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Notes on Expansion Chambers

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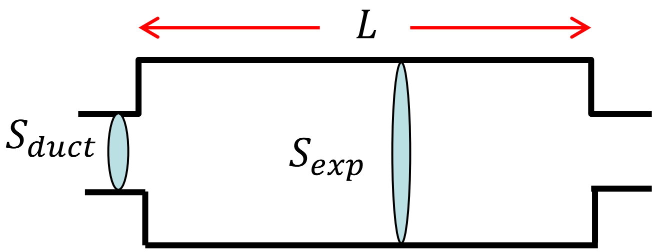
Simple Expansion Chamber



Transmission Loss

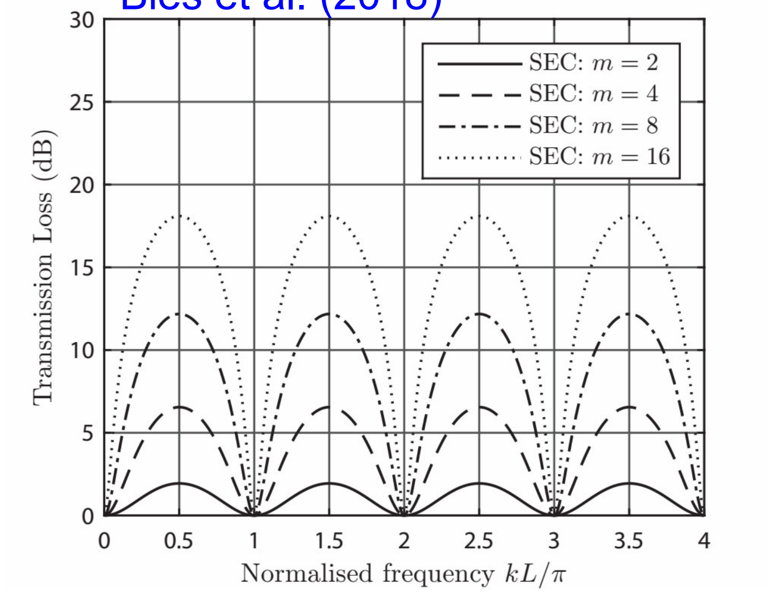
$$TL = 10\log_{10}\left(1 + \frac{1}{4}\left(\frac{S_{exp}}{S_{duct}} - \frac{S_{duct}}{S_{exp}}\right)^2 \sin^2(kL)\right)$$

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)

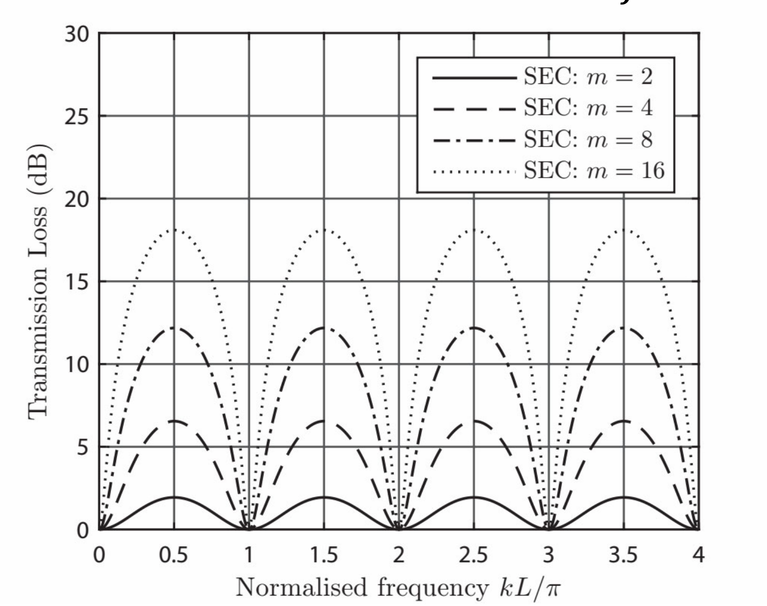


Simple Expansion Chamber

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

$$kL = \frac{\pi}{2} \qquad kL = \frac{2\pi f L}{c} = \frac{\pi}{2}$$

$$f = \frac{1}{4}\frac{c}{L} \qquad L = \frac{1}{4}\frac{c}{f} \qquad L = \frac{1}{4}\frac{343\ \text{m/s}}{120\ \text{Hz}} = 0.71\ \text{m}$$



