AED Acoustic Engineering Dresden

create silence

AED Acoustic Engineering Dresden

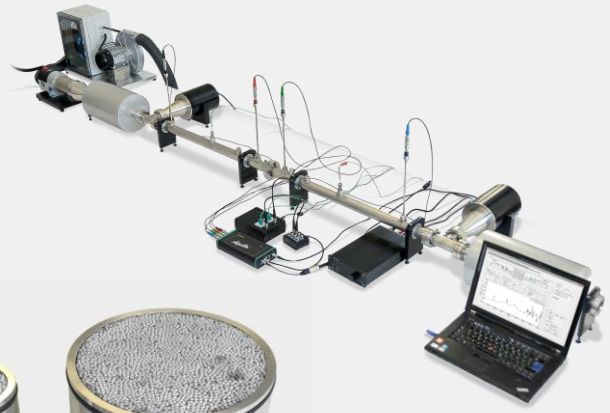
Gesellschaft für Akustikforschung Dresden mbH
Acoustic Engineering Dresden – AED

Acoustic Measuring Instruments & Analysis Software

AED Acoustic Engineering Dresden

Overview

- Measuring Systems
  - AcoustiFlow® – Airflow resistivity meter
  - AcoustiAdrienne – Sound absorption meter
  - AcoustiTube® – Impedance tube
  - AcoustiTube® HighTemp – Test setup for mufflers
  - AcoustiCam® – Acoustic camera



- Application Software
  - AcoustiCalc® Absorber – Sound absorber software
  - AcoustiCalc® Silencer – Muffler software

Overview

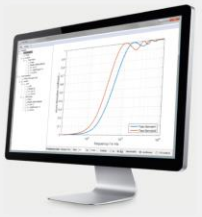
Sound absorption meter
AcoustiAdrienne

Airflow resistivity meter
AcoustiFlow®

Material values (independent of geometry)
Ξ Airflow resistivity
k_a, Z_a Wave number, Impedance

Application values (dependent on geometry)
α Sound absorption coefficient
D_{TL} Transmission loss
T Transfer matrix

Measurement
Import
Ξ
Import
T
Import
Measurement
Simulation
α
Import
k_a, Z_a
Import
Simulation
D_{TL}
Measurement
Measurement
Measurement
Measurement

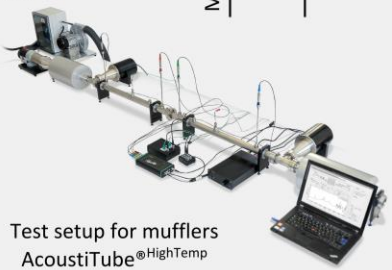


Simulation software
for sound absorbers
AcoustiCalc®Absorber

Simulation software
for silencers and mufflers
AcoustiCalc®Silencer

Impedance tube
AcoustiTube®

Transmission tube
AcoustiTube®



Test setup for mufflers
AcoustiTube®HighTemp

Muffler Software AcoustiCalc® Silencer

Sound absorption meter
AcoustiAdrienne

Airflow resistivity meter
AcoustiFlow®

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Material values (independent of geometry)
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Measurement
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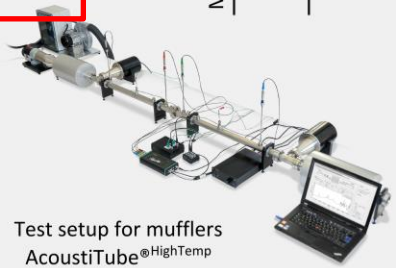
Simulation software
for sound absorbers
AcoustiCalc®Absorber

Simulation software
for silencers and mufflers
AcoustiCalc®Silencer

Impedance tube
AcoustiTube®

Transmission tube
AcoustiTube®



Test setup for mufflers
AcoustiTube®HighTemp

Acoustic design of silencers and mufflers with AcoustiCalc® Silencer – AED 8001

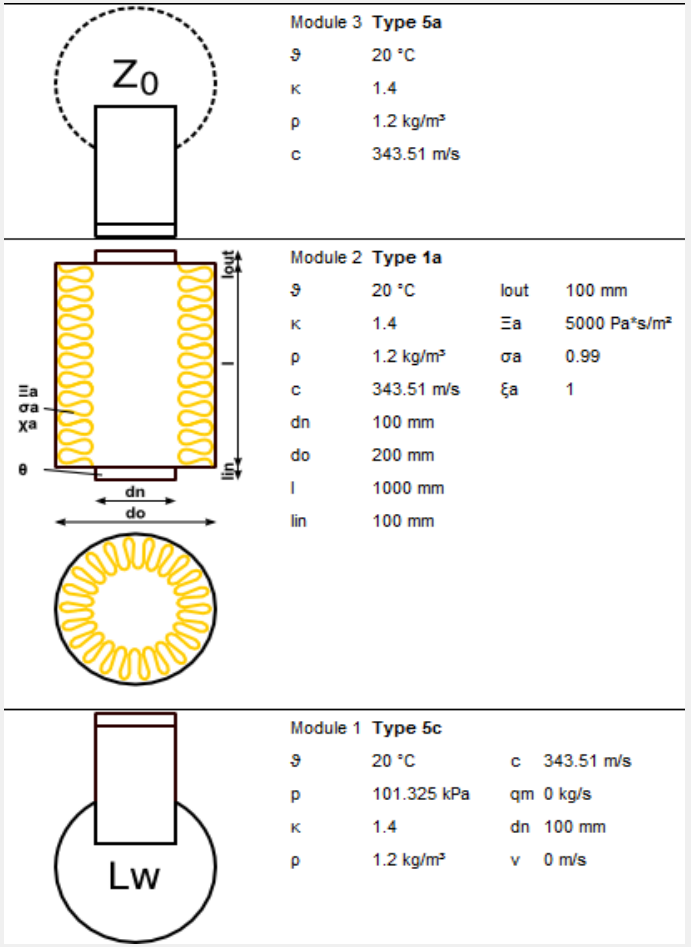
- acoustic efficiency of silencers and mufflers depends on **geometry** and **position** within the overall system of silencers and mufflers
- determination of transmission loss and insertion loss of **complete systems** of silencers and mufflers by describing as four-poles according to linear network theory

