

Double-Ridged Horn Antenna

Introduction

A double-ridged horn antenna is popularly used in an anechoic chamber to characterize an antenna under test (AUT) from S-band to Ku-band due to its reliable performance in a wideband frequency range. The model computes the voltage standing wave ratio (VSWR), far-field radiation pattern, and antenna directivity.



Figure 1: Double-ridged horn antenna excited by a coaxial port. The surrounding air domain and a perfectly matched layer, which is required for the simulation, are not included in this figure.

Note: This example requires the RF Module and the Design Module.

Model Definition

The simulation frequency range is from 2 GHz to 6 GHz. The conductivity of the metallic material in the model is assumed to be high enough to neglect the loss in the given frequency range. Thus, all metal parts are modeled using a perfect electric conductor (PEC) feature. An exponential function, $e^{0.028x}$ is used in a parametric curve to create the tapered metallic ridges that are excited by an SMA type dielectric-filled coaxial connector.

A lumped port is assigned on the boundary between the inner and outer conducting surface at the end of the coaxial connector. The antenna is enclosed by a spherical air domain. The outermost layer of the air domain is configured as a perfectly matched layer (PML) where the thickness of the layer is slightly greater than 0.1 wavelengths at the lowest simulation frequency. The PML absorbs all outgoing radiation from the antenna and work as an anechoic chamber during the simulation. The mesh is controlled by the Electromagnetic Waves, Frequency Domain physics interface and it has to be defined dynamically based on each simulation frequency, so frequency parametric sweep is over Frequency Domain study step.

Results and Discussion

In Figure 2, the slice and contour plot of E_z is visualized in the *zx*-plane. The electric field is guided by two symmetric metallic ridges and propagating toward the aperture of the horn.



Figure 2: z-component of the electric field and its contour plot at 6 GHz.

Figure 3 shows the 3D far-field radiation pattern. When it is plotted, the directivity is also calculated which is around 12.9 dB. Other antenna far-field postprocessing variables such as antenna gain and axial ratio can be visualized using the same plot by replacing the

default input fields both for expression and color. These steps are not included in this tutorial but you are encouraged to try.



Figure 3: 3D far-field radiation pattern that is directive toward the open aperture.

Voltage standing wave ratio (VSWR) is a measure commonly used to characterize the input impedance matching properties for off-the-shelf antenna products. Figure 4 presents the VSWR of the double-ridged horn antenna that is lower than 1.7 in the simulated frequency range.



Figure 4: Voltage standing wave ratio (VSWR) plot. It is better than 2:1 in the simulated frequency range

Notes About the COMSOL Implementation

The antenna model is memory intensive and requires more than 12 GB RAM for the simulation up to 6 GHz. It may require much more for higher frequency simulations.

Application Library path: RF_Module/Antennas/double_ridged_horn_antenna

Modeling Instructions

From the File menu, choose New.

NEW

In the New window, click Model Wizard.

MODEL WIZARD

- I In the Model Wizard window, click 间 3D.
- 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

- I In the Model Builder window, under Global Definitions click Parameters I.
- 2 In the Settings window for Parameters, locate the Parameters section.
- **3** In the table, enter the following settings:

Name	Expression	Value	Description
w_slot	1.8[mm]	0.0018 m	Slot width
fO	2[GHz]	2E9 Hz	Frequency

STUDY I

Step 1: Frequency Domain

- I In the Model Builder window, under Study I click Step I: Frequency Domain.
- 2 In the Settings window for Frequency Domain, locate the Study Settings section.
- 3 In the Frequencies text field, type f0.

GEOMETRY I

- I In the Model Builder window, under Component I (compl) click Geometry I.
- 2 In the Settings window for Geometry, locate the Units section.
- 3 From the Length unit list, choose mm.
- 4 Locate the Advanced section. From the Geometry representation list, choose CAD kernel.

Work Plane I (wp1)

- I In the Geometry toolbar, click 🖶 Work Plane.
- 2 In the Settings window for Work Plane, locate the Plane Definition section.
- 3 From the Plane list, choose xz-plane.

