Created in COMSOL Multiphysics 6.2

Designing a Waveguide Diplexer for the 5G Mobile Network

Introduction

A diplexer is a device that combines or splits signals into two different frequency bands, widely used in mobile communication systems. This example simulates splitting properties using a simplified 2D geometry. The computed S-parameters and electric fields at the lower and upper bands will show the diplexer characteristics in the Ka-band.

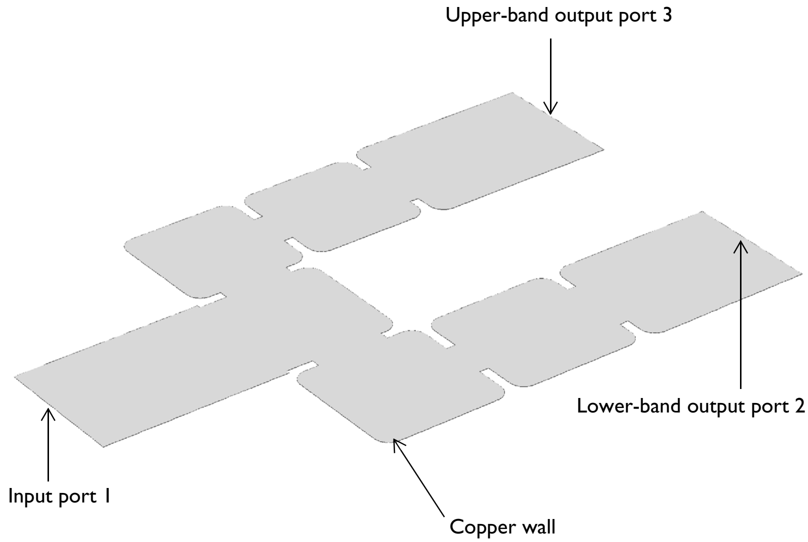


Figure 1: 2D layout of the diplexer composed of 3-port waveguide structures.

Model Definition

This example is based on a WR-28 waveguide for Ka-band applications. The width of the 2D waveguide is 0.28 inches, which is the length of the longer side of a WR-28 waveguide aperture. The model considers only the dominant TE_1 mode. The cutoff frequency of the dominant mode is 21.08 GHz. There are two cavities working as bandpass structures between the input and each output port that are connected with irises. The waveguides, cavities, and irises are modeled as copper with finite conductivity using an Impedance Boundary condition to evaluate loss at a high frequency range and the inside of the waveguide is filled with air. On each end of the waveguide, a port boundary condition is applied with the predefined rectangular TE_1 mode. Only one port is excited to observe the S-parameters of the example.

S-parameters are plotted in Figure 2. The lower passband is around 28 GHz and the upper passband is around 30.4 GHz. The insertion loss in each passband is about 0.1 dB, mainly caused by the finite conductivity of the copper walls. In Figure 3 and Figure 4, the E-field norm is visualized for each passband, showing that the input power at each passband is not split into two output ports, but separately distributed without being coupled to the other port.

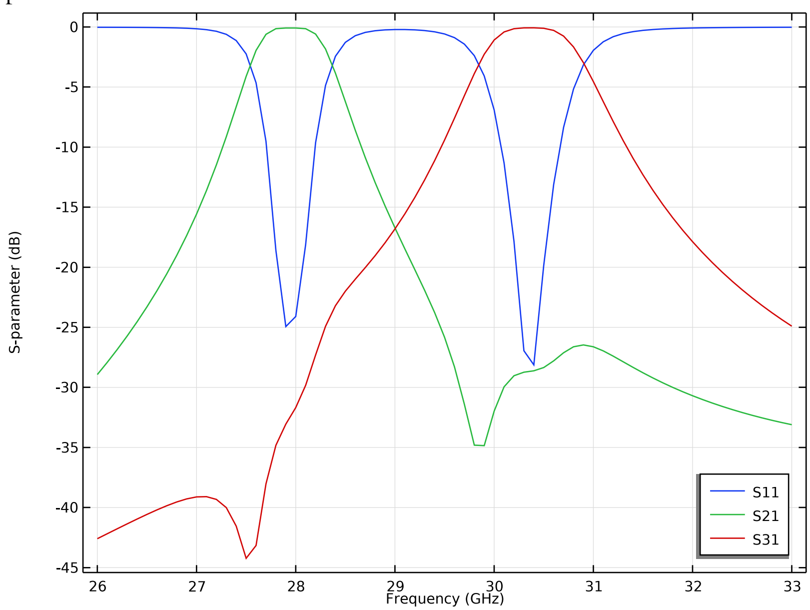


Figure 2: The S-parameter plot shows the lower and upper passband of the diplexer.

