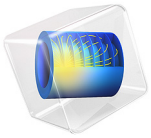


Model created in COMSOL Multiphysics 6.4

Schroeder Diffuser in 2D

Introduction

Sound diffusers are objects or surfaces that are designed to reflect incident sound energy evenly across angles. They are widely used in room acoustics as a way to influence the spatial distribution of the sound field without necessarily attenuating it. One common type of diffuser is the Schroeder diffuser, also called well-based diffuser, which consists of a series of wells of different depths. The depths are determined from a mathematical sequence, such as quadratic residue or primitive root. The principle behind this type of diffuser is that each well will re-emit the incident wave with a different phase shift, causing interferences between the waves emitted by the different wells. The mathematical sequence used to determine the depths of the wells will then dictate the interference pattern and, hence, the polar response of the diffuser.

This model demonstrates how to calculate the scattering coefficient with the *Pressure Acoustics, Frequency Domain* interface. This coefficient is one of the main inputs for expressing boundary conditions in typical room acoustic simulations. Its measurement procedure can be complicated to set up. Therefore. it is more efficient to determine the data numerically. In addition, the effect of periodicity is investigated by studying the responses from different arrangements of the same diffuser.

Model Definition

The model represents a primitive root diffuser, a type of Schroeder diffuser which aims at eliminating the specular component in the reflected energy polar response (see Ref. 1). The model at hand is based on the primitive root sequence with 7 as odd prime, resulting in a diffuser with six wells. The study is carried out in 2D in order to considerably reduce the number of degrees of freedom in the simulation. Two cases are taken into account as shown in Figure 1:

- A single diffuser with its corresponding flat reference.
- An infinite arrangement of diffusers (a single unit cell is shown)

In the first case, a semicircle with radius $r_0 = 10$ m is added to act as an integration line in the far field. The diffuser and flat reference are surrounded by an air domain terminated by a **Perfectly Matched Boundary**, and the sound field outside of the calculation domain is obtained from **Exterior Field Calculation**. In the case of the infinite arrangement, a **Periodic Port** and **Periodic Condition** > **Floquet periodicity** is used to virtually extend the domain in both directions along the x-axis.

A plane wave with incidence angle θ_0 from the y-axis is defined as incoming on the diffuser arrangements. The incidence angle is varied in an **Auxiliary Sweep** from $\theta_0 = 0°$ to $\theta_0 = 89°$

with 25 angle steps, resulting in an increment approximately of 3.7°. Frequencies from 50 Hz to 3150 Hz with a third-octave interval are taken into account.

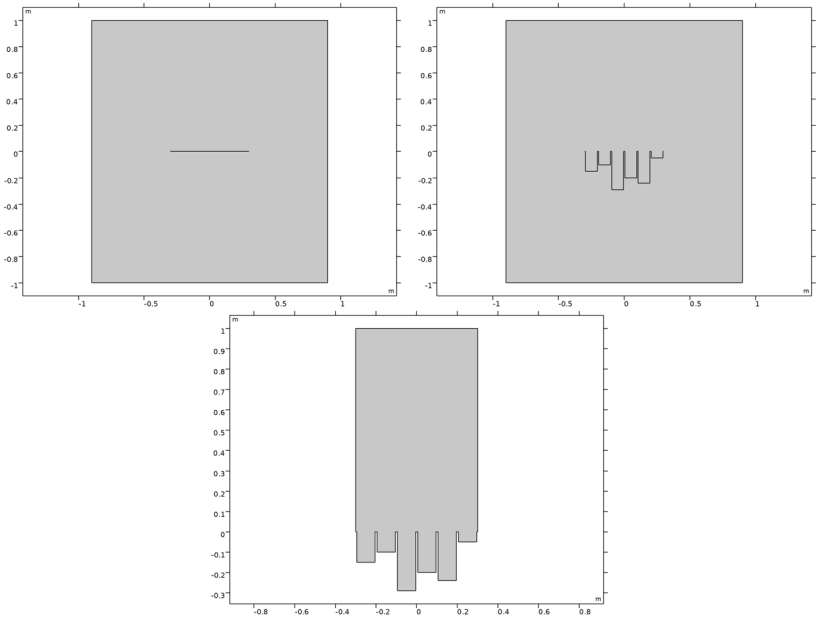


Figure 1: Geometries of the diffuser arrangements. Top left: flat reference; Top right: single diffuser; Bottom: infinite arrangement.

SCATTERING COEFFICIENT

The scattering coefficient s is defined as the power ratio (see Ref. 1)

$$s = 1 - \frac{P_{\text{spec}}}{P_{\text{tot}}} \tag{1}$$

with P_{spec} the power reflected in the specular direction and P_{tot} the total reflected power. In the infinite arrangement case, P_{spec} and P_{tot} are included as built-in variables in the **Periodic Port** feature, which allows to calculate the scattering coefficient directly. In the case of the single diffuser, the correlation scattering coefficient s_c is defined as (see Ref. 1)

$$s_c = 1 - \frac{\left| \sum_{i=1}^{N} p_1(\theta_i) p_0{}^*(\theta_i) \right|^2}{\sum_{i=1}^{N} \left| p_1(\theta_i) \right|^2 \sum_{i=1}^{N} \left| p_0(\theta_i) \right|^2} \tag{2}$$

where p_0 is the scattered sound pressure from the flat reference, p_1 is the scattered sound pressure from the diffuser, and θ_i is the angle of the i^{th} receiver on the evaluation semicircle Ω with radius r_0 located in the far field.

The coefficient in Equation 1 or Equation 2 gives a value for each incidence angle and frequency included in the study. To obtain the random incidence scattering coefficient in octave bands, the Paris formula is used such that (see Ref. 2)

$$\int_0^{\pi/2} s(\theta)\sin(2\theta)d\theta \tag{3}$$

with θ the incident angle. Although the diffuser studied is asymmetrical, the error due to integrating from 0 to $\pi/2$can be tolerated.

Results and Discussion

The sum of incident and scattered sound pressure by the diffuser arrangements and the flat reference is shown in Figure 2 for $\theta_0 = 33.3°$ and $f = 1000$ Hz. In this case, the plane waves propagating in the wells of the Schroeder diffuser are clearly visible. Moreover, it is seen that the sound field that would result from a flat solid surface is disrupted by the presence of the wells. This is especially true in front of the diffuser arrangements, where the wavefront tends to a cylindrical wave. It also appears that destructive interferences create directions with greatly reduced energy. Although this effect is present in the single diffuser, it is seen to be more prominent in the infinite arrangement.

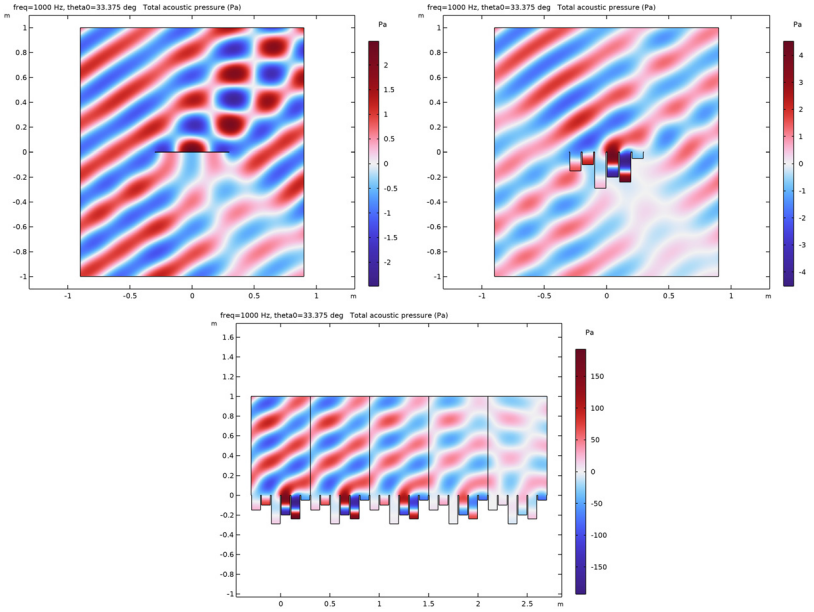


Figure 2: Scattered pressure for $\theta_0 = 33.3°$ *and* $f = 1000$ Hz. *Top left: flat reference; Top right: single diffuser; Bottom: infinite arrangement.*

Further investigation of the scattered sound field can be made from the SPL polar responses of the single diffuser in Figure 3. It is evaluated in the far field at a distance $r_0 = 10$ m, for $\theta_0 = 33.3°$ and frequencies around 1000 Hz. This type of plot could not be generated for the infinite arrangement as it requires to evaluate sound pressure on a surrounding semicircle. It can be observed that the primitive root diffuser does reduce the energy reflected in the specular direction as intended. The difference between the SPL in

the specular direction and the maximum SPL lies between 10 dB and 25 dB for the single diffuser, with energy being distributed across a few lobes.