Fields of Application

- acoustic design of single components or complete systems of silencers of mufflers with respect to given constraints, e. g.
  - spectral sound power level
  - operating conditions
  - available space
  - applicable material
  - permitted airflow generated noise
  - permitted pressure drop
- computational integration of single silencers and mufflers within defined periphery
  - import of measurement data
  - import of numerical results

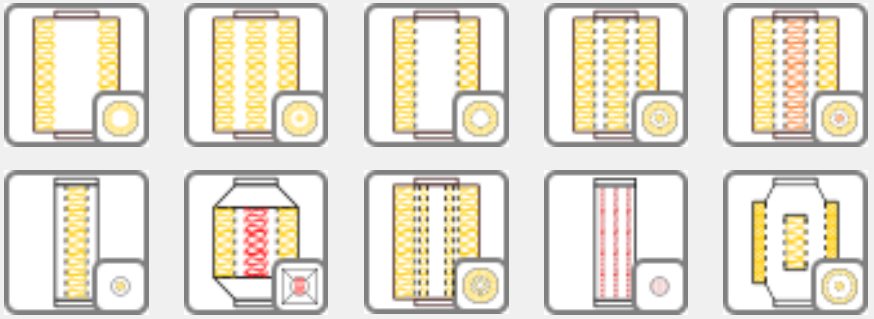
Principle

- definition of complete system
  - type of silencer / muffler / duct element
  - geometrical dimensions
  - material
- definition of operating conditions of source
  - temperature
  - volume airflow
  - pressure
- evaluation of acoustic efficiency of complete system
  - computation of transmission loss / insertion loss (definition of acoustical termination)

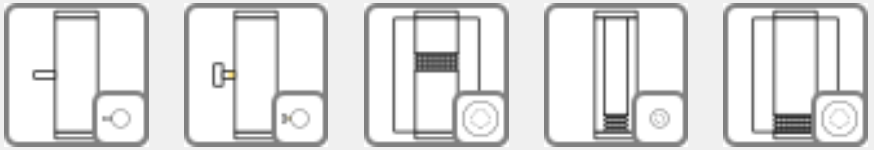


Elements

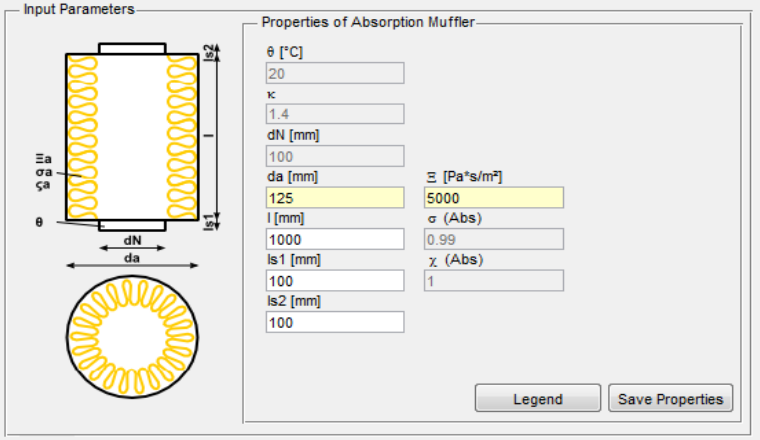
- type of silencer / muffler / duct element
  - absorption mufflers



