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The Use of Internal Constraints to Enhance the Sound Transmission Loss of Poroelastic Linings

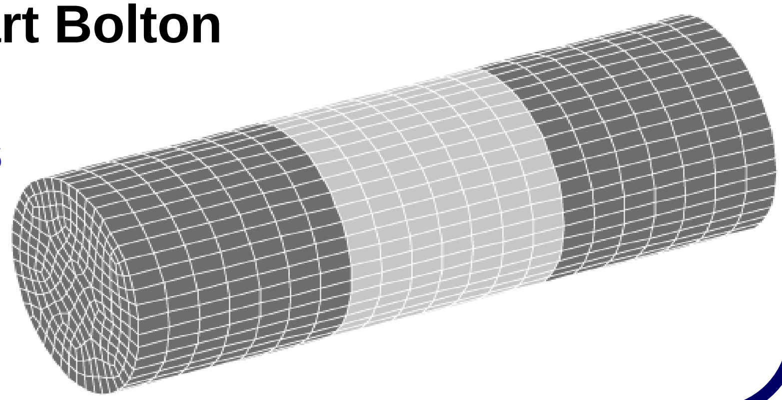
J Stuart Bolton
Purdue University, bolton@purdue.edu

Bryan H. Song

THE USE OF INTERNAL CONSTRAINTS TO ENHANCE THE SOUND TRANSMISSION LOSS OF POROELASTIC LININGS

B. Heukjin Song and J. Stuart Bolton

Ray W. Herrick Laboratories
Purdue University



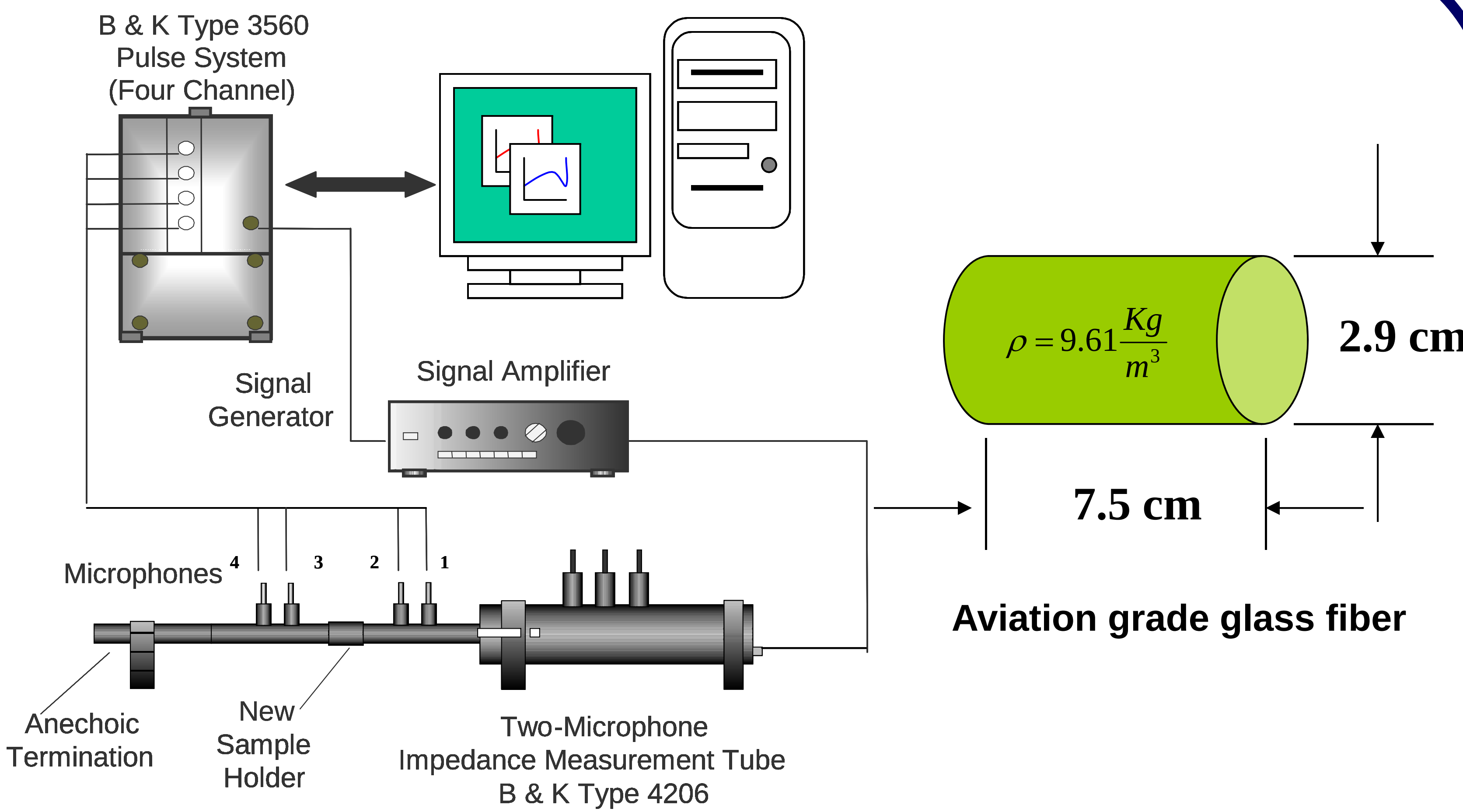
Introduction

- **Investigation of edge constraint effect on samples placed in a modified standing wave tube (B. H. Song et al., *JASA* 1999; J. S. Bolton et al., *SAE* 1997).**

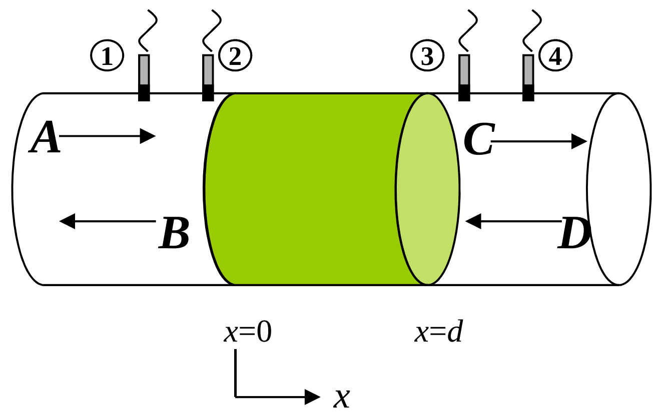
- **Internal constraints may be used to selectively enhance the transmission loss of lining materials at low frequencies**

- **Implications for design of low frequency noise control barriers following from constraint of porous lining materials around their edges.**

Experimental Setup High Frequency Tube



Transfer Matrix Approach I



$$\begin{bmatrix} P \\ V \end{bmatrix}_{x=0} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} P \\ V \end{bmatrix}_{x=d}$$

$T_{11} = T_{22}$ ⇒ **symmetry**

$T_{11}T_{22} - T_{12}T_{21} = 1$ ⇒ **reciprocity**

4 Equations

- **Solve for transfer matrix elements**

Transfer Matrix Approach II

$$\begin{bmatrix} 1+R_a \\ \dfrac{1-R_a}{\rho_0 c_0} \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} T_a e^{-jkd} \\ \dfrac{T_a e^{-jkd}}{\rho_0 c_0} \end{bmatrix}$$

