"Design and analysis of cylindrical reflector-backed antenna operating at 1 GHz"

Special Assignment Report

Submitted in Partial Fulfillment of the Requirements for completion of

Course on

2EC701 Microwave and Antenna Theory

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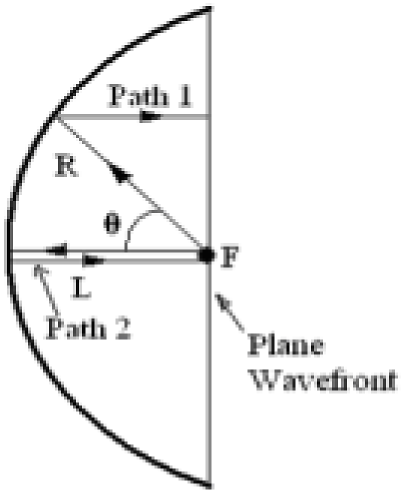
November 2022

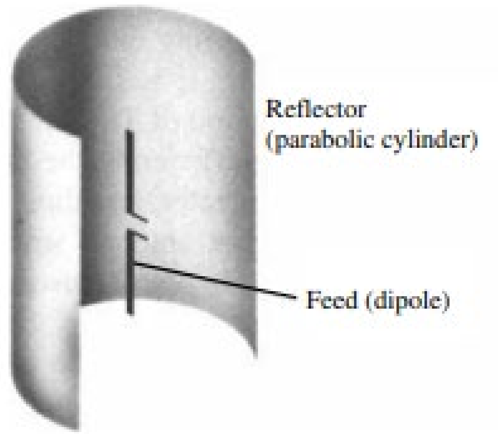
Introduction:

Radio transmissions over great distances require high-gain antennas. High-resolution radars, radio astronomy, and satellite communications etc. The most popular high-gain antennas are most likely reflector designs. For microwave and higher, they can easily reach increases of more than 30 dB frequencies. Reflector antennas work using concepts that were known from optical geometry (GO). Hertz created the first RF reflector system in the past. in 1888 (a cylindrical reflector fed by a dipole) (a cylindrical reflector fed by a dipole). However, the skill of precisely Creating such antenna systems was mostly developed during World War II. when a wide range of radar uses emerged. A reflecting surface plus a considerably smaller feed antenna located at the reflector's focal point make up the simplest reflector antenna. A secondary reflector (also known as a sub reflector) near the focal point of more complicated constructions is lighted by a primary feed. Dual-reflector antennas are what they are known as. The parabolic main reflector is the most popular. Cylindrical, corner, and spherical reflectors are additional common types.

Antenna Structure and Design equation:

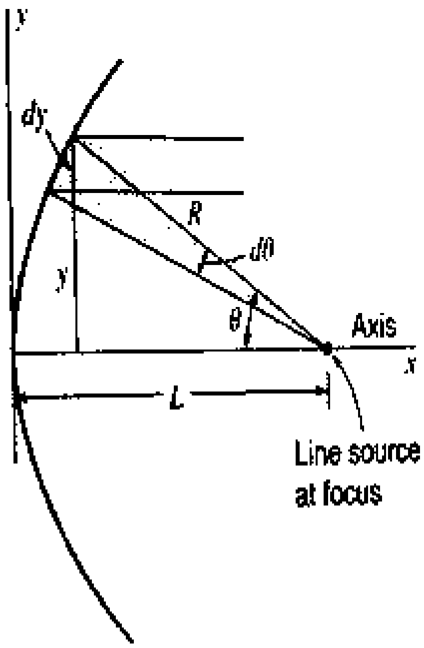
- Cylindrical antenna is generated by moving the parabolic contour parallel to itself. It provides mouth and has a line instead of a point as the focus. Followings are equation for the required surface contour.