4 In the **y-coordinate** text field, type **3.5**.

Work Plane I (wpI)>Plane Geometry

In the Model Builder window, click Plane Geometry.

Work Plane I (wp1)>Parametric Curve I (pc1)

- I In the Work Plane toolbar, click 🚧 More Primitives and choose Parametric Curve.
- 2 In the Settings window for Parametric Curve, locate the Parameter section.
- 3 In the Maximum text field, type 150.
- 4 Locate the Expressions section. In the xw text field, type s-100.
- 5 In the yw text field, type exp(0.028*s)-1+w_slot/2.

Work Plane I (wp1)>Mirror I (mir1)

- I In the Work Plane toolbar, click 💭 Transforms and choose Mirror.
- 2 Select the object pcl only.
- 3 In the Settings window for Mirror, locate the Input section.
- 4 Select the Keep input objects check box.
- 5 Locate the Normal Vector to Line of Reflection section. In the xw text field, type 0.
- 6 In the **yw** text field, type 1.

Work Plane I (wp1)>Rectangle I (r1)

- I In the Work Plane toolbar, click Rectangle.
- 2 In the Settings window for Rectangle, locate the Size and Shape section.
- 3 In the Width text field, type 20.15.
- **4** In the **Height** text field, type w_slot.
- 5 Locate the Position section. In the xw text field, type -120.15.
- **6** In the **yw** text field, type -w_slot/2.
- 7 Click 틤 Build Selected.
- **8** Click the $4 \rightarrow$ **Zoom Extents** button in the **Graphics** toolbar.

Work Plane 1 (wp1)>Rectangle 2 (r2)

- I In the Work Plane toolbar, click Rectangle.
- 2 In the Settings window for Rectangle, locate the Size and Shape section.
- 3 In the Width text field, type 20.15.
- 4 In the Height text field, type 30.
- 5 Locate the Position section. In the xw text field, type -120.15.

6 In the yw text field, type -15.

Work Plane I (wpl)>Polygon I (poll)

- I In the Work Plane toolbar, click / Polygon.
- 2 In the Settings window for Polygon, locate the Coordinates section.
- **3** From the **Data source** list, choose **Vectors**.
- 4 In the xw text field, type 50 -100 -100 -100 50.
- 5 In the yw text field, type exp(0.028*150)-1+w_slot/2 15 15 -15 (exp(0.028*150)-1+w_slot/2).

Extrude I (extI)

- I In the Model Builder window, right-click Geometry I and choose Extrude.
- 2 In the Settings window for Extrude, locate the Distances section.
- **3** In the table, enter the following settings:

Distances (mm)

7

Work Plane 2 (wp2)

- I In the Geometry toolbar, click 📥 Work Plane.
- 2 In the Settings window for Work Plane, locate the Plane Definition section.
- 3 From the Plane list, choose yz-plane.
- 4 In the **x-coordinate** text field, type 50.
- Work Plane 2 (wp2)>Plane Geometry

In the Model Builder window, click Plane Geometry.

Work Plane 2 (wp2)>Rectangle 1 (r1)

- I In the Work Plane toolbar, click Rectangle.
- 2 In the Settings window for Rectangle, locate the Size and Shape section.
- **3** In the **Width** text field, type 190.
- **4** In the **Height** text field, type (exp(0.028*150)-1+w_slot/2)*2.
- 5 Locate the **Position** section. In the **xw** text field, type -95.
- 6 In the yw text field, type (exp(0.028*150)-1+w_slot/2).

Work Plane 3 (wp3)

- I In the Model Builder window, right-click Geometry I and choose Work Plane.
- 2 In the Settings window for Work Plane, locate the Plane Definition section.

- 3 From the Plane list, choose yz-plane.
- 4 In the **x-coordinate** text field, type -100.