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

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

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

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

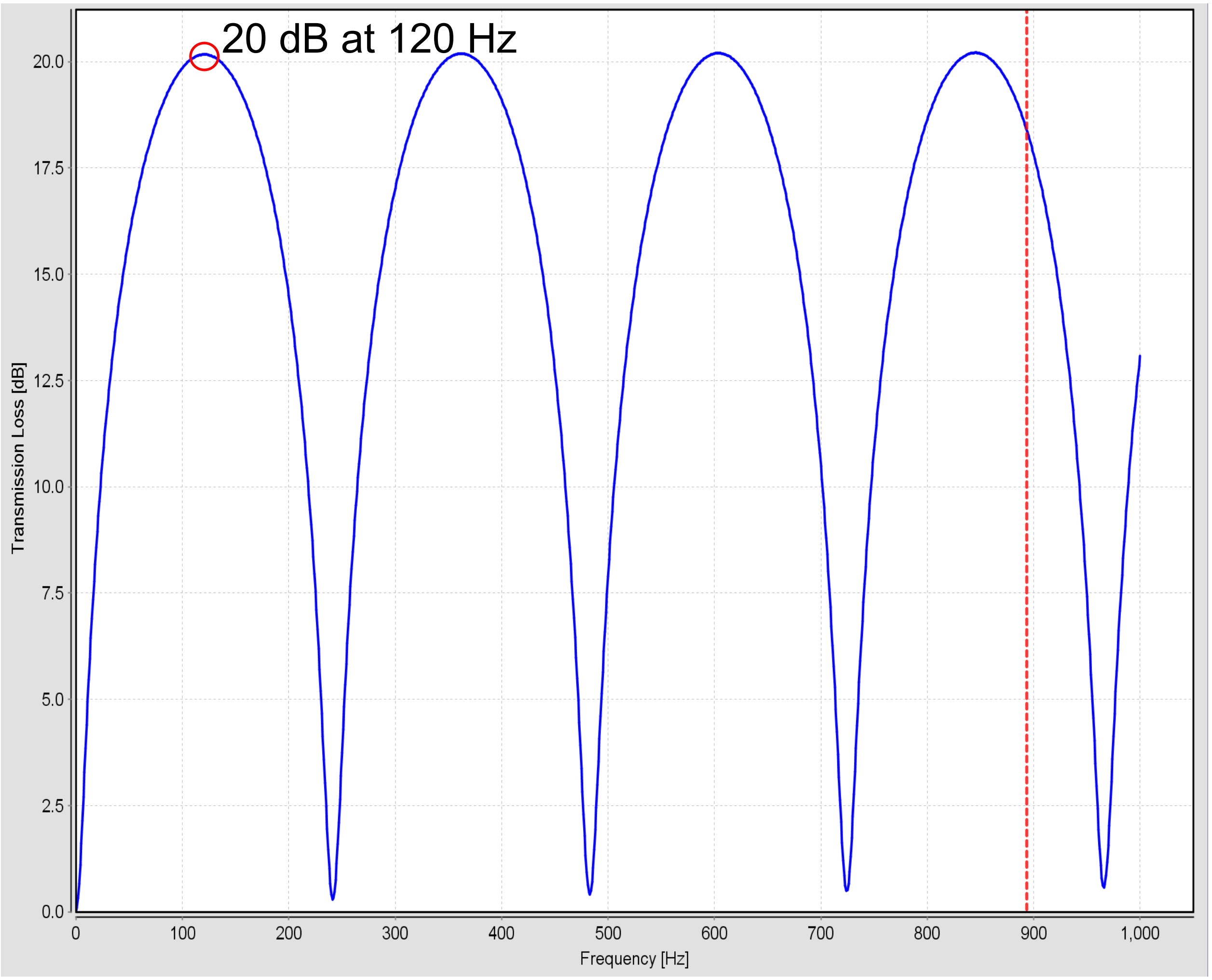
Simple Expansion Chamber

SIDLAB

$d_{duct} = 5$ cm