The isolation properties between two output ports are not reviewed in this example but users are encouraged to try by exciting port 2 or 3 only.

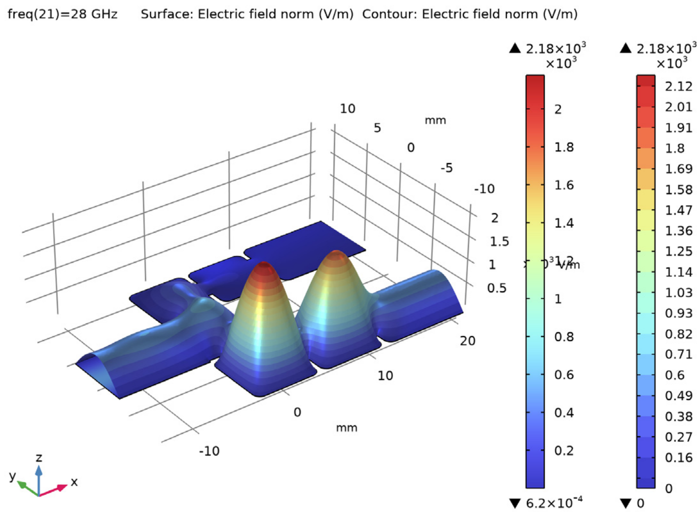


Figure 3: The E-field norm plot for a frequency of 28 GHz. The input power flows into port 2 only.

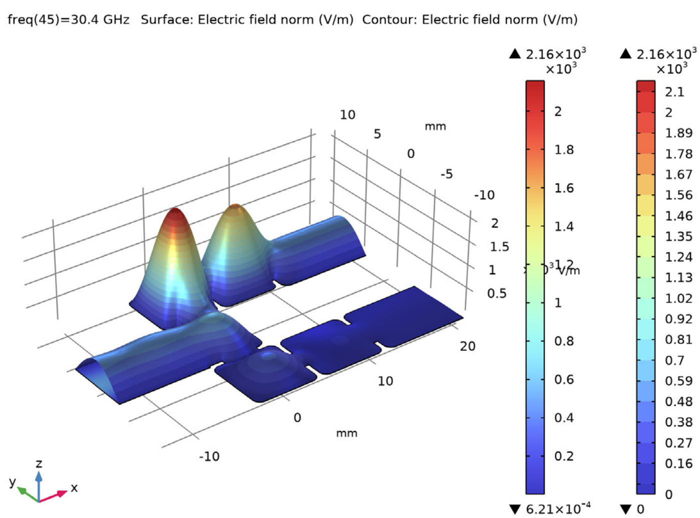


Figure 4: The E-field norm plot for a frequency of 30.4 GHz. The input power flows into port 3 only.

Application Library path: `RF_Module/Filters/waveguide_diplexer`

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**.

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**.

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 highest frequency value in the specified range.

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 `range(26[GHz],0.1[GHz],33[GHz])`.

GEOMETRY 1

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

2 In the **Settings** window for **Geometry**, locate the **Units** section.

3 From the **Length unit** list, choose **mm**.

Import 1 (imp1)

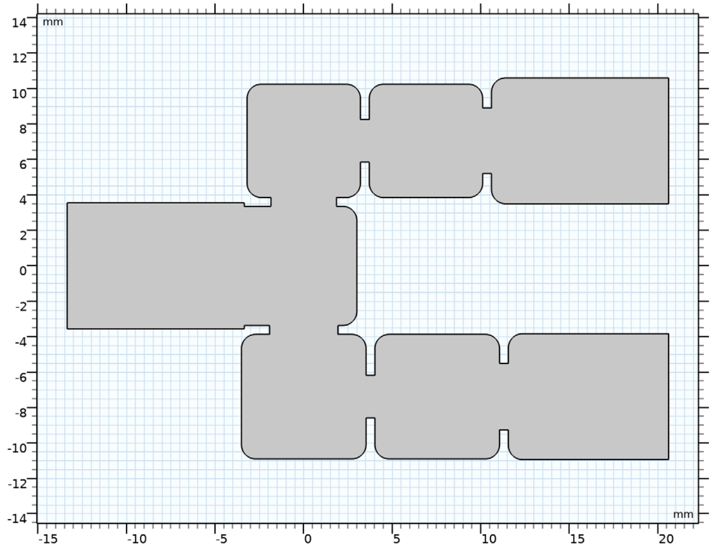
1 In the **Home** toolbar, click **Import**.

