Electromagnetic Modeling of Radar Cross Section (RCS) Using CST

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Project Report for

ECE432: Radar System

1. Objective:

- **Model Radar Cross Section(RCS) of a cylinder:**

    a. Generate results for RCS versus aspect angle (azimuth, elevation).

    b. Generate results for RCS versus frequency.

    c. Generate results for RCS versus different ratios of lengths/diameters of the cylinder.

    d. Generate results for RCS versus different polarization.

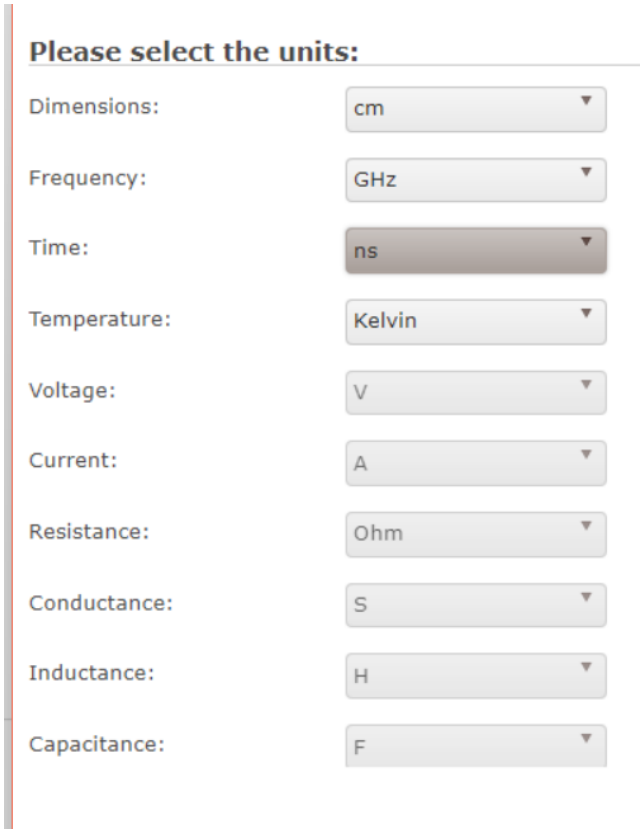
    e. Generate results for RCS for metallic cylinder versus dielectric cylinder (FR4).

2. Methodology:

- Software used:
    1. CST studio
    2. Matlab

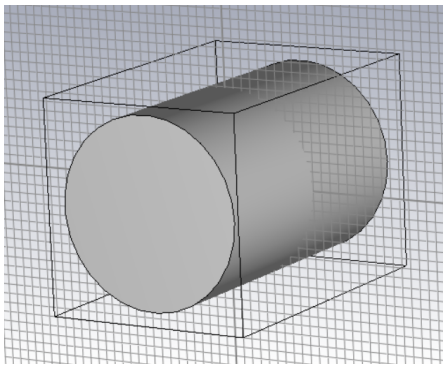
- Important Values:
  Frequency Range: 1GHz to 12GHz
  For parts a,b: radius of cylinder = 30cm and length of cylinder = 30cm.
  For parts c,d: radius of cylinder = 10cm and length of cylinder = 30cm.

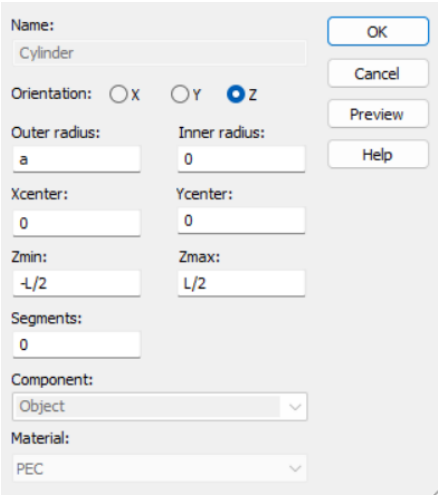
- Units:



- Object:

For this project, it was given that we have to generate results for the RCS of a cylinder. Hence we used the cylinder plotter in CST to make a cylinder with a radius “a” and length “L” with the following properties.





- Parameters List:

Parameter List

Name	Expression	Value	Description
alpha	= -90	-90	Rotation angle of E-field Vector (r...
theta	= 90	90	spherical angle of incident plane ...
phi	= 180	180	spherical angle of incident plane ...
a	= 10	10	radius
L	= 30	30	Length of cylinder

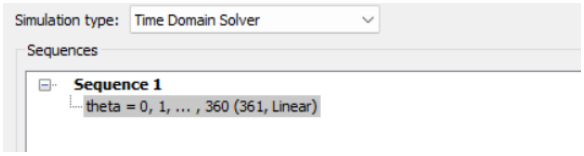
<new parameter>

- Setup the Simulation:

First, we set up the Farfield monitor with a frequency of 1GHz. Setting the polarization to linear and the parameter value according to the above data in the parameter list.

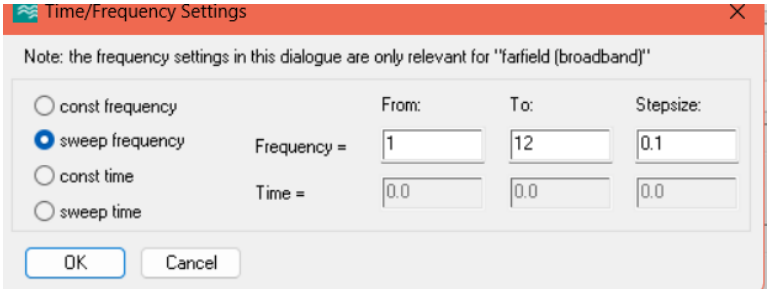
- Running the simulation:

a. Generate results for RCS versus aspect angle (azimuth, elevation).
For part a, we sweep the theta value from 0 to 360 and calculate the RCS of the cylinder for each theta which is the Azimuth and plot the data in Matlab.



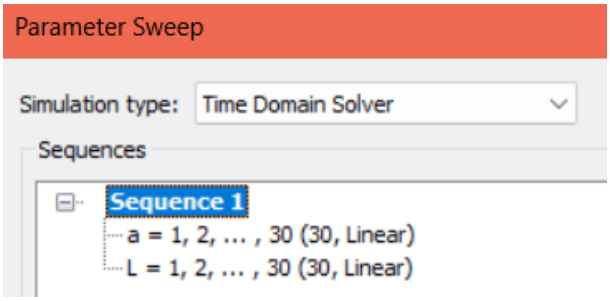
Then we did the same for the Elevation and sweep phi from 0-360 and plotted the data in Matlab.

b. Generate results for RCS versus frequency.
For part b, firstly, we created a new Farfield monitor with transient broadband and added a result template of Farfield results with given data.



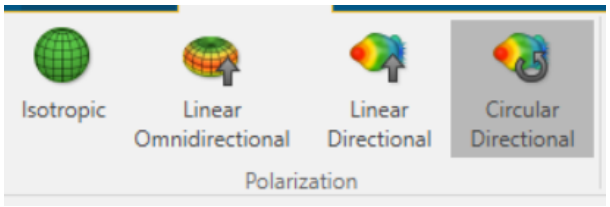
After doing this, we run the simulation and obtain the data of RCS of cylinders of different sizes vs frequency. And finally, generated graphs using Matlab.

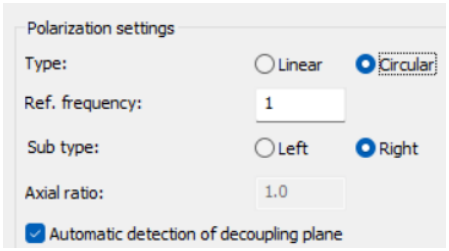
c. Generate results for RCS versus different ratios of lengths/diameters of the cylinder.
To obtain the result for part c, firstly, we simulated the RCS of the cylinder for different values of Length(using sweep), making the radius constant. Then we simulated the RCS of the cylinder for different values of Radius(using sweep)., making the length constant. And finally, generate results for different ratios of radius and length (using sweep).



