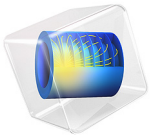


Model created in COMSOL Multiphysics 6.4

# Dielectric Resonator Antenna

## *Introduction*

A slot-coupled dielectric resonator antenna (DRA) utilizes a dielectric resonator to enhance radiation and bandwidth. By incorporating a slot in the ground plane to couple with the resonator, this design achieves effective impedance matching and signal efficiency, making it ideal for compact, high-frequency applications such as wireless communications and radar.

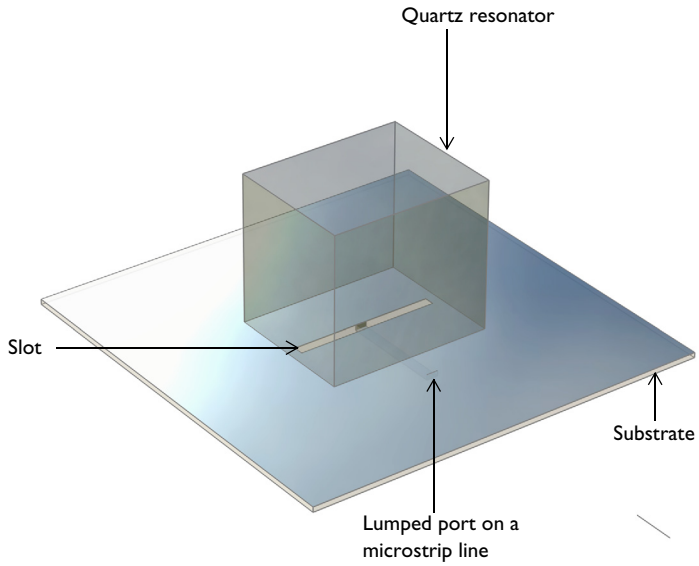



*Figure 1: Slot-coupled dielectric resonator antenna. The surrounding PML is not visualized.*

## *Model Definition*

A slot antenna is created by removing a rectangular section from a ground plane. This slot antenna is excited by a 50 Ω microstrip line, which is connected to a lumped port simulating the power source. The microstrip line is shorted to one edge of the slot, functioning similarly to an open-end quarter-wave stub. To simplify the computation, both the ground plane and the microstrip line are treated as geometrically thin and lossless, and are modeled as perfect electric conductor (PEC) surfaces.

Above the slot antenna, a block of quartz dielectric is positioned. This block serves both as a resonant structure and as a radiating element. The entire antenna setup is enclosed

within a sphere representing a vacuum. The sphere is bounded by a perfectly matched layer (PML) domain, which acts as an open boundary for the free space.

## *Results and Discussion*

The antenna structure is analyzed for operation at frequencies approximately around 10 GHz. The resulting far-field radiation patterns are illustrated in Figure 2 and Figure 3. Notably, the radiation guided by the dielectric resonator is directional, focusing predominantly toward the top side of the structure. This directionality highlights the effectiveness of the dielectric resonator in shaping and directing the emitted radiation.

