Validation of the Acoustic FE-Model of a Very Light Jet Cavity Mock-up

Fabrice Teuma; K. Kochan; T. Kletschkowski; D. Sachau

Helmut-Schmidt-University / University of the Federal Armed Forces, Hamburg

Department of Mechanical Engineering

Mechatronics

Prof. Dr.-Ing. Delf Sachau

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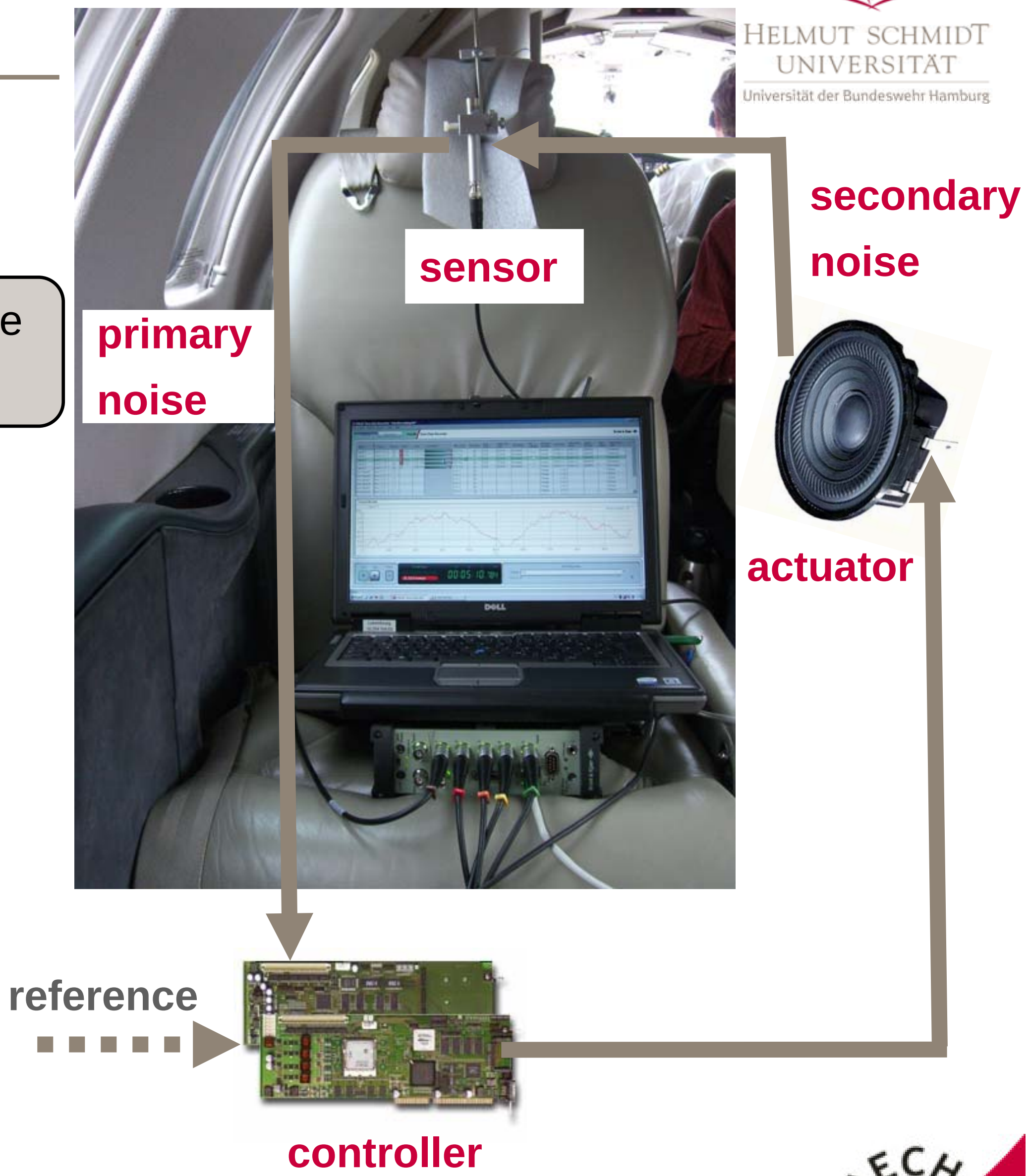
Universität der Bundeswehr Hamburg