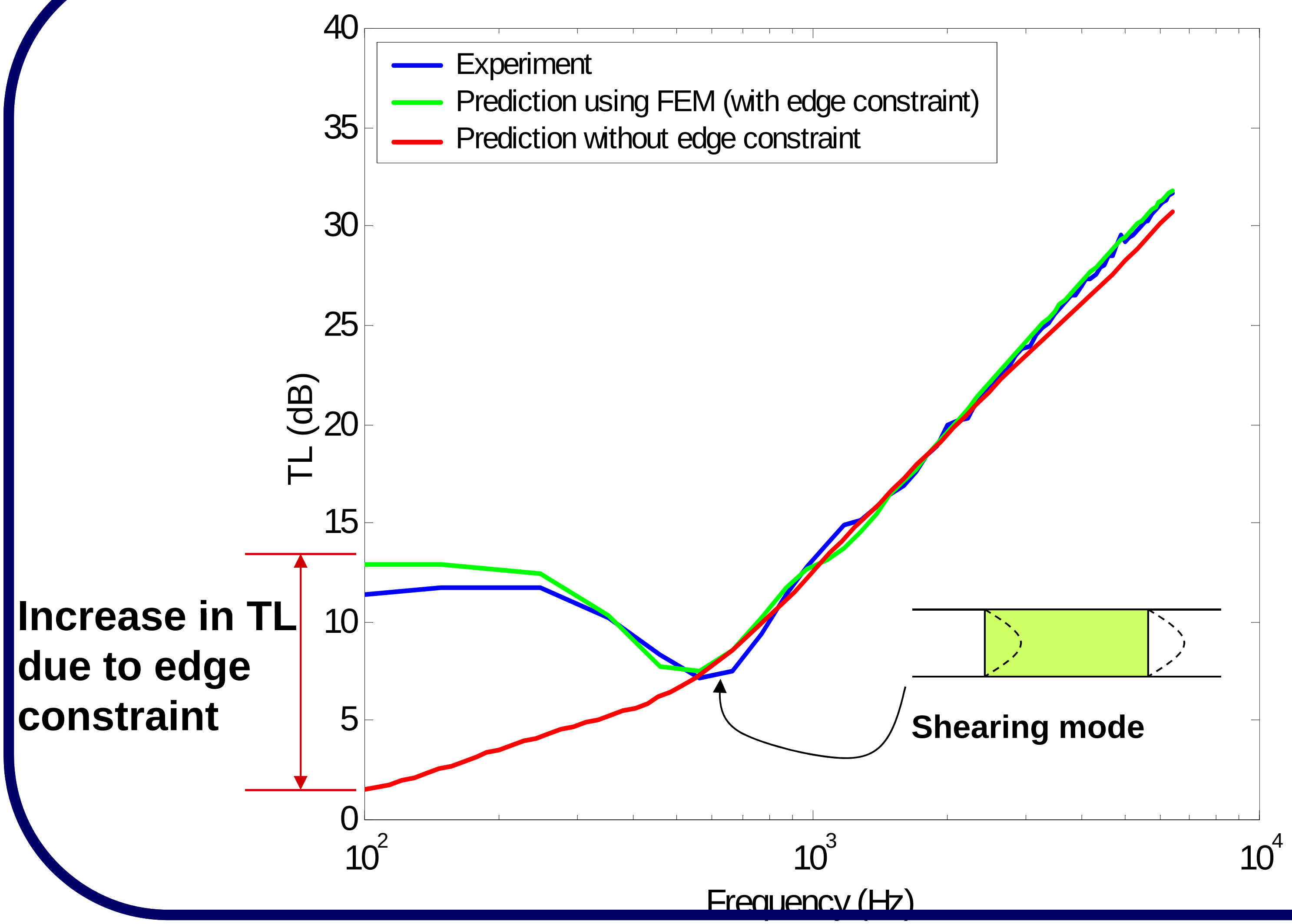
- **Anechoic Reflection Coefficient**

$$R_a = \frac{T_{11} + \dfrac{T_{12}}{\rho_0 c} - \rho_0 c T_{21} - T_{22}}{T_{11} + \dfrac{T_{12}}{\rho_0 c} + \rho_0 c T_{21} + T_{22}} \quad \Rightarrow \quad \alpha = 1 - |R_a|^2, \quad Z_n = \frac{1+R_a}{1-R_a}$$

- **Anechoic Transmission Coefficient**

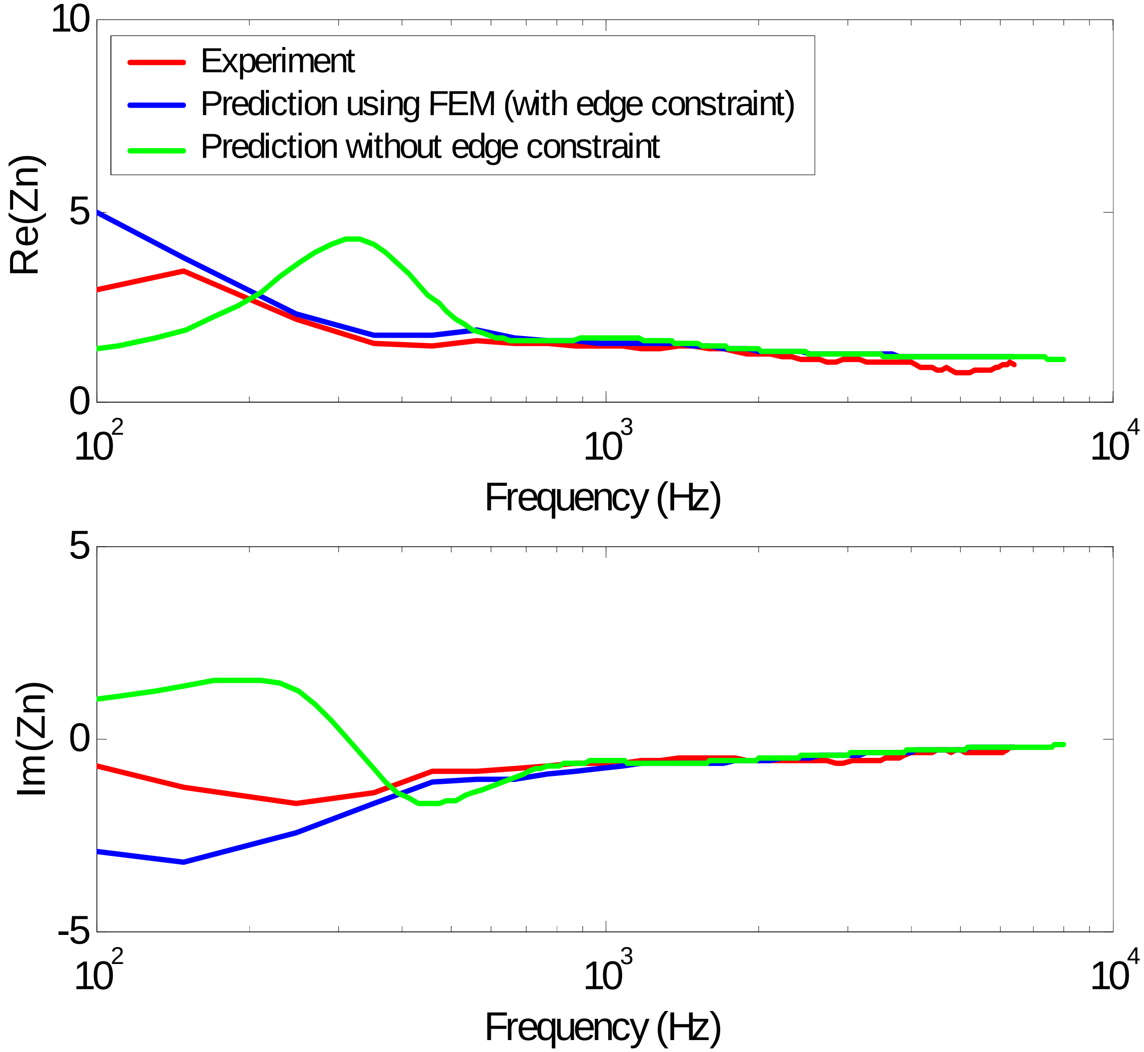
$$T_a = \frac{2e^{jkd}}{T_{11} + \dfrac{T_{12}}{\rho_0 c} + \rho_0 c T_{21} + T_{22}} \quad \Rightarrow \quad TL = 10\log(1/|T_a|^2)$$

