Acoustics of a Living Room

COMSOL

Introduction

- The sound we experience from our stereo or home theater systems in our living rooms is influenced not only by the quality of the loudspeakers, but also by factors such as the shape of the room and the type and placement of the furniture
- Reflections from walls and windows can both enhance and distort the sound that reaches our ears, and the low bass notes from the speaker woofer units can shake the windows and make the floor vibrate
- This happens only for certain frequencies — the eigenfrequencies of the room. The simulation set up in this tutorial solves for the eigenfrequencies of a living room in the low-frequency range and analyzes the acoustic field in the room when the sound sources are the woofer units
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Introduction

- The analysis is useful, for example, when optimizing for loudspeaker locations inside a living room

Model Definition

Geometry

- The geometry for the living room used in this analysis is synchronized from Revit® through the LiveLink interface
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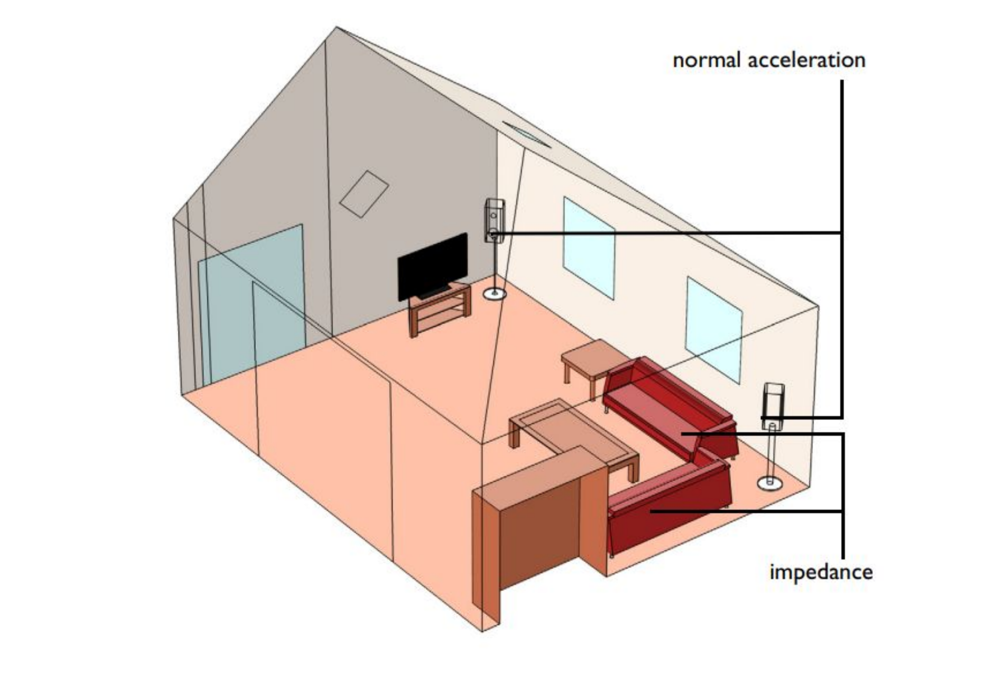
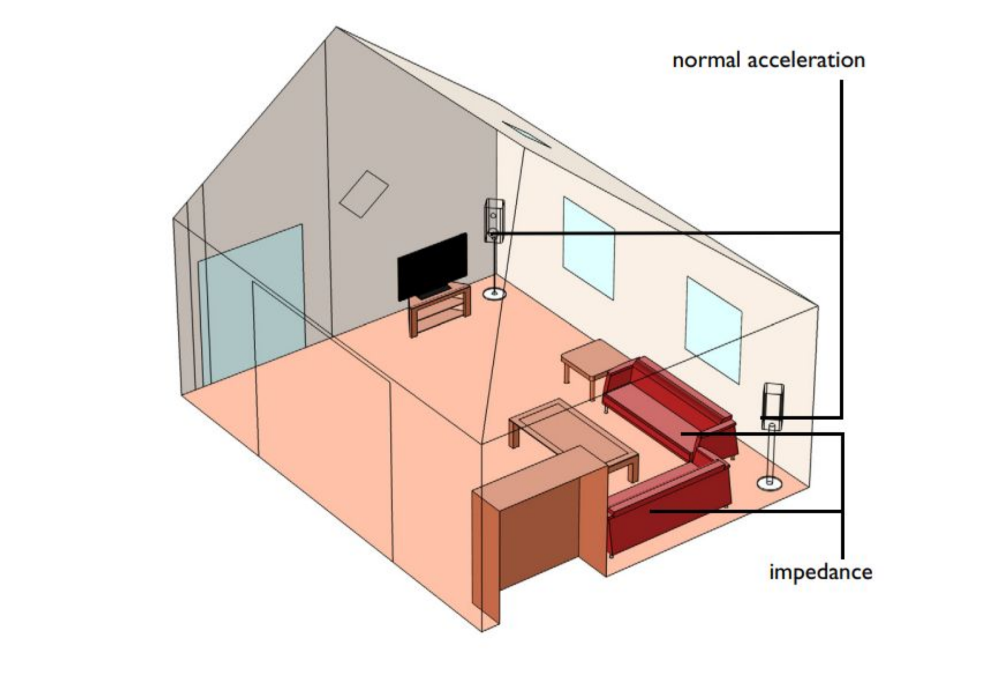


