

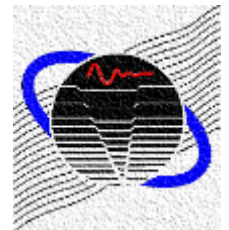
October 23, 2020

VAC Toolbox

Muffler Modeling Module

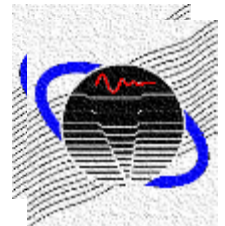
Caoyang LI
University of Kentucky

Vibro-Acoustics Consortium



VAC Toolbox

- The VAC Toolbox muffler module has been thoroughly updated and is current with the latest MATLAB version. It runs with MATLAB Runtime 9.9 which can be accessed on the MathWorks website.
- The software does not require you to have MATLAB.
- Software is available to VAC members.



Transfer Matrix Method Based

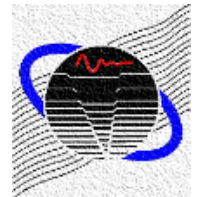
Assumes that all elements are in series with each other.

$$\begin{Bmatrix} p_1 \\ Q_1 \end{Bmatrix} = \begin{bmatrix} T_{11}^1 & T_{12}^1 \\ T_{21}^1 & T_{22}^1 \end{bmatrix} \begin{Bmatrix} p_2 \\ Q_2 \end{Bmatrix}$$

$$T_1 = \begin{bmatrix} T_{11}^1 & T_{12}^1 \\ T_{21}^1 & T_{22}^1 \end{bmatrix} \quad T_2 = \begin{bmatrix} T_{11}^2 & T_{12}^2 \\ T_{21}^2 & T_{22}^2 \end{bmatrix} \quad T_3 = \begin{bmatrix} T_{11}^3 & T_{12}^3 \\ T_{21}^3 & T_{22}^3 \end{bmatrix} \quad \dots \dots$$

$$[T_{Global}] = [T_1][T_2] \dots [T_{10}]$$

$$\begin{Bmatrix} p_1 \\ Q_1 \end{Bmatrix} = [T_{Global}] \begin{Bmatrix} p_{10} \\ Q_{10} \end{Bmatrix}$$



User Interface

Muffler_modeling

Environment Setting

Calculate Parameters

Start Frequency (Hz): 10
 Step size (Hz): 10
 End Frequency (Hz): 3000
 Fluid Speed (m/s): 343
 Fluid Density (kg/m³): 1.21
 Default Temperature: 20
 End Correction: Anechoic End
 Set

Source Impedance

☒ Anechoic $Z_s = \rho c$
☐ Infinite $Z_s = 0$
☐ $Y_0(A - iA)$, Y_0 is Characteristic Impedance
 Constant A: 0.707
☐ User Input file:
 Load Impedance File

Velocity Source tab **Pressure Source tab**

Velocity Source

☒ Constant Particle Velocity (m/s): 1
☐ User input Load Velocity Source File
 Plot and Set

Calculate

Four Pole Parameters
 Transmission Loss
 Insertion Loss
 Pressure at Opening

Muffler Modeling

Element Library

☒ Uniform Tube Parameters
☐ Helmholtz Resonator Parameters
☐ Quarter-Wavelength Tube Parameters
☐ Extended Inlet/Outlet Parameters
☐ Series Impedance Parameters
 Add into Model

Muffler Overview

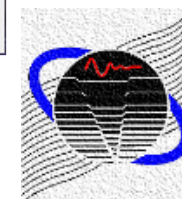
☒ Element 1 ☐ Element 2 ☐ Element 3 ☐ Element 4 ☐ Element 5 ☐ Element 6 ☐ Element 7 ☐ Element 8 ☐ Element 9 ☐ Element 10

N/A N/A N/A N/A N/A N/A N/A N/A N/A N/A

N/A N/A N/A N/A N/A N/A N/A N/A N/A N/A

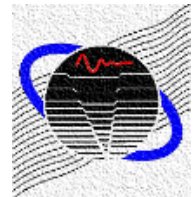
Off On Off On Off On Off On Off On Off On Off On Off On