Motivation

- sound pressure Level of up to **91.4 dB** in certain areas
- Development of a combined active noise control (ANC) and an audio system



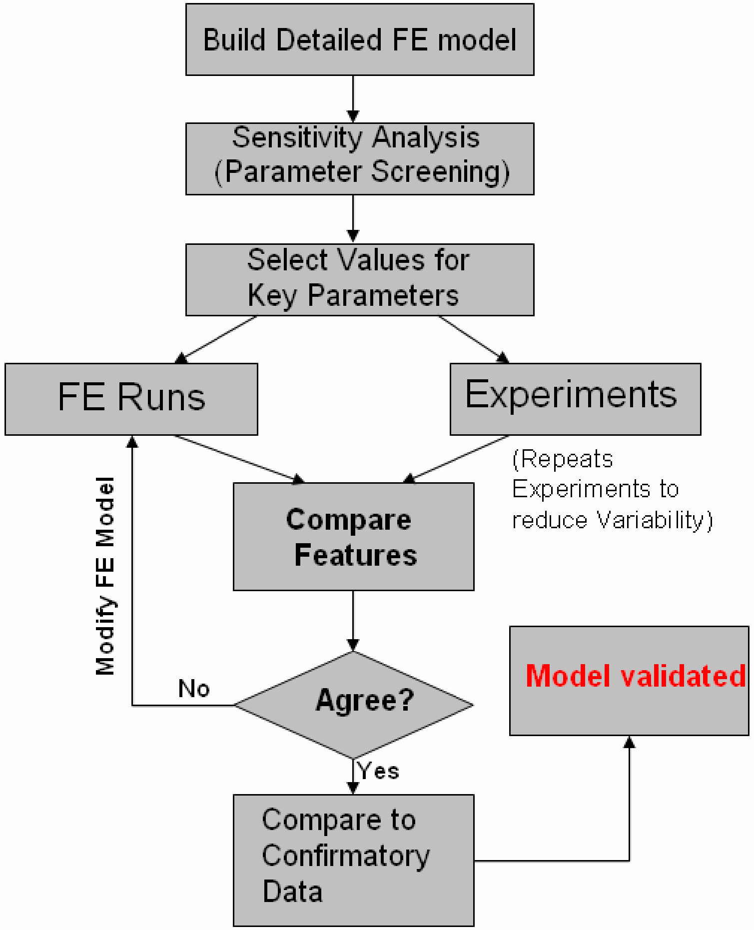
Principe of ANC

Overview

- *Model validation approaches*
- *Description of test rig and experiment*
- *Description of the FE model of the acoustic cavity*
  - *- Model geometry and mesh*
  - *- Sensitivity study*
- *FE model adjustment*
  - *- Fit of model parameters*
  - *- Validation of model performance*
- *Conclusion/Outlook*

Model validation approaches

“ the process of assessing and improving confidence in the usefulness of computational predictions for a particular application”



General approaches

- Graphical comparison
- Confidence interval approach
- *r*² approach

Parameter depending approaches

- Validation using modal parameters
- Validation using operating modes

Source:

Doebling, S.W.; Hemez, F.M. (Los Alamos National Laboratory): Finite Element Model Validation, Updating and Uncertainty Quantification, *Short Course for Aerospace, Civil, and Mechanical Engineers*, (2002)

