

Vivaldi Antenna

Introduction

A tapered slot antenna, also known as a Vivaldi antenna, is useful for wideband applications. Here, an exponential function is used for the taper profile. The objective of this example is to compute the far-field pattern and to compute the impedance of the structure. Good matching is observed over a wide frequency band.



Figure 1: The Vivaldi antenna is realized on a thin dielectric substrate. The entire domain is bounded by a perfectly matched layer.

Model Definition

In this Vivaldi antenna model, the tapered slot is patterned on the top of the dielectric substrate. A perfect electric conductor (PEC) is used for the ground plane. A simple exponential function, $e^{0.044x}$ is used to create the tapered slot curves. One end of the slot is open to air and the other end is finished with a circular slot. On the bottom of the substrate, the shorted 50 Ω microstrip feed line is modeled as PEC surfaces. The entire modeling domain is bounded by a perfectly matched layer (PML) which acts like an anechoic chamber absorbing all radiated energy. To excite the antenna, a lumped port is used. The model is meshed using a tetrahedral mesh with approximately five elements per wavelength in each material and simulation frequency.

The simulated SWR plot, Figure 2, shows good wideband matching properties. A Vivaldi antenna utilizes traveling waves generating a directive radiation pattern toward the open end of the tapered slot. The 3D far-field pattern in Figure 3 shows a directive radiation pattern.



Figure 2: The frequency response SWR of the Vivaldi antenna shows wideband impedance matching, better than 2:1 in most of the simulated frequency range.



Figure 3: 3D far-field pattern at 5.5 GHz shows a directional radiation pattern.

Application Library path: RF_Module/Antennas/vivaldi_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 \bigcirc Study.
- 5 In the Select Study tree, select General Studies>Frequency Domain.
- 6 Click **M** Done.

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 range(2[GHz],0.5[GHz],6.5[GHz]).

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.

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
thickness	60[mil]	0.001524 m	Substrate thickness
w_slot	0.5[mm]	5E-4 m	Slot with

Here, mil refers to the unit milliinch.

GEOMETRY I

Create a block for the antenna substrate.

Substrate

- I In the **Geometry** toolbar, click **[]** Block.
- 2 In the Settings window for Block, type Substrate in the Label text field.
- 3 Locate the Size and Shape section. In the Width text field, type 110.
- 4 In the **Depth** text field, type 80.
- 5 In the **Height** text field, type thickness.

6 Locate the Position section. From the Base list, choose Center.

Next, add a block for the 50Ω microstrip feed line.

Feed line

- I In the **Geometry** toolbar, click 🗍 **Block**.
- 2 In the Settings window for Block, type Feed line in the Label text field.
- 3 Locate the Size and Shape section. In the Width text field, type 3.2.
- 4 In the **Depth** text field, type 40+w_slot/2.
- 5 In the **Height** text field, type thickness.
- 6 Locate the Position section. From the Base list, choose Center.
- 7 In the x text field, type -26.
- 8 In the y text field, type -20+w_slot/4.

Next, create a work plane where you will draw the Vivaldi antenna pattern. Use two parametric curves for the tapered slot.

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 In the **z-coordinate** text field, type thickness/2.
- 4 Click 📥 Show Work Plane.

Work Plane I (wp1)>Plane Geometry

Click the 4 **Zoom Extents** button in the **Graphics** toolbar.

Add a parametric curve using the exponential profile.

Work Plane I (wpl)>Parametric Curve I (pcl)

- 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 70.
- 4 Locate the Expressions section. In the xw text field, type s-15.
- 5 In the **yw** text field, type exp(0.044*s)-1+w_slot/2.

Generate the other parametric curve by mirroring the first one.

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

I In the Work Plane toolbar, click 💭 Transforms and choose Mirror.

- 2 In the Settings window for Mirror, locate the Normal Vector to Line of Reflection section.
- **3** In the **yw** text field, type 1.
- **4** In the **xw** text field, type 0.
- 5 Locate the Input section. Select the Keep input objects check box.
- 6 Select the object **pc1** only.



7 Click 틤 Build Selected.



Add a rectangle describing the thin slot connected to the tapered slot.

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.
- **4** In the **Height** text field, type w_slot.
- 5 Locate the **Position** section. In the **xw** text field, type -35.
- 6 In the **yw** text field, type -w_slot/2.

Add a circle attached to the end of the slot.

Work Plane I (wp1)>Circle I (c1)

- I In the Work Plane toolbar, click 🕢 Circle.
- 2 In the Settings window for Circle, locate the Size and Shape section.

- 3 In the Radius text field, type 12.
- 4 Locate the **Position** section. In the **xw** text field, type -40.5.

Create a union of the circle and the rectangle to remove unnecessary boundaries.

Work Plane I (wp1)>Union I (uni1)

- I In the Work Plane toolbar, click 💻 Booleans and Partitions and choose Union.
- 2 Select the objects cl and rl only.
- 3 In the Settings window for Union, locate the Union section.
- 4 Clear the Keep interior boundaries check box.
- 5 In the Work Plane toolbar, click 🟢 Build All.



Add a sphere for the PMLs. Use a layer definition to create a shell-type structure.

