A Boundary Element model to calculate HRTFs. Comparison between calculated and measured data

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Overview

1. Model
   - How do we get our data
2. Results
   - Measurement-Calculation
   - Temperature
   - Mesh-Perturbation

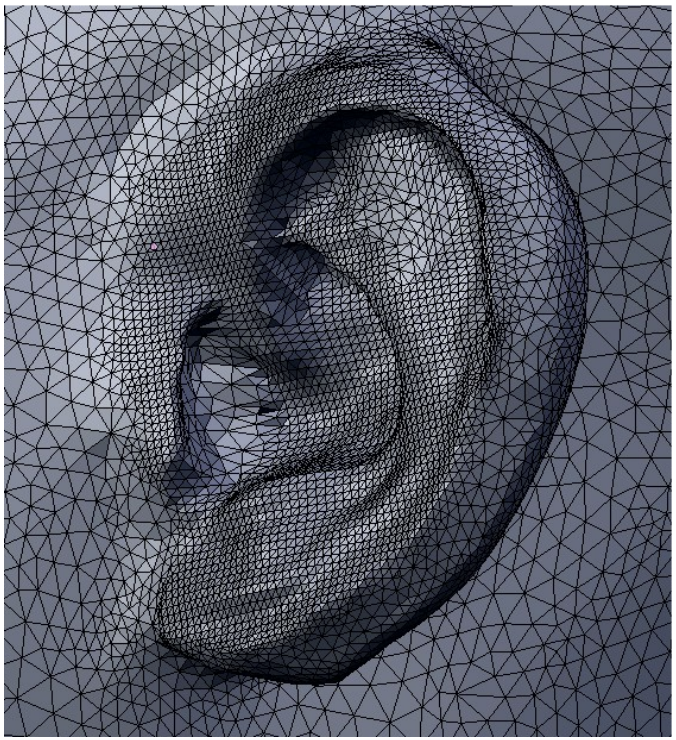
Measurement of HRTFs

- Anechoic chamber
- Rather long and complicated

Numerical Model

- 3D-Scan of a head
- Discretization with triangular elements
- Calculation using the boundary element method

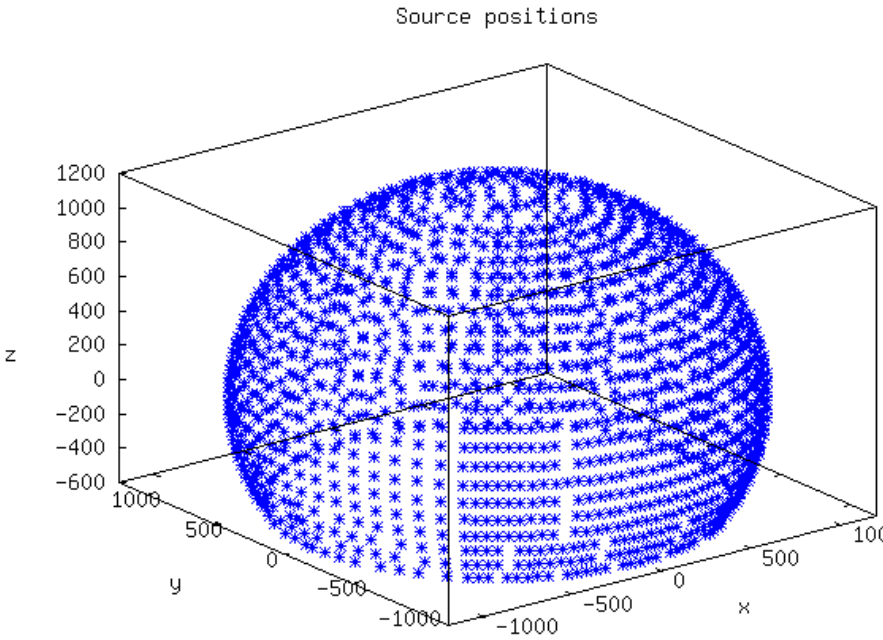
BEM-mesh



- Frequencies up to 20000 Hz $\rightarrow$ fine grid
- 8 elements per wavelength
- About 37.000 nodes and 70.000 elements
- Collocation BEM with constant elements
- Calculation with Fast Multipole Method

Set-up

- 1550 nodes around the head as source
  - Elevation from $-30°$ to $80°$
  - Distance to head = 1.2 m
- One element near the ear canal as receiver
- Different setups
  - Additional shoulder mesh
  - Different levels of smoothness/mesh-size
  - Different temperatures



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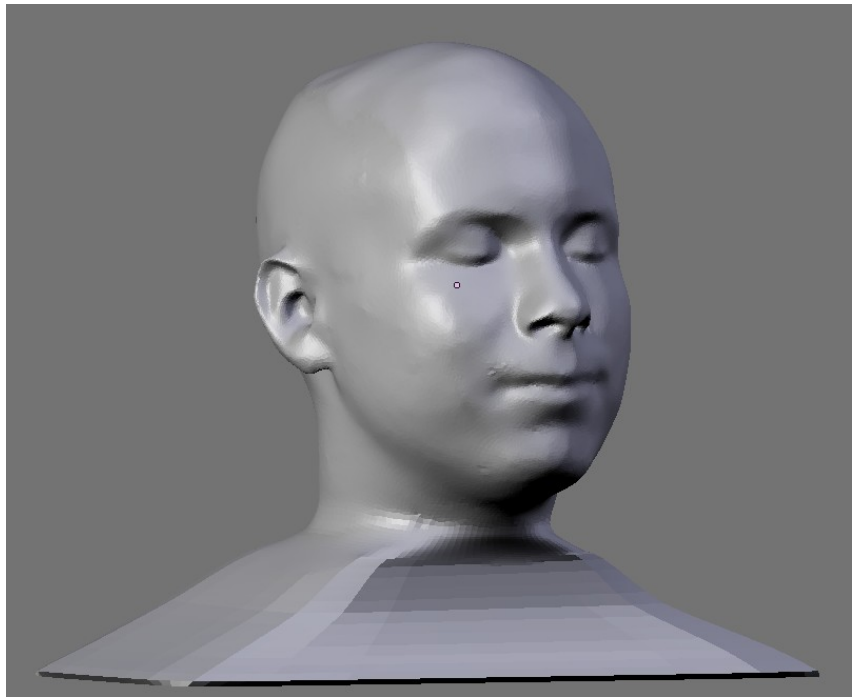