Description of test rig & experiment

Interior of the acoustic mock-up

System excitation with a loudspeaker

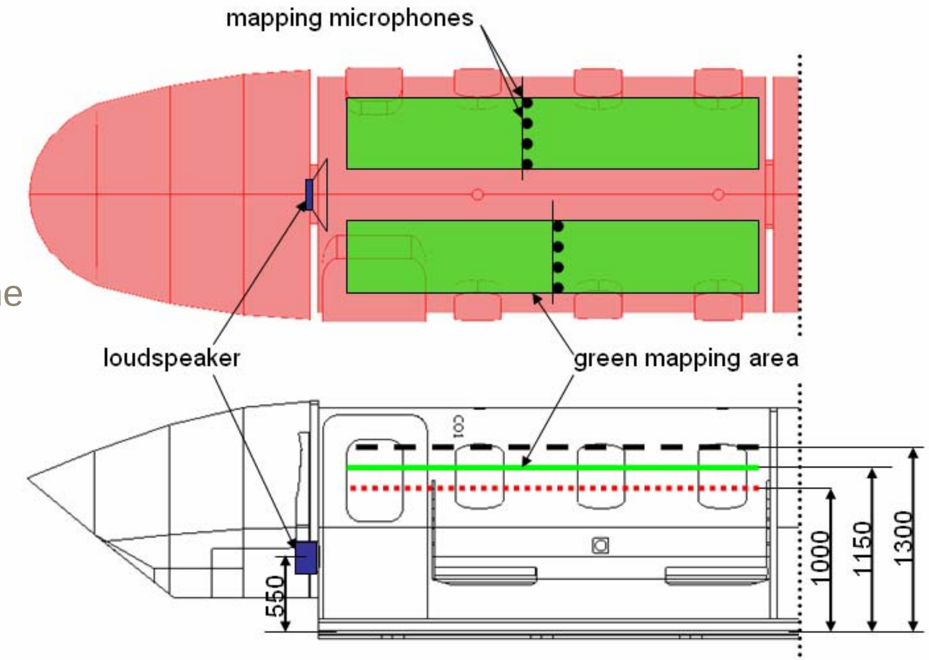
Loudspeaker Characteristics:

→ Chassis type 6ND430 Eighteen Sound

Excitation signal:

→ Band limited white noise

→ Frequencies: 0-800 Hz



Excitation position and measurement areas

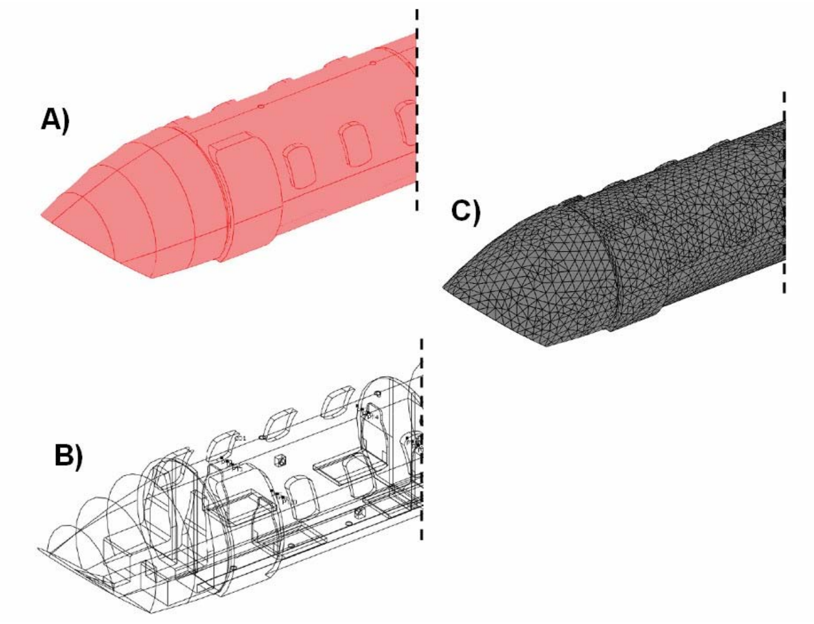
Measurements signals:

→ An accelerometer recorded the membrane acceleration of the loudspeaker

→ Frequency responses between mapping microphones and loudspeaker

Description of the FE model

Model geometry and mesh



60989 Elements

92162 DOF

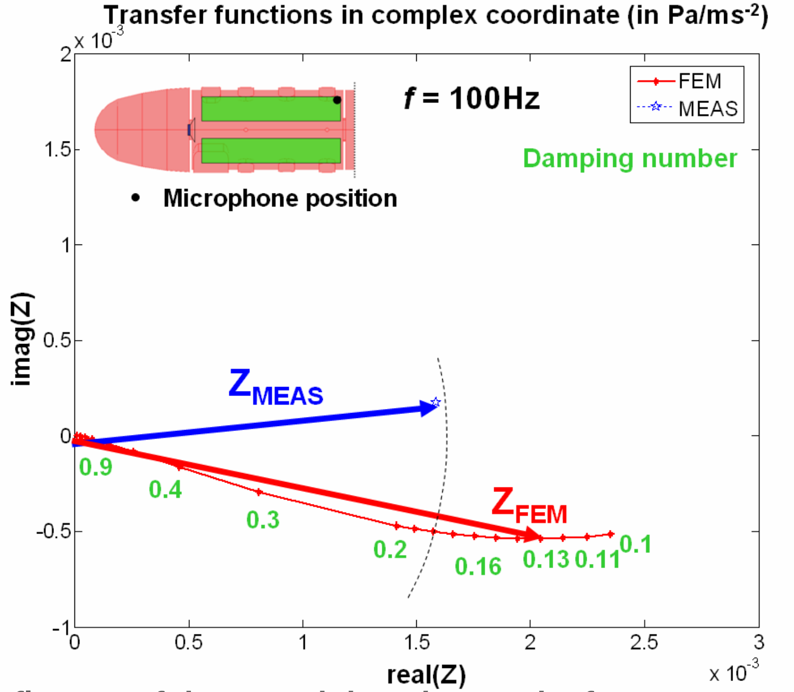
Lagrange 2nd order Tetra elements

Helmholtz Equation

$$\Delta p(\underline{x}) + k^2 p(\underline{x}) = 0;$$

$$k = \frac{\omega}{c};$$

Sensitivity study



Influence of the sound damping on the frequency response

Complex wave number can influence the sound damping in the cavity.

$$k_c = \frac{\omega}{c}(1 - j \cdot \beta) = \hat{k} e^{j\vartheta}$$

β = damping number; c = speed of sound;

ω = angular frequency and $j^2 = -1$.

Description of the FE model (Sensitivity study)