The room geometry and boundary conditions

Model Definition

- The room is equipped with a flat-screen TV, a TV stand, a sideboard, a table, two speakers, a bookcase, and two couches
- The Revit project file has been saved with the synchronization settings that generate and transfer the volume of the living room, the walls as solid objects, and the furniture



The room geometry and boundary conditions

Model Definition

Geometry

- The analysis does not require a fully detailed geometry for the furniture in the room
- The bookcase is synchronized as a bounding box, the other furniture items include the original detail level
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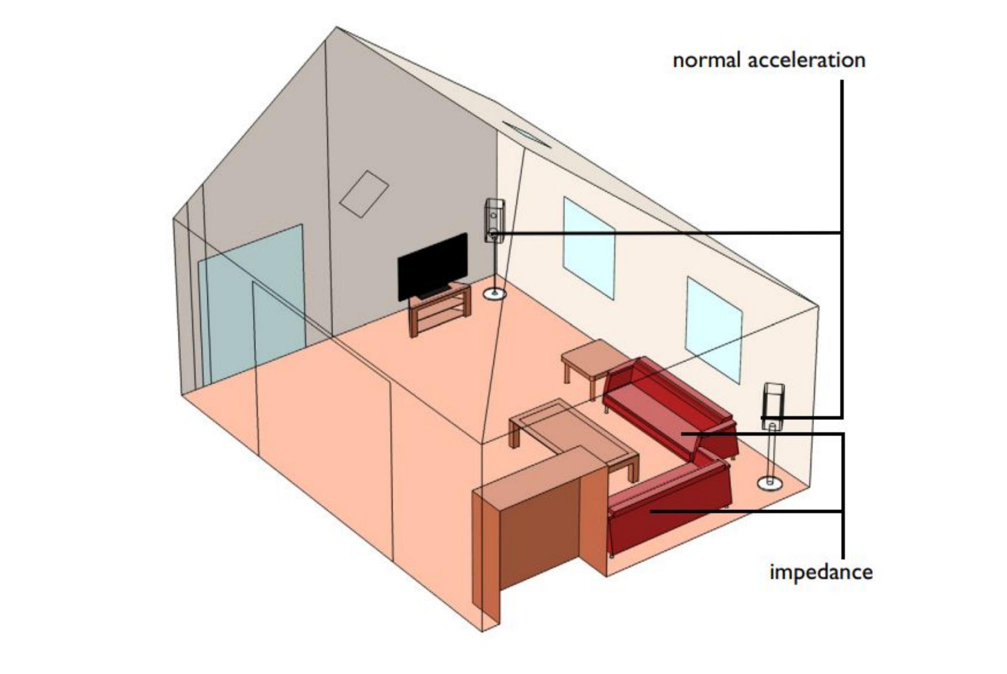
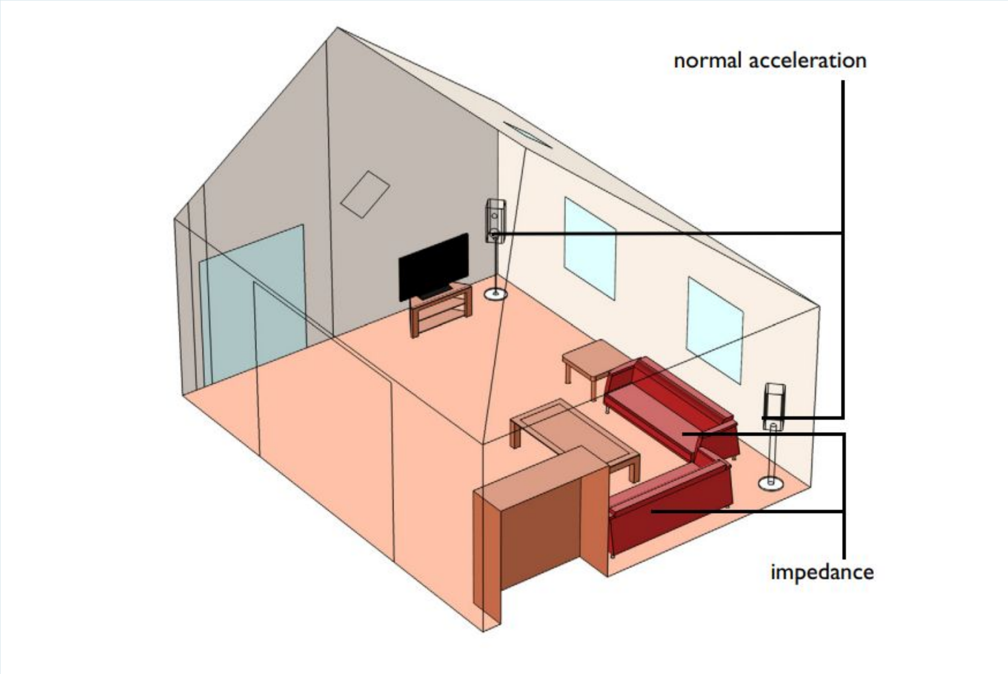