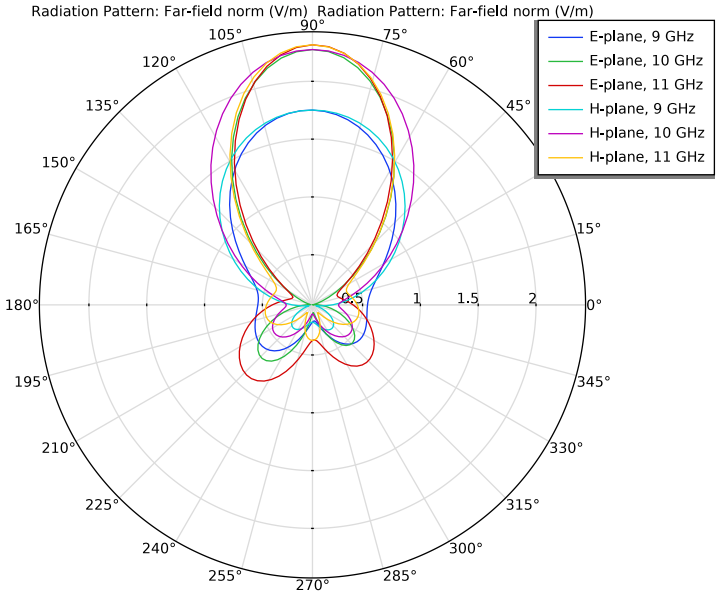



*Figure 2: Far-field radiation pattern on the E-plane and H-plane.*

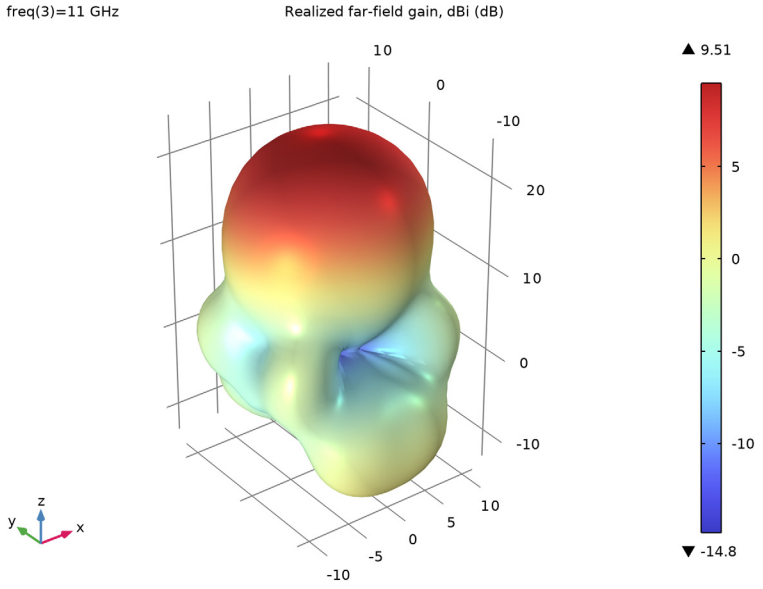



*Figure 3: 3D far-field radiation pattern shows the directivity is increased by the dielectric resonator.*

**Application Library path:** `RF_Module/Antennas/dielectric_resonator_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 **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*

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 |
|---|---|---|---|
| thickness | 20[mil] | 5.08E-4 m | Substrate thickness |
| l_substrate | 40[mm] | 0.04 m | Length, substrate |
| w_line | 1.12[mm] | 0.00112 m | Width, feed line |
| l_line | 10[mm] | 0.01 m | Length, feed line |
| w_resonator | 16[mm] | 0.016 m | Width, dielectric resonator |
| l_resonator | 13[mm] | 0.013 m | Length, dielectric resonator |
| h_resonator | 14.5[mm] | 0.0145 m | Height, dielectric resonator |
| w_slot | 1[mm] | 0.001 m | Width, slot |
| l_slot | 14[mm] | 0.014 m | Length, slot |

Here, `mil` refers to the unit milliinch. `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 `9 10 11`.

## GEOMETRY 1

First, create a block for the dielectric resonator.

*Dielectric resonator*

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

2 In the **Settings** window for **Block**, type `Dielectric resonator` in the **Label** text field.

3 Locate the **Size and Shape** section. In the **Width** text field, type `w_resonator`.

4 In the **Depth** text field, type `l_resonator`.

5 In the **Height** text field, type `h_resonator`.

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

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

Add a block for the substrate.

*Substrate*

1 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 `l_substrate`.

4 In the **Depth** text field, type `l_substrate`.

5 In the **Height** text field, type `thickness`.

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

7 In the **z** text field, type `-thickness/2`.

Add a block for the microstrip feed line.

*Feed line*

1 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 `w_line`.