$$2L = R(1 + \cos\theta)$$
$$R = \frac{2L}{1 + \cos\theta}$$

- The line source is isotropic in a plane perpendicular to its axis. For unit distance in the z direction the power P in a strip of width dy is



$$P = dyS_y$$

S_y is power density at yW/m^2 However

$$P = d\theta U'$$

Where U' is power per unit angle per unit length in z direction
Equating 1 and 2

$$dyS_y = \theta U'$$

and

$$\frac{S_y}{U'} = \frac{1}{\left(\frac{d}{d\theta}\right)(R\sin\ \theta)}$$

Where,

$$R = \frac{2L}{1 + \cos\ \theta}$$

This yield

$$S_y = \frac{1 + \cos\ \theta}{2L} U'$$

The ratio of the power density S_θ at θ to the power density of S_0 at $\theta = 0$ is then

$$\frac{S_\theta}{S_0} = \frac{1 + \cos\ \theta}{2}$$

The filed intensity ratio in the aperture plane is equal to the square toot of the power ratio is

$$\frac{E_\theta}{E_0} = \sqrt{\frac{1 + \cos\ \theta}{2}}$$

Where E_θ/E_0 is relative filed intensity at a distance y from the axis as given by

$$y = R\sin\ \theta$$

The gain and beam width obtained are given by:

$$G = \frac{(\pi \times D)^2}{\lambda^3} \times \eta$$

$$BW = \frac{70\lambda}{D}$$

The directivity can be calculated by,

$$D = \frac{4\pi |G|^2_{max}}{P} = \frac{4\pi}{\lambda^2} \frac{\mathrm{erf}^4\left(\frac{d}{2\rho_\mathrm{a}}\right)}{\mathrm{erf}^2\left(\frac{\sqrt{2}d}{2\rho_\mathrm{a}}\right)}$$

Antenna Specifications:

1. **Cylindrical reflector-backed antenna**
   - Groundplane length: 0.17601m
   - Groundplane width: 0.17601m
   - Spacing: 0.066 m
   - Depth: 0.066 m
   - Operating Frequency Range: 900 MHz to 1.1 GHz
   - Impedance: 50 Ω
   - Return Loss: 13.2260
   - Directivity: 6.1307

   MATLAB Calculated:

reflectorCylindrical	
GroundPlaneLength (m)	0.17601
GroundPlaneWidth (m)	0.17601
Spacing (m)	0.066014
Depth (m)	0.066014
EnableProbeFeed	0
Tilt (deg)	0
TiltAxis	[1 0 0]

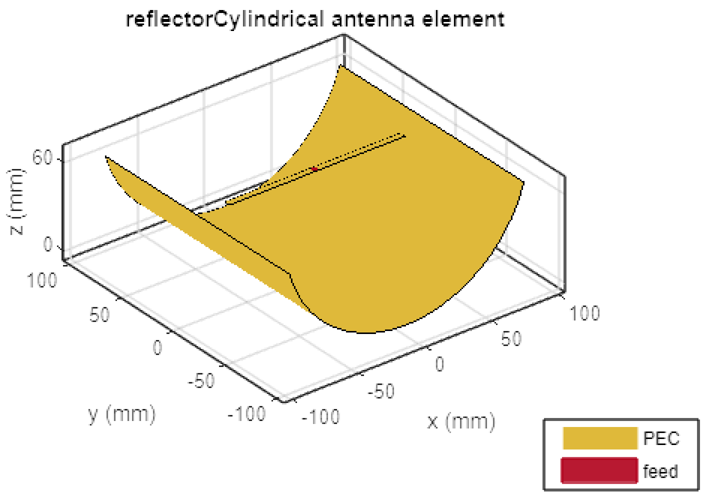
2. **Excitor Dipole**
   - Length: 0.132 m
   - Width: 0.0044 m
   - FeedOffset: 0 m
   - Impedance: 50 Ω

   MATLAB Calculated:

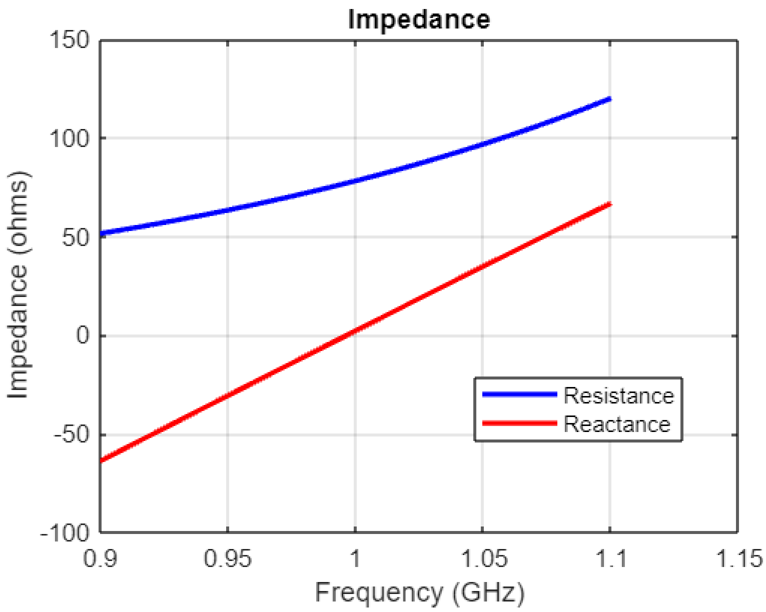
reflectorCylindrical - Exciter - dipole	
Length (m)	0.132
Width (m)	0.0044069
FeedOffset (m)	0
Tilt (deg)	90
TiltAxis	Y

