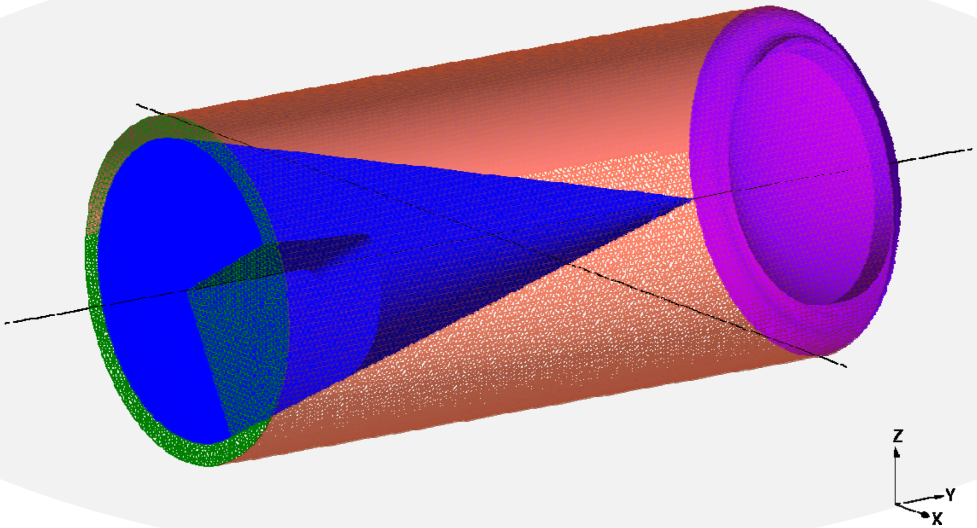
BEUTH HOCHSCHULE FÜR TECHNIK BERLIN
Beuth University of Applied Sciences Berlin

in cooperation with the WTD71 (Bundeswehr Technical Center for Ships and Naval Weapons,
Maritime Technology and Research), Eckernförde & Kiel, Germany

The Abused Can - A comparison of the results from numerical simulations and measurements of scattered sound pressure field on a “special” object within the higher frequency range



ICTCA 2017 VIENNA

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Overview

- Introduction / motivation
  - The problem, the model and the can
  - Real model and experimental setup
  - Numerical model
  - Numerical methods / frequency range
- Results
  - Monostatic case, evaluated on a spherical sector
  - Comparison of numerical and experimental results
  - FEM results
- Conclusions and future work

The problem, the model and the can

- In the high-frequency range, the simulation of the scattered sound pressure of complex structures, which can interact acoustically with each other and with the surrounding medium, results in high demands on the numerical methods used.
- Often there are qualitative deviations due to numerical inaccuracies or the required memory space exceeds the available capacities.
- The results obtained are often compared only between the different methods, but experimental data are seldom used to verify the simulations.
- Therefore, an object should be looked at, which
  - is a bit more complex in structure (→ double & triple mirror, multiple reflection)
  - includes different boundary conditions (→ elastic thin shells)
  - can be numerically simulated within reasonable time (→ “useful” size)
  - and can also be verified by measurement techniques available

Therefore, a thin-walled can has been chosen, which was “abused” by an additional "inner life".

Real model and experimental setup

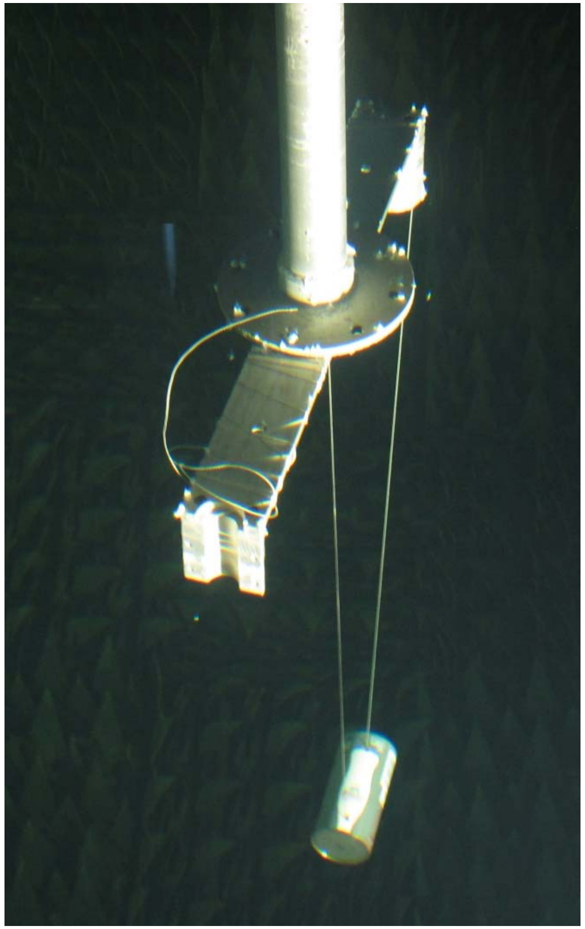
An ordinary beverage can was used whose “open” top lid was removed and replaced by a solid cone with a milled cut out at one side and a bottom plate.

