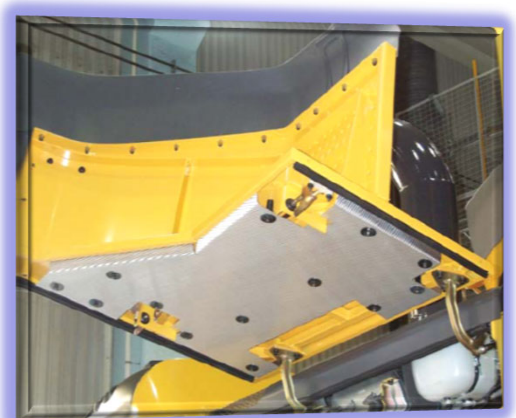
September 18, 2020

Effective Implementation of Microperforated Panel Absorbers

David Herrin
University of Kentucky

Microperforated Panel Absorbers



Advantages

- High temperature resistant
- Chemically stable
- Non-combustible
- Wear resistant / Rugged
- Fiber free
- Washable
- Aesthetic appearance
- Acoustically tunable

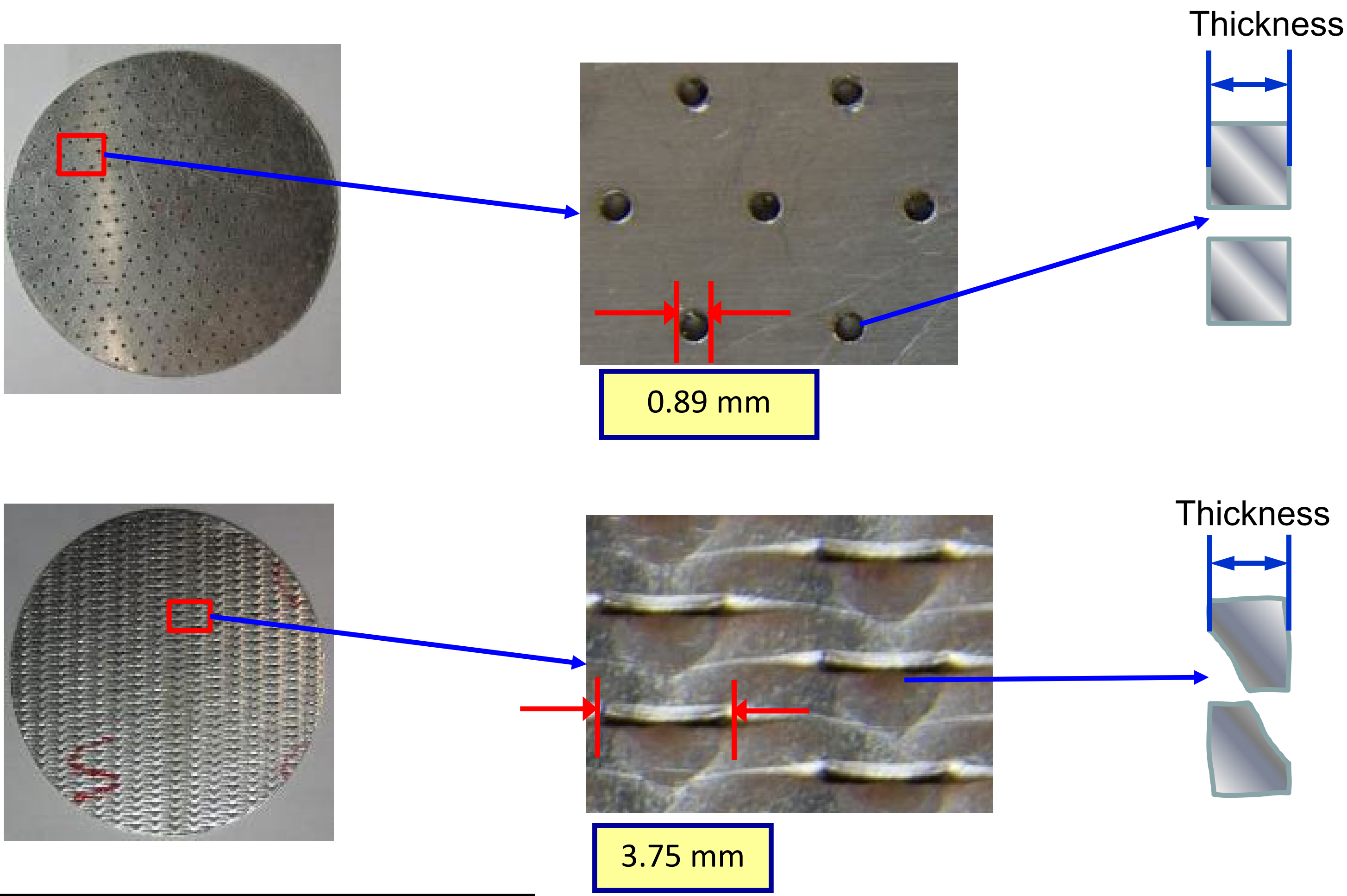
Hindrances to Use

- More expensive than traditional absorbers
- Properties must be measured
- Requires thoughtful integration into the product

Suggested Design Process

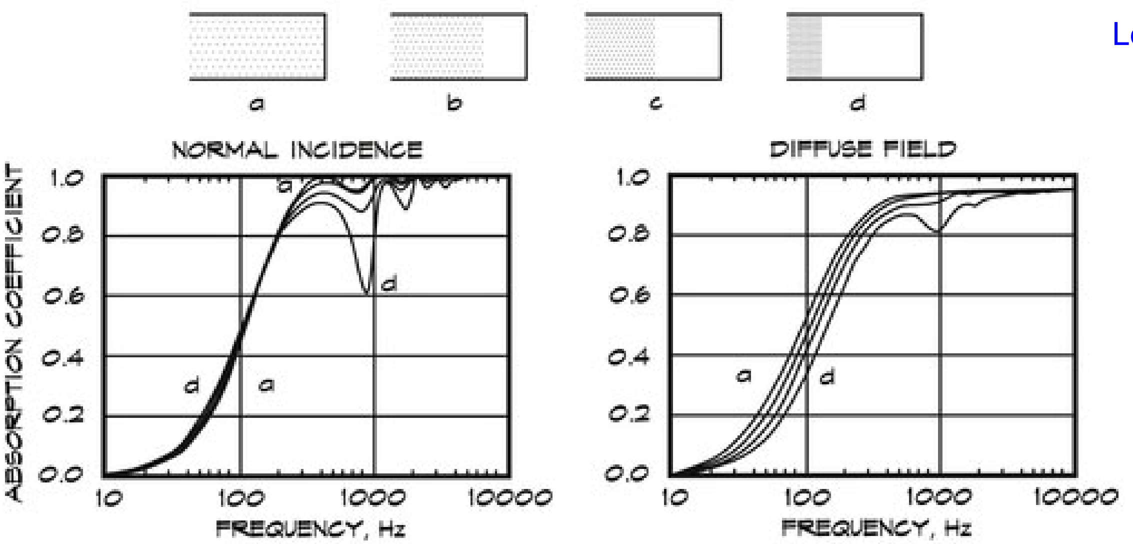
- Select a MPP and measure transfer impedance.
- Consider the environment the MPP is placed in.
- Partition the backing cavity so it behaves in a locally reactive sense.
- Vary the depth of the backing cavity to improve low and broadband frequency attenuation.