A first look

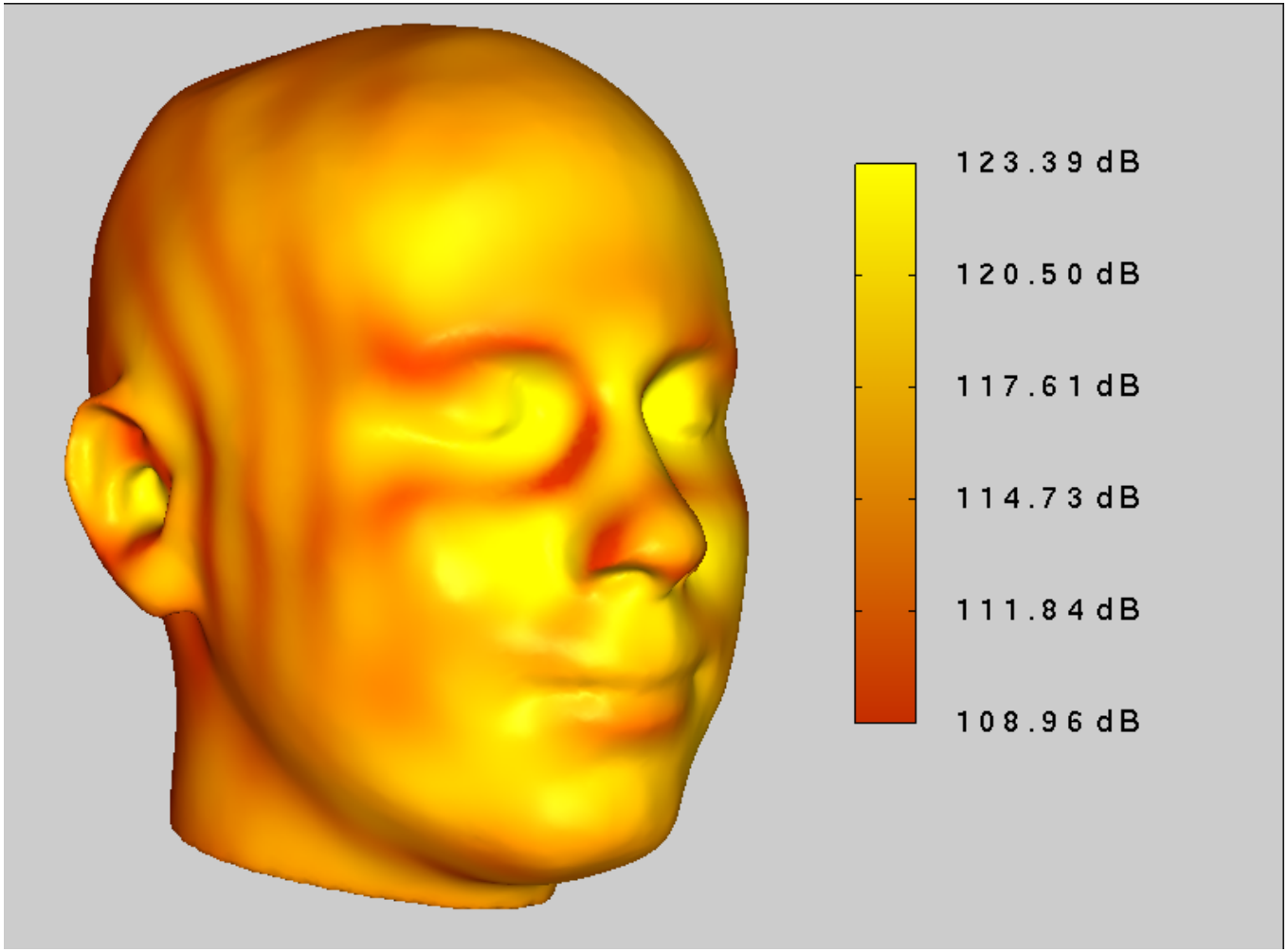

Figure: Sound source in front of the head. Frequency = 8kHz