The room geometry and boundary conditions

Model Definition

- Further simplifications are made to the synchronized furniture objects inside COMSOL Multiphysics
- Selections used for model settings are generated for all geometric objects during synchronization



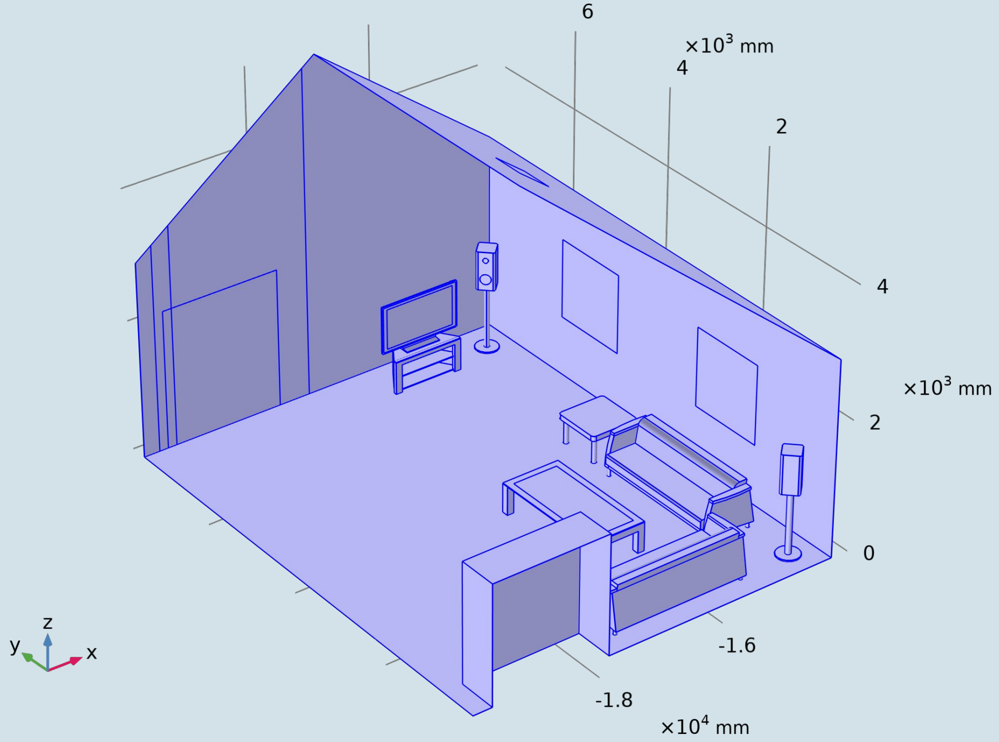
The room geometry and boundary conditions