Anechoic Transmission Loss



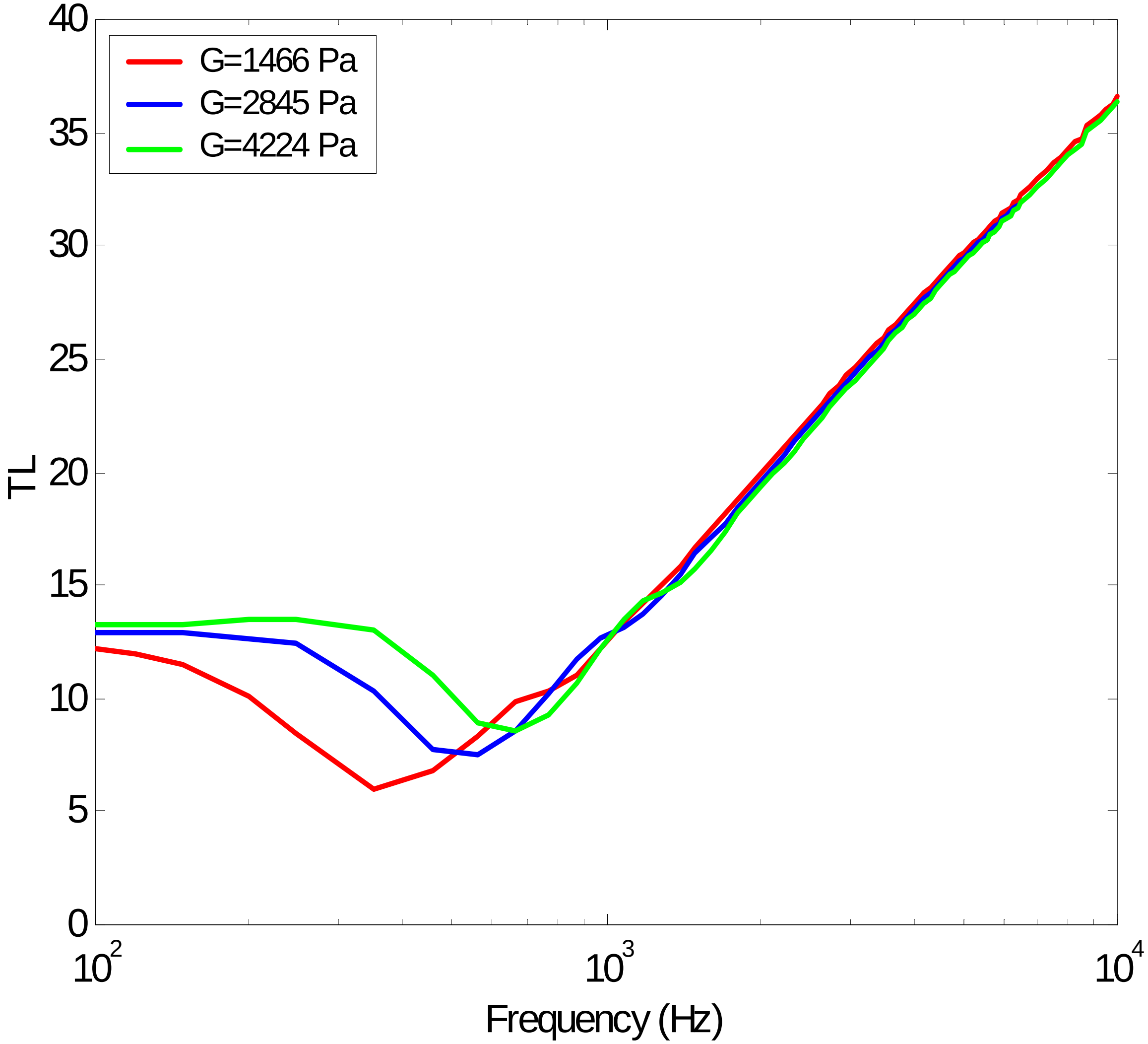
Surface Normal Impedance

(Change from mass-like reactance to stiffness reactance)



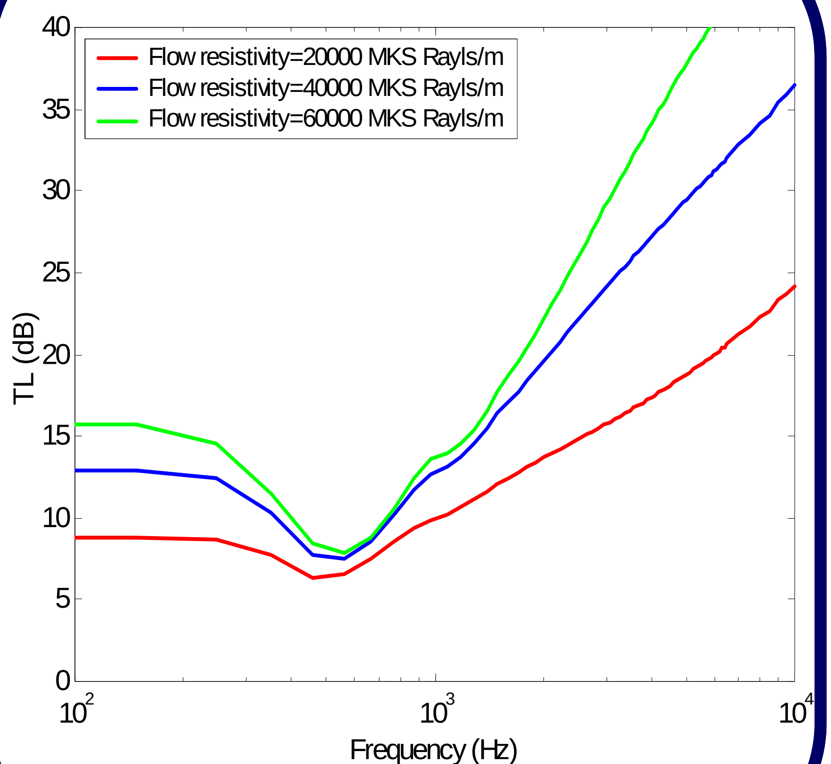
Variation of Shear Modulus

(As G increases, the shearing resonance moves to higher frequency)



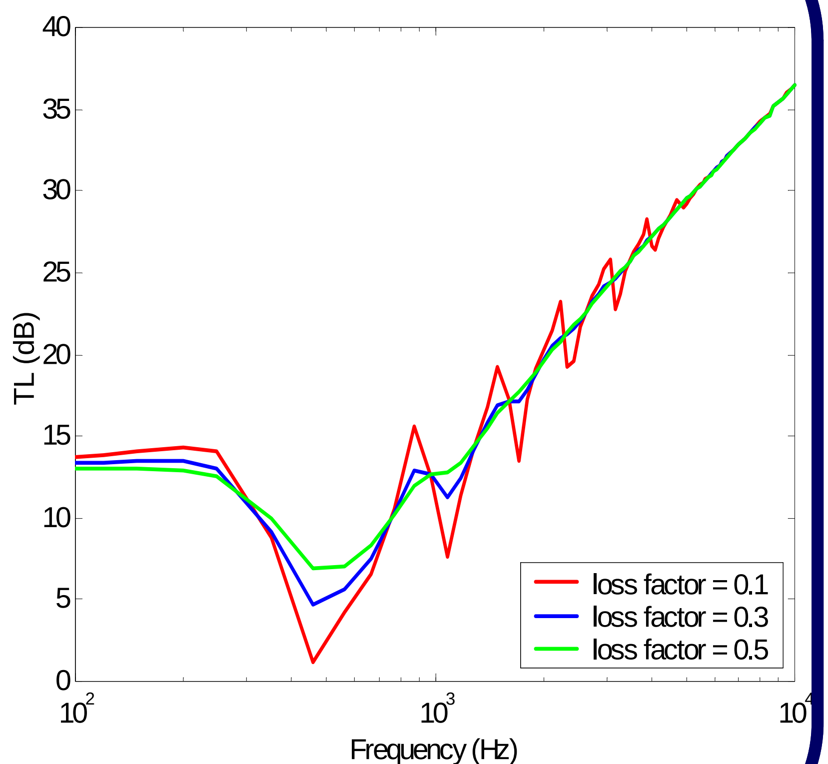
Flow Resistivity

(Controls TL in low and high frequency limits)