  - resonance mufflers

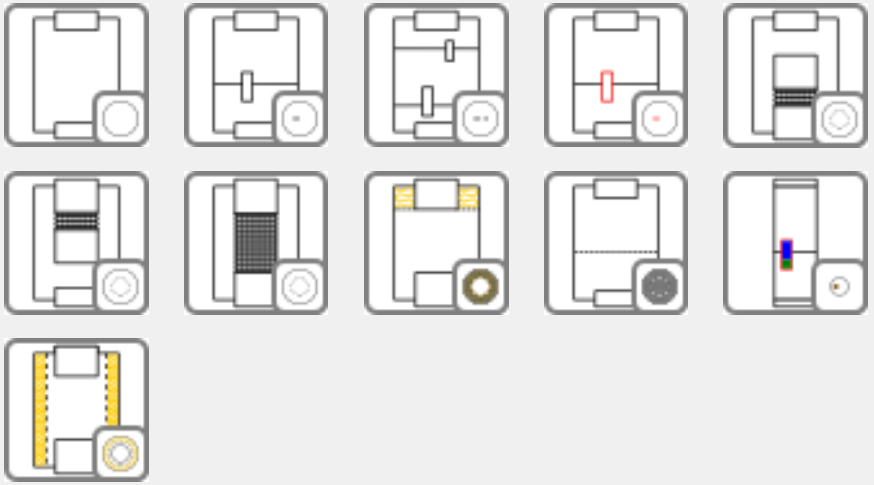


parametrized geometry

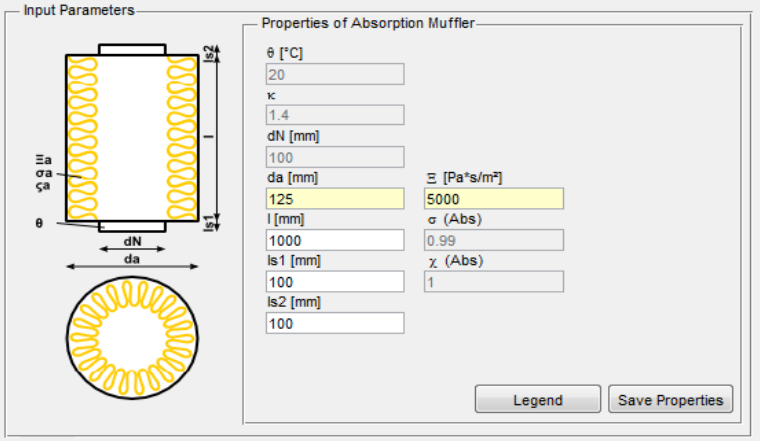


Elements

- type of silencer / muffler / duct element
  - reflection mufflers



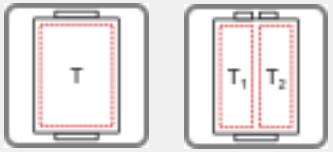
parametrized geometry



Elements

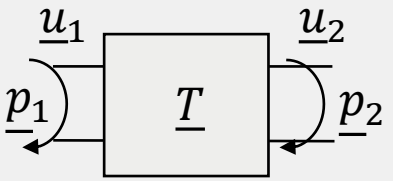
- type of silencer / muffler / duct element
  - duct elements

  - import of measured elements



  - special functional elements

four-pole



$$\begin{pmatrix} \underline{p}_1 \\ \underline{u}_1 \end{pmatrix} = \underline{T} \begin{pmatrix} \underline{p}_2 \\ \underline{u}_2 \end{pmatrix}$$

Physical Definition

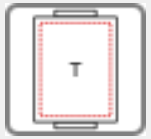
- sound propagation along silencer / muffler / duct elements
  - Transmission function of rigid duct

$$T_i = \mathrm{e}^{-\mathrm{j}Mk_\mathrm{c}l} \begin{pmatrix} \cos k_\mathrm{c}l & \mathrm{j}Z \sin k_\mathrm{c}l \\ \mathrm{j}\frac{1}{Z} \sin k_\mathrm{c}l & \cos k_\mathrm{c}l \end{pmatrix} \qquad k_\mathrm{c} = \frac{k}{1-M^2}$$

  - Absorption muffler with internal baffle

$$\begin{vmatrix} \frac{-k_{\mathrm{r}1}\mathrm{J}_1(k_{\mathrm{r}1}r_1)}{k_\mathrm{w}Z_\mathrm{w}} & \frac{k_{\mathrm{r}2}\mathrm{J}_1(k_{\mathrm{r}2}r_1)}{k_0Z_0} & \frac{k_{\mathrm{r}2}\mathrm{Y}_1(k_{\mathrm{r}2}r_1)}{k_0Z_0} & 0 & 0 \\ \mathrm{J}_0(k_{\mathrm{r}1}r_1) & -\mathrm{J}_0(k_{\mathrm{r}2}r_1) & -\mathrm{Y}_0(k_{\mathrm{r}2}r_1) & 0 & 0 \\ 0 & -\frac{k_{\mathrm{r}2}\mathrm{J}_1(k_{\mathrm{r}2}r_2)}{k_0Z_0} & -\frac{k_{\mathrm{r}2}\mathrm{Y}_1(k_{\mathrm{r}2}r_2)}{k_0Z_0} & \frac{k_{\mathrm{r}3}\mathrm{J}_1(k_{\mathrm{r}3}r_2)}{k_\mathrm{w}Z_\mathrm{w}} & \frac{k_{\mathrm{r}3}\mathrm{Y}_1(k_{\mathrm{r}3}r_2)}{k_\mathrm{w}Z_\mathrm{w}} \\ 0 & \mathrm{J}_0(k_{\mathrm{r}2}r_2) & \mathrm{Y}_0(k_{\mathrm{r}2}r_2) & -\mathrm{J}_0(k_{\mathrm{r}3}r_2) & -\mathrm{Y}_0(k_{\mathrm{r}3}r_2) \\ 0 & 0 & 0 & \frac{k_{\mathrm{r}3}\mathrm{J}_1(k_{\mathrm{r}3}r_3)}{k_\mathrm{w}Z_\mathrm{w}} & \frac{k_{\mathrm{r}3}\mathrm{Y}_1(k_{\mathrm{r}3}r_3)}{k_\mathrm{w}Z_\mathrm{w}} \end{vmatrix} = 0$$

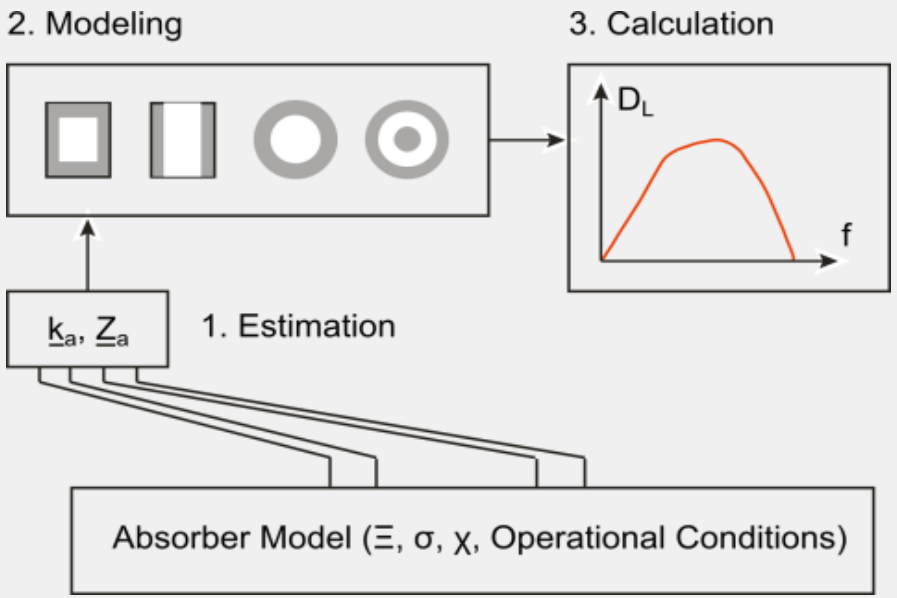
  - Transmission function of overall system



