DFM
Danish National Metrology Institute

DFM + BKSV-DPLA: current research activities

11th CCAUV Meeting
September 2017

Danish Metrological Infrastructure

DPLA

NMI

DFM
Danish National Metrology Institute

Designated Institute

Brüel & Kjær

Main research activities

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- **Microphone calibration**
  - *Low-frequency pressure calibration*
  - *Primary calibration of WS microphones*
  - ***High-Frequency free-field calibration –***
    Environmental coefficients

Brüel & Kjær

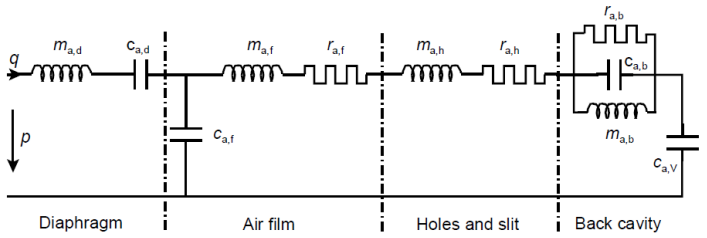
- **Microphone calibration**
  - *Very low-frequency calibration*
- **Vibration transducer calibration**
  - *Extended frequency range for vibration transducer calibration*

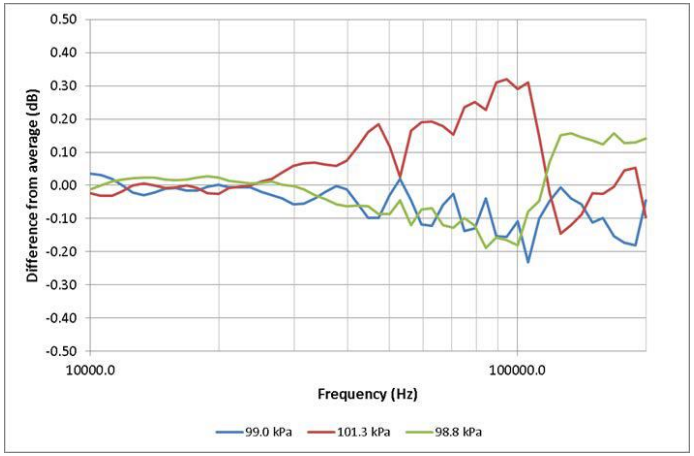
ears II

- BKSV-DPLA: refinement and definition of the specifications of the new generation of universal ear simulators, its calibration and manufacturing
- DFM: calibration of the ear simulator, and the development of the traceability chain for ultrasound measurements

Environmental free-field coefficients – state of the art

- **Analytical models for predicting the coefficients**
  - Only for pressure sensitivity of Laboratory Standard (LS) microphones
  - Based on lumped parameter models
- **Experimental values**
  - LS Microphones (reciprocity)
  - Working Standard microphones (some few models, based on actuator measurements)
- **Different coefficiens for different sound fields**
  - Free-field coefficient based on pressure coefficients + diffraction data
- **Needed for increasing accuracy in an extended frequency range above 100 kHz**





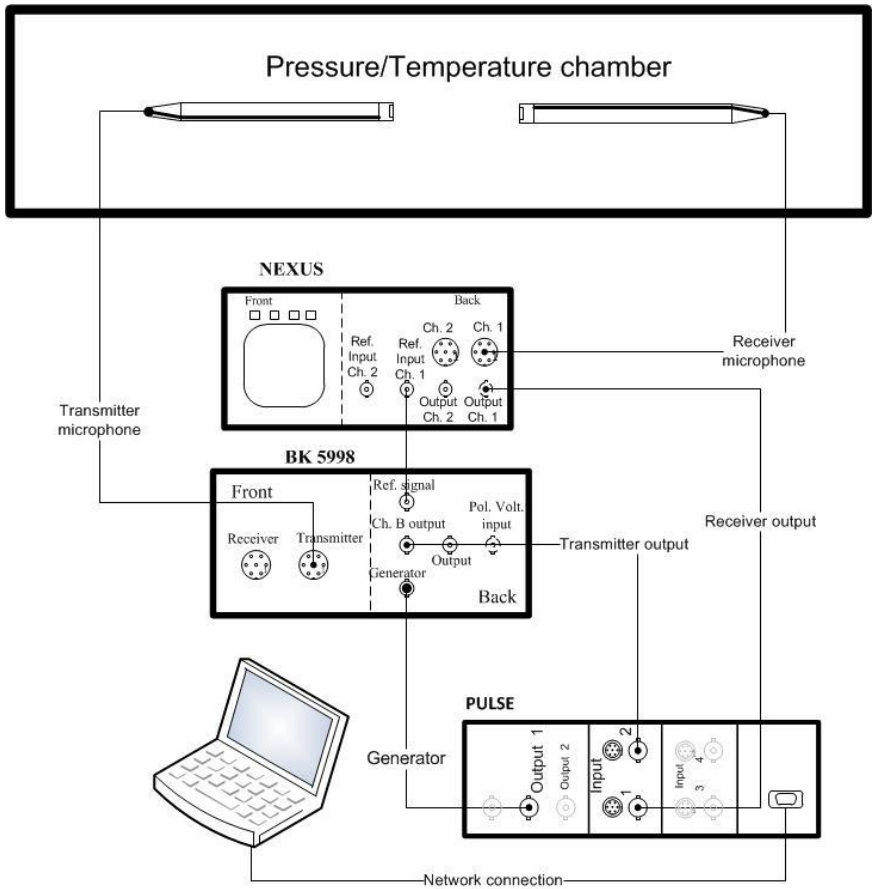
What did we do?

