Created in COMSOL Multiphysics 6.2

Corrugated Circular Horn Antenna

Introduction

The excited TE mode from a circular waveguide passes through the corrugated inner surface of a circular horn antenna where a TM mode is also generated. When combined, these two modes give lower cross-polarization at the antenna aperture than the excited TE mode. This example is designed using a 2D axisymmetric model.

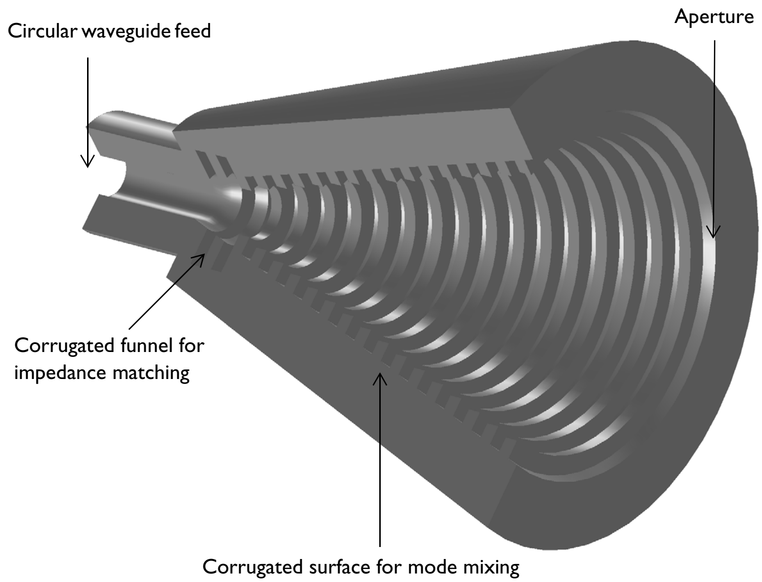


Figure 1: 3D visualization of the corrugated horn antenna from a 2D axisymmetric model.

Model Definition

The shape of a horn antenna provides a gradual change in impedance from the feeding waveguide to free space, resulting in low standing wave ratio. The corrugations are used to mix different modes at a given frequency to reduce cross-polarization. In particular, the horn antenna can be used to illuminate a parabolic reflector as part of a satellite communication system. Reduced cross-polarization results in reduced interference between adjacent channels that have alternating vertical and horizontal polarization.

The antenna is fed with the TE_{m1} mode of a circular waveguide, where $m = \pm 1$, azimuthal mode number. The mode TE_1 is defined in the port settings while the azimuthal mode number m is configured in the physics interface settings. As the mode propagates through the antenna, it becomes mixed with the TM_{m1} mode. The inner walls on the corrugated surface act as the boundary for the TE mode and the outer walls act as the boundary for the TM mode. The first and second corrugations near the waveguide feed are used for impedance tuning.

The model is made using the 2D axisymmetric formulation of The Electromagnetic Waves, Frequency Domain Interface. The temporal and angular dependence are assumed to be $e^{j(\omega t - m\phi)}$, where m is the azimuthal mode number. The model is solved for $m = +1$ and $m = -1$. Since the field propagates predominantly in the $+z$ direction, positive and negative values of m correspond to right-handed and left-handed circular polarization, respectively. A linear superposition of the $m = +1$ and $m = -1$ solutions is taken to examine the cross-polarization, specifically to compare the linear polarization in the x direction and y direction at the exit of the horn.

Results and Discussion

The far field plot in Figure 2 illustrates the directive beam pattern of the horn antenna.

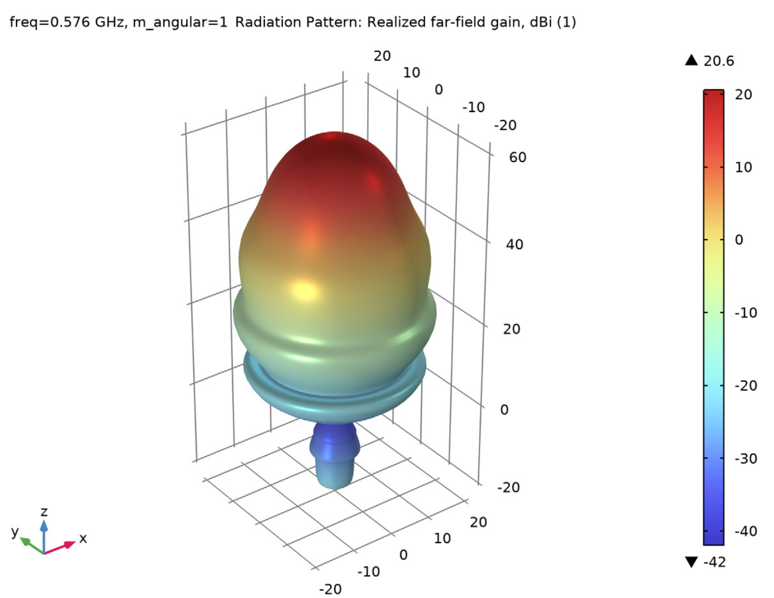


Figure 2: Far field plot of the magnitude of the electric field for the corrugated horn antenna.

In Figure 3, the electric field is plotted at the entrance and exit of the horn antenna for the linear superposition of the $m = +1$ and $m = -1$ solutions. The electric field at the waveguide feed is predominantly in the x direction, although it is not linearly polarized. The field is nonzero at the waveguide boundary where it must be perpendicular to the PEC surface. At the horn antenna aperture, the field is nearly zero at the boundary and appears to be linearly polarized in the x direction.

