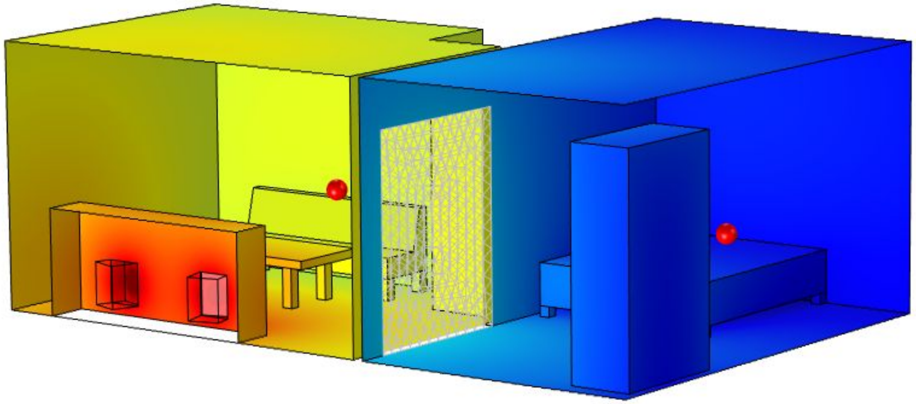
Apartment Acoustics Analyzed using the Acoustic Diffusion Equation

#24311

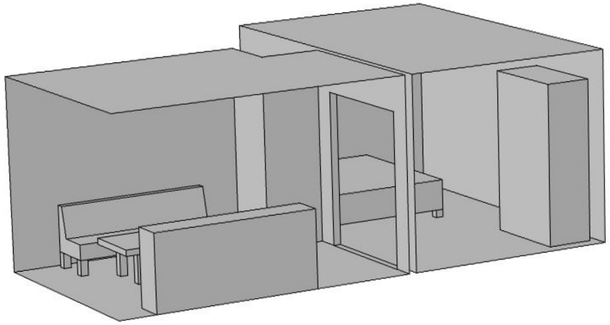
Overview

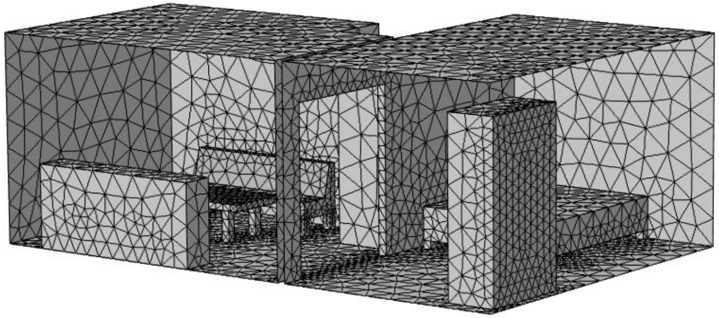
- The steady state sound pressure level distribution from a TV in a two-room apartment is computed
- The simulation uses the Acoustic Diffusion Equation interface
- An approximate expression for the direct sound is added in the living room



Geometry and Mesh

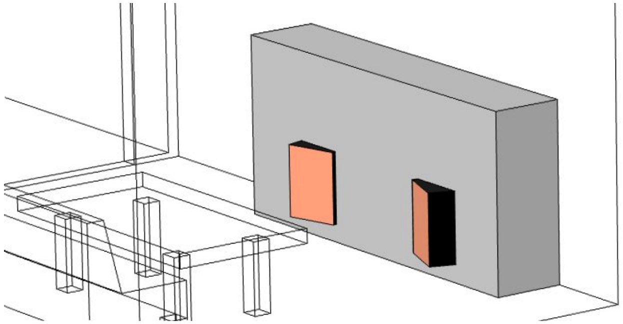
- The geometry consists of a living room, a bedroom, and some rudimentary furniture
- The acoustic diffusion equation does not have any strong demands on the mesh





Physics

- The simulation is driven by an energy flux assigned to the speaker fronts



- Both rooms have their diffusion coefficient calculated using the cubic room mean free path model:

$$D = \frac{4cV}{3S}$$

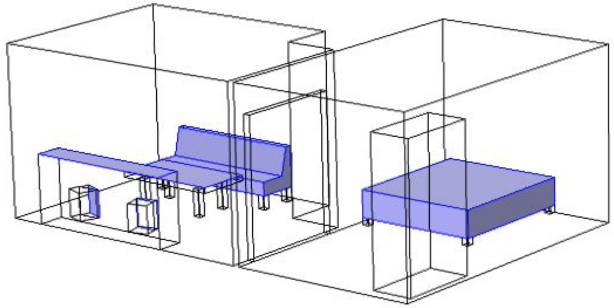
c = speed of sound
V = room volume
S = area of walls, floor, ceiling

- Between the rooms, a room coupling condition applies a 10 dB transmission loss (TL) representing a door

COMSOL

Physics, cont.

- The simulation is solved for a flat band, i.e. with absorption coefficients considered independent of the frequency
- An absorption coefficient of 0.7 is applied to the soft surfaces and an absorption coefficient of 0.25 to the hard surfaces. Especially the latter is a little higher than typical, to compensate for the lack of carpets, curtains, etc.