4 In the **Depth** text field, type `l_line`.

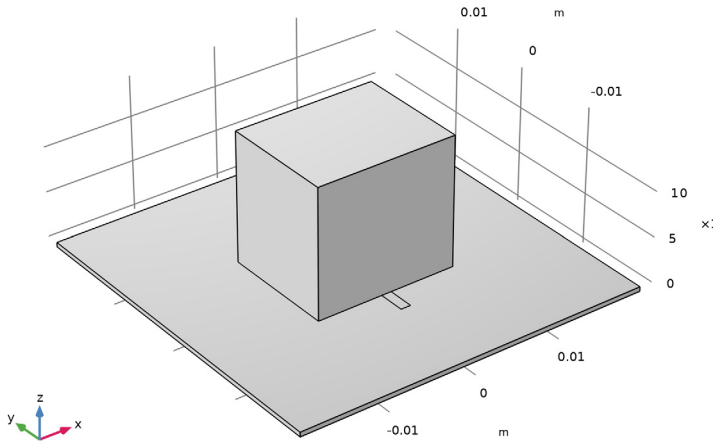
5 In the **Height** text field, type `thickness`.

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

7 In the **y** text field, type `-l_line/2+w_slot/2`.

8 In the **z** text field, type `-thickness/2`.

9 Click **Build Selected**.




Then, add a work plane for the slot. The slot is located between the dielectric resonator and substrate.

*Work Plane 1 (wp1)*

1 In the **Geometry** toolbar, click **Work Plane**.

2 In the **Settings** window for **Work Plane**, click **Go to Plane Geometry**.

*Work Plane 1 (wp1) > Plane Geometry*

In the **Model Builder** window, click **Plane Geometry**.

Create a rectangle for the slot.

*Work Plane 1 (wp1) > Rectangle 1 (r1)*

1 In the **Work Plane** toolbar, click **Rectangle**.

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

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

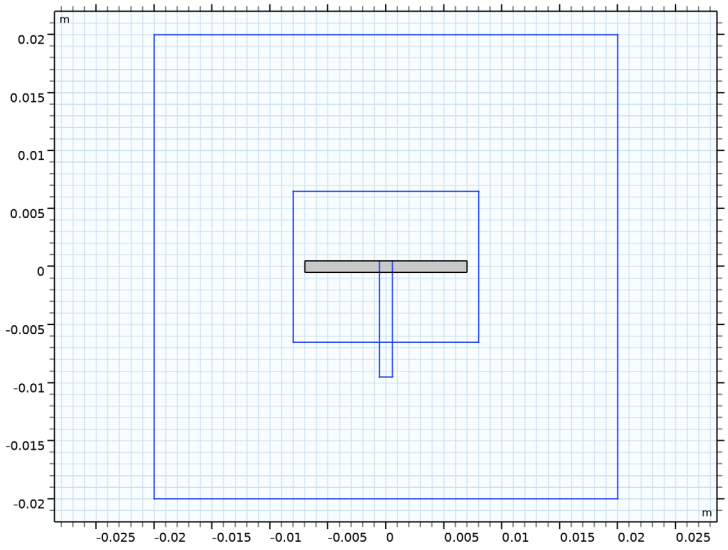
4 In the **Width** text field, type `l_slot`.

5 In the **Height** text field, type `w_slot`.

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

7 Click **Build Selected**.

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




Create a sphere with a layer. The outer layer presents the PML.