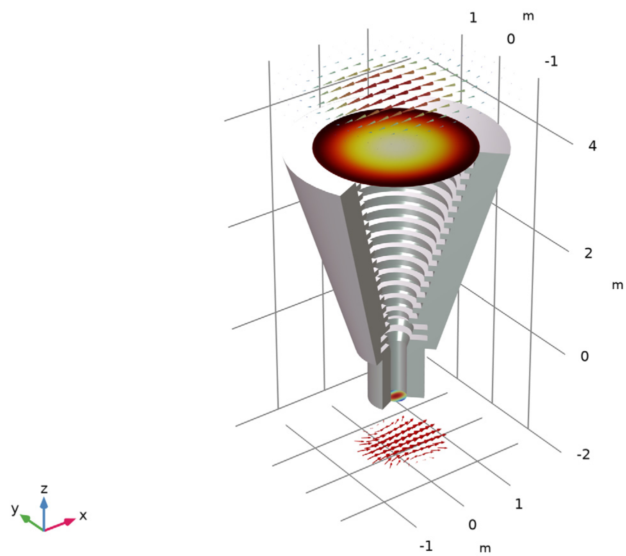


Figure 3: Electric field at entrance and exit of corrugated horn antenna.

The amount of linear polarization in the x direction and y direction can be quantified by evaluating the integral of the absolute value of each field component, $|E_x|$ and $|E_y|$, over the entrance and exit of the horn antenna. The ratio at the waveguide feed is approximately 5:1 and the ratio at the antenna aperture is approximately 40:1. Thus, the cross-polarization is reduced by approximately a factor of 8.

The far-field radiation pattern in Figure 2 is just a simple body of revolution of the 2D plot data that is useful to measure quickly the maximum gain and review the overall shape of the pattern. The effective 3D far-field radiation pattern of the antenna excited by TE_{11} mode can be estimated using the predefined postprocessing function, `normdB3DEfar_TE11(angle)`, that is shown in Figure 4.

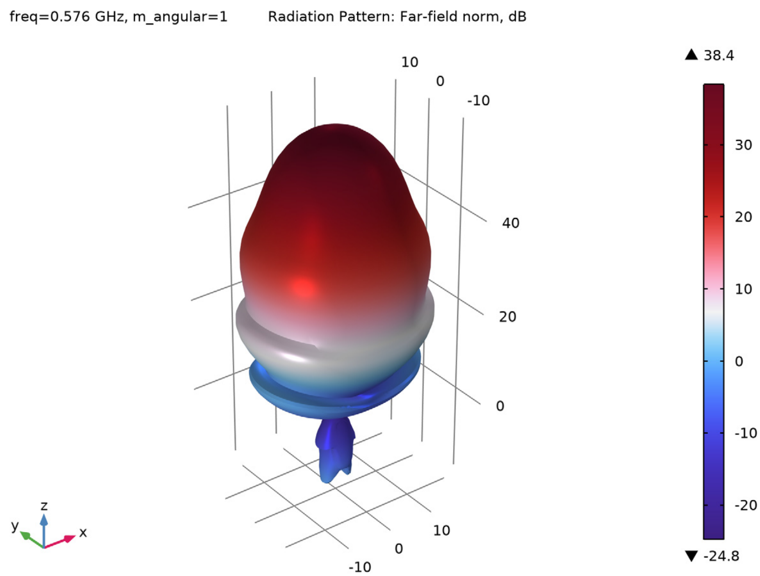


Figure 4: Effective 3D far-field radiation pattern plotted in dB scale using far-far field function normdB3DEfar_TE11(angle).

Notes About the COMSOL Implementation

The horn antenna is assumed to be a perfect electric conductor (PEC). Since the electric field is known *a priori* to be zero inside the PEC, it is removed from the modeling domain. The domain is truncated with a perfectly matched layer (PML) at the free space boundary. The PML region contains a mapped mesh.

Application Library path: `RF_Module/Antennas/corrugated_circular_horn_antenna`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **2D Axisymmetric**.
2 In the **Select Physics** tree, select **Radio Frequency>Electromagnetic Waves, Frequency Domain (emw)**.
3 Click **Add**.
4 Click **Study**.
5 In the **Select Study** tree, select **General Studies>Frequency Domain**.
6 Click **Done**.

GLOBAL DEFINITIONS

Parameters 1

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.
2 In the **Settings** window for **Parameters**, locate the **Parameters** section.
3 Click **Load from File**.
4 Browse to the model's Application Libraries folder and double-click the file `corrugated_circular_horn_antenna_parameters.txt`.

   First load the geometric parameters. Then calculate the cutoff frequency `fc` to ensure that a higher value is chosen for the simulation frequency `f0`.
5 In the table, enter the following settings:

Name	Expression	Value	Description
m_angular	1	1	Azimuthal mode number
fc	1.841*c_const/2/pi/r1	4.8E8 1/s	Cutoff frequency
f0	1.2*fc	5.76E8 1/s	Frequency

   Here, `c_const` is a predefined COMSOL constant for the speed of light in vacuum.

STUDY 1

Step 1: Frequency Domain

Define the study frequency ahead of performing any frequency-dependent operation such as building mesh. The physics-controlled mesh uses the specified frequency value.

1 In the **Model Builder** window, under **Study 1** click **Step 1: Frequency Domain**.

2 In the **Settings** window for **Frequency Domain**, locate the **Study Settings** section.

3 In the **Frequencies** text field, type `f0`.

GEOMETRY 1

Create a semicircle for the domain that includes a layer for the PML.

Circle 1 (c1)

1 In the **Geometry** toolbar, click **Circle**.

2 In the **Settings** window for **Circle**, locate the **Size and Shape** section.

3 In the **Radius** text field, type `hl*1.8`.

4 In the **Sector angle** text field, type `180`.

5 Locate the **Position** section. In the **z** text field, type `3`.

6 Locate the **Rotation Angle** section. In the **Rotation** text field, type `270`.

7 Click to expand the **Layers** section. In the table, enter the following settings:

Layer name	Thickness (m)
Layer 1	c_const/f0

Draw a short section of waveguide, followed by the outline of the horn.