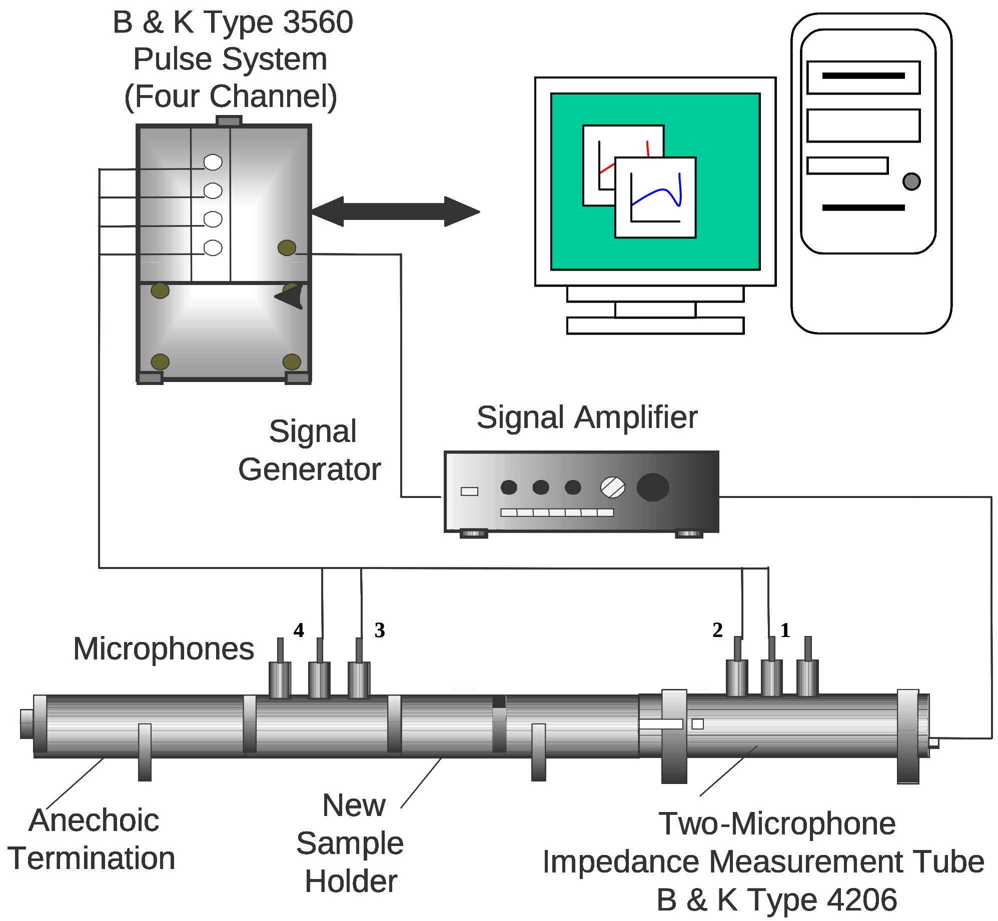


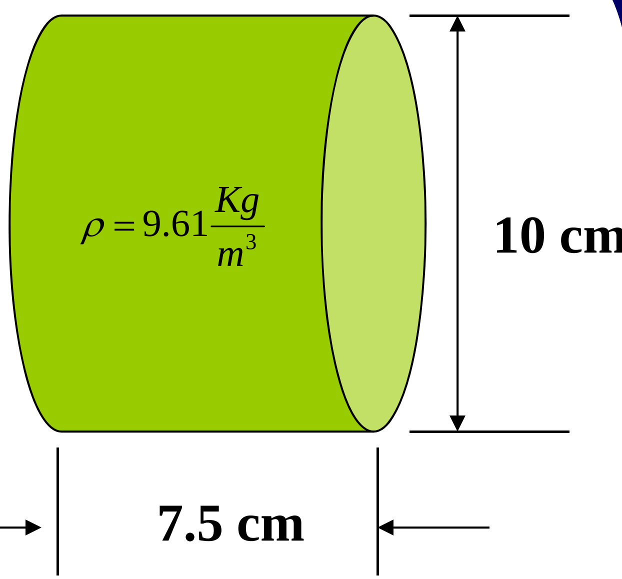
Loss Factor

(Loss factor controls depth of TL minimum)



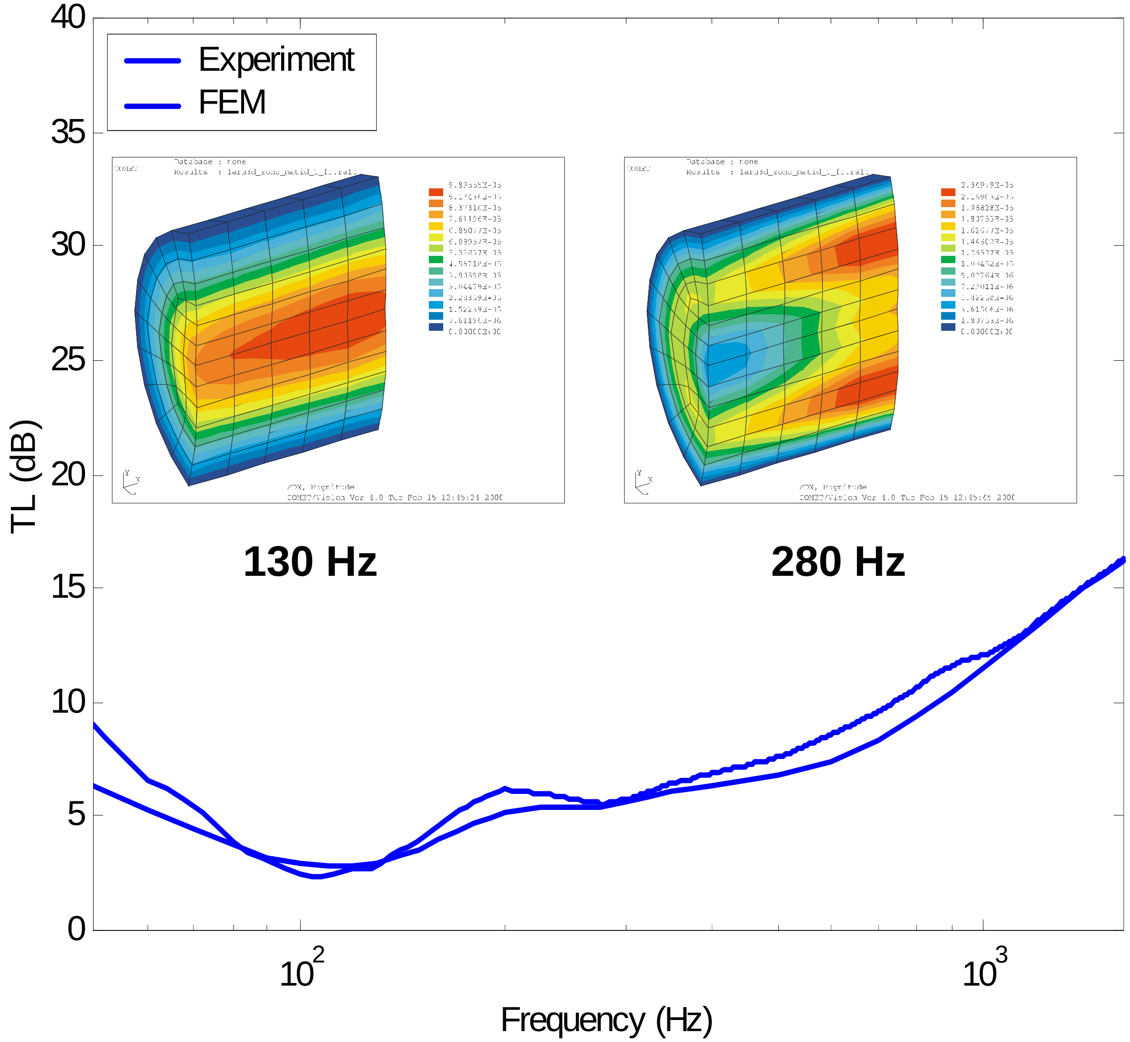
Effect of Sample Size
Experimental Setup for Low Frequency Tube



