



Model created in COMSOL Multiphysics 6.4

# Porous Absorber with Local and Extended Reacting Approximations for Time-Domain Modeling

## Introduction

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This tutorial studies the propagation of sound in the presence of a porous absorber in the time domain. It demonstrates how to model a porous absorber using the local and extended reacting approximations and compares the two approaches for absorbers of various thickness. The dissipative and resonant behavior of the absorber is frequency dependent. The use of the **Partial Fraction Fit** functionality makes it possible to account for the frequency dependency in the time-domain simulations.

## Model Definition

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The sound propagation is induced by an initial pressure pulse given by a Ricker wavelet of the form

$$p_0(x, y) = \left(1 - \frac{(x - x_s)^2 + (y - y_s)^2}{B^2}\right) \exp\left(-\frac{(x - x_s)^2 + (y - y_s)^2}{2B^2}\right)$$

with the width  $B = 0.045$  m which has sufficient energy up to 4 kHz. The source center is located 0.5 m above a porous layer, and the receiver is located at the same height 2 m away from the source.

The porous layer is rigidly backed and made of melamine foam. It has the thickness of 5 or 15 cm. This tutorial studies two approaches to modeling of sound absorption: local reacting (LR) and extended reacting (ER) (see [Ref. 1](#), [Ref. 2](#)). In the LR approximation, the absorbing properties of the porous layer are taken into account through the impedance boundary condition imposed that establishes a relation between the acoustic pressure and the acoustic particle velocity on the absorber boundary. That is,

$$v_n(\omega) = \frac{p(\omega)}{Z(\omega, \theta)} = p(\omega)Y(\omega, \theta), \quad (1)$$

The impedance values,  $Z$ , are in general angle-dependent ( $\theta$ ) and vary over frequency ( $\omega$ ). In the time domain, the boundary admittance,  $Y$ , is used instead. Those can either be measured or computed as demonstrated in the *Acoustic Treatment Boundary Calculator* application.

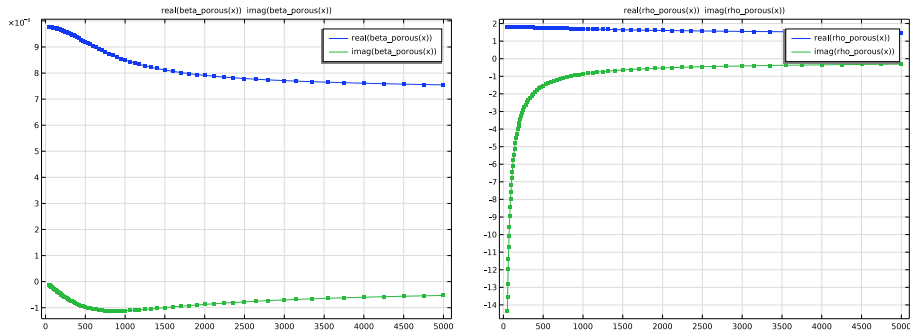
The ER approximation is more accurate, because it is based on modeling of the sound propagation inside the porous domain. The absorbing properties of the porous media are described by various equivalent fluid models with the complex-valued frequency-dependent bulk modulus and density. In the absence of domain sources the governing equations read

$$\begin{aligned} i\omega\beta_s(\omega)p + \nabla \cdot \mathbf{u} &= 0 \\ \rho(\omega)\mathbf{u} + \nabla p &= 0 \end{aligned} \quad (2)$$

where  $\beta_s$  is the isentropic compressibility, which is the inverse of the bulk modulus, and  $\rho$  is the density. This tutorial relies on the Johnson–Champoux–Allard (JCA) poroacoustic model for the absorber with the porosity of 0.99, tortuosity factor of 1, flow resistivity of 4500 Pa·s/m<sup>2</sup>, and viscous and thermal characteristic lengths of 130 and 160  $\mu\text{m}$ , respectively.

In the time domain, the products of the frequency-dependent quantities in [Equation 1](#) and [Equation 2](#) turn into convolutions. Their efficient computation is possible with the use of the **Partial Fraction Fit** functionality which creates a rational approximant to a complex-valued function, allowing for analytical calculation of its inverse Laplace transform (see *Wave-Based Time-Domain Room Acoustics with Frequency-Dependent Impedance* for details).

The frequency-dependent isentropic compressibility and density as well as the frequency-dependent admittance for the absorber thickness of 5 and 15 cm are fitted within the frequency range from 50 Hz to 5 kHz with 12 samples per octave. The sampled and the fitted curves are shown in [Figure 1](#) and [Figure 2](#) below.