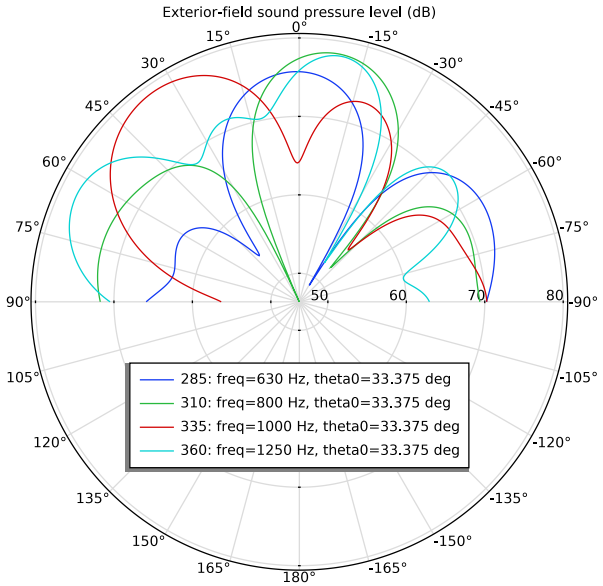


Figure 3: Polar response of the single diffuser for $\theta_0 = 33.3°$ around 1000 Hz.

The scattering coefficients of the two diffuser arrangements are shown in Figure 4 and Figure 5. It is seen that the single diffuser returns similar values to the analytical expression except at 500 Hz. The infinite arrangement also gives interesting results. In this case, the scattering coefficient takes much lower values especially at low frequencies. This is a sign that scattering is dominated by diffraction from the finite size effect at low frequencies, and the wells' influence is only effective at mid and high frequencies. The values of the scattering coefficients are also tabulated in the model and can be exported.

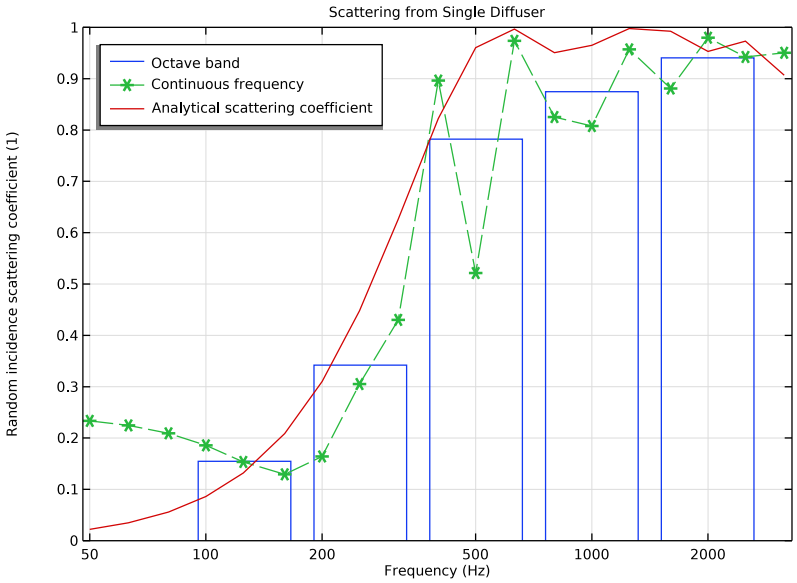


Figure 4: Random incidence scattering coefficient of the single diffuser.

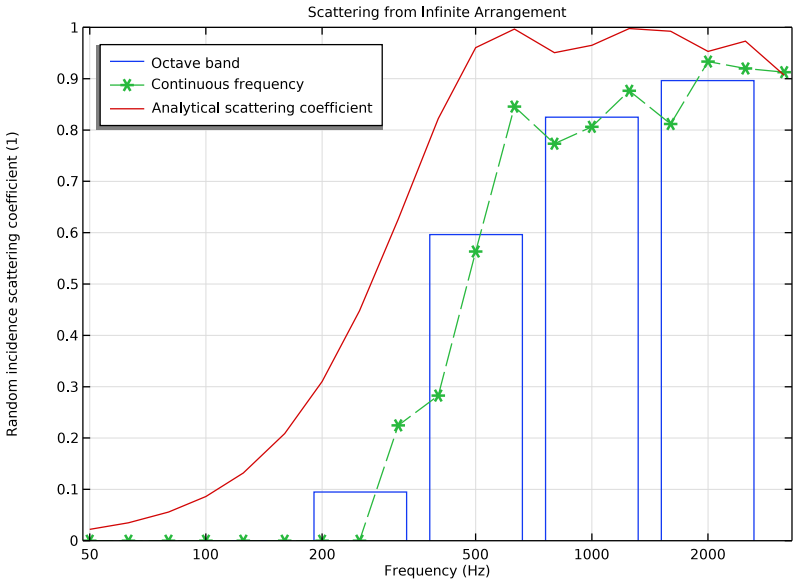


Figure 5: Random incidence scattering coefficient of the infinite arrangement.

Notes About the COMSOL Implementation

The model is readily set up to investigate a finite arrangement of the Schroeder diffuser. To change the number of periods, simply change the value of the parameter N_p in **Parameters 2 - Physics** and rebuild the geometries for the flat reference and the diffuser.

The infinite arrangement case in this model is set up with the **Periodic Port** feature. To learn more about how to use this feature, see the *Porous Absorber* model, also included in the Acoustics Module Application Library.

References

1. T.J. Cox and P. D'Antonio, *Acoustics Absorbers and Diffusers: Theory, Design and Application*, 2nd edition, Taylor & Francis, 2009.

2. H. Kuttruff, *Room Acoustics*, 5th edition, CRC Press, 2009.

Application Library path: `Acoustics_Module/Building_and_Room_Acoustics/diffuser_schroeder_2d`

Modeling Instructions

This section contains the modeling instructions for the Schroeder Diffuser in 2D model. They are followed by the Geometry Modeling Instructions section.

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 **Acoustics** > **Pressure Acoustics** > **Pressure Acoustics, Frequency Domain (acpr)**.
3. Click **Add**.
4. Click **Study**.
5. In the **Select Study** tree, select **General Studies** > **Frequency Domain**.
6. Click **Done**.

Start by importing the geometry cases and the parameters needed for the study.

FLAT REFERENCE

1. In the **Model Builder** window, click **Component 1 (comp1)**.
2. In the **Settings** window for **Component**, type `Flat Reference` in the **Label** text field.

GEOMETRY 1

1. In the **Geometry** toolbar, click **Insert Sequence** and choose **Insert Sequence**.
2. Browse to the model's Application Libraries folder and double-click the file `diffuser_schroeder_2d_geom_sequence.mph`.
3. In the **Insert Sequence** dialog, select **Geometry 3** in the **Select geometry sequence to insert** list.
4. Click **OK**.

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

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

ADD COMPONENT

Right-click **Flat Reference (comp1)** > **Geometry 1** and choose **Add Component** > **2D**.

SINGLE DIFFUSER

In the **Settings** window for **Component**, type `Single Diffuser` in the **Label** text field.

GEOMETRY 2

1 In the **Geometry** toolbar, click **Insert Sequence** and choose **Insert Sequence**.

2 Browse to the model's Application Libraries folder and double-click the file `diffuser_schroeder_2d_geom_sequence.mph`.

3 In the **Insert Sequence** dialog, select **Geometry 2** in the **Select geometry sequence to insert** list.

4 Click **OK**.

1 In the **Model Builder** window, under **Single Diffuser (comp2)** click **Geometry 2**.

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

ADD COMPONENT

Right-click **Single Diffuser (comp2)** > **Geometry 2** and choose **Add Component** > **2D**.

INFINITE ARRANGEMENT

In the **Settings** window for **Component**, type `Infinite Arrangement` in the **Label** text field.