Rectangle 1 (r1)

1 In the **Geometry** toolbar, click **Rectangle**.

2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.

3 In the **Width** text field, type `r1`.

4 In the **Height** text field, type `wl`.

5 Locate the **Position** section. In the **z** text field, type `-wl`.

6 Click **Build Selected**.

Polygon 1 (pol1)

1 In the **Geometry** toolbar, click **Polygon**.

2 In the **Settings** window for **Polygon**, locate the **Coordinates** section.

3 In the table, enter the following settings:

r (m)	z (m)
0	hl*cos(angle)
r1+hl*sin(angle)	hl*cos(angle)

Polygon 2 (pol2)

1 In the **Geometry** toolbar, click **Polygon**.

2 In the **Settings** window for **Polygon**, locate the **Coordinates** section.

3 In the table, enter the following settings:

r (m)	**z (m)**
`r1`	`0`
`r1+hl*sin(angle)`	`hl*cos(angle)`
`r1+hl*sin(angle)+ht`	`hl*cos(angle)`
`r1+ht`	`0`

Draw an array of rectangles that will form the corrugations.

Rectangle 2 (r2)

1 In the **Geometry** toolbar, click **Rectangle**.

2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.

3 In the **Width** text field, type `grid_x`.

4 In the **Height** text field, type `grid_y`.

5 Locate the **Position** section. From the **Base** list, choose **Center**.

6 In the **r** text field, type `0.39`.

7 In the **z** text field, type `0.53`.

Array 1 (arr1)

1 In the **Geometry** toolbar, click **Transforms** and choose **Array**.

2 Select the object **r2** only.

3 In the **Settings** window for **Array**, locate the **Size** section.

4 From the **Array type** list, choose **Linear**.

5 In the **Size** text field, type `floor(hl/grid_y/2*0.85)`.

6 Locate the **Displacement** section. In the **r** text field, type `grid_y*2*tan(angle)`.

7 In the **z** text field, type `grid_y*2`.

8 Click **Build Selected**.

Make separate corrugations near the waveguide feed that are used for tuning.

Rectangle 3 (r3)

1 In the **Geometry** toolbar, click **Rectangle**.

2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.

3 In the **Width** text field, type `grid_x`.

4 In the **Height** text field, type `grid_y`.

5 Locate the **Position** section. From the **Base** list, choose **Center**.

6 In the **r** text field, type `0.36`.

7 In the **z** text field, type `0.53`.

Copy 1 (copy1)

1 In the **Geometry** toolbar, click **Transforms** and choose **Copy**.

2 Select the object **r3** only.

3 In the **Settings** window for **Copy**, locate the **Displacement** section.

4 In the **z** text field, type `-grid_y, -grid_y*3`.

5 Locate the **Input** section. Clear the **Keep input objects** check box.

Add a section of the antenna body outside the short section of waveguide. Then union that section with angled antenna body part and all of the corrugations that were made with the array. This excludes the two separate corrugations near the waveguide feed.

Rectangle 4 (r4)

1 In the **Geometry** toolbar, click **Rectangle**.

2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.

3 In the **Width** text field, type `0.3`.

4 In the **Height** text field, type `wl`.

5 Locate the **Position** section. In the **r** text field, type `r1`.

6 In the **z** text field, type `-wl`.

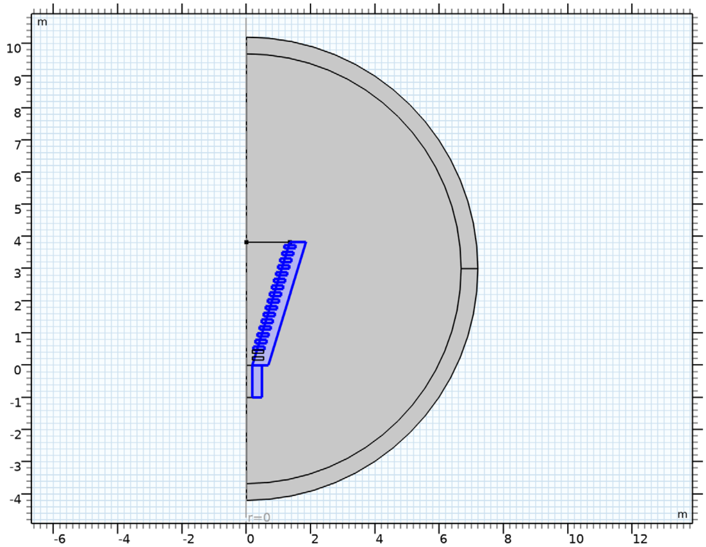
7 Click **Build Selected**.

Union 1 (uni1)

1 In the **Geometry** toolbar, click **Booleans and Partitions** and choose **Union**.

2 Click the **Zoom Extents** button in the **Graphics** toolbar.

3 Select the objects **arr1(1)**, **arr1(10)**, **arr1(11)**, **arr1(12)**, **arr1(13)**, **arr1(14)**, **arr1(15)**, **arr1(16)**, **arr1(2)**, **arr1(3)**, **arr1(4)**, **arr1(5)**, **arr1(6)**, **arr1(7)**, **arr1(8)**, **arr1(9)**, **pol2**, and **r4** only.



4 In the **Settings** window for **Union**, locate the **Union** section.

5 Clear the **Keep interior boundaries** check box.

6 Click **Build Selected**.

Subtract the two corrugations near the waveguide feed from the antenna body formed in the preceding step.