Remove
 New Case
 Save Project



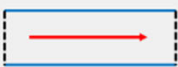
Environment Settings

The screenshot displays the 'Muffler_modeling' software window. A red rectangle highlights the 'Environment Setting' section on the left. This section includes a 'Calculate Parameters' panel with input fields for Start Frequency (10 Hz), Step size (10 Hz), End Frequency (3000 Hz), Fluid Speed (343 m/s), Fluid Density (1.21 kg/m³), Default Temperature (20), and End Correction (Anechoic End). Below these is a 'Set' button. To the right of the highlighted area is the 'Source Impedance' section with three radio button options: 'Anechoic' (selected, $Z_s = \rho c$), 'Infinite' ($Z_s = 0$), and 'Y0*(A - iA)' (where Y0 is Characteristic Impedance, Constant A = 0.707). There is also a 'User Input file' option and a 'Load Impedance File' button. The main area of the window has two tabs: 'Velocity Source tab' (active) and 'Pressure Source tab'. The 'Velocity Source' panel has two radio button options: 'Constant' (selected, Particle Velocity = 1 m/s) and 'User input' (with a 'Load Velocity Source File' button). A 'Plot and Set' button is at the bottom right of this panel. On the far right, a 'Calculate' section contains four buttons: 'Four Pole Parameters', 'Transmission Loss', 'Insertion Loss', and 'Pressure at Opening'.

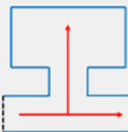


Muffler Modeling

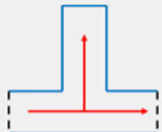
Element Library




☒ Uniform Tube
Parameters




☐ Helmholtz Resonator
Parameters



☐ Quarter-Wavelength Tube
Parameters



☐ Extended Inlet/Outlet
Parameters



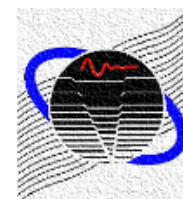
☐ Series Impedance
Parameters

Add into Model

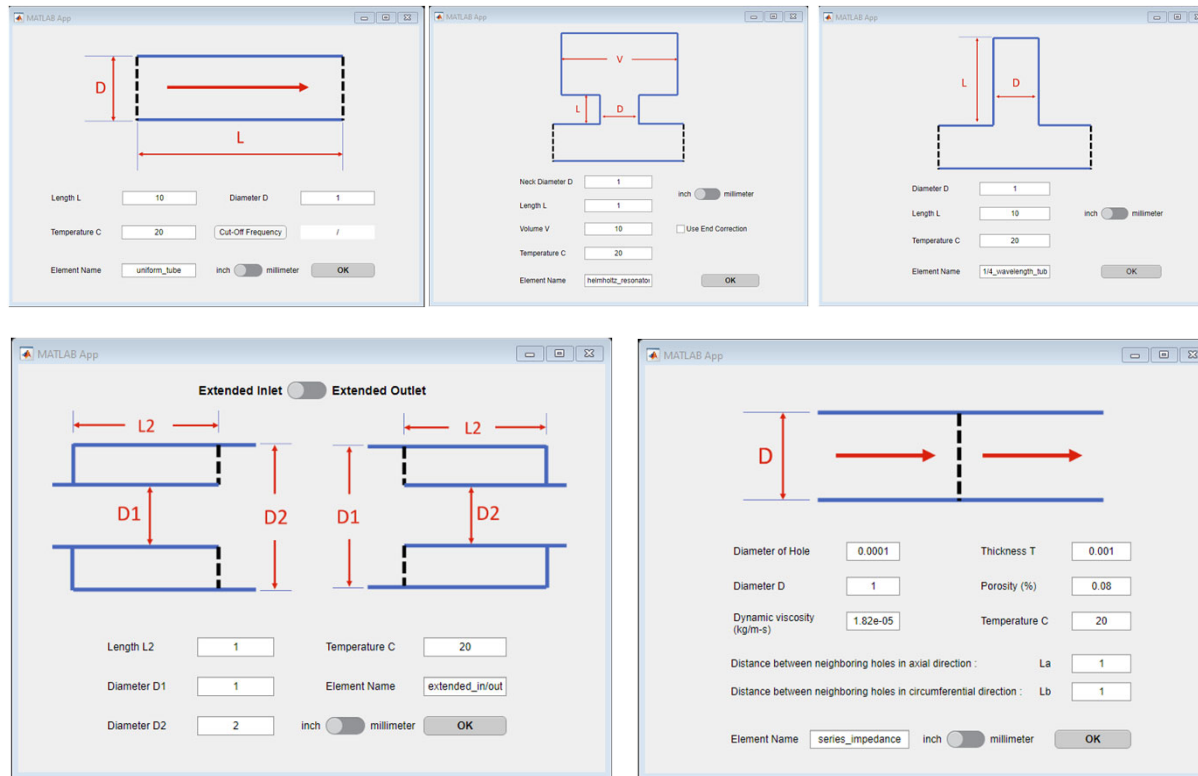
Muffler Overview

☒ Element 1
 ☐ Element 2
 ☐ Element 3
 ☐ Element 4
 ☐ Element 5
 ☐ Element 6
 ☐ Element 7
 ☐ Element 8
 ☐ Element 9
 ☐ Element 10

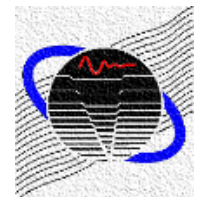
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Remove New Case Save Project
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	



Define Element Parameters



Temperature for each element may be considered.