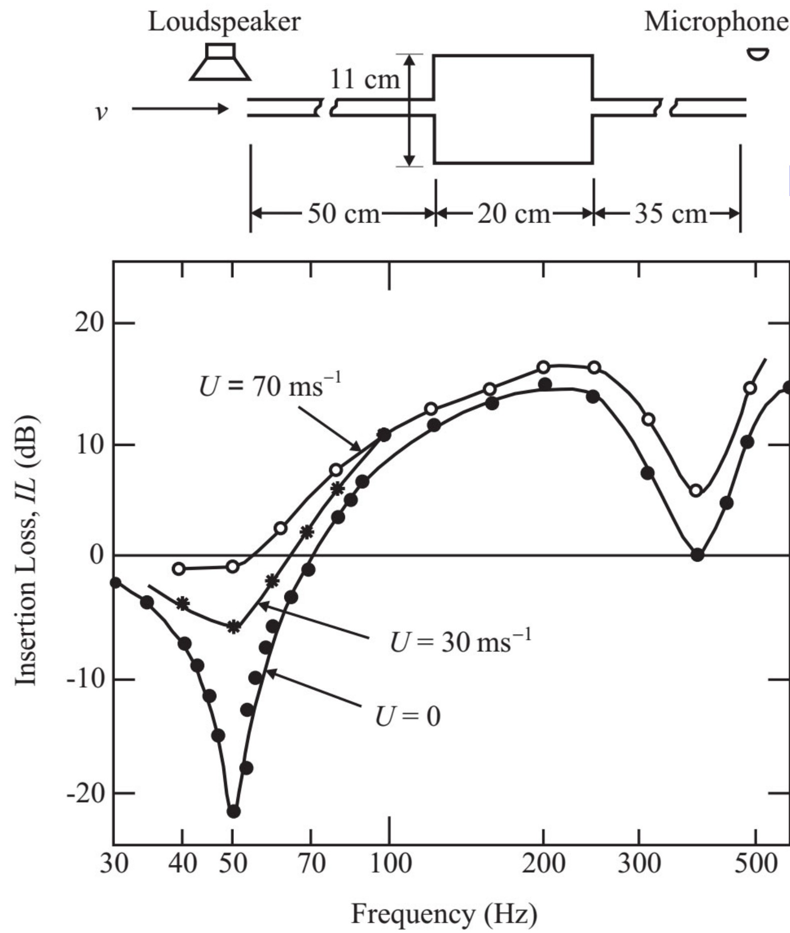
$d_{exp} = 22.5$ cm

$L = 71$ cm



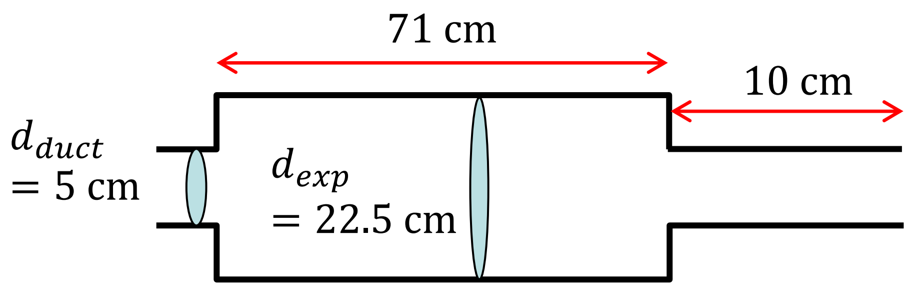
Simple Expansion Chamber

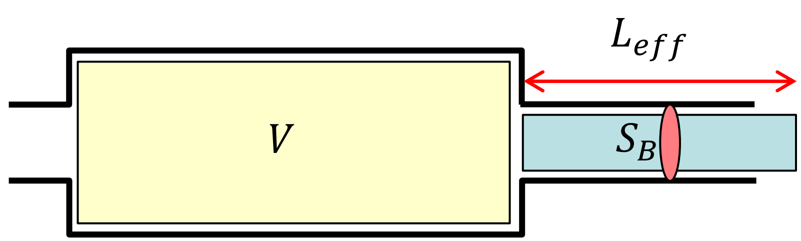
Insertion Loss



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

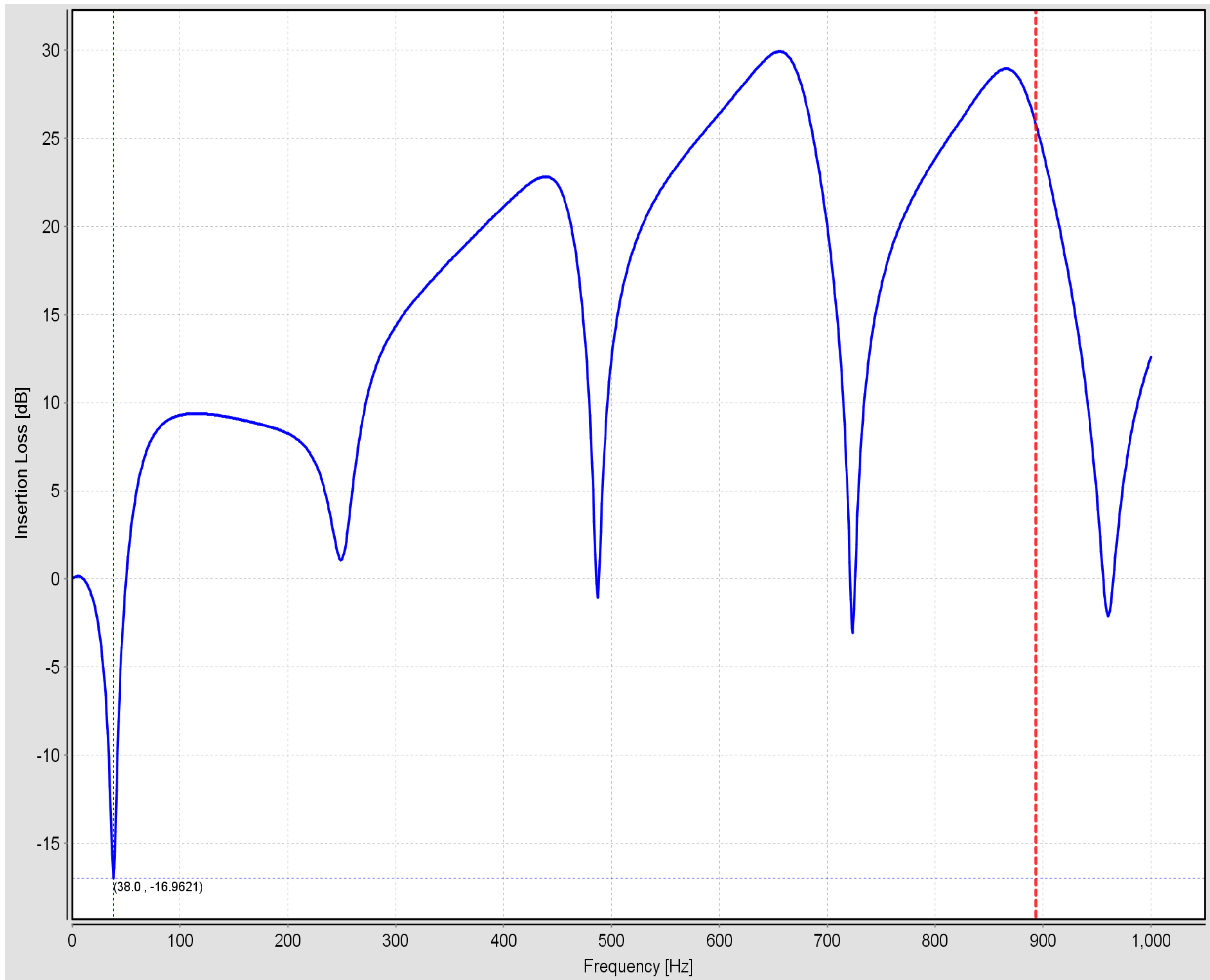
SIDLAB

use tailpipe length (10 cm)

