

October 23, 2020

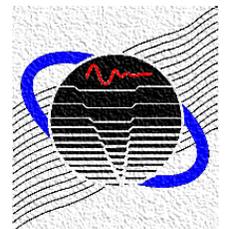
# Notes on Expansion Chambers

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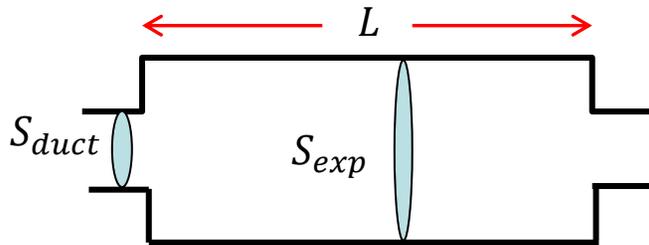
David Herrin  
University of Kentucky

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**Vibro-Acoustics Consortium**



# Simple Expansion Chamber



## Transmission Loss

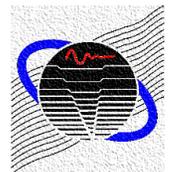
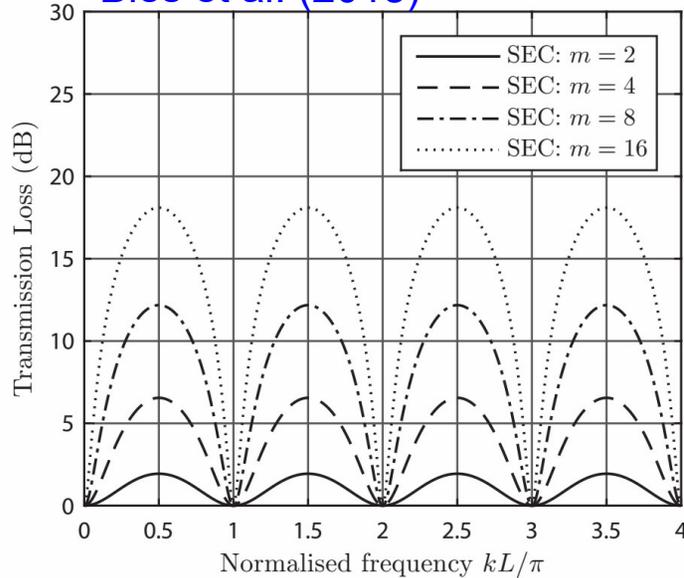
$$TL = 10 \log_{10} \left( 1 + \frac{1}{4} \left( \frac{S_{exp}}{S_{duct}} - \frac{S_{duct}}{S_{exp}} \right)^2 \sin^2(kL) \right)$$

Normally  $\frac{S_{exp}}{S_{duct}} \gg \frac{S_{duct}}{S_{exp}}$

$$m = \frac{S_{exp}}{S_{duct}}$$

$$TL \approx 10 \log_{10} \left( \frac{1}{4} m^2 \sin^2(kL) \right)$$

Bies et al. (2018)

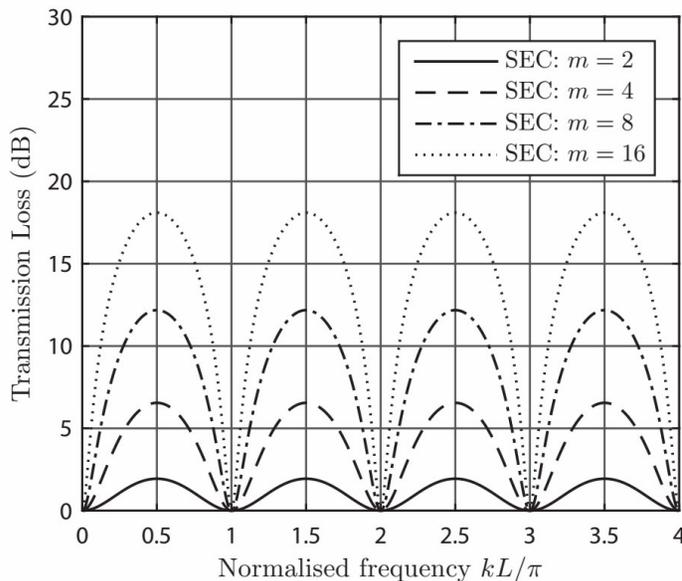


# Simple Expansion Chamber

**Example** Design an expansion chamber to attenuate 20 dB at 120 Hz.

$$kL = \frac{\pi}{2} \quad kL = \frac{2\pi fL}{c} = \frac{\pi}{2}$$

$$f = \frac{1}{4} \frac{c}{L} \quad L = \frac{1}{4} \frac{c}{f} \quad L = \frac{1}{4} \frac{1343 \text{ m/s}}{120 \text{ Hz}} = 0.71 \text{ m}$$