*Sphere 1 (sph1)*

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

2 In the **Settings** window for **Sphere**, locate the **Size** section.

3 In the **Radius** text field, type `l_substrate`.

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

| Layer name | Thickness (m) |
|---|---|
| Layer 1 | 0.1*l_substrate |

5 Click **Build Selected**.

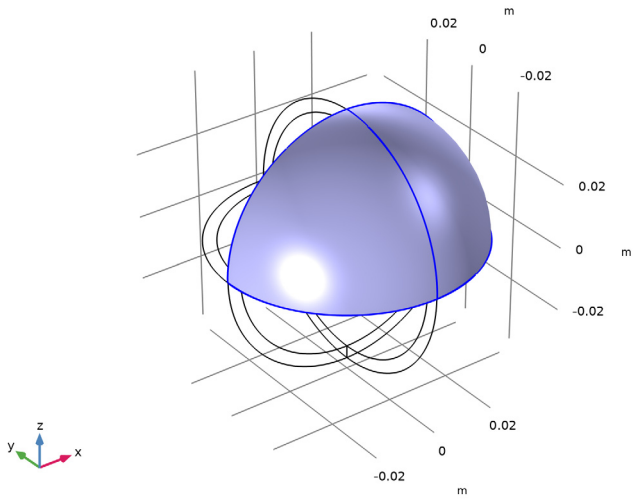
Choose wireframe rendering to get a better view of the interior parts.

6 Click the **Wireframe Rendering** button in the **Graphics** toolbar.

7 In the **Geometry** toolbar, click **Build All**.

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

**9** In the **Model Builder** window, click **Geometry 1**.




## DEFINITIONS

Add a perfectly matched layer on the outermost domain of the sphere.

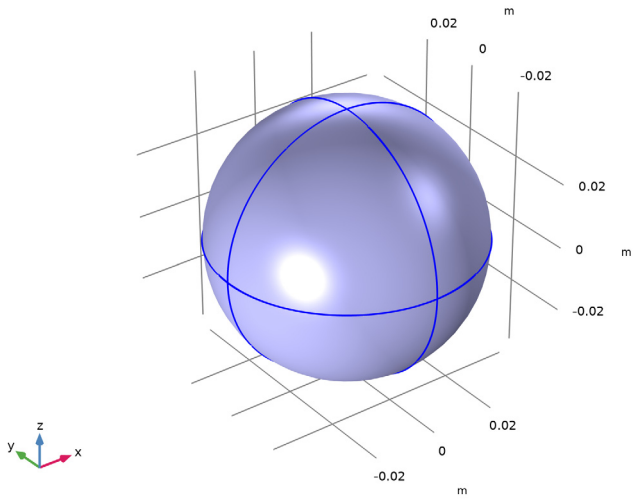
*Perfectly Matched Layer 1 (pml1)*

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

**2** Select Domains 1–4 and 9–12 only.

**3** In the **Settings** window for **Perfectly Matched Layer**, locate the **Geometry** section.

4 From the **Type** list, choose **Spherical**.




### MATERIALS

Next, assign material properties on the model. Begin by specifying air for all domains.

### ADD MATERIAL

1 In the **Materials** 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 the **Add to Component** button in the window toolbar.

### MATERIALS

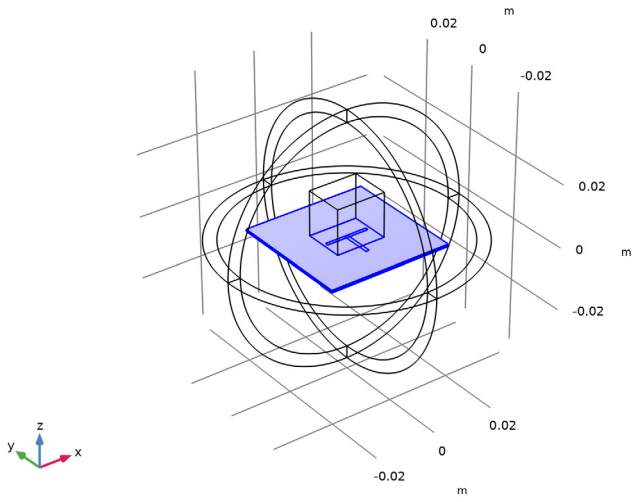
Override the substrate with the dielectric material of $\varepsilon_r = 3.38$.