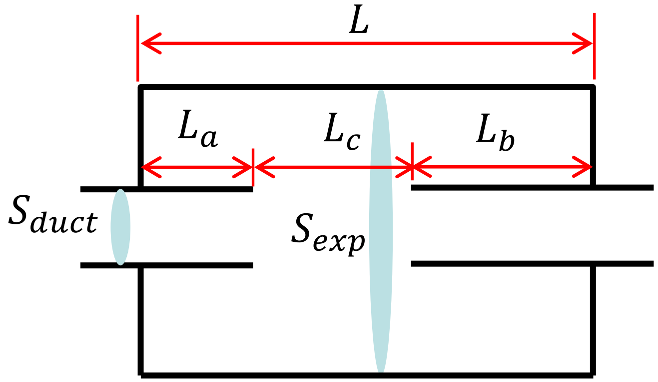
$f_{helm} = 45 \text{ Hz}$

add 5 cm

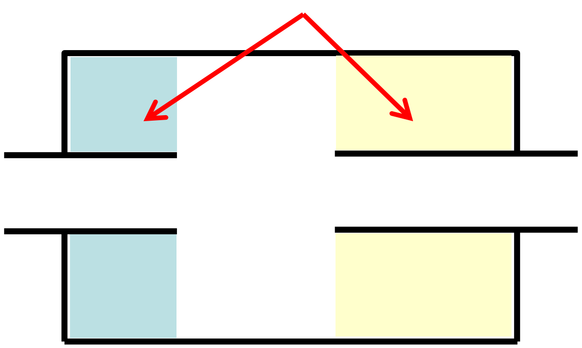
$f_{helm} = 38 \text{ Hz}$



Double Tuned Expansion Chamber

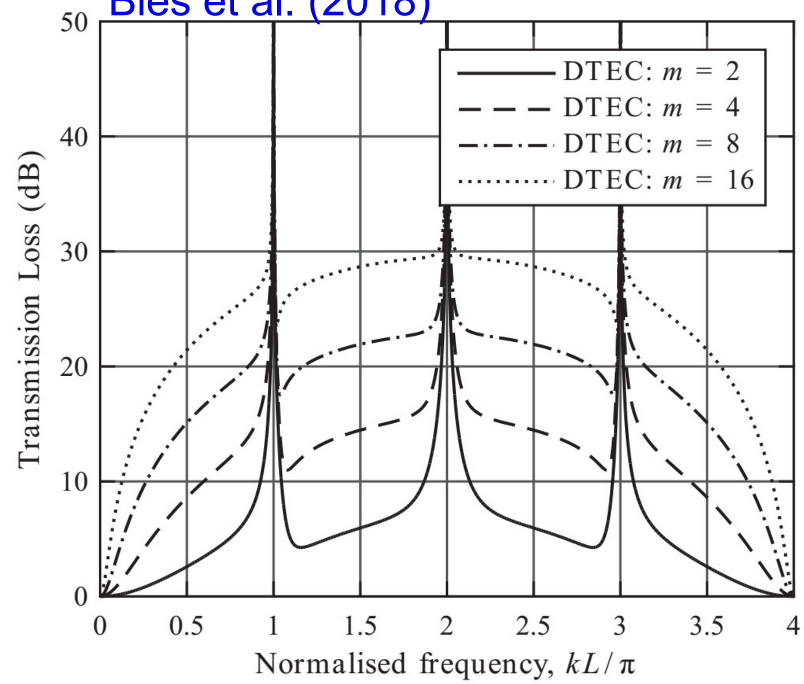


Quarter Wave Tubes



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

Bies et al. (2018)