Thin beverage can without top hat

Notches for the strings

Triple mirror within the solid cone

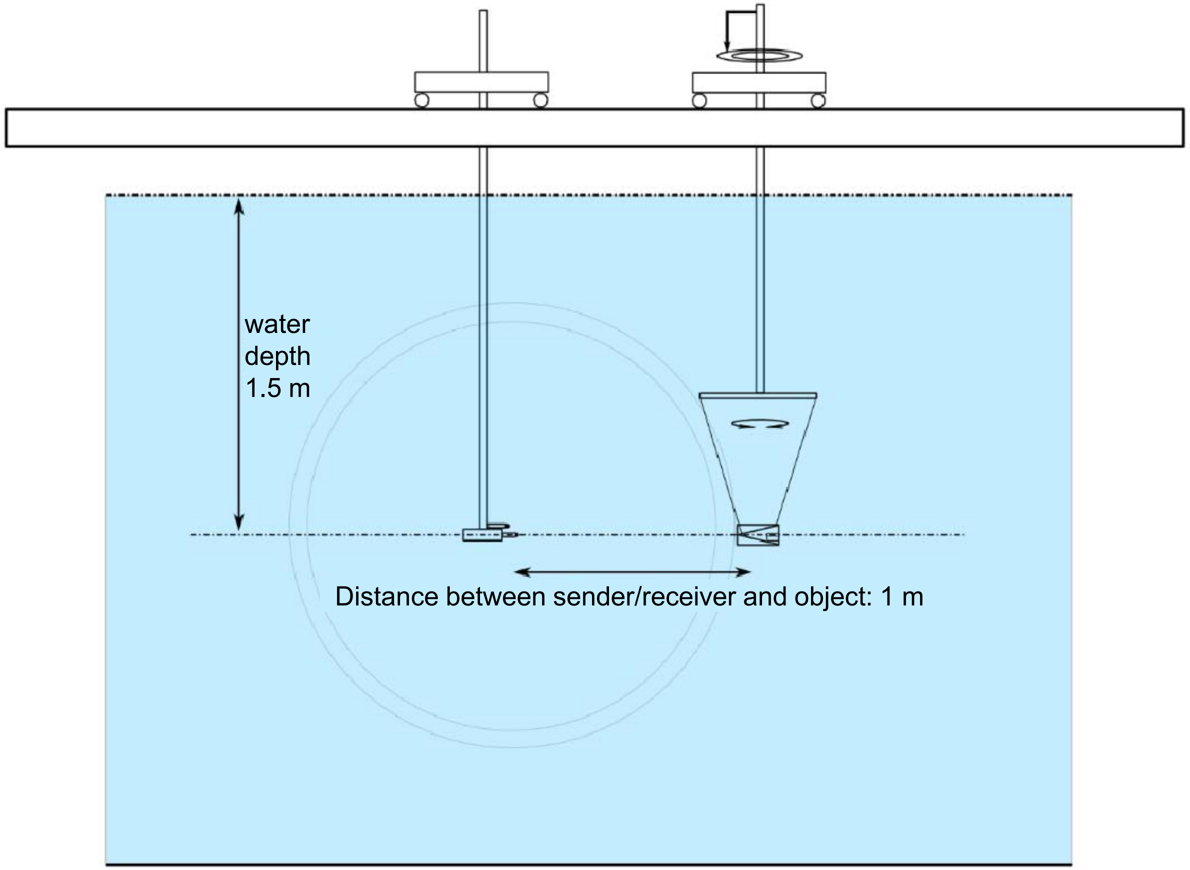
Bottom plate



All parts were glued together and the construction was lowered into a low-reflective water tank at 1.5m depth using thin strings.