Soft surfaces

- For more realistic results, it is recommended that you modify the application to include different absorption coefficients for different materials and in different frequency bands

Physics, cont.

- The acoustic diffusion equation does not include direct sound
- Assuming that the speakers send out sound isotropically in a half-space, most of the living room is expected to experience a direct sound intensity from each speaker approximated by the expression

$$I_n = \frac{P_n}{2\pi {r_n}^2}$$

corresponding to a squared pressure amplitude

$$|p_n|^2 = 2Z_0 I_n$$

- The total sound pressure level then becomes

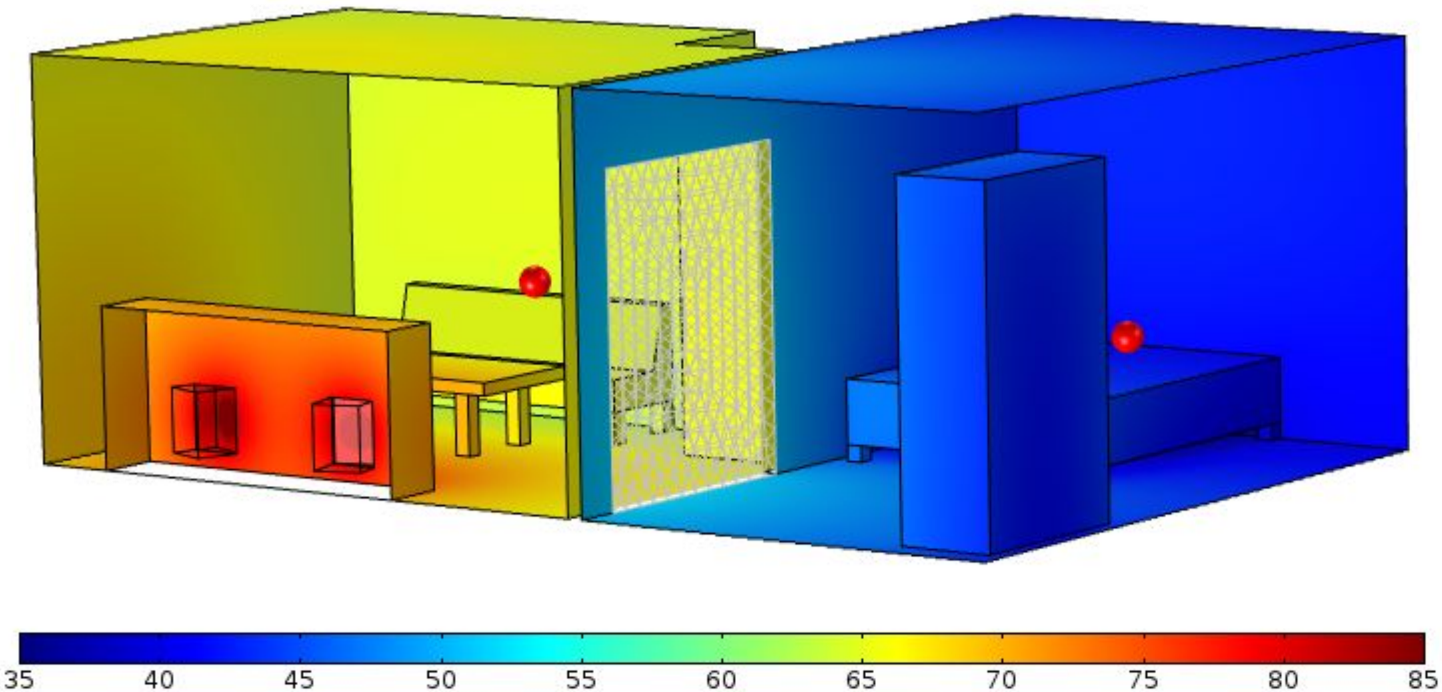
P_n = Power from speaker n
r_n = distance to center of speaker n
Z_0 = characteristic air impedance
p_d = diffuse pressure

$$\begin{cases} 10\log_{10}\left(\left(|p_d|^2 + |p_1|^2 + |p_2|^2\right)/\left|p_{ref}\right|^2\right) & \text{in the living room} \\ 10\log_{10}\left(|p_d|^2/\left|p_{ref}\right|^2\right) & \text{in the bedroom} \end{cases}$$

See also reference: A. Billon, J. Picaut, V. Valeau, and A. Sakout, “Acoustic Predictions in Industrial Spaces Using a Diffusion Model”, Advances in Acoustics and Vibration, Volume 2012 (2012).

Results

- 23 dB drop between the red dots (listening and sleeping positions)



Sound pressure level (dB)

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Results, cont.

- The Schroeder frequencies for the bedroom and living room evaluate to 183 Hz and 167 Hz respectively. The acoustic diffusion equation is a better approximation the higher the frequency, and should not be used below the Schroeder frequency.
- Adding the direct sound has increased the sound pressure level in the listening position above the couch by 1.8 dB.