Model Definition

$$\nabla \cdot \left(-\frac{1}{\rho_c} (\nabla p_t - \mathbf{q}_d) \right) - \frac{k_{eq}^2 p_t}{\rho_c} = Q_m$$

$$p_t = p + p_b$$

$$k_{eq}^2 = \left(\frac{\omega}{c_c} \right)^2$$



Pressure Acoustics, Frequency Domain

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Results

- The eigenmodes show the pressure distribution at the resonance frequencies
- Specifically, they allow us to identify where there will be no sound (at the nodes) and where the sound will be amplified (at the antinodes)
- The absolute values in an eigenfrequency study do not have any physical meaning
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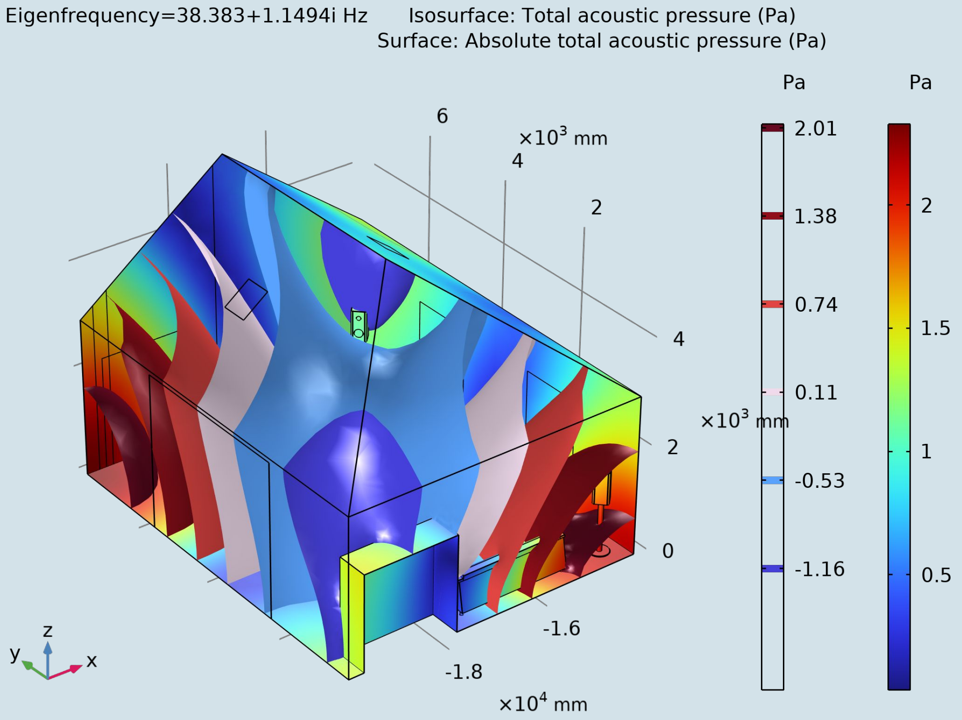
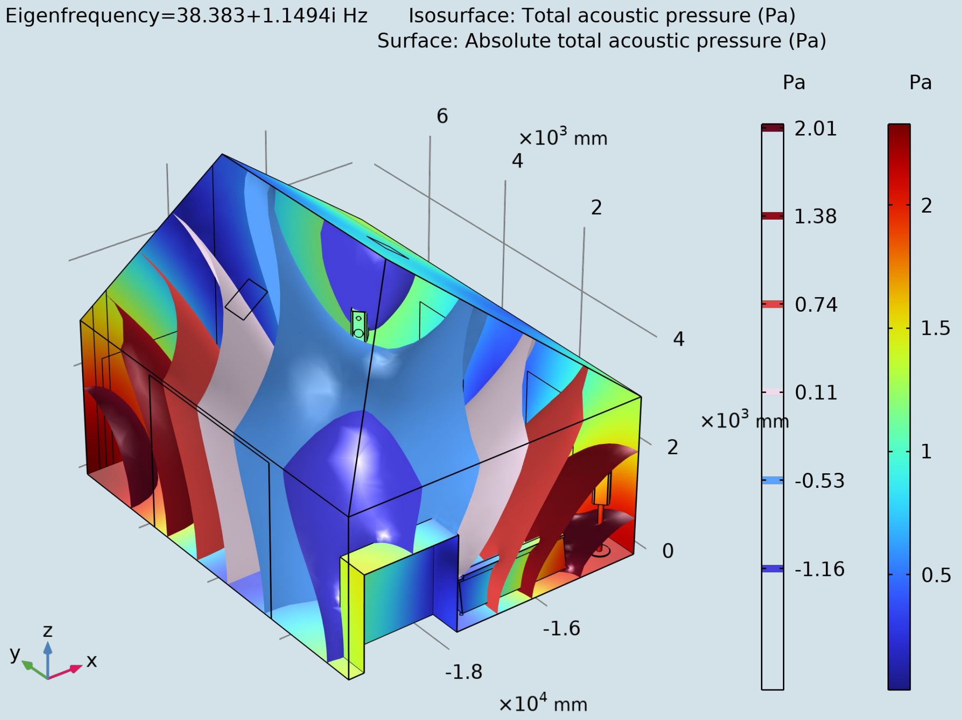