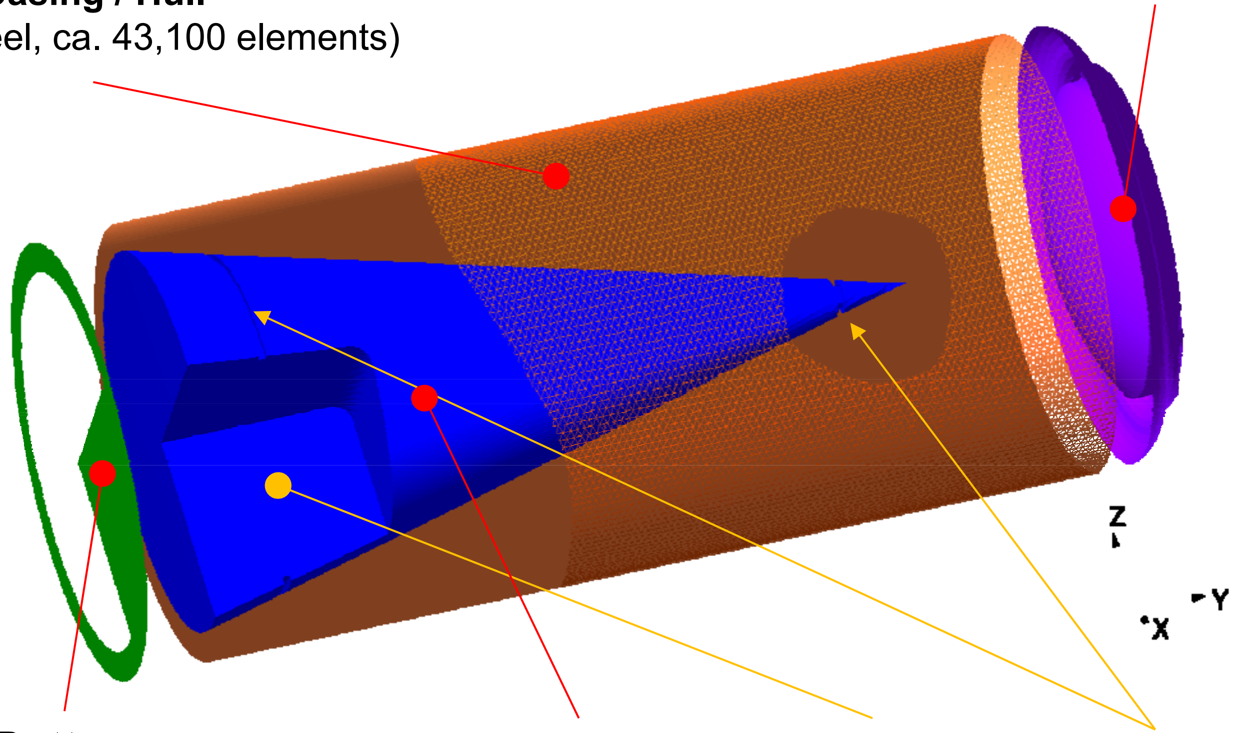
Real model and experimental setup

Experimental setup in the measuring tank (5 × 5 × 3 m, concrete with sound absorbers), using a turntable with manual operation (1° stepping, > 10 measurements per step)



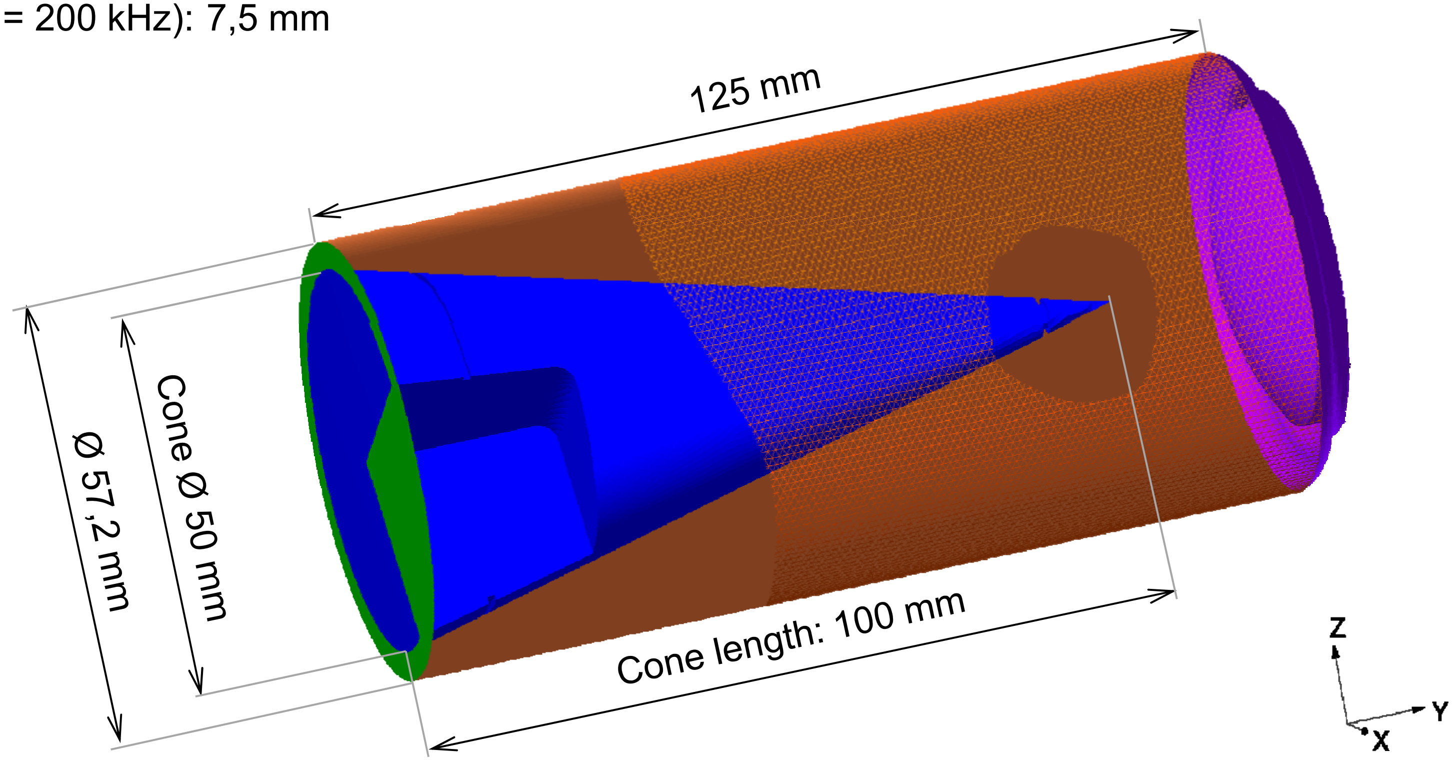
Numerical model (exploded view!)

The numerical model with about 76,500 elements consists of 4 surface areas:



Numerical model – main dimensions

Cone angle: ca. 14°
λ (f = 200 kHz): 7,5 mm



Numerical methods

The calculations were carried out using three different methods

- **Boundary Element Method (BEM)**
  These results were calculated with an own code using the direct BEM for the rigid inner cone and the indirect BEM for the different thin steel areas (using a mass inertia coupling, presented in [1]). The full complex matrix required about 45 GB.
- **Raytracing method (BEAM)**
  These results were calculated using an own raytracing code presented in [2].
- **Finite Element Method (FEM)**
  Some additional results were calculated in 2D using the commercial software COMSOL 5 to explain some specific features. A 3D calculation was not possible with the available resources.