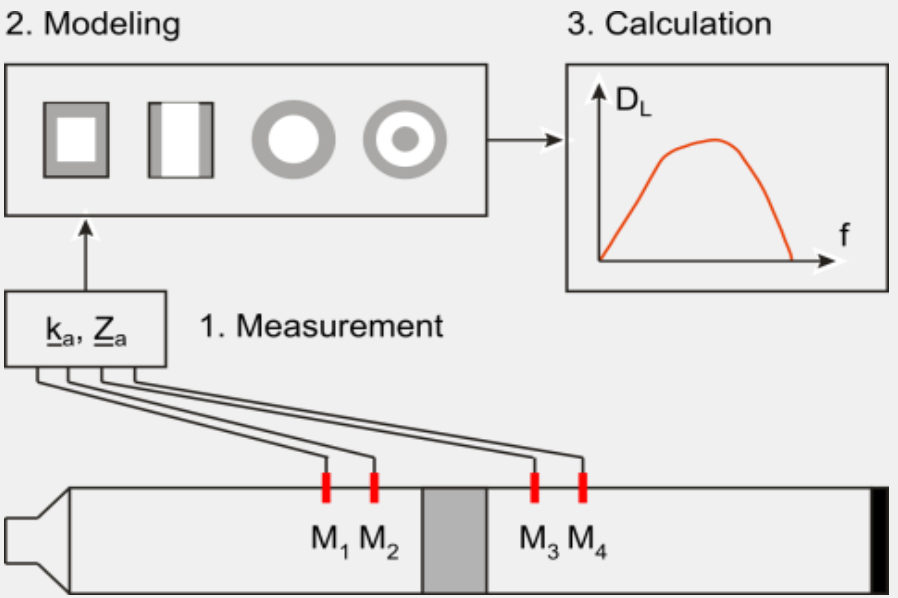
$$T = \prod_i T_i$$

Calculation Method

- description of absorber materials by characteristic absorber values



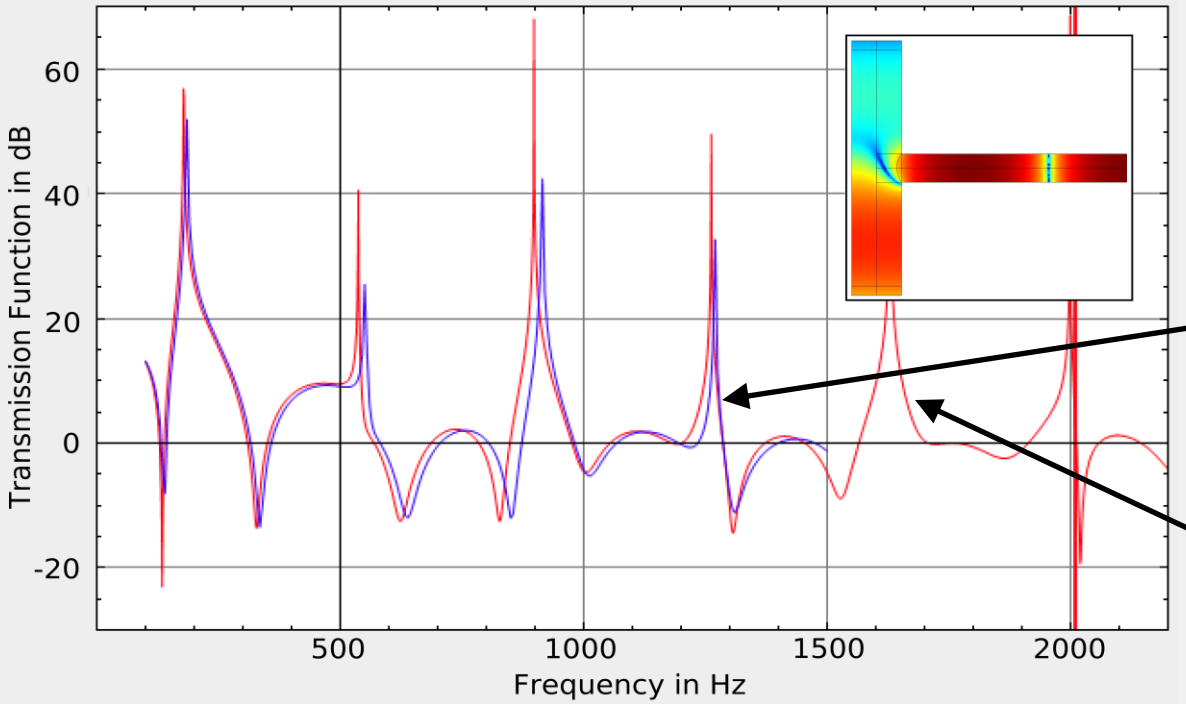
estimation by application of absorber model