The sound pressure distribution for an eigenfrequency of 38.4 Hz. The real part of the pressure is visualized as an isosurface plot, and the absolute value of the pressure as a boundary plot

Results

- The real part of the complex-valued eigenfrequency represents the frequency at which the system is resonant



The sound pressure distribution for an eigenfrequency of 38.4 Hz. The real part of the pressure is visualized as an isosurface plot, and the absolute value of the pressure as a boundary plot

Results

- The imaginary part is related to the losses at the eigenfrequency and thus the Q-factor of the resonance
- All modes have local maxima in the corners of an empty room so speakers in the corners excite all eigenfrequencies
- This simulation predicts eigenmodes that resemble those of the corresponding empty room
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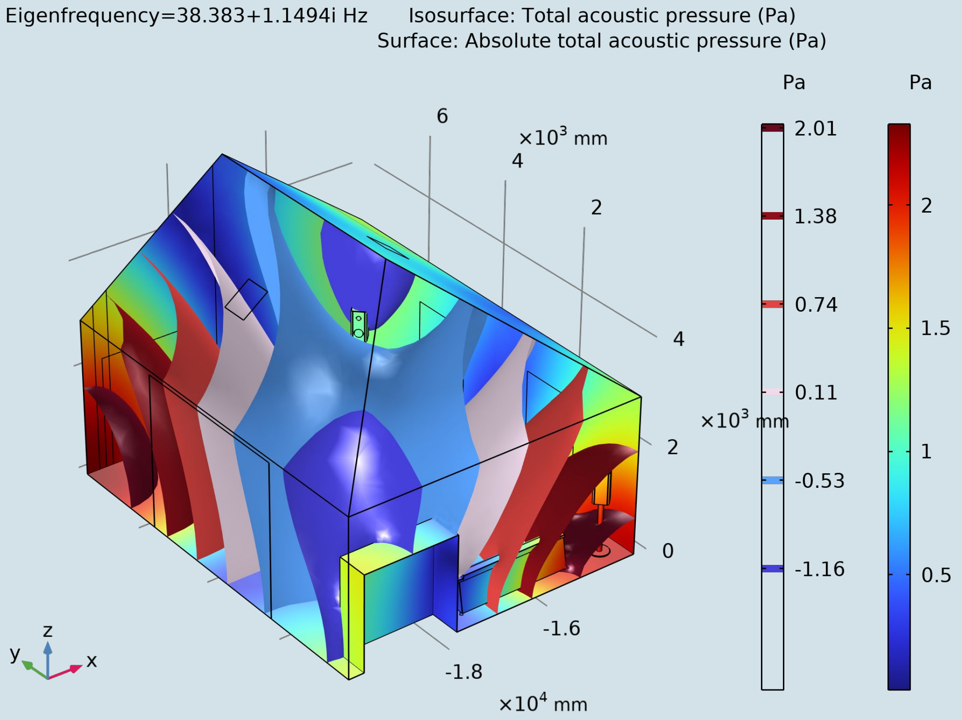

The sound pressure distribution for an eigenfrequency of 38.4 Hz. The real part of the pressure is visualized as an isosurface plot, and the absolute value of the pressure as a boundary plot

