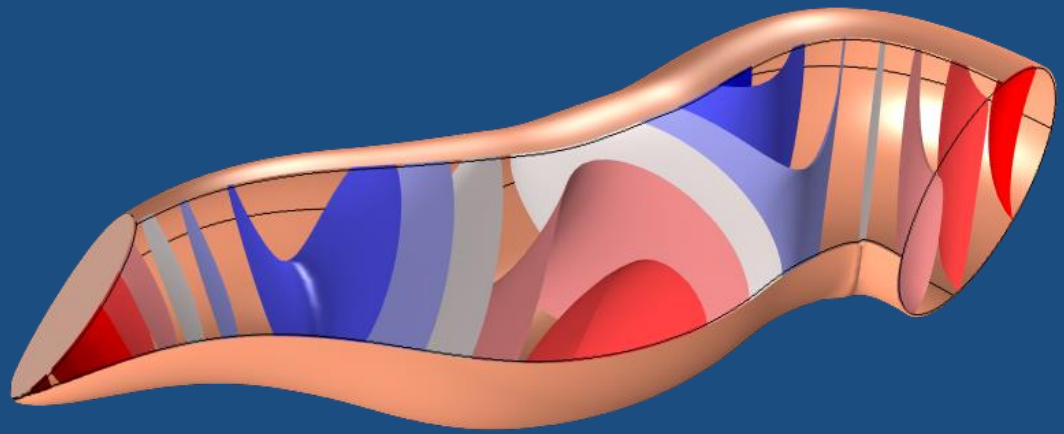
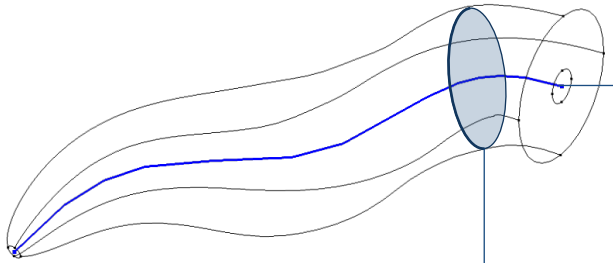


Tutorial:
Ear Canal Acoustics

Background and Motivation

- In this tutorial, the acoustics of the human ear canal are investigated. The output includes the input impedance and the transfer impedance, as well as the level transformation from the entrance to the eardrum.
- The geometry of the ear canal used is based on measurements from test subjects reported in literature. The eardrum is modeled using the built-in physiological model for the human eardrum and the impedance of the ear canal boundaries is modeled using the Skin impedance model. To include the thermoviscous boundary layer losses, the Thermoviscous Boundary Layer Impedance feature is used.

Geometry and Operating Conditions

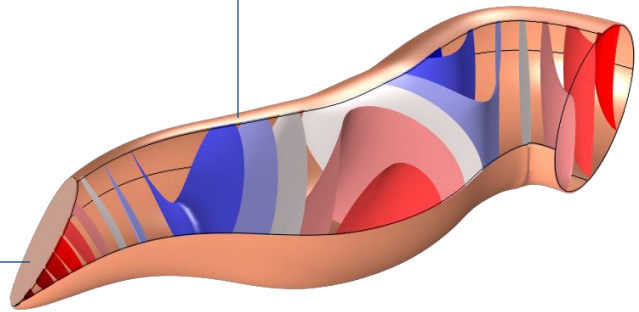


Ear canal center line curve: g(s)

Ear canal area function: A(s)