direct measurement by application of AcoustiTube®

Calculation Method

- accuracy of calculation

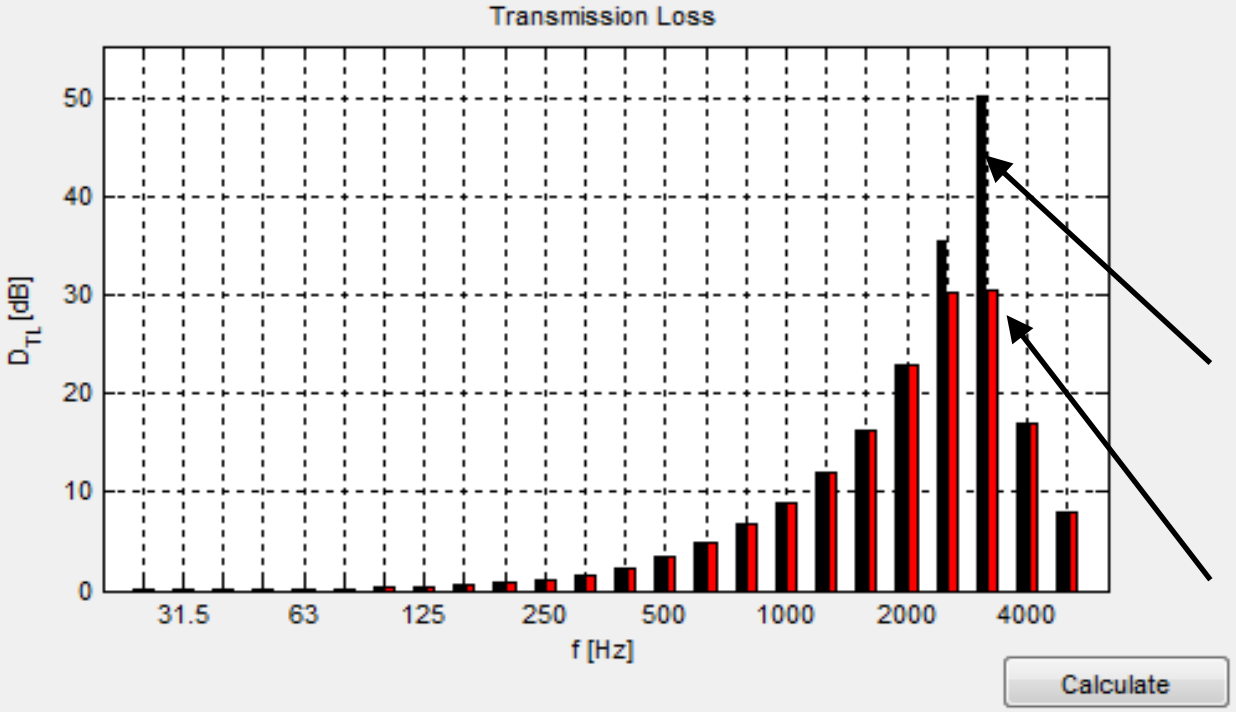


analytical calculation
by fast and easy application
of AcoustiCalc®

numerical calculation
by complex and time consuming
application of FEM-software

Calculation Method

- accuracy of calculation

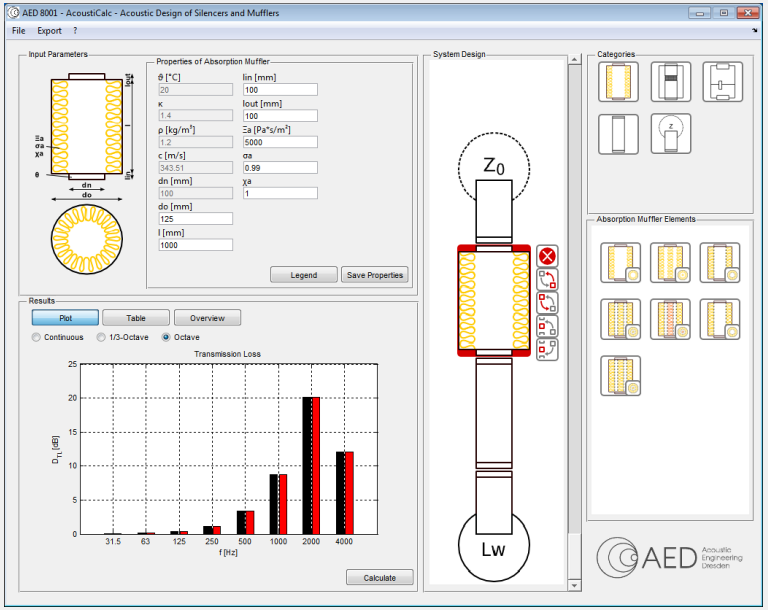


with
...

without
consideration of structure-borne sound propagation (construction / fabrication)

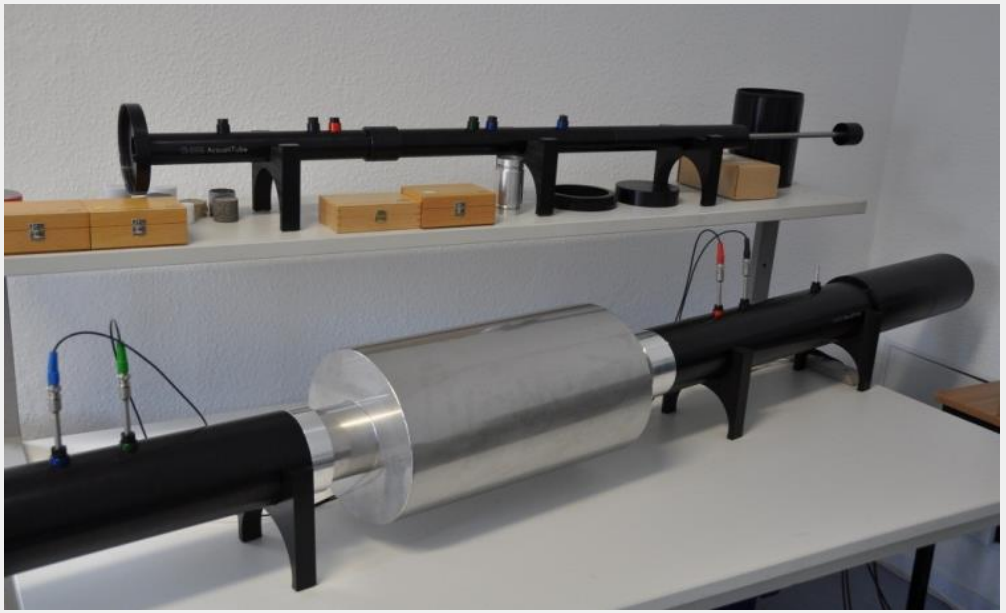
Analysis software AED 8001 – AcoustiCalc® Silencer