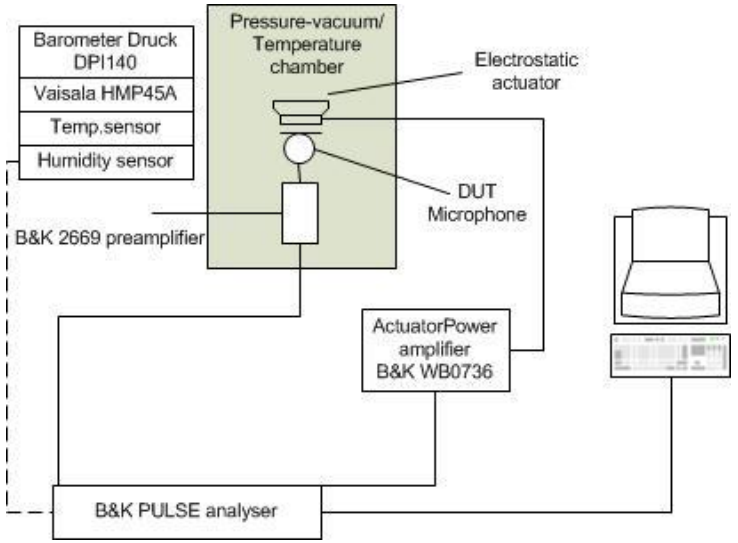
- **Numerical Boundary Element Method calculations instead of analytical solutions**
  - An axi-symmetrical model that includes viscous and thermal losses
  - Full coupling between the interior problem, the membrane and the exterior problem in a free-field.

- **Determined the pressure and temperature coefficients by calibrating microphones at different pressures and temperatures**
  - Setting the free-field reciprocity system inside environmentally controlled spaces
  - Using time-selective techniques to remove any disturbance from the spaces
  - Set-up an actuator measurement system inside the same spaces