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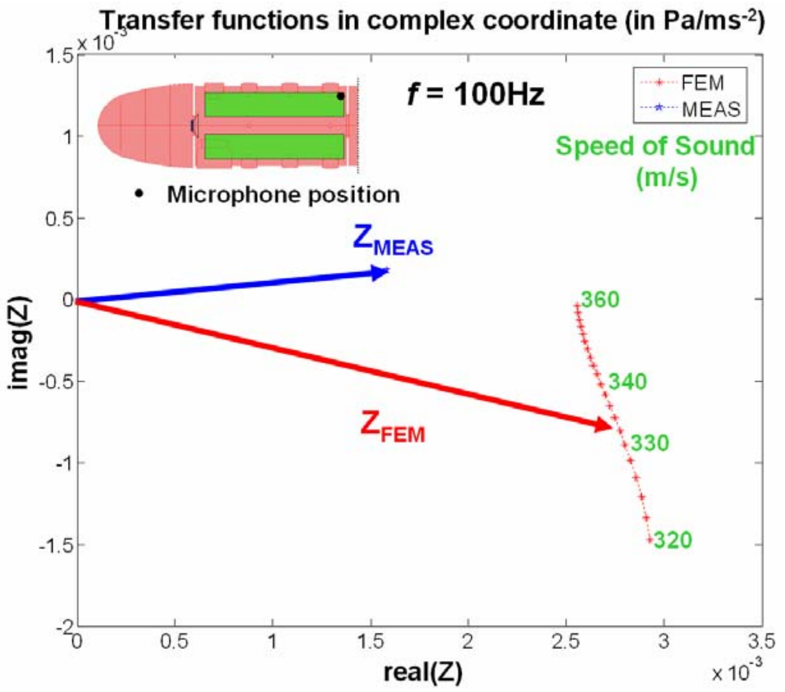
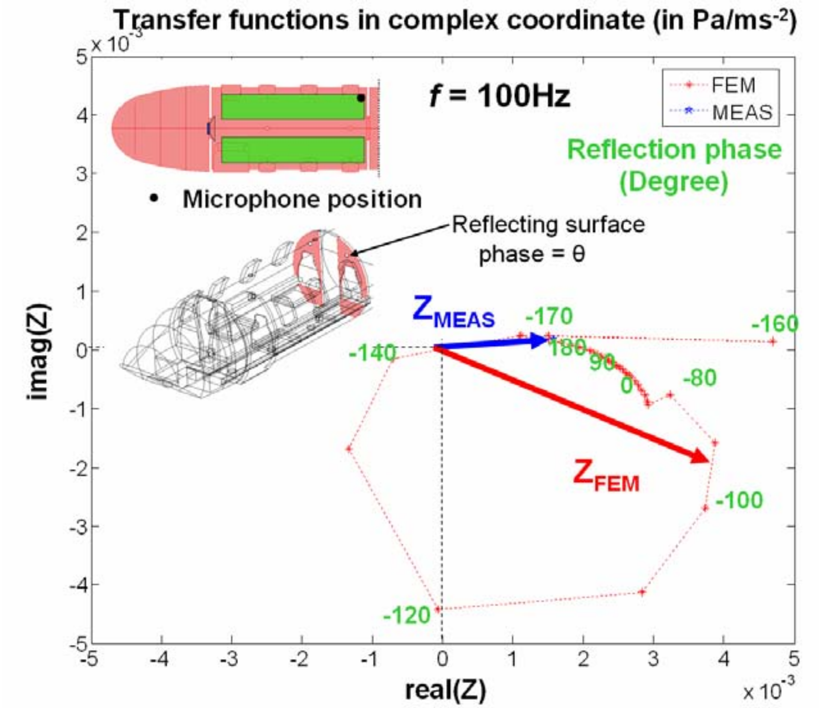


Influence of the speed of sound on the frequency response



Influence of the reflection phase on the frequency response

Loudspeaker radiation correction factor:

$$K_{Ls} = a \cdot e^{j\phi}$$

where *a* and *Φ* adjust the magnitude and the phase of the normal acceleration respectively

characteristic sound impedance:

$$Z_r = \frac{1+r}{1-r}\rho c$$

$r = \hat{r}e^{j\theta}$ (refection factor of a reflecting surface)

where ρ = air density

θ = reflection phase.

MECHA-TRONIK

Fit of model parameters

Parameter depending on the wave number

The following cost function is needed to determine the optimal wave number:

$$J = \alpha \frac{(e_{Norm}{}^{H} e_{Norm})}{M \cdot max(e_{Norm})^2} + (1-\alpha)\frac{(e_{Phase}{}^{H} e_{Phase})}{M \cdot max(e_{Phase})^2}$$