MPP and MSP Absorbers



Porous Absorbers Basics for Designers

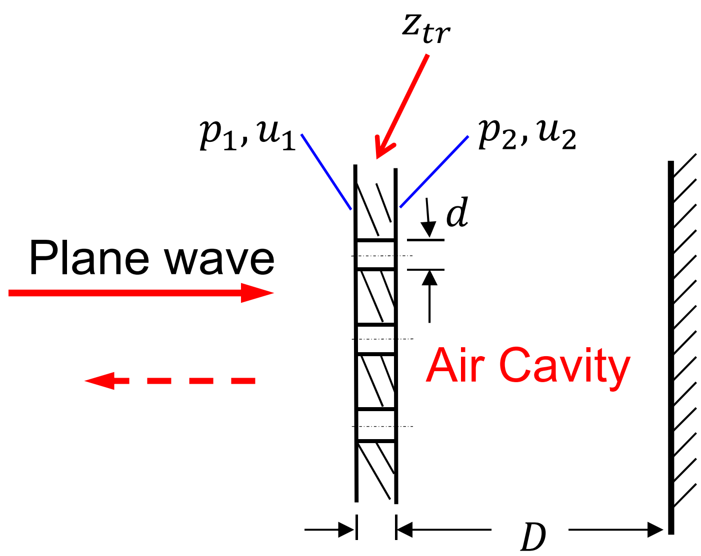
Thin layer with flow resistance $\sigma_r t$ where σ_r is the flow resistivity and t is the thickness.



Long, 2014 based on Ingard, 1994

$\sigma_r t = 2\rho c$ for each case

Sound Absorption of MPP



$$z_{tr} = \frac{1}{\rho c}\frac{p_1 - p_2}{u_1}$$

$$z = z_{tr} - j\cot(kD)$$

MPP Transfer Impedance

$$z_{tr} = r_c + jx_c$$

$$r_c = \mathrm{Re}\left(\frac{j\omega t}{\sigma c}\left(1 - \frac{2}{\kappa\sqrt{-j}}\frac{J_1(\kappa\sqrt{-j})}{J_0(\kappa\sqrt{-j})}\right)^{-1}\right) + \frac{2\beta R_s}{\sigma\rho c} + \frac{|u_h|}{\sigma c} + \frac{KM_g}{\sigma}$$

$$x_c = \mathrm{Im}\left(\frac{j\omega t}{\sigma c}\left(1 - \frac{2}{\kappa\sqrt{-j}}\frac{J_1(\kappa\sqrt{-j})}{J_0(\kappa\sqrt{-j})}\right)^{-1}\right) + \frac{0.85 d\omega F_\delta\left(1 + \frac{|u_h|}{\sigma c}\right)^{-1}}{\sigma c}$$

Grazing Flow

High SPL

$$\kappa = d\sqrt{\frac{\omega}{4\nu}}$$

$$R_s = \frac{\sqrt{2}}{2}\sqrt{\eta\rho\omega}$$

$$F_\delta = \frac{1}{1 + \left(12.6 M_g\right)^3}$$

Symbols

D	cavity depth
d	hole diameter
σ	porosity
t	thickness
J_0	zeroth order Bessel function
J_1	first order Bessel function
β	2 for rounded and 4 for sharp edged holes
K	0.15 ± 0.0125
ν	kinematic viscosity
η	dynamic viscosity
M_g	grazing flow Mach number
u_h	peak particle velocity

Maa’s Equation

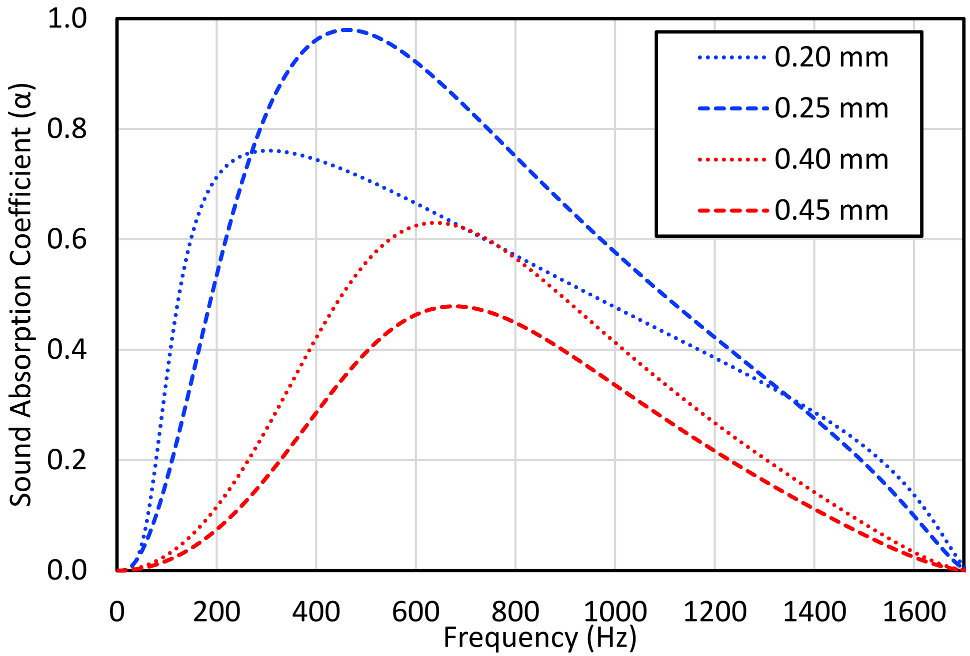
$$z_{tr} = \frac{32\eta t}{\sigma\rho c d^2}\left(\left(1+\frac{\beta^2}{32}\right)^{\frac{1}{2}} + \frac{\sqrt{2}}{32}\beta\frac{d}{t}\right) + j\left(\frac{\omega t}{\sigma c}\left(1+\left(3^2+\frac{\beta^2}{2}\right)^{-\frac{1}{2}} + 0.85\frac{d}{t}\right)\right)$$