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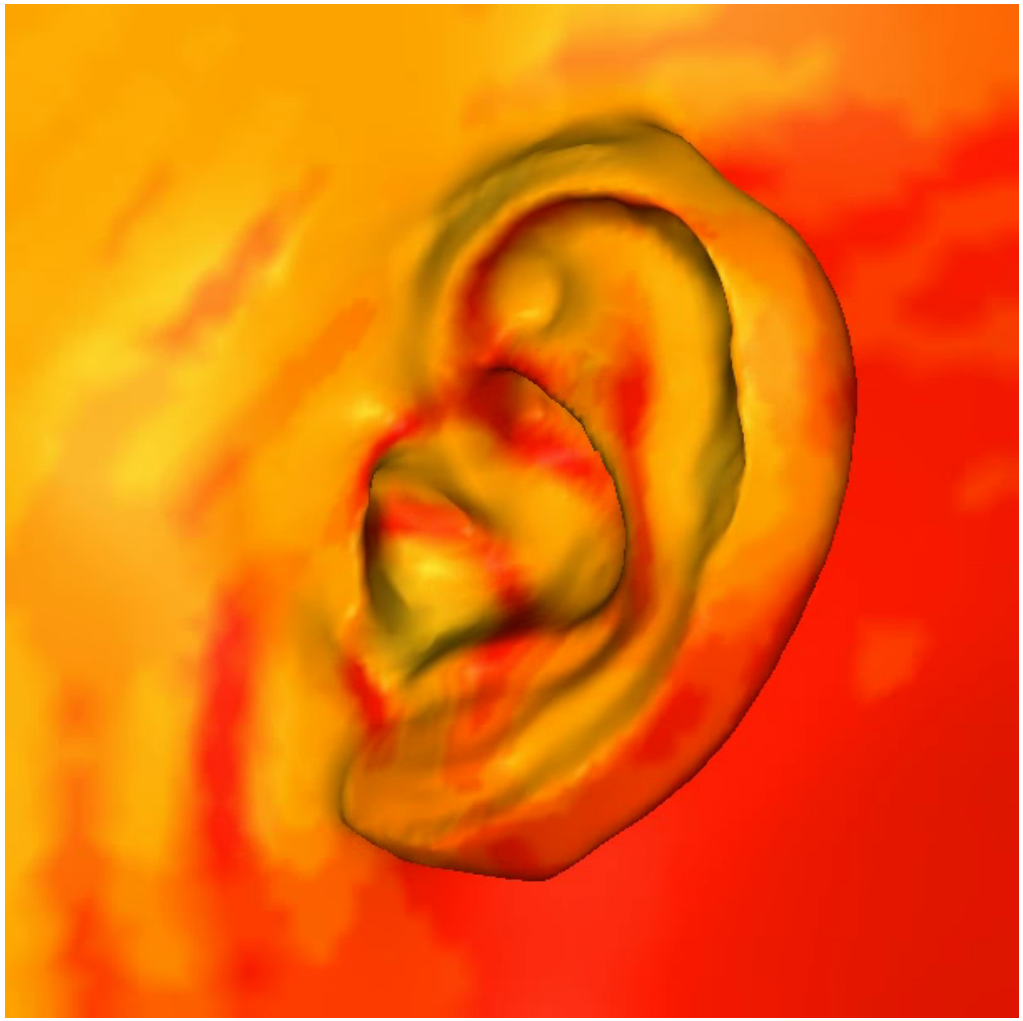
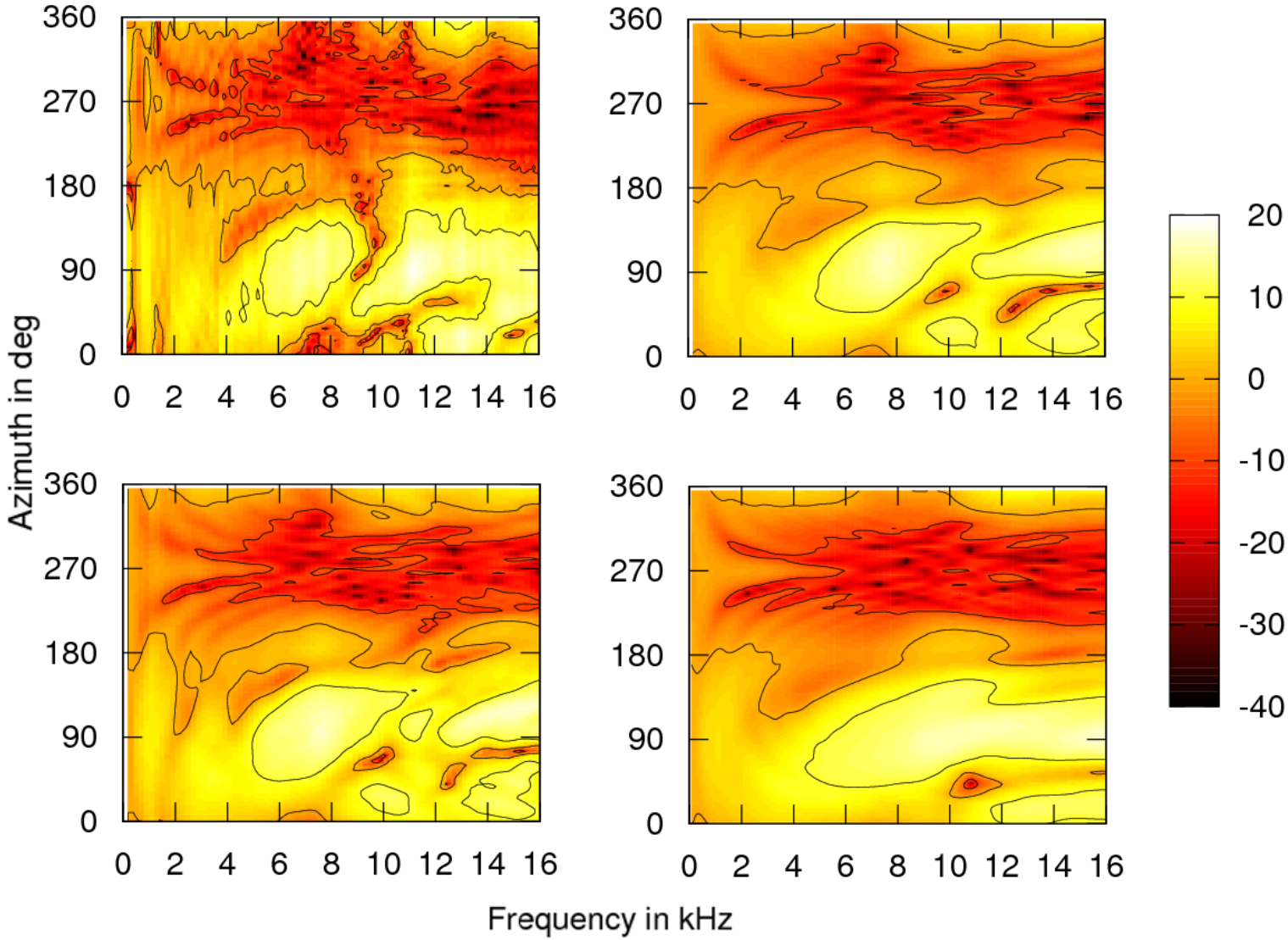