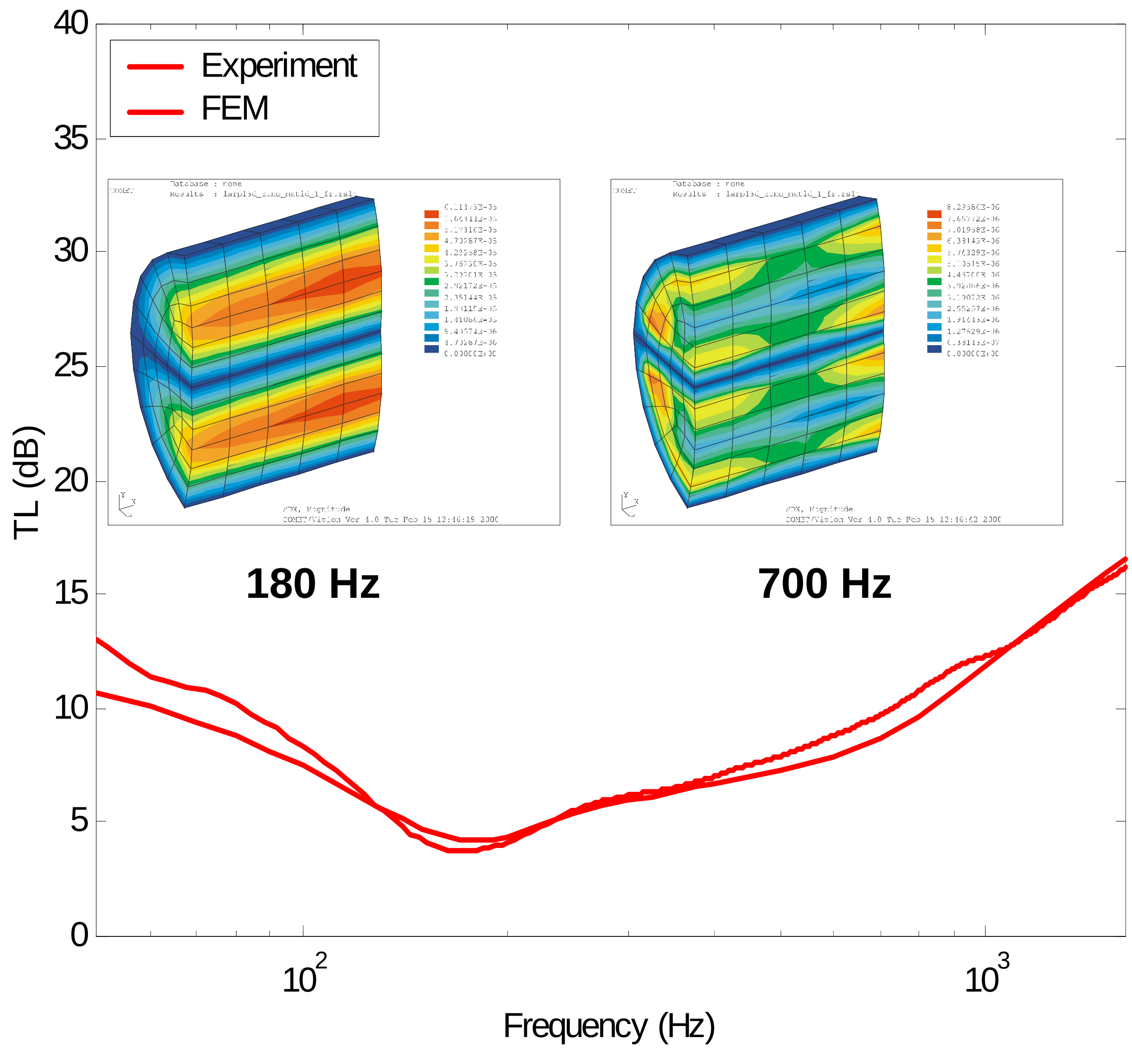


Aviation grade glass fiber

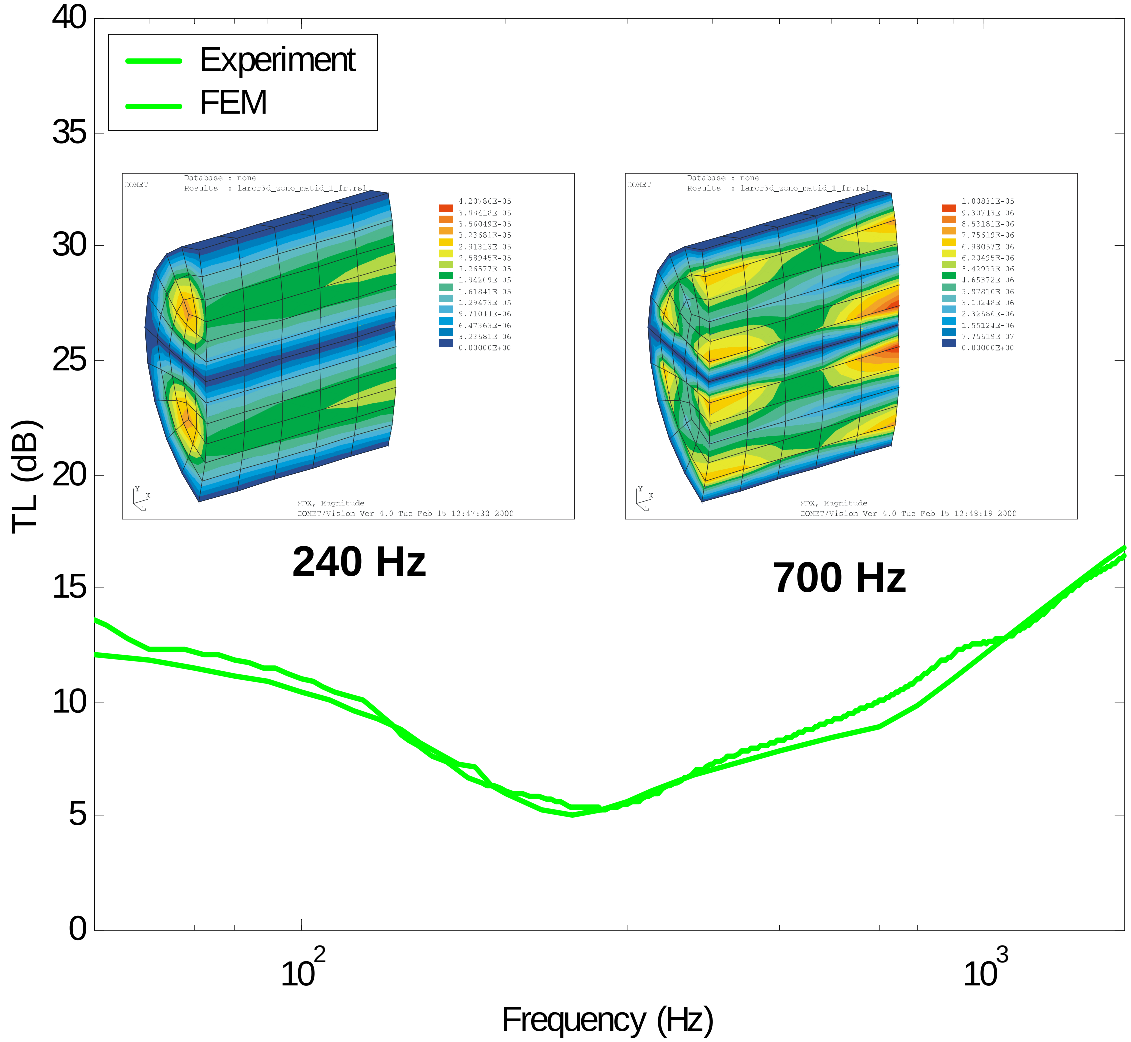
Constrained around Edge (50 Hz - 1600 Hz)



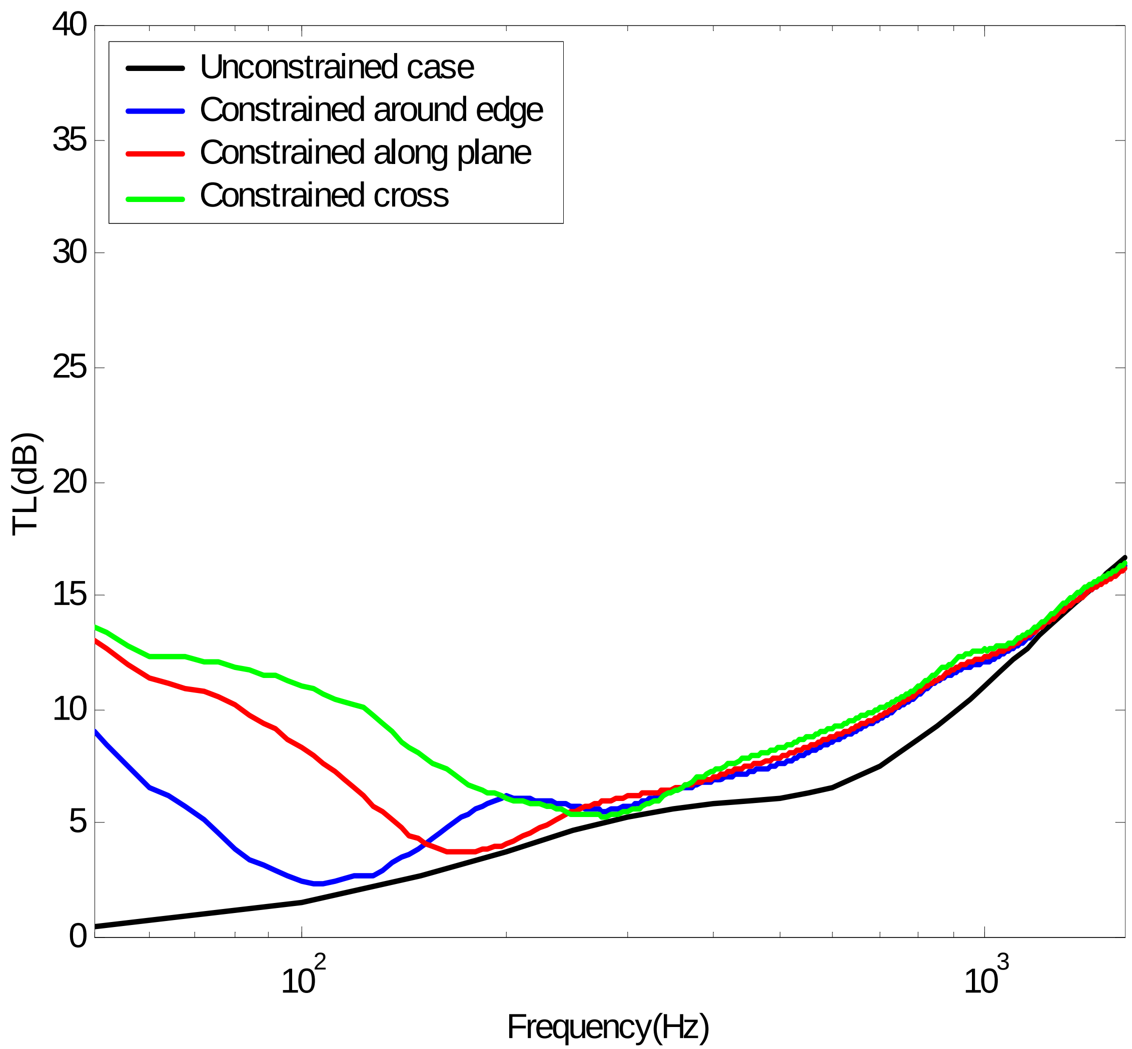
Constrained along Plane (50 Hz - 1600 Hz)