Difference 1 (dif1)

1 In the **Geometry** toolbar, click **Booleans and Partitions** and choose **Difference**.

2 Select the object **uni1** only.

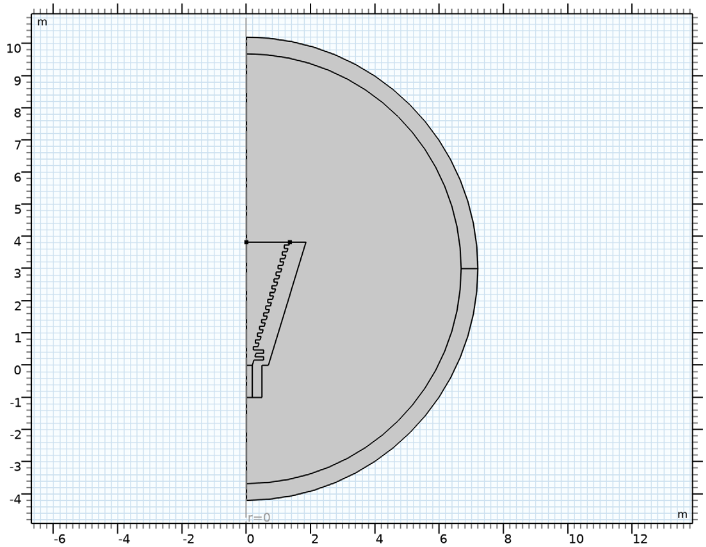
3 In the **Settings** window for **Difference**, locate the **Difference** section.

4 Click to select the **Activate Selection** toggle button for **Objects to subtract**.

5 Select the objects **copy1(1)** and **copy1(2)** only.

6 Clear the **Keep interior boundaries** check box.

7 Click **Build All Objects**.



The geometry should look the same as the outline seen in the above figure.

DEFINITIONS

Perfectly Matched Layer 1 (pml1)

1 In the **Definitions** toolbar, click **Perfectly Matched Layer**.

2 Select Domains 1 and 5 only.

ELECTROMAGNETIC WAVES, FREQUENCY DOMAIN (EMW)

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Electromagnetic Waves, Frequency Domain (emw)**.

2 In the **Settings** window for **Electromagnetic Waves, Frequency Domain**, locate the **Out-of-Plane Wave Number** section.

3 In the *m* text field, type `m_angular`.

Perfect Electric Conductor 2

1 In the **Physics** toolbar, click **Domains** and choose **Perfect Electric Conductor**.

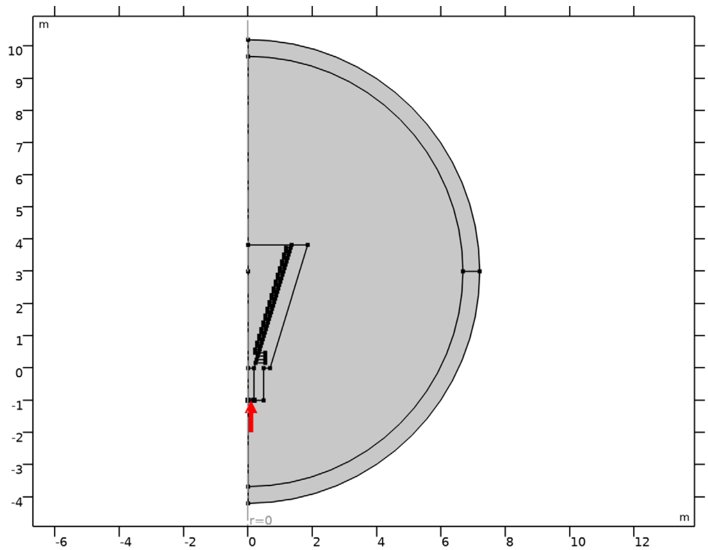
2 Select Domain 6 only.

Port 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Port**.

Assign a Port boundary condition to the bottom edge of the short waveguide section.

2 Select Boundary 4 only.



3 In the **Settings** window for **Port**, locate the **Port Properties** section.

4 From the **Type of port** list, choose **Circular**.

For the first port, wave excitation is **on** by default.

5 Select the **Activate slit condition on interior port** check box.

6 Click **Toggle Power Flow Direction**.

Setting the **Port orientation** to **Reverse** makes the propagation direction opposite to the arrow shown in the graphics window. Note that by default the mode is TEm1, where m is the azimuthal mode number in **Electromagnetic Wave, Frequency Domain**.

Far-Field Domain 1

In the **Physics** toolbar, click **Domains** and choose **Far-Field Domain**.

MATERIALS

Add a new material for the vacuum.

Material 1 (mat1)

1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Materials** and choose **Blank Material**.