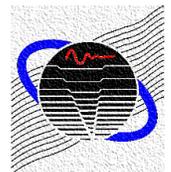


$$TL \approx 10 \log_{10} \left( \frac{1}{4} m^2 \sin^2(kL) \right)$$

$$20 \approx 10 \log_{10} \left( \frac{1}{4} m^2 \sin^2(kL) \right)$$

$$\frac{20}{10} \approx \log_{10} \left( \frac{1}{4} m^2 \right) \rightarrow 10^2 \approx \left( \frac{1}{4} m^2 \right) \rightarrow m = 20$$

$$\frac{d_{exp}}{d_{duct}} \approx \sqrt{20} = 4.5$$



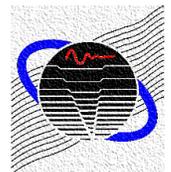
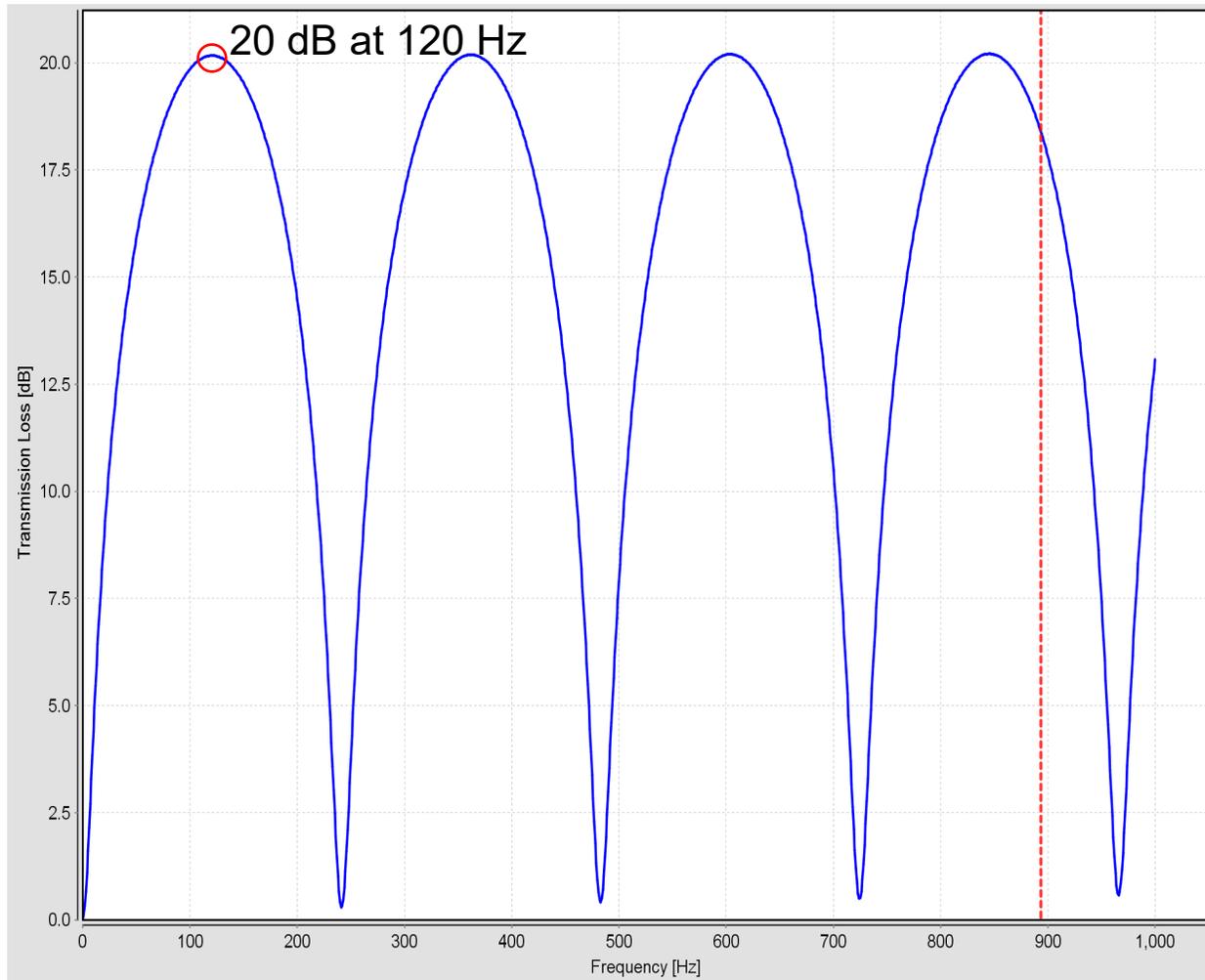
# Simple Expansion Chamber