*Figure 1: Fitted frequency-dependent isentropic compressibility (left) and density (right).*

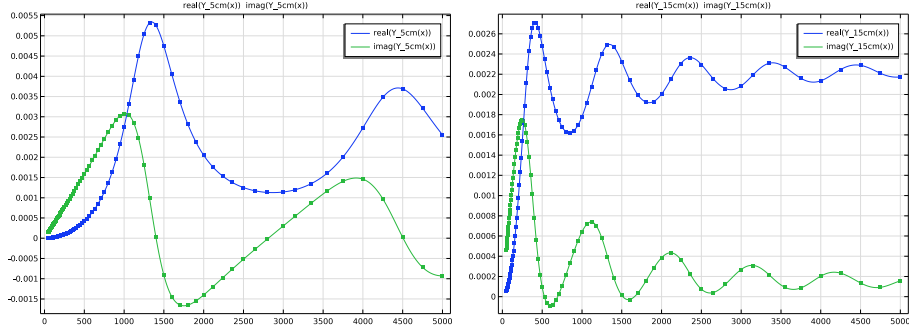


Figure 2: Fitted admittance for 5 (left) and 15 (right) cm thick porous layer at  $\theta = 0^\circ$ .

## Results and Discussion

The acoustic pressure profiles at  $t = 5.5$  ms are depicted in Figure 3. It shows only a slight visual difference between the results from the ER (top) and LR (bottom) approaches. At the same time, the signal reflected from the absorber is different for the thinner (left) and thicker (right) layers. The thicker layer absorbs more acoustic energy, which is seen from the magnitude of the reflected signal.

Figure 4 shows the profiles of the signal that has reached the receiver. The direct sound is the same regardless of the absorber thickness and the approach used to model it. However, the reflected sound is different. The ER approximation results in the peaks and troughs at the same locations for both 5 and 15 cm thick layers: 6.2 and 6.7 ms for the peaks and 6.5 and 6.9 ms for the troughs. Only their magnitude differs. On the other hand, the LR approximation yields the reflected sound with peaks and troughs at different locations. This indicates that the ER approach has a higher accuracy. At the same time, it is computationally more demanding, as it involves solving the governing equations in the porous domain thus resulting in a larger number of degrees of freedom compared to the LR approach.

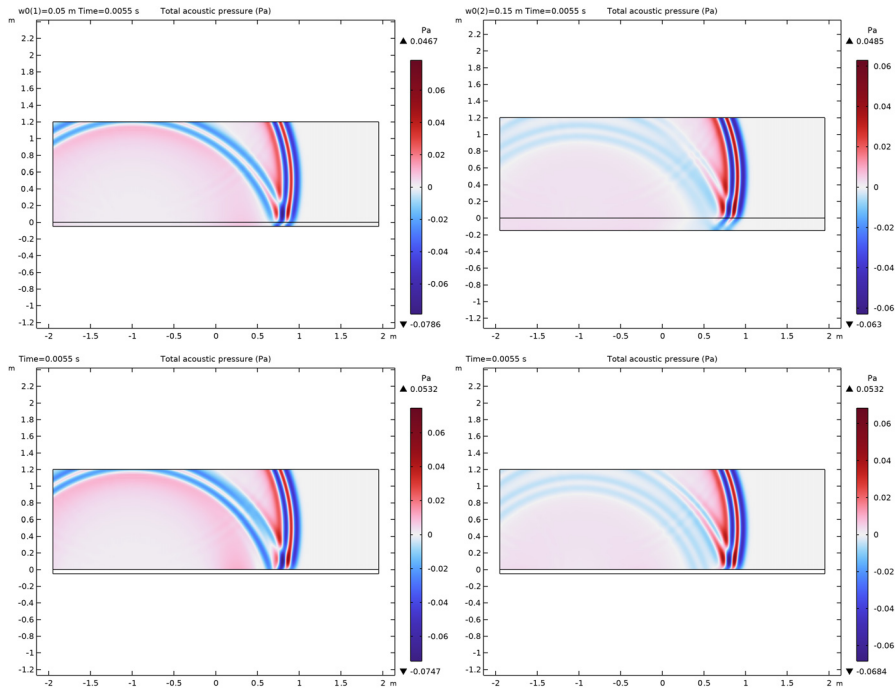


Figure 3: Acoustic pressure computed using the ER (top) and LR (bottom) approximations for the 5 (left) and 15 (right) cm thick porous layer.

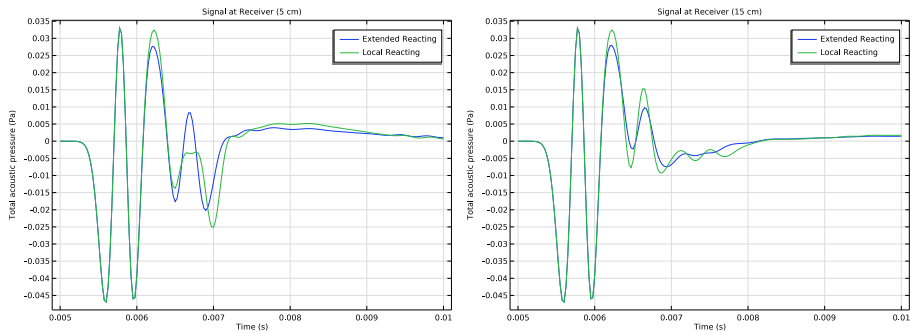


Figure 4: Acoustic pressure at the receiver for the 5 (left) and 15 (right) cm thick porous layer.