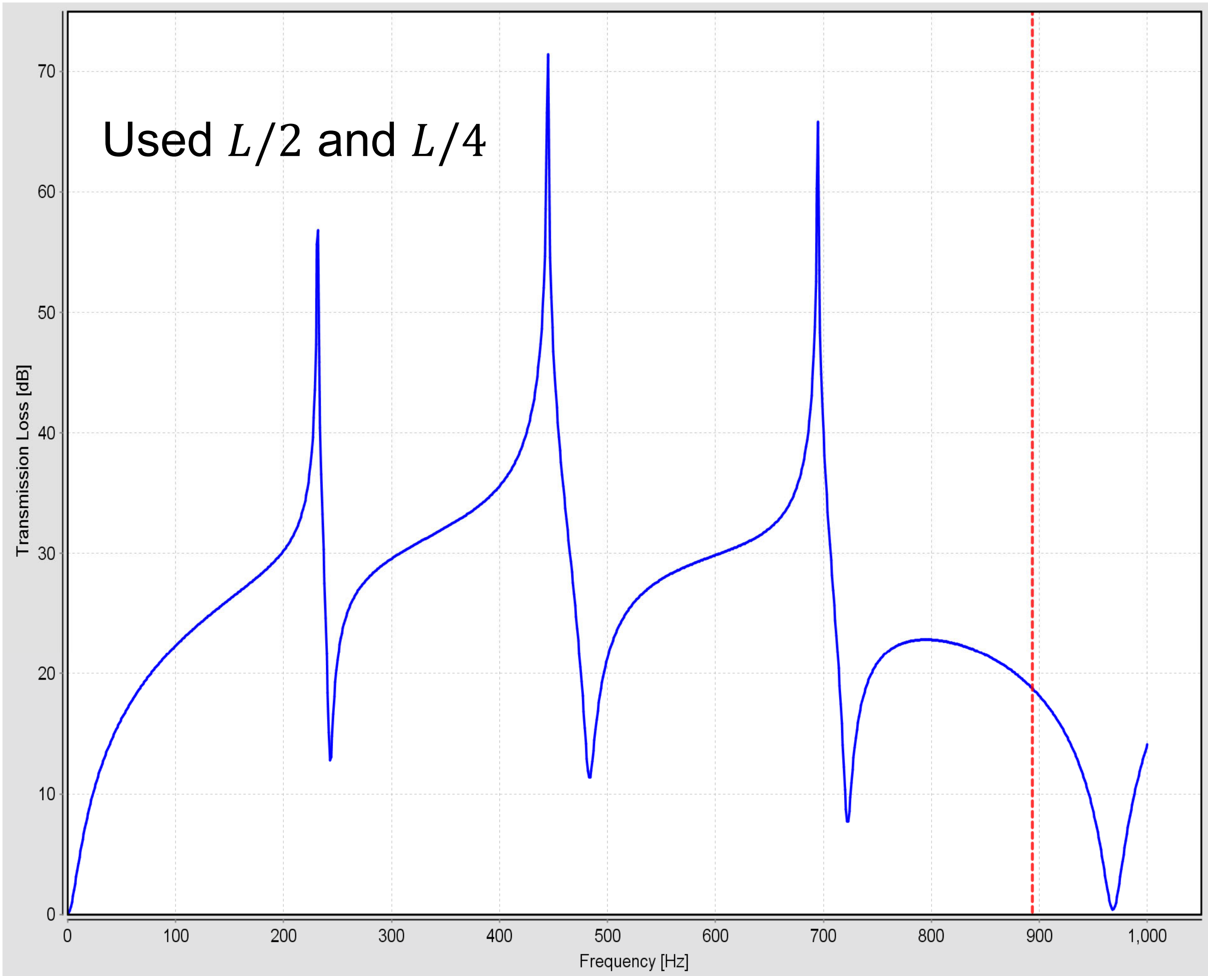
Double Tuned Expansion Chamber

SIDLAB

$d_{duct} = 5$ cm

$d_{exp} = 22.5$ cm

$L = 71$ 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