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

3 Click **Browse**.

4 Browse to the model's Application Libraries folder and double-click the file `waveguide_diplexer.mphbin`.

5 Click **Import**.



DEFINITIONS

Waveguide walls

1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, type `Waveguide walls` in the **Label** text field.

3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Boundary**.

4 Click **Paste Selection**.

5 In the **Paste Selection** dialog box, type `2-54, 57-78` in the **Selection** text field.

6 Click **OK**.

ADD MATERIAL

1 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 tree, select **Built-in>Copper**.

6 Click **Add to Component** in the window toolbar.

7 In the **Home** toolbar, click **Add Material** to close the **Add Material** window.

MATERIALS

Copper (mat2)

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

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

3 From the **Selection** list, choose **Waveguide walls**.

ELECTROMAGNETIC WAVES, FREQUENCY DOMAIN (EMW)

Port 1

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

2 Select Boundary 1 only.

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

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

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

Port 2

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

2 Select Boundary 56 only.

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

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

5 Select Boundary 55 only.

6 Right-click **Port 2** and choose **Duplicate**.

Port 3

1 In the **Model Builder** window, click **Port 3**.

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

3 Click **Clear Selection**.

4 Select Boundary 56 only.

With TE waves, only the z-component of the electric field needs to be solved for.

5 In the **Model Builder** window, click **Electromagnetic Waves, Frequency Domain (emw)**.

6 In the **Settings** window for **Electromagnetic Waves, Frequency Domain**, locate the **Components** section.

7 From the **Electric field components solved for** list, choose **Out-of-plane vector**.

Impedance Boundary Condition 1

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

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

3 From the **Selection** list, choose **Waveguide walls**.

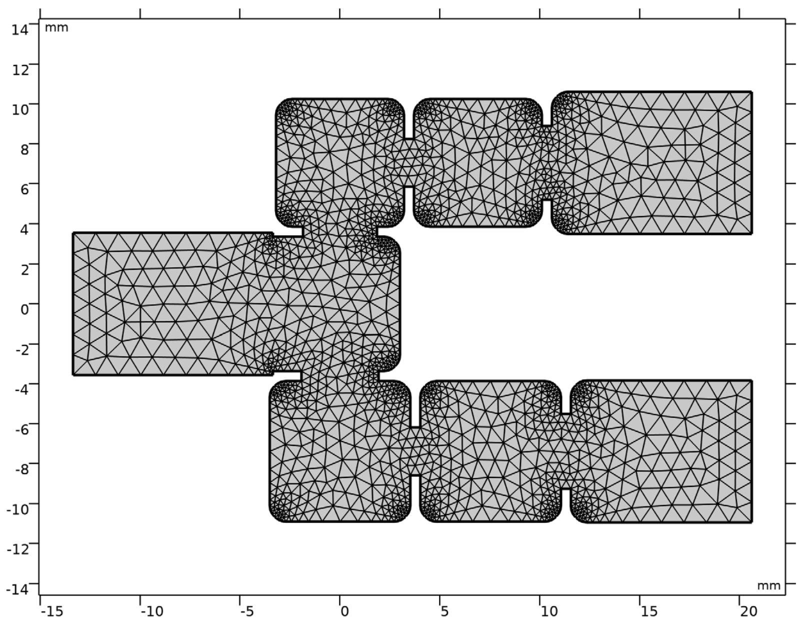
MESH 1

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

2 In the **Settings** window for **Mesh**, locate the **Physics-Controlled Mesh** section.

3 From the **Element size** list, choose **Fine**.

4 In the **Home** toolbar, click **Build Mesh**.



It is not necessary to review the mesh, but it is a good practice to take a look at it before running the simulation.

STUDY 1

Step 1: Frequency Domain

Click **Compute**.