Simulated Antenna:

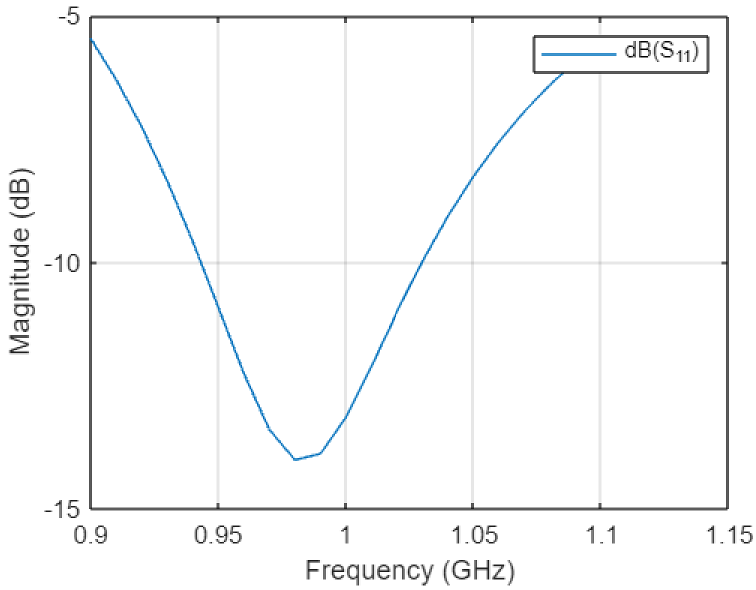
```
%% Antenna Properties

antennaObject = design(reflectorCylindrical('Exciter', dipole), 1000*1e6);
% Show
figure;
show(antennaObject)
```



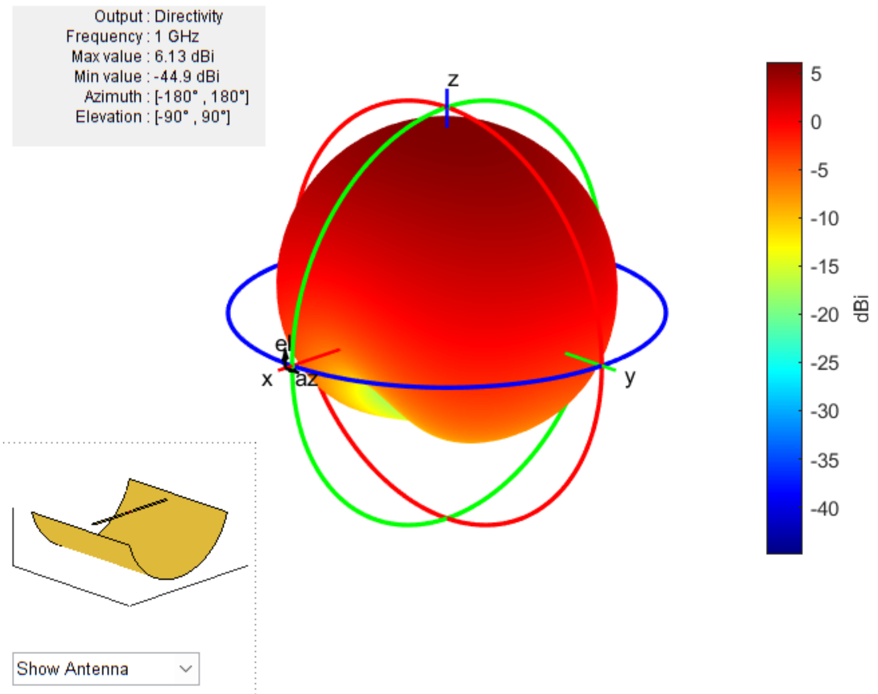

```
%% Antenna Analysis
% Define plot frequency
plotFrequency = 1*1e9;
% Define frequency range
freqRange = (900:10:1100)*1e6;
% Reference Impedance
refImpedance = 50;
% impedance
figure;
impedance(antennaObject, freqRange)
```