$$\beta = d\sqrt{\frac{\omega\rho}{4\eta}}$$

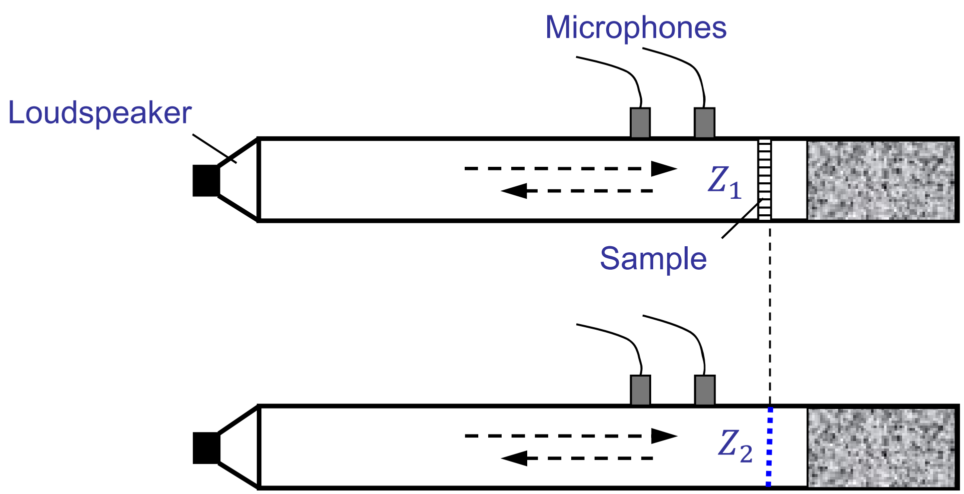
Given

$D = 0.1$ m

$t = 1.0$ mm



Measure Transfer Impedance



$$Z_{tr} = \rho c z_{tr} = Z_1 - Z_2$$

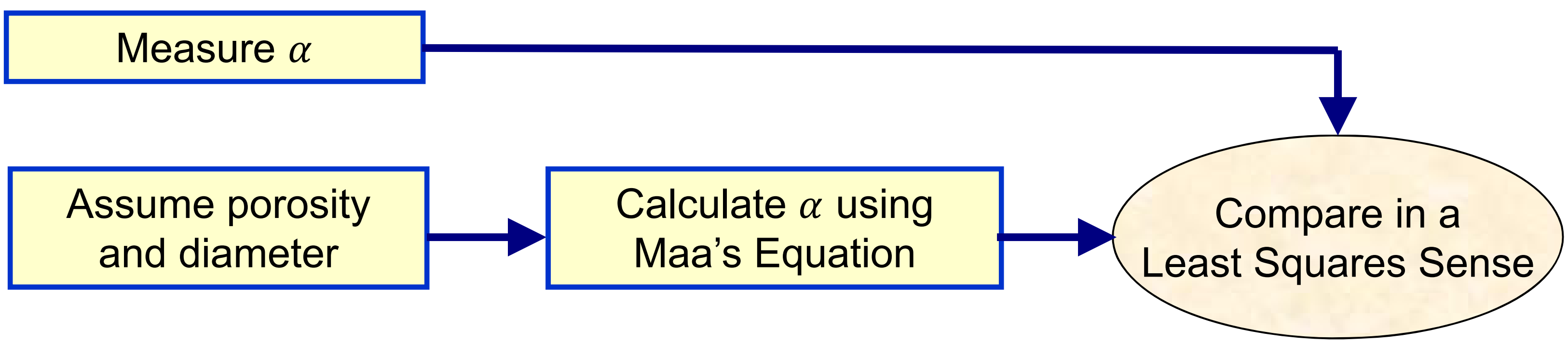
Determine Equivalent Parameters

Assumptions:

1. A MPP can be simulated using Maa's equation with an effective hole diameter and porosity.

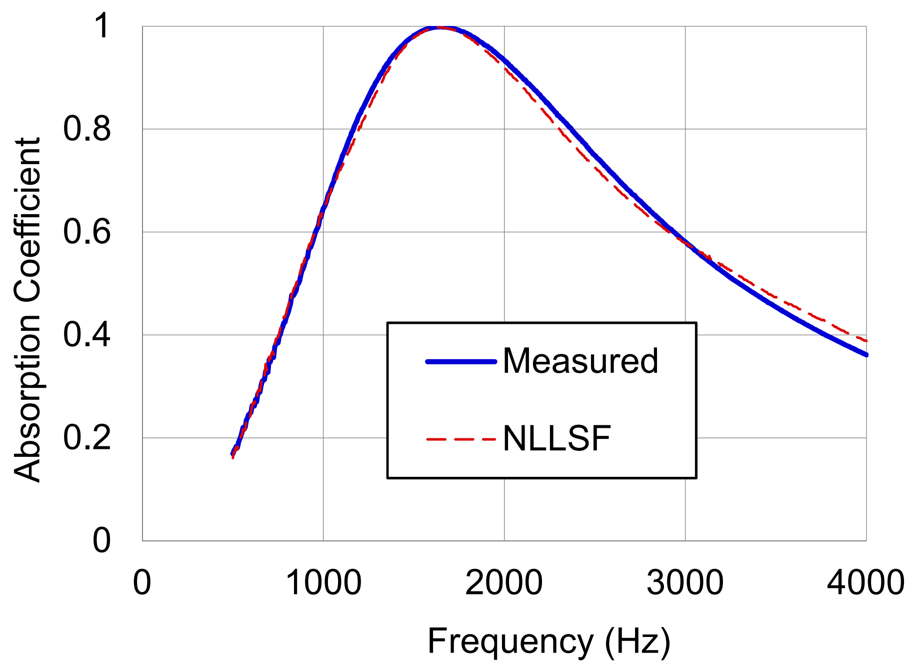
2. Measured absorption coefficient α is accurate.

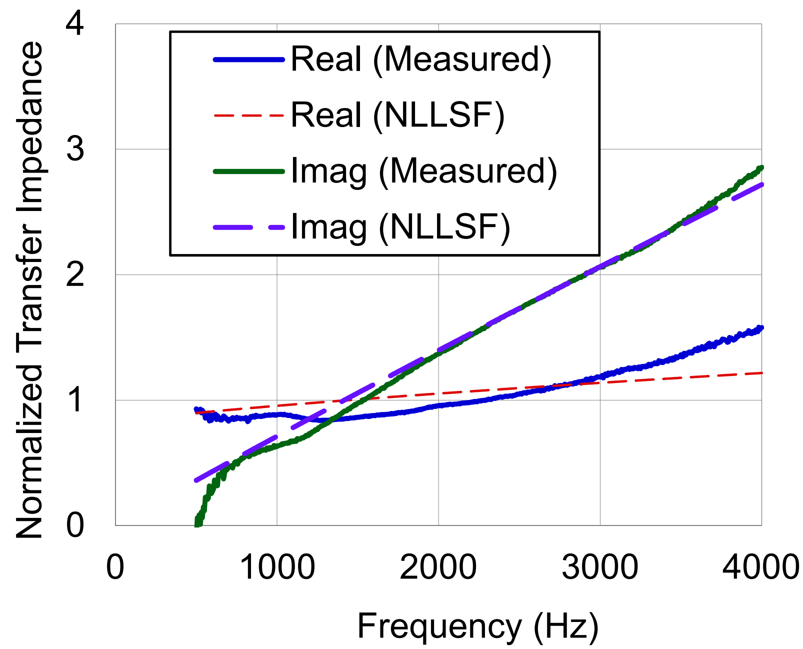
Procedure (Liu et al., 2014)



Minimize the error to find effective porosity and holed diameter.