GEOMETRY 3

1 In the **Geometry** toolbar, click **Insert Sequence** and choose **Insert Sequence**.

2 Browse to the model's Application Libraries folder and double-click the file `diffuser_schroeder_2d_geom_sequence.mph`.

3 In the **Insert Sequence** dialog, click **OK**.

1 In the **Model Builder** window, under **Infinite Arrangement (comp3)** click **Geometry 3**.

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

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 right end of the **Add to Component** split button in the window toolbar.

5 From the menu, choose **Add to Flat Reference (comp1)**.

6 Click the **Add to Single Diffuser (comp2)** button in the window toolbar.

7 Click the **Add to Infinite Arrangement (comp3)** button in the window toolbar.

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

GLOBAL DEFINITIONS

Parameters 1 - Geometry

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.

2 In the **Settings** window for **Parameters**, type `Parameters 1 - Geometry` in the **Label** text field.

Parameters 2 - Physics

1 In the **Home** toolbar, click **Parameters** and choose **Add** > **Parameters**.

2 In the **Settings** window for **Parameters**, type `Parameters 2 - Physics` in the **Label** text field.

3 Locate the **Parameters** section. Click **Load from File**.

4 Browse to the model's Application Libraries folder and double-click the file `diffuser_schroeder_2d_parameters_physics.txt`.

Proceed with setting up the physics and local variables for the flat reference and single diffuser.

PRESSURE ACOUSTICS, FREQUENCY DOMAIN (ACPR)

In the **Model Builder** window, under **Flat Reference (comp1)** click **Pressure Acoustics, Frequency Domain (acpr)**.

Background Pressure Field 1

1 In the **Physics** toolbar, click **Domains** and choose **Background Pressure Field**.

2 In the **Settings** window for **Background Pressure Field**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **All domains**.

4 Locate the **Background Pressure Field** section. In the p_0 text field, type `p0`.

5 In the c text field, type `c0`.

6 Specify the $\mathbf{e}_k$ vector as

sin(theta0)	x
-cos(theta0)	y

Perfectly Matched Boundary 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Perfectly Matched Boundary**.

2 Select Boundaries 1–3 and 5 only.

Exterior Field Calculation 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Exterior Field Calculation**.

2 Select Boundaries 1–3 and 5 only.

Interior Sound Hard Boundary (Wall) 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Interior Sound Hard Boundary (Wall)**.

2 Select Boundary 4 only.

SINGLE DIFFUSER (COMP2)

In the **Model Builder** window, click **Single Diffuser (comp2)**.

ADD PHYSICS

1 In the **Home** toolbar, click **Add Physics** to open the **Add Physics** window.

2 Go to the **Add Physics** window.

3 In the tree, select **Acoustics** > **Pressure Acoustics** > **Pressure Acoustics, Frequency Domain (acpr)**.

4 Click the **Add to Single Diffuser** button in the window toolbar.

5 In the **Home** toolbar, click **Add Physics** to close the **Add Physics** window.

DEFINITIONS (COMP2)

Integration 1 (intop1)

1 In the **Definitions** toolbar, click **Nonlocal Couplings** and choose **Integration**.

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

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

4 Select Boundary 30 only.

Variables 1

1 In the **Model Builder** window, right-click **Definitions** and choose **Variables**.

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

3 Click **Load from File**.

4 Browse to the model's Application Libraries folder and double-click the file `diffuser_schroeder_2d_variables_single.txt`.

PRESSURE ACOUSTICS, FREQUENCY DOMAIN 2 (ACPR2)

Background Pressure Field 1

1 In the **Physics** toolbar, click **Domains** and choose **Background Pressure Field**.

2 In the **Settings** window for **Background Pressure Field**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **All domains**.

4 Locate the **Background Pressure Field** section. In the p_0 text field, type `p0`.

5 In the c text field, type `c0`.

6 Specify the $\mathbf{e}_k$ vector as

`sin(theta0)`	`x`
`-cos(theta0)`	`y`

Perfectly Matched Boundary 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Perfectly Matched Boundary**.

2 Select Boundaries 1–3 and 29 only.

Exterior Field Calculation 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Exterior Field Calculation**.

2 Select Boundaries 1–3 and 29 only.

Interior Sound Hard Boundary (Wall) 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Interior Sound Hard Boundary (Wall)**.

2 In the **Settings** window for **Interior Sound Hard Boundary (Wall)**, locate the **Boundary Selection** section.

3 From the **Selection** list, choose **Array 1**.

Set up the study to calculate the single diffuser and its corresponding flat reference.

STUDY 1 - SINGLE DIFFUSER

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

2 In the **Settings** window for **Study**, type `Study 1 - Single Diffuser` in the **Label** text field.

Step 1: Frequency Domain

1 In the **Model Builder** window, under **Study 1 - Single Diffuser** click **Step 1: Frequency Domain**.

2 In the **Settings** window for **Frequency Domain**, locate the **Study Settings** section.

3 Click **Range**.

4 In the **Range** dialog, choose **ISO preferred frequencies** from the **Entry method** list.

5 In the **Start frequency** text field, type `fmin`.

6 In the **Stop frequency** text field, type `fmax`.

7 From the **Interval** list, choose **1/3 octave**.

8 Click **Replace**.

9 In the **Settings** window for **Frequency Domain**, locate the **Physics and Variables Selection** section.

10 In the **Solve for** column of the table, clear the checkbox for **Infinite Arrangement (comp3)**.

11 Click to expand the **Study Extensions** section. Select the **Auxiliary sweep** checkbox.

12 Click **Add**.

13 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
theta0 (Incidence polar angle from normal direction)	`range(0,dtheta, theta_max)`	`deg`

Generate the mesh based on the **Physics-controlled mesh** suggestion. The frequency controlling the maximum element size is per default taken **From study**, that is, from the **Maximum frequency to resolve**. In general, 5 to 6 second-order elements per wavelength are needed to resolve the waves. For more details, see *Meshing (Resolving the Waves)* in the *Acoustics Module User's Guide*. In this model, use the default **Automatic** option, which gives 5 elements per wavelength. An **Edge** mesh is then added on the circular arc.

MESH 1

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

MESH 2

1 In the **Model Builder** window, under **Single Diffuser (comp2)** click **Mesh 2**.

2 In the **Settings** window for **Mesh**, locate the **Sequence Type** section.

3 From the list, choose **User-controlled mesh**.

Edge 1

1 In the **Mesh** toolbar, click **More Generators** and choose **Edge**.

2 Select Boundary 30 only.

Distribution 1

1 Right-click **Edge 1** and choose **Distribution**.

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

3 In the **Number of elements** text field, type 100.

Free Triangular 1

1 In the **Model Builder** window, under **Single Diffuser (comp2)** > **Mesh 2** click **Free Triangular 1**.

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

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

4 From the **Selection** list, choose **All domains**.

5 In the **Model Builder** window, right-click **Mesh 2** and choose **Build All**.

Define the third component with a Periodic Condition to model an infinite arrangement of diffusers. As a consequence, the sound pressure in the exterior field cannot be evaluated on a circular arc in this case; the calculation of the energy reflected in the specular direction is thus based on a Periodic Port.

INFINITE ARRANGEMENT (COMP3)

In the **Model Builder** window, click **Infinite Arrangement (comp3)**.

ADD PHYSICS

1 In the **Home** toolbar, click **Add Physics** to open the **Add Physics** window.

2 Go to the **Add Physics** window.

3 In the tree, select **Acoustics** > **Pressure Acoustics** > **Pressure Acoustics, Frequency Domain (acpr)**.

4 Click the **Add to Infinite Arrangement** button in the window toolbar.

5 In the **Home** toolbar, click **Add Physics** to close the **Add Physics** window.

DEFINITIONS (COMP3)

Variables 2

1 In the **Model Builder** window, under **Infinite Arrangement (comp3)** right-click **Definitions** and choose **Variables**.

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

3 Click **Load from File**.

4 Browse to the model's Application Libraries folder and double-click the file `diffuser_schroeder_2d_variables_infinite.txt`.

Set up the Periodic Port. It must include all the propagating diffraction orders in order to be correct.

