Created in COMSOL Multiphysics 6.0

Parabolic Reflector Antenna

Introduction

A large reflector can be modeled easily with the 2D axisymmetric formulation. In this example, the radius of the reflector is greater than 20 wavelengths and the reflector is illuminated by an axial feed circular horn antenna. The simulated far-field shows a high-gain sharp beam pattern.

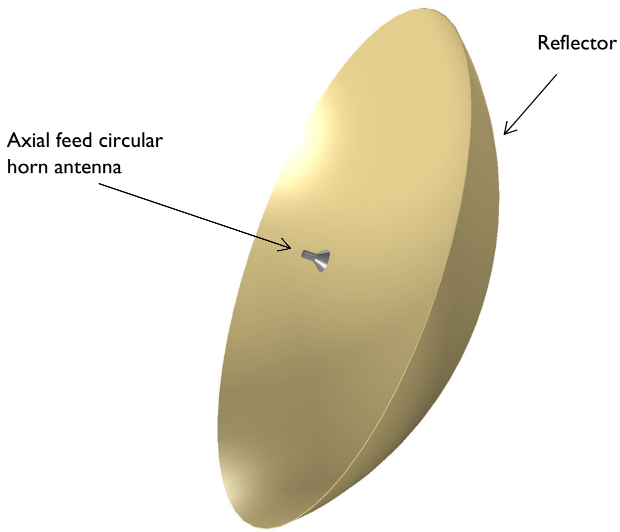


Figure 1: This is a 3D visualization of the parabolic reflector antenna that is solved using the 2D axisymmetric formulation.

Model Definition

Since the axial feed circular horn and parabolic reflector antenna are solids of revolution, the antenna can be simulated using the 2D axisymmetric formulation of the electromagnetic wave equation (Figure 1). This approach overcomes a general difficulty when optimizing a reflector antenna: due to its very large size in terms of wavelength, the 3D calculation is computationally intensive.

In this example, all metal surfaces are modeled as perfect electric conductors (PECs) and all domains are filled with air.

The radius of the circular horn feed waveguide is 0.01 m and the cutoff frequency of the TE_{11} mode is approximately 8.8 GHz. The operating frequency of the antenna should be higher than the cutoff frequency. The horn aperture radius is 0.03 m and the overall horn length is 0.06 m. A slit-conditioned circular port is assigned on the end of the waveguide to excite the antenna with the TE_{1m} mode. The azimuthal mode number, m, is defined from the Electromagnetic Waves, Frequency Domain interface. In this example, $m = 1$.

The reflector is built using a 53 degree sector of a circle with a radius of 0.85 m. The reflector body is removed from the model domain and, consequently, the PEC is automatically applied to its boundary. The model domain is enclosed by perfectly matched layers (PMLs). The PMLs are thicker than that of other antenna examples in the Application Libraries since high gain and stronger propagation are expected from the reflector.

A Free Triangular mesh is used for the antenna and air domains. The maximum element size is one-fifth of the wavelength at the simulation frequency. A mapped mesh with 10 layers is used for the PMLs.

Results and Discussion

In Figure 2, the norm of the electric field is plotted in decibels with arrows indicating the direction and relative magnitude of power flow. The field from the horn antenna is reflected by the parabola and propagates in the $+z$ direction, confined near the axis of rotation.

The 3D far-field radiation pattern is plotted with a visualization of the antenna body in Figure 3. The low gain radiation from the axial feed horn results in a very high gain pattern created by the reflector.

The far-field radiation pattern in Figure 3 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.