*Substrate*

1 In the **Model Builder** window, under **Component 1 (comp1)** 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 8 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 | 1 | Basic |
| Relative permeability | mur_iso ; murii = mur_iso, murij = 0 | 1 | 1 | Basic |
| Electric conductivity | sigma_iso ; sigmaii = sigma_iso, sigmaij = 0 | 0 | S/m | Basic |

Override the dielectric resonator with the quartz.

### ADD MATERIAL

**1** Go to the **Add Material** window.

**2** In the tree, select **AC/DC** > **Quartz**.

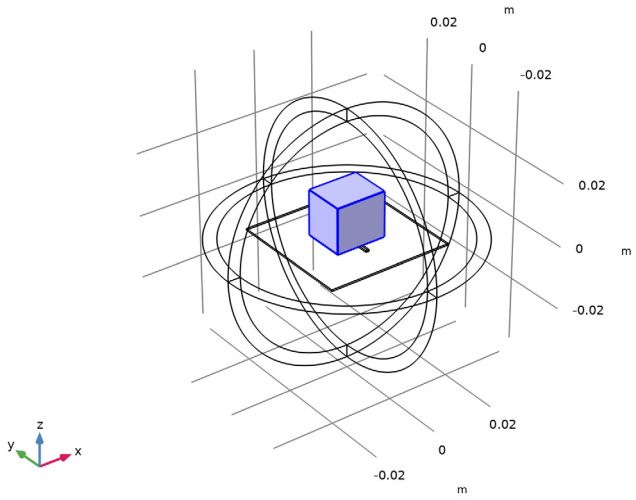
**3** Click the **Add to Component** button in the window toolbar.

**4** In the **Materials** toolbar, click **Add Material** to close the **Add Material** window.

## MATERIALS

*Quartz (mat3)*

Select Domain 7 only.

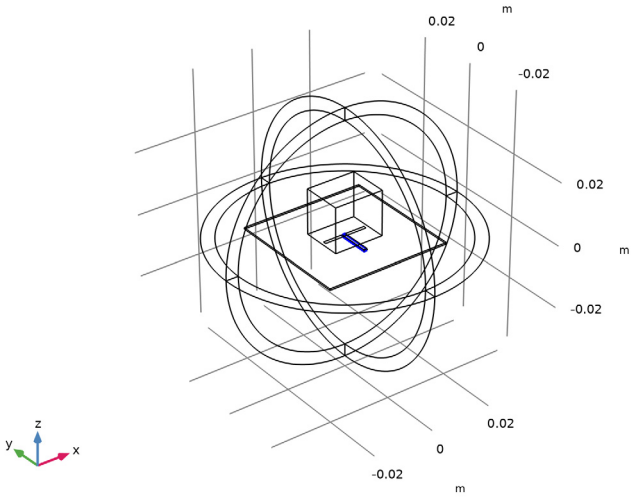



## ELECTROMAGNETIC WAVES, FREQUENCY DOMAIN (EMW)

*Perfect Electric Conductor 2*

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

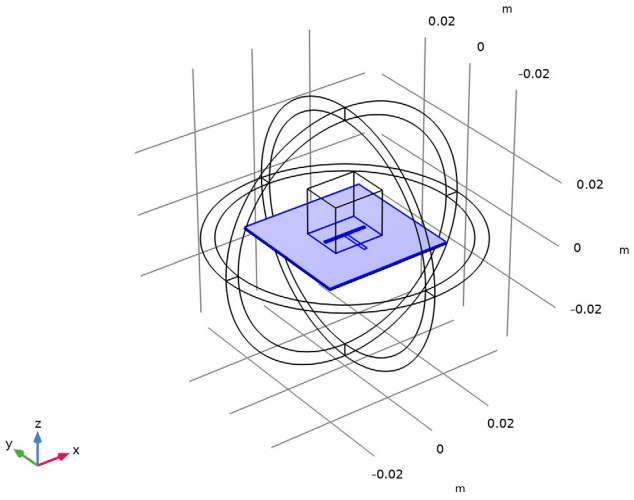
**2** Select Boundaries 26 and 30 only.