## References

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1. F. Pind, A.P. Eising-Karup, C-H Jeong, J.S. Hesthaven, and J. Strømmand-Andersen, “Time-domain room acoustic simulations with extended-reacting porous absorbers using the discontinuous Galerkin method,” *J. Acoust. Soc. Am.*, vol. 148, p. 2851, 2020; [doi.org/10.1121/10.0002448](https://doi.org/10.1121/10.0002448).
2. H. Wang and M. Hornikx, “Extended reacting boundary modeling of porous materials with thin coverings for time-domain room acoustic simulations,” *J. Sound Vib.*, vol. 548, 117550, 2023; [doi.org/10.1016/j.jsv.2022.117550](https://doi.org/10.1016/j.jsv.2022.117550).

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**Application Library path:** Acoustics\_Module/Building\_and\_Room\_Acoustics/porous\_absorber\_time\_domain


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## Modeling Instructions


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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 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
L0	1.5[m]	1.5 m	Computational domain height
w0	5[cm]	0.05 m	Porous layer width
xs	-1[m]	-1 m	Source location, x-coordinate
xr	1[m]	1 m	Receiver location, x-coordinate

Name	Expression	Value	Description
ys	0.5[m]	0.5 m	Source and receiver location, y-coordinate
B	0.045[m]	0.045 m	Pulse width

Create an **Analytic** function for the initial pressure pulse that initiates the sound.





#### *Analytic 1 (an1)*

- 1 In the **Home** toolbar, click  **Functions** and choose **Global > Analytic**.
- 2 In the **Settings** window for **Analytic**, type p\_init in the **Function name** text field.
- 3 Locate the **Definition** section. In the **Expression** text field, type  $(1 - ((x - xs)^2 + (y - ys)^2)/B^2) * \exp(-((x - xs)^2 + (y - ys)^2)/B^2/2)$ .
- 4 In the **Arguments** text field, type x, y.


Then, create four **Partial Fraction Fit** functions for the partial fraction representation of the frequency-dependent data used in the model.



Make sure that the results fulfill the causality and reality conditions, that is, that the poles have negative real parts, as well as the passivity condition, that is, that the functions have non-negative real parts.

#### *Partial Fraction Fit 1 (pff1)*




- 1 In the **Home** toolbar, click  **Functions** and choose **Global > Partial Fraction Fit**.
- 2 In the **Settings** window for **Partial Fraction Fit**, type beta\_porous in the **Function name** text field.
- 3 Locate the **Data** section. Click  **Browse**.
- 4 Browse to the model's Application Libraries folder and double-click the file porous\_absorber\_time\_domain\_compressibility.txt.
- 5 Click  **Fit Parameters**.
- 6 Click  **Plot**.
- 7 In the **Function Plot** window, click the **x-Axis Log Scale** button in the window toolbar.

#### *Partial Fraction Fit 2 (beta\_porous2)*

- 1 Right-click **Partial Fraction Fit 1 (beta\_porous)** and choose **Duplicate**.
- 2 In the **Settings** window for **Partial Fraction Fit**, type rho\_porous in the **Function name** text field.
- 3 Locate the **Data** section. Click  **Browse**.

- 4 Browse to the model's Application Libraries folder and double-click the file porous\_absorber\_time\_domain\_density.txt.
- 5 Click  **Fit Parameters**.
- 6 Click  **Plot**.
- 7 In the **Function Plot** window, click the **x-Axis Log Scale** button in the window toolbar.



*Partial Fraction Fit 3 (rho\_porous3)*

- 1 Right-click **Partial Fraction Fit 2 (rho\_porous)** and choose **Duplicate**.
- 2 In the **Settings** window for **Partial Fraction Fit**, type Y\_5cm in the **Function name** text field.
- 3 Locate the **Data** section. Click  **Browse**.
- 4 Browse to the model's Application Libraries folder and double-click the file porous\_absorber\_time\_domain\_admittance.txt.
- 5 Click  **Fit Parameters**.
- 6 Click  **Plot**.
- 7 In the **Function Plot** window, click the **x-Axis Log Scale** button in the window toolbar.

*Partial Fraction Fit 4 (Y\_5cm4)*


- 1 Right-click **Partial Fraction Fit 3 (Y\_5cm)** and choose **Duplicate**.
- 2 In the **Settings** window for **Partial Fraction Fit**, type Y\_15cm in the **Function name** text field.
- 3 Locate the **Data Column Settings** section. In the table, enter the following settings:

Columns	Type	Settings
1 real(Y), 15[cm] (m <sup>2</sup> *s/kg)	Real	
4 imag(Y), 15[cm] (m <sup>2</sup> *s/kg)	Imaginary	

- 4 Click  **Fit Parameters**.
- 5 Click  **Plot**.
- 6 In the **Function Plot** window, click the **x-Axis Log Scale** button in the window toolbar.

## GEOMETRY I

*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 3\*L0.