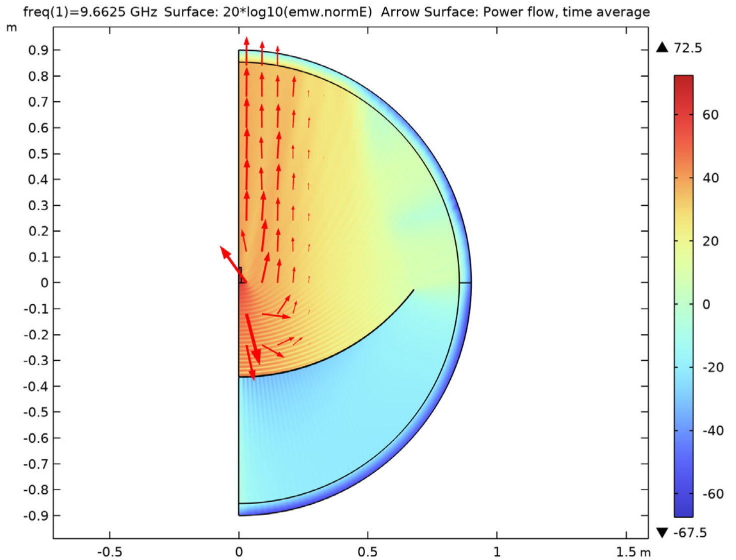


Figure 2: The norm of the electric field is plotted in decibels. The field from the horn antenna is reflected by the parabola and propagates in the +z direction.

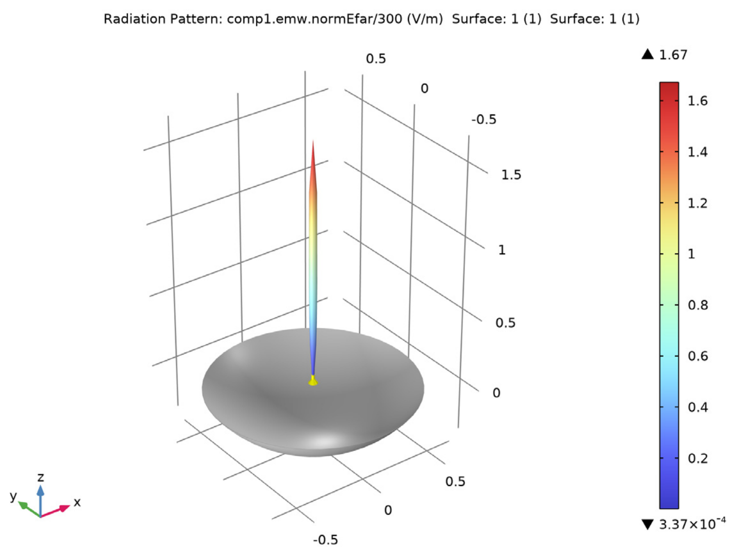


Figure 3: The very sharp 3D far-field radiation pattern is visualized over the axial feed circular horn and parabolic reflector.

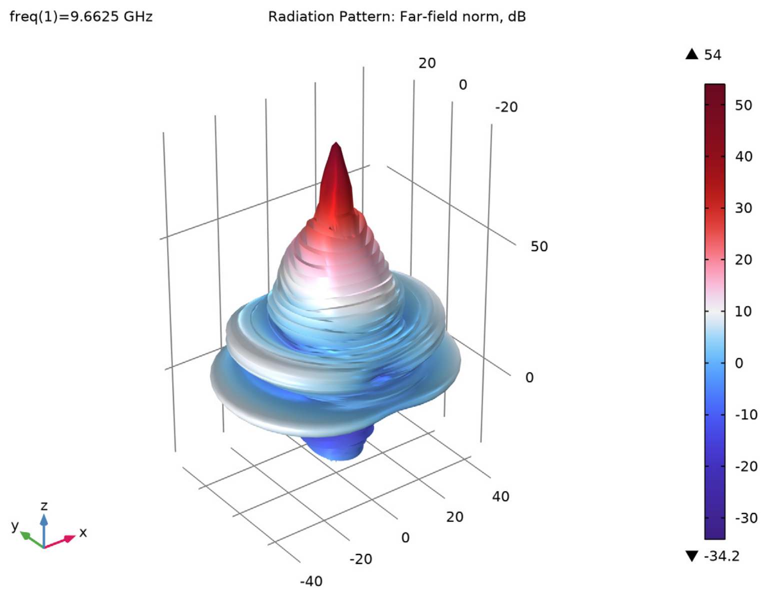


Figure 4: Effective 3D far-field radiation pattern plotted in 80 dB dynamic range using far-far field function normdB3DEfar_TE11(angle).