PRESSURE ACOUSTICS, FREQUENCY DOMAIN 3 (ACPR3)

Periodic Port 1

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

2 Select Boundary 3 only.

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

4 From the **Define incident wave** list, choose **Power per unit length**.

5 In the P^{in} text field, type `1`.

6 In the θ_{in} text field, type `theta0`.

Diffraction Order Port 1

1 In the **Physics** toolbar, click **Attributes** and choose **Diffraction Order Port**.

2 In the **Settings** window for **Diffraction Order Port**, locate the **Diffraction Order Port** section.

3 In the m text field, type `1`.

Repeat this operation for all the diffraction orders needed.

Periodic Condition 1

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

2 Select Boundaries 1 and 28 only.

3 In the **Settings** window for **Periodic Condition**, locate the **Periodicity Settings** section.

4 From the **Type of periodicity** list, choose **Floquet periodicity**.

5 From the $\mathbf{k}_{\text{F}}$ list, choose **Periodic port Floquet wave number vector (acpr3/pport1)**.

Proceed with setting up the study.

ADD STUDY

1 In the **Home** toolbar, click **Add Study** to open the **Add Study** window.

2 Go to the **Add Study** window.

3 Find the **Studies** subsection. In the **Select Study** tree, select **General Studies** > **Frequency Domain**.

4 Click the **Add Study** button in the window toolbar.

5 In the **Home** toolbar, click **Add Study** to close the **Add Study** window.

STUDY 2 - INFINITE ARRANGEMENT

1 In the **Settings** window for **Study**, type `Study 2 - Infinite arrangement` in the **Label** text field.

2 Locate the **Study Settings** section. Clear the **Generate default plots** checkbox.

Step 1: Frequency Domain

1 In the **Model Builder** window, under **Study 2 - Infinite arrangement** click **Step 1: Frequency Domain**.

2 In the **Settings** window for **Frequency Domain**, locate the **Study Settings** section.

3 Click **Range**.

4 In the **Range** dialog, choose **ISO preferred frequencies** from the **Entry method** list.

5 In the **Start frequency** text field, type `fmin`.

6 In the **Stop frequency** text field, type `fmax`.

7 From the **Interval** list, choose **1/3 octave**.

8 Click **Replace**.

9 In the **Settings** window for **Frequency Domain**, locate the **Physics and Variables Selection** section.

10 In the **Solve for** column of the table, clear the checkboxes for **Flat Reference (comp1)** and **Single Diffuser (comp2)**.

11 Locate the **Study Extensions** section. Select the **Auxiliary sweep** checkbox.

12 Click **Add**.

13 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
theta0 (Incidence polar angle from normal direction)	`range(0,dtheta, theta_max)`	deg

MESH 3

In the **Model Builder** window, under **Infinite Arrangement (comp3)** right-click **Mesh 3** and choose **Build All**.

Now solve the two studies.

STUDY 1 - SINGLE DIFFUSER

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

STUDY 2 - INFINITE ARRANGEMENT

Click **Compute**.

RESULTS

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

2 In the **Settings** window for **Results**, locate the **Update of Results** section.

3 Select the **Only plot when requested** checkbox.

Before investigating the results, remove the circular arc from the datasets. It only serves a purpose for calculating integrals and does not need to be shown in the result plots. Also remove unnecessary datasets and duplicate default plots.

In the **Model Builder** window, expand the **Results** > **Datasets** node.

Study 1 - Single Diffuser/Solution 1 (3) (sol1), Study 2 - Infinite arrangement/Solution 2 (4) (sol2), Study 2 - Infinite arrangement/Solution 2 (5) (sol2)

1 In the **Model Builder** window, under **Results** > **Datasets**, Ctrl-click to select **Study 1 - Single Diffuser/Solution 1 (3) (sol1)**, **Study 2 - Infinite arrangement/Solution 2 (4) (sol2)**, and **Study 2 - Infinite arrangement/Solution 2 (5) (sol2)**.

2 Right-click and choose **Delete**.

Study 1 - Single Diffuser/Solution 1 (2) (sol1)

In the **Model Builder** window, under **Results** > **Datasets** click **Study 1 - Single Diffuser/Solution 1 (2) (sol1)**.

Selection

1 Right-click **Study 1 - Single Diffuser/Solution 1 (2) (sol1)** 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 From the **Selection** list, choose **All domains**.

Create an Array dataset to show multiple periods of the infinite arrangement of diffusers.

Array 2D - 5 periods of the infinite arrangement

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

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

3 From the **Dataset** list, choose **Study 2 - Infinite arrangement/Solution 2 (sol2)**.

4 In the **Label** text field, type `Array 2D - 5 periods of the infinite arrangement`.

5 Locate the **Array Size** section. In the **X size** text field, type `5`.

6 Click to expand the **Advanced** section. Select the **Floquet–Bloch periodicity** checkbox.

7 Find the **Wave vector** subsection. In the **X** text field, type `acpr3.pport1.kitx`.

8 In the **Y** text field, type `acpr3.pport1.kity`.

Acoustic Pressure (acpr2), Exterior-Field Pressure (acpr2), Exterior-Field Sound Pressure Level (acpr2), Sound Pressure Level (acpr2)

1 In the **Model Builder** window, under **Results**, Ctrl-click to select **Acoustic Pressure (acpr2)**, **Sound Pressure Level (acpr2)**, **Exterior-Field Sound Pressure Level (acpr2)**, and **Exterior-Field Pressure (acpr2)**.

2 Right-click and choose **Delete**.

Acoustic Pressure (acpr)

1 In the **Model Builder** window, under **Results** click **Acoustic Pressure (acpr)**.

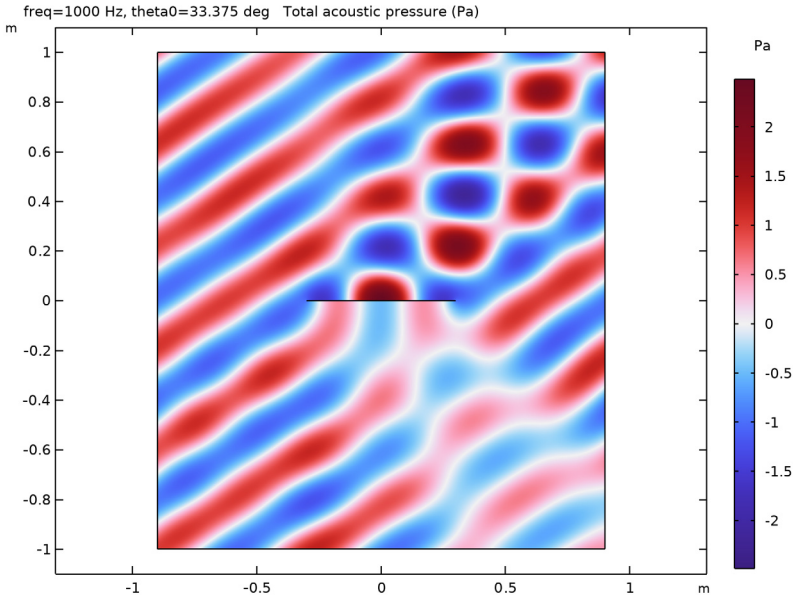
2 In the **Settings** window for **2D Plot Group**, locate the **Data** section.

3 From the **Parameter value (freq (Hz))** list, choose **1000**.

4 From the **Parameter value (theta0 (deg))** list, choose **33.375**.

5 In the **Acoustic Pressure (acpr)** toolbar, click **Plot**.

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



7 In the **Model Builder** window, click **Acoustic Pressure (acpr)**.

8 From the **Dataset** list, choose **Study 1 - Single Diffuser/Solution 1 (2) (sol1)**.

Surface 1

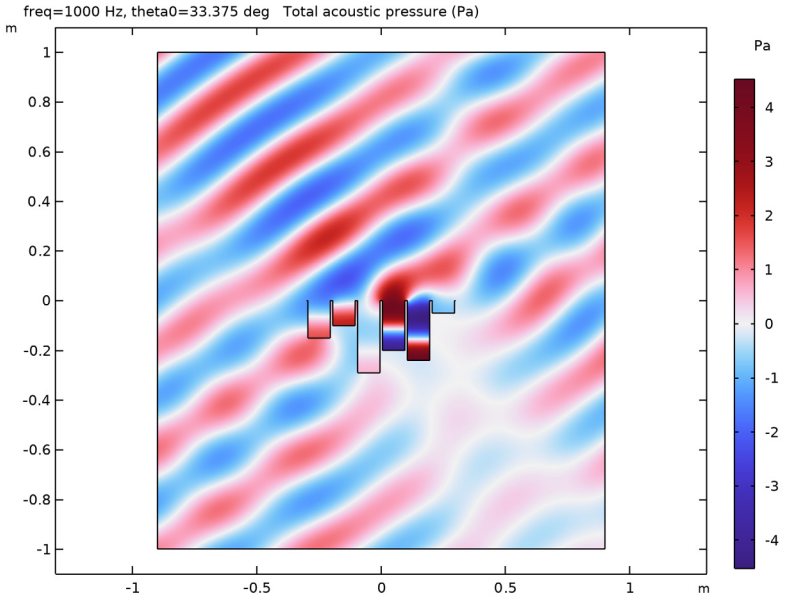
1 In the **Model Builder** window, expand the **Acoustic Pressure (acpr)** node, then click **Surface 1**.