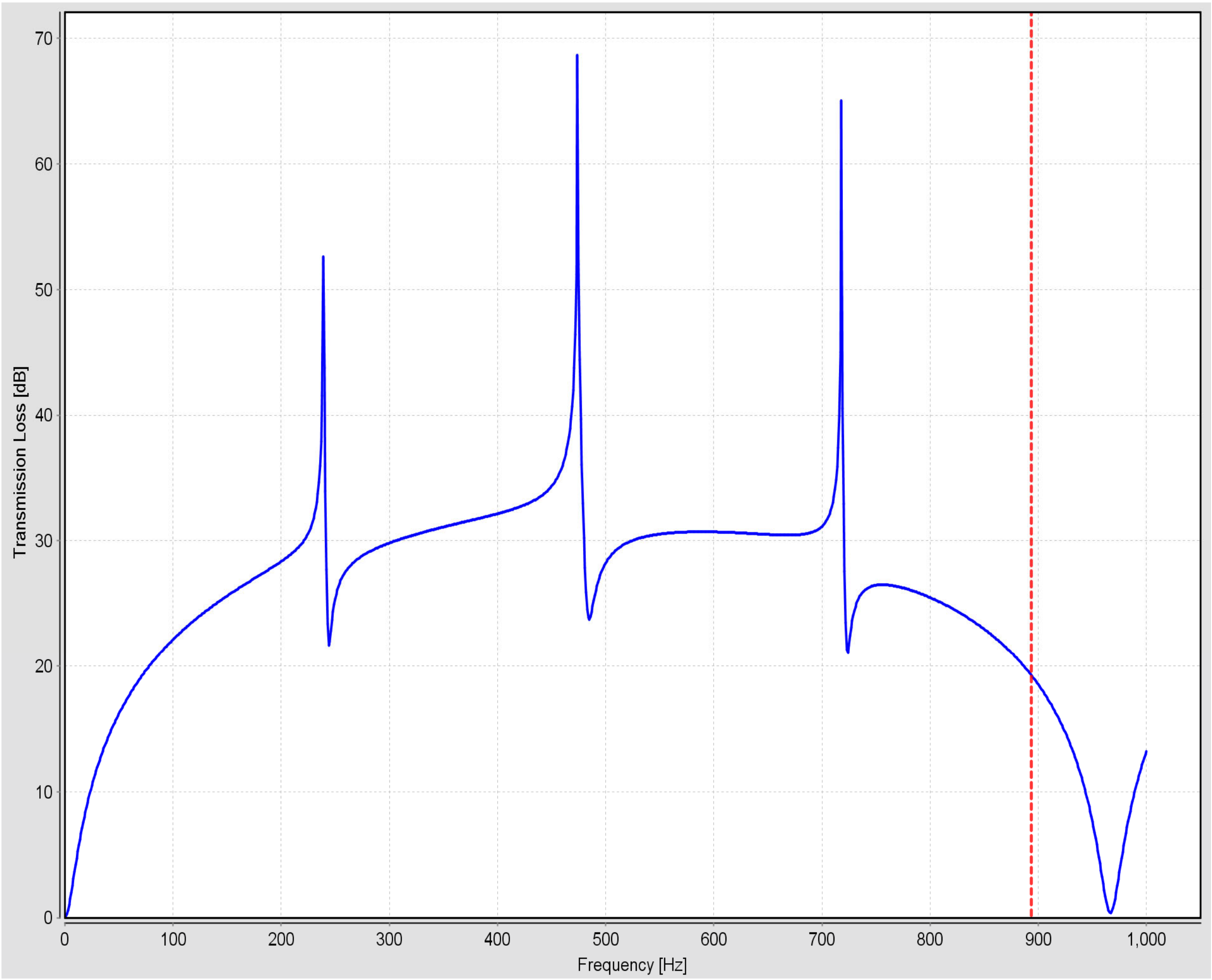
SIDLAB

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

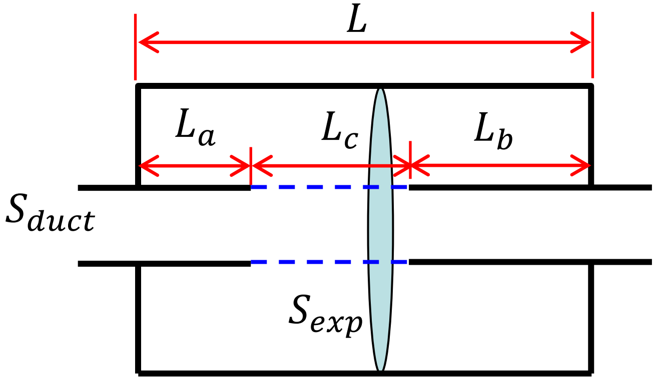
$d_{exp} = 22.5 \text{ cm}$

$L = 71 \text{ cm}$

$l_0 = 1.2 \text{ cm}$