Application Library path: `RF_Module/Antennas/parabolic_reflector`

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 In the table, enter the following settings:

Name	Expression	Value	Description
r0	0.85[m]	0.85 m	Reflector, radius
r1	0.01[m]	0.01 m	Feed horn waveguide, radius
fc	(1.841*c_const/2/pi/r1)	8.784E9 1/s	Feed horn waveguide, cutoff frequency
f0	fc*1.1	9.6625E9 1/s	Frequency
lda0	c_const/f0	0.031027 m	Wavelength
l_horn	0.028[m]	0.028 m	Horn length

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

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**, locate the **Study Settings** section.

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

GEOMETRY 1

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 0.06.

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)
0.01	l_horn
0.03	0
0.01	0

4 Click **Build Selected**.

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 `0.9`.

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

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

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

Layer name	Thickness (m)
Layer 1	1.5*lda0

7 Click **Build Selected**.

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

Circle 2 (c2)

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 `r0`.

4 In the **Sector angle** text field, type `53`.

5 Locate the **Position** section. In the **z** text field, type `r0-0.365`.

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

7 Locate the **Layers** section. In the table, enter the following settings:

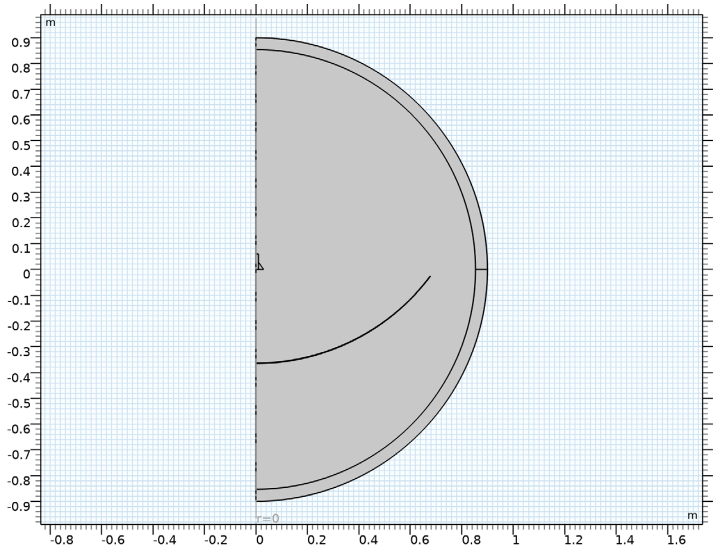
Layer name	Thickness (m)
Layer 1	0.002

Delete Entities 1 (del1)

1 In the **Model Builder** window, right-click **Geometry 1** and choose **Delete Entities**.

2 On the object **c2**, select Boundary 1 only.

3 In the **Settings** window for **Delete Entities**, click **Build All Objects**.



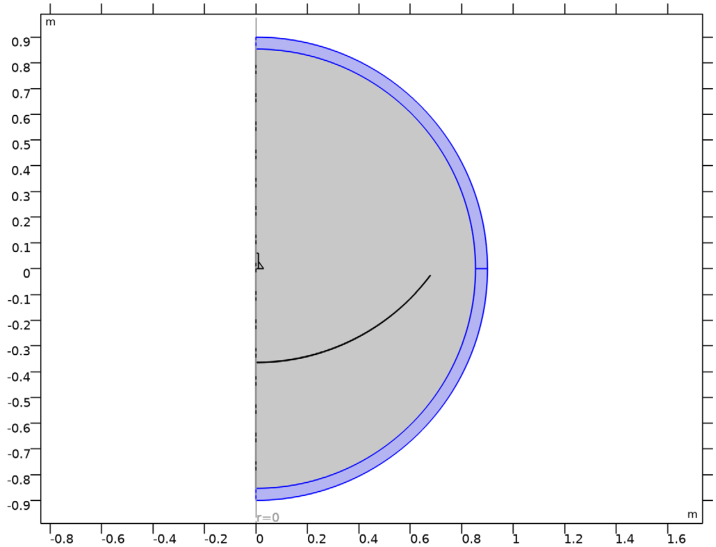
The finished geometry should look like this.