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

3 In the **Expression** text field, type `acpr2.p_t`.

4 In the **Acoustic Pressure (acpr)** toolbar, click **Plot**.

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



Acoustic Pressure (acpr)

1 In the **Model Builder** window, click **Acoustic Pressure (acpr)**.

2 In the **Settings** window for **2D Plot Group**, locate the **Data** section.

3 From the **Dataset** list, choose **Array 2D - 5 periods of the infinite arrangement**.

Surface 1

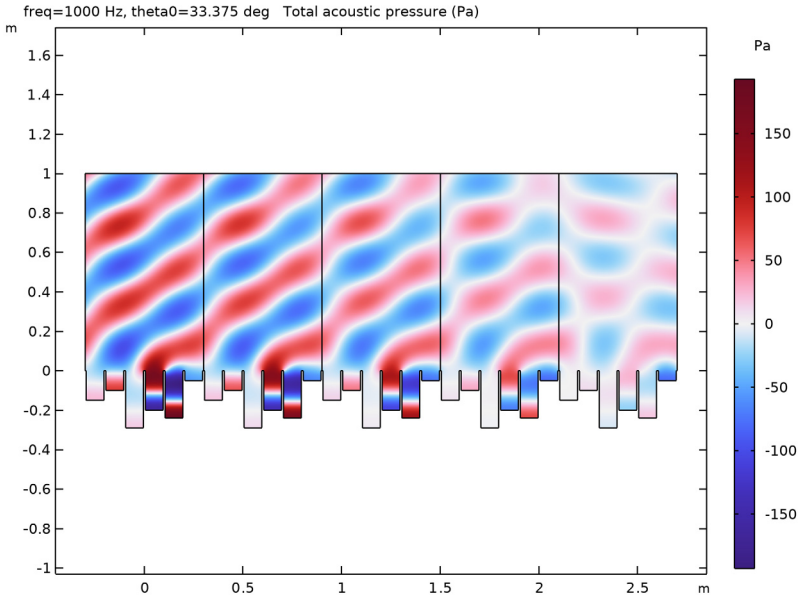
1 In the **Model Builder** window, click **Surface 1**.

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

3 In the **Expression** text field, type `acpr3.p_t`.

4 In the **Acoustic Pressure (acpr)** toolbar, click **Plot**.

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



Sound Pressure Level (acpr)

1 In the **Model Builder** window, under **Results** click **Sound Pressure Level (acpr)**.

2 In the **Settings** window for **2D Plot Group**, locate the **Data** section.

3 From the **Dataset** list, choose **Array 2D - 5 periods of the infinite arrangement**.

4 From the **Parameter value (freq (Hz))** list, choose **1000**.

5 From the **Parameter value (theta0 (deg))** list, choose **33.375**.

Surface 1

1 In the **Model Builder** window, expand the **Sound Pressure Level (acpr)** node, then click **Surface 1**.

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

3 In the **Expression** text field, type `acpr3.Lp_t`.

4 In the **Sound Pressure Level (acpr)** toolbar, click **Plot**.

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

Exterior-Field Sound Pressure Level (acpr)

1 In the **Model Builder** window, under **Results** click **Exterior-Field Sound Pressure Level (acpr)**.

2 In the **Settings** window for **Polar Plot Group**, locate the **Data** section.

3 From the **Dataset** list, choose **Study 1 - Single Diffuser/Solution 1 (2) (sol1)**.

4 From the **Parameter selection (freq)** list, choose **From list**.

5 In the **Parameter values (freq (Hz))** list, choose **630**, **800**, **1000**, and **1250**.

6 From the **Parameter selection (theta0)** list, choose **From list**.

7 In the **Parameter values (theta0 (deg))** list box, select **33.375**.

8 Locate the **Axis** section. Select the **Symmetric angle range** checkbox.

9 From the **Zero angle** list, choose **Up**.

10 Locate the **Legend** section. From the **Position** list, choose **Manual**.

11 In the **x-position** text field, type `0.5`.

12 In the **y-position** text field, type `0.25`.

Radiation Pattern 1

1 In the **Model Builder** window, expand the **Exterior-Field Sound Pressure Level (acpr)** node, then click **Radiation Pattern 1**.

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

3 In the **Expression** text field, type `acpr2.efc1.Lp_pext`.

4 Locate the **Evaluation** section. Find the **Angles** subsection. In the **Number of angles** text field, type `360`.

5 From the **Restriction** list, choose **Manual**.

6 In the ϕ **start** text field, type `-90`.

7 In the ϕ **range** text field, type `180`.

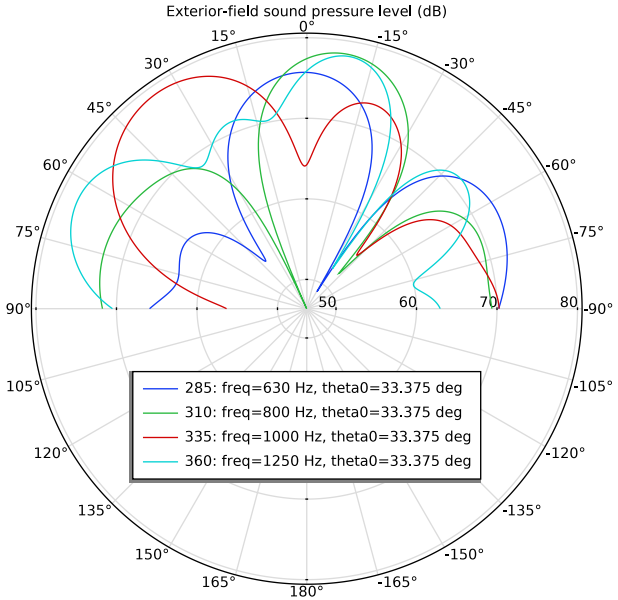
8 Find the **Circle** subsection. From the **Circle** list, choose **Manual**.

9 Find the **Evaluation distance** subsection. In the **Radius** text field, type `r0`.

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

11 In the **y** text field, type `1`.

12 In the **Exterior-Field Sound Pressure Level (acpr)** toolbar, click **Plot**.



Exterior-Field Pressure (acpr)

1 In the **Model Builder** window, under **Results** click **Exterior-Field Pressure (acpr)**.

2 In the **Settings** window for **Polar Plot Group**, locate the **Data** section.

3 From the **Dataset** list, choose **Study 1 - Single Diffuser/Solution 1 (2) (sol1)**.

4 From the **Parameter selection (freq)** list, choose **From list**.

5 In the **Parameter values (freq (Hz))** list, choose **630**, **800**, **1000**, and **1250**.

6 From the **Parameter selection (theta0)** list, choose **From list**.

7 In the **Parameter values (theta0 (deg))** list box, select **40.792**.

8 Locate the **Axis** section. Select the **Symmetric angle range** checkbox.

9 From the **Zero angle** list, choose **Up**.

10 Locate the **Legend** section. From the **Position** list, choose **Manual**.

11 In the **x-position** text field, type `0.5`.

12 In the **y-position** text field, type `0.25`.

Radiation Pattern 1

1 In the **Model Builder** window, expand the **Exterior-Field Pressure (acpr)** node, then click **Radiation Pattern 1**.