SIDLAB

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

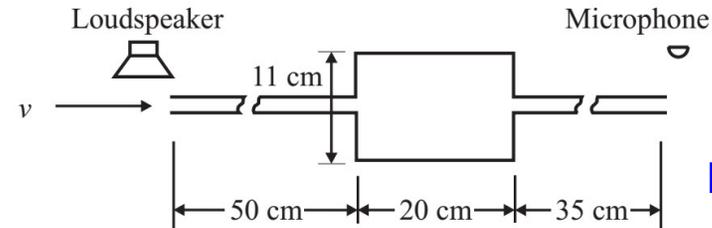
$$d_{exp} = 22.5 \text{ cm}$$

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

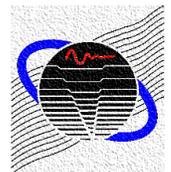
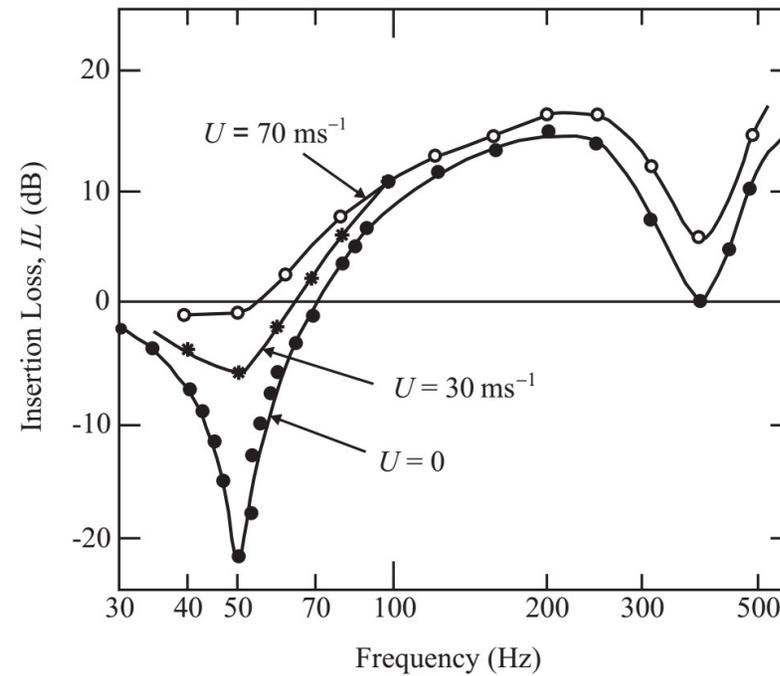


# Simple Expansion Chamber

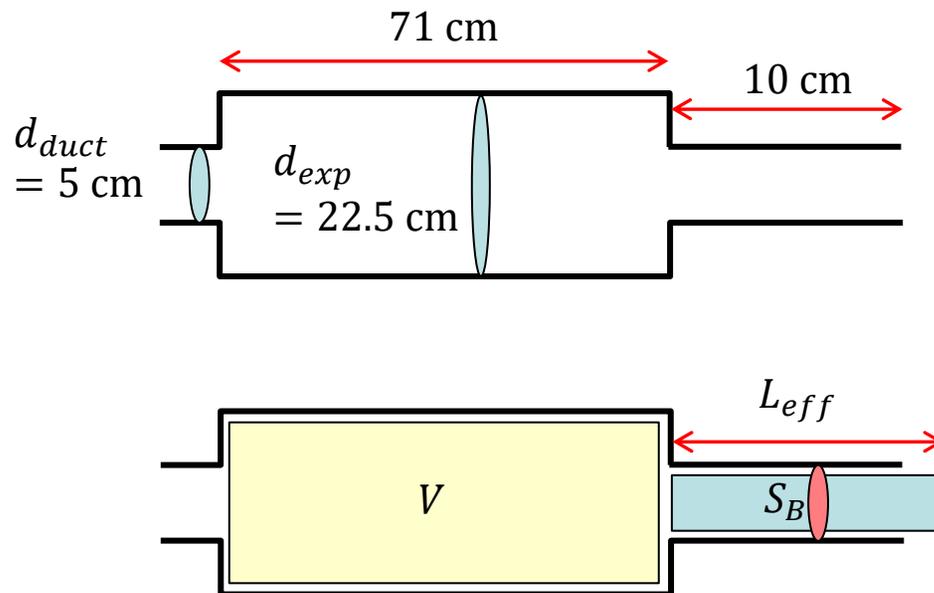
## Insertion Loss



Bies et al. (2018)

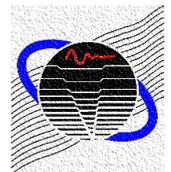


# Simple Expansion Chamber



$$f_{helm} = \frac{c}{2\pi} \sqrt{\frac{S_B}{L_{eff}V}}$$

$L_{eff}$  will be longer than the tailpipe length.