DEFINITIONS

Perfectly Matched Layer 1 (pml1)

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

2 Select Domains 1 and 5 only.

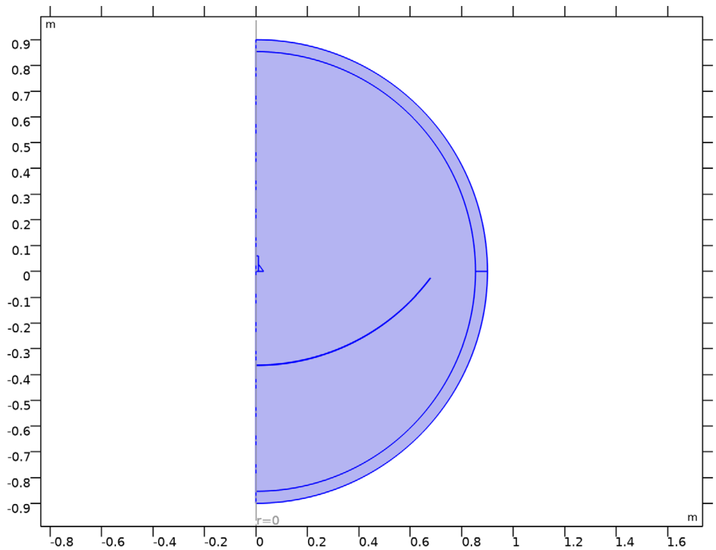


ELECTROMAGNETIC WAVES, FREQUENCY DOMAIN (EMW)

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

2 Select Domains 1, 2, and 4–6 only.

The reflector body is removed from the model domain and, consequently, the PEC is automatically applied to its boundary.



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

4 In the m text field, type 1.

Perfect Electric Conductor 2

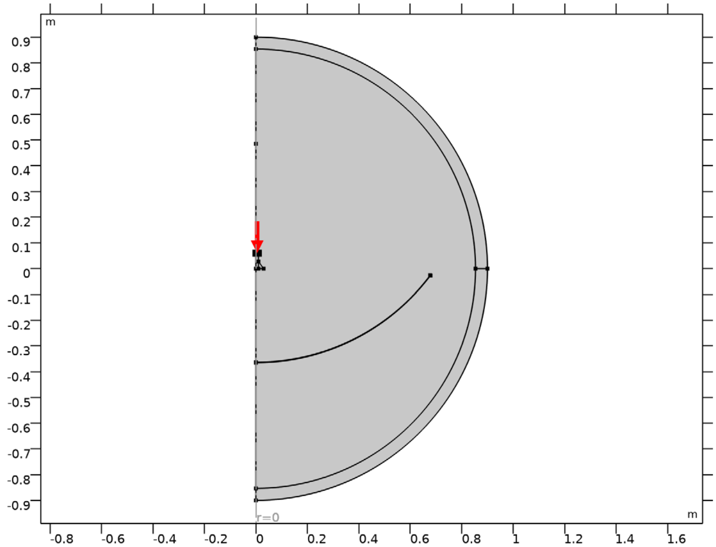
1 In the **Physics** toolbar, click **Boundaries** and choose **Perfect Electric Conductor**.

2 Select Boundaries 13 and 14 only.

Port 1

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

2 Select Boundary 8 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.

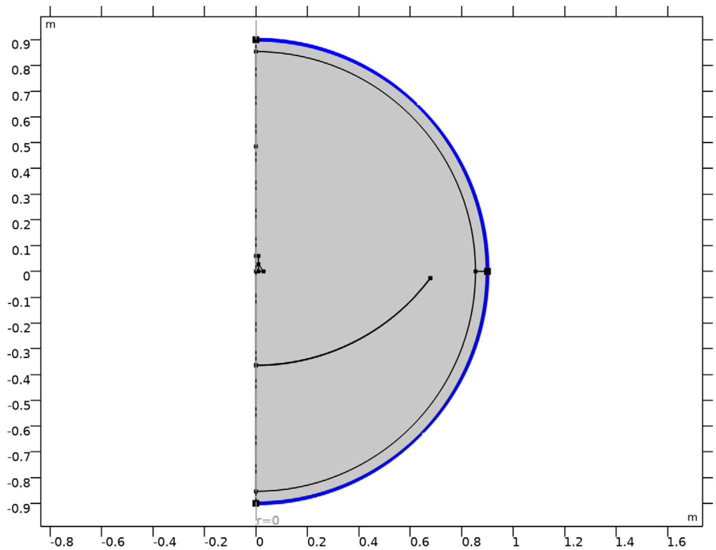
5 Select the **Activate slit condition on interior port** check box.