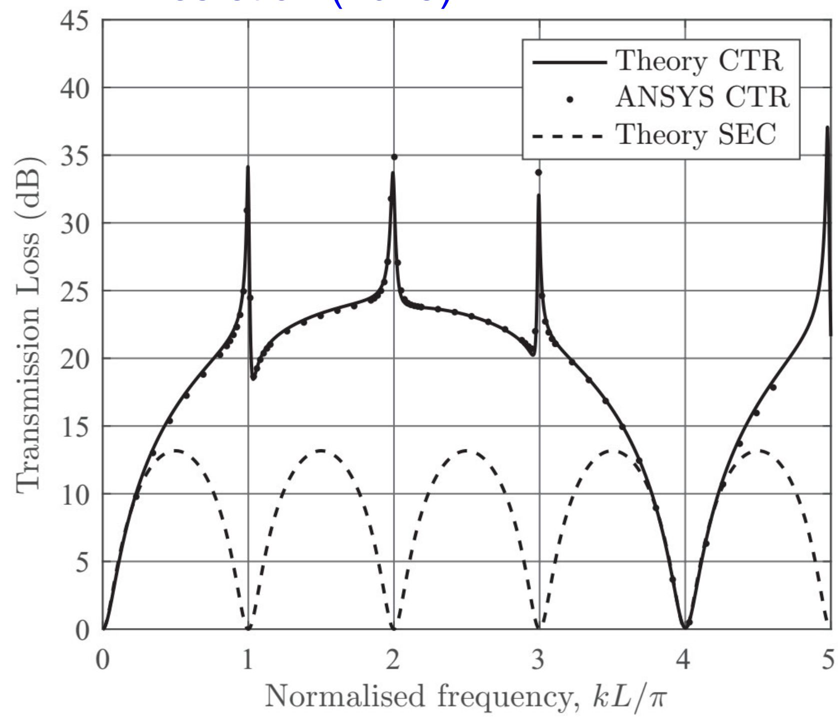


DTEC with Perforations

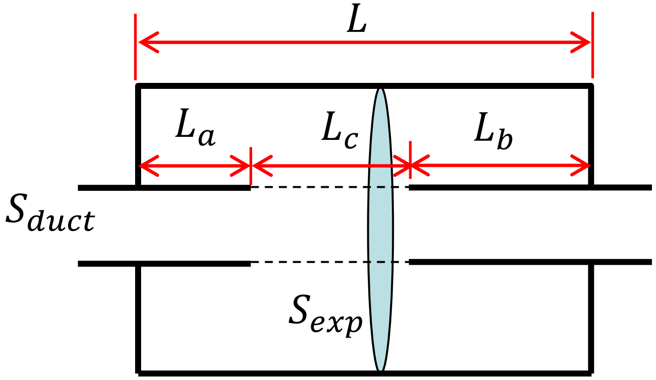


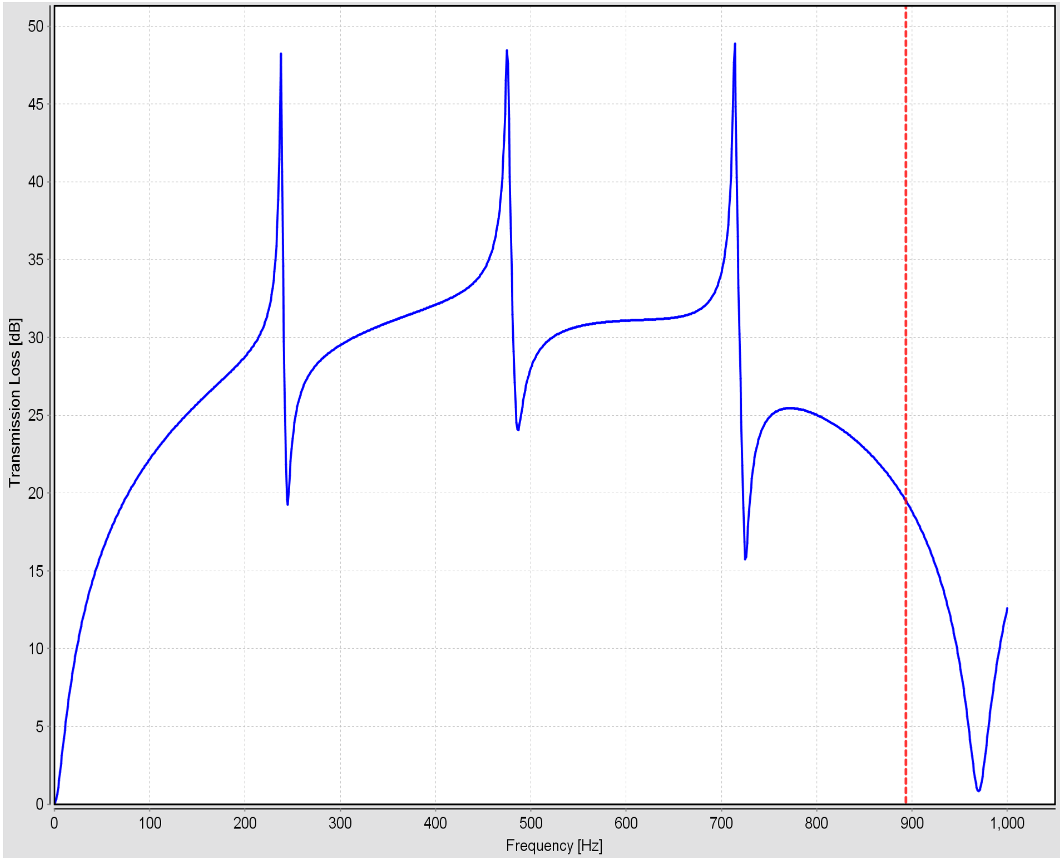
Also called concentric tube resonator (CTR).