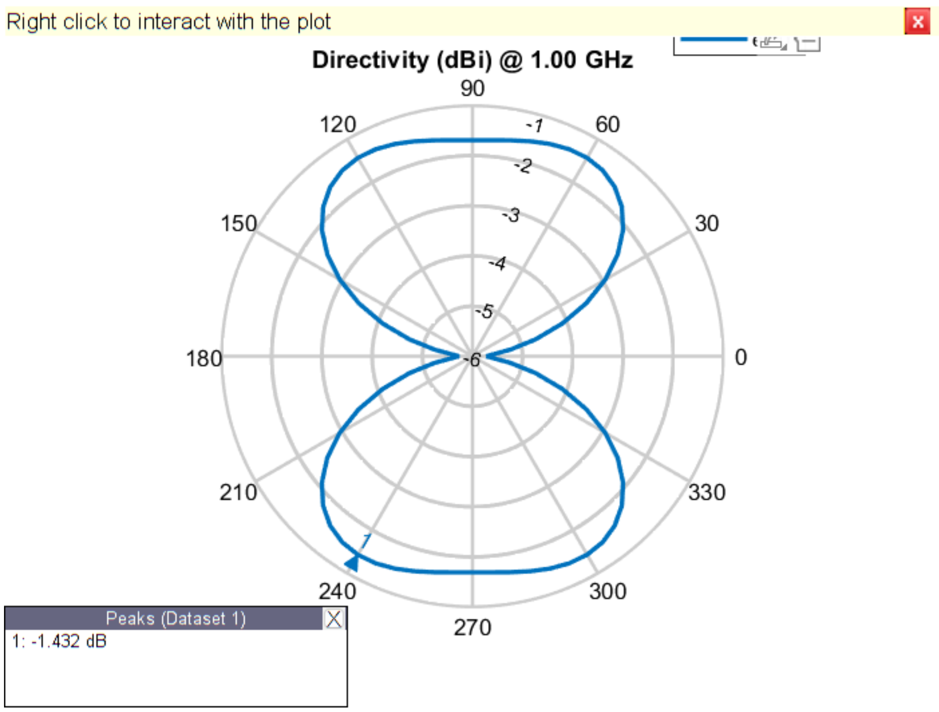

```
% sparameter
figure;
s = sparameters(antennaObject, freqRange, refImpedance);
rfplot(s)
```



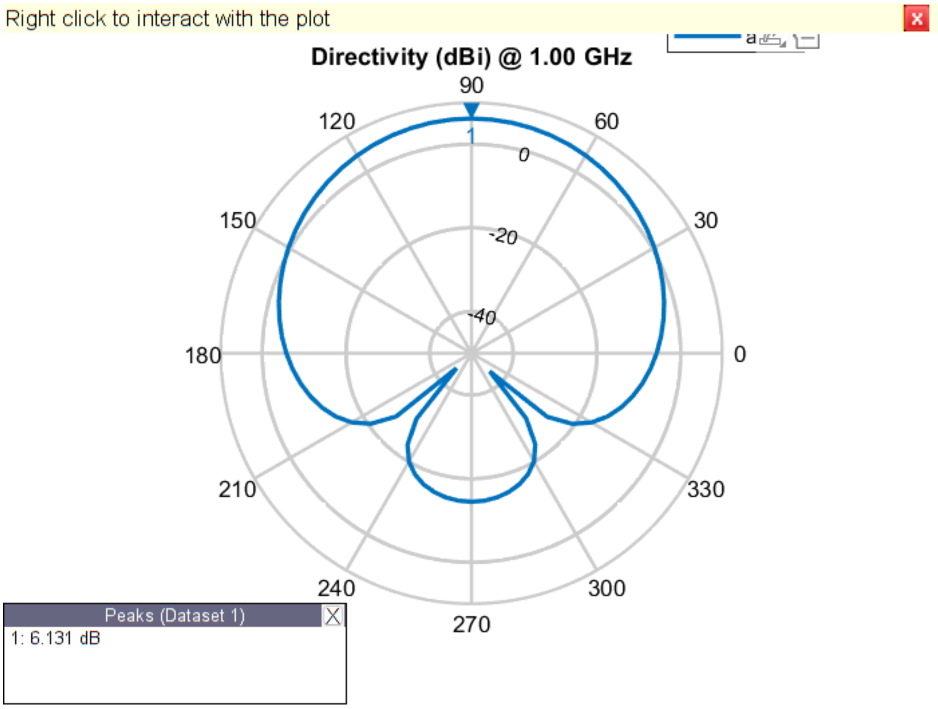

```
% pattern
figure;
pattern(antennaObject, plotFrequency)
```