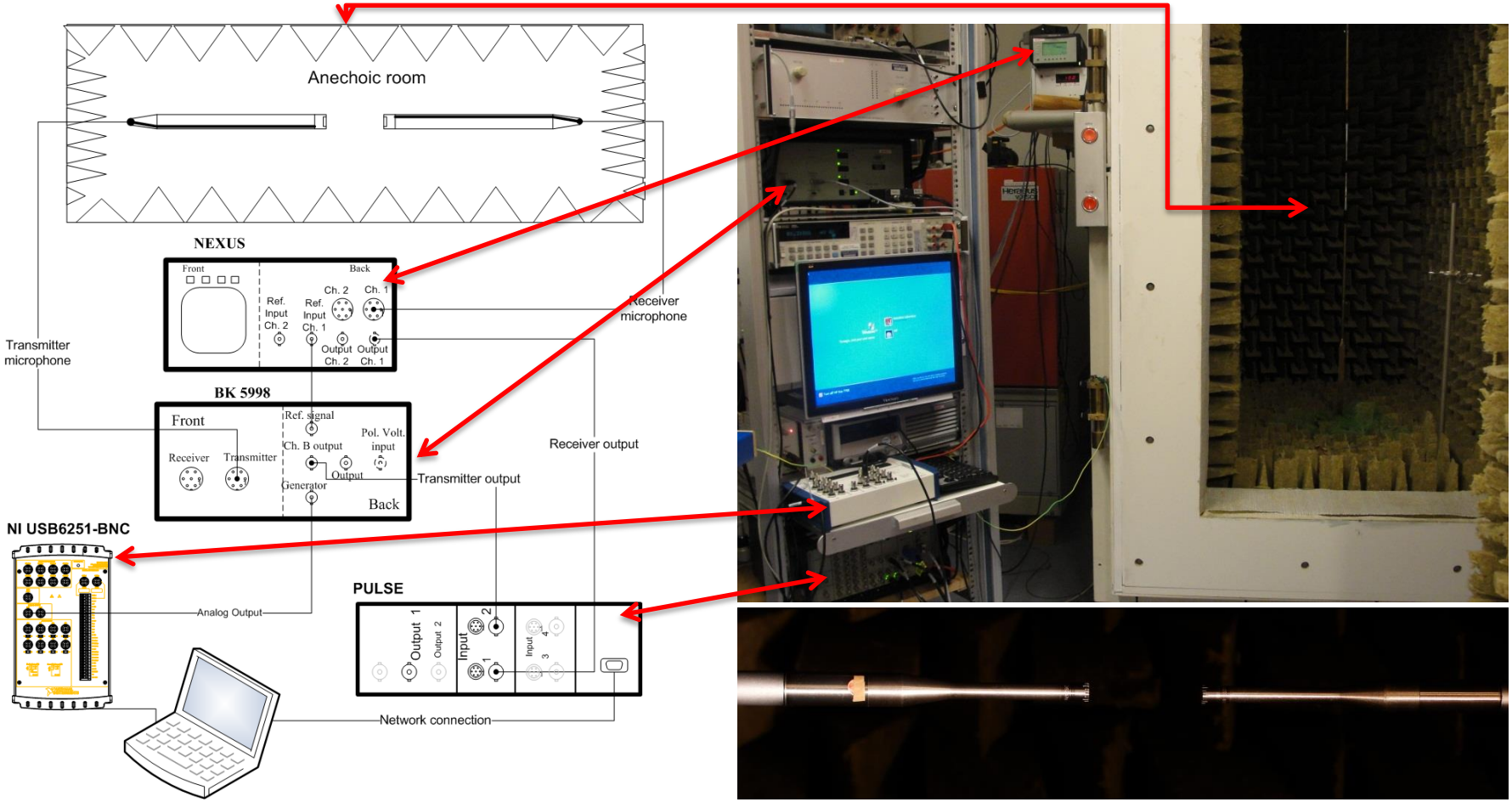
- **Analysed an alternative solution for the temperature coefficient**
  - Additive Free-field coefficients based on actuator coefficients + diffraction data