*Perfect Electric Conductor 3*

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

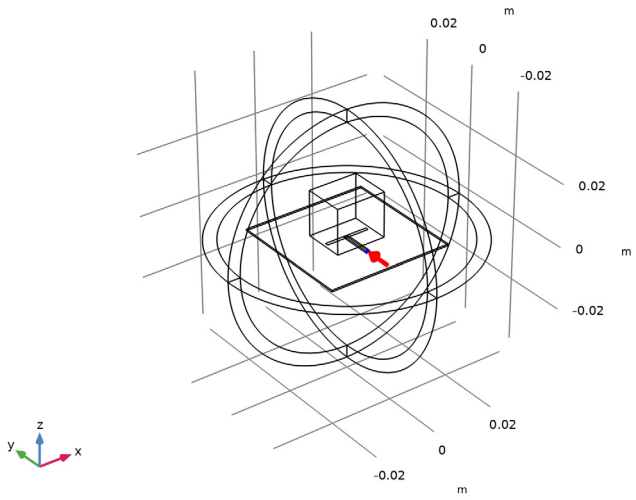
**2** Select Boundaries 16, 20, 27, and 28 only.



*Lumped Port 1*

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

2 Select Boundary 25 only.




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**.

## MESH 1

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

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

## DEFINITIONS

*Hide for Physics 1*

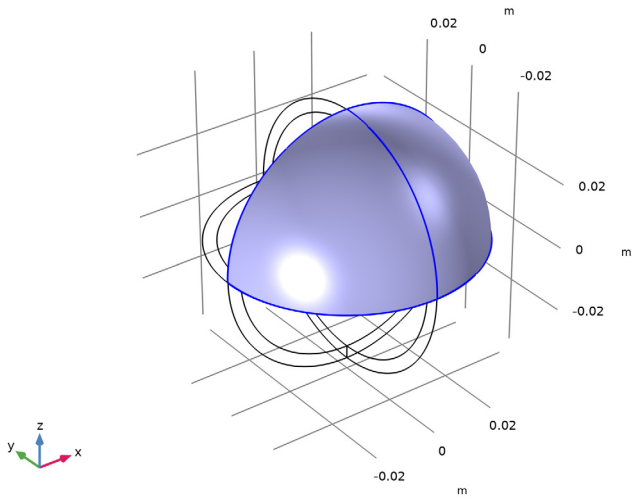
1 In the **Model Builder** window, expand the **Component 1 (comp1)** > **Definitions** node.

2 Right-click **View 1** and choose **Hide for Physics**.

3 In the **Settings** window for **Hide for Physics**, locate the **Geometric Entity Selection** section.

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

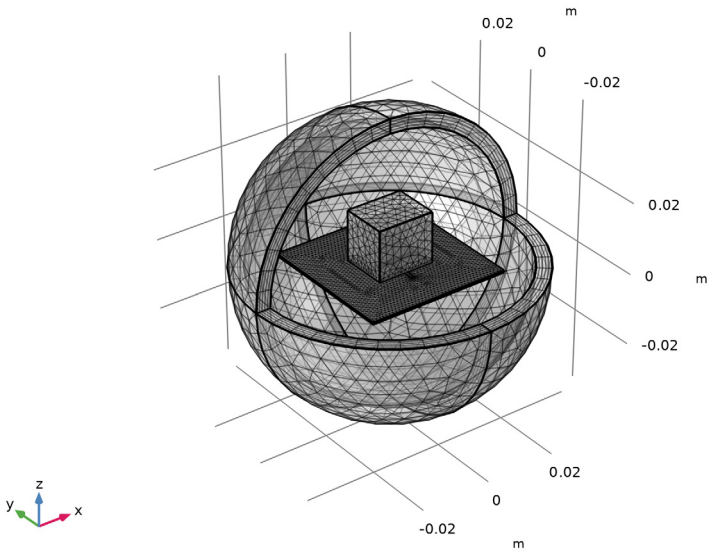
**5** Select Boundaries 6, 10, 32, 35, and 37 only.