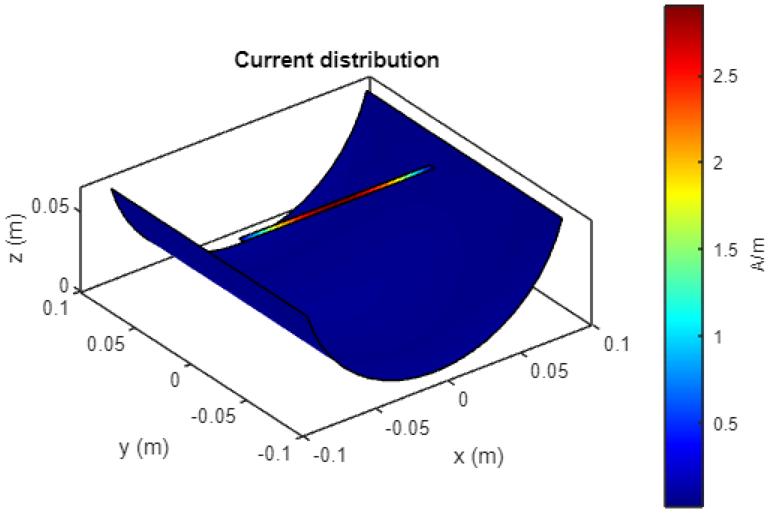

```
% azimuth
figure;
patternAzimuth(antennaObject, plotFrequency, 0, 'Azimuth', 0:5:360)
```



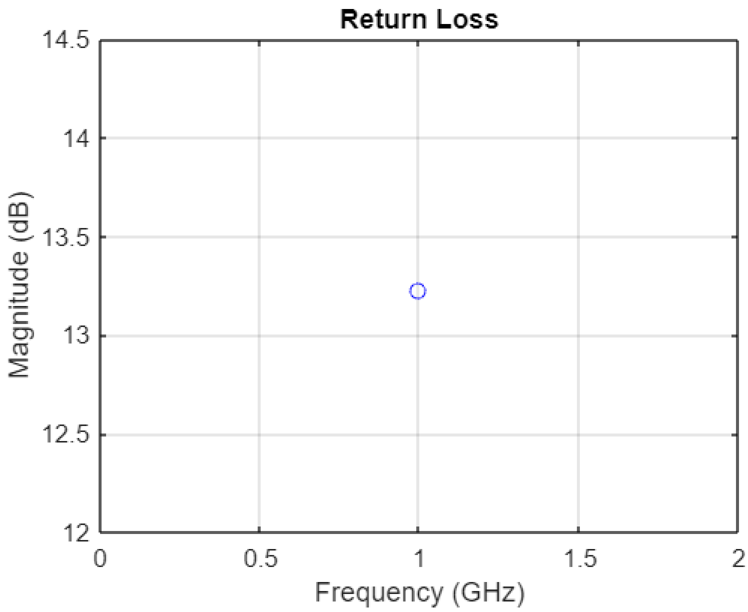

```
% elevation
figure;
patternElevation(antennaObject, plotFrequency,0,'Elevation',0:5:360)
```