# Simple Expansion Chamber

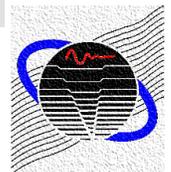
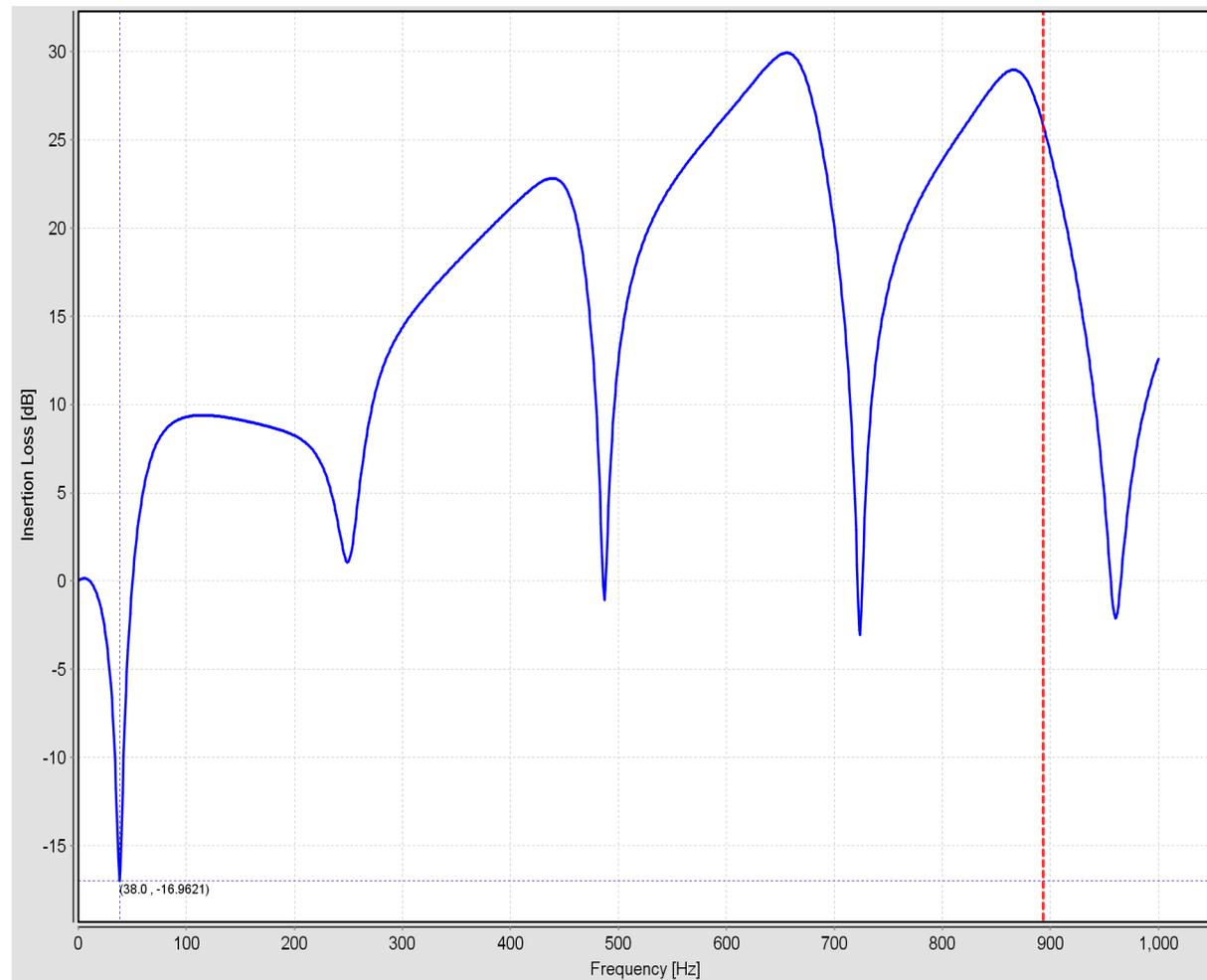
SIDLAB

use tailpipe length (10 cm)

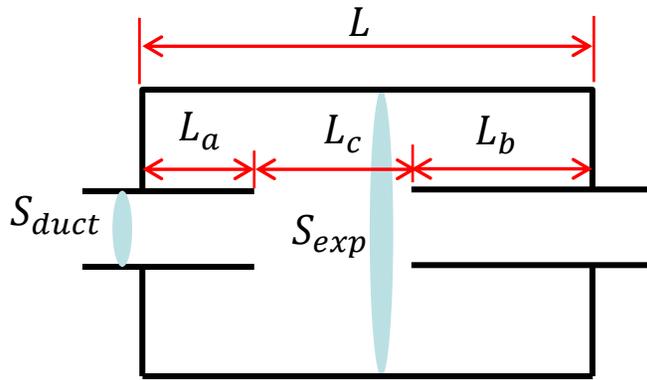
$$f_{helm} = 45 \text{ Hz}$$

add 5 cm

$$f_{helm} = 38 \text{ Hz}$$

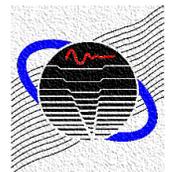
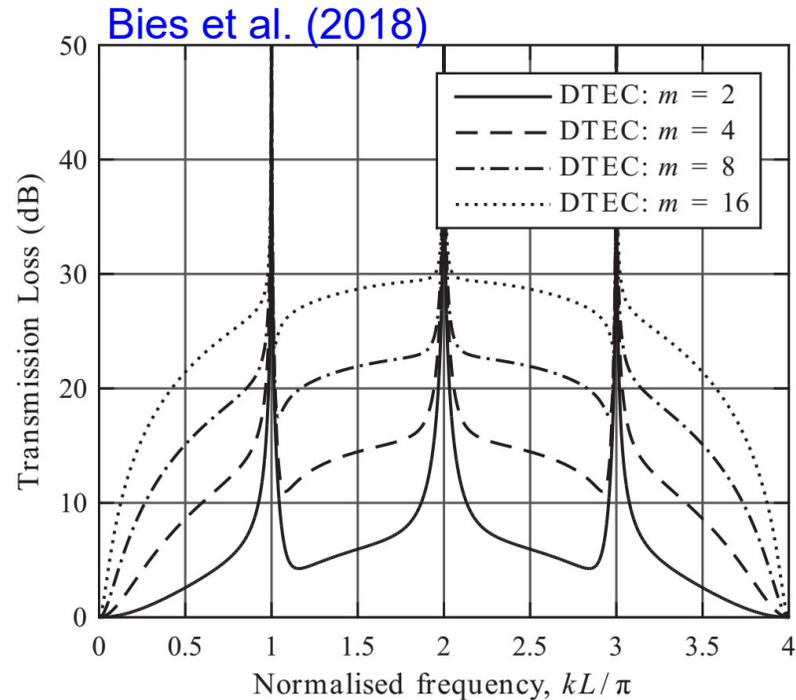
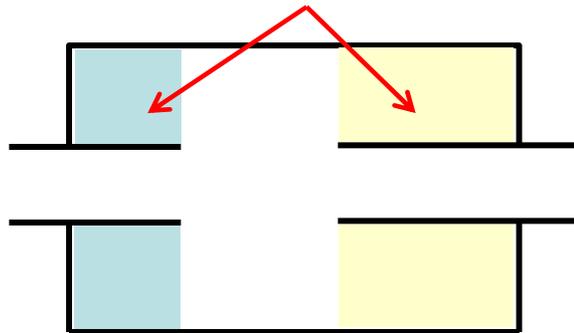