- 4 In the **Height** text field, type  $L_0$ .
- 5 Locate the **Position** section. In the **x** text field, type  $-1.5 \cdot L_0$ .
- 6 Click to expand the **Layers** section. Select the **Layers to the left** checkbox.
- 7 Select the **Layers to the right** checkbox.
- 8 Clear the **Layers on bottom** checkbox.
- 9 Select the **Layers on top** checkbox.
- 10 In the table, enter the following settings:

Layer name	Thickness (m)
Layer 1	$L_0/5$

11 Click  **Build Selected**.



#### *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  $3 \cdot L_0$ .
- 4 In the **Height** text field, type  $w_0$ .
- 5 Locate the **Position** section. In the **x** text field, type  $-1.5 \cdot L_0$ .
- 6 In the **y** text field, type  $-w_0$ .
- 7 Locate the **Layers** section. Select the **Layers to the right** checkbox.
- 8 Select the **Layers to the left** checkbox.
- 9 Clear the **Layers on bottom** checkbox.
- 10 In the table, enter the following settings:


Layer name	Thickness (m)
Layer 1	$L_0/5$

11 Click  **Build Selected**.

#### *Point 1 (pt1)*

- 1 In the **Geometry** toolbar, click  **Point**.
- 2 In the **Settings** window for **Point**, locate the **Point** section.
- 3 In the **x** text field, type  $x_s$ .
- 4 In the **y** text field, type  $y_s$ .
- 5 Click  **Build Selected**.


### *Point 2 (pt2)*

- 1 Right-click **Point 1 (pt1)** and choose **Duplicate**.
- 2 In the **Settings** window for **Point**, locate the **Point** section.
- 3 In the **x** text field, type **xr**.
- 4 Click  **Build Selected**.


Create selections to simplify the model setup.

## **DEFINITIONS**


### *Air*

- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 Select Domains 2, 3, 5, 6, 8, and 9 only.
- 3 In the **Settings** window for **Explicit**, type **Air** in the **Label** text field.




### *Porous Layer*


- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 Select Domains 1, 4, and 7 only.
- 3 In the **Settings** window for **Explicit**, type **Porous Layer** in the **Label** text field.

### *Absorbing Layer*


- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 Select Domains 1–3 and 6–9 only.
- 3 In the **Settings** window for **Explicit**, type **Absorbing Layer** in the **Label** text field.

### *Physical Domain*



- 1 In the **Definitions** toolbar, click  **Difference**.
- 2 In the **Settings** window for **Difference**, locate the **Input Entities** section.
- 3 Under **Selections to add**, click  **Add**.
- 4 In the **Add** dialog, select **Air** in the **Selections to add** list.
- 5 Click **OK**.
- 6 In the **Settings** window for **Difference**, locate the **Input Entities** section.
- 7 Under **Selections to add**, click  **Add**.
- 8 In the **Add** dialog, select **Porous Layer** in the **Selections to add** list.
- 9 Click **OK**.
- 10 In the **Settings** window for **Difference**, locate the **Input Entities** section.

- 11 Under **Selections to subtract**, click  **Add**.
- 12 In the **Add** dialog, select **Absorbing Layer** in the **Selections to subtract** list.
- 13 Click **OK**.
- 14 In the **Settings** window for **Difference**, type Physical Domain in the **Label** text field.



#### *Interface*

- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.
- 3 From the **Geometric entity level** list, choose **Boundary**.
- 4 Select Boundaries 4, 11, and 18 only.
- 5 In the **Label** text field, type Interface.



#### *Outer Boundary*

- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.
- 3 From the **Geometric entity level** list, choose **Boundary**.
- 4 Select Boundaries 1, 3, 5, 7, 14, and 21–24 only.
- 5 In the **Label** text field, type Outer Boundary.
- 6 Click the  **Zoom Extents** button in the **Graphics** toolbar.

#### **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.
- 5 In the **Materials** toolbar, click  **Add Material** to close the **Add Material** window.

#### **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, Time Explicit (pate)**.
- 4 Click the **Add to Component I** button in the window toolbar.
- 5 In the **Home** toolbar, click  **Add Physics** to close the **Add Physics** window.

## PRESSURE ACOUSTICS, TIME EXPLICIT (PATE)

### *Initial Values I*


- 1 In the **Settings** window for **Initial Values**, locate the **Initial Values** section.
- 2 In the  $p$  text field, type  $p_{init}(x, y)$ .

### *Poroacoustics I*

- 1 In the **Physics** toolbar, click  **Domains** and choose **Poroacoustics**.
- 2 In the **Settings** window for **Poroacoustics**, locate the **Domain Selection** section.
- 3 From the **Selection** list, choose **Porous Layer**.
- 4 Locate the **Poroacoustics Model** section. From the **Poroacoustics model** list, choose **User defined**.
- 5 Click to expand the **Isoentropic Compressibility** section. From the **Partial fraction fit** list, choose **From function**.
- 6 From the **Reference** list, choose **Partial Fraction Fit 1 (beta\_porous)**.
- 7 Click  **Import**.
- 8 Click to collapse the **Isoentropic Compressibility** section. Click to expand the **Density** section. From the **Partial fraction fit** list, choose **From function**.
- 9 From the **Reference** list, choose **Partial Fraction Fit 2 (rho\_porous)**.
- 10 Click  **Import**.


Note that the material discontinuity across the interface between the fluid and porous material domains is handled automatically by the **Continuity of Total Fields** feature.