Experiments – Measurement set-up

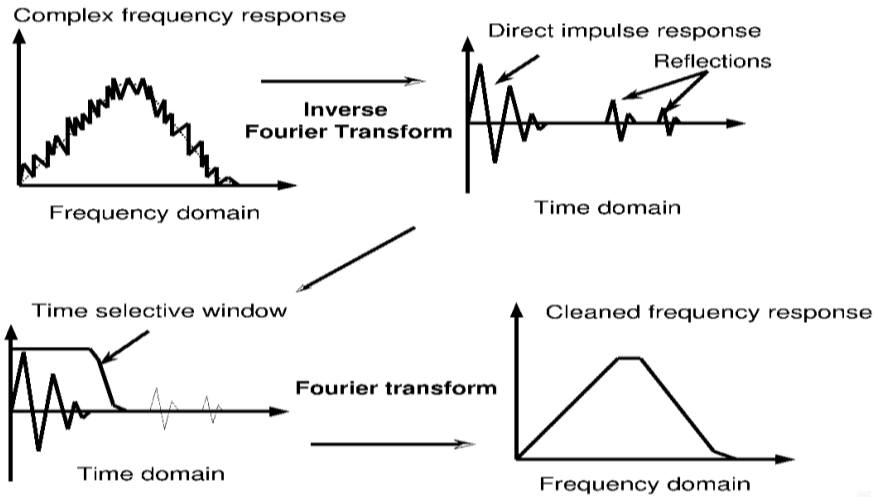


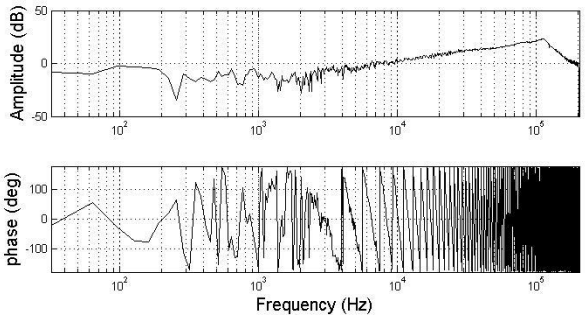


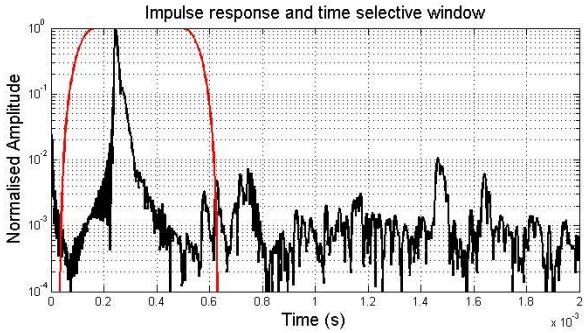
Experiments – Measurement set-up

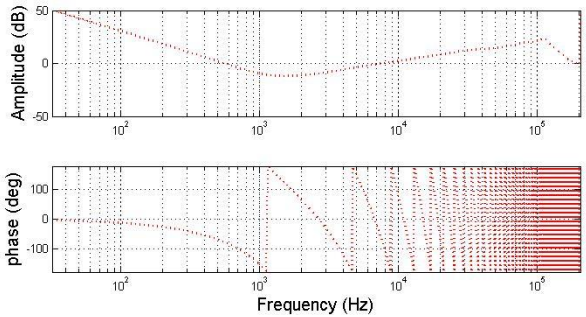


Experiments – Time-selective technique

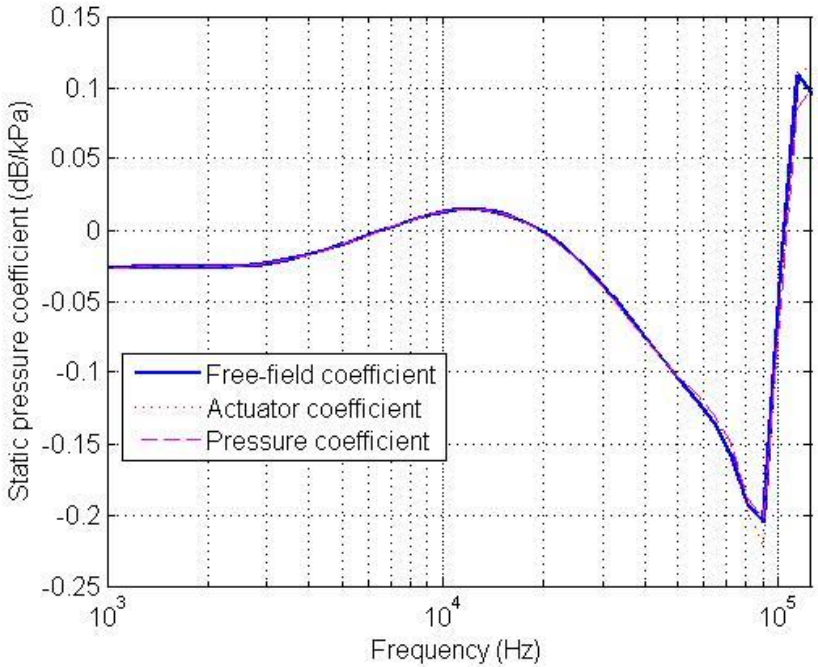