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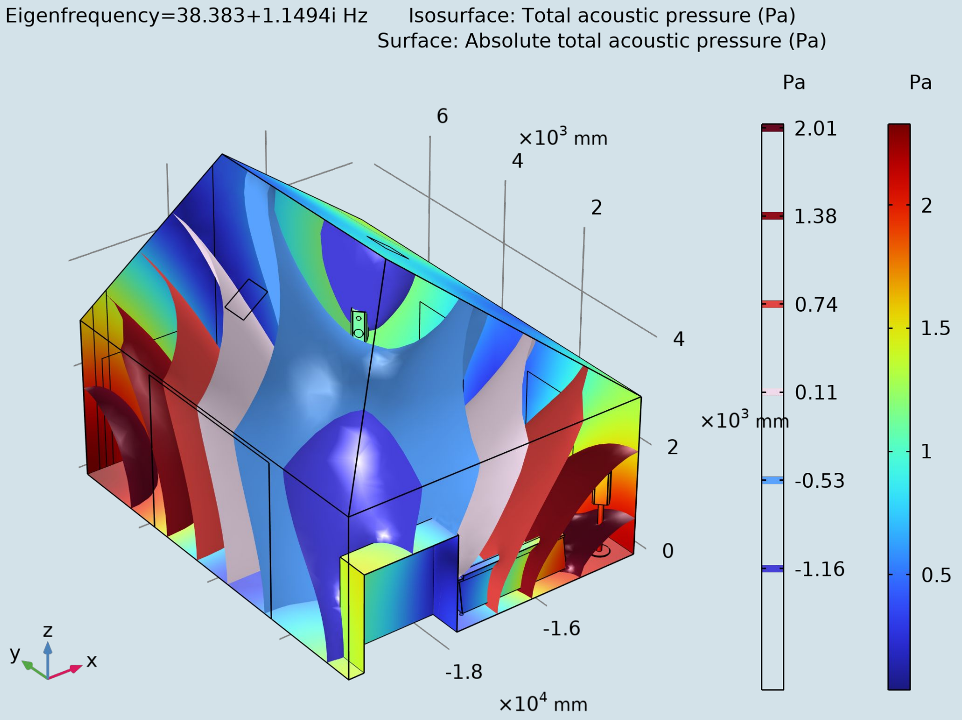
Results

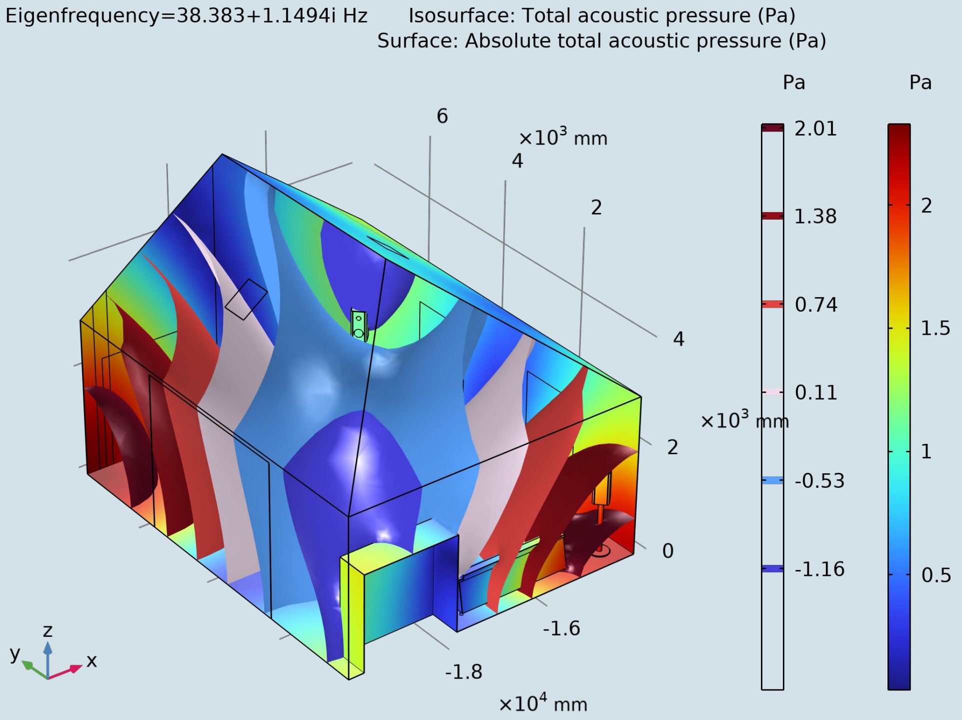
- The higher the frequency, the more the placing of the furniture matters



The sound pressure distribution for an eigenfrequency of 38.4 Hz. The real part of the pressure is visualized as an isosurface plot, and the absolute value of the pressure as a boundary plot