### *Impedance I*

- 1 In the **Physics** toolbar, click  **Boundaries** and choose **Impedance**.
- 2 In the **Settings** window for **Impedance**, locate the **Boundary Selection** section.
- 3 From the **Selection** list, choose **Outer Boundary**.


## DEFINITIONS

### *Absorbing Layer I (abl)*


- 1 In the **Definitions** toolbar, click  **Absorbing Layer**.
- 2 In the **Settings** window for **Absorbing Layer**, locate the **Domain Selection** section.
- 3 From the **Selection** list, choose **Absorbing Layer**.

## MESH 1



### *Mapped 1*

In the **Mesh** toolbar, click  **Mapped**.

### *Size*

- 1 In the **Model Builder** window, click **Size**.
- 2 In the **Settings** window for **Size**, click to expand the **Element Size Parameters** section.
- 3 In the **Maximum element size** text field, type  $343[\text{m/s}] / 4000[\text{Hz}] / 1.5$ .
- 4 Click  **Build All**.

## 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** > **Time Dependent**.
- 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 1 - EXTENDED REACTING


- 1 In the **Settings** window for **Study**, type Study 1 - Extended Reacting in the **Label** text field.  
The plots will be generated manually.
- 2 Locate the **Study Settings** section. Clear the **Generate default plots** checkbox.

### *Step 1: Time Dependent*

- 1 In the **Model Builder** window, under **Study 1 - Extended Reacting** click **Step 1: Time Dependent**.
- 2 In the **Settings** window for **Time Dependent**, locate the **Study Settings** section.
- 3 In the **Output times** text field, type  $\text{range}(0, 1[\text{ms}], 5[\text{ms}]) \text{ range}(5.025[\text{ms}], 0.025[\text{ms}], 10[\text{ms}])$ .

It takes about 5 ms for the signal to reach the receiver. Therefore, use a coarser time resolution before that point in time. This will reduce the file size of the saved model.

### *Parametric Sweep*

- 1 In the **Study** toolbar, click  **Parametric Sweep**.
- 2 In the **Settings** window for **Parametric Sweep**, locate the **Study Settings** section.


3 Click  **Add**.

4 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
w0 (Porous layer width)	5 [cm] 15 [cm]	m

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

## 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 **Recently Used** > **Pressure Acoustics, Time Explicit (pate)**.

4 Click the **Add to Selection** button in the window toolbar.

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

## PRESSURE ACOUSTICS, TIME EXPLICIT 2 (PATE2)

### *Initial Values 1*

1 In the **Settings** window for **Initial Values**, locate the **Initial Values** section.

2 In the *p2* text field, type `p_init(x, y)`.

3 In the **Model Builder** window, click **Pressure Acoustics, Time Explicit 2 (pate2)**.

4 In the **Settings** window for **Pressure Acoustics, Time Explicit**, locate the **Domain Selection** section.

5 From the **Selection** list, choose **Air**.

### *Impedance 1*

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

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

3 From the **Selection** list, choose **Outer Boundary**.


### *Impedance 2 - Local Reacting, 5 cm*

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



2 In the **Settings** window for **Impedance**, type **Impedance 2 - Local Reacting, 5 cm** in the **Label** text field.

3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Interface**.


4 Locate the **Impedance** section. From the **Impedance model** list, choose **General local reacting (rational approximation)**.

- 5 From the **Partial fraction fit** list, choose **From function**.
- 6 From the **Reference** list, choose **Partial Fraction Fit 3 (Y\_5cm)**.
- 7 Click  **Import**.

#### *Impedance 3 - Local Reacting, 15 cm*

- 1 In the **Physics** toolbar, click  **Boundaries** and choose **Impedance**.
- 2 In the **Settings** window for **Impedance**, type Impedance 3 - Local Reacting, 15 cm in the **Label** text field.
- 3 Locate the **Boundary Selection** section. From the **Selection** list, choose **Interface**.
- 4 Locate the **Impedance** section. From the **Impedance model** list, choose **General local reacting (rational approximation)**.
- 5 From the **Partial fraction fit** list, choose **From function**.
- 6 From the **Reference** list, choose **Partial Fraction Fit 4 (Y\_15cm)**.
- 7 Click  **Import**.

#### **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 > Time Dependent**.
- 4 Click the **Add Study** button in the window toolbar.

#### **STUDY 2 - LOCAL REACTING, 5 CM**


- 1 In the **Settings** window for **Study**, type Study 2 - Local Reacting, 5 cm in the **Label** text field.
- 2 Locate the **Study Settings** section. Clear the **Generate default plots** checkbox.

#### *Step 1: Time Dependent*


- 1 In the **Model Builder** window, under **Study 2 - Local Reacting, 5 cm** click **Step 1: Time Dependent**.
- 2 In the **Settings** window for **Time Dependent**, locate the **Study Settings** section.
- 3 In the **Output times** text field, type range(0, 1[ms], 5[ms]) range(5.025[ms], 0.025[ms], 10[ms]).
- 4 Locate the **Physics and Variables Selection** section. Select the **Modify model configuration for study step** checkbox.
- 5 In the tree, select **Component 1 (comp1) > Pressure Acoustics, Time Explicit (pate)**.