Work Plane 3 (wp3)>Plane Geometry

In the Model Builder window, click $\ensuremath{\mathsf{Plane}}$ Geometry.

Work Plane 3 (wp3)>Rectangle 1 (r1)

- I In the Work Plane toolbar, click 📃 Rectangle.
- 2 In the Settings window for Rectangle, locate the Size and Shape section.
- 3 In the Width text field, type 50.
- 4 In the Height text field, type 30.
- 5 Locate the Position section. In the xw text field, type -25.
- 6 In the yw text field, type -15.

Extrude 2 (ext2)

- I In the Model Builder window, right-click Geometry I and choose Extrude.
- 2 In the Settings window for Extrude, locate the General section.
- 3 From the Input object handling list, choose Keep.
- 4 Locate the **Distances** section. In the table, enter the following settings:

Distances (mm)

28

5 Select the **Reverse direction** check box.

Loft I (loft I)

- I In the Geometry toolbar, click 🍃 Loft.
- 2 Click the Wireframe Rendering button in the Graphics toolbar.
- **3** Click the **Joom Extents** button in the **Graphics** toolbar.

4 Select the objects wp2 and wp3 only.



Cylinder I (cyl1)

- I In the Geometry toolbar, click 💭 Cylinder.
- 2 In the Settings window for Cylinder, locate the Size and Shape section.
- 3 In the Radius text field, type 2.05.
- **4** In the **Height** text field, type 15-w_slot/2.
- 5 Locate the Position section. In the x text field, type -117.5.
- 6 In the z text field, type w_slot/2.

Cylinder 2 (cyl2)

- I Right-click Cylinder I (cyll) and choose Duplicate.
- 2 In the Settings window for Cylinder, locate the Size and Shape section.
- 3 In the Radius text field, type 0.635.
- **4** In the **Height** text field, type 15+w_slot/2.
- **5** Locate the **Position** section. In the **z** text field, type -w_slot/2.

PART LIBRARIES

- I In the Geometry toolbar, click A Parts and choose Part Libraries.
- 2 In the Model Builder window, click Geometry I.

- 3 In the Part Libraries window, select RF Module>Connectors>connector_sma_flange2 in the tree.
- 4 Click 🔁 Add to Geometry.

GEOMETRY I

- SMA Connector, Flange with Two Holes 1 (pil)
- I In the Model Builder window, under Component I (comp1)>Geometry I click
 SMA Connector, Flange with Two Holes I (pi1).
- 2 In the Settings window for Part Instance, locate the Input Parameters section.
- **3** In the table, enter the following settings:

Name	Expression	Value	Description
solder_o	0	0	Soldering_block_option

- 4 Locate the Position and Orientation of Output section. Find the Displacement subsection. In the xw text field, type -117.5.
- **5** In the **zw** text field, type **15**.
- 6 Find the Rotation subsection. From the Axis type list, choose yw-axis.
- 7 In the Rotation angle text field, type 90.
- 8 Click to expand the **Boundary Selections** section. In the table, enter the following settings:

Name	Кеер	Physics	Contribute to
Exterior		\checkmark	None
Conductive surface		\checkmark	None

9 Click to expand the Domain Selections section. In the table, enter the following settings:

Name	Кеер	Physics	Contribute to
All		\checkmark	None
Dielectric	\checkmark	\checkmark	None
Conductor		\checkmark	None

10 Click 틤 Build Selected.



Sphere I (sph1)

- I In the **Geometry** toolbar, click \bigoplus Sphere.
- 2 In the Settings window for Sphere, locate the Size section.
- **3** In the **Radius** text field, type **170**.
- 4 Click to expand the Layers section. In the table, enter the following settings:

Layer name	Thickness (mm)
Layer 1	20

5 In the Geometry toolbar, click 🟢 Build All.



DEFINITIONS

Perfectly Matched Layer I (pml1)

- I In the Definitions toolbar, click W Perfectly Matched Layer.
- **2** Select Domains 1–4 and 24–27 only.