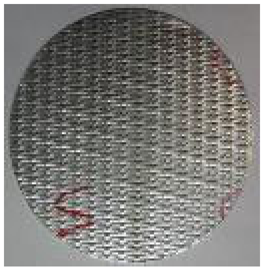
Determine Effective Parameters

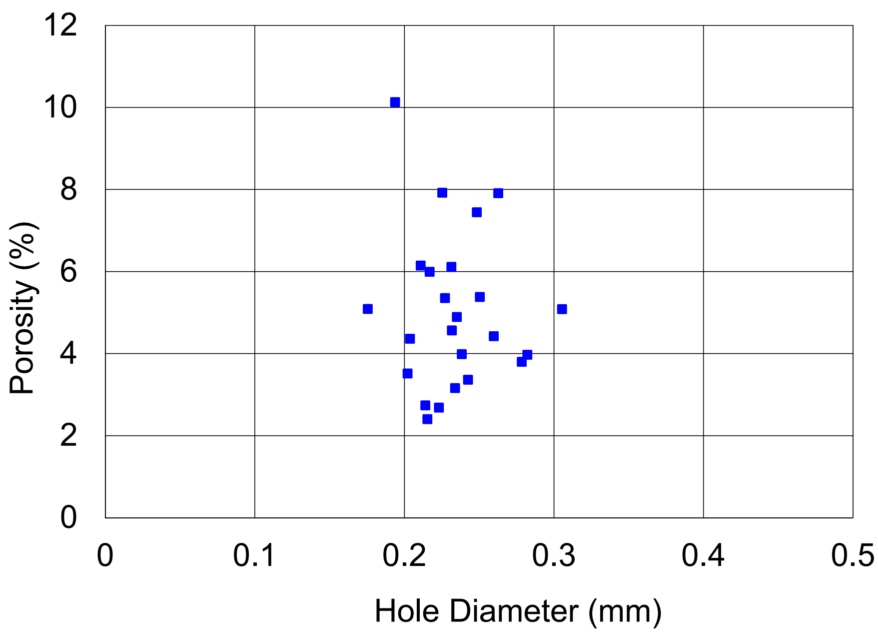


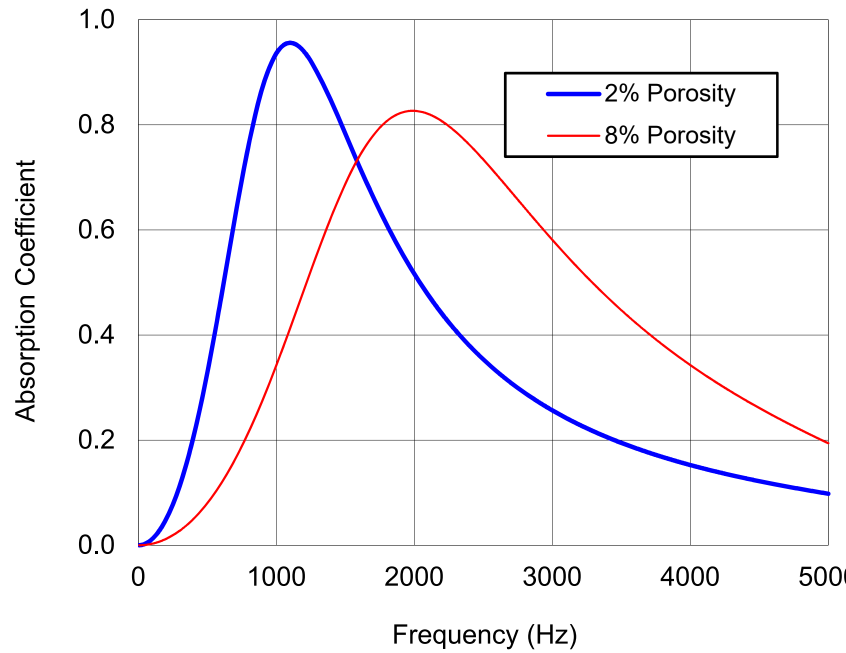


Fitted Hole Diameter: 0.242 mm
Fitted Porosity: 4.11%

Manufacturing Variability







Suggested Design Process

- Select a MPP and measure transfer impedance.
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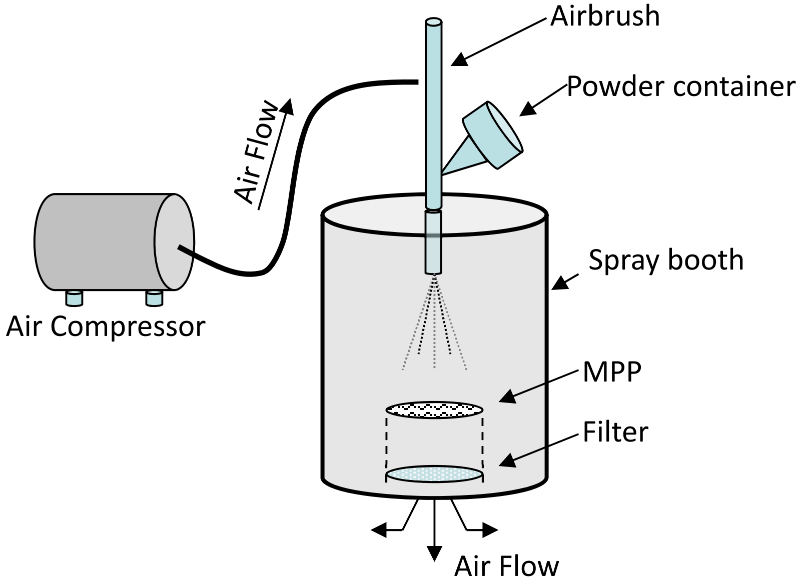
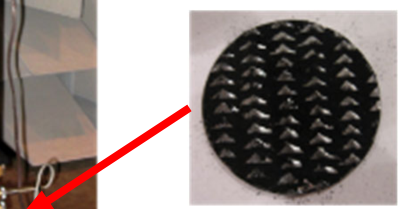
- Vary the depth of the backing cavity to improve low and broadband frequency attenuation.