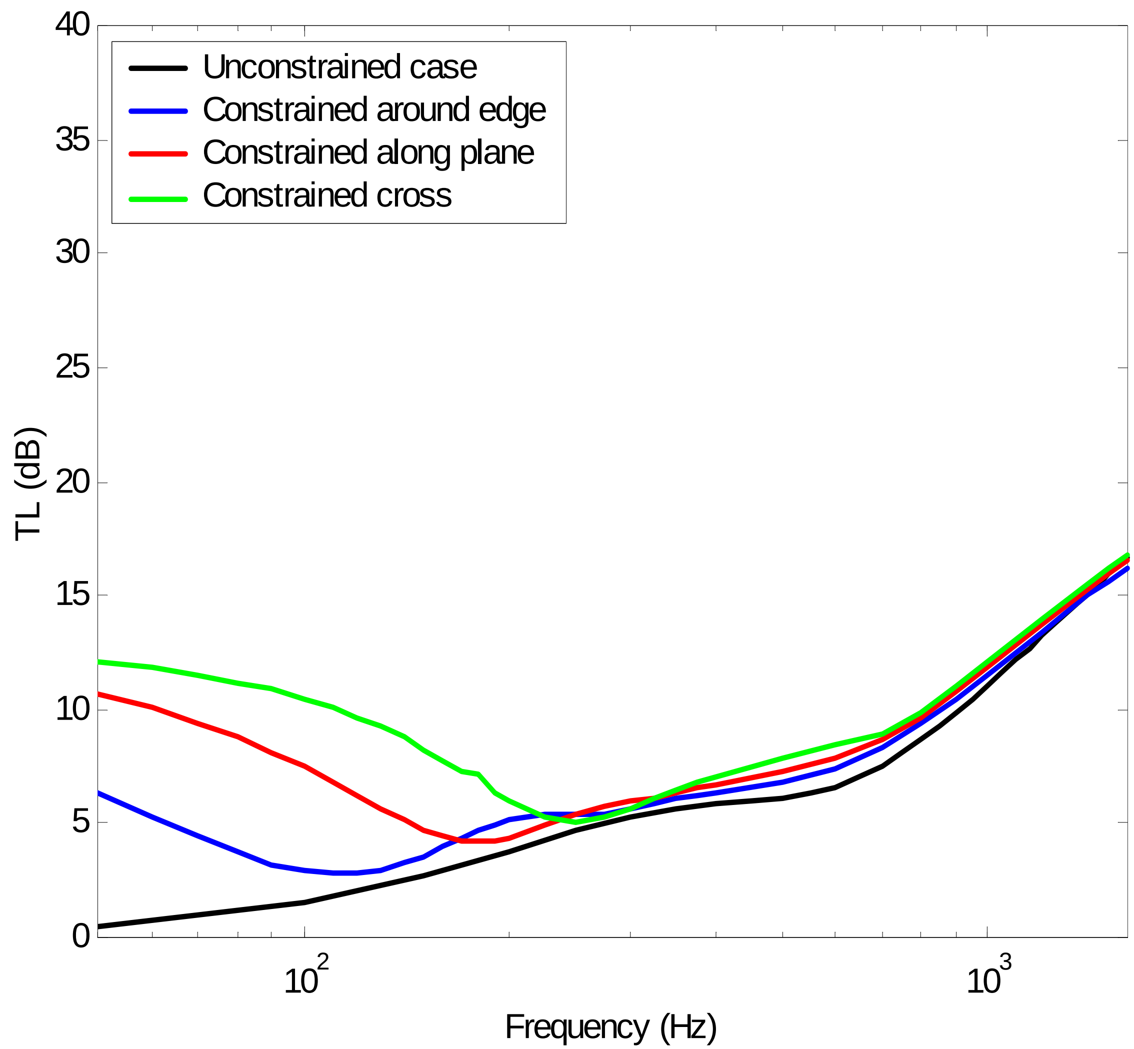
Constrained Cross (50 Hz - 1600 Hz)



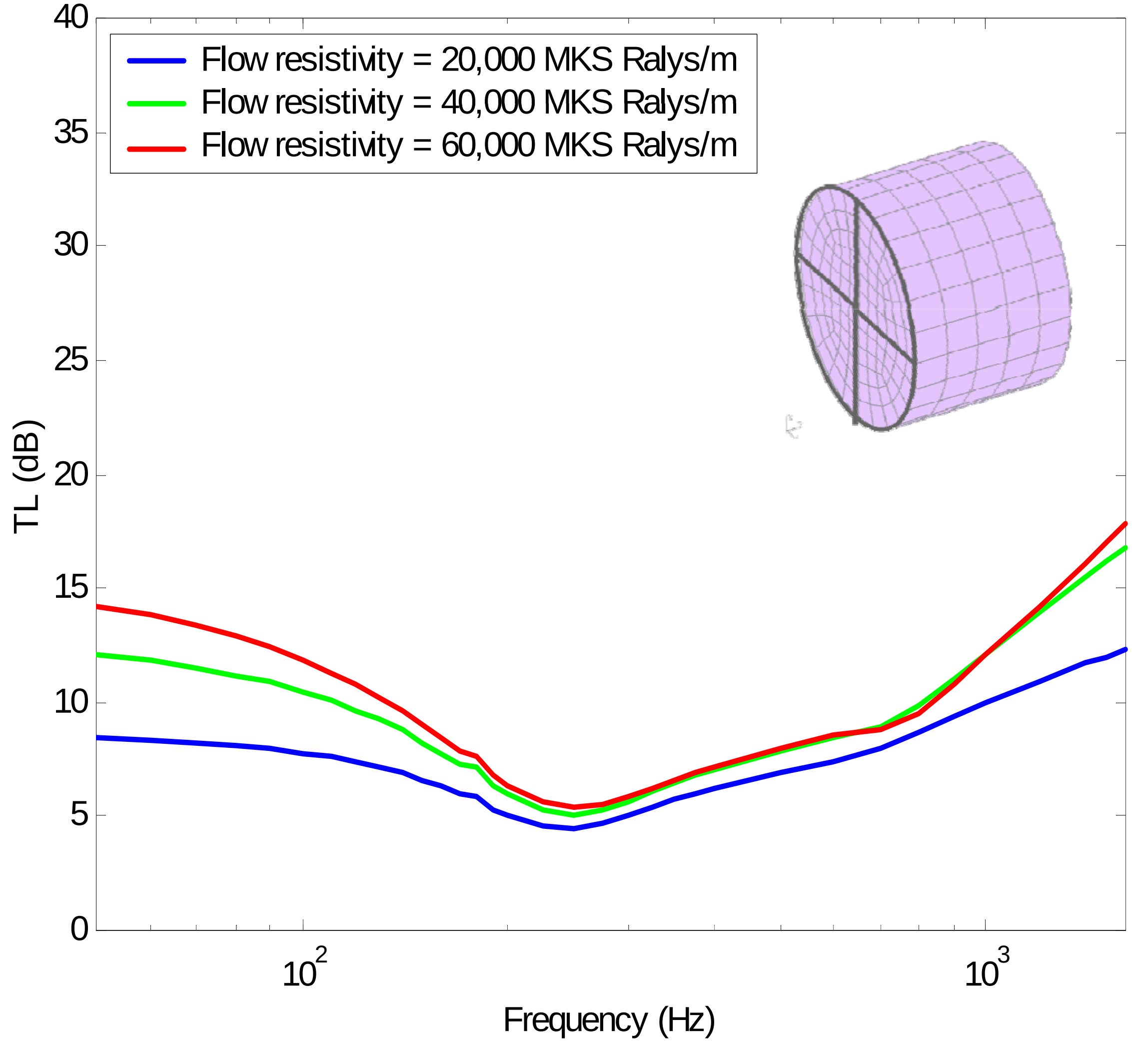
Transmission Loss (Experiment)