**MESH 1**

**1** Click the **Transparency** button in the **Graphics** toolbar.

2 In the **Model Builder** window, under **Component 1 (comp1)** click **Mesh 1**.




### STUDY 1

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

Adjust settings to see the E-field norm as a dB scale.

### RESULTS

*Surface 1*

Right-click **Electric Field (emw)** and choose **Surface**.

*Selection 1*

1 In the **Model Builder** window, right-click **Surface 1** and choose **Selection**.

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

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

4 Select Domains 6–8 only.

*Surface 1*

1 In the **Model Builder** window, click **Surface 1**.

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**.

5 Locate the **Coloring and Style** section. From the **Color table** list, choose **HeatCameraLight**.

*Multislice 1*

1 In the **Model Builder** window, click **Multislice 1**.

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

3 Find the **X-planes** subsection. In the **Planes** text field, type `0`.

4 Find the **Z-planes** subsection. In the **Planes** text field, type `0`.

5 Locate the **Expression** section. In the **Expression** text field, type `emw.normE`.

6 Locate the **Coloring and Style** section. From the **Scale** list, choose **Logarithmic**.

7 Click to expand the **Range** section. Select the **Manual color range** checkbox.

8 Set the **Maximum** value to **200**.

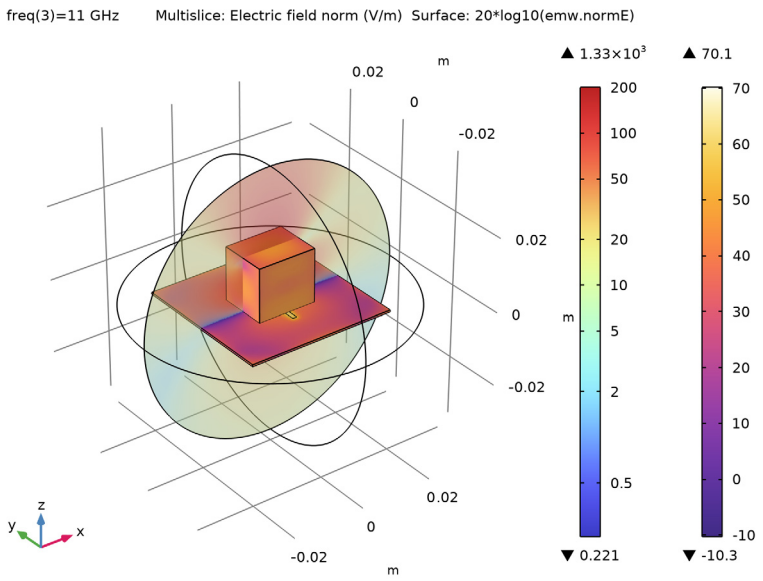
*Transparency 1*

1 Right-click **Multislice 1** and choose **Transparency**.

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

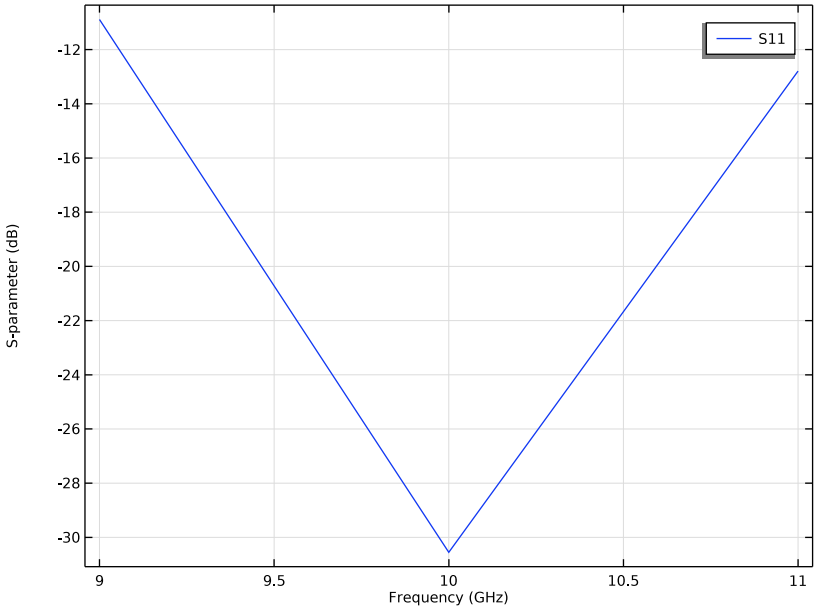
3 Click the **Zoom In** button in the **Graphics** toolbar.