# Double Tuned Expansion Chamber



$$L_a = \frac{L}{4} \quad L_b = \frac{L}{2} \quad L_c = \frac{L}{4}$$

Quarter Wave Tubes



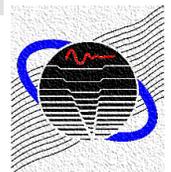
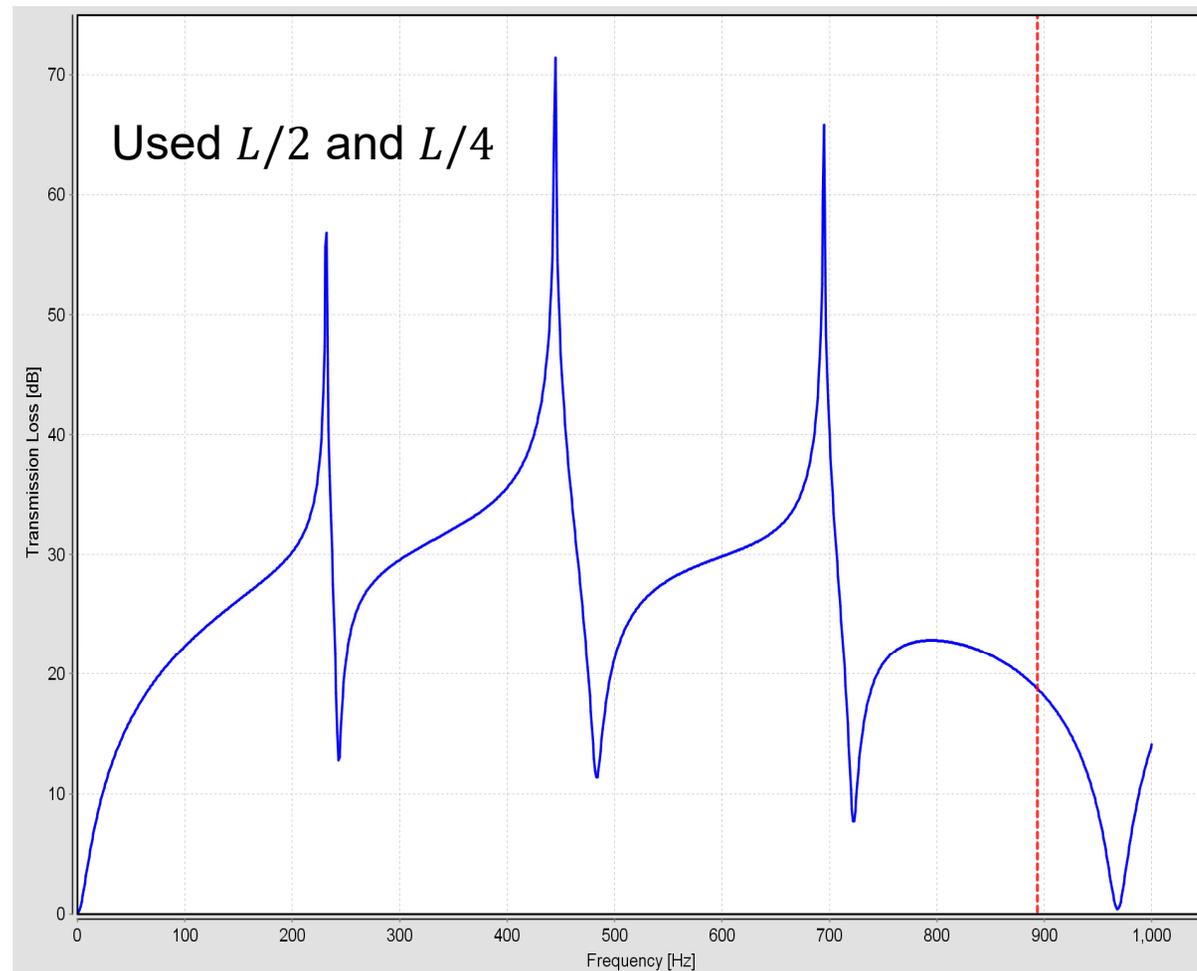
# Double Tuned Expansion Chamber

SIDLAB

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

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

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



# Double Tuned Expansion Chamber

End Corrections (all dimensions in m)

$$l_0 = d_{duct} \left( a_0 + a_1 \left( \frac{d_{exp}}{d_{duct}} \right) + a_2 \left( \frac{t_w}{d_{duct}} \right) + a_3 \left( \frac{d_{exp}}{d_{duct}} \right)^2 + a_4 \left( \frac{d_{exp} t_w}{d_{duct}} \right) + a_5 \left( \frac{t_w}{d_{duct}} \right)^2 \right)$$