- determination of transmission loss and insertion loss of complete systems of silencers and mufflers as a function of frequency
- estimation of airflow generated noise
- estimation of pressure drop



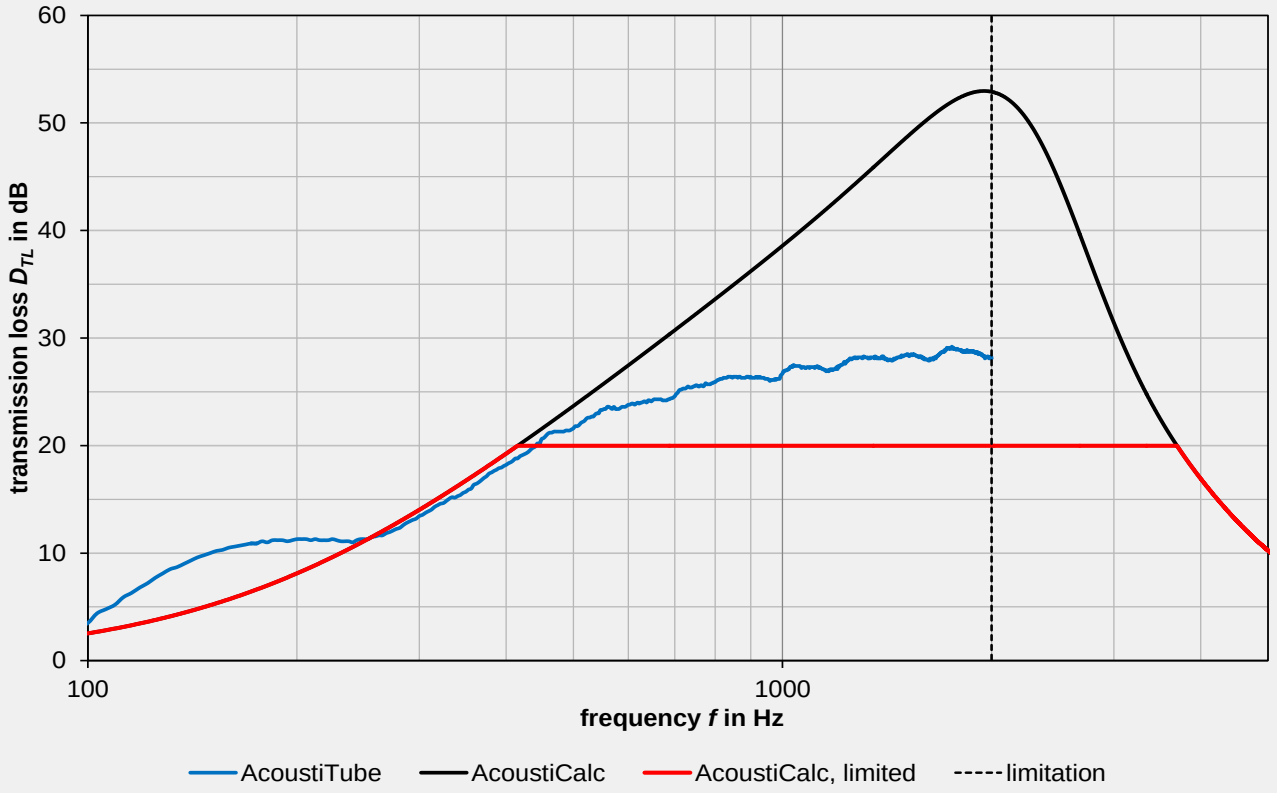
Measurement vs. Simulation Results – Absorption Muffler

- acoustic evaluation of absorption muffler at room temperature
  - measurement with transmission tube AED 1200 – AcoustiTube®
  - analytical calculation by means of muffler software AED 8001 – AcoustiCalc® Silencer