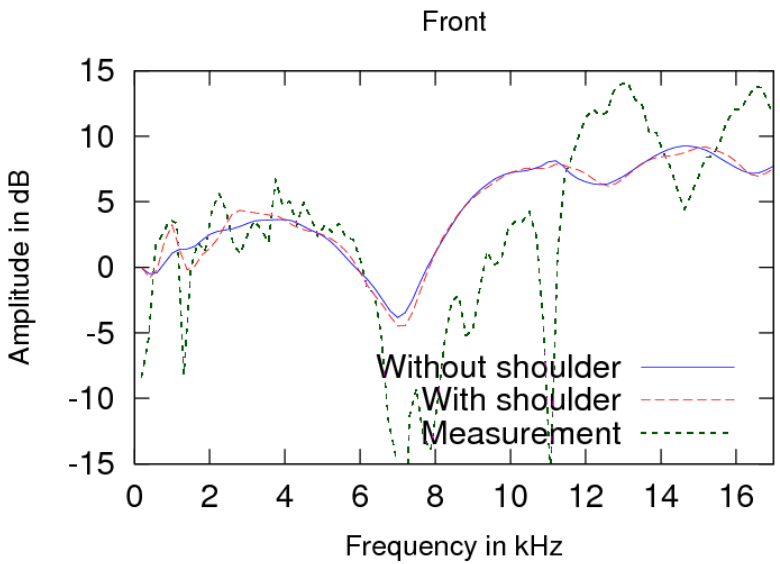
Start

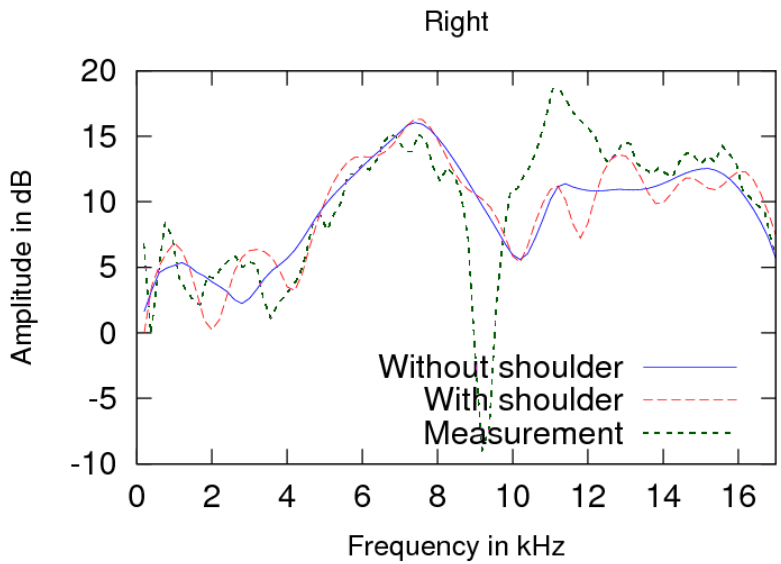
Comparison Measurement Calculation

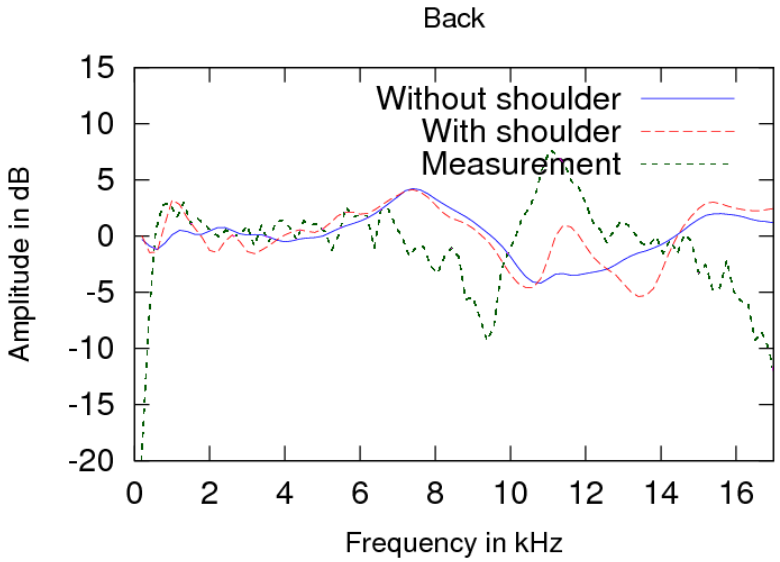
Horizontal Plane

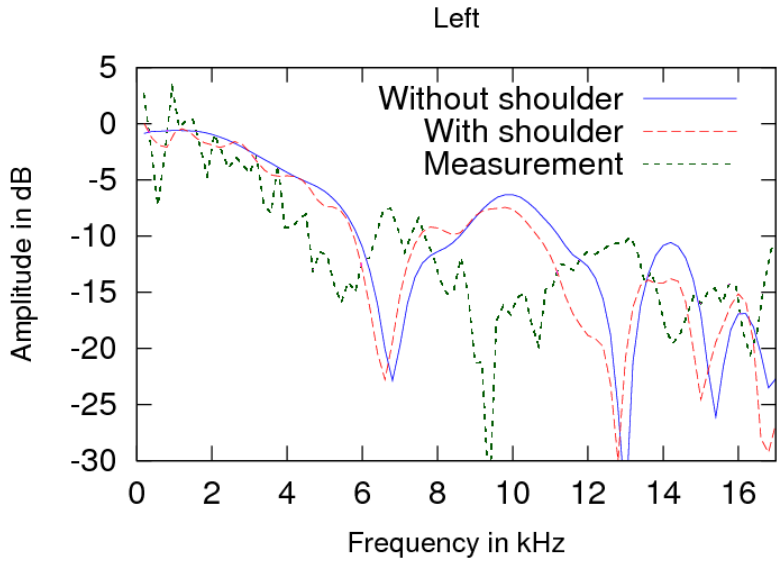