Transmission Loss (FEM)

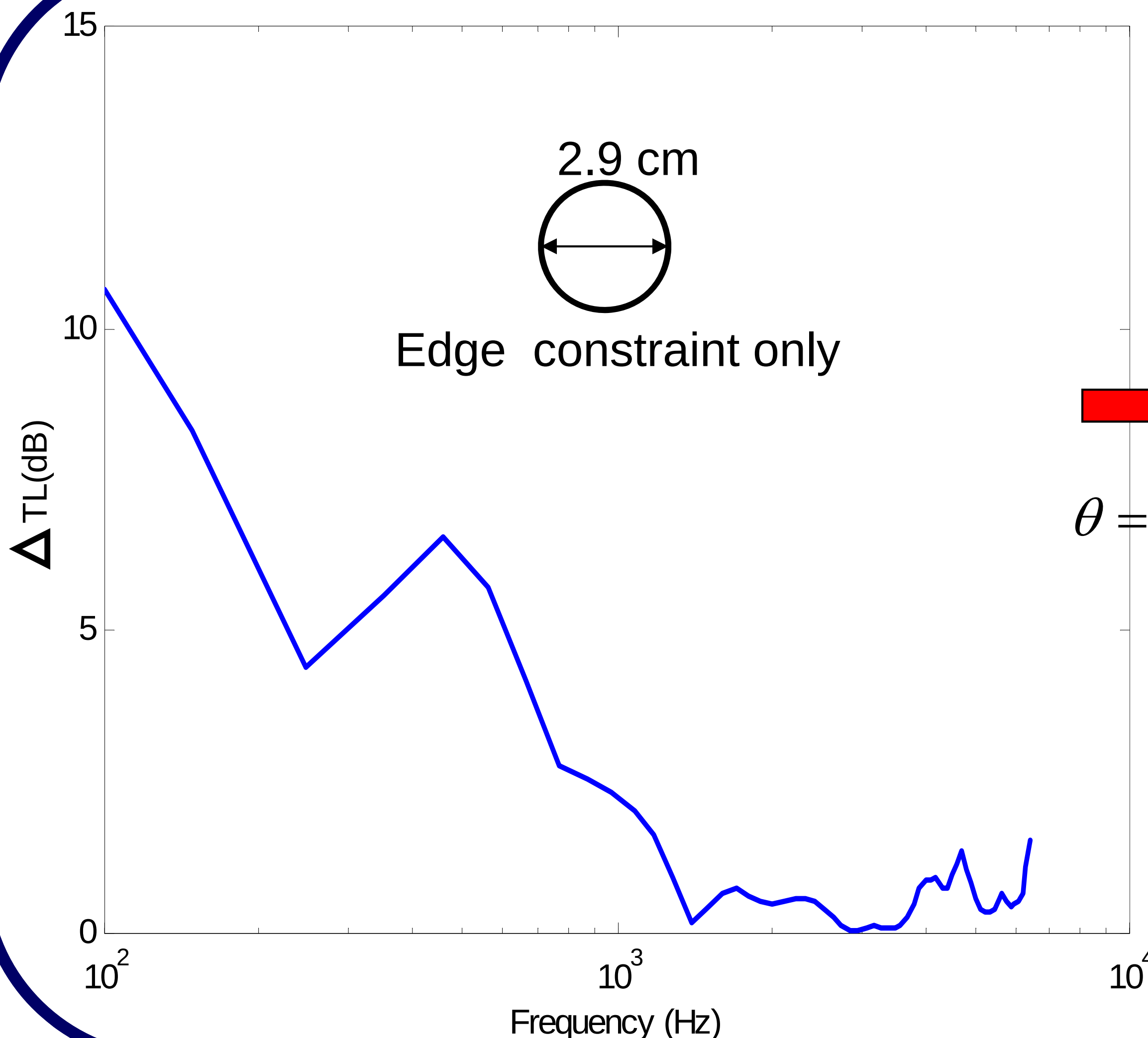


Effect of flow resistivity on TL for cross constrained case

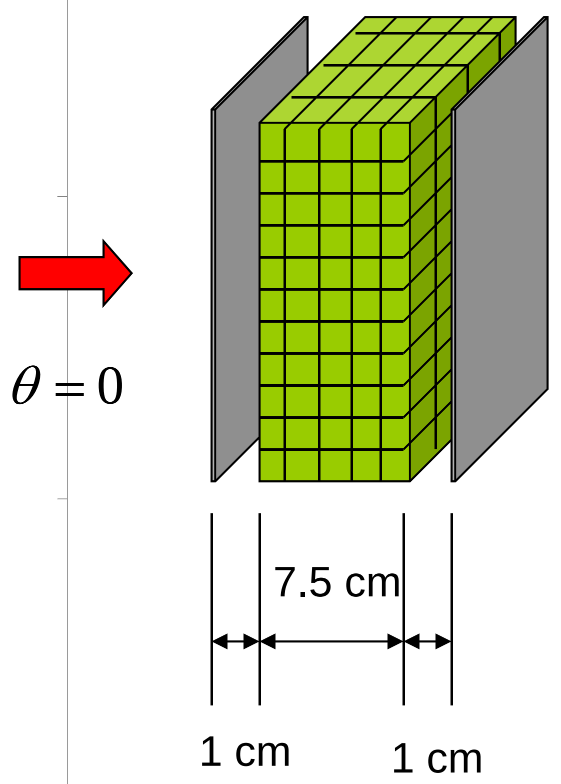


Δ TL constrained and unconstrained cases

[Panel (Al, 0.762 mm)+Air+Glass fiber (7.5 cm)+Air+panel (Al, 0.762 mm)]