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

3 In the **Expression** text field, type `abs(acpr2.efc1.pext)^2`.

4 In the **Unit** field, type `Pa^2`.

5 Select the **Description** checkbox. In the associated text field, type `Exterior-field sound energy`.

6 Locate the **Evaluation** section. Find the **Angles** subsection. In the **Number of angles** text field, type `360`.

7 From the **Restriction** list, choose **Manual**.

8 In the ϕ **start** text field, type `-90`.

9 In the ϕ **range** text field, type `180`.

10 Find the **Circle** subsection. From the **Circle** list, choose **Manual**.

11 Find the **Evaluation distance** subsection. In the **Radius** text field, type `r0`.

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

13 In the **y** text field, type `1`.

14 In the **Exterior-Field Pressure (acpr)** toolbar, click **Plot**.

Scattering from Single Diffuser

In the **Home** toolbar, click **Add Plot Group** and choose **1D Plot Group**.

Plot the scattering coefficients for the single diffuser and the infinite arrangement. The Octave Band plots automatically create tables to easily export data.

1 In the **Settings** window for **1D Plot Group**, type `Scattering from Single Diffuser` in the **Label** text field.

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

3 From the **Parameter selection (theta0)** list, choose **First**.

4 Click to expand the **Title** section. From the **Title type** list, choose **Label**.

5 Locate the **Plot Settings** section.

6 Select the **x-axis label** checkbox. In the associated text field, type `Frequency (Hz)`.

7 Select the **y-axis label** checkbox. In the associated text field, type `Random incidence scattering coefficient (1)`.

8 Locate the **Axis** section. Select the **Manual axis limits** checkbox.

9 In the **x minimum** text field, type `48`.

10 In the **x maximum** text field, type `3300`.

11 In the **y minimum** text field, type `0`.

12 Select the **x-axis log scale** checkbox.

13 Locate the **Legend** section. From the **Position** list, choose **Upper left**.

Octave Band 1

1 In the **Scattering from Single Diffuser** toolbar, click **More Plots** and choose **Octave Band**.

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

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

4 Locate the **y-Axis Data** section. In the **Expression** text field, type `s_ran`.

5 From the **Expression type** list, choose **General (non-dB)**.

6 Locate the **Plot** section. From the **Quantity** list, choose **Band average power spectral density**.

7 Click to expand the **Coloring and Style** section. From the **Type** list, choose **Outline**.

8 Click to expand the **Legends** section. Select the **Show legends** checkbox.

9 From the **Legends** list, choose **Manual**.

10 In the table, enter the following settings:

Legends
`Octave band`

Octave Band 2

1 Right-click **Octave Band 1** and choose **Duplicate**.

2 In the **Settings** window for **Octave Band**, locate the **Plot** section.

3 From the **Quantity** list, choose **Continuous power spectral density**.

4 Locate the **Coloring and Style** section. Find the **Line style** subsection. From the **Line** list, choose **Dashed**.

5 Find the **Line markers** subsection. From the **Marker** list, choose **Asterisk**.

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

Legends
`Continuous frequency`

Global 1

1 In the **Model Builder** window, right-click **Scattering from Single Diffuser** and choose **Global**.

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

3 From the **Dataset** list, choose **Study 2 - Infinite arrangement/Solution 2 (sol2)**.

4 From the **Parameter selection (theta0)** list, choose **First**.

5 Locate the **y-Axis Data** section. In the table, enter the following settings:

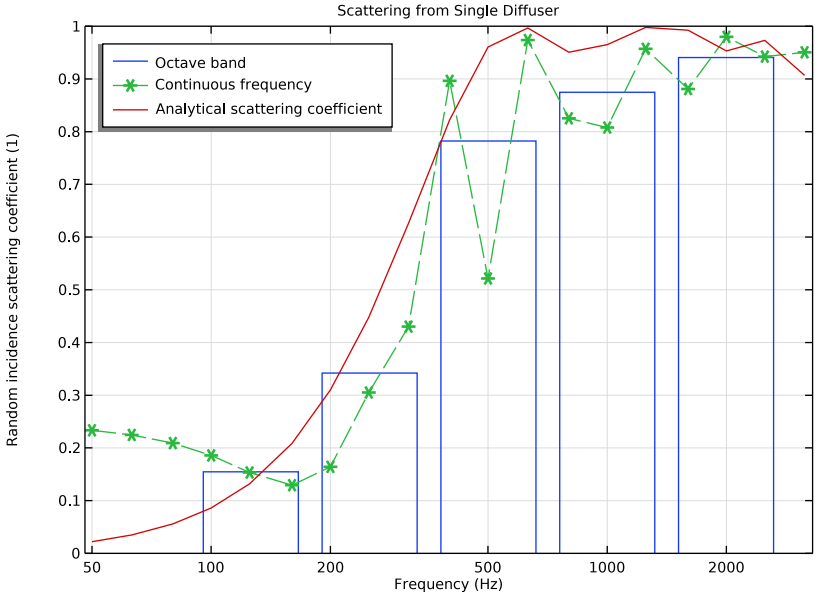
Expression	Unit	Description
`s_th`		`Analytical scattering coefficient`

6 Locate the **x-Axis Data** section. From the **Axis source data** list, choose **freq**.

7 Click to expand the **Legends** section. Find the **Include** subsection. Clear the **Solution** checkbox.

Before plotting, note that the single diffuser case may take a long time to render. The infinite arrangement case is much faster thanks to the Periodic Port setup

In the **Scattering from Single Diffuser** toolbar, click **Plot**.



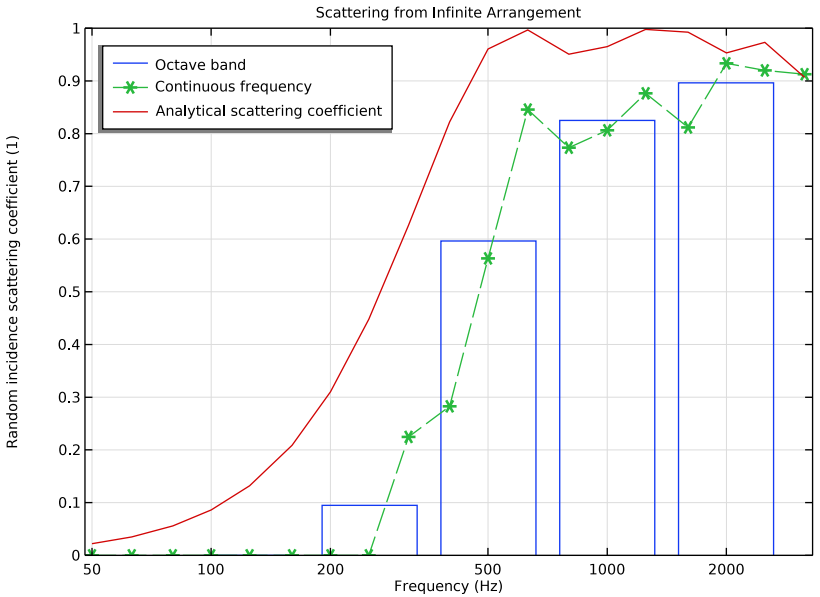
Scattering from Infinite Arrangement

1 Right-click **Scattering from Single Diffuser** and choose **Duplicate**.

2 In the **Settings** window for **1D Plot Group**, type `Scattering from Infinite Arrangement` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Study 2 - Infinite arrangement/ Solution 2 (sol2)**.

4 In the **Scattering from Infinite Arrangement** toolbar, click **Plot**.



Periodic Port Mode Powers

In the **Home** toolbar, click **Add Plot Group** and choose **1D Plot Group**.

Investigate the behavior of the Periodic Port by plotting the powers of the diffraction orders.

1 In the **Settings** window for **1D Plot Group**, type `Periodic Port Mode Powers` in the **Label** text field.

2 Locate the **Data** section. From the **Dataset** list, choose **Study 2 - Infinite arrangement/ Solution 2 (sol2)**.

3 From the **Parameter selection (freq)** list, choose **Last**.

4 Click to expand the **Title** section. From the **Title type** list, choose **Label**.

5 Locate the **Plot Settings** section.

6 Select the **x-axis label** checkbox. In the associated text field, type `Incidence angle (deg)`.

7 Select the **y-axis label** checkbox. In the associated text field, type `Power per unit length (W/m)`.

8 Locate the **Legend** section. From the **Position** list, choose **Middle left**.

Global 1

1 Right-click **Periodic Port Mode Powers** and choose **Global**.

2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.

3 In the table, enter the following settings:

Expression	Unit	Description
acpr3.pport1.P_in	W/m	Power per unit length of incident mode
acpr3.pport1.P_out	W/m	Power per unit length of outgoing mode

4 Click to expand the **Coloring and Style** section. Find the **Line markers** subsection. From the **Marker** list, choose **Point**.