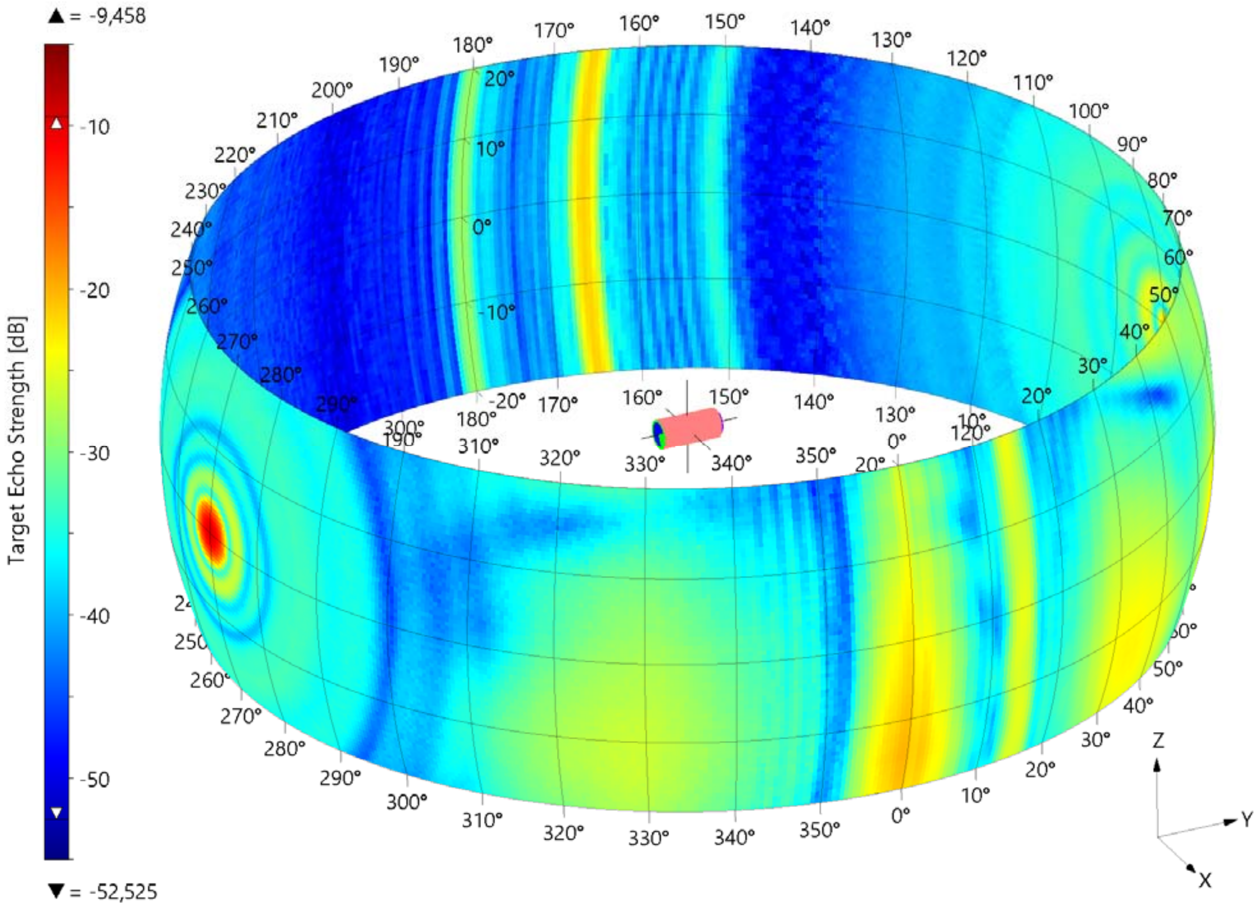
Frequency range and averaging

Most of the calculations were done within a frequency range between 180 and 220 kHz where applicable, followed by an averaging over frequency (f_{aver} = 200 kHz).
This also corresponds roughly to the measuring technique, in which a multi-frequency “ping" is generally used.