6 Click **Toggle Power Flow Direction**.

Scattering Boundary Condition 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Scattering Boundary Condition**.

2 Select Boundaries 17 and 22 only.



Far-Field Domain 1

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

MATERIALS

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:

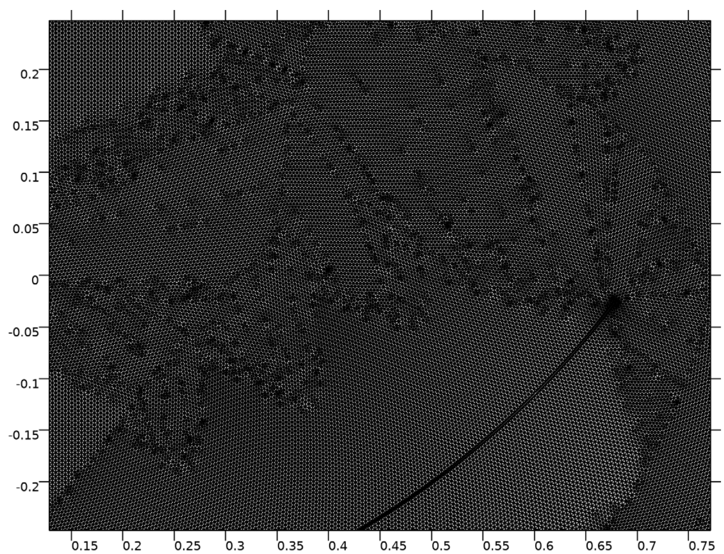
Property	**Variable**	**Value**	**Unit**	**Property group**
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	1	1	Basic

Property	Variable	Value	Unit	Property group
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

MESH 1

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

2 Click the **Zoom In** button in the **Graphics** toolbar, a couple of times to get a better view of the meshed structure.



STUDY 1

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

RESULTS

Surface

1 In the **Model Builder** window, expand the **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**.

Arrow Surface 1

1 In the **Model Builder** window, right-click **Electric Field (emw)** and choose **Arrow Surface**.

2 In the **Settings** window for **Arrow Surface**, click **Replace Expression** in the upper-right corner of the **Expression** section. From the menu, choose **Component 1 (comp1)>Electromagnetic Waves, Frequency Domain>Energy and power>emw.Poavr,emw.Poavz - Power flow, time average**.

3 Locate the **Coloring and Style** section. From the **Arrow length** list, choose **Logarithmic**.

4 Select the **Scale factor** check box.

5 In the associated text field, type `0.004`.

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

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

Compare with the plot in Figure 2.

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**.

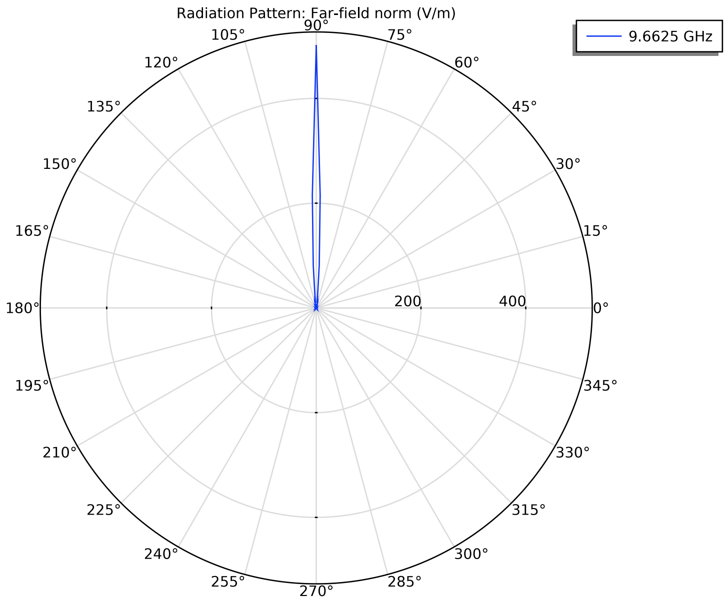
2 In the **Settings** window for **Radiation Pattern**, locate the **Evaluation** section.