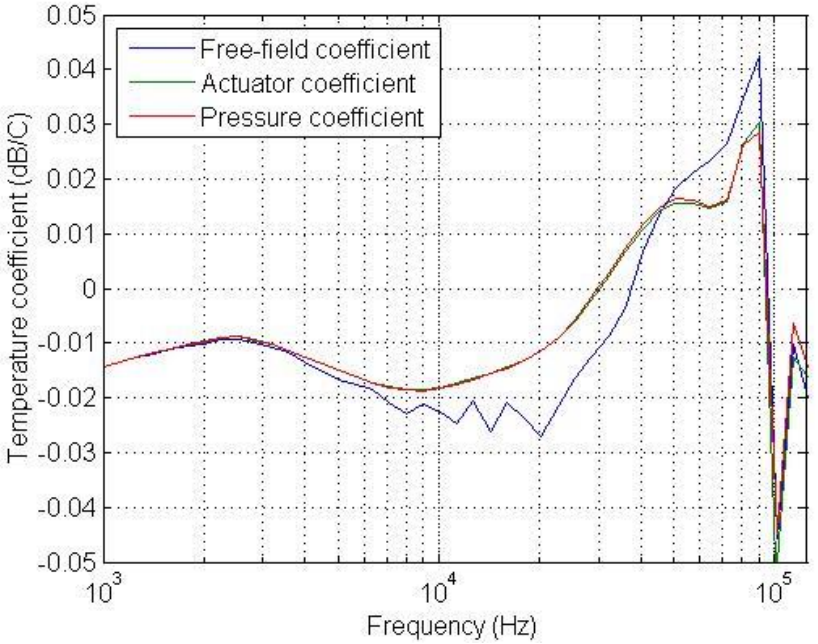






Numerical results – Environmental coefficients



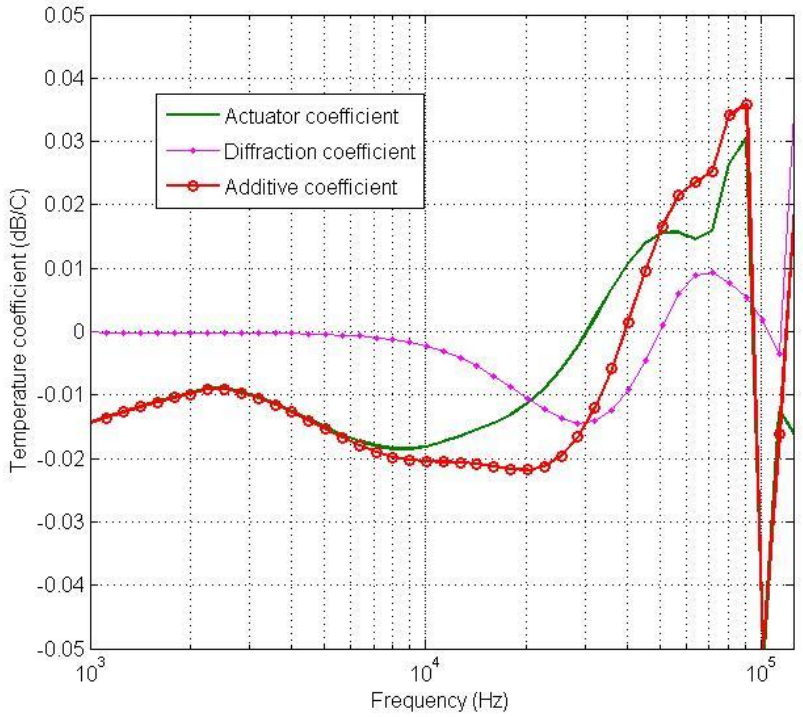


Temperature coefficient – Additive method

$$M_{\mathrm{f}} = M_{\mathrm{p}} \cdot S(\theta) \cdot \frac{Z_{\mathrm{a}}}{Z_{\mathrm{a}} + Z_{\mathrm{a,r}}},$$