2 In the **Settings** window for **Material**, locate the **Material Contents** section.

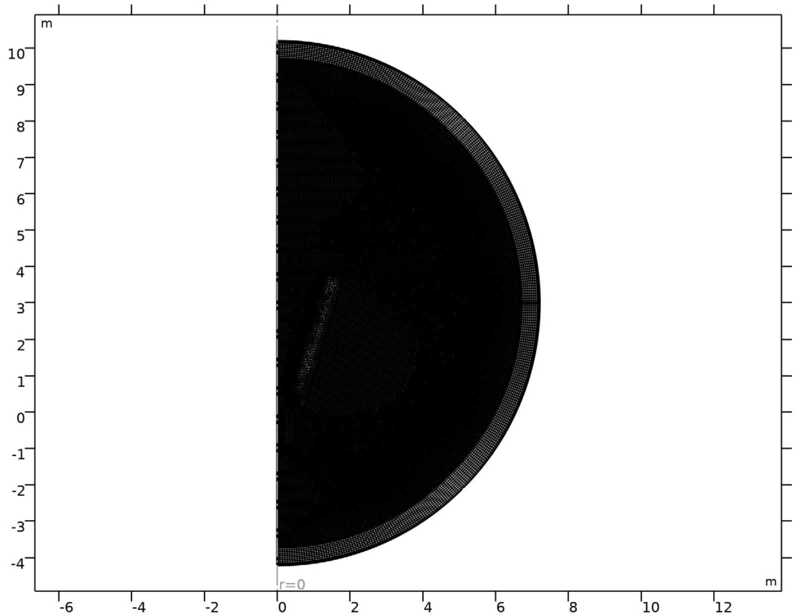
3 In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	1	1	Basic
Relative permeability	mur_iso ; murii = mur_iso, murij = 0	1	1	Basic
Electrical conductivity	sigma_iso ; sigmaii = sigma_iso, sigmaij = 0	0	S/m	Basic

The PML will contain a Mapped mesh with 10 layers. The other domains will contain a Free Triangular mesh with a maximum size of 0.2 Wavelengths to ensure 10 degrees of freedom for the free space wavelength.

MESH 1

In the **Model Builder** window, under **Component 1 (comp1)** right-click **Mesh 1** and choose **Build All**.



STUDY 1

Step 1: Frequency Domain

1 In the **Model Builder** window, under **Study 1** click **Step 1: Frequency Domain**.

2 In the **Settings** window for **Frequency Domain**, click to expand the **Study Extensions** section.

3 Select the **Auxiliary sweep** check box.

4 Click **Add**.

5 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
m_angular (Azimuthal mode number)	-1 1	

6 In the **Home** toolbar, click **Compute**.

RESULTS

Surface

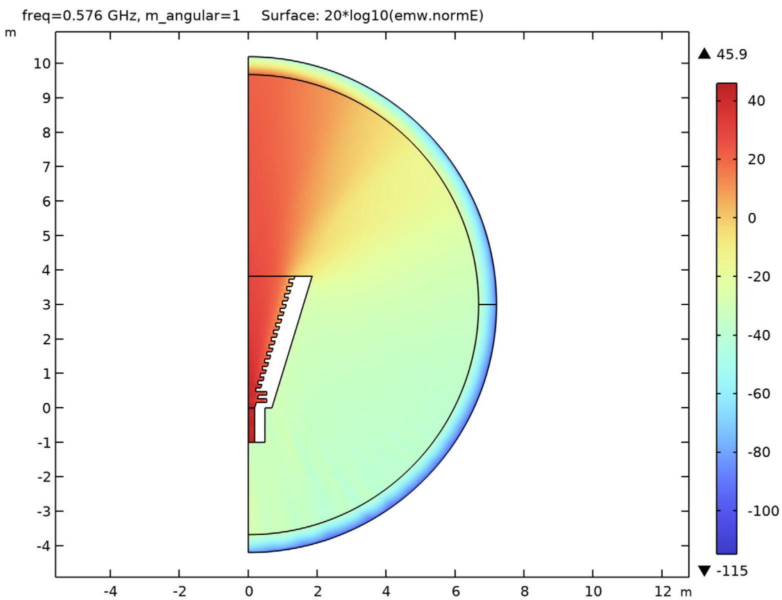
The electric field intensity is highest inside the waveguide. Plot the electric field intensity in dB for a better view of the field intensity outside the antenna.

1 In the **Model Builder** window, expand the **Results>Electric Field (emw)** node, then click **Surface**.

2 In the **Settings** window for **Surface**, locate the **Expression** section.

3 In the **Expression** text field, type `20*log10(emw.normE)`.

4 In the **Electric Field (emw)** toolbar, click **Plot**.



Smith Plot (emw)

In the **Model Builder** window, expand the **Smith Plot (emw)** node.

Color Expression 1

1 In the **Model Builder** window, expand the **Results>Smith Plot (emw)>Reflection Graph 1** node, then click **Color Expression 1**.

2 In the **Settings** window for **Color Expression**, locate the **Expression** section.

3 In the **Expression** text field, type `m_angular`.

Reflection Graph 1

1 In the **Model Builder** window, click **Reflection Graph 1**.

2 In the **Settings** window for **Reflection Graph**, click to expand the **Title** section.

3 In the **Title** text area, type `Reflection Graph: S-parameter, Azimuthal mode number`.

Radiation Pattern 1

Increase the resolution of the far field polar plot.

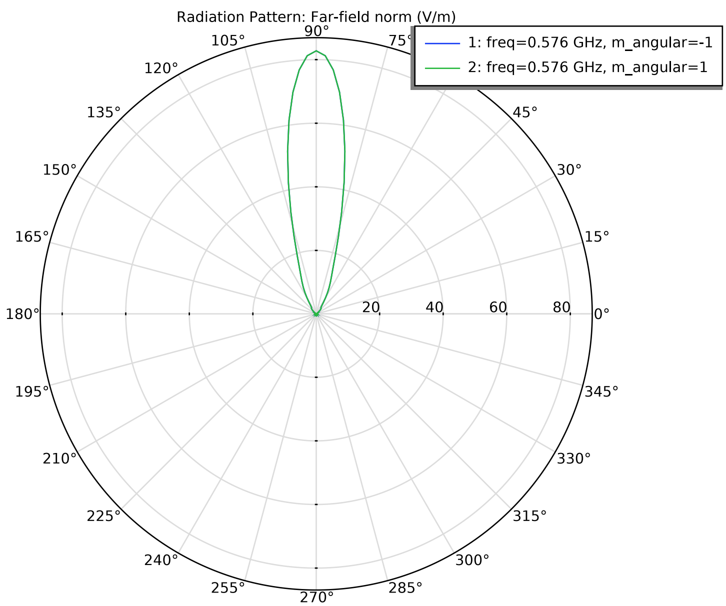
1 In the **Model Builder** window, expand the **Results>2D Far Field (emw)** node, then click **Radiation Pattern 1**.