Bies et al. (2018)



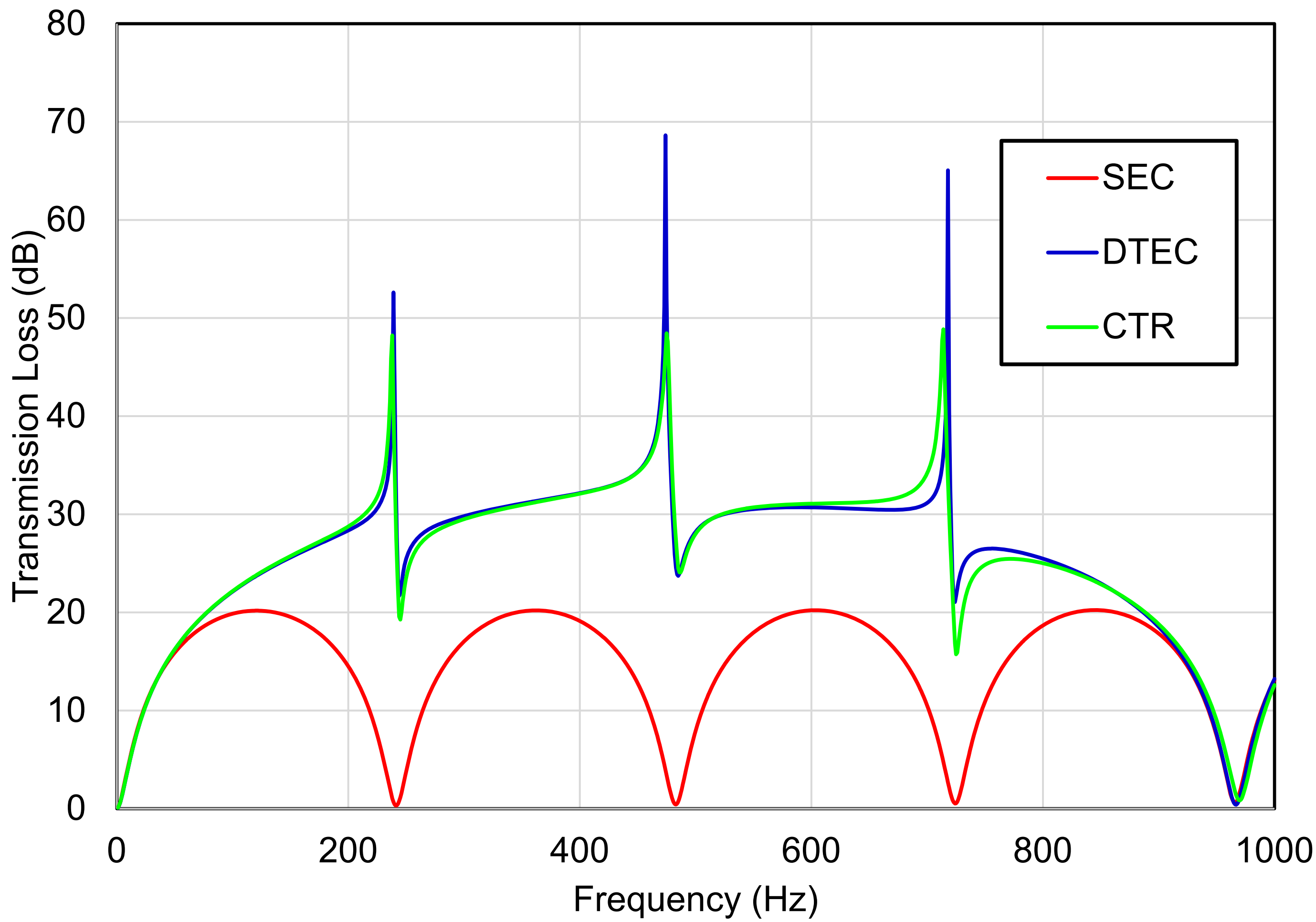
DTEC with Perforations





SIDLAB	Perforate
$d_{duct} = 5$ cm	$t = 1$ mm
$d_{exp} = 22.5$ cm	$d_h = 0.5$ cm
$L = 71$ cm	$\sigma = 0.30$
$l_0 = 1.2$ cm	

Combined Results



References

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