future Scope

Microstrip patch antennas have been of interest for a long time due to their low profile, low cost, easy printability, and fabrication, as well as the capability of being embedded within other devices. However, there are many disadvantages associated to it, such as low gain and narrow bandwidth.

We can Increase Mircrostrip Patch Antenna’s Bandwidth by:-

- Increasing substrate height
- Including partial ground

Also, the optimized response was obtained by using parameters slightly different from the theoretical ones. This can be due to various extrinsic factors and material properties, which must be considered while designing the same.

Experimental radiation patterns of the constructed antenna could
not be obtained and compared with the theoretical patterns. Though we were able to simulate patch antennas, but were unable to fabricate one and compare the practical and simulated results.

Conclusion

- The simulation of microstrip patch antenna is carried out.
- The various methodology necessary for simulation are done.
- The substrate and patches are created.
- The radiation pattern are observed. Rectangular patch antenna at 3 GHz is designed on Ansys HFSS.
- The designed antenna is suitable for mobile communication, cell phone antennas etc.
- The simulation gave results good enough to satisfy our requirements to fabricate it on hardware which can be used in various applications.

References

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Thank You