Calculation

Muffler_modeling

Environment Setting

Calculate Parameters

Start Frequency (Hz)
Step size (Hz)
End Frequency (Hz)
Fluid Speed (m/s)
Fluid Density (kg/m³)
Default Temperature
End Correction

Source Impedance

☒ Anechoic $Z_s = pc$
☐ Infinite $Z_s = 0$
☐ $Y_0(A - iA)$, Y_0 is Characteristic Impedance
Constant A
☐ User Input file:

Velocity Source tab **Pressure Source tab**

Velocity Source

☒ Constant Particle Velocity (m/s)
☐ User input

Calculate

Muffler Modeling

Element Library

☒ Uniform Tube
☐ Helmholtz Resonator
☐ Quarter-Wavelength Tube
☐ Extended Inlet/Outlet
☐ Series Impedance

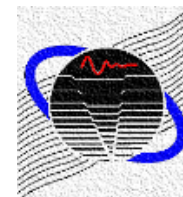
Muffler Overview

☒ Element 1 ☐ Element 2 ☐ Element 3 ☐ Element 4 ☐ Element 5 ☐ Element 6 ☐ Element 7 ☐ Element 8 ☐ Element 9 ☐ Element 10

N/A N/A N/A N/A N/A N/A N/A N/A N/A N/A

N/A N/A N/A N/A N/A N/A N/A N/A N/A N/A

Off On Off On Off On Off On Off On Off On Off On Off On Off On



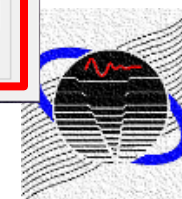
Muffler Modeling Workflow

The screenshot displays the Muffler Modeling software interface, which is divided into several sections. The top section, titled "Muffler_modeling", contains three main panels. The left panel, "Environment Setting", includes fields for "Calculate Parameters" (Start Frequency, Step size, End Frequency, Fluid Speed, Fluid Density, Default Temperature) and "End Correction" (Anechoic End). The middle panel, "Source Impedance", has radio buttons for "Anechoic", "Infinite", and "Y0*(A - iA)", with corresponding fields for "Zs", "Constant A", and "Load Impedance File". The right panel, "Velocity Source tab", has a "Velocity Source" section with radio buttons for "Constant" (Particle Velocity) and "User input" (Load Velocity Source File). The bottom right of this section has a "Plot and Set" button. The rightmost panel, "Calculate", contains buttons for "Four Pole Parameters", "Transmission Loss", "Insertion Loss", and "Pressure at Opening".

The middle section, "Muffler Modeling", is titled "Element Library" and shows five element types: "Uniform Tube", "Helmholtz Resonator", "Quarter-Wavelength Tube", "Extended Inlet/Outlet", and "Series Impedance". Each element has a schematic diagram and a "Parameters" button. A large blue number "2" is overlaid on the "Quarter-Wavelength Tube" element.

The bottom section, "Muffler Overview", shows a list of 10 elements. Each element has a status indicator (N/A or a red dot) and a toggle switch (Off/On). A large blue number "3" is overlaid on the "Element 6" status indicator. To the right of the list are buttons for "Remove", "New Case", and "Save Project".

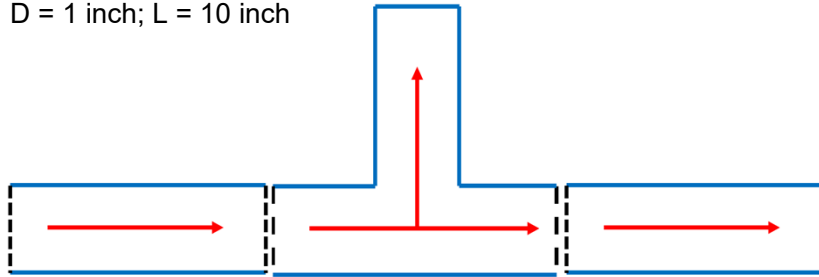
A large blue number "4" is overlaid on the "Calculate" panel in the top right section.