3 Find the **Angles** subsection. In the **Number of angles** text field, type `180`.

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

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

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



Study 1/Solution 1 (2) (sol1)

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

Selection

1 In the **Results** toolbar, click **Attributes** 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 Domains 4 and 6 only.

Revolution 2D Feed horn

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

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

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

Study 1/Solution 1 (3) (sol1)

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

Selection

1 In the **Results** toolbar, click **Attributes** 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 3 only.

Revolution 2D Reflector

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

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

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

Surface 1

1 In the **Model Builder** window, right-click **3D Far Field, Gain (emw)** and choose **Surface**.

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

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

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

5 Locate the **Coloring and Style** section. From the **Coloring** list, choose **Uniform**.

6 From the **Color** list, choose **Yellow**.

Surface 2

1 Right-click **3D Far Field, Gain (emw)** and choose **Surface**.

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

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

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

5 Locate the **Coloring and Style** section. From the **Coloring** list, choose **Uniform**.

6 From the **Color** list, choose **Gray**.

Radiation Pattern 1

1 In the **Model Builder** window, click **Radiation Pattern 1**.

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

3 In the **Expression** text field, type `comp1.emw.normEfar/300`.

4 In the **3D Far Field, Gain (emw)** toolbar, click **Plot**.

TABLE

1 Go to the **Table** window.

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

The plotted figure describes the axial feed circular horn and parabolic reflector as well as the 3D far-field pattern as shown in Figure 3.

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.

RESULTS

3D Plot Group 4

1 In the **Home** toolbar, click **Add Plot Group** and choose **3D Plot Group**.
2 In the **Settings** window for **3D Plot Group**, locate the **Data** section.
3 From the **Dataset** list, choose **None**.
4 Locate the **Color Legend** section. Select the **Show maximum and minimum values** check box.

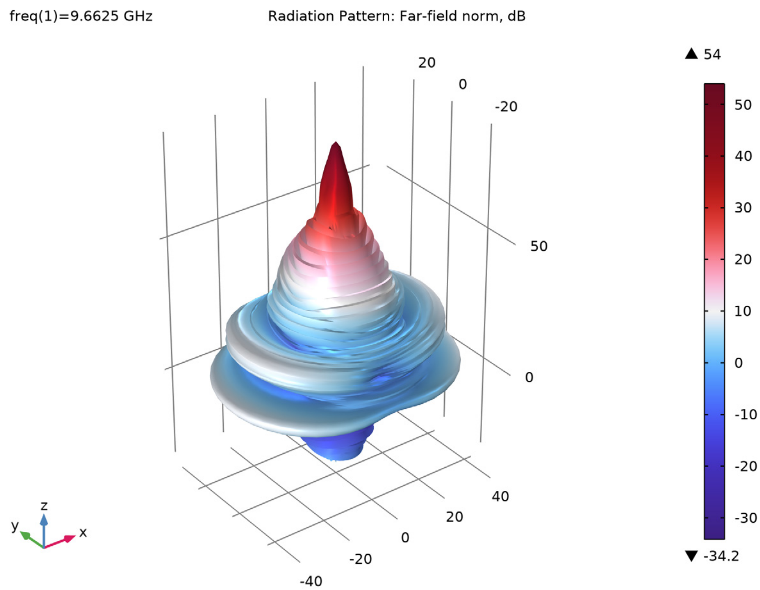
Radiation Pattern 1

1 In the **3D Plot Group 4** 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 Locate the **Evaluation** section. Find the **Angles** subsection. In the **Number of elevation angles** text field, type `180`.
6 In the **Number of azimuth angles** text field, type `45`.
7 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. This plot would take up to several minutes.

8 Locate the **Coloring and Style** section. From the **Color table** list, choose **Wave**.

9 In the **3D Plot Group 4** toolbar, click **Plot**.



Compare the plot with Figure 4.