Measurement vs. Simulation Results – Absorption Muffler

- comparison of transmission loss of measurement and analytical calculation



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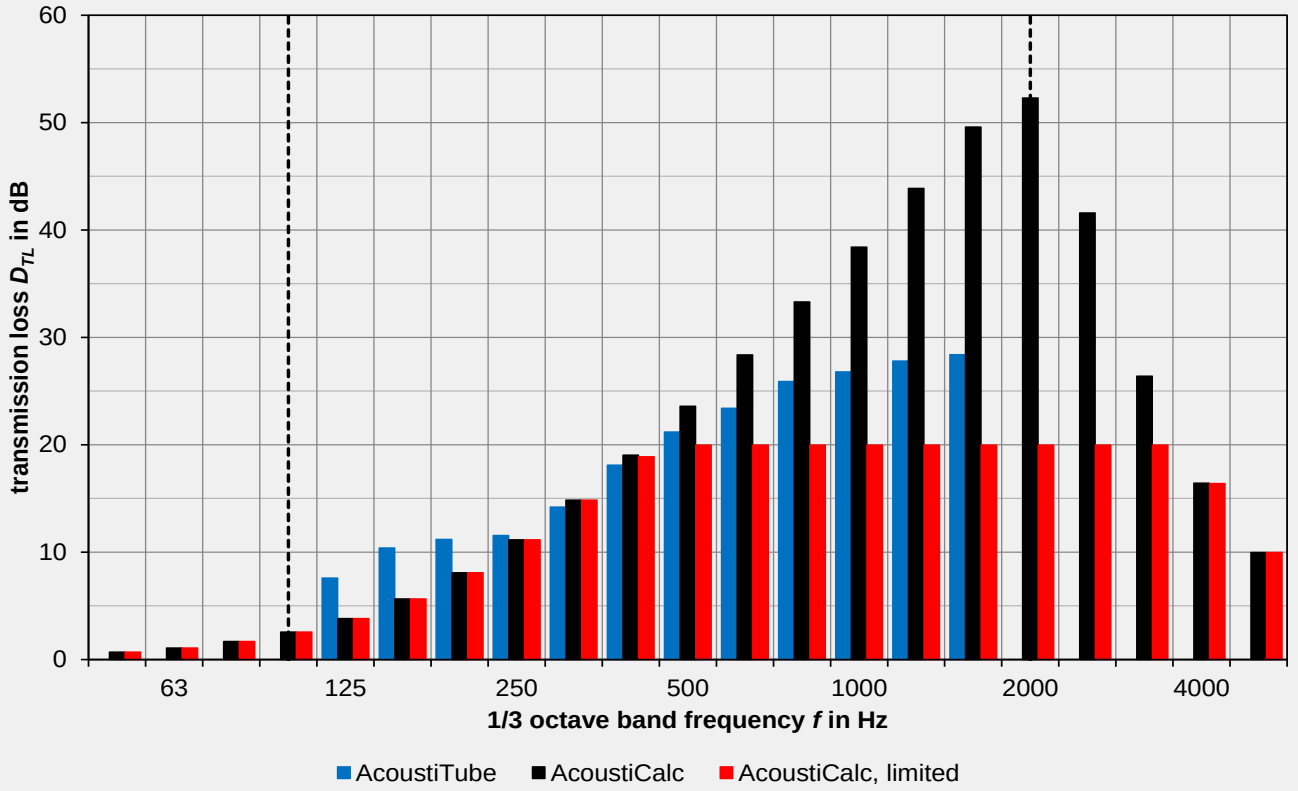
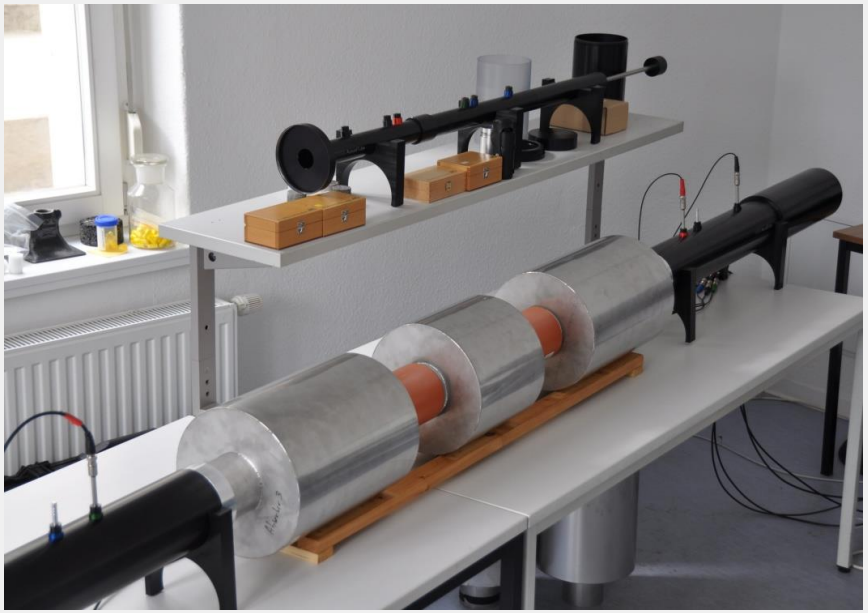