- 6 Click  **Disable in Solvers**.
- 7 In the tree, select **Component 1 (comp1) > Pressure Acoustics, Time Explicit 2 (pate2) > Impedance 3 - Local Reacting, 15 cm**.
- 8 Click  **Disable**.
- 9 In the **Study** toolbar, click  **Compute**.

#### ADD STUDY

- 1 Go to the **Add Study** window.
- 2 Find the **Studies** subsection. In the **Select Study** tree, select **General Studies > Time Dependent**.
- 3 Click the **Add Study** button in the window toolbar.
- 4 In the **Study** toolbar, click  **Add Study** to close the **Add Study** window.

#### STUDY 3 - LOCAL REACTING, 15 CM

- 1 In the **Settings** window for **Study**, type **Study 3 - Local Reacting, 15 cm** in the **Label** text field.
- 2 Locate the **Study Settings** section. Clear the **Generate default plots** checkbox.
  - 1 In the **Model Builder** window, under **Study 3 - Local Reacting, 15 cm** click **Step 1: Time Dependent**.
- 2 In the **Settings** window for **Time Dependent**, locate the **Study Settings** section.
- 3 In the **Output times** text field, type **range(0, 1[ms], 5[ms]) range(5.025[ms], 0.025[ms], 10[ms])**.
- 4 Locate the **Physics and Variables Selection** section. In the **Solve for** column of the table, under **Component 1 (comp1)**, clear the checkbox for **Pressure Acoustics, Time Explicit (pate)**.
- 5 In the **Study** toolbar, click  **Compute**.

Before creating plots, process the datasets to only plot the results in the physical domains.


#### RESULTS

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

*Study 1 - Extended Reacting/Parametric Solutions 1 (sol2)*

In the **Model Builder** window, expand the **Results > Datasets** node, then click **Study 1 - Extended Reacting/Parametric Solutions 1 (sol2)**.


### Selection

- 1 In the **Results** toolbar, click  **Attributes** 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 **Physical Domain**.

### Study 2 - Local Reacting, 5 cm/Solution 5 (sol5)

In the **Model Builder** window, under **Results** > **Datasets** click **Study 2 - Local Reacting, 5 cm/Solution 5 (sol5)**.


### Selection

- 1 In the **Results** toolbar, click  **Attributes** 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 **Physical Domain**.


### Study 3 - Local Reacting, 15 cm/Solution 6 (sol6)

In the **Model Builder** window, under **Results** > **Datasets** click **Study 3 - Local Reacting, 15 cm/Solution 6 (sol6)**.



### Selection

- 1 In the **Results** toolbar, click  **Attributes** 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 **Physical Domain**.
- 5 In the **Model Builder** window, collapse the **Results** > **Datasets** node.


### Acoustic Pressure, Extended Reacting (5 cm)

- 1 In the **Results** toolbar, click  **2D Plot Group**.
- 2 In the **Settings** window for **2D Plot Group**, type Acoustic Pressure, Extended Reacting (5 cm) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Study 1 - Extended Reacting/Parametric Solutions 1 (sol2)**.
- 4 From the **Parameter value (w0 (m))** list, choose **0.05**.
- 5 From the **Time (s)** list, choose **0.0055**.
- 6 Locate the **Color Legend** section. Select the **Show units** checkbox.
- 7 Select the **Show maximum and minimum values** checkbox.


### *Surface 1*

- 1 Right-click **Acoustic Pressure, Extended Reacting (5 cm)** and choose **Surface**.
- 2 In the **Settings** window for **Surface**, locate the **Coloring and Style** section.
- 3 From the **Color table** list, choose **Wave**.
- 4 From the **Scale** list, choose **Linear symmetric**.
- 5 In the **Acoustic Pressure, Extended Reacting (5 cm)** toolbar, click  **Plot**.
- 6 Click the  **Zoom Extents** button in the **Graphics** toolbar.


### *Acoustic Pressure, Extended Reacting (15 cm)*

- 1 In the **Model Builder** window, right-click **Acoustic Pressure, Extended Reacting (5 cm)** and choose **Duplicate**.
- 2 In the **Settings** window for **2D Plot Group**, type Acoustic Pressure, Extended Reacting (15 cm) in the **Label** text field.
- 3 Locate the **Data** section. From the **Parameter value (w0 (m))** list, choose **0.15**.
- 4 In the **Acoustic Pressure, Extended Reacting (15 cm)** toolbar, click  **Plot**.


### *Acoustic Pressure, Local Reacting (5 cm)*

- 1 In the **Results** toolbar, click  **2D Plot Group**.
- 2 In the **Settings** window for **2D Plot Group**, type Acoustic Pressure, Local Reacting (5 cm) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Study 2 - Local Reacting, 5 cm/ Solution 5 (sol5)**.
- 4 From the **Time (s)** list, choose **0.0055**.
- 5 Locate the **Color Legend** section. Select the **Show units** checkbox.
- 6 Select the **Show maximum and minimum values** checkbox.