Skin impedance and BLI impedance

Eardrum impedance

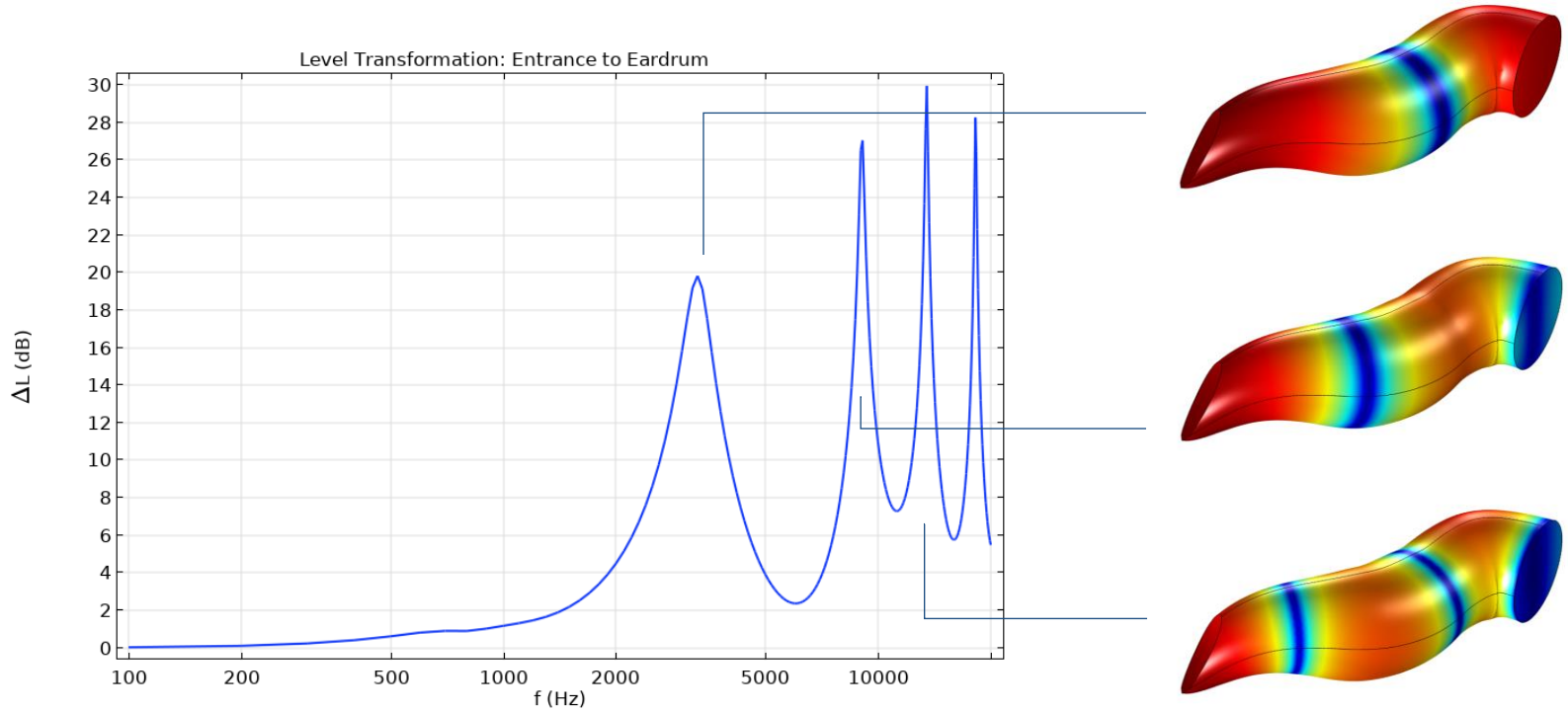


Reference: M. R. Stinson and B. W. Lawton, "Specification of the geometry of the human ear canal for the prediction of sound-pressure level distribution," J. Acoust. Soc. Am. 85, 2492-2503 (1989).