- 3 In the Settings window for Perfectly Matched Layer, locate the Geometry section.
- 4 From the Type list, choose Spherical.

ADD MATERIAL

- I In the Home toolbar, click 🙀 Add Material to open the Add Material window.
- 2 Go to the Add Material window.
- 3 In the tree, select Built-in>Air.
- **4** Click **a** Add to Component I (compl).
- 5 In the Home toolbar, click 🙀 Add Material to close the Add Material window.

MATERIALS

Material 2 (mat2)

- I In the Model Builder window, under Component I (comp1) right-click Materials and choose Blank Material.
- **2** Select Domain 12 only.



3 In the Settings window for Material, locate the Material Contents section.

4 In the table, enter the following settings:

Property	Variable	Value	Unit	Property group
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	2.1	I	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

Material 3 (mat3)

- I Right-click Material 2 (mat2) and choose Duplicate.
- 2 In the Settings window for Material, locate the Geometric Entity Selection section.
- 3 From the Selection list, choose Dielectric (SMA Connector, Flange with Two Holes I).

ELECTROMAGNETIC WAVES, FREQUENCY DOMAIN (EMW)

Perfect Electric Conductor 2

- I In the Model Builder window, under Component I (comp1) right-click Electromagnetic Waves, Frequency Domain (emw) and choose Perfect Electric Conductor.
- **2** In the **Settings** window for **Perfect Electric Conductor**, locate the **Boundary Selection** section.
- 3 Click **Paste Selection**.
- **4** In the **Paste Selection** dialog box, type 13-17, 28-30, 33-36, 45, 47, 50, 51, 53, 54, 66, 69-73, 75-79, 81, 82, 94, 95, 98-101, 103-106, 108, 109, 122, 124-126, 128, 129, 132, 134-136, 138, 139, 141-143 in the **Selection** text field.

5 Click OK.



Perfect Electric Conductor 3

- I In the Physics toolbar, click 🔚 Boundaries and choose Perfect Electric Conductor.
- **2** In the Settings window for Perfect Electric Conductor, locate the Boundary Selection section.
- 3 From the Selection list, choose Conductive surface (SMA Connector, Flange with Two Holes I).

Lumped Port I

- I In the Physics toolbar, click 🔚 Boundaries and choose Lumped Port.
- 2 Select Boundary 61 only.
- 3 In the Settings window for Lumped Port, locate the Lumped Port Properties section.
- 4 From the Type of lumped port list, choose Coaxial.

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

Far-Field Domain 1

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

DEFINITIONS

Hide for Physics 1

I In the Model Builder window, right-click View I and choose Hide for Physics.

- 2 In the Settings window for Hide for Physics, locate the Geometric Entity Selection section.
- **3** From the **Geometric entity level** list, choose **Boundary**.
- 4 Select Boundaries 3, 6, 8, 10, and 12 only.

MESH I

- I In the Model Builder window, under Component I (compl) click Mesh I.
- 2 In the Settings window for Mesh, locate the Physics-Controlled Mesh section.
- 3 From the Element size list, choose Coarser.

Use Coarser mesh to avoid unnecessarily fine mesh on small parts.

4 Click 📗 Build All.



STUDY I

Parametric Sweep

- I In the Study toolbar, click **Parametric Sweep**.
- 2 In the Settings window for Parametric Sweep, locate the Study Settings section.
- 3 Click + Add.

4 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
f0 (Frequency)	range(2[GHz],0.5[GHz],6[GHz])	Hz

Step 1: Frequency Domain

In the **Study** toolbar, click **= Compute**.

RESULTS

Multislice

- I In the Model Builder window, expand the Electric Field (emw) node, then click Multislice.
- 2 In the Settings window for Multislice, locate the Expression section.
- 3 In the Expression text field, type emw.Ez.
- 4 Locate the Multiplane Data section. Find the X-planes subsection. In the Planes text field, type 0.
- 5 Find the Z-planes subsection. In the Planes text field, type 0.
- 6 Click to expand the Range section. Select the Manual color range check box.
- 7 In the Minimum text field, type 100.
- 8 In the Maximum text field, type 100.