### *Surface 1*


- 1 Right-click **Acoustic Pressure, Local Reacting (5 cm)** and choose **Surface**.
- 2 In the **Settings** window for **Surface**, locate the **Expression** section.
- 3 In the **Expression** text field, type `pat@2.p_t`.
- 4 Locate the **Coloring and Style** section. From the **Color table** list, choose **Wave**.
- 5 From the **Scale** list, choose **Linear symmetric**.
- 6 In the **Acoustic Pressure, Local Reacting (5 cm)** toolbar, click  **Plot**.

*Acoustic Pressure, Local Reacting (15 cm)*

- 1 In the **Model Builder** window, right-click **Acoustic Pressure, Local Reacting (5 cm)** and choose **Duplicate**.
- 2 In the **Settings** window for **2D Plot Group**, type Acoustic Pressure, Local Reacting (15 cm) in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Study 3 - Local Reacting, 15 cm/ Solution 6 (sol6)**.
- 4 In the **Acoustic Pressure, Local Reacting (15 cm)** toolbar, click  **Plot**.

Plot the signal recorded by the receiver starting from 5 ms.

*Signal at Receiver (5 cm)*

- 1 In the **Results** toolbar, click  **ID Plot Group**.
- 2 In the **Settings** window for **ID Plot Group**, locate the **Data** section.
- 3 From the **Dataset** list, choose **None**.
- 4 In the **Label** text field, type Signal at Receiver (5 cm).
- 5 Click to expand the **Title** section. From the **Title type** list, choose **Label**.

*Point Graph 1*

- 1 Right-click **Signal at Receiver (5 cm)** and choose **Point Graph**.
- 2 In the **Settings** window for **Point Graph**, locate the **Data** section.
- 3 From the **Dataset** list, choose **Study 1 - Extended Reacting/Parametric Solutions 1 (sol2)**.
- 4 From the **Parameter selection (w0)** list, choose **First**.
- 5 From the **Time selection** list, choose **Manual**.
- 6 In the **Time indices (1-206)** text field, type range(6, 1, 206).
- 7 Select Point 10 only.
- 8 Locate the **x-Axis Data** section. From the **Axis source data** list, choose **Time**.
- 9 Click to expand the **Legends** section. Select the **Show legends** checkbox.
- 10 From the **Legends** list, choose **Manual**.
- 11 In the table, enter the following settings:

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**Legends**

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Extended Reacting

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### *Point Graph 2*

- 1 In the **Model Builder** window, right-click **Signal at Receiver (5 cm)** and choose **Point Graph**.
- 2 In the **Settings** window for **Point Graph**, locate the **Data** section.
- 3 From the **Dataset** list, choose **Study 2 - Local Reacting, 5 cm/Solution 5 (sol5)**.
- 4 From the **Time selection** list, choose **Manual**.
- 5 In the **Time indices (1-206)** text field, type range(6, 1, 206).
- 6 Select Point 10 only.
- 7 Locate the **y-Axis Data** section. In the **Expression** text field, type `comp1.pate2.p_t`.
- 8 Locate the **Legends** section. Select the **Show legends** checkbox.
- 9 From the **Legends** list, choose **Manual**.
- 10 In the table, enter the following settings:


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#### **Legends**

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Local Reacting

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- 11 In the **Signal at Receiver (5 cm)** toolbar, click  **Plot**.


### *Signal at Receiver (15 cm)*

- 1 Right-click **Signal at Receiver (5 cm)** and choose **Duplicate**.
- 2 In the **Settings** window for **ID Plot Group**, type **Signal at Receiver (15 cm)** in the **Label** text field.

### *Point Graph 1*

- 1 In the **Model Builder** window, expand the **Signal at Receiver (15 cm)** node, then click **Point Graph 1**.
- 2 In the **Settings** window for **Point Graph**, locate the **Data** section.
- 3 From the **Parameter selection (w0)** list, choose **Last**.

### *Point Graph 2*

- 1 In the **Model Builder** window, click **Point Graph 2**.
- 2 In the **Settings** window for **Point Graph**, locate the **Data** section.
- 3 From the **Dataset** list, choose **Study 3 - Local Reacting, 15 cm/Solution 6 (sol6)**.
- 4 In the **Signal at Receiver (15 cm)** toolbar, click  **Plot**.

## *Poroacoustics Data for Fitting*

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In these final steps, set up a small model to generate the frequency domain poroacoustics data used for the fitting. Add a new component with a **Poroacoustics** domain feature in the frequency domain. Run the model with no sources and on a coarse mesh; then use the **Results Templates** to set up evaluation groups for the complex-valued compressibility and density.

### **ADD COMPONENT**



In the **Model Builder** window, right-click the root node and choose **Add Component > 2D**.

### **GEOMETRY 2**

*Rectangle 1 (r1)*


In the **Geometry** toolbar, click  **Rectangle**.

### **ADD PHYSICS**

- 1 In the **Home** toolbar, click  **Windows** and choose **Add Physics**.
- 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 Component 2** button in the window toolbar.
- 5 In the **Home** toolbar, click  **Add Physics** to close the **Add Physics** window.