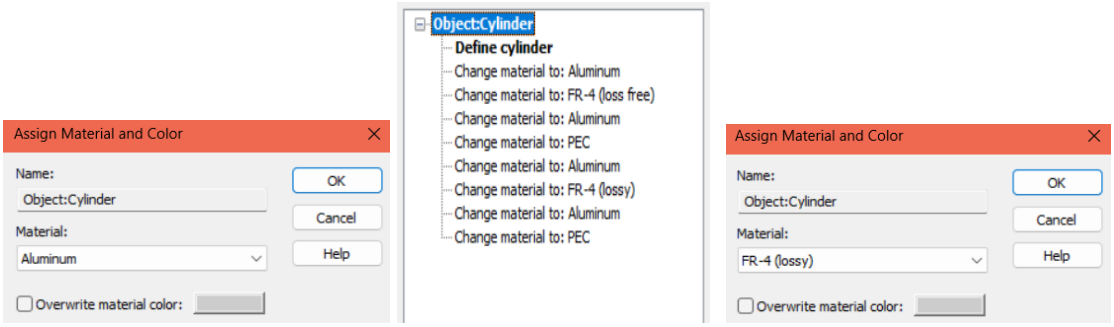
Then we plotted the data obtained on Matlab.

d. Generate results for RCS versus different polarization.
Till now, we have generated data for linear polarization. Now we will use the polarization tab in the Farfield plot and polarization setting in the "Plane wave" in the navigation tree, toggle around different settings, obtain the data, and plot the final graph on Matlab.





e. Generate results for RCS for metallic cylinder versus dielectric cylinder (FR4).
For the final part, we need to change the cylinder material to a metallic component and FR-4, which is dielectric and run simulations to get the RCS values.

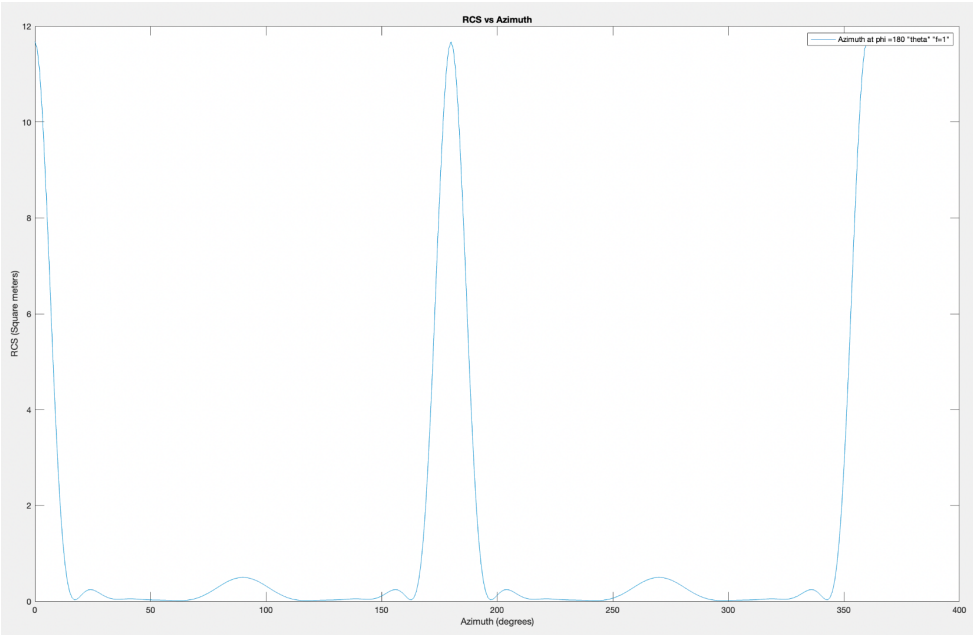


Finally, plot the required graph using Matlab and write overall conclusion.

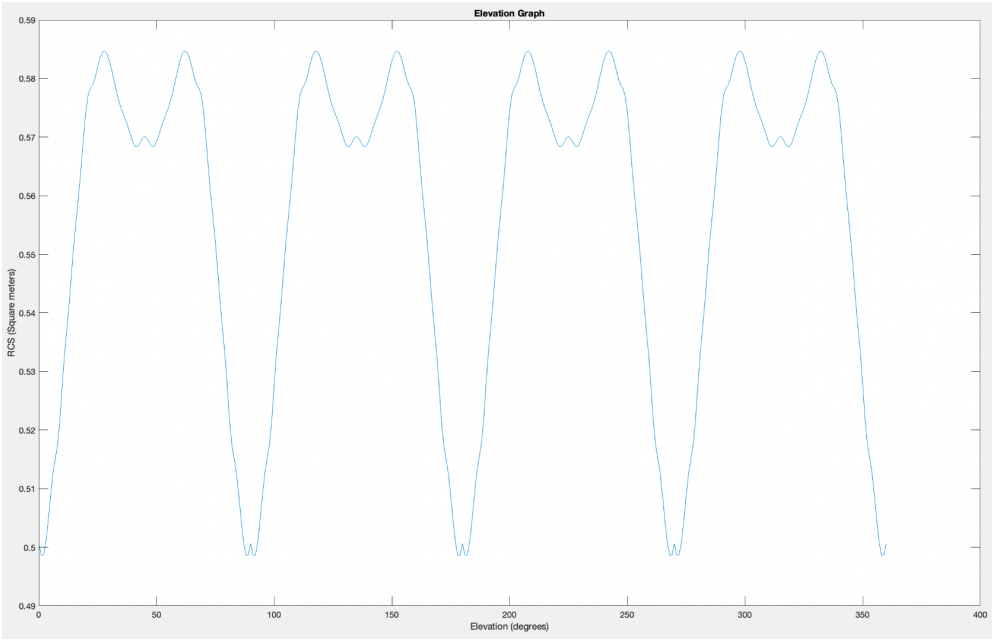
3. Result:

a. Generate results for RCS versus aspect angle (azimuth, elevation).

- RCS vs Azimuth:



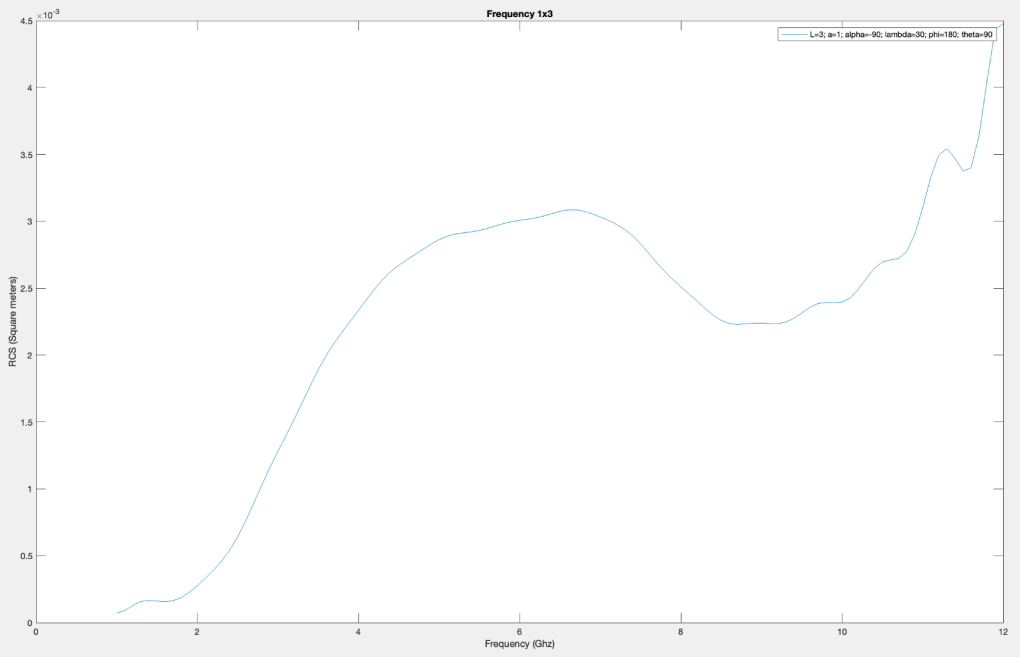
- RCS vs Elevation:



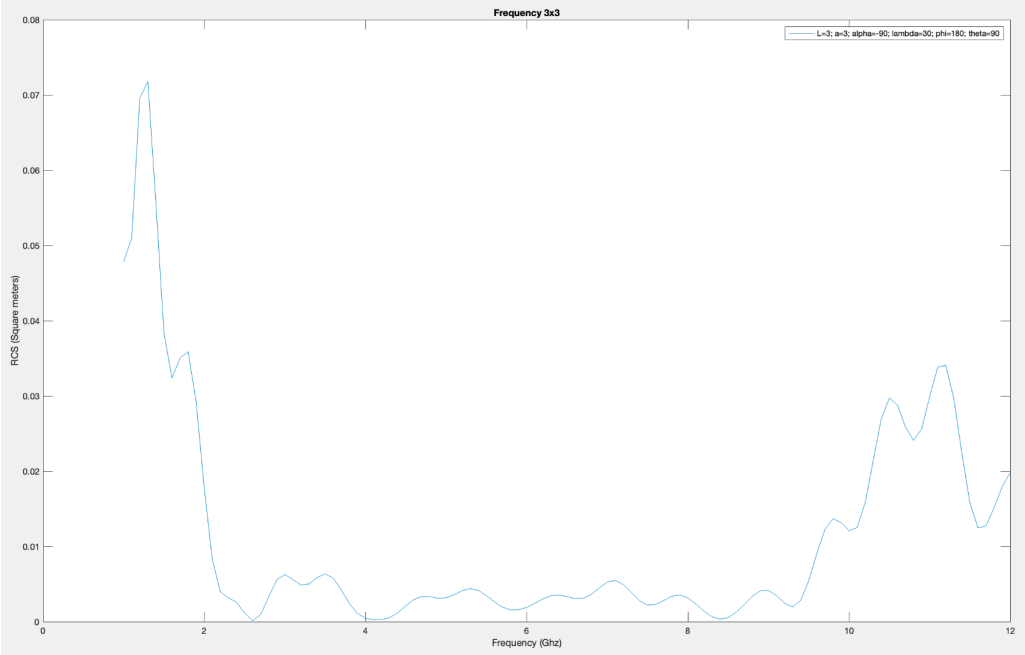
b. Generate results for RCS versus frequency.

RCS vs Frequency for:

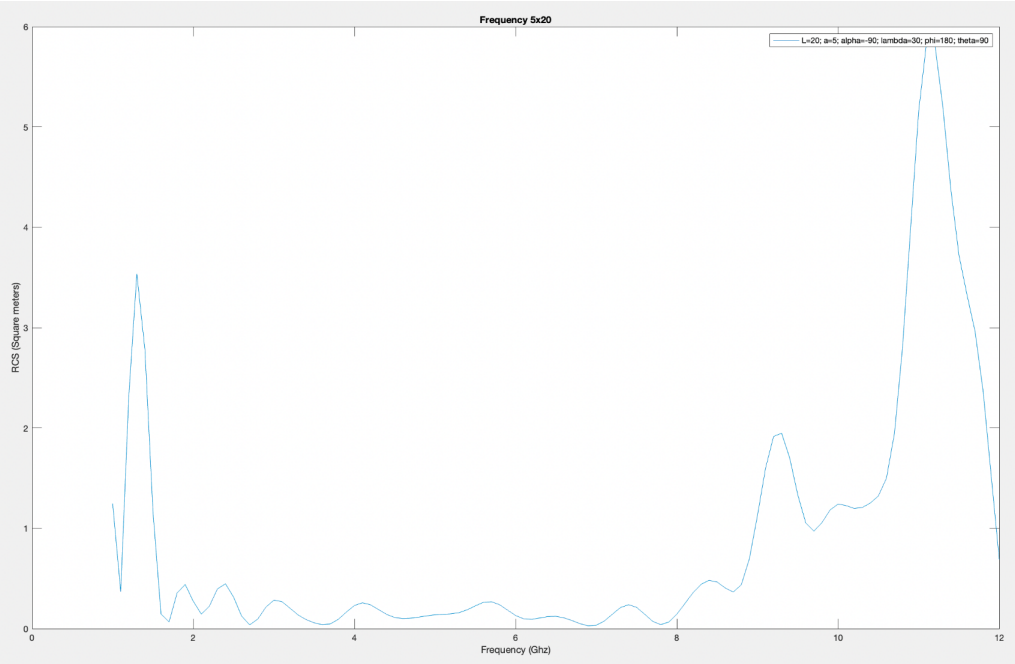
- Radius = 1 cm and Length = 3 cm:



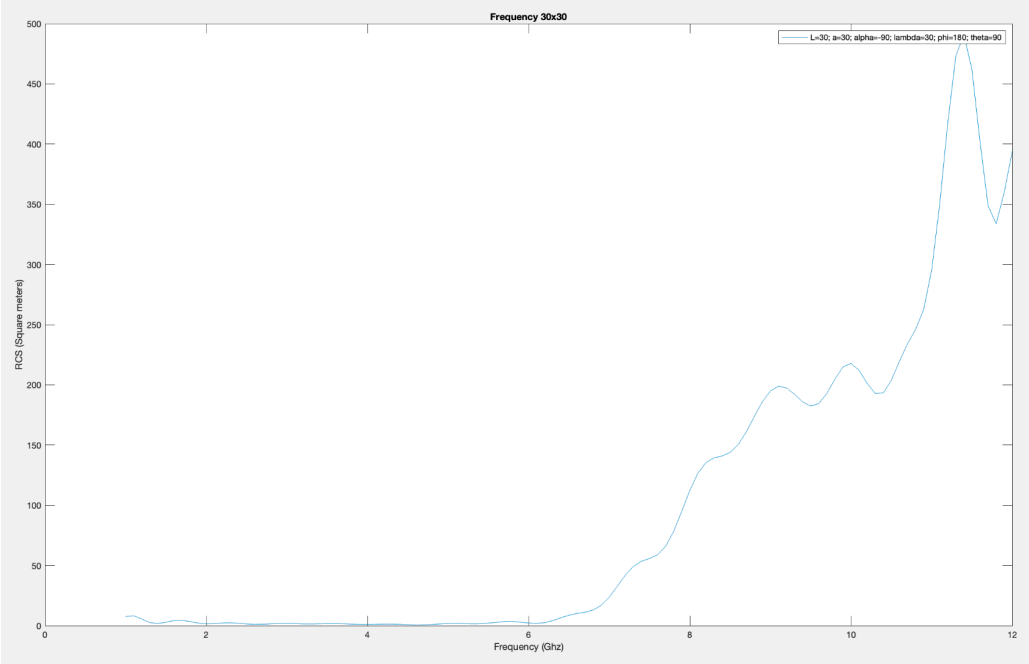
- Radius = 3 cm and Length = 3 cm:



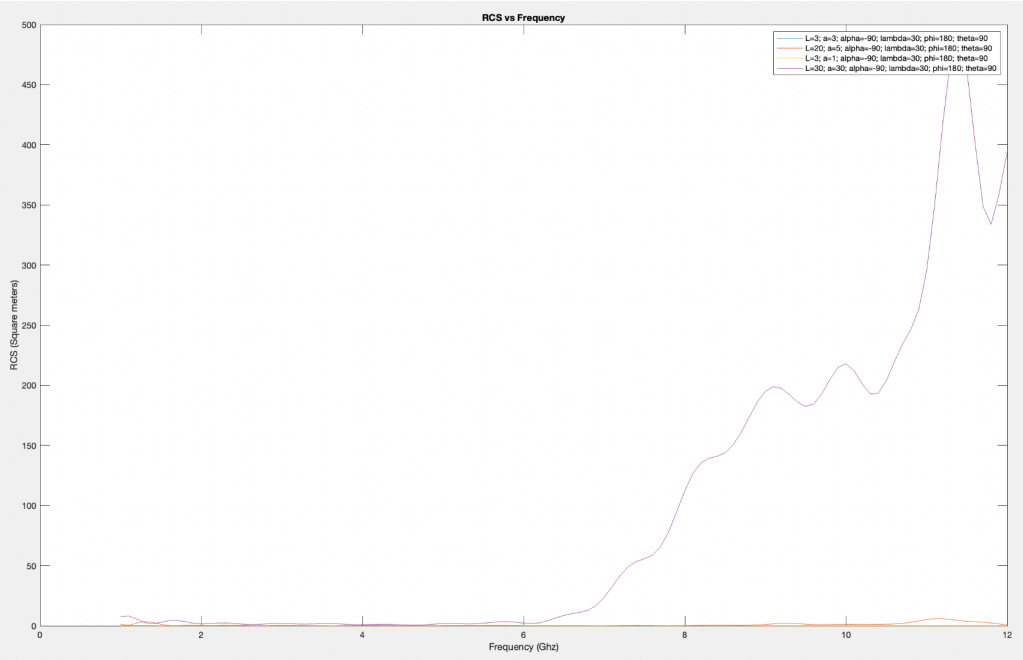
- Radius = 5 cm and Length = 20 cm:

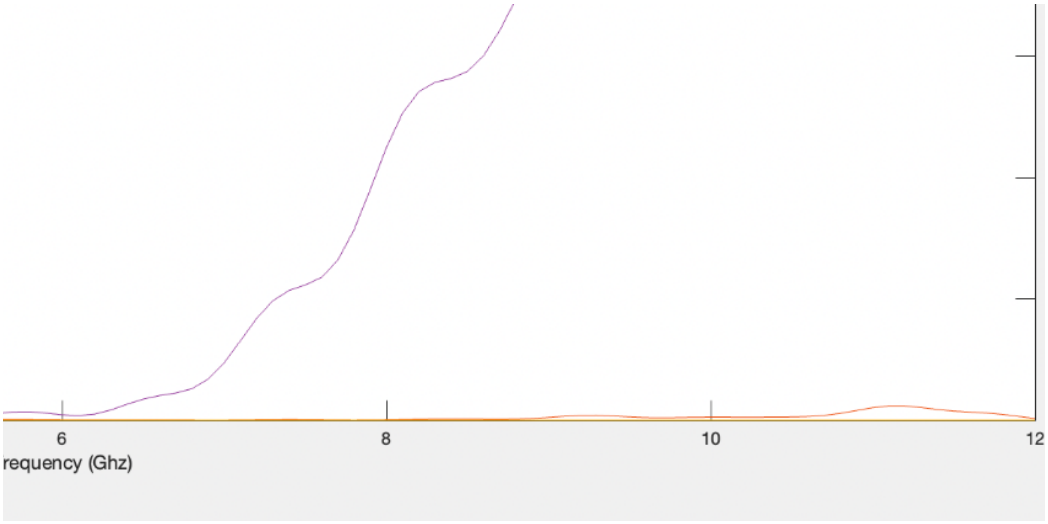


- Radius = 30 cm and Length = 30 cm:



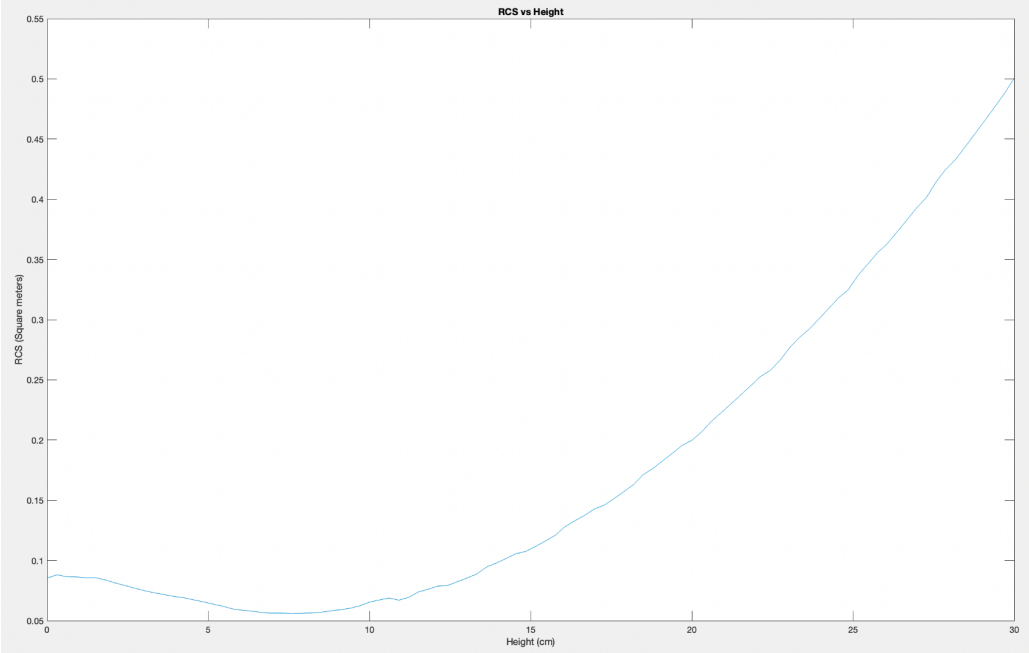
- Graph for the comparison of the above data:



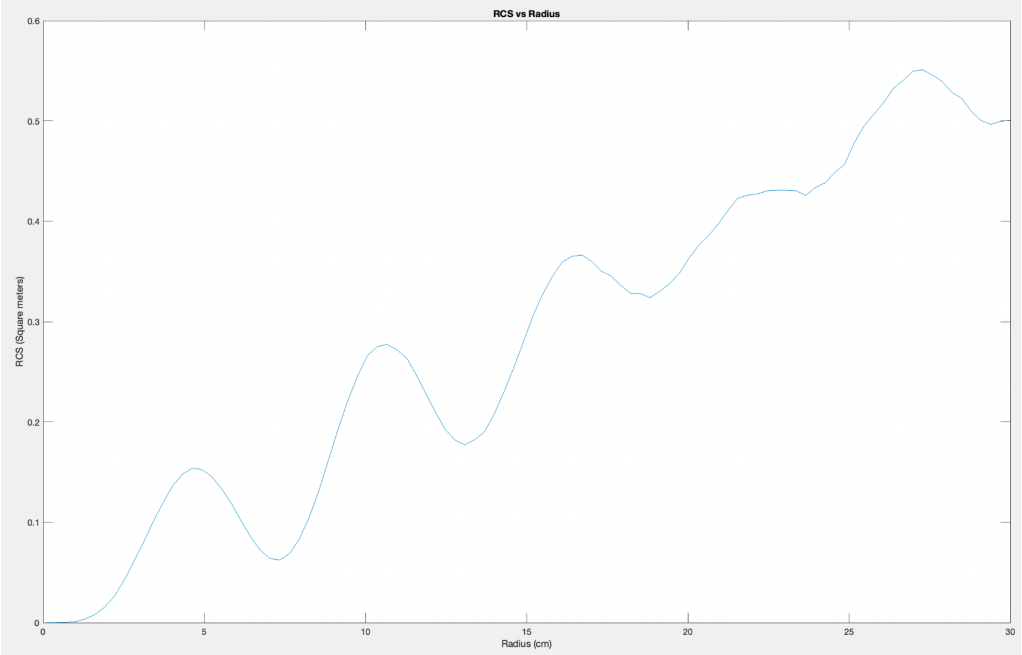


c. Generate results for RCS versus different ratios of lengths/diameters of the cylinder.

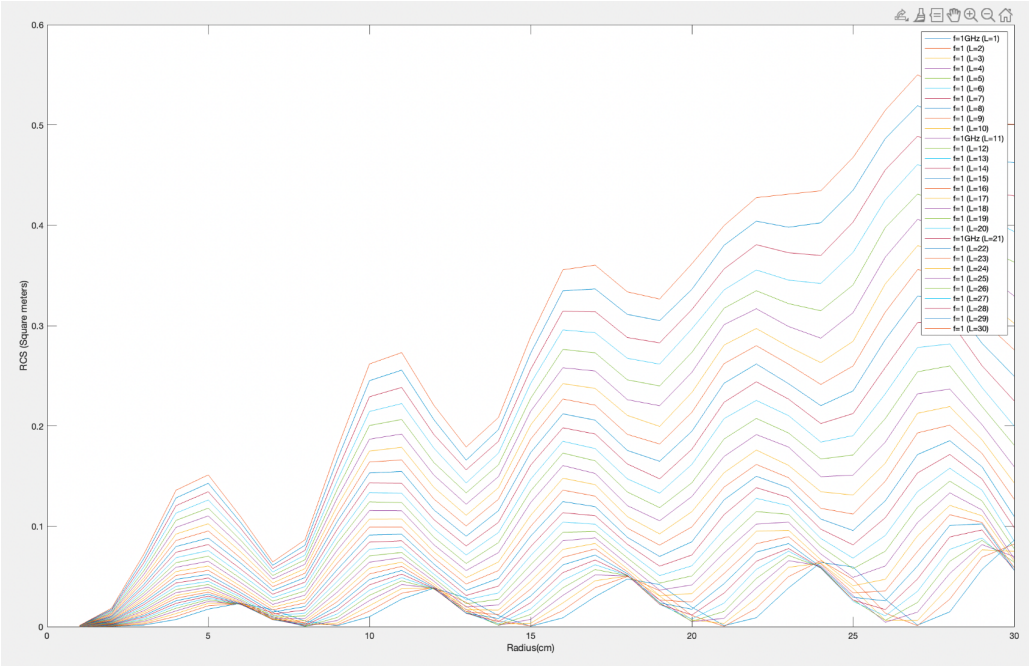
- For different values of the length of the cylinder:



- For different values of the diameters of the cylinder:

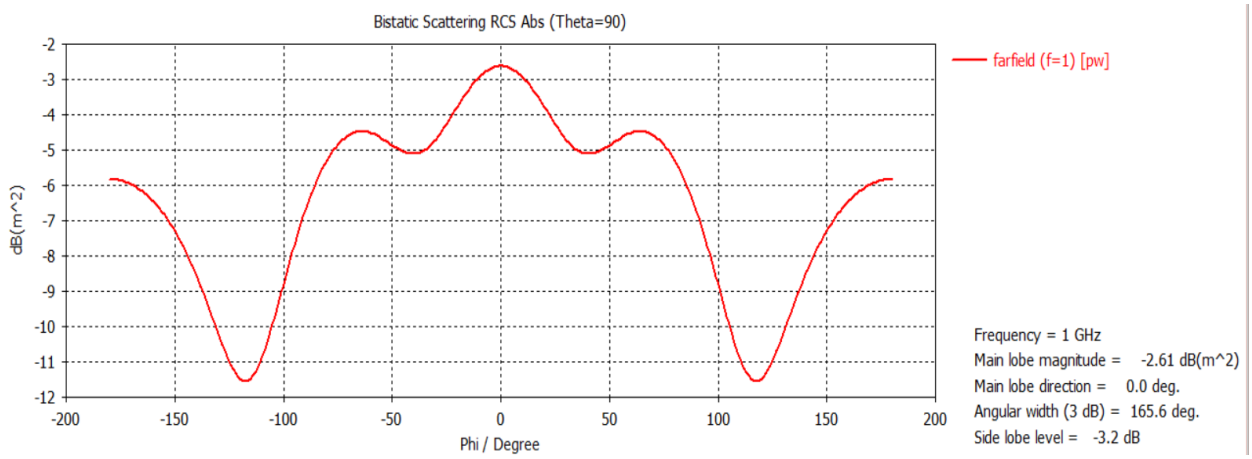


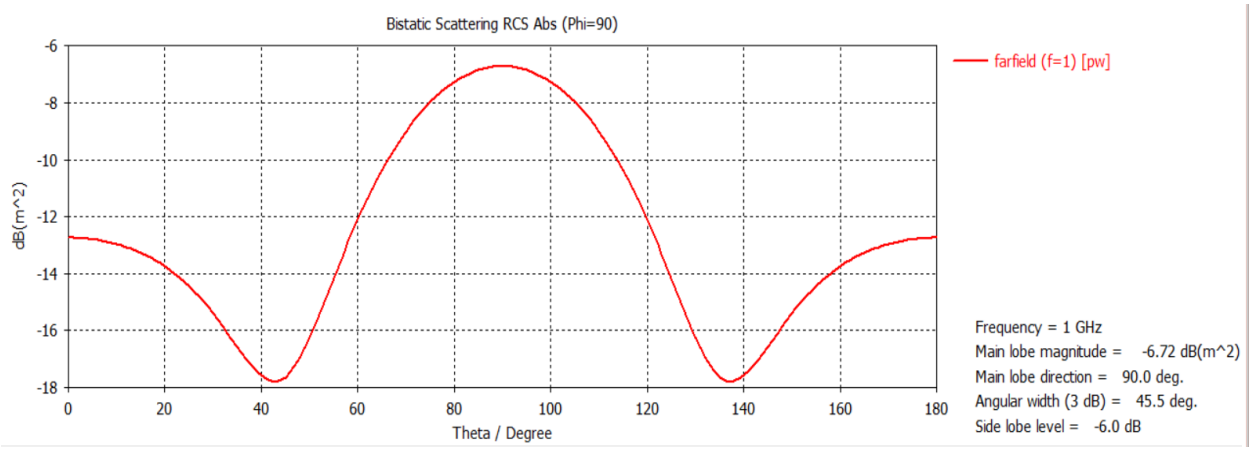
- For different ratios of length/diameters of cylinder:



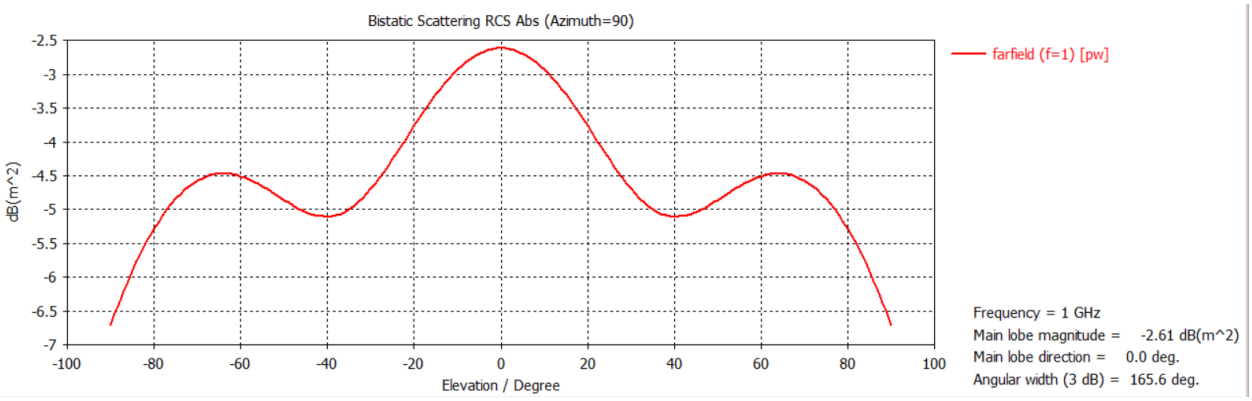
d. Generate results for RCS versus different polarization.

- Isotropic:

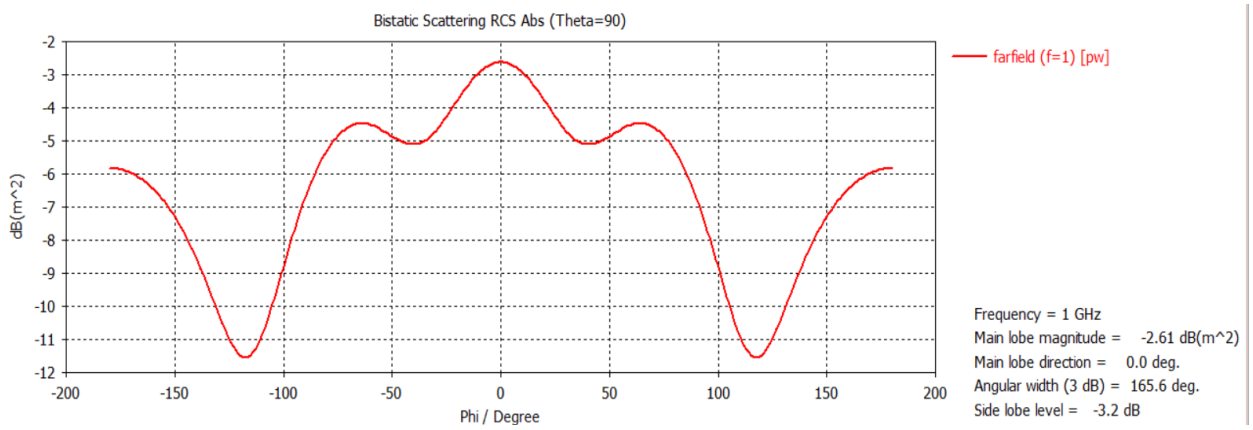


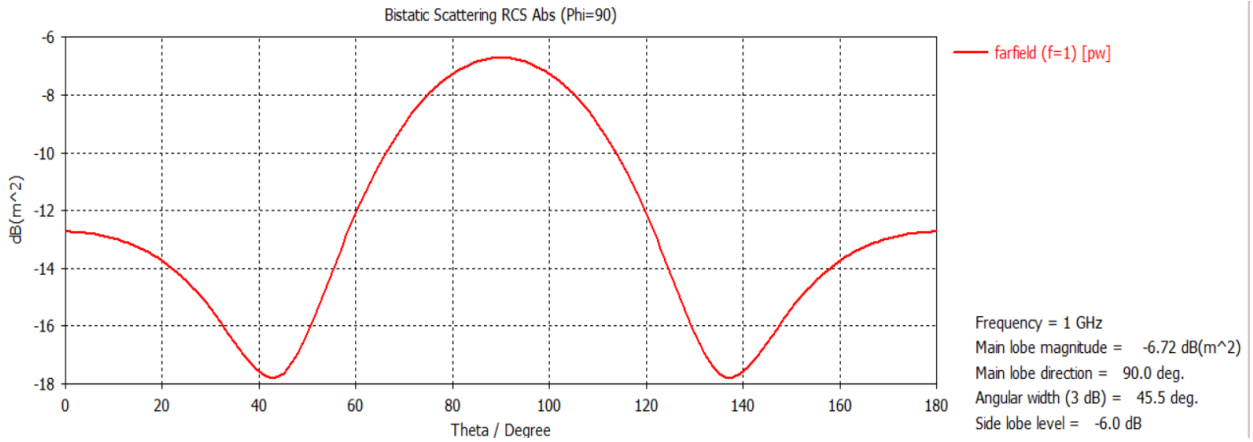


- Linear Omnidirectional:



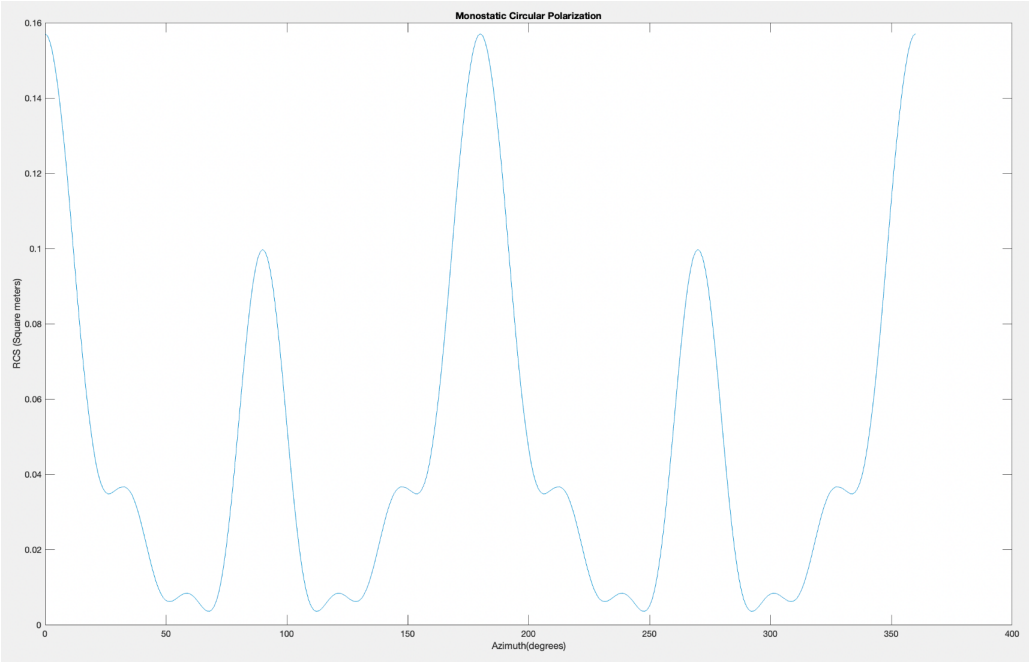
- Linear Directional:



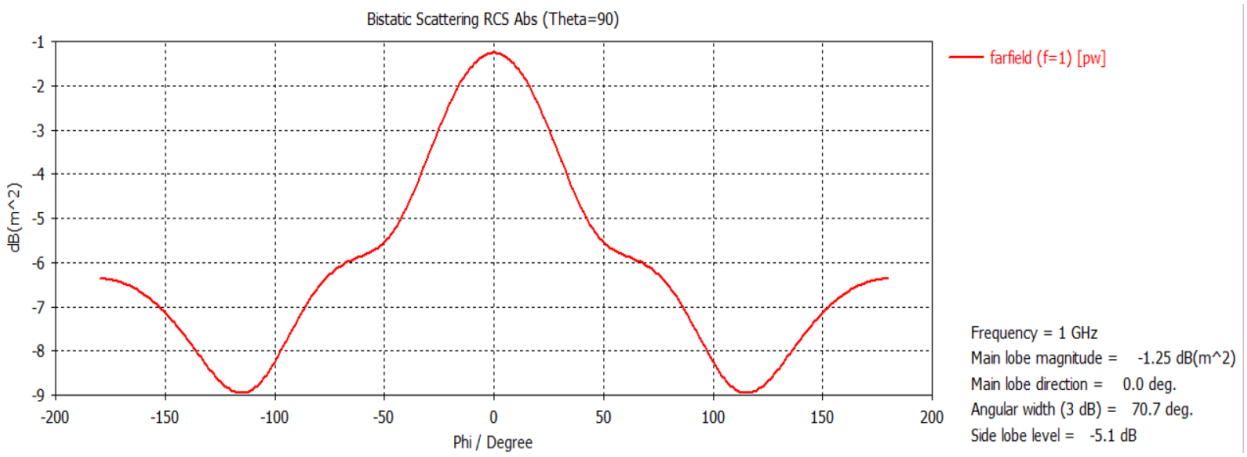


- Circular:

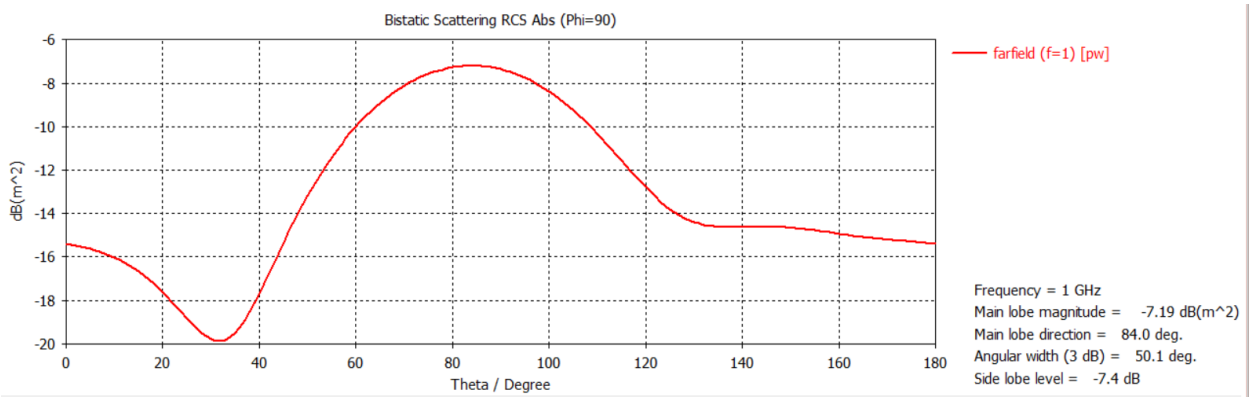
For Monostatic Radar:



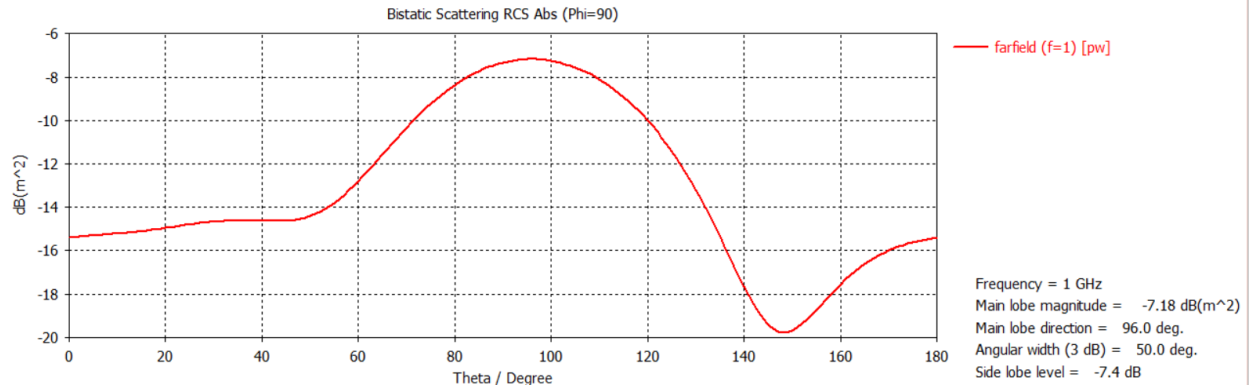
For Bistatic Radar:



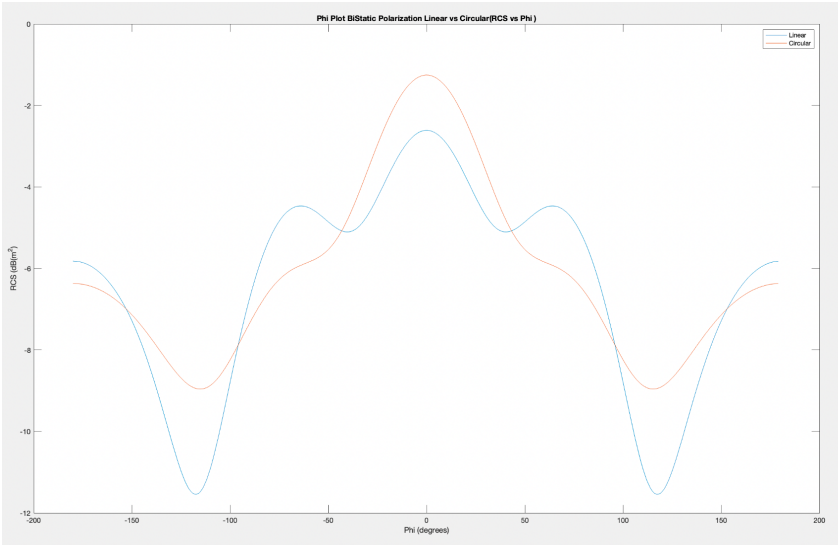
Left Polarization For Bistatic Radar:



Right Polarization For Bistatic Radar:

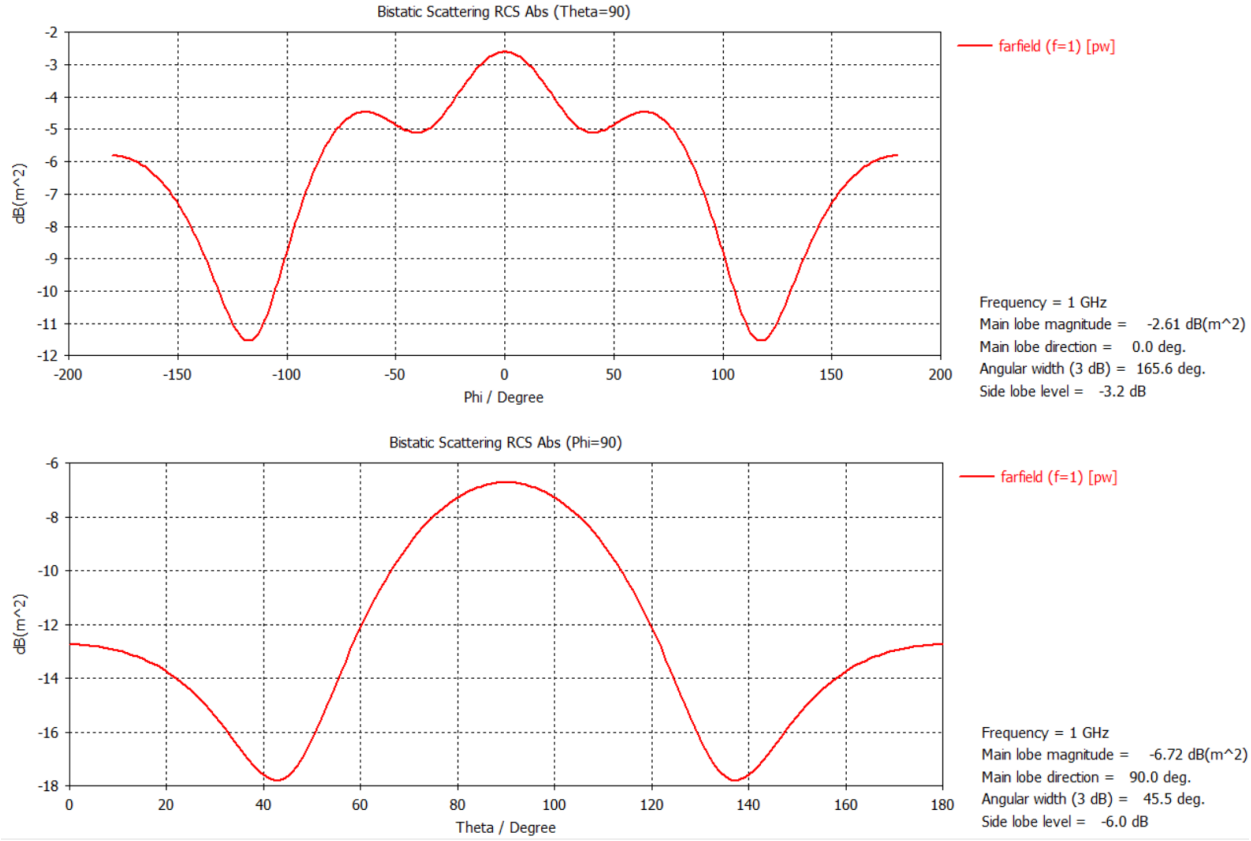


Plot for RCS versus different polarization for bistatic radar:

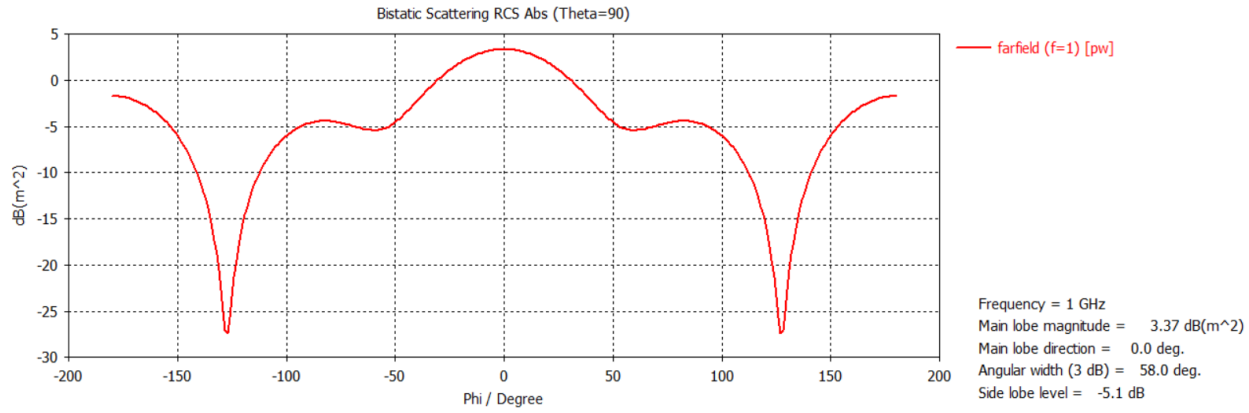


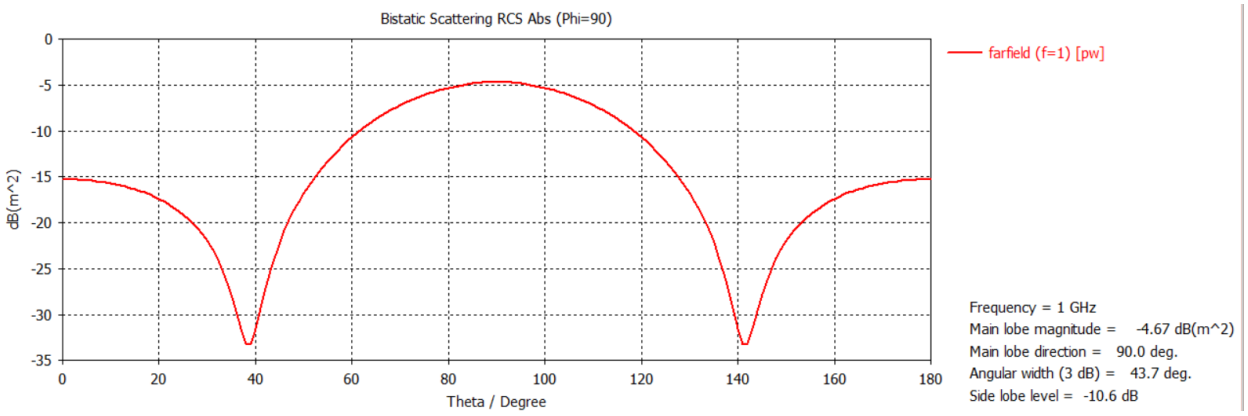
e. Generate results for RCS for metallic cylinder versus dielectric cylinder (FR4).

- Metallic Cylinder:

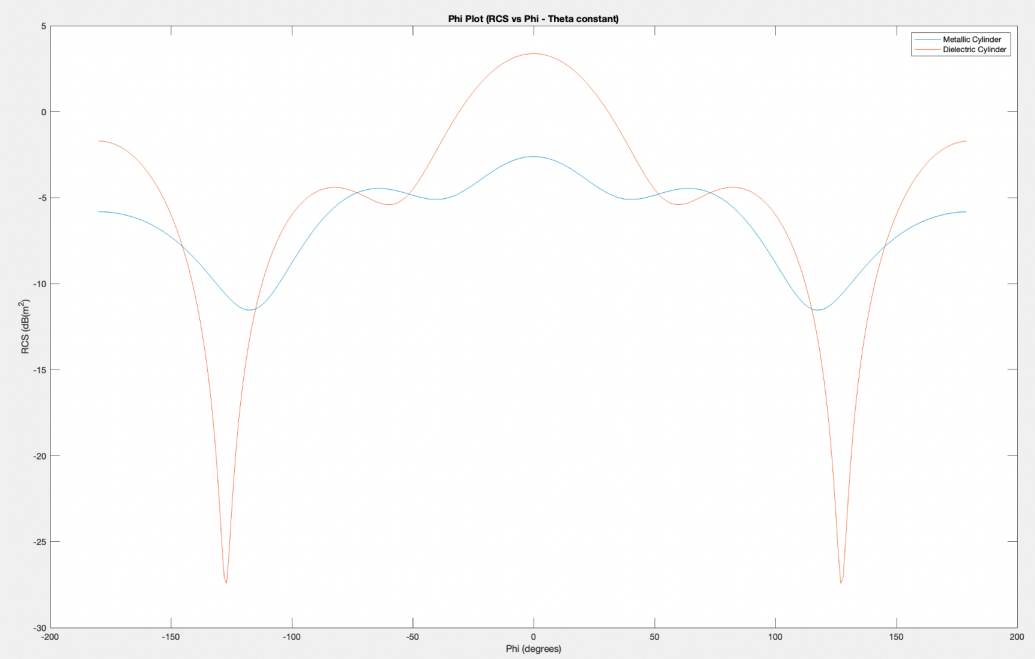


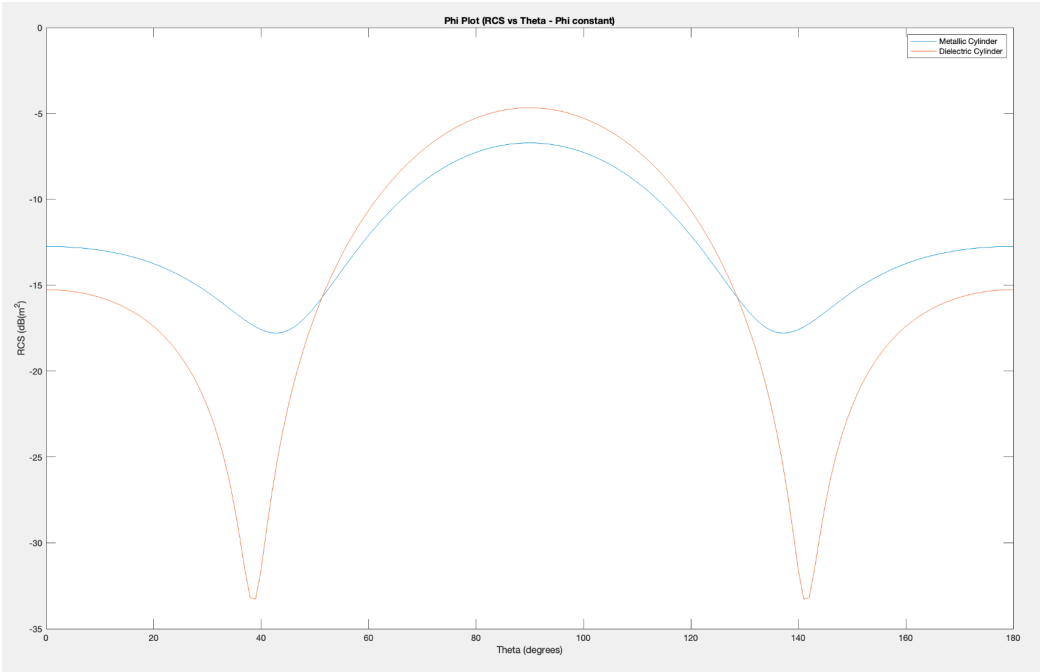
- Dielectric Cylinder(FR4)





- Plot for RCS of different materials:




Phi Plot (RCS vs Theta - Phi constant)
Metallic Cylinder
Dielectric Cylinder
RCS (dB/m²)
Theta (degrees)
0
-5
-10
-15
-20
-25
-30
-35
0
20
40
60
80
100
120
140
160
180

4. Conclusion:

a. **Conclusion on RCS versus aspect angle (azimuth, elevation):**
   Upon analyzing the RCS of a cylinder concerning aspect angles, it was observed that the RCS exhibits a complex pattern. At specific azimuth and elevation angles, the RCS reaches peak values, which can be attributed to the constructive interference of scattered fields. Conversely, the RCS reduces at other angles due to destructive interference. Understanding this behavior is essential for developing more accurate radar models and improving target identification.

b. **Conclusion on RCS versus frequency:**
   The study of the RCS as a function of frequency revealed that the RCS experiences fluctuations, with peaks occurring at resonant frequencies. The relationship between RCS and frequency is not linear, and an increase in frequency does not necessarily correlate to a higher RCS. These results have important implications for choosing operating frequencies that can maximize radar detection capabilities.

c. **Conclusion on RCS versus different ratios of lengths/diameters of the cylinder:**
   The RCS analysis of cylinders with varying length-to-diameter ratios showed an explicit dependency. Cylinders with larger length-to-diameter ratios exhibited higher RCS values, particularly at lower frequencies. In contrast, cylinders with smaller ratios displayed lower RCS values, particularly at higher frequencies. This knowledge can be utilized in designing objects with controlled RCS values for specific applications, such as radar-absorbent materials or stealth technology.

d. Conclusion on RCS versus different polarization:

The study on the impact of polarization on RCS indicated that the RCS of the cylinder is sensitive to incident wave polarization. For example, when the cylinder was illuminated with linearly polarized waves, the RCS values were generally higher than when illuminated with circularly polarized waves. This suggests that radar systems should consider utilizing multiple polarizations to enhance target detection and tracking.

e. Conclusion on RCS for metallic cylinder versus dielectric cylinder (FR4):

Comparing the RCS of metallic and dielectric (FR4) cylinders showed that the metallic cylinder's RCS values were consistently higher across all tested frequencies. The dielectric cylinder's RCS values were lower and exhibited a more frequency-dependent behavior. This difference can be attributed to metallic surfaces' stronger reflection and scattering of electromagnetic waves. These findings can inform material selection for radar applications and the development of stealth technologies.