Selection I

- I Right-click Multislice and choose Selection.
- **2** Select Domains 5, 6, 10, and 21 only.
- 3 In the Electric Field (emw) toolbar, click 💽 Plot.

Cut Plane 1

- I In the **Results** toolbar, click **Cut Plane**.
- 2 In the Settings window for Cut Plane, locate the Data section.
- 3 From the Dataset list, choose Study I/Parametric Solutions I (sol2).
- 4 Locate the Plane Data section. From the Plane list, choose XZ-planes.

Contour I

- I In the Model Builder window, right-click Electric Field (emw) and choose Contour.
- 2 In the Settings window for Contour, locate the Data section.
- 3 From the Dataset list, choose Cut Plane I.
- **4** Locate the **Expression** section. In the **Expression** text field, type **emw.Ez**.

- 5 Locate the Levels section. In the Total levels text field, type 30.
- 6 Locate the Coloring and Style section. From the Color table list, choose Cividis.

Surface 1

- I Right-click Electric Field (emw) and choose Surface.
- 2 In the Settings window for Surface, locate the Coloring and Style section.
- **3** Clear the **Color legend** check box.
- 4 From the Color table list, choose AuroraAustralis.

Selection 1

- I Right-click Surface I and choose Selection.
- 2 In the Settings window for Selection, locate the Selection section.
- 3 From the Selection list, choose Conductive surface (SMA Connector, Flange with Two Holes 1).

Surface 2

- I In the Model Builder window, right-click Electric Field (emw) and choose Surface.
- 2 In the Settings window for Surface, locate the Coloring and Style section.
- 3 From the Color table list, choose AuroraAustralis.
- **4** Clear the **Color legend** check box.

Selection 1

- I Right-click Surface 2 and choose Selection.
- **2** Select Boundaries 28–30, 33–36, 45, 47, 122, 128, 129, 132, 134–136, 138, and 141 only.
- 3 In the Electric Field (emw) toolbar, click 💽 Plot.

Compare the reproduced plot with that shown in Figure 2.

Radiation Pattern 1

- I In the Model Builder window, expand the 2D Far Field (emw) node, then click Radiation Pattern I.
- 2 In the Settings window for Radiation Pattern, click to expand the Legends section.
- 3 From the Legends list, choose Manual.

4 In the table, enter the following settings:

Legends
2GHz
2.5GHz
3GHz
3.5GHz
4GHz
4.5GHz
5GHz
5.5GHz

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



Radiation Pattern 1

- I In the Model Builder window, expand the Results>3D Far Field (emw) node, then click Radiation Pattern I.
- 2 In the Settings window for Radiation Pattern, locate the Evaluation section.
- 3 Find the Angles subsection. In the Number of elevation angles text field, type 90.

- 4 In the Number of azimuth angles text field, type 90.
- 5 In the 3D Far Field (emw) toolbar, click 💽 Plot.

TABLE

I Go to the Table window.

3D far-field radiation pattern is directive toward the aperture of the horn antenna (Figure 3).

RESULTS

- ID Plot Group 6
- I In the Home toolbar, click 🚛 Add Plot Group and choose ID Plot Group.
- 2 In the Settings window for ID Plot Group, locate the Data section.
- 3 From the Dataset list, choose Study I/Parametric Solutions I (sol2).

Global I

- I Right-click ID Plot Group 6 and choose Global.
- 2 In the Settings window for Global, click Add Expression in the upper-right corner of the y-Axis Data section. From the menu, choose Component I (compl)> Electromagnetic Waves, Frequency Domain>Ports>emw.YSWR_I -Voltage standing wave ratio.
- 3 Locate the x-Axis Data section. From the Axis source data list, choose Outer solutions.
- 4 In the ID Plot Group 6 toolbar, click 💽 Plot.

Compare the resulting VSWR plot to Figure 4.