Effect of Contamination

Spray Booth

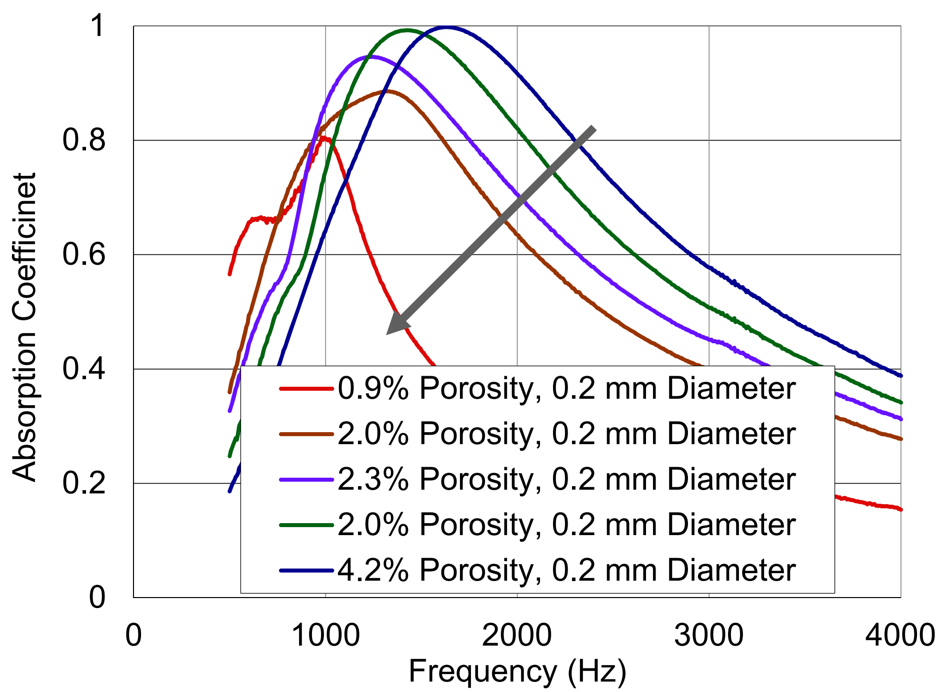


Impedance Tube

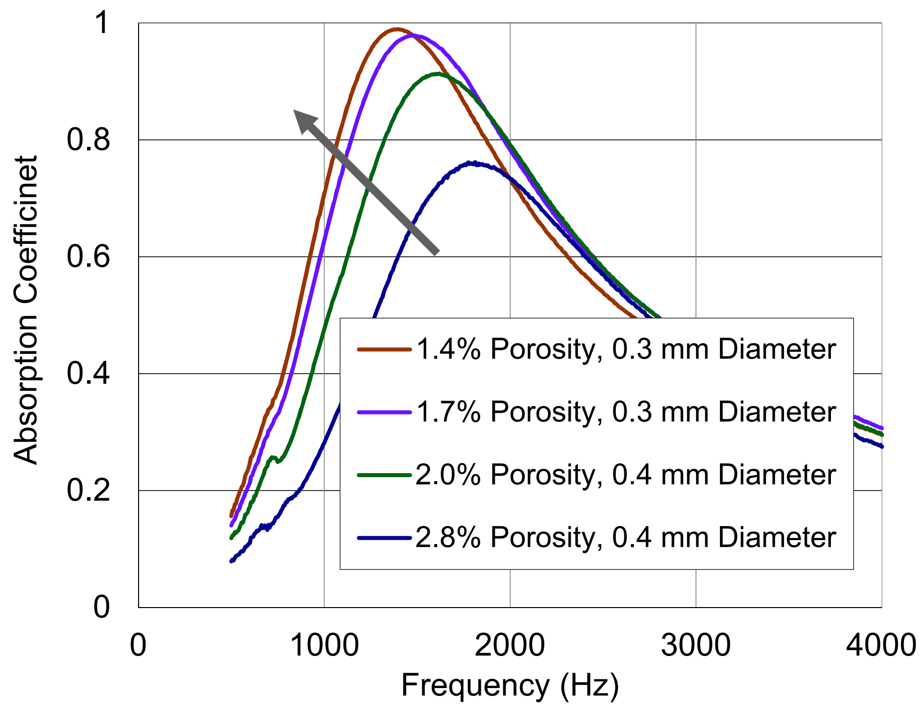


Effect of Contamination

1.0 mm thick MPP with slit perforations



0.6 mm thick MPP with circular perforations



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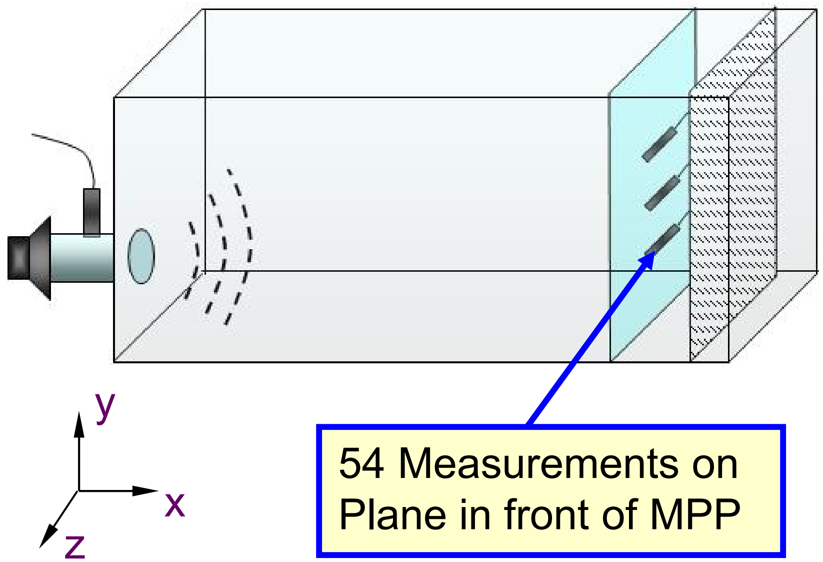
Test Case

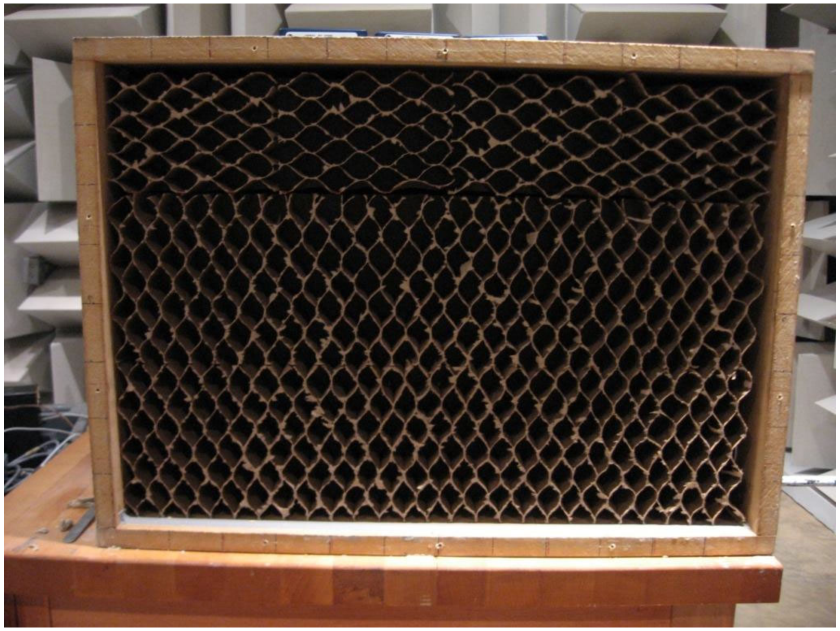


3 Cases

1. Without MPP (Reference)
2. With MPP
3. With MPP + Partitioning

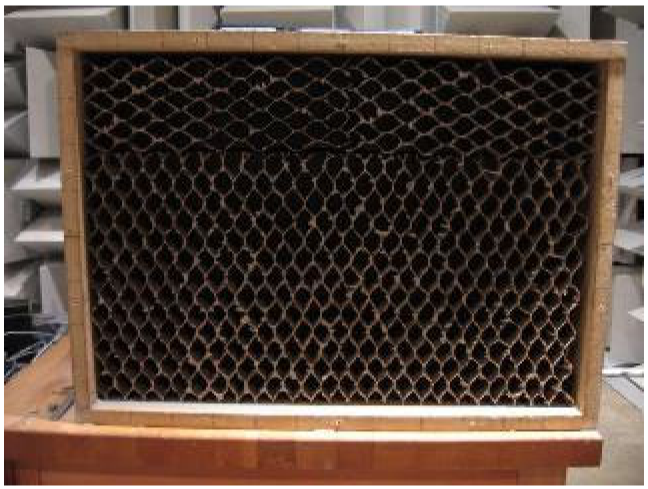
$$IL = \bar{L}_P^{\text{no mpp}} - \bar{L}_P^{\text{mpp}}$$