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

6 In the table, enter the following settings:

Legends
Incident mode
Outgoing mode

Global 2

1 In the **Model Builder** window, right-click **Periodic Port Mode Powers** and choose **Global**.

2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.

3 In the table, enter the following settings:

Expression	Unit	Description
acpr3.pport1.dport1.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport2.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport3.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport4.P_out	W/m	Power per unit length of outgoing mode

Expression	Unit	Description
acpr3.pport1.dport5.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport6.P_out	W/m	Power per unit length of outgoing mode

4 Locate the **Legends** section. Clear the **Show legends** checkbox.

Global 3

1 Right-click **Periodic Port Mode Powers** and choose **Global**.

2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.

3 In the table, enter the following settings:

Expression	Unit	Description
acpr3.pport1.dport7.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport8.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport9.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport10.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport11.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport12.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport13.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport14.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport15.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport16.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport17.P_out	W/m	Power per unit length of outgoing mode
acpr3.pport1.dport18.P_out	W/m	Power per unit length of outgoing mode

4 Locate the **Coloring and Style** section. Find the **Line style** subsection. From the **Line** list, choose **Dashed**.

5 Locate the **Legends** section. Clear the **Show legends** checkbox.

6 In the **Periodic Port Mode Powers** toolbar, click **Plot**.

Evaluation Group 1 - Propagating Diffraction Orders

In the **Results** toolbar, click **Evaluation Group**.

To make sure that all the propagating modes have been included in the Periodic Port, evaluate the imaginary part of the mode wave number for each diffraction order.

1 In the **Settings** window for **Evaluation Group**, type `Evaluation Group 1 - Propagating Diffraction Orders` in the **Label** text field.

2 Locate the **Data** section. From the **Dataset** list, choose **Study 2 - Infinite arrangement/ Solution 2 (sol2)**.

3 From the **Parameter selection (freq)** list, choose **Last**.

Global Evaluation 1

1 Right-click **Evaluation Group 1 - Propagating Diffraction Orders** and choose **Global Evaluation**.

2 In the **Settings** window for **Global Evaluation**, locate the **Expressions** section.

3 In the table, enter the following settings:

Expression	Unit	Description
imag(acpr3.pport1.dport1.kn)	rad/m	imag(kn), m=1
imag(acpr3.pport1.dport2.kn)	rad/m	imag(kn), m=2
imag(acpr3.pport1.dport3.kn)	rad/m	imag(kn), m=3
imag(acpr3.pport1.dport4.kn)	rad/m	imag(kn), m=4
imag(acpr3.pport1.dport5.kn)	rad/m	imag(kn), m=5
imag(acpr3.pport1.dport6.kn)	rad/m	imag(kn), m=6
imag(acpr3.pport1.dport7.kn)	rad/m	imag(kn), m=-1
imag(acpr3.pport1.dport8.kn)	rad/m	imag(kn), m=-2
imag(acpr3.pport1.dport9.kn)	rad/m	imag(kn), m=-3
imag(acpr3.pport1.dport10.kn)	rad/m	imag(kn), m=-4
imag(acpr3.pport1.dport11.kn)	rad/m	imag(kn), m=-5
imag(acpr3.pport1.dport12.kn)	rad/m	imag(kn), m=-6
imag(acpr3.pport1.dport13.kn)	rad/m	imag(kn), m=-7
imag(acpr3.pport1.dport14.kn)	rad/m	imag(kn), m=-8
imag(acpr3.pport1.dport15.kn)	rad/m	imag(kn), m=-9
imag(acpr3.pport1.dport16.kn)	rad/m	imag(kn), m=-10

Expression	Unit	Description
imag(acpr3.pport1.dport17.kn)	rad/m	imag(kn), m=-11
imag(acpr3.pport1.dport18.kn)	rad/m	imag(kn), m=-12

4 In the **Evaluation Group 1 - Propagating Diffraction Orders** toolbar, click **Evaluate**.

Geometry Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Blank Model**.

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 Click **Load from File**.

4 Browse to the model's Application Libraries folder and double-click the file `diffuser_schroeder_2d_geom_sequence_parameters.txt`.

ADD COMPONENT

In the **Home** toolbar, click **Add Component** and choose **2D**.

INFINITE ARRANGEMENT

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

2 In the **Settings** window for **Component**, type `Infinite arrangement` in the **Label** text field.

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 `W`.

4 In the **Height** text field, type `d1`.

5 In the **Width** text field, type `Lw`.

6 Locate the **Position** section. In the **x** text field, type `-L/2+Li/2`.

7 In the **y** text field, type `-d1`.

Rectangle 2 (r2)

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 `Lw`.

4 In the **Height** text field, type `d2`.

5 Locate the **Position** section. In the **x** text field, type `-L/2+3*Li/2+Lw`.

6 In the **y** text field, type `-d2`.

Rectangle 3 (r3)

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 `Lw`.

4 In the **Height** text field, type `d3`.

5 Locate the **Position** section. In the **x** text field, type `-L/2+5*Li/2+2*Lw`.

6 In the **y** text field, type `-d3`.

Rectangle 4 (r4)

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 `Lw`.

4 In the **Height** text field, type `d4`.

5 Locate the **Position** section. In the **x** text field, type `-L/2+7*Li/2+3*Lw`.

6 In the **y** text field, type `-d4`.

Rectangle 5 (r5)

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 `Lw`.

4 In the **Height** text field, type `d5`.

5 Locate the **Position** section. In the **x** text field, type `-L/2+9*Li/2+4*Lw`.

6 In the **y** text field, type `-d5`.

Rectangle 6 (r6)

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 `Lw`.

4 In the **Height** text field, type `d6`.

5 Locate the **Position** section. In the **x** text field, type `-L/2+11*Li/2+5*Lw`.

6 In the **y** text field, type `-d6`.

Rectangle 1 (r1), Rectangle 2 (r2), Rectangle 3 (r3), Rectangle 4 (r4), Rectangle 5 (r5), Rectangle 6 (r6)

1 In the **Model Builder** window, under **Infinite arrangement (comp1)** > **Geometry 1**, Ctrl-click to select **Rectangle 1 (r1)**, **Rectangle 2 (r2)**, **Rectangle 3 (r3)**, **Rectangle 4 (r4)**, **Rectangle 5 (r5)**, and **Rectangle 6 (r6)**.

2 Right-click and choose **Group**.

Wells

In the **Settings** window for **Group**, type `Wells` in the **Label** text field.

Rectangle 7 (r7)

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 `L`.

4 In the **Height** text field, type `Hair`.

5 Locate the **Position** section. In the **x** text field, type `-L/2`.

Union 1 (uni1)

1 In the **Geometry** toolbar, click  **Booleans and Partitions** and choose **Union**.

2 Click in the **Graphics** window and then press Ctrl+A to select all objects.

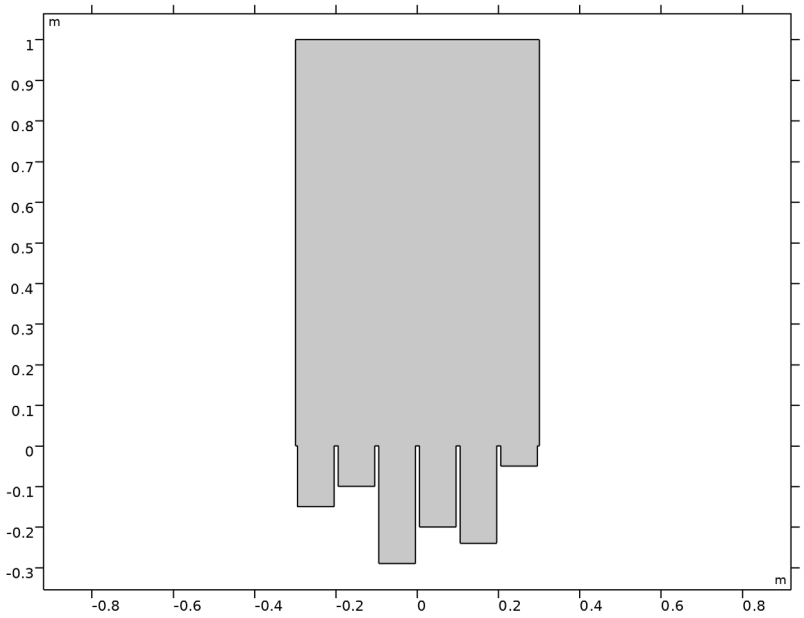
3 In the **Settings** window for **Union**, locate the **Union** section.