**4** In the **Model Builder** window, click **Transparency 1**.



*S-Parameter (emw)*

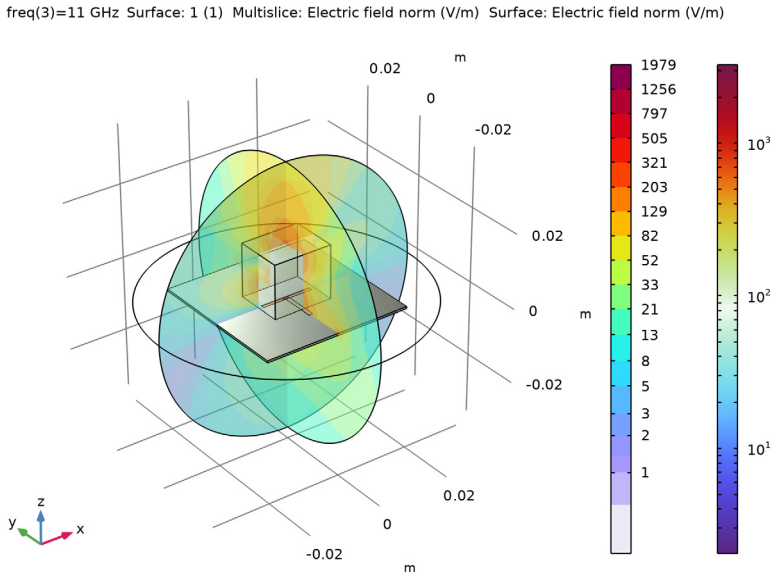
In the **Model Builder** window, under **Results** click **S-Parameter (emw)**.




Inspect the input matching property ($S_{11}$) at the simulated frequencies.

*Electric Field, Logarithmic (emw)*

In the **Model Builder** window, click **Electric Field, Logarithmic (emw)**.




*Radiation Pattern 1*

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 100.

4 Find the **Normal vector** subsection. In the **x** text field, type 1.

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

6 Find the **Reference direction** subsection. In the **x** text field, type 0.

7 In the **y** text field, type 1.

8 Click to expand the **Legends** section. From the **Legends** list, choose **Manual**.

9 In the table, enter the following settings:

| Legends |
|---|
| E-plane, 9 GHz |
| E-plane, 10 GHz |
| E-plane, 11 GHz |

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

*Radiation Pattern 2*

**1** Right-click **Results** > **2D Far Field (emw)** > **Radiation Pattern 1** and choose **Duplicate**.

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

**3** Find the **Normal vector** subsection. In the **x** text field, type `0`.

**4** In the **y** text field, type `-1`.

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

**6** In the **y** text field, type `0`.

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

| Legends |
| --- |
| `H-plane, 9 GHz` |
| `H-plane, 10 GHz` |
| `H-plane, 11 GHz` |

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

This is the far-field radiation patterns on the E-plane and H-plane (Figure 2).

*3D Far Field, Gain (emw)*

Compare the 3D far-field radiation pattern plot with Figure 3.