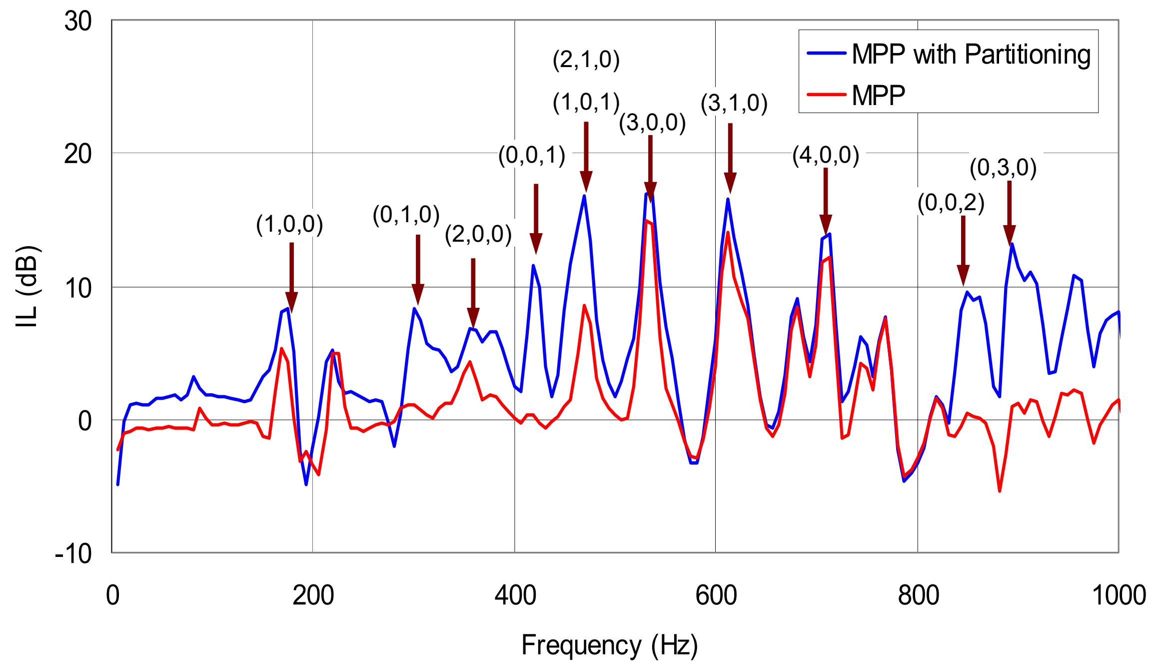
Measurement Setup



Cardboard Partitioning

Partition the Backing Cavity





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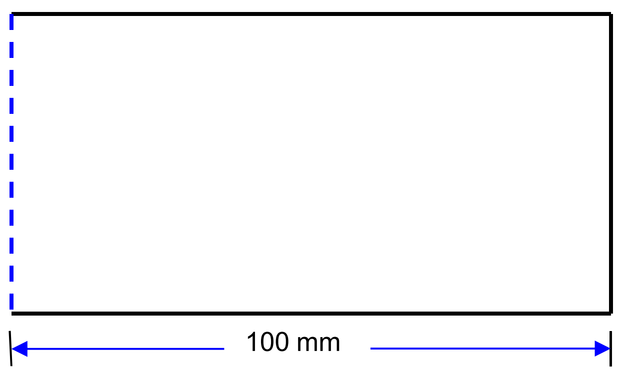
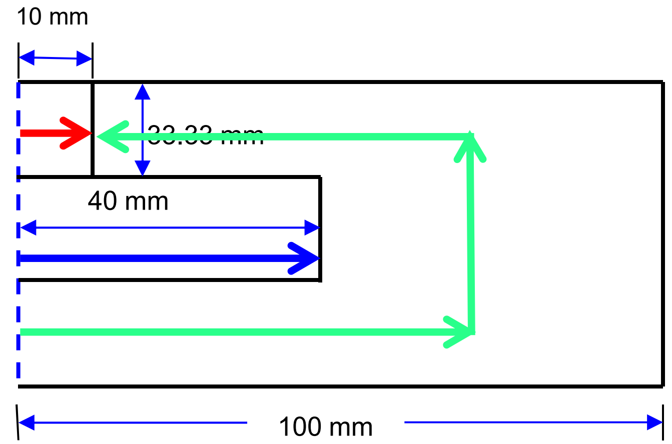
Vary the Cavity Depth