Horizontal Plane

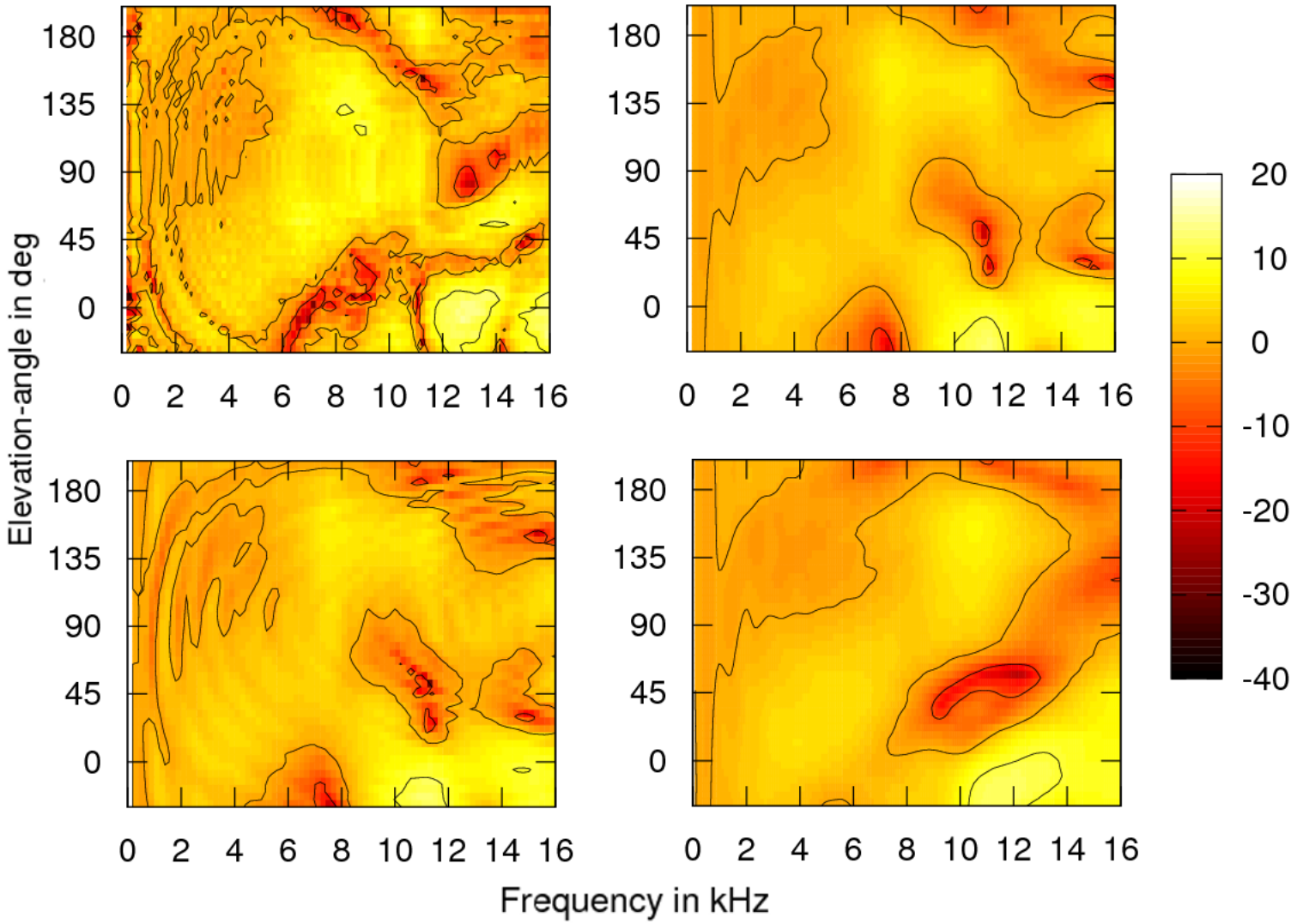




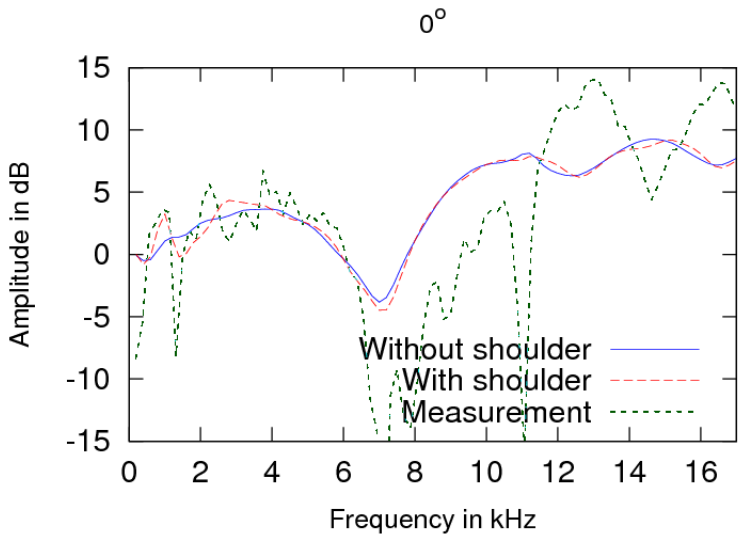


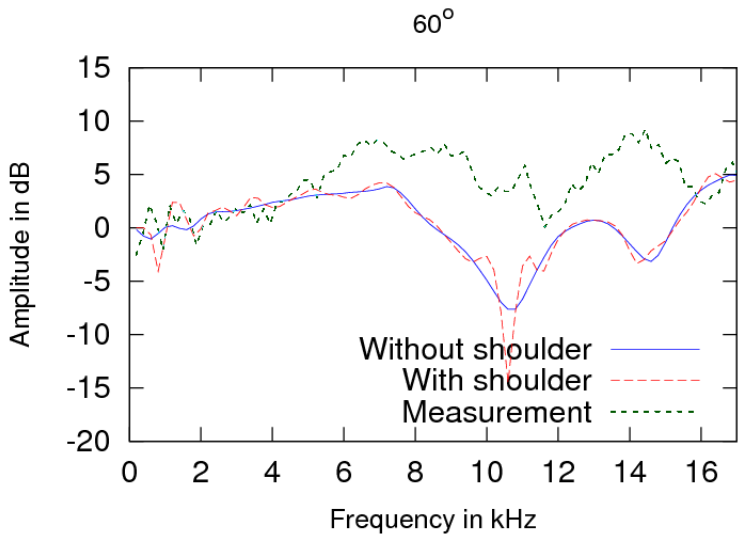


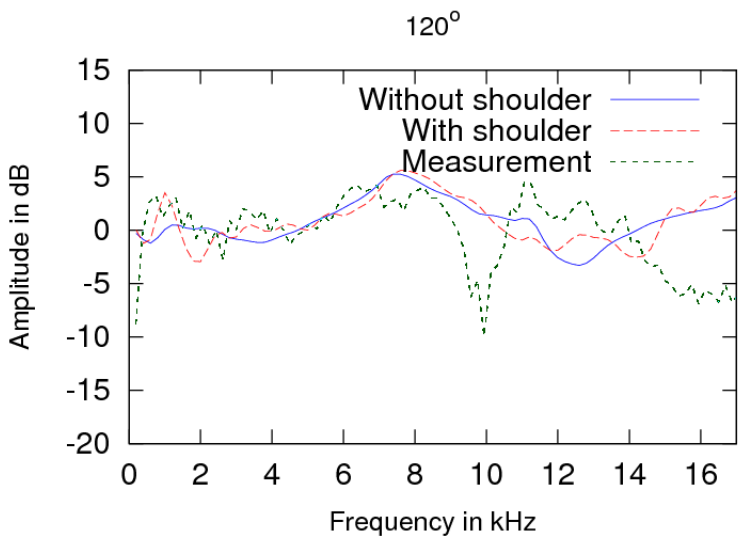
Vertical Plane