PML

- I In the Model Builder window, right-click Geometry I and choose Sphere.
- 2 In the Settings window for Sphere, type PML in the Label text field.
- 3 Locate the Size section. In the Radius text field, type 110.
- 4 Click to expand the Layers section. In the table, enter the following settings:

Layer name	Thickness (mm)		
Layer 1	30		

5 Click 📑 Build All Objects.

6 Click the + Zoom Extents button in the Graphics toolbar.

Choose wireframe rendering to get a better view of the interior parts.

7 Click the 🔁 Wireframe Rendering button in the Graphics toolbar.



DEFINITIONS

Add a perfectly matched layer.

Perfectly Matched Layer 1 (pml1)

- I In the Definitions toolbar, click Mr. Perfectly Matched Layer.
- **2** Select Domains 1–4 and 8–11 only.
- 3 In the Settings window for Perfectly Matched Layer, locate the Geometry section.
- 4 From the Type list, choose Spherical.

DEFINITIONS

View I

Hide some domains to get a better view of the interior parts when setting up the physics and reviewing the mesh.

Hide for Physics 1

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

2 Select Domains 2 and 9 only.



Hide for Physics 2

- I 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 10 and 36 only.



ELECTROMAGNETIC WAVES, FREQUENCY DOMAIN (EMW)

Now set up the physics. Use the selections already defined when assigning boundary conditions.

Perfect Electric Conductor 2

- In the Model Builder window, under Component I (compl) right-click
 Electromagnetic Waves, Frequency Domain (emw) and choose the boundary condition
 Perfect Electric Conductor.
- **2** Select Boundaries 16, 21, 22, 24, and 27 only.

Far-Field Domain 1

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

Lumped Port I

- I In the Physics toolbar, click 🔚 Boundaries and choose Lumped Port.
- 2 Click the 🔍 Zoom In button in the Graphics toolbar, a couple of times to get a better view.

3 Select Boundary 20 only.



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

MATERIALS

Assign material properties for the model. First, use air for all domains.

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 Add to Component in the window toolbar.
- 5 In the Home toolbar, click 🙀 Add Material to close the Add Material window.

MATERIALS

Air (mat1)

Override the substrate with a dielectric material of $\varepsilon_r = 3.38$.

Substrate

- I In the Model Builder window, right-click Materials and choose Blank Material.
- 2 In the Settings window for Material, type Substrate in the Label text field.
- **3** Select Domains 6 and 7 only.

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

Property	Variable	Value	Unit	Property group
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	3.38	I	Basic
Relative permeability	mur_iso ; murii = mur_iso, murij = 0	1	I	Basic
Electrical conductivity	sigma_iso ; sigmaii = sigma_iso, sigmaij = 0	0	S/m	Basic

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 **Coarse**.
- 4 Click 🏢 Build All.



STUDY I

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

RESULTS

Multislice

- I In the Model Builder window, expand the Results>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.Ey.
- 4 Locate the Multiplane Data section. Find the X-planes subsection. In the Planes text field, type 0.
- 5 Find the Y-planes subsection. In the Planes text field, type 0.
- 6 Find the Z-planes subsection. From the Entry method list, choose Coordinates.
- 7 In the **Coordinates** text field, type thickness/2.
- 8 Click to expand the Range section. Select the Manual color range check box.
- 9 In the Minimum text field, type -400.
- **IO** In the **Maximum** text field, type 400.
- II Locate the Coloring and Style section. Click Change Color Table.
- 12 In the Color Table dialog box, select Wave>Wave in the tree.

I3 Click OK.



Electric fields are guided along the tapered slot.

S-parameter (emw)



Smith Plot (emw)



Radiation Pattern 1

- I In the Model Builder window, expand the Results>2D 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 angles text field, type 100.
- 4 In the 2D Far Field (emw) toolbar, click 💿 Plot.



2D far-field radiation patterns in the xy-plane plotted for all frequencies.

3D Far Field, Gain (emw)

- I In the Model Builder window, under Results click 3D Far Field, Gain (emw).
- 2 In the Settings window for 3D Plot Group, locate the Data section.
- 3 From the Parameter value (freq (GHz)) list, choose 5.5.

Radiation Pattern 1

- I In the Model Builder window, expand the 3D Far Field, Gain (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, Gain (emw) toolbar, click 💽 Plot.

TABLE

I Go to the Table window.

Compare the resulting 3D radiation pattern plot with Figure 3.

RESULTS

ID Plot Group 6

In the Home toolbar, click 🚛 Add Plot Group and choose ID Plot Group.

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 Click to expand the Legends section. Clear the Show legends check box.
- 4 In the ID Plot Group 6 toolbar, click 🗿 Plot.

This VSWR plot replicates the wideband frequency response shown in Figure 2.

3D Plot Group 7

In the Home toolbar, click 🚛 Add Plot Group and choose 3D Plot Group.

Isosurface 1

- I Right-click **3D Plot Group 7** and choose Isosurface.
- 2 In the Settings window for Isosurface, locate the Expression section.
- 3 In the **Expression** text field, type 20*log10(emw.normE+0.1).
- 4 Locate the Levels section. In the Total levels text field, type 20.

Selection I

- I Right-click Isosurface I and choose Selection.
- **2** Select Domains 5 and 6 only.

Filter I

- I In the Model Builder window, right-click Isosurface I and choose Filter.
- 2 In the Settings window for Filter, locate the Element Selection section.
- **3** In the **Logical expression for inclusion** text field, type y>0 && z<0.



4 In the 3D Plot Group 7 toolbar, click 💽 Plot.

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