Where,

$$e_{Norm} = |Z_{MEAS}| - |Z_{FEM}|;$$

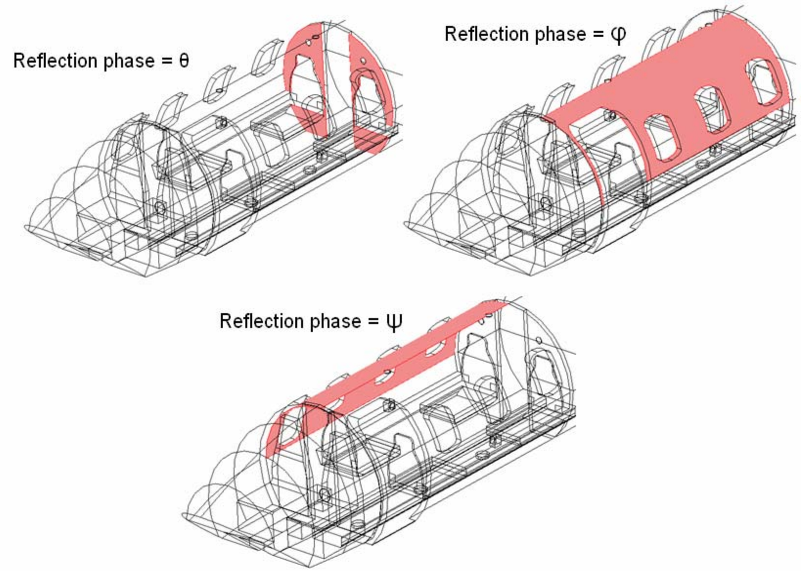
$$e_{Phase} = angle(Z_{MEAS}) - angle(Z_{MEAS});$$

Z_{MEAS} = Column matrix of the measured FRFs
Z_{FEM} = Column matrix of the computed FRFs
M = Number of measurement points
α = 0.5(Magnitude/Phase weighting factor).

➡ The optimal wave number corresponds to the values of the cost function minimum.

Parameter depending on the surface reflection

The Sound field can be arbitrary modified by changing the lining material reflection factor



	Parameters									
	wave number		Reflection factors (Magnitude and phase)						Loudspeaker correction	
	c[m/s]	β[1]	rθ [1]	θ [°]	rφ[1]	φ [°]	rψ[1]	ψ [°]	a[1]	Φ [°]
100 Hz	350	0,1	0,8	0	0,8	0	0,8	0	0,4	30
300 Hz	370	0,09	0,99	0	0,99	35	0,99	35	1	-10