2 In the **Settings** window for **Radiation Pattern**, locate the **Evaluation** section.

3 Find the **Reference direction** subsection. In the **x** text field, type `-1`.

4 In the **z** text field, type `0`.

5 In the **2D Far Field (emw)** toolbar, click **Plot**.



3D Far Field, Gain (emw)

3D far-field radiation pattern is generated by default. See Figure 2.

Create a dataset for 3D plots of field quantities at the aperture of the antenna. This is done in two steps: first select the boundary in the axisymmetric geometry, then revolve that around the axis.

Study 1/Solution 1 (2) (sol1)

In the **Results** toolbar, click **More Datasets** and choose **Solution**.

Selection

1 Right-click **Study 1/Solution 1 (2) (sol1)** and choose **Selection**.

2 In the **Settings** window for **Selection**, locate the **Geometric Entity Selection** section.

3 From the **Geometric entity level** list, choose **Boundary**.

4 Select Boundary 9 only.

Revolution 2D Aperture

1 In the **Results** toolbar, click **More Datasets** and choose **Revolution 2D**.

2 In the **Settings** window for **Revolution 2D**, type `Revolution 2D Aperture` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Study 1/Solution 1 (2) (sol1)**.

4 Click to expand the **Advanced** section. Select the **Define variables** check box.

Create a dataset for 3D plots of field quantities at the waveguide feed, similar to the preceding steps for the aperture.

Study 1/Solution 1 (3) (sol1)

In the **Results** toolbar, click **More Datasets** and choose **Solution**.

Selection

1 Right-click **Study 1/Solution 1 (3) (sol1)** and choose **Selection**.

2 In the **Settings** window for **Selection**, locate the **Geometric Entity Selection** section.

3 From the **Geometric entity level** list, choose **Boundary**.

4 Select Boundary 4 only.

Revolution 2D Feed

1 In the **Results** toolbar, click **More Datasets** and choose **Revolution 2D**.

2 In the **Settings** window for **Revolution 2D**, type `Revolution 2D Feed` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Study 1/Solution 1 (3) (sol1)**.

4 Locate the **Advanced** section. Select the **Define variables** check box.

Study 1/Solution 1 (4) (sol1)

In the **Results** toolbar, click **More Datasets** and choose **Solution**.

Selection

1 Right-click **Study 1/Solution 1 (4) (sol1)** and choose **Selection**.

2 In the **Settings** window for **Selection**, locate the **Geometric Entity Selection** section.

3 From the **Geometric entity level** list, choose **Domain**.

4 Select Domain 6 only.

Revolution 2D Horn

1 In the **Results** toolbar, click **More Datasets** and choose **Revolution 2D**.

2 In the **Settings** window for **Revolution 2D**, type `Revolution 2D Horn` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Study 1/Solution 1 (4) (sol1)**.

4 Click to expand the **Revolution Layers** section. In the **Start angle** text field, type `-45`.

5 In the **Revolution angle** text field, type `250`.

3D View

1 In the **Results** toolbar, click **3D Plot Group**.

2 In the **Settings** window for **3D Plot Group**, type `3D View` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **None**.

Plot the cut-away section of the antenna.

4 Click to expand the **Title** section. From the **Title type** list, choose **None**.

Surface 1

1 Right-click **3D View** and choose **Surface**.

2 In the **Settings** window for **Surface**, locate the **Data** section.

3 From the **Dataset** list, choose **Revolution 2D Horn**.

4 Locate the **Expression** section. In the **Expression** text field, type `1`.

Material Appearance 1

1 Right-click **Surface 1** and choose **Material Appearance**.

2 In the **Settings** window for **Material Appearance**, locate the **Appearance** section.

3 From the **Appearance** list, choose **Custom**.

4 From the **Material type** list, choose **Aluminum (anodized)**.

5 Click the **Zoom Extents** button in the **Graphics** toolbar.

3D View

Plot the electric field at the waveguide feed.

Arrow Surface 1

1 In the **Model Builder** window, right-click **3D View** and choose **Arrow Surface**.

   The field that is plotted is a linear superposition of the m=1 and m=-1 solutions.