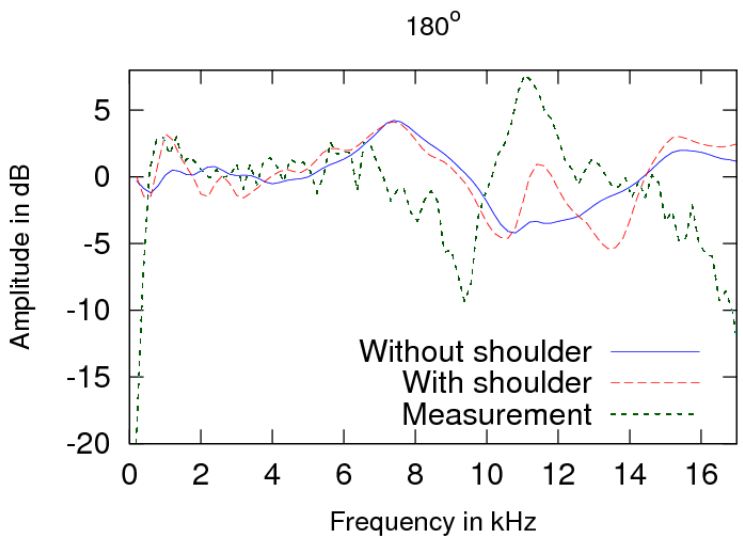


Vertical Plane



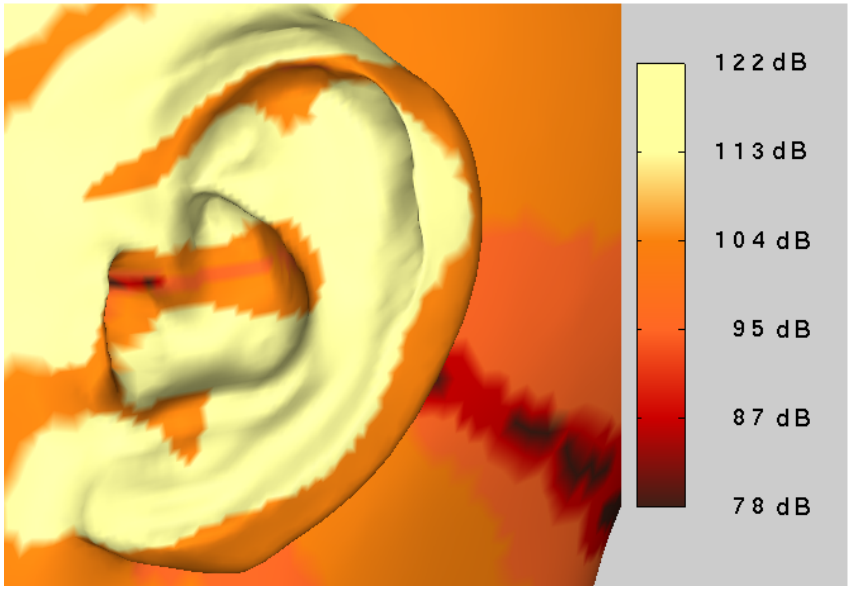






Possible Reasons

- Mesh not accurate enough
- Problems at mesh generation
- Position of the evaluation element