Transmission Loss Quarter Wavelength Tube

Uniform Tubes:

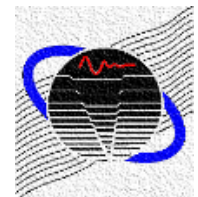
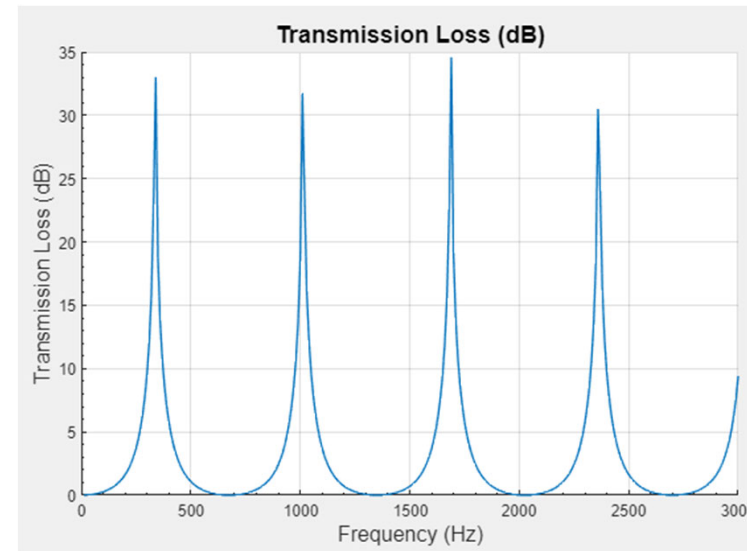
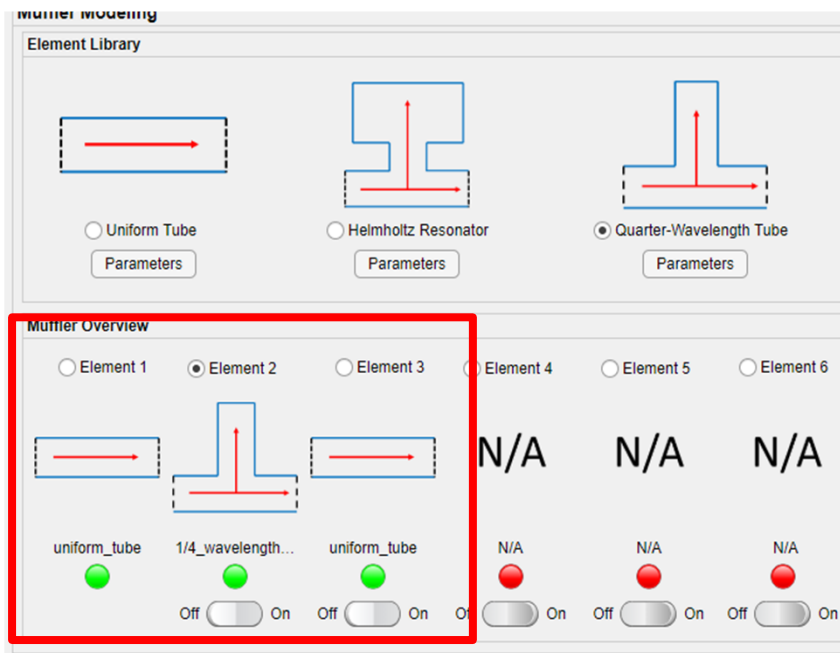
D = 1 inch; L = 10 inch



Quarter Wavelength Tubes:

Branch Diameter = 1 inch

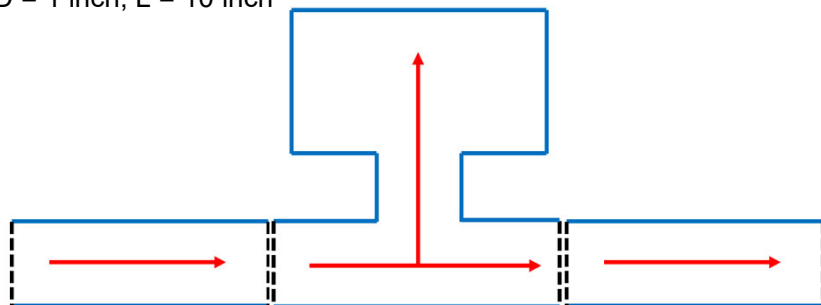
Branch Length = 10 inch



Transmission Loss Helmholtz Resonator

Uniform Tubes:

D = 1 inch; L = 10 inch



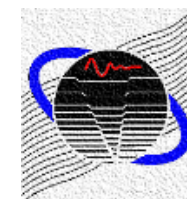
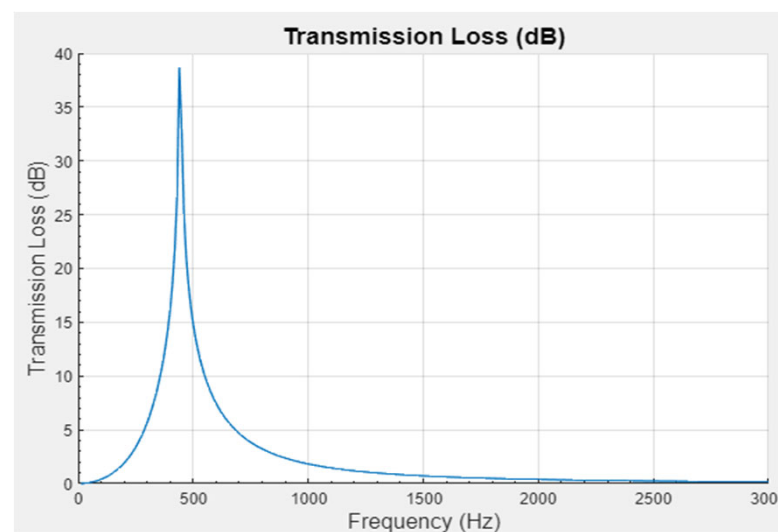
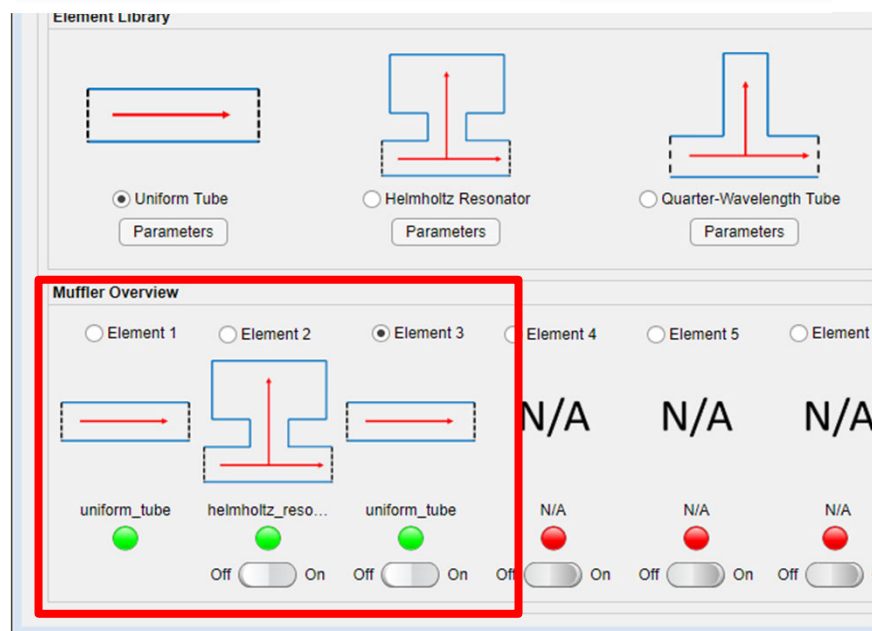
Helmholtz Resonator:

Neck Diameter = 1 inch

Neck Length = 10 inch

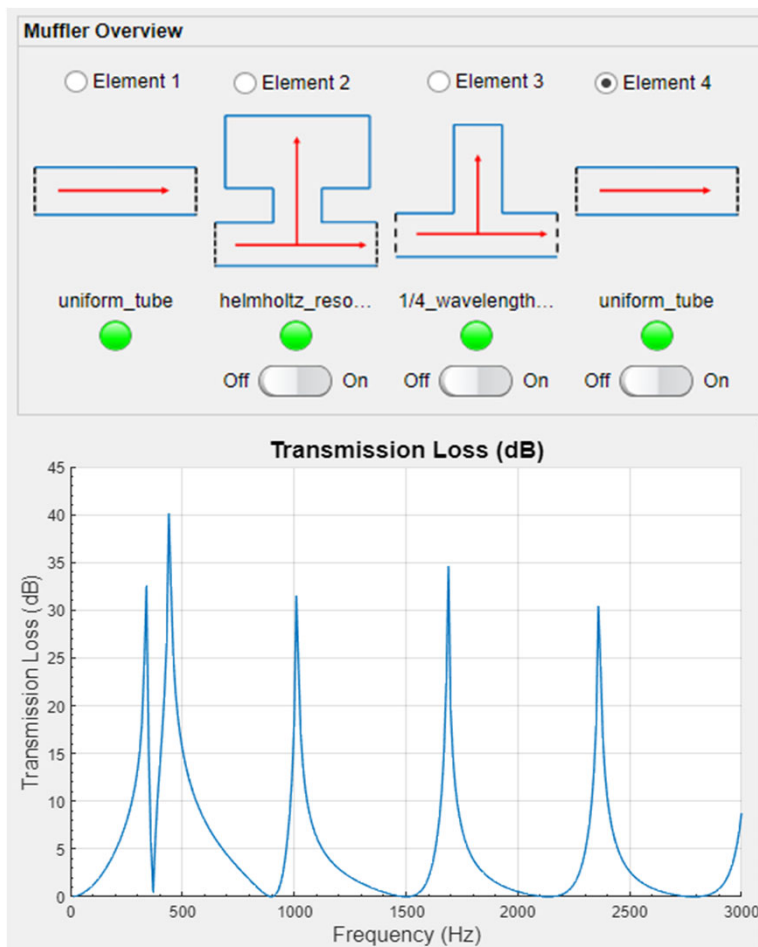
Volume = 10 cubic inch

(neck end correction used)

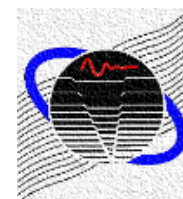
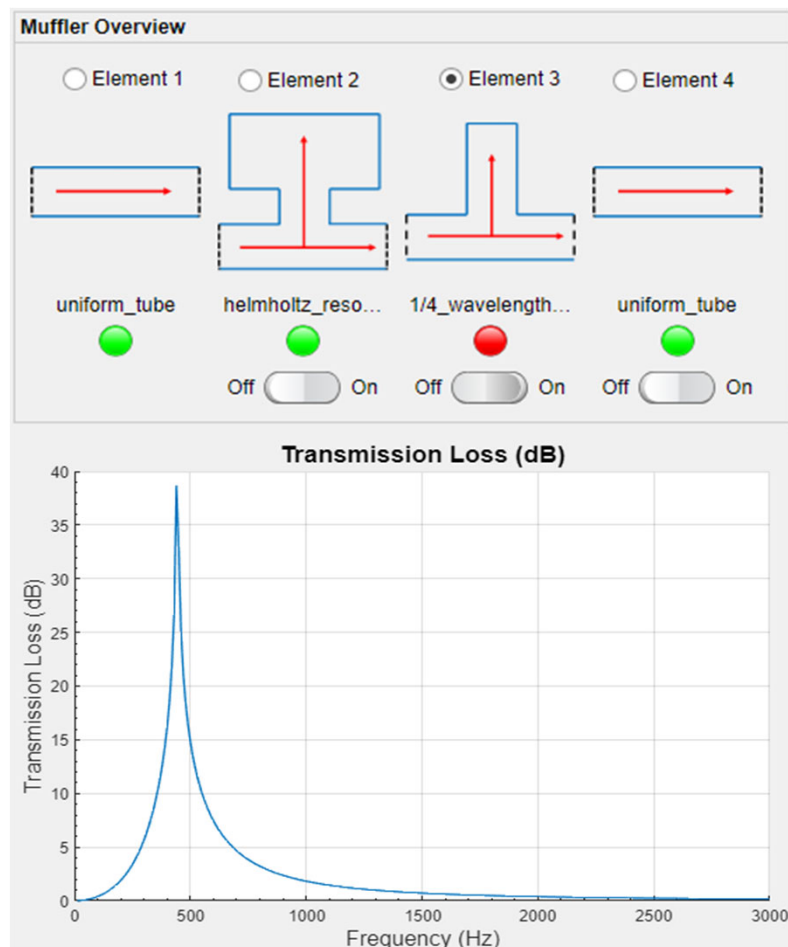


Transmission Loss Simple Muffler

With quarter wavelength tube



Without quarter wavelength tube



Compare with SIDLAB

Helmholtz Resonator:

Neck Diameter = 1 inch

Neck Length = 10 inch

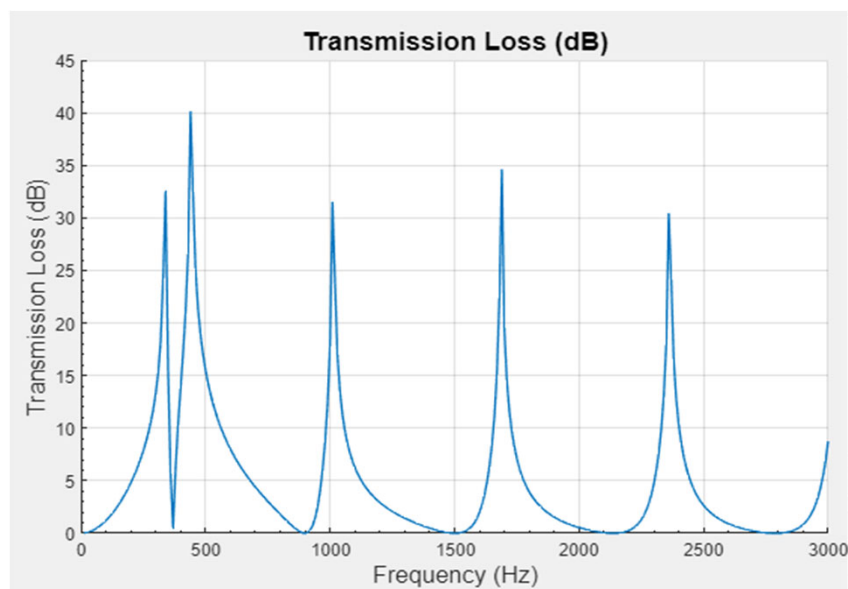
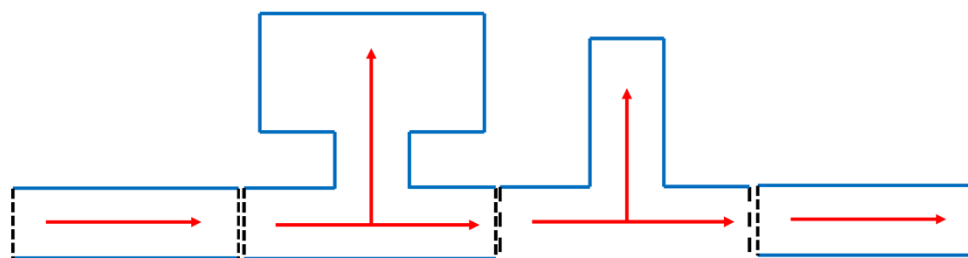
Volume = 10 cubic inch

(neck end correction used)

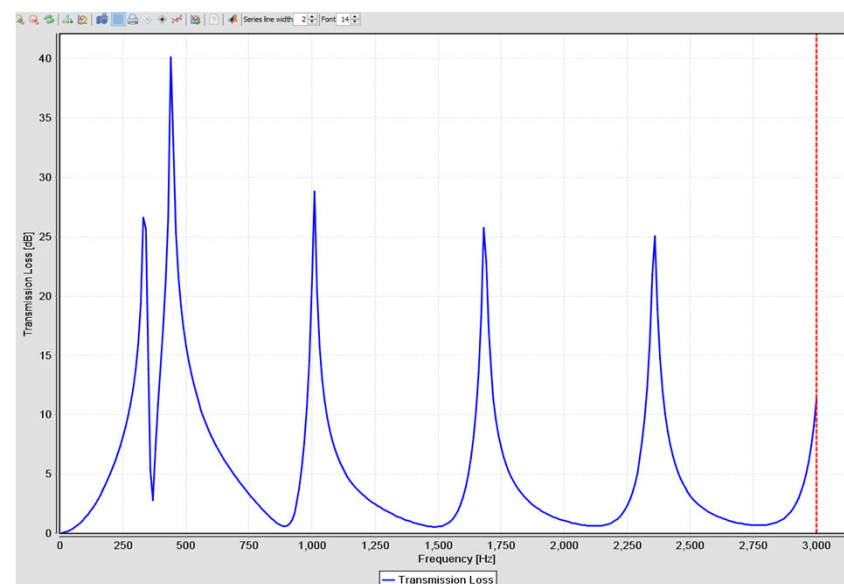
Quarter Wavelength Tubes:

Branch Diameter = 1 inch

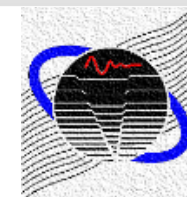
Branch Length = 10 inch



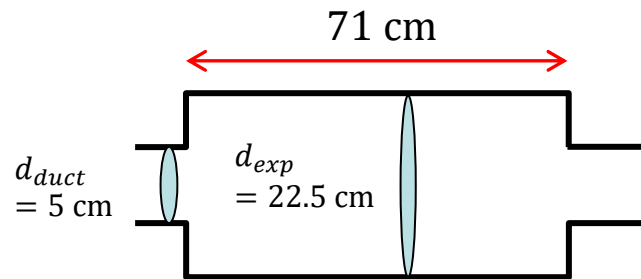
VAC Toolbox



SIDLAB



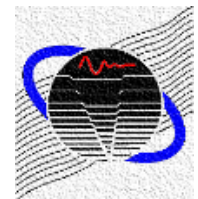
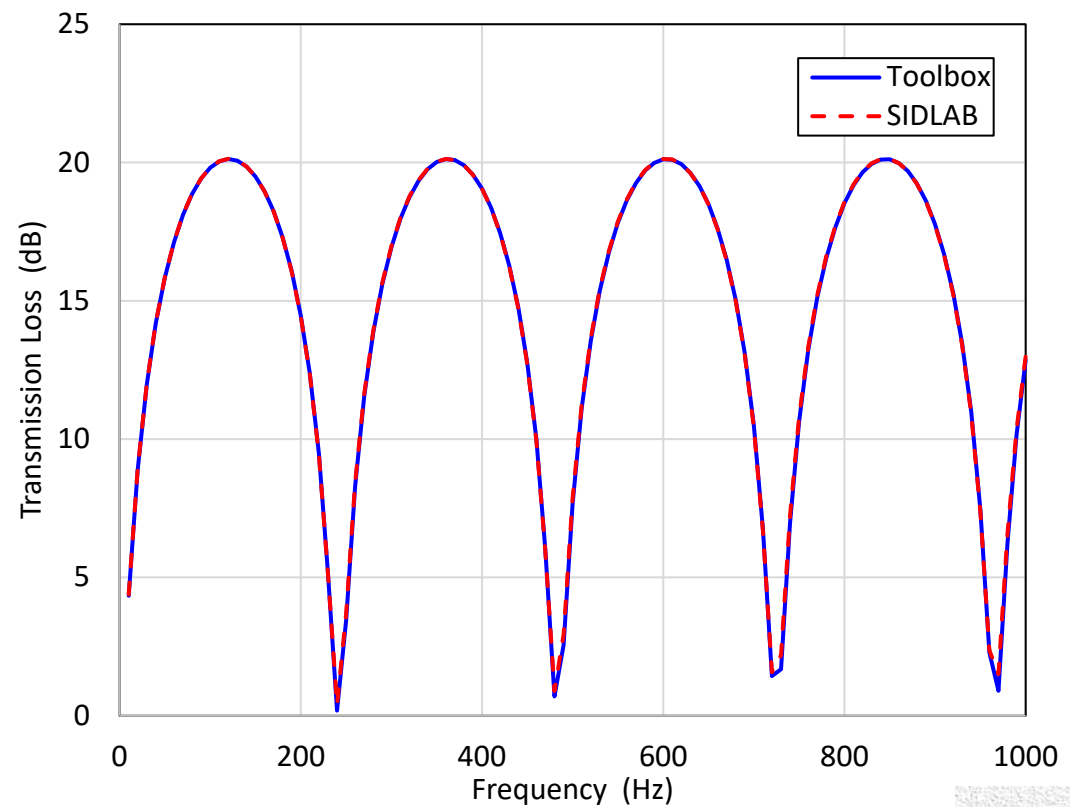
Transmission Loss SEC



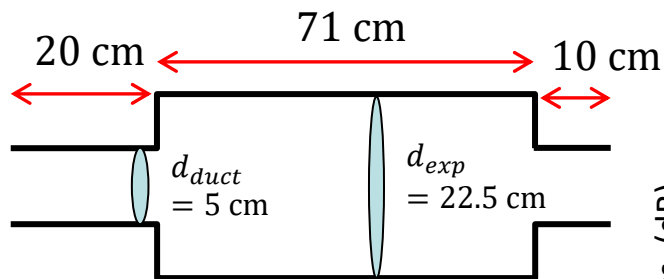
$$d_{duct} = 5 \text{ cm}$$

$$d_{exp} = 22.5 \text{ cm}$$

$$L = 71 \text{ cm}$$



Insertion Loss SEC



$$d_{duct} = 5 \text{ cm}$$

$$d_{exp} = 22.5 \text{ cm}$$

$$L = 71 \text{ cm}$$