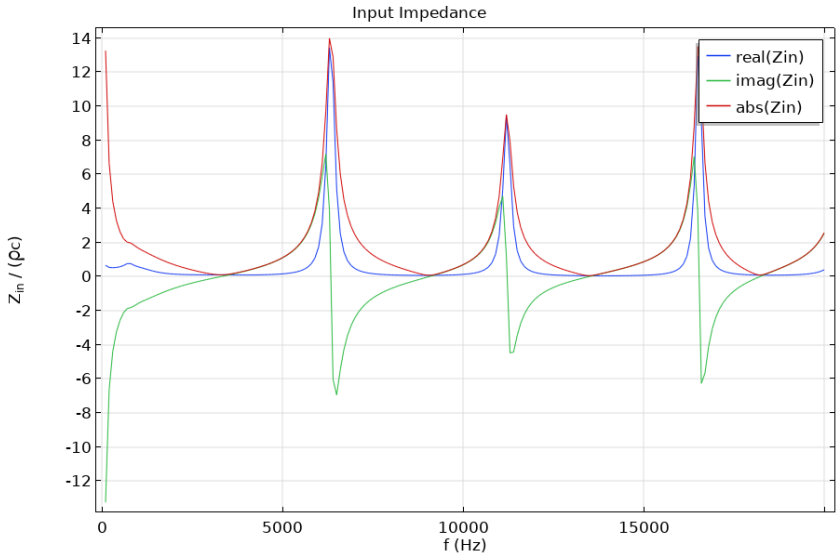
Thermoviscous Boundary Layer Impedance

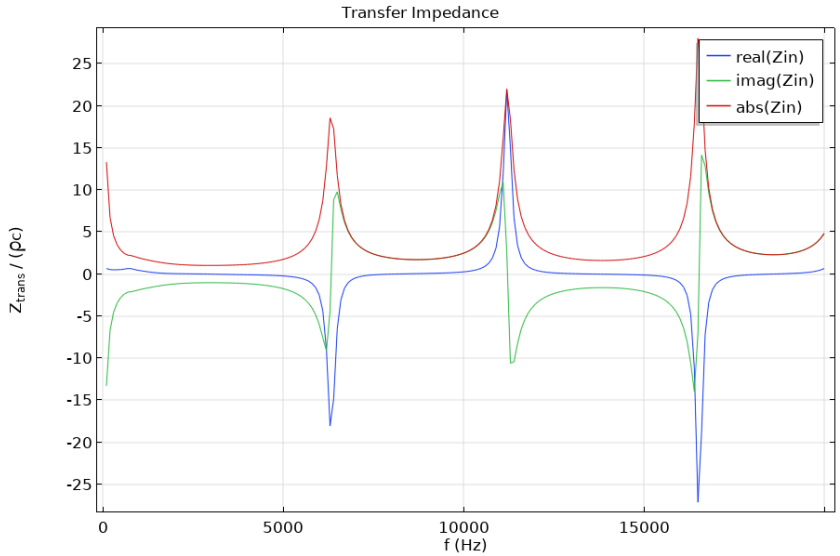
- The ear canal in this model has a radius of 4 mm at the entrance and narrows down toward the eardrum. The dimensions indicate that some losses due to the thermal and viscous boundary layers exist. The boundary layer thickness is about 0.22 mm at 100 Hz and decreases with increasing frequency. This indicated that the layers are not overlapping and the so-called boundary layer impedance (BLI) model can be used to model these losses.
- The Thermoviscous Boundary Layer Impedance feature represents a way to handle the thermoviscous losses using an impedance-like boundary condition. The formulation is only valid for non-overlapping boundary layers (it is not valid in very narrow regions) and only valid for geometries with radii of curvature much larger than the boundary layer length scale.
- The formulation is discussed in two recent papers:
  - M. Berggren, A. Bernland, and D. Noreland, "Acoustic boundary layers as boundary condition," JCP 371, 633-650 (2018).
  - J. S. Bach and H. Bruus, "Theory for acoustics with viscous boundary layers and streaming in curved elastic cavities," JASA 144, 766-784 (2018).