Influence of Temperature and Perturbation

Other Experiments

- Different speed of sound and density for different temperatures
- Random perturbations of length 0.5 mm

Temp [C]	c [m/s]	ρ [kg/m^3]
$-15°$	322.2	1.36
$0°$	331.3	1.29
$15°$	340.5	1.23
$30°$	349.0	1.17

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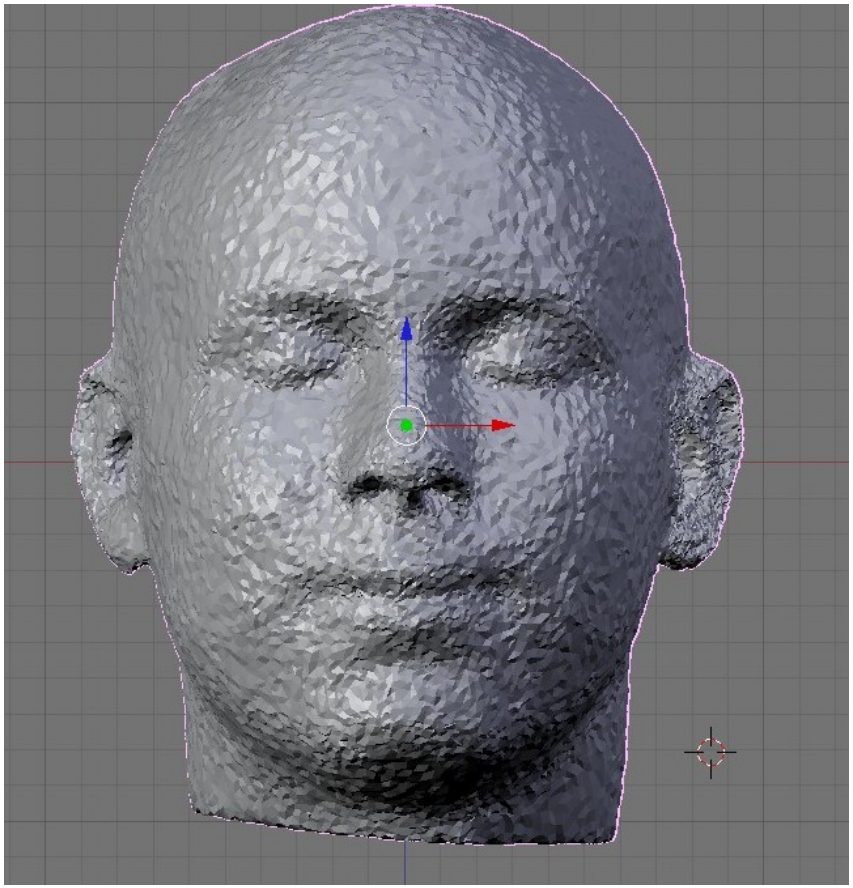

Figure: Jittered ear mesh

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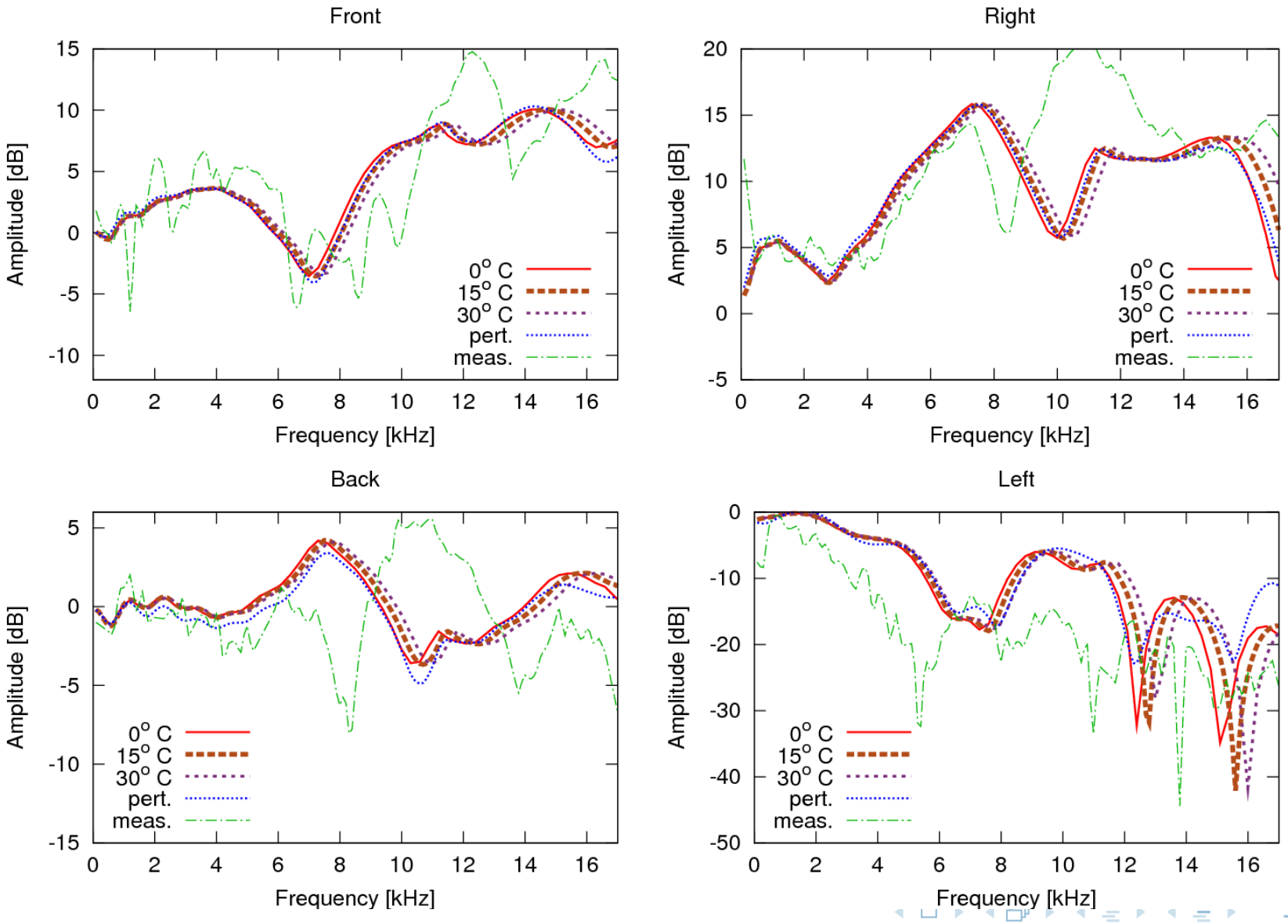
Results