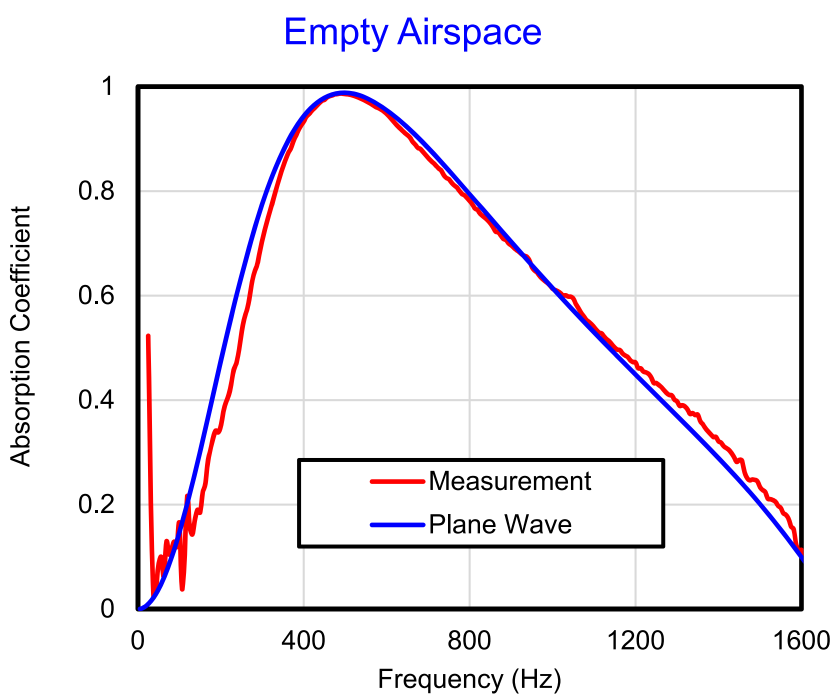
Baseline

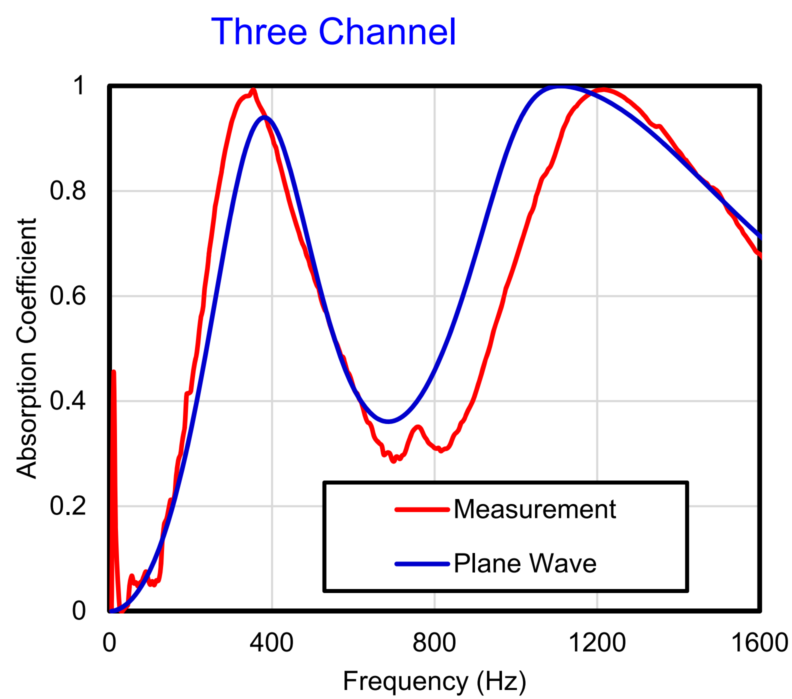


Three-Channel



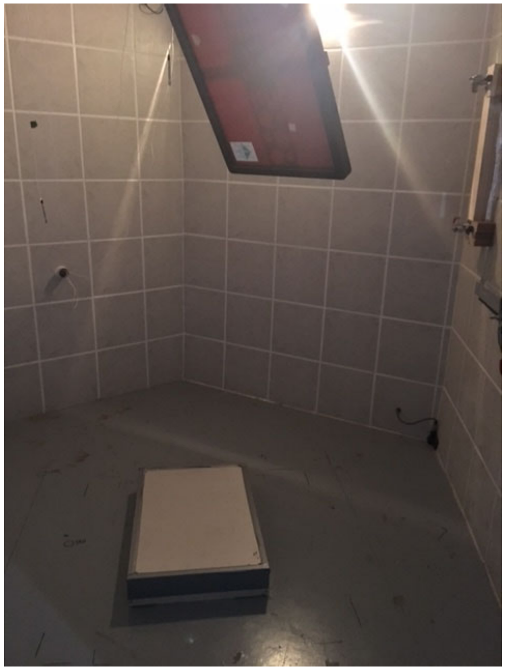
Impedance Tube Measurements





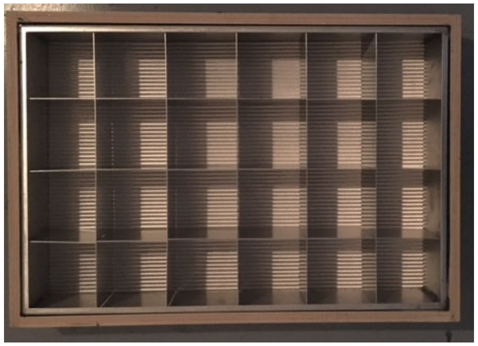
Reverberation Room Test

- AAP Reverberation room: 10.87 m^3 with no parallel walls, and the noise source was a distributed loudspeaker
- Humidity: 56%~ 60%, temperature: 21ºC
- Box: 60 cm X 40 cm
- 24 cells (10 cm X 10 cm)