Monostatic case, evaluated on a spherical sector

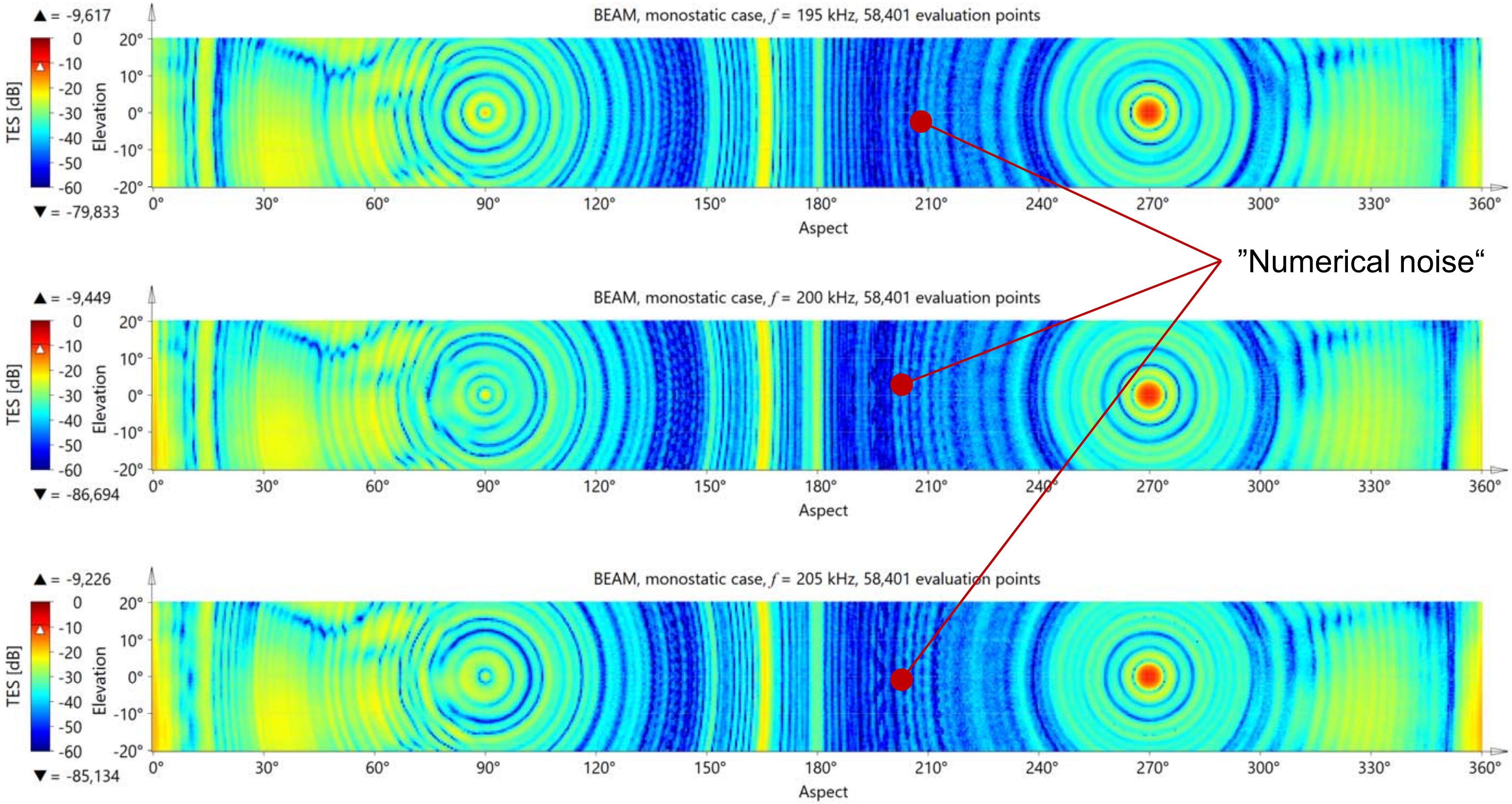
f = 180 … 220 kHz, averaged

- aspect angle range 0...360°
- elevation angle range ±20°
- angle step 0.5°
- 58,401 evaluation points
  = no. of calculations