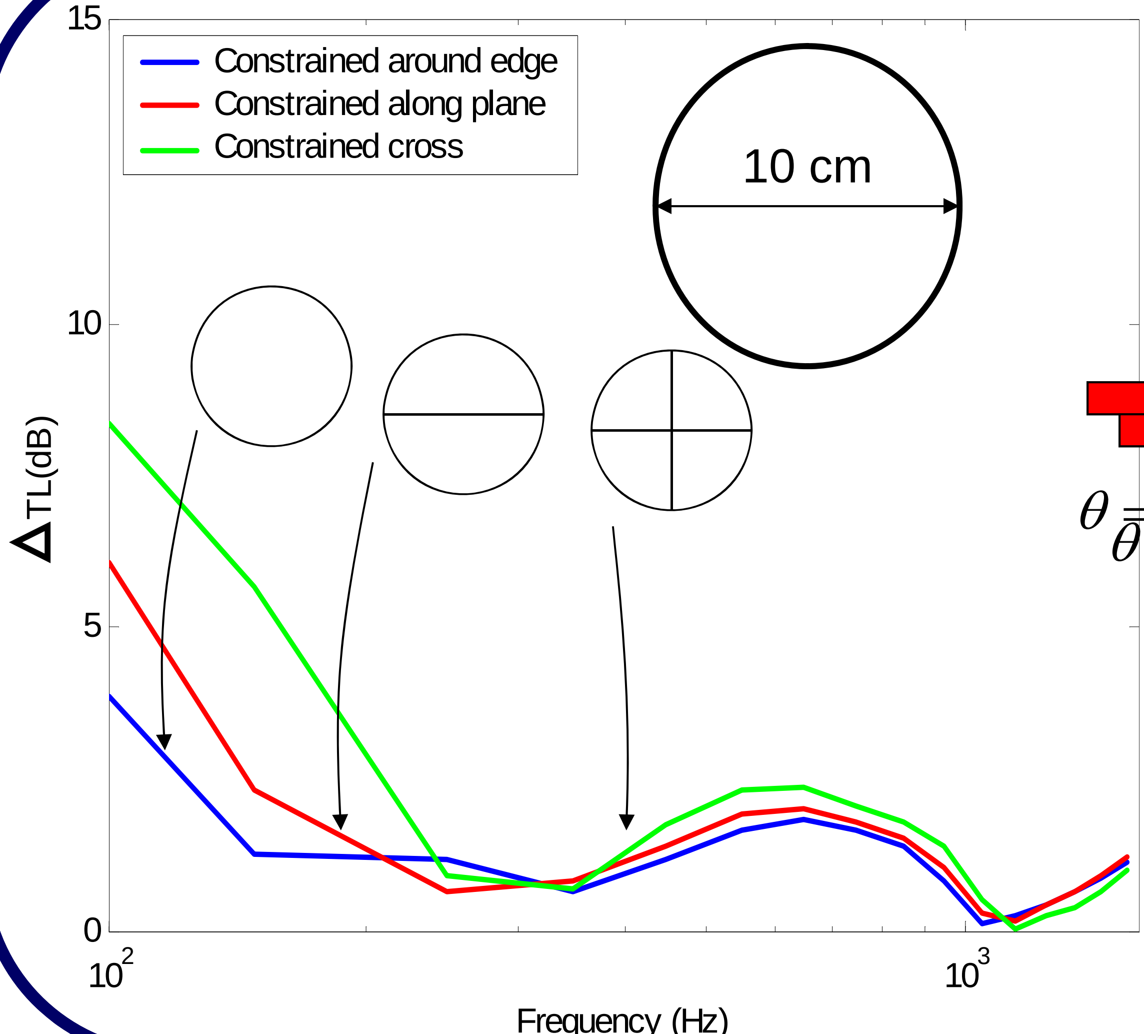


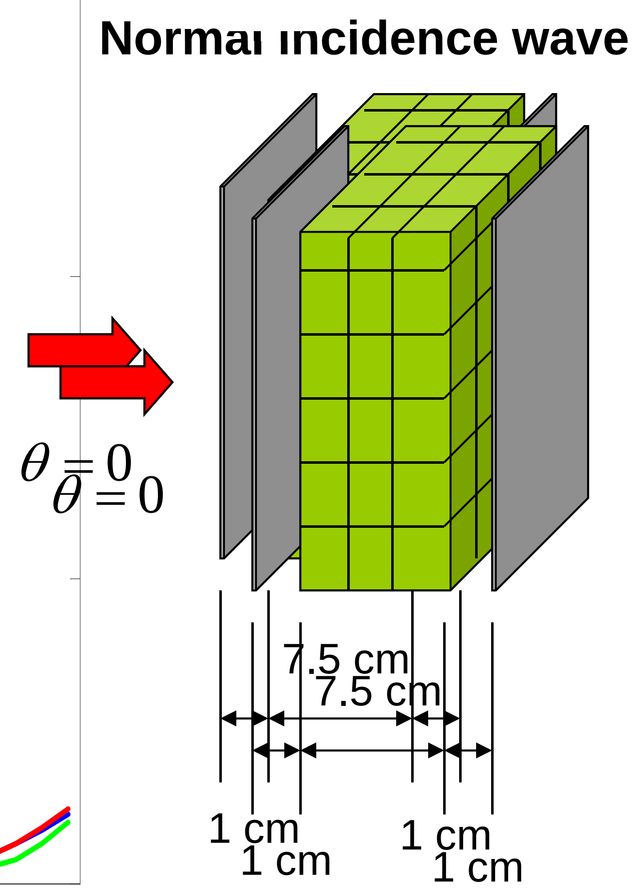
Normal incidence wave



Δ TL constrained and unconstrained cases

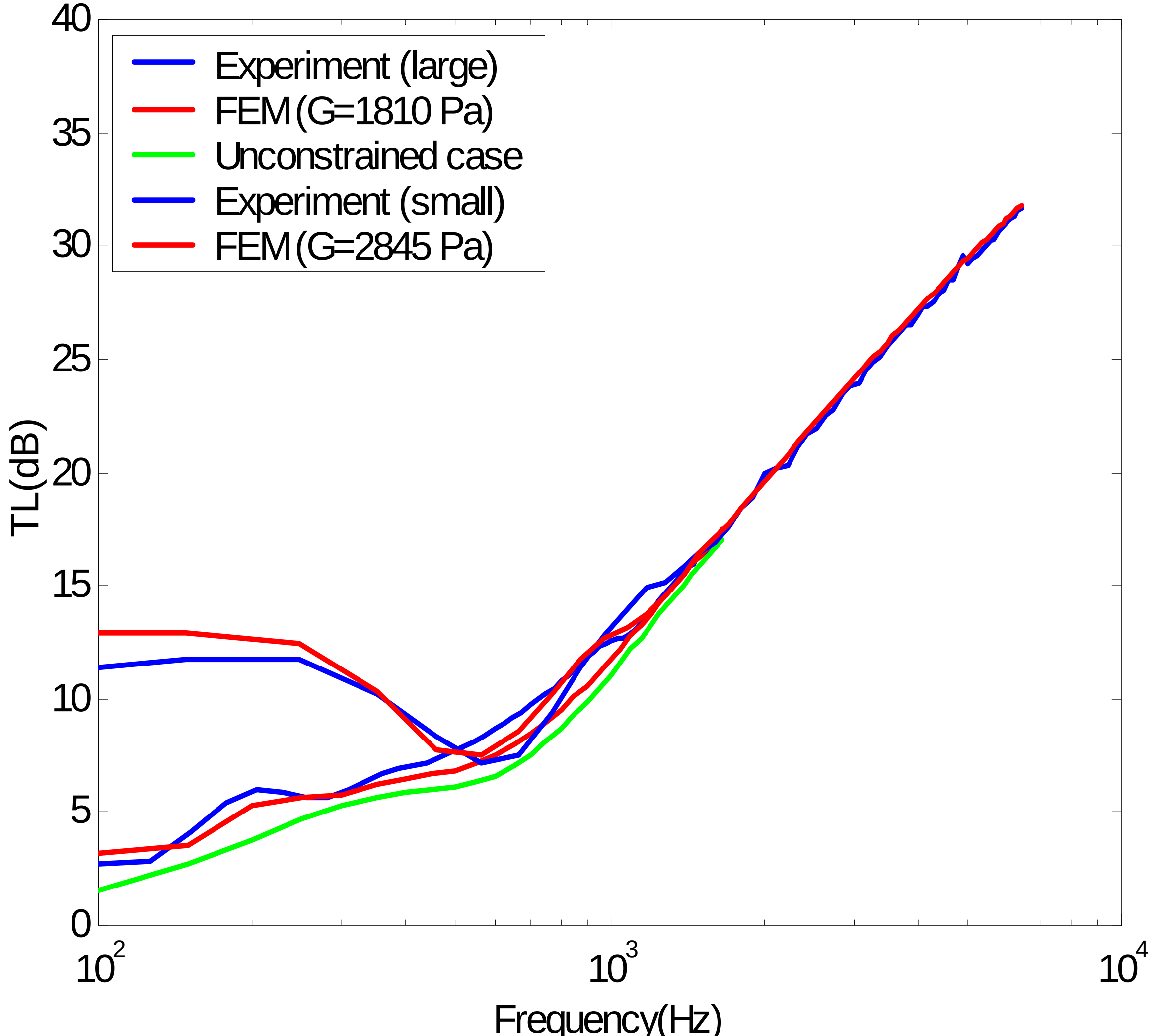
[Panel (Al, 0.762 mm)+Air+Glass fiber (7.5 cm)+Air+panel (Al, 0.762 mm)]

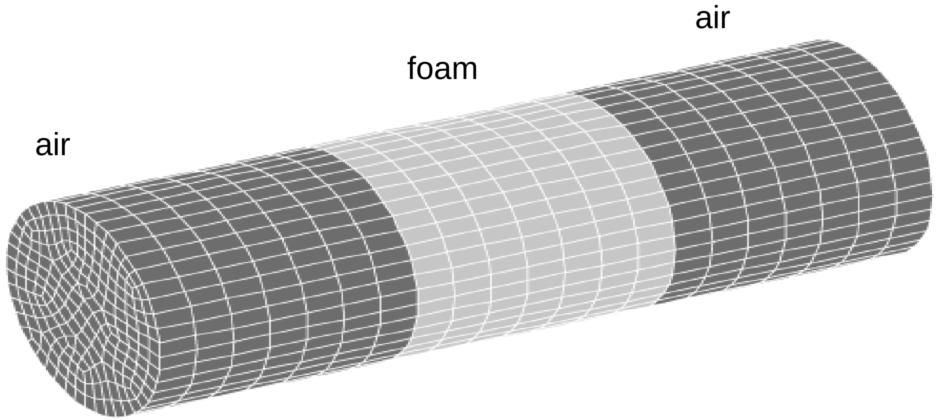




Transmission Loss (100 Hz - 6400 Hz)

(10 cm samples very nearly approximates unconstrained case)





Conclusions

- **Acoustical performances of fibrous layers such as transmission loss and absorption coefficient are affected by constraint on the boundary of the samples.**
- **The various constrained effects are well predicted by using poroelastic FEM model (COMET/SAFE).**
- **<u>Light and stiff fibrous materials</u> combined with edge and internal constraint mechanisms can be used to design, light, high performance low frequency noise control barriers.**