RESULTS

Contour 1

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

2 In the **Settings** window for **Contour**, locate the **Coloring and Style** section.

3 From the **Contour type** list, choose **Filled**.

Height Expression 1

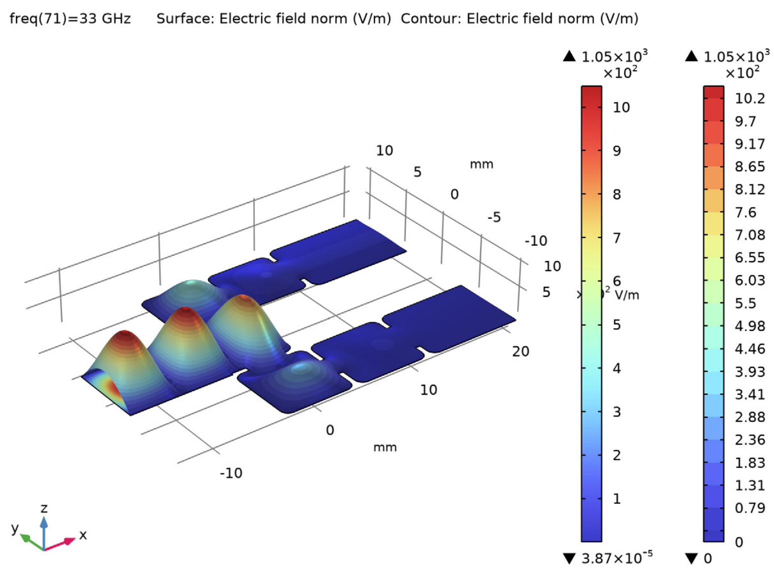
1 Right-click **Contour 1** and choose **Height Expression**.

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

3 Select the **Scale factor** check box. In the associated text field, type `0.005`.

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

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



The E-field norm is visualized at the last frequency, which is out of the passband. The plot shows that the input wave does not propagate to any of the output ports.

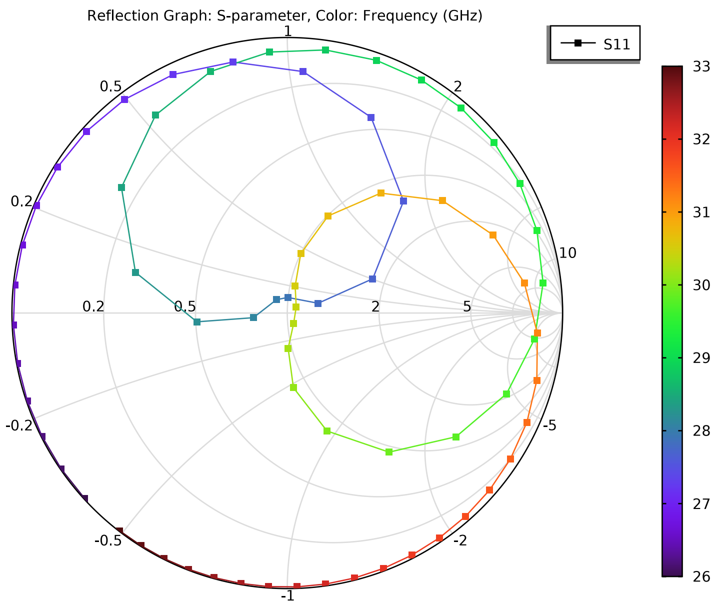
S-parameter (emw)

1. In the **Model Builder** window, under **Results** click **S-parameter (emw)**.
2. In the **Settings** window for **1D Plot Group**, locate the **Legend** section.
3. From the **Position** list, choose **Lower right**.

   Compare the reproduced plot to Figure 2. The lower and upper passband frequencies are around 28 GHz, and 30.4 GHz, respectively.

Smith Plot (emw)

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



Electric Field (emw)

1. In the **Model Builder** window, click **Electric Field (emw)**.
2. In the **Settings** window for **2D Plot Group**, locate the **Data** section.
3. From the **Parameter value (freq (GHz))** list, choose **28**.
4. In the **Electric Field (emw)** toolbar, click **Plot**.

   The E-field norm plot at the lower passband is shown in Figure 3.

5. From the **Parameter value (freq (GHz))** list, choose **30.4**.

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

Finish the result analysis by reproducing Figure 4, which is the E-field norm plot at the upper passband.