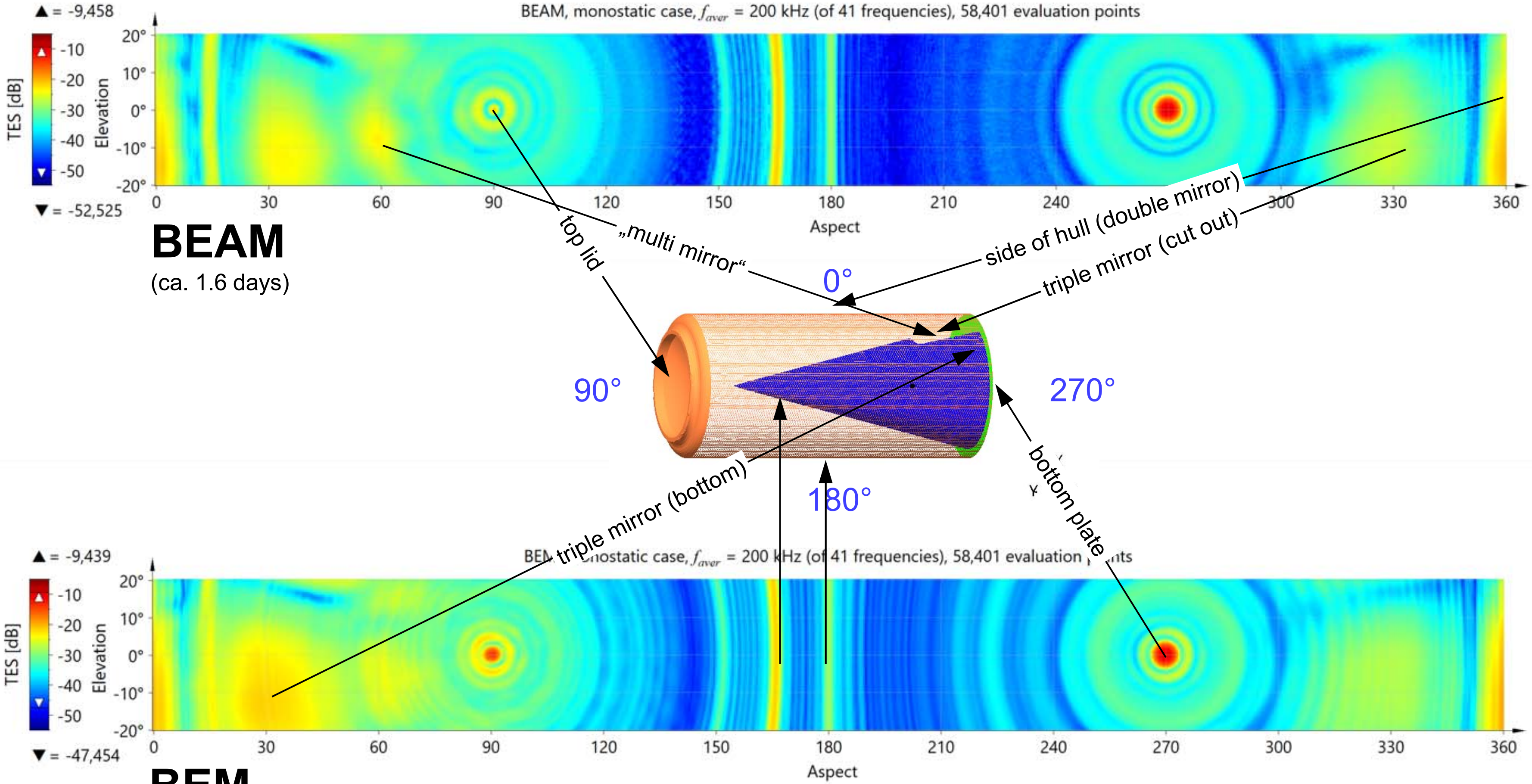


The evaluation is carried out in a distance of 10 km in the far field, all results will use the normalized sound pressure level within 1m distance (target echo strength, TES)

Numerical results (BEAM, monostatic case, f = 195, 200, 205 kHz)



Numerical results (monostatic case, f = 180 … 220 kHz, averaged)

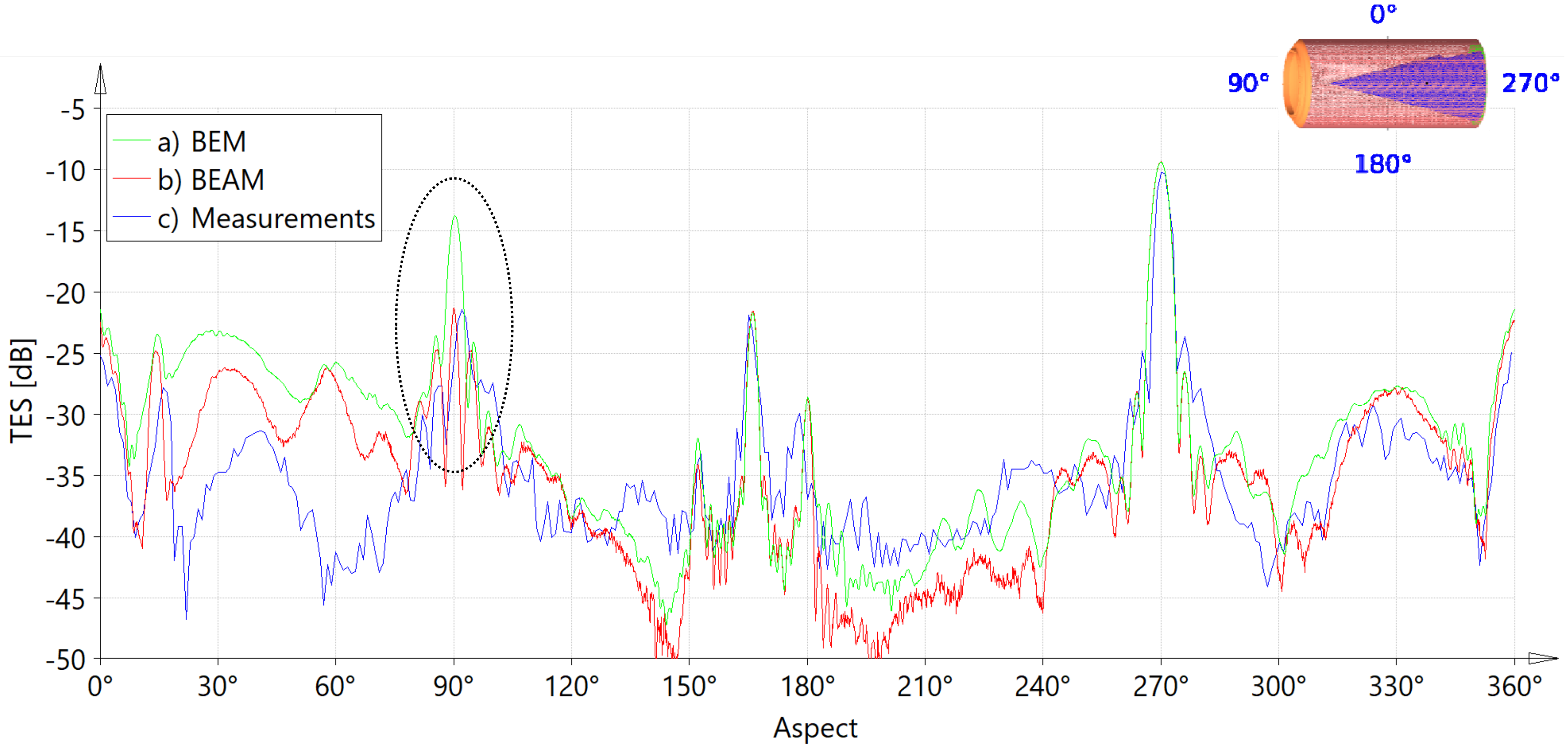


BEAM
(ca. 1.6 days)

BEM
(ca. 3.5 weeks, single precision)

Comparison of numerical and experimental results (XY-plane)