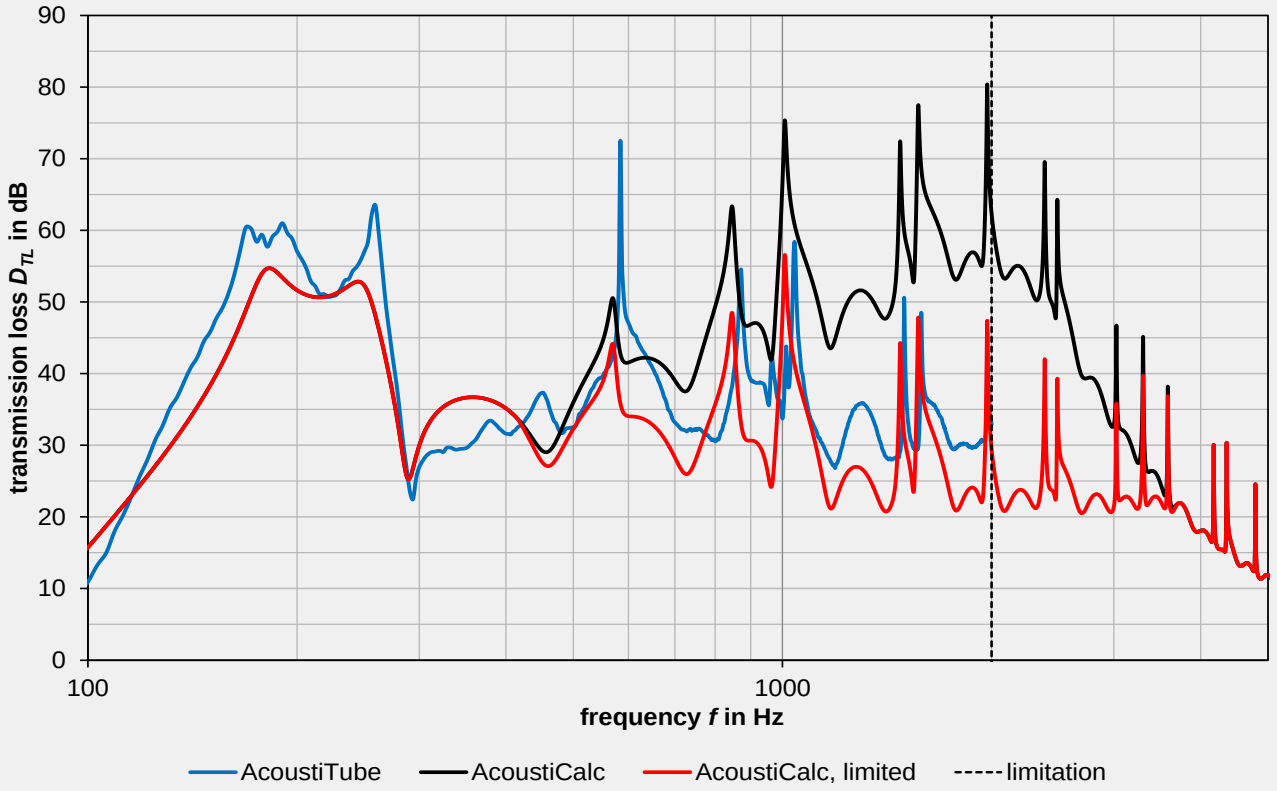
Measurement vs. Simulation Results – Absorption + Resonance Mufflers

- acoustic evaluation of absorption muffler + two resonance mufflers at room temperature
  - measurement with transmission tube AED 1200 – AcoustiTube®
  - analytical calculation by means of muffler software AED 8001 – AcoustiCalc® Silencer



Measurement vs. Simulation Results – Absorption + Resonance Mufflers

- comparison of transmission loss of measurement and analytical calculation



Measurement vs. Simulation Results – Absorption + Resonance Mufflers

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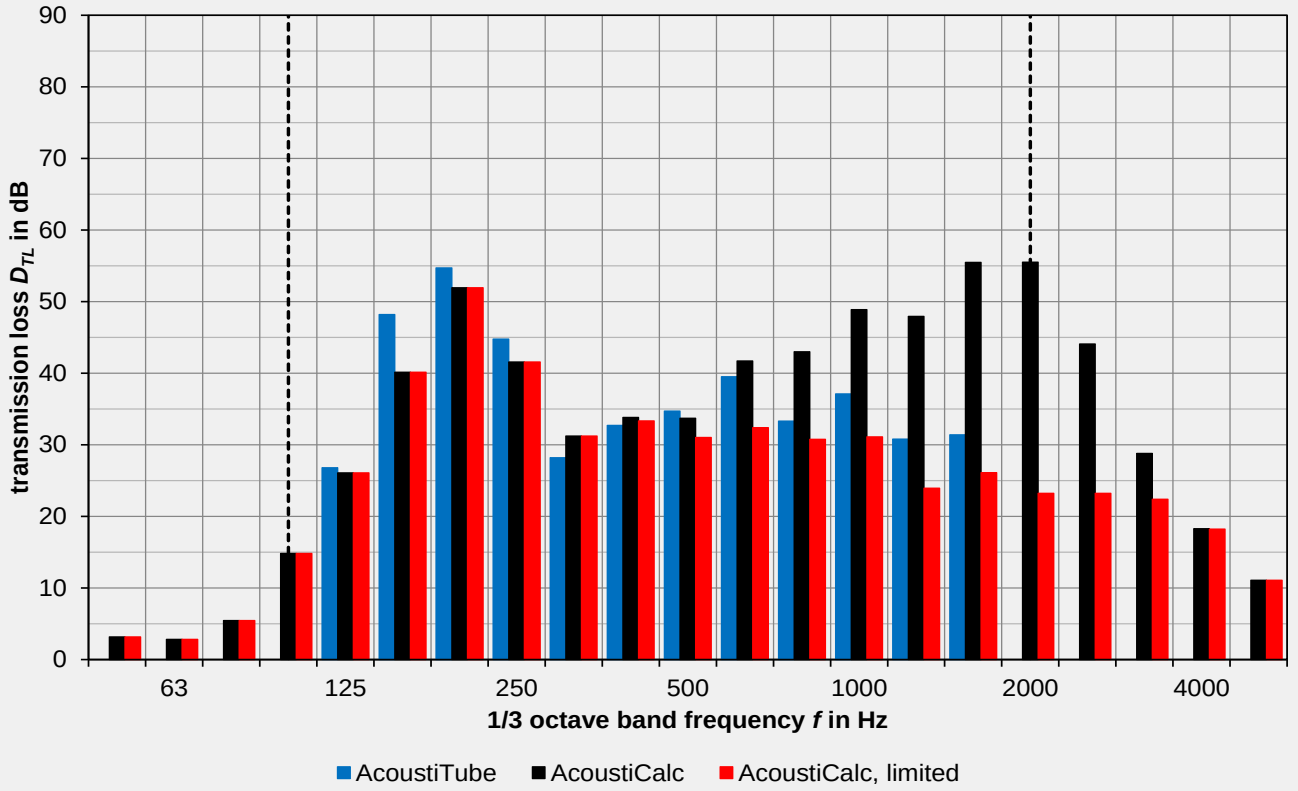

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