$$a_0 = 0.005177$$

$$a_1 = 0.0909$$

$$a_2 = 0.537$$

$$a_3 = -0.008594$$

$$a_4 = 0.2616$$

$$a_5 = -5.435$$

Corrected Lengths

$$L_a = \frac{L}{4} - l_0$$

$$L_b = \frac{L}{2} - l_0$$

$$L_c = L - L_a - L_b$$

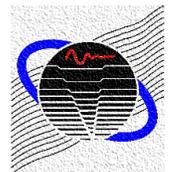
Example

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

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

$$d_{duct} \gg t_w$$

$$l_0 = 1.2 \text{ cm}$$



# Double Tuned Expansion Chamber

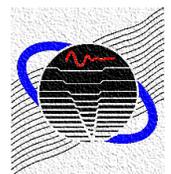
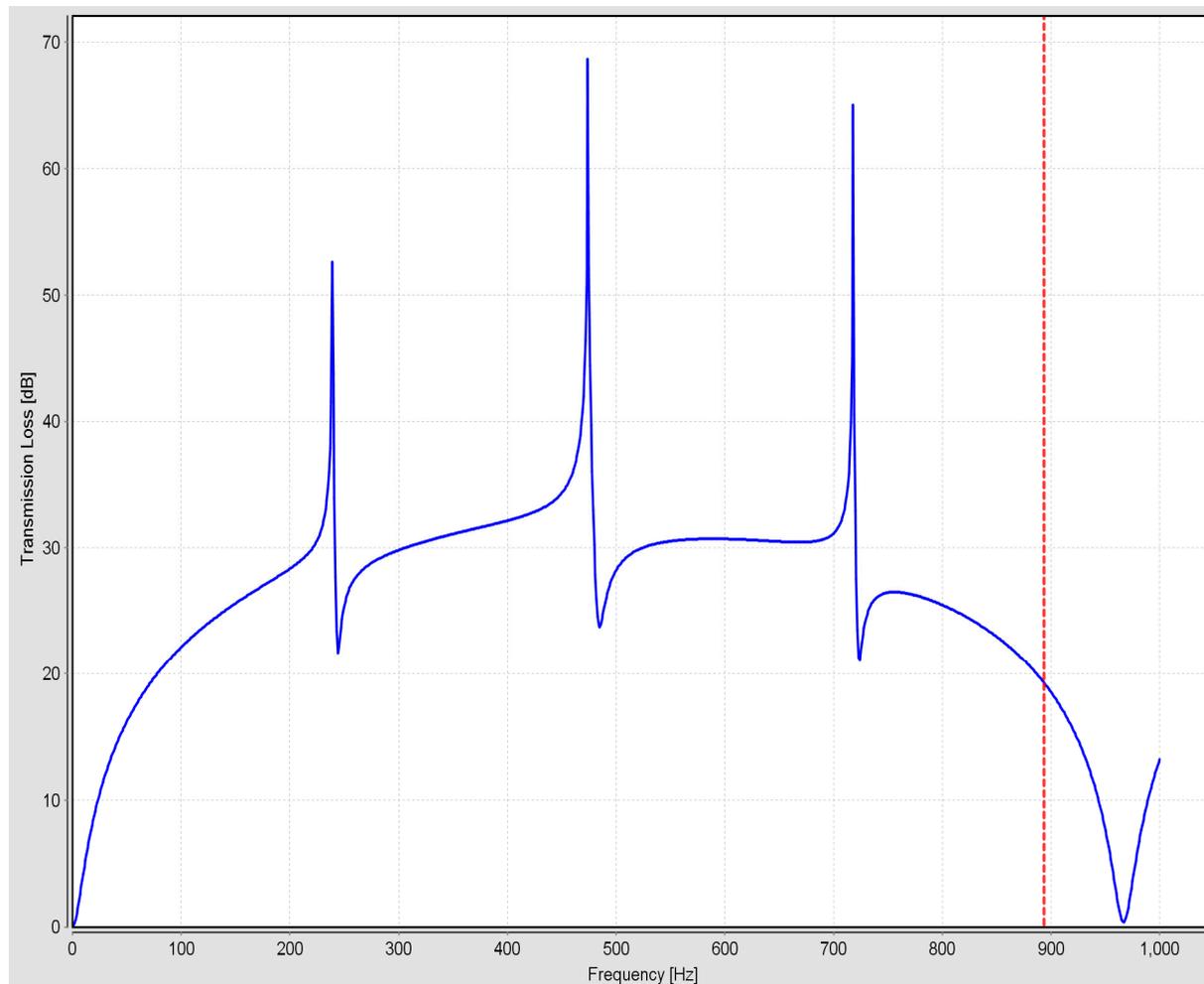
SIDLAB