4 Clear the **Keep interior boundaries** checkbox.

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

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

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



ADD COMPONENT

Right-click **Geometry 1** and choose **Add Component** > **2D**.

SINGLE DIFFUSER

In the **Settings** window for **Component**, type `Single Diffuser` in the **Label** text field.

GEOMETRY 1

Wells

In the **Model Builder** window, under **Infinite arrangement (comp1)** > **Geometry 1** right-click **Wells** and choose **Copy**.

GEOMETRY 2

In the **Model Builder** window, under **Single Diffuser (comp2)** right-click **Geometry 2** and choose **Paste Group**.

Line Segment 1 (ls1)

1 In the **Geometry** toolbar, click **More Primitives** and choose **Line Segment**.

2 In the **Settings** window for **Line Segment**, locate the **Starting Point** section.

3 From the **Specify** list, choose **Coordinates**.

4 In the **x** text field, type `-L/2`.

5 Locate the **Endpoint** section. From the **Specify** list, choose **Coordinates**.

6 In the **x** text field, type `-L/2+Li/2`.

Line Segment 2 (ls2)

1 In the **Geometry** toolbar, click **More Primitives** and choose **Line Segment**.

2 In the **Settings** window for **Line Segment**, locate the **Starting Point** section.

3 Click to select the **Activate Selection** toggle button for **Start vertex**.

4 On the object **r1**, select Point 3 only.

5 Locate the **Endpoint** section. Click to select the **Activate Selection** toggle button for **End vertex**.

6 On the object **r2**, select Point 4 only.

Line Segment 3 (ls3)

1 In the **Geometry** toolbar, click **More Primitives** and choose **Line Segment**.

2 On the object **r2**, select Point 3 only.

3 In the **Settings** window for **Line Segment**, locate the **Endpoint** section.

4 Click to select the **Activate Selection** toggle button for **End vertex**.

5 On the object **r3**, select Point 4 only.

Line Segment 4 (ls4)

1 In the **Geometry** toolbar, click **More Primitives** and choose **Line Segment**.

2 On the object **r3**, select Point 3 only.

3 In the **Settings** window for **Line Segment**, locate the **Endpoint** section.

4 Click to select the **Activate Selection** toggle button for **End vertex**.

5 On the object **r4**, select Point 4 only.

Line Segment 5 (ls5)

1 In the **Geometry** toolbar, click **More Primitives** and choose **Line Segment**.

2 On the object **r4**, select Point 3 only.

3 In the **Settings** window for **Line Segment**, locate the **Endpoint** section.

4 Click to select the **Activate Selection** toggle button for **End vertex**.

5 On the object **r5**, select Point 4 only.

Line Segment 6 (ls6)

1 In the **Geometry** toolbar, click **More Primitives** and choose **Line Segment**.

2 On the object **r5**, select Point 3 only.

3 In the **Settings** window for **Line Segment**, locate the **Endpoint** section.

4 Click to select the **Activate Selection** toggle button for **End vertex**.

5 On the object **r6**, select Point 4 only.

Line Segment 7 (ls7)

1 In the **Geometry** toolbar, click **More Primitives** and choose **Line Segment**.

2 In the **Settings** window for **Line Segment**, locate the **Starting Point** section.

3 From the **Specify** list, choose **Coordinates**.

4 In the **x** text field, type `L/2-Li/2`.

5 Locate the **Endpoint** section. From the **Specify** list, choose **Coordinates**.

6 In the **x** text field, type `L/2`.

Delete Entities 1 (del1)

1 In the **Model Builder** window, right-click **Geometry 2** and choose **Delete Entities**.

2 On the object **r1**, select Boundary 3 only.

3 On the object **r2**, select Boundary 3 only.

4 On the object **r3**, select Boundary 3 only.

5 On the object **r4**, select Boundary 3 only.

6 On the object **r5**, select Boundary 3 only.

7 On the object **r6**, select Boundary 3 only.

Array 1 (arr1)

1 In the **Geometry** toolbar, click **Transforms** and choose **Array**.

2 In the **Settings** window for **Array**, locate the **Input** section.

3 From the **Input objects** list, choose **All objects**.

4 Locate the **Size** section. In the **x size** text field, type `Np`.

5 Locate the **Displacement** section. In the **x** text field, type `L`.

6 Locate the **Selections of Resulting Entities** section. Select the **Resulting objects selection** checkbox.

7 From the **Show in physics** list, choose **Boundary selection**.

Move 1 (mov1)

1 In the **Geometry** toolbar, click **Transforms** and choose **Move**.

2 In the **Settings** window for **Move**, locate the **Input** section.

3 From the **Input objects** list, choose **All objects**.

4 Locate the **Displacement** section. In the **x** text field, type `-(Np-1)*L/2`.

Rectangle 7 (r7)

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 `Wair`.

4 In the **Height** text field, type `2*Hair`.

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

Union 1 (uni1)

1 In the **Geometry** toolbar, click **Booleans and Partitions** and choose **Union**.

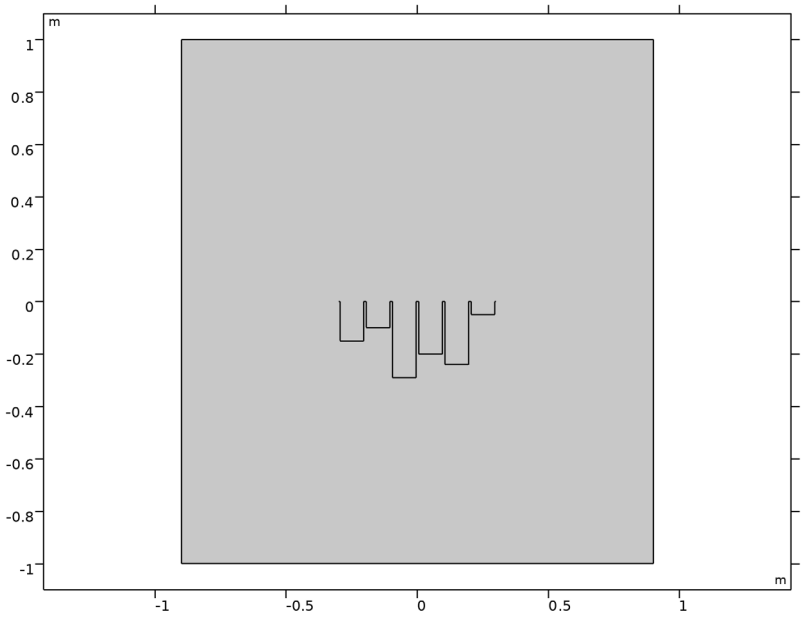
2 In the **Settings** window for **Union**, locate the **Union** section.

3 From the **Input objects** list, choose **All objects**.

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

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

6 In the **Model Builder** window, click **Geometry 2**.



Circular Arc 1 (ca1)

1 In the **Geometry** toolbar, click **More Primitives** and choose **Circular Arc**.

2 In the **Settings** window for **Circular Arc**, locate the **Radius** section.

3 In the **Radius** text field, type `r0`.

4 Locate the **Angles** section. In the **End angle** text field, type `180`.

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

ADD COMPONENT

Right-click **Geometry 2** and choose **Add Component** > **2D**.

FLAT REFERENCE

In the **Settings** window for **Component**, type `Flat Reference` in the **Label** text field.

GEOMETRY 2

Rectangle 7 (r7)

In the **Model Builder** window, under **Single Diffuser (comp2)** > **Geometry 2** right-click **Rectangle 7 (r7)** and choose **Copy**.

GEOMETRY 3

Rectangle 7 (r1)

In the **Model Builder** window, under **Flat Reference (comp3)** right-click **Geometry 3** and choose **Paste Rectangle**.

Line Segment 1 (ls1)

1 In the **Geometry** toolbar, click **More Primitives** and choose **Line Segment**.

2 In the **Settings** window for **Line Segment**, locate the **Starting Point** section.

3 From the **Specify** list, choose **Coordinates**.

4 In the **x** text field, type `-Np*L/2`.

5 Locate the **Endpoint** section. From the **Specify** list, choose **Coordinates**.

6 In the **x** text field, type `Np*L/2`.

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 3**.