Front
Amplitude [dB]
Frequency [kHz]
0° C
15° C
30° C
pert.
meas.
Right
Amplitude [dB]
Frequency [kHz]
0° C
15° C
30° C
pert.
meas.
Back
Amplitude [dB]
Frequency [kHz]
0° C
15° C
30° C
pert.
meas.
Left
Amplitude [dB]
Frequency [kHz]
0° C
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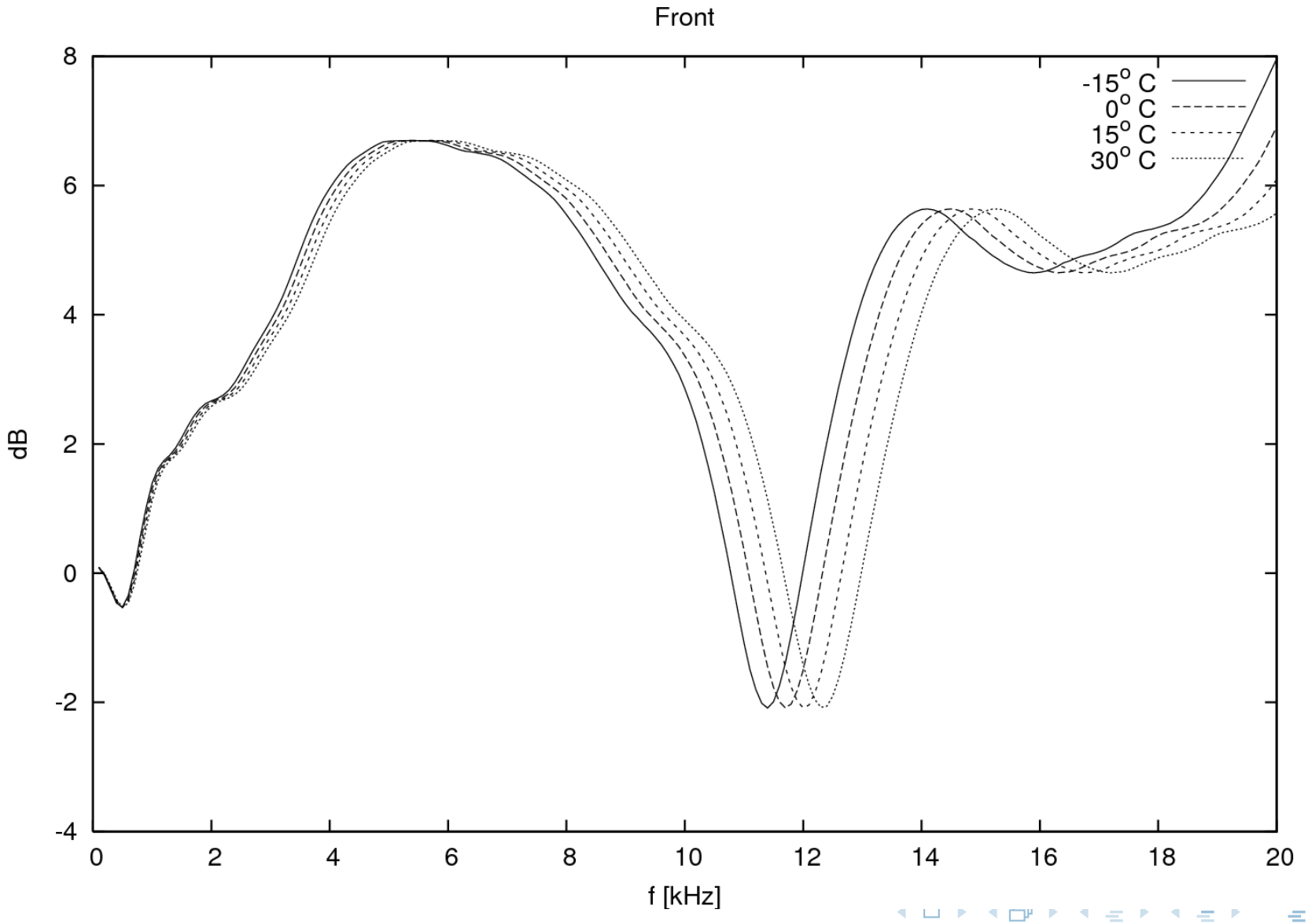

Conclusion and Outlook

- Possible to calculate HRTFs for high frequencies
- Difference between measured and calculated data
- Mesh with all “characteristic features” is essential
- Temperature does not seem to have much influence
- Localization tests will be necessary

Thank you for your attention