Validation of model performance

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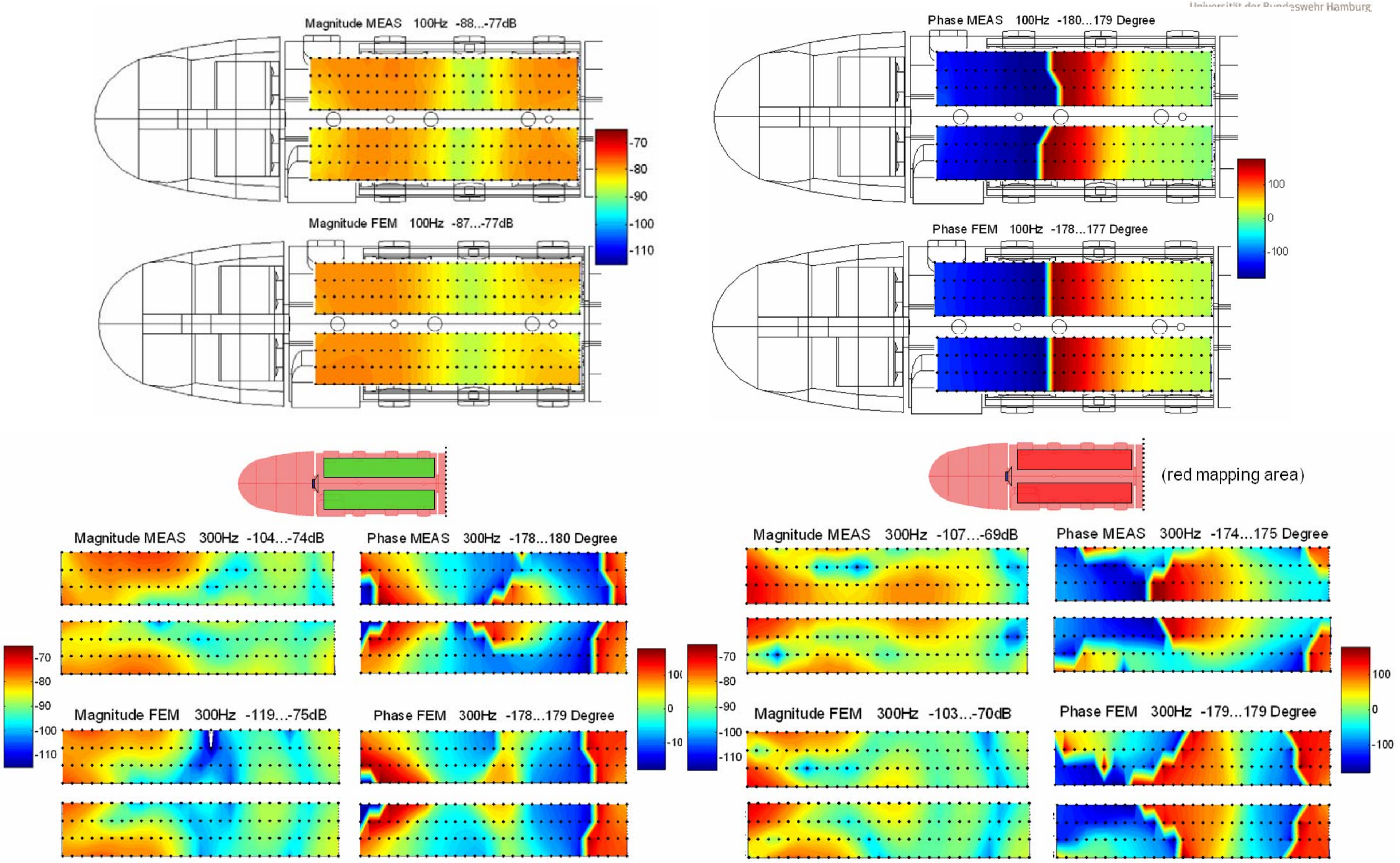

Error Analysis:

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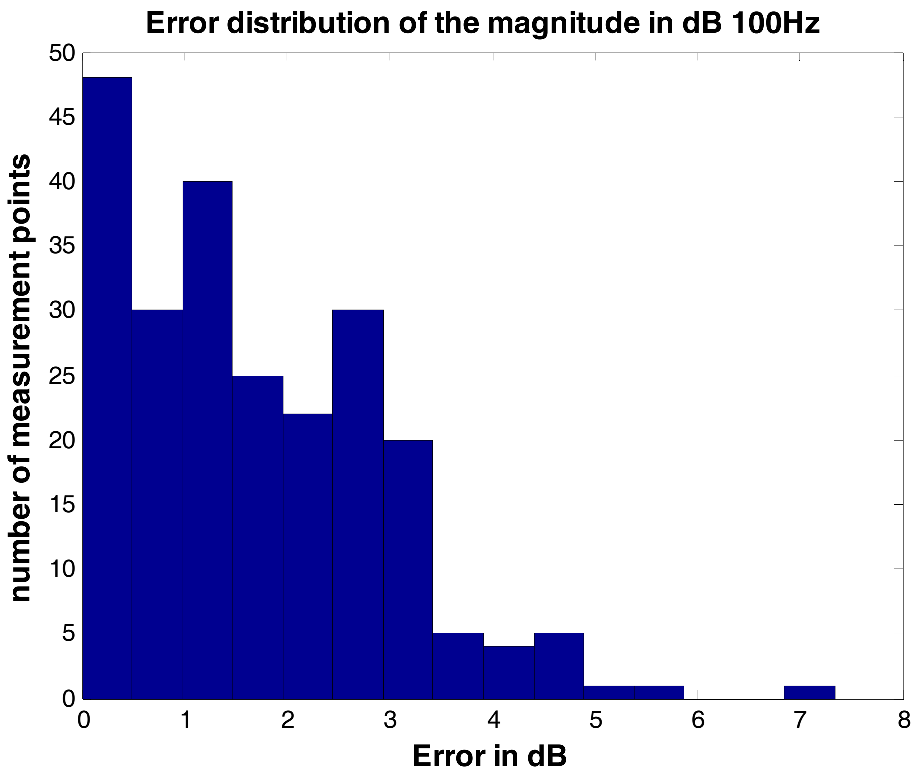
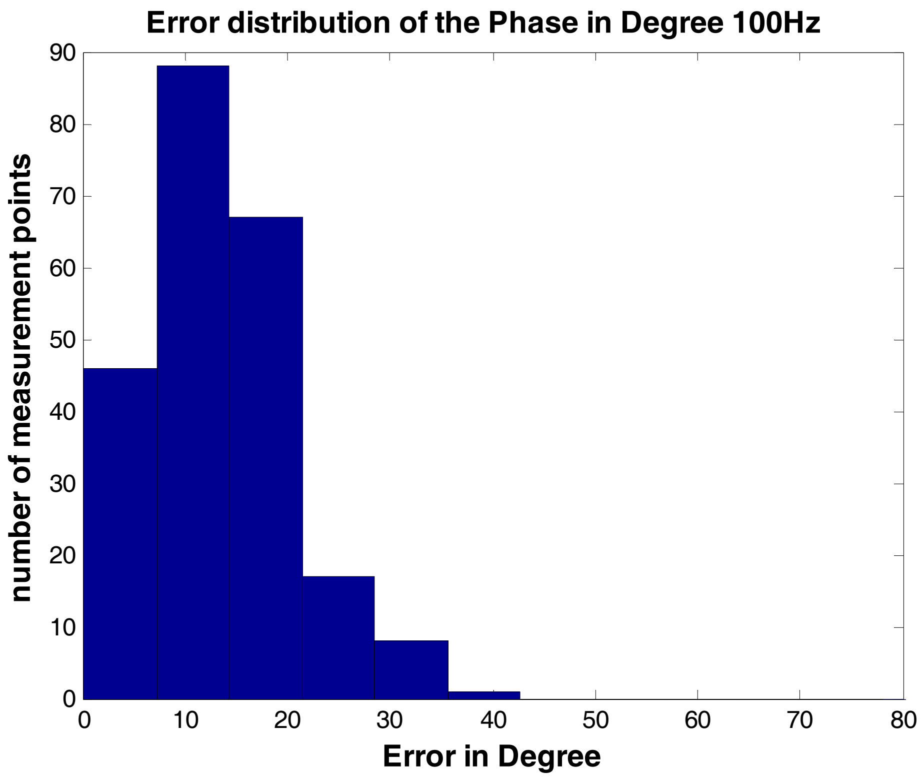
f=100 Hz; Green mapping area





Conclusion

- A FE-model of an acoustic mock-up cavity was presented. The model geometry was created in COMSOL MULTIPHYSICS 3.4.
- To validate the FE-model, a direct method for comparison without the consideration of uncertainty was used.
- The sound field in the mock-up cavity was mapped for one excitation position and three mapping areas.
- A sensitivity test was conducted in order to select the model adjustment parameters.
- Three main groups of adjustment parameters were defined:
  - the parameter depending on the wave number (sound speed and damping number)
  - the reflection factor for model boundaries (magnitude and phase)
  - the loudspeaker radiation correction factor (magnitude and phase).
- After adjustment, the results of the measurements and the FE-simulation for the frequencies 100Hz and 300Hz were presented.
- In the frequency 100Hz the FE-model presents a high accuracy level and can be used for both a qualitative and quantitative investigations.
- In the frequency 300Hz the FE-model can only be used for qualitative investigations.

Outlook

- Improvement of the FE-model accuracy using the **Monte Carlo Method** to fit all adjustment parameters at the same time.
- A **sequential algorithm** can be used to optimize the loudspeaker and the microphones positions.

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