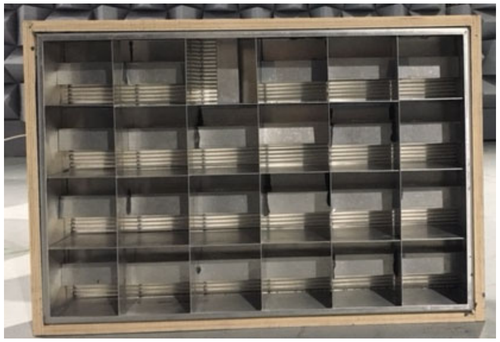


Design Configurations

Partitioned

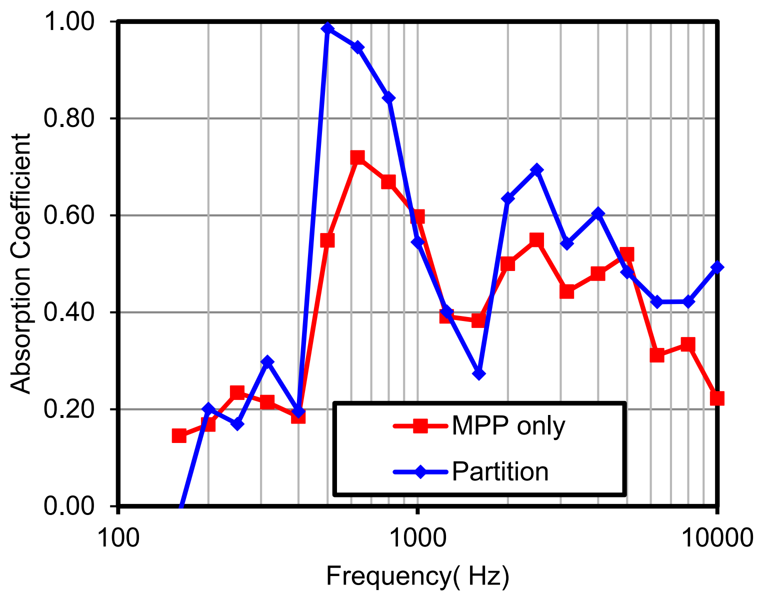


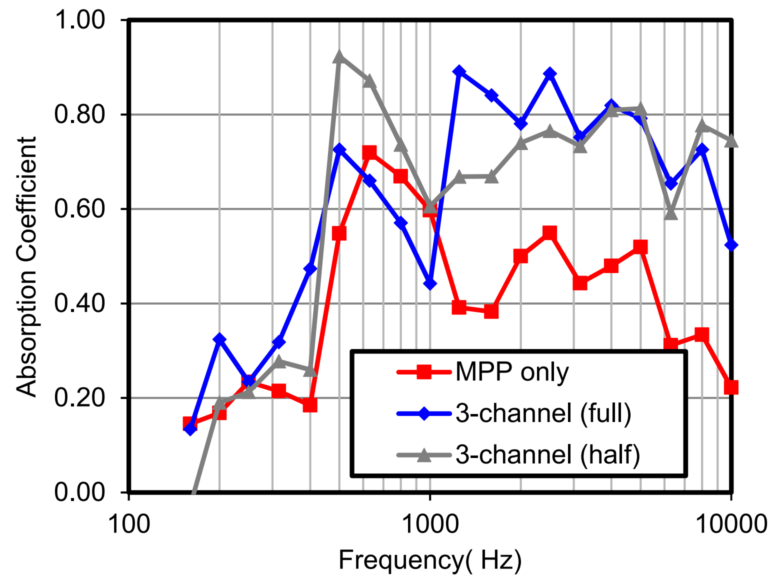
Three channel



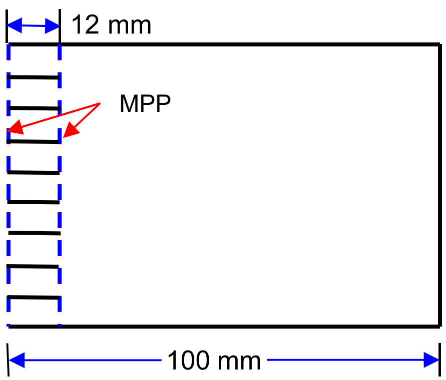
Half Three channel

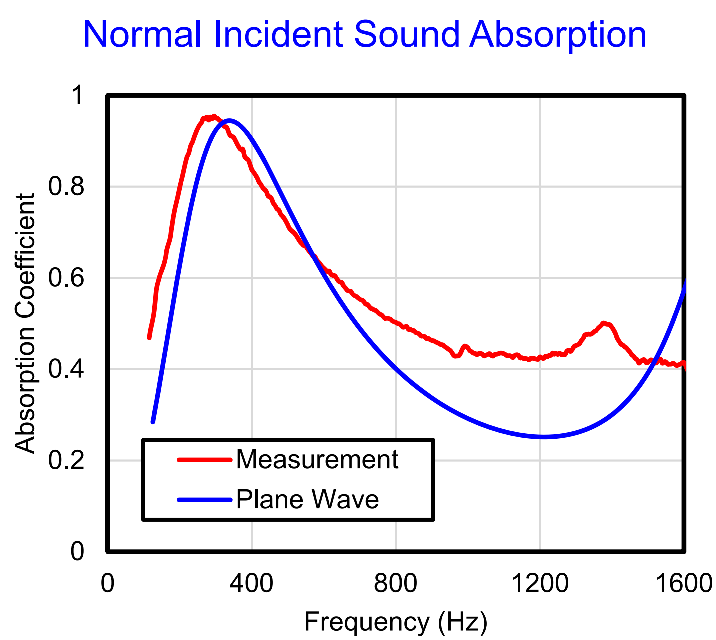
Partition and Three-Channel



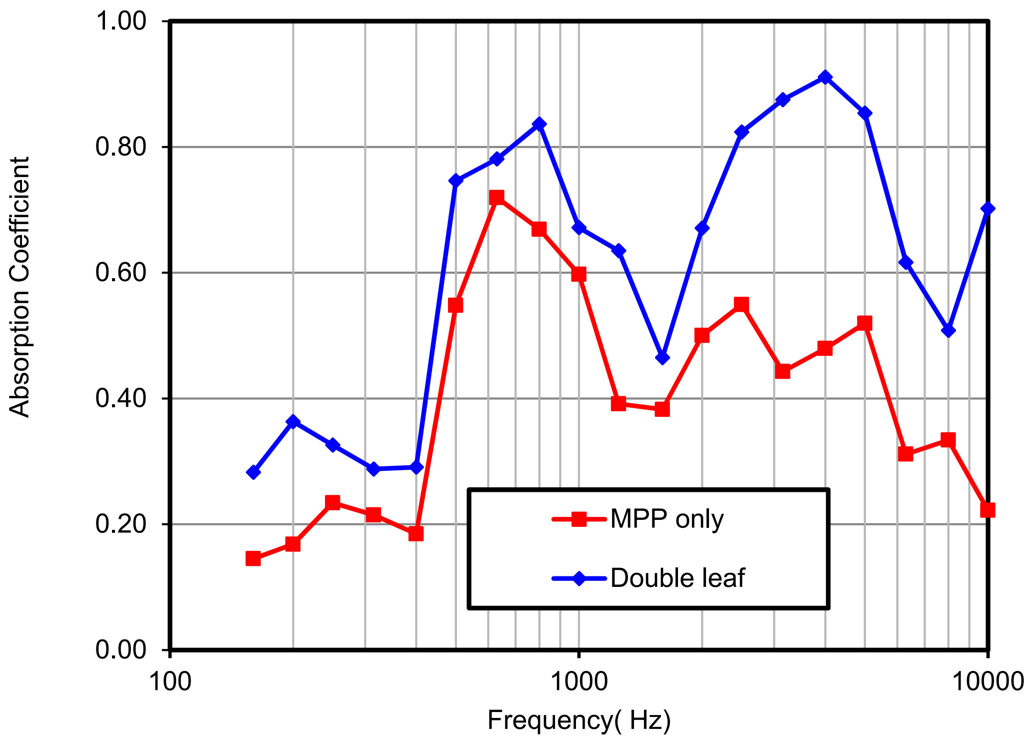


Double Leaf Configuration





Double Leaf Configuration



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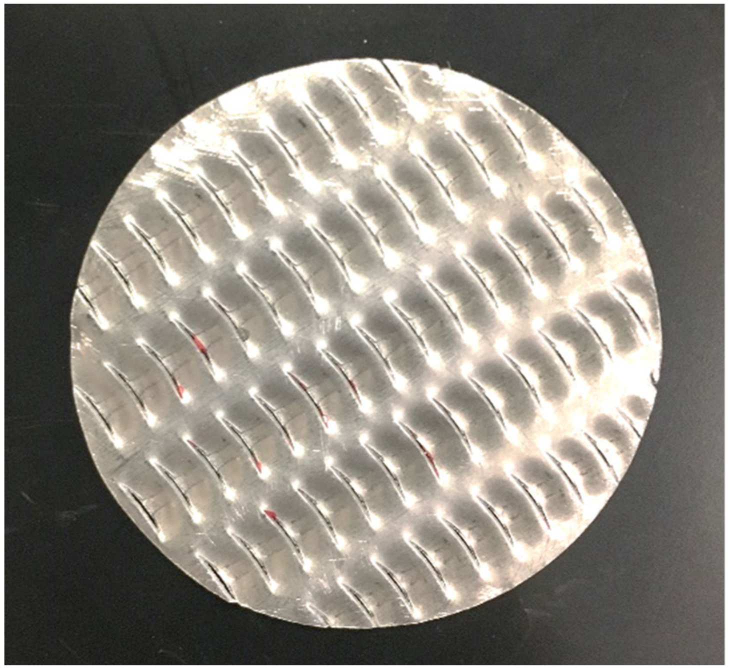