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

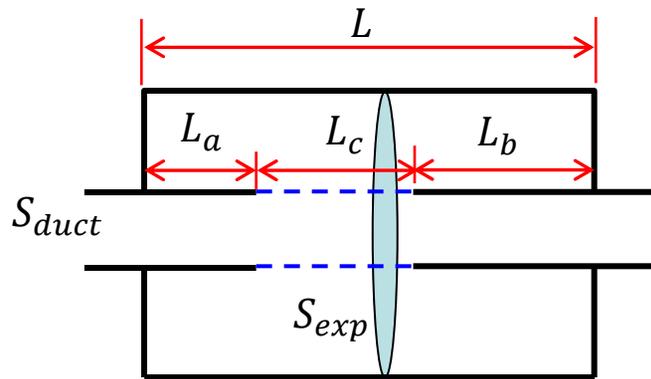
$$d_{exp} = 22.5 \text{ cm}$$

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

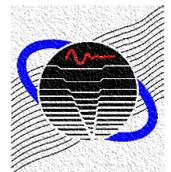
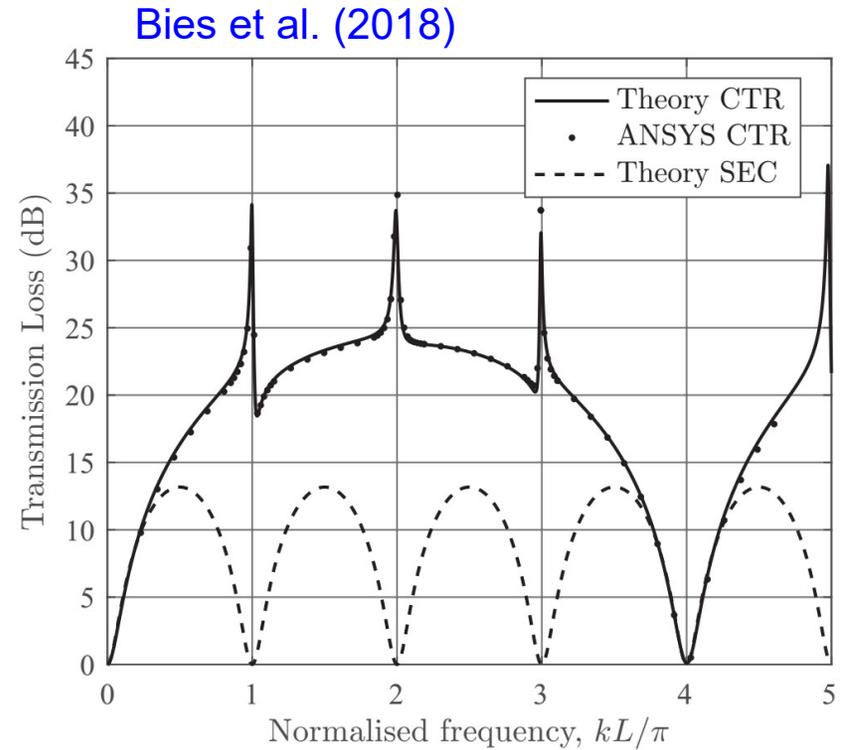
$$l_0 = 1.2 \text{ cm}$$



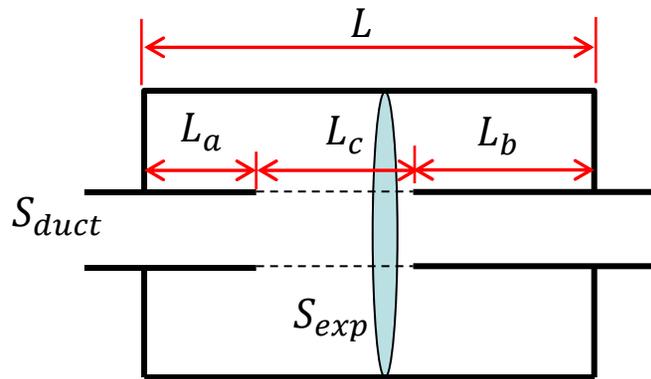
# DTEC with Perforations



Also called concentric tube resonator (CTR).



# DTEC with Perforations



SIDLAB

Perforate

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

$$t = 1 \text{ mm}$$

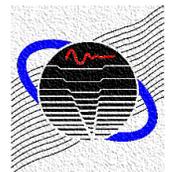
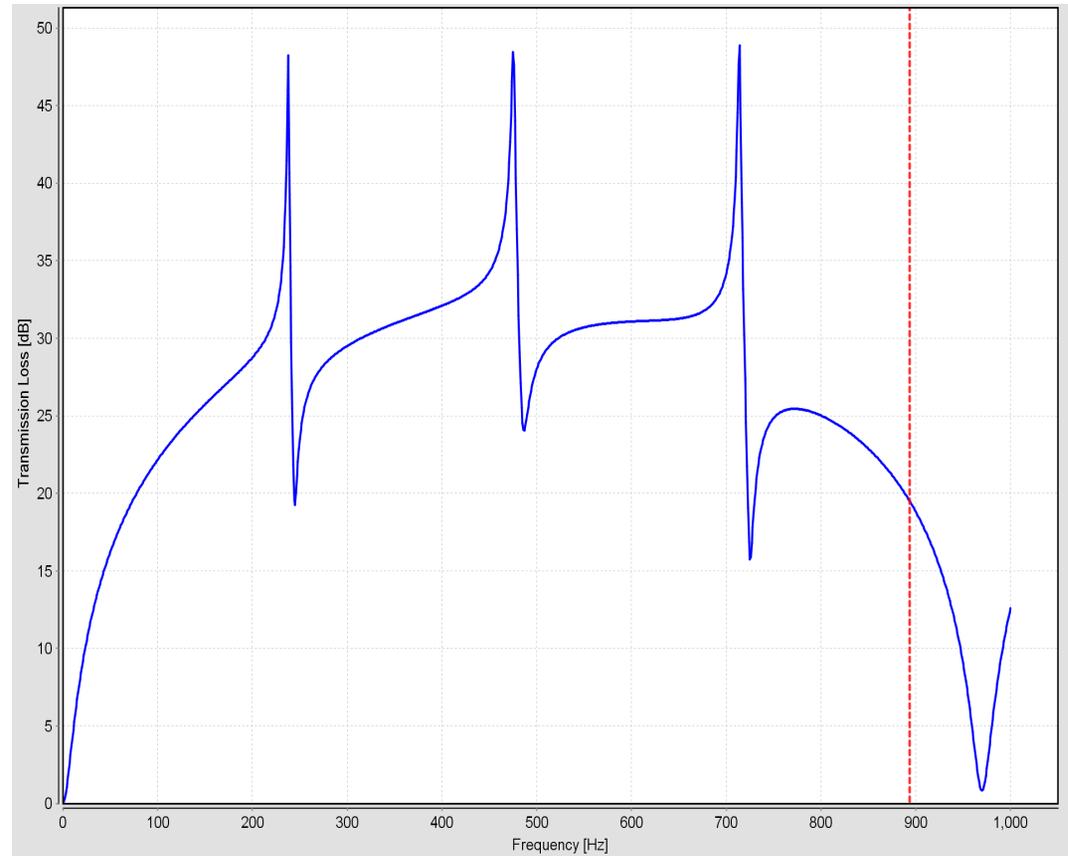
$$d_{exp} = 22.5 \text{ cm}$$