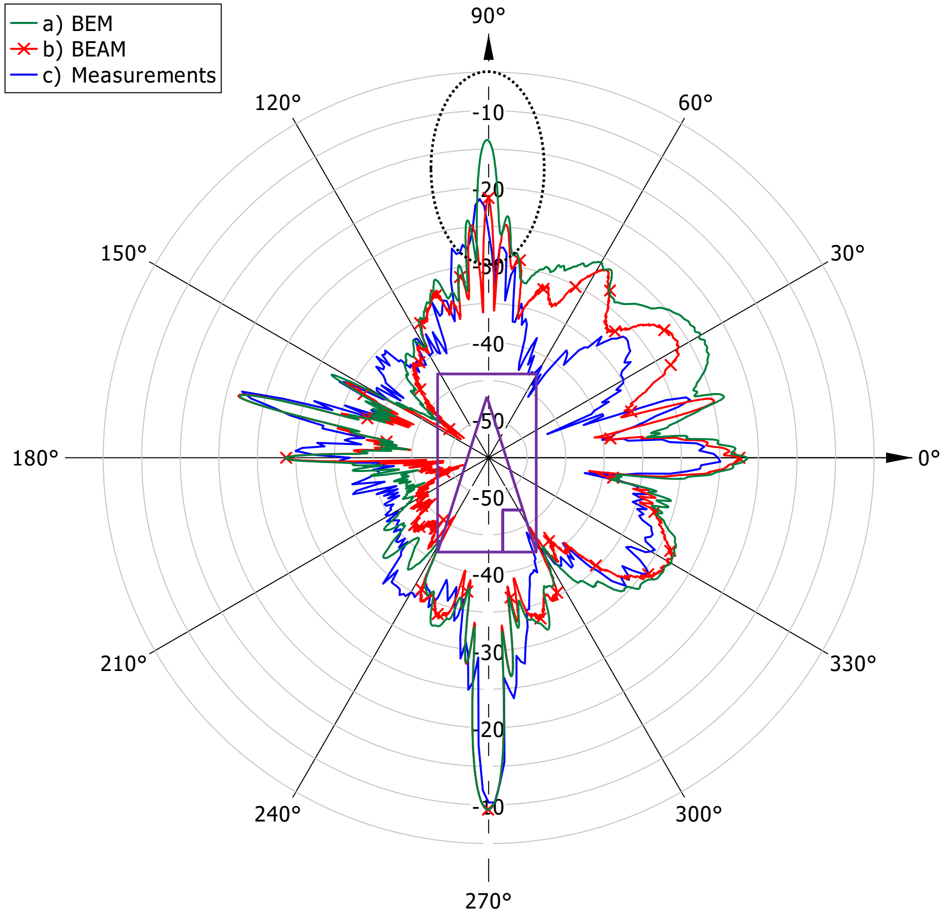
The results of the numerical simulations and the measurements agree well, except for one area around 90° (see circle), where the BEM has a peak with a difference of approx. 8 dB.



TES [dB], monostatic, XY-plane (elev. 0°), f = 200 kHz (average over 21 frequencies)

Comparison of numerical and experimental results

The results of the numerical simulations and the measurements agree well, except for one area around 90° (see circle), where the BEM has a peak with an offset of +8 dB.

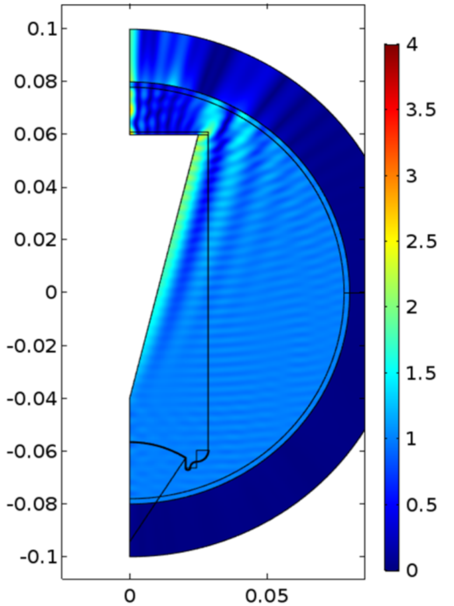


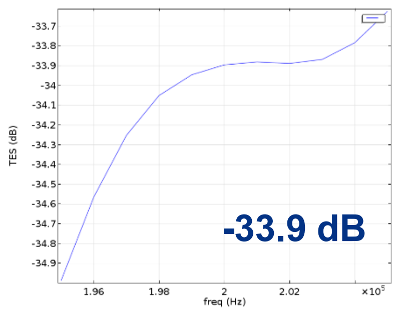
TES [dB],
monostatic,
XY-plane (elev. 0°),
f = 200 kHz
(average over 21
frequencies)

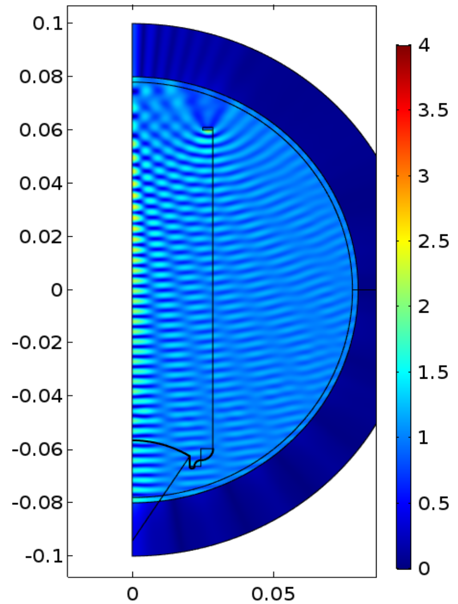
FEM results – "Horn effect" (calculated without can!)