### **PRESSURE ACOUSTICS, FREQUENCY DOMAIN (ACPR)**

*Poroacoustics 1*


- 1 In the **Physics** toolbar, click  **Domains** and choose **Poroacoustics**.
- 2 Select Domain 1 only.
- 3 In the **Settings** window for **Poroacoustics**, locate the **Poroacoustics Model** section.
- 4 From the **Poroacoustics model** list, choose **Johnson–Champoux–Allard (JCA)**.

### **ADD MATERIAL FROM LIBRARY**

In the **Home** toolbar, click  **Windows** and choose **Add Material from Library**.

### **ADD MATERIAL**

- 1 Go to the **Add Material** window.
- 2 In the tree, select **Built-in > Air**.

- 3 Click the **Add to Component** button in the window toolbar.
- 4 In the **Home** toolbar, click  **Add Material** to close the **Add Material** window.

## MATERIALS

### *Generic Melamine Foam*

- 1 In the **Model Builder** window, under **Component 2 (comp2)** right-click **Materials** and choose **Blank Material**.
- 2 In the **Settings** window for **Material**, type *Generic Melamine Foam* in the **Label** text field.

## PRESSURE ACOUSTICS, FREQUENCY DOMAIN (ACPR)

### *Poroacoustics 1*

- 1 In the **Model Builder** window, under **Component 2 (comp2)** > **Pressure Acoustics**, **Frequency Domain (acpr)** click **Poroacoustics 1**.
- 2 In the **Settings** window for **Poroacoustics**, locate the **Porous Matrix Properties** section.
- 3 From the **Porous elastic material** list, choose **Generic Melamine Foam (mat3)**.

## MATERIALS

### *Generic Melamine Foam (mat3)*

- 1 In the **Model Builder** window, under **Component 2 (comp2)** > **Materials** click **Generic Melamine Foam (mat3)**.
- 2 In the **Settings** window for **Material**, locate the **Material Contents** section.
- 3 In the table, enter the following settings:

Property	Variable	Value	Unit	Property group
Porosity	epsilon	0.99	l	Basic
Viscous characteristic length	Lv_iso ; Lvii = Lv_iso, Lvij = 0	130 [um]	m	Poroacoustics model
Thermal characteristic length	Lth	160 [um]	m	Poroacoustics model

Property	Variable	Value	Unit	Property group
Tortuosity factor	tau_iso ; tau_ii = tau_iso, tau_ij = 0	1		Poroacoustics model
Flow resistivity	Rf_iso ; Rf_ii = Rf_iso, Rf_ij = 0	4500 [N*s / m^4]	Pa·s/m <sup>2</sup>	Poroacoustics model

## MESH 2



### Free Triangular 1

In the **Mesh** toolbar, click  **Free Triangular**.

#### Size

- 1 In the **Model Builder** window, click **Size**.
- 2 In the **Settings** window for **Size**, locate the **Element Size** section.
- 3 From the **Predefined** list, choose **Extremely coarse**.

## ADD STUDY



- 1 In the **Home** toolbar, click  **Windows** and choose **Add Study**.
- 2 Go to the **Add Study** window.
- 3 Find the **Physics interfaces in study** subsection. In the table, clear the **Solve** checkboxes for **Pressure Acoustics**, **Time Explicit (pate)** and **Pressure Acoustics, Time Explicit 2 (pate2)**.
- 4 Find the **Studies** subsection. In the **Select Study** tree, select **General Studies > Frequency Domain**.
- 5 Click the **Add Study** button in the window toolbar.
- 6 In the **Home** toolbar, click  **Add Study** to close the **Add Study** window.

## STUDY 4 - POROACOUSTICS DATA FOR FITTING

- 1 In the **Settings** window for **Study**, type Study 4 - Poroacoustics Data for Fitting 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 4 - Poroacoustics Data for Fitting** 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 50.
- 6 In the **Stop frequency** text field, type 5000.
- 7 From the **Interval** list, choose **1/6 octave**.
- 8 Click **Replace**.
- 9 In the **Study** toolbar, click  **Compute**.

### RESULT TEMPLATES

In the **Home** toolbar, click  **Windows** and choose **Result Templates**.

### RESULT TEMPLATES

- 1 In the **Home** toolbar, click  **Windows** and choose **Result Templates**.
- 2 Go to the **Result Templates** window.
- 3 In the tree, select **Study 4 - Poroacoustics Data for Fitting/Solution 7 (6) (sol7) > Pressure Acoustics, Frequency Domain > Poroacoustics Compressibility (acpr)**.
- 4 Click the **Add Result Template** button in the window toolbar.
- 5 In the tree, select **Study 4 - Poroacoustics Data for Fitting/Solution 7 (6) (sol7) > Pressure Acoustics, Frequency Domain > Poroacoustics Density (acpr)**.
- 6 Click the **Add Result Template** button in the window toolbar.
- 7 In the **Results** toolbar, click  **Result Templates** to close the **Result Templates** window.

Two evaluation groups have been generated with the necessary data to perform a **Partial Fraction Fit** for the computed frequency range. The data can be exported to a .txt file by selecting the **Export** action on the table. In this model, the data is imported to the **Partial Fraction Fit** from a file. It is also possible to directly point to the computed data by selecting the **Data source** to be a **Results table**.