2 In the **Settings** window for **Arrow Surface**, locate the **Data** section.

3 From the **Dataset** list, choose **Revolution 2D Feed**.

4 Locate the **Expression** section. From the **Coordinate system** list, choose **Cylindrical**.

5 In the **R-component** text field, type `sum(with(N+1,emw.Er*exp(-j*(2*N-1)*rev3phi)),N,0,1)`.

6 In the **PHI-component** text field, type `sum(with(N+1,emw.Ephi*exp(-j*(2*N-1)*rev3phi)),N,0,1)`.

7 In the **Z-component** text field, type `sum(with(N+1,emw.Ez*exp(-j*(2*N-1)*rev3phi)),N,0,1)`.

8 Locate the **Arrow Positioning** section. In the **Number of arrows** text field, type `80`.

9 Locate the **Coloring and Style** section.

10 Select the **Scale factor** check box. In the associated text field, type `0.02`.

Deformation 1

1 Right-click **Arrow Surface 1** and choose **Deformation**.

2 In the **Settings** window for **Deformation**, locate the **Expression** section.

3 In the **R-component** text field, type `3*r`.

4 In the **PHI-component** text field, type `0`.

5 In the **Z-component** text field, type `-1`.

6 Locate the **Scale** section.

7 Select the **Scale factor** check box. In the associated text field, type `1`.

8 In the **3D View** toolbar, click **Plot**.

Arrow Surface 2

1 In the **Model Builder** window, right-click **3D View** and choose **Arrow Surface**.

2 In the **Settings** window for **Arrow Surface**, locate the **Data** section.

3 From the **Dataset** list, choose **Revolution 2D Aperture**.

4 Locate the **Expression** section. From the **Coordinate system** list, choose **Cylindrical**.

5. In the **R-component** text field, type `sum(with(N+1,emw.Er*exp(-j*(2*N-1)*rev2phi)),N,0,1)`.
6. In the **PHI-component** text field, type `sum(with(N+1,emw.Ephi*exp(-j*(2*N-1)*rev2phi)),N,0,1)`.
7. In the **Z-component** text field, type `sum(with(N+1,emw.Ez*exp(-j*(2*N-1)*rev2phi)),N,0,1)`.
8. Locate the **Coloring and Style** section. From the **Arrow type** list, choose **Cone**.
9. Select the **Scale factor** check box. In the associated text field, type `0.01`.

Color Expression 1

1. Right-click **Arrow Surface 2** and choose **Color Expression**.
2. In the **Settings** window for **Color Expression**, locate the **Coloring and Style** section.
3. Clear the **Color legend** check box.

Deformation 1

1. In the **Model Builder** window, right-click **Arrow Surface 2** and choose **Deformation**.
2. In the **Settings** window for **Deformation**, locate the **Expression** section.
3. In the **R-component** text field, type `0.5*r`.
4. In the **PHI-component** text field, type `0`.
5. In the **Z-component** text field, type `1`.
6. Locate the **Scale** section.
7. Select the **Scale factor** check box. In the associated text field, type `1`.
8. In the **3D View** toolbar, click **Plot**.

Surface 2

1. In the **Model Builder** window, right-click **3D View** and choose **Surface**.
2. In the **Settings** window for **Surface**, locate the **Data** section.
3. From the **Dataset** list, choose **Revolution 2D Feed**.
4. Locate the **Expression** section. In the **Expression** text field, type `sqrt(abs(sum(with(N+1,(emw.Er*cos(rev3phi)-emw.Ephi*sin(rev3phi))*exp(-j*(2*N-1)*rev3phi)),N,0,1))^2+abs(sum(with(N+1,(emw.Er*sin(rev3phi)+emw.Ephi*cos(rev3phi))*exp(-j*(2*N-1)*rev3phi)),N,0,1))^2+abs(sum(with(N+1,emw.Ez*exp(-j*(2*N-1)*rev3phi)),N,0,1))^2)`.
5. Locate the **Coloring and Style** section. Clear the **Color legend** check box.
6. In the **3D View** toolbar, click **Plot**.

Surface 3

1 Right-click **3D View** and choose **Surface**.

2 In the **Settings** window for **Surface**, locate the **Data** section.

3 From the **Dataset** list, choose **Revolution 2D Aperture**.

4 Locate the **Expression** section. In the **Expression** text field, type `sqrt(abs(sum(with(N+1,(emw.Er*cos(rev2phi)-emw.Ephi*sin(rev2phi))*exp(-j*(2*N-1)*rev2phi)),N,0,1))^2+abs(sum(with(N+1,(emw.Er*sin(rev2phi)+emw.Ephi*cos(rev2phi))*exp(-j*(2*N-1)*rev2phi)),N,0,1))^2+abs(sum(with(N+1,emw.Ez*exp(-j*(2*N-1)*rev2phi)),N,0,1))^2)`.

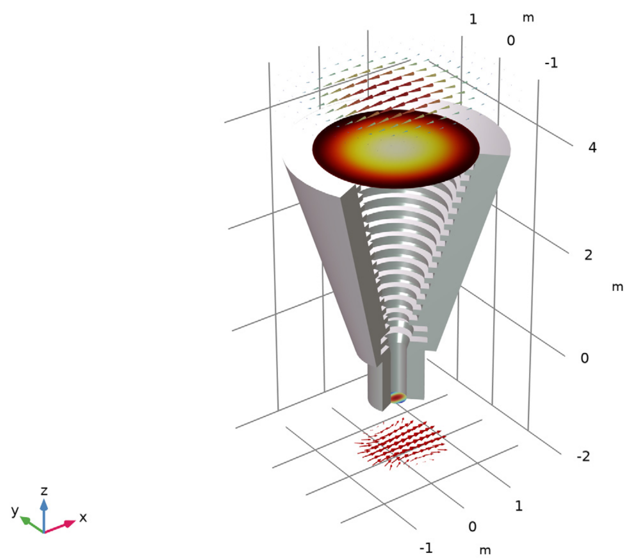
5 Locate the **Coloring and Style** section. Clear the **Color legend** check box.

6 Click **Change Color Table**.

7 In the **Color Table** dialog box, select **Thermal>ThermalDark** in the tree.

8 Click **OK**.

9 In the **3D View** toolbar, click **Plot**.



The resulting plot should look like Figure 3.

Check S_{11}.

Estimate the amount of linear polarization in the *x* direction at the waveguide feed by integrating the magnitude of E_x over the surface.

Feed x-component

1 In the **Model Builder** window, expand the **Results>Derived Values** node.

2 Right-click **Results>Derived Values** and choose **Integration>Surface Integration**.

3 In the **Settings** window for **Surface Integration**, type `Feed x-component` in the **Label** text field.

4 Locate the **Data** section. From the **Dataset** list, choose **Revolution 2D Feed**.

5 Locate the **Expressions** section. In the table, enter the following settings:

Expression	Unit	Description
`abs(sum(with(N+1,(emw.Er*cos(rev3phi)-emw.Ephi* sin(rev3phi))*exp(-j*(2*N-1)*rev3phi)),N,0,1))`	`V*m`	

6 Click **Evaluate**.

Similarly, estimate the amount of linear polarization in the y direction at the waveguide feed by integrating the magnitude of E_y over the surface.