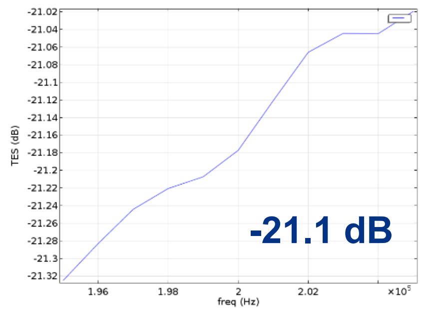
2D case (rotational symmetric without cutout), aspect angle 90° ("hit the peak"), f = 200 kHz

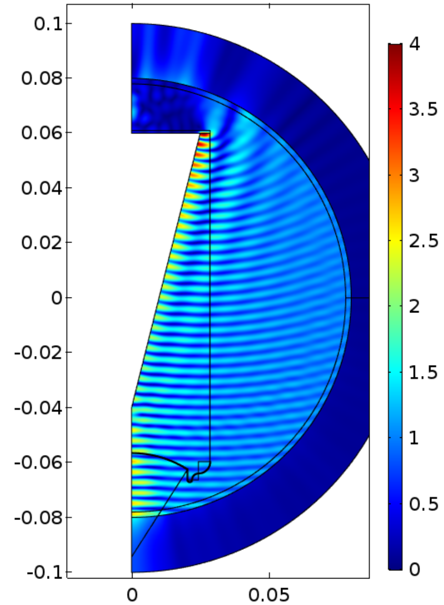
rigid cone - **alone**	circular **disc with hole**	**cone & circular disc**

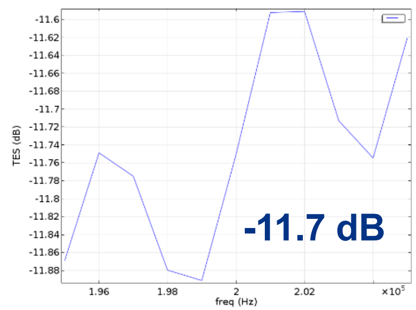








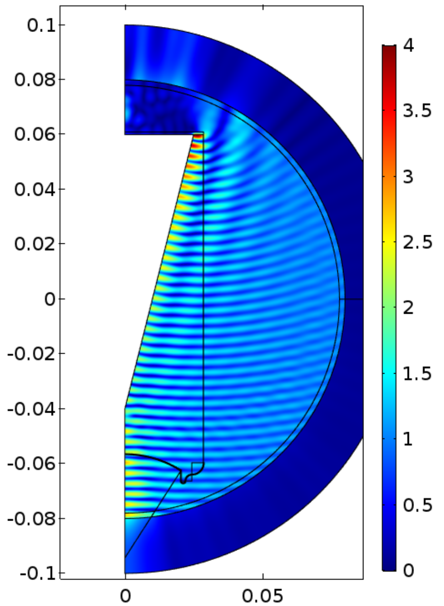


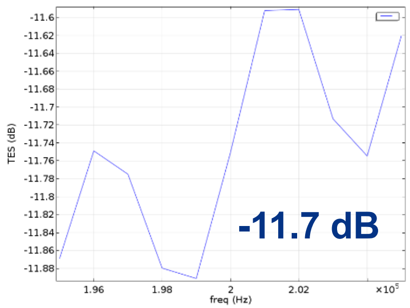


FEM results – "Horn effect"

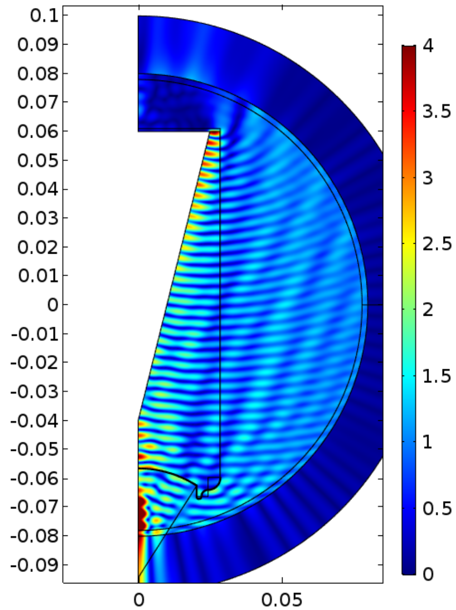
2D case (rotational symmetric without cutout), aspect angle 90°, f = 200 kHz

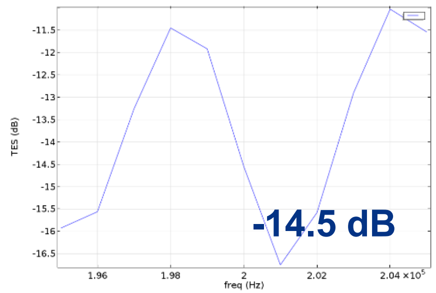
cone & circular disc





with can, cone & circular disc





Conclusions

- The various acoustic effects resulting from the shape of the object have been clearly shown.
- The results show a good agreement between the numerical simulations and the measurements.
- A peak at 90° in the BEM which was not visible within the raytracing method and the measurements resulted from a kind of horn effect, which could be confirmed by corresponding FEM simulations.

Future work

- The measurements should be carried out again, possibly using fine plastic wires for stabilization and under more controlled conditions with positioning by a stepping motor to avoid manual inaccuracies.

Thanks for your attention! ☺

References / useful links:

[1] Burgschweiger, R., Schäfer, I. and Ochmann, M., *Implementation and results of a mass inertia coupling as an extension of the BEM for thin shells*, Proceedings of the 22nd International Congress on Sound and Vibration (ICSV22), Florence, Italy (07/2015).

[2] Burgschweiger, R., Schäfer, I., Ochmann, M. and Nolte, B., *Results of the ray-tracing based solver BEAM for the approximate determination of acoustic backscattering from thin-walled objects*, Proceedings of the InterNoise 2014, Melbourne, Australia (11/2014).