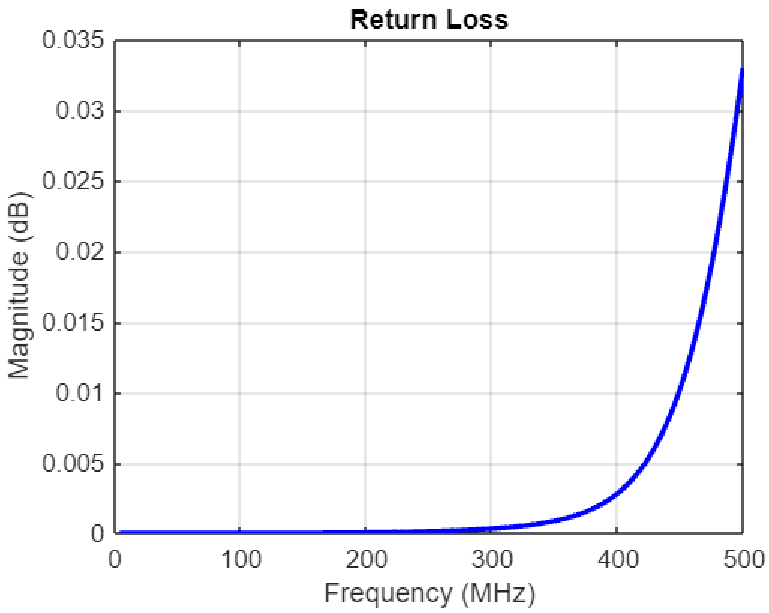

```
% current
figure;
current(antennaObject, plotFrequency)
```




```
% Return Loss
returnLoss(antennaObject,plotFrequency)
```




```
returnLoss(antennaObject,4e6:3e6:500e6)
```




```
rl = returnLoss(antennaObject,plotFrequency)
```

```
rl = 13.2260
```

```
directivity = max(pattern(antennaObject,plotFrequency,0,0:1:360))
```

```
directivity = 6.1307
```

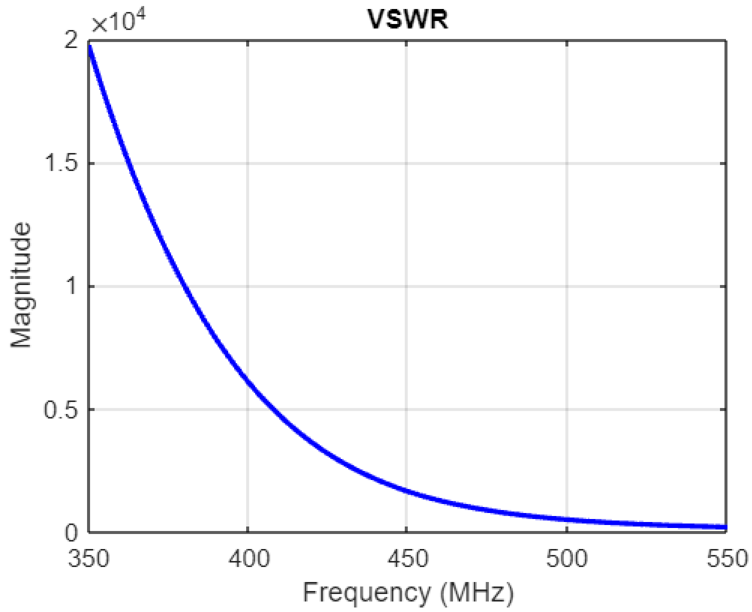
```
directivity = max(pattern(antennaObject,plotFrequency,0,180))
```

```
directivity = -5.7330
```

```
imp = impedance(antennaObject,plotFrequency)
```

```
imp = 77.8117 + 1.9772i
```

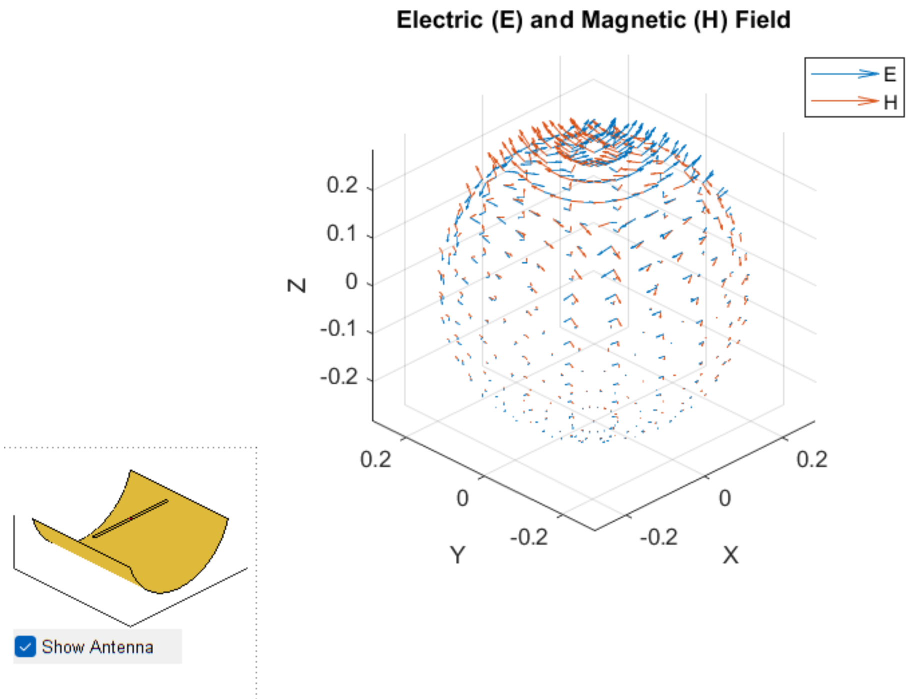
```
vswr(antennaObject,350e6:2e6:550e6)
```




```
[bw,angles] = beamwidth(antennaObject,plotFrequency,0,0:1:360)
```

```
bw = 86
angles = 1×2
    47   133
```

```
EHfields(antennaObject,plotFrequency)
```




```
h = antennaObject
```