Feed y-component

1 In the **Results** toolbar, click 8.85 e-12 **More Derived Values** and choose **Integration> Surface Integration**.

2 In the **Settings** window for **Surface Integration**, type `Feed y-component` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Revolution 2D Feed**.

4 Locate the **Expressions** section. In the table, enter the following settings:

Expression	Unit	Description
`abs(sum(with(N+1,(emw.Er*sin(rev3phi)+emw.Ephi* cos(rev3phi))*exp(-j*(2*N-1)*rev3phi)),N,0,1))`	`V*m`	

5 Click **Evaluate**.

Estimate the amount of linear polarization in the x direction at the antenna aperture by integrating the magnitude of E_x over the surface.

Aperture x-component

1 In the **Results** toolbar, click 8.85 e-12 **More Derived Values** and choose **Integration> Surface Integration**.

2 In the **Settings** window for **Surface Integration**, type `Aperture x-component` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Revolution 2D Aperture**.

4 Locate the **Expressions** section. In the table, enter the following settings:

Expression	Unit	Description
`abs(sum(with(N+1,(emw.Er*cos(rev2phi)-emw.Ephi* sin(rev2phi))*exp(-j*(2*N-1)*rev2phi)),N,0,1))`	`V*m`	

5 Click **Evaluate**.

Similarly, estimate the amount of linear polarization in the y direction at the antenna aperture by integrating the magnitude of E_y over the surface.

Aperture y-component

1 In the **Results** toolbar, click **More Derived Values** and choose **Integration> Surface Integration**.

2 In the **Settings** window for **Surface Integration**, type `Aperture y-component` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Revolution 2D Aperture**.

4 Locate the **Expressions** section. In the table, enter the following settings:

Expression	Unit	Description
`abs(sum(with(N+1,(emw.Er*sin(rev2phi)+emw.Ephi* cos(rev2phi))*exp(-j*(2*N-1)*rev2phi)),N,0,1))`	`V*m`	

5 Click **Evaluate**.

The 3D far-field radiation pattern plotted by default is just a simple body of revolution of the 2D plot that is useful to measure quickly the maximum gain. Using the predefined postprocessing function, it is possible to estimate an effective 3D far-field radiation pattern of the antenna that is excited by the dominant mode of the 3D model of a circular waveguide, TE_{11} mode.

3D Radiation Pattern for TE11 Mode

1 In the **Results** toolbar, click **3D Plot Group**.

2 In the **Settings** window for **3D Plot Group**, type `3D Radiation Pattern for TE11 Mode` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **None**.

4 Locate the **Color Legend** section. Select the **Show maximum and minimum values** check box.

Radiation Pattern 1

1 In the **3D Radiation Pattern for TE11 Mode** toolbar, click **More Plots** and choose **Radiation Pattern**.

2 In the **Settings** window for **Radiation Pattern**, locate the **Data** section.

3 From the **Dataset** list, choose **Study 1/Solution 1 (1) (sol1)**.

4 Locate the **Expression** section. In the **Expression** text field, type `emw.normdB3DEfar_TE11(angle)`.

5 Select the **Threshold** check box. In the associated text field, type `-20`.

6 Locate the **Evaluation** section. Find the **Angles** subsection. In the **Number of elevation angles** text field, type `90`.

7 In the **Number of azimuth angles** text field, type `90`.

8 In the **Azimuthal angle variable** text field, type `angle`.

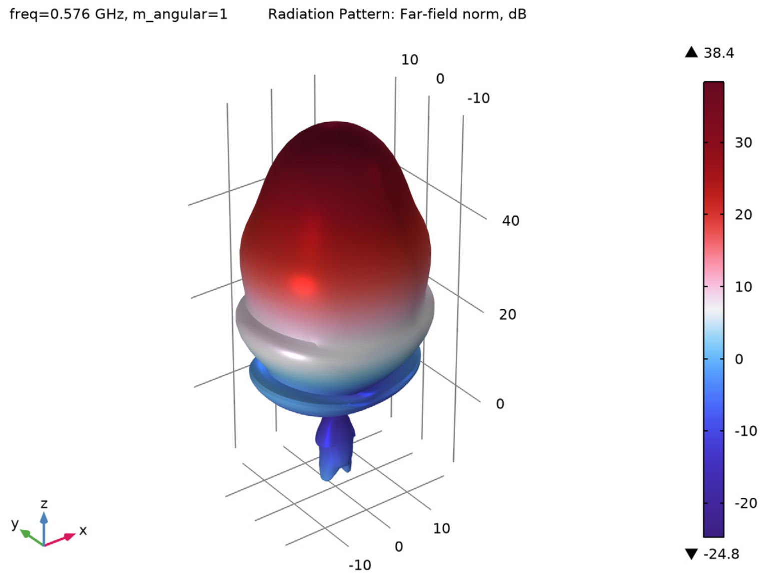
The far-field function contains an argument, which is given the name `angle` by default. For the azimuthal angle variable field in the Evaluation section, enter `angle` to match the function argument. Note that the name can be chosen freely as long as the function argument matches the azimuth angle variable specified in the Evaluation section.

9 Locate the **Coloring and Style** section. Click **Change Color Table**.

10 In the **Color Table** dialog box, select **Wave>Wave** in the tree.

11 Click **OK**.

12 In the **3D Radiation Pattern for TE11 Mode** toolbar, click **Plot**.



Compare the plot with Figure 4.