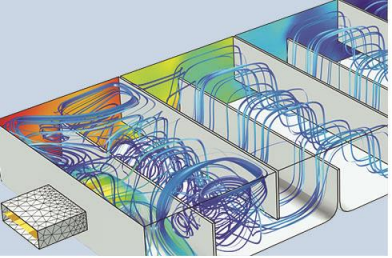
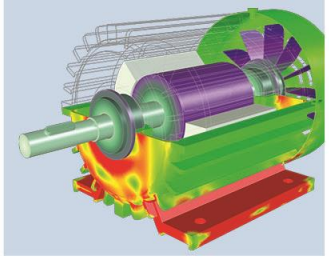
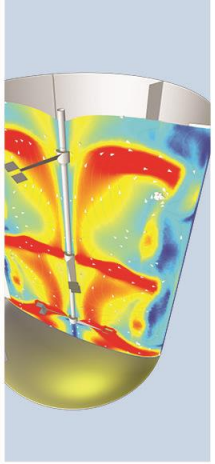
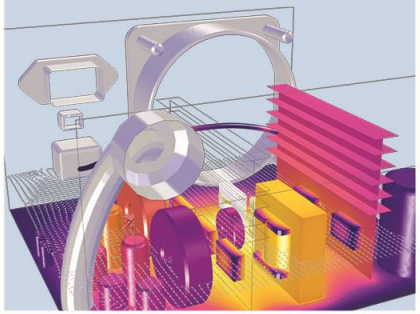
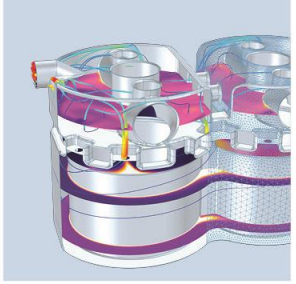
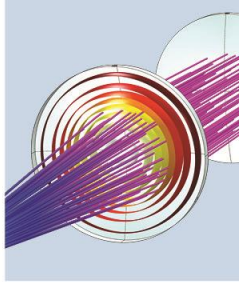
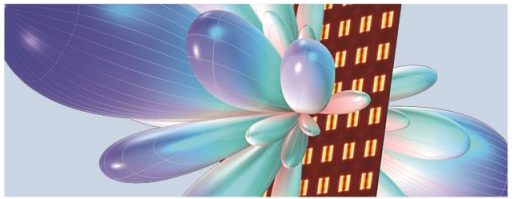
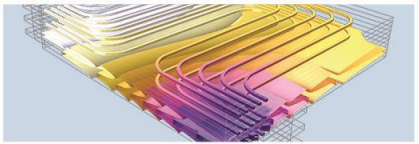
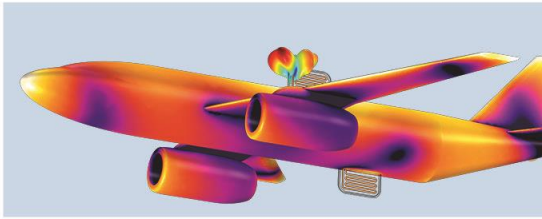
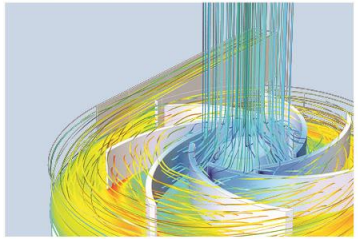
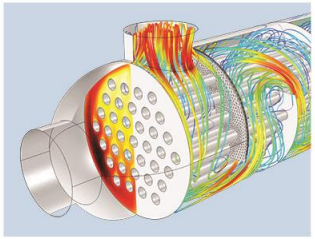
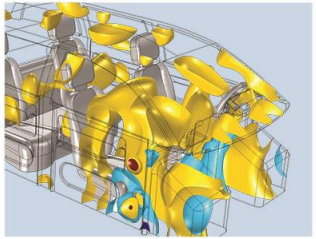
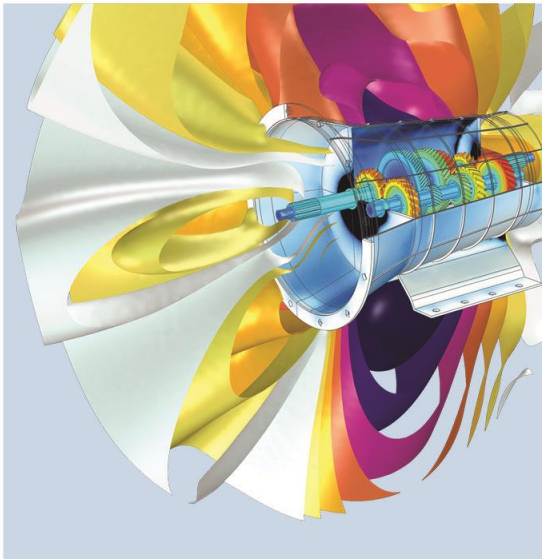
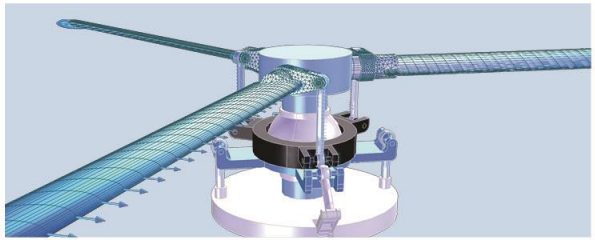
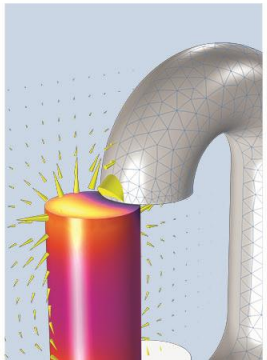
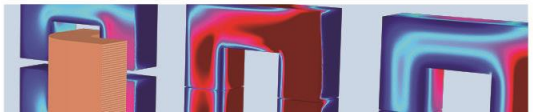
Results: Level Transform



Results: Impedances





Contact Us

info@comsol.com