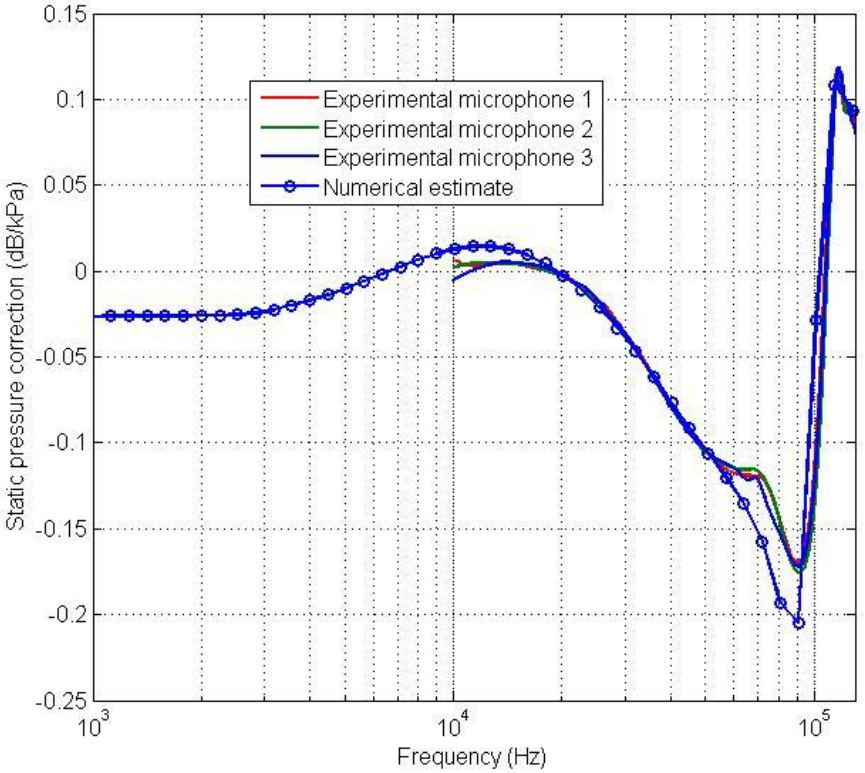
$$L_{Mf} = L_{Mp} + \Delta_S + \Delta_Z,$$

$$\delta_{Mf} = \delta_{Mp} + \delta_S + \delta_Z$$

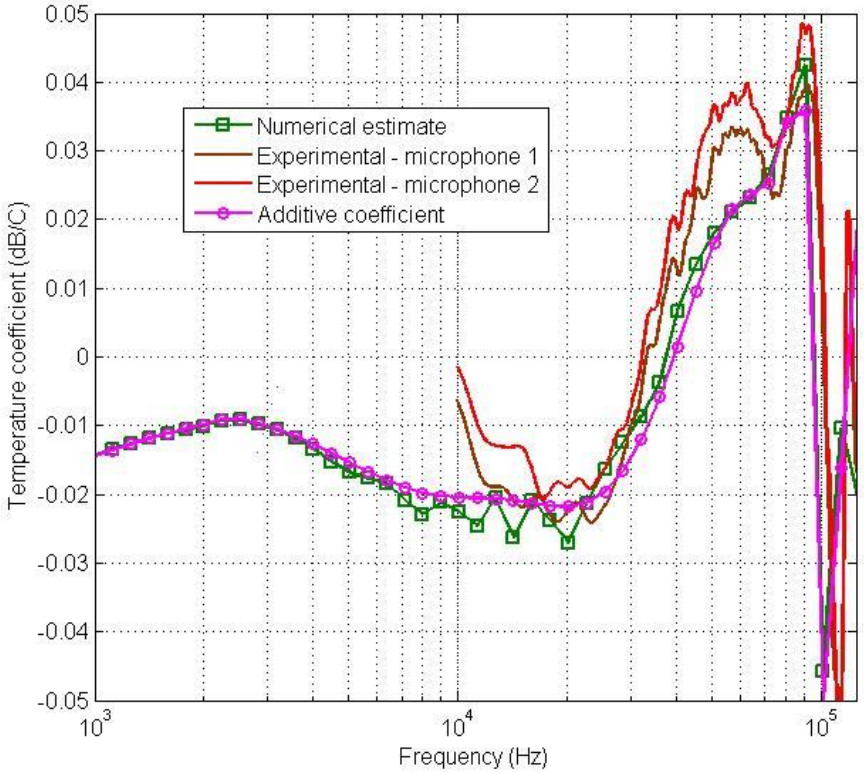


Experimental results

Pressure coefficient



Temperature coefficient



Conclusions

- Temperature and static pressure coefficients of the free-field sensitivity of Working Standard microphones type 3 (Brüel & Kjær type 4939) have been determined using a BEM formulation that includes losses.
  - An accurate description of the internal geometry and membrane properties is needed.

- Temperature and static pressure coefficients of the free-field sensitivity of Working Standard microphones type 3 (Brüel & Kjær type 4939) have been determined experimentally, and compared to the numerically determined coefficients.
  - Experimental determination of the free-field coefficients is challenging

- Experimental and numerical results have a good coincidence, and differences can be traced to individual variations of the measured microphones as opposed to *typical* or *design* specifications used in the simulation.