$$d_h = 0.5 \text{ cm}$$

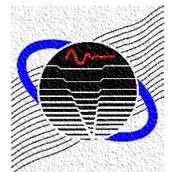
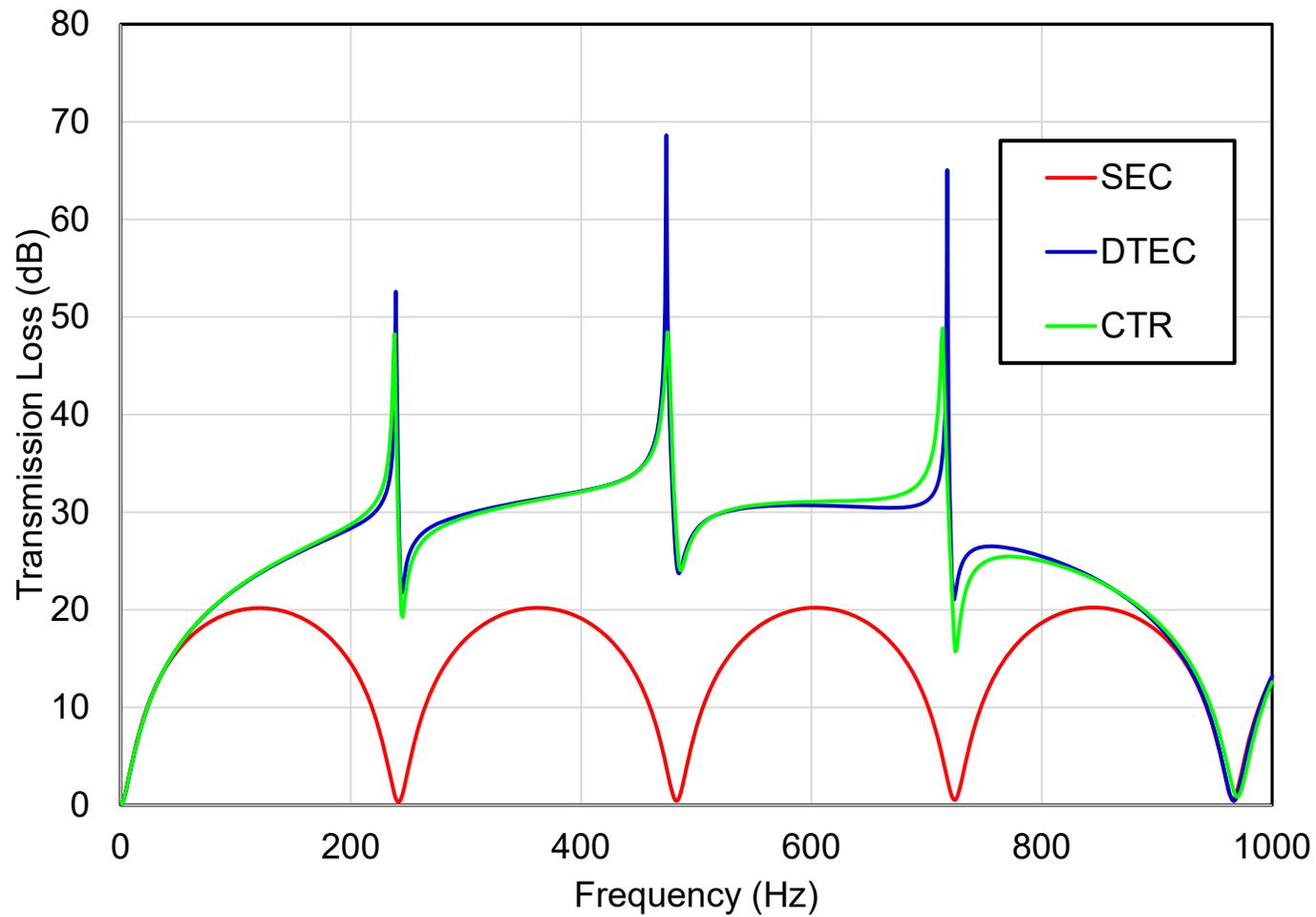
$$L = 71 \text{ cm}$$

$$\sigma = 0.30$$

$$l_0 = 1.2 \text{ cm}$$



# Combined Results



# References

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D. A. Bies, C. H. Hansen, and C. Q. Howard, Engineering Noise Control, CRC Press, Boca Raton (2018).