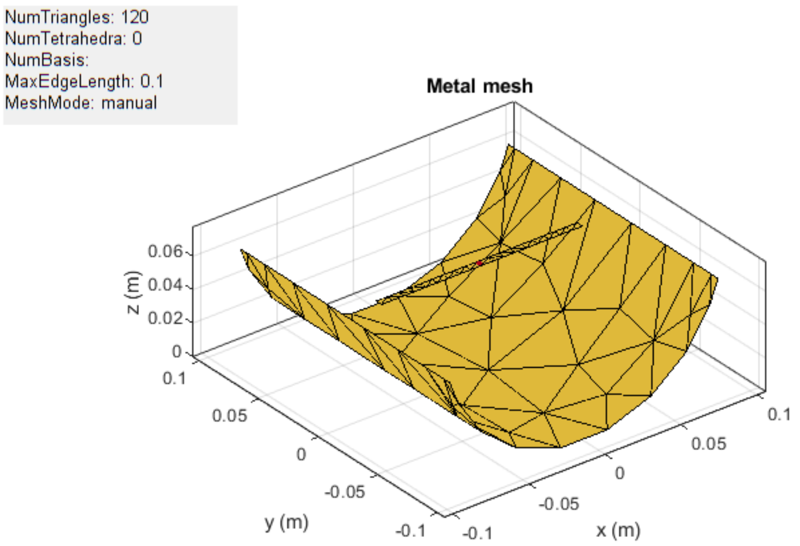
```
h = reflectorCylindrical with properties:
```

```
              Exciter: [1×1 dipole]
    GroundPlaneLength: 0.1760
     GroundPlaneWidth: 0.1760
              Spacing: 0.0660
                Depth: 0.0660
       EnableProbeFeed: 0
            Conductor: [1×1 metal]
                 Tilt: 0
             TiltAxis: [1 0 0]
                 Load: [1×1 lumpedElement]
```

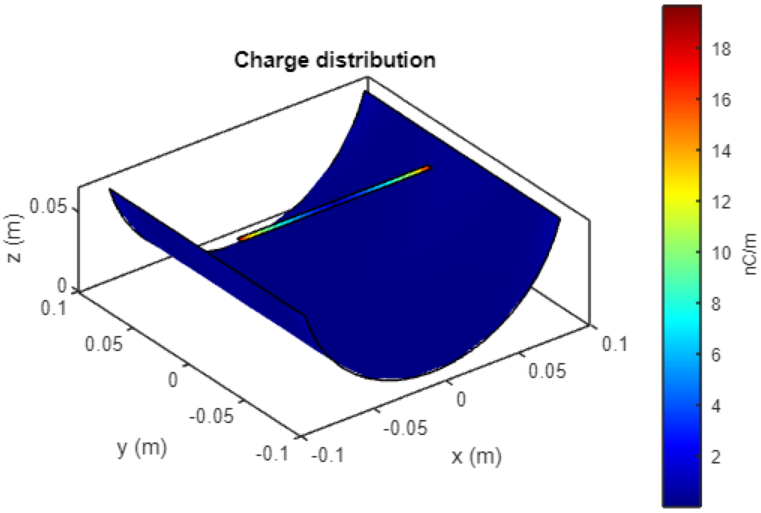
```
m = meshconfig(h,'manual')
```

```
m = struct with fields:
     NumTriangles: 324
    NumTetrahedra: 0
         NumBasis: 435
    MaxEdgeLength: 0.0172
    MinEdgeLength: 0.0129
       GrowthRate: 0.7500
         MeshMode: 'manual'
```