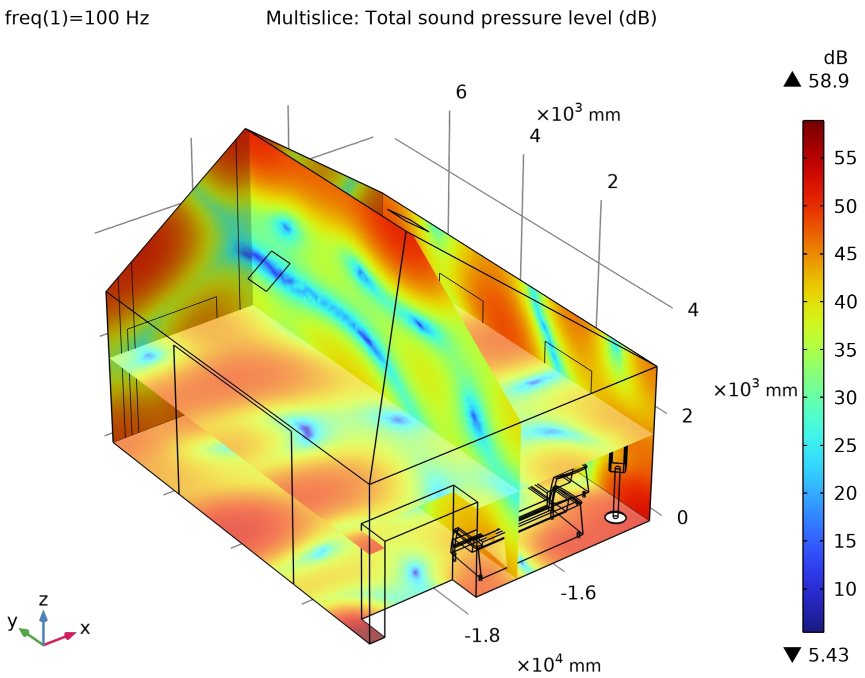
Results

- The prediction that speakers placed in the corners of the room excite many eigenmodes and give a fuller and more neutral sound, however, holds for real-life rooms



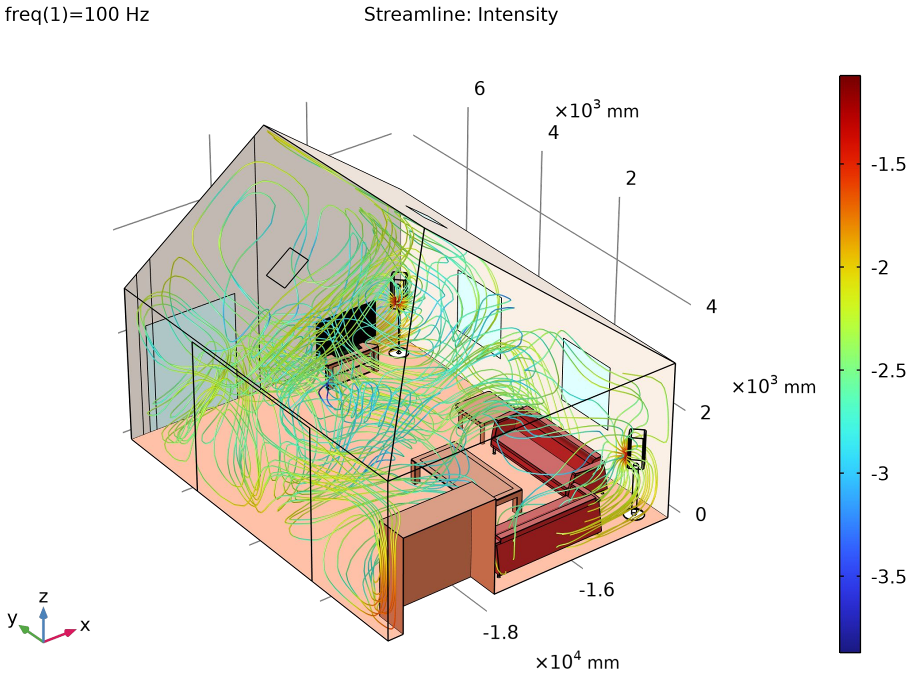
The sound pressure distribution for an eigenfrequency of 38.4 Hz. The real part of the pressure is visualized as an isosurface plot, and the absolute value of the pressure as a boundary plot

Results



The sound pressure level produced from the speaker for a frequency of 100 Hz

Results



Streamline plot that visualizes the energy flow from the sound sources at 100 Hz