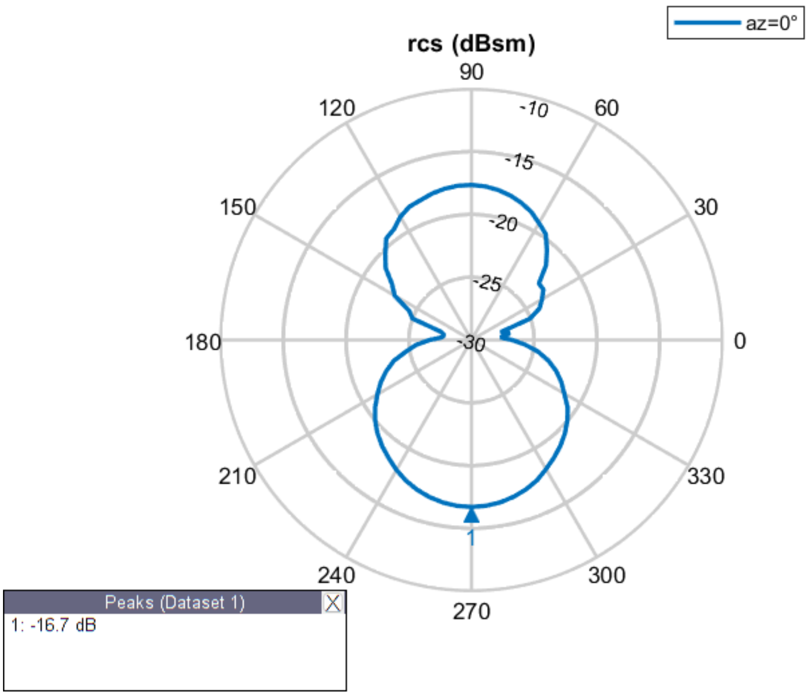
```
mesh(h,'MaxEdgeLength',0.1)
```




```
% Charge
charge(antennaObject,plotFrequency)
```




```
rcs(antennaObject,450e6)
```



Applications:

- Domestic Satellite TV reception.
- Terrestrial Microwave Data
- General Satellite Communications
- Radio Communications
- Deep-Space Telemetry
- Radio Astronomy

Key takeaways:

- **Advantages**
  1. Reduction of minor lobes.
  2. Wastage of power is reduced.
  3. Equivalent focal length is achieved.
  4. Feed can be placed in any location, according to our convenience.
  5. Adjustment of beam (narrowing or widening) is done by adjusting the reflecting surfaces.

- **Disadvantages**
  1. Some of the power that gets reflected from the cylindrical reflector is obstructed. This becomes a problem with small dimension reflector.

- Different elements, such as the antenna type, design, direction, and frequency, affect the beamwidth.

- The reactance of capacitive and inductive components determines the resonance frequency. The capacitive and inductive reactance's cancel each other out at the resonance frequency.

- An antenna's directivity is influenced by its physical size in relation to wavelength.

- It was discovered that whereas Wavelength, Directivity, Impedance, and Return Loss are linearly proportional to operating frequency, Efficiency and Reflection Coefficient are inversely related to operating frequency.

References:

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2. Jazi, Bahram & Davoudi-Rahaghi, Bahareh & Khajemirzaei, Muhammadreza & Niknam, Ali Reza. (2014). Energy Distribution Along the Focal Axis of a Metallic Cylindrical Parabolic Reflector Covered With a Plasma Layer. Plasma Science, IEEE Transactions on. 42. 286-292. 10.1109/TPS.2013.2294404.

3. Greco, F.; Boccia, L.; Arnieri, E.; Amendola, G. A Ka-Band Cylindrical Paneled Reflectarray Antenna. Electronics 2019, 8, 654.

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5. Jacob W. M. Baars" Metrology of Refl ector Antennas: A Historical Review" The Radio Science Bulletin No 375 (December 2020).

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7. A. W. Rudge and N. A. Adatia, "Offset-parabolic-reflector antennas: A review," in Proceedings of the IEEE, vol. 66, no. 12, pp. 1592-1618, Dec. 1978, doi: 10.1109/PROC.1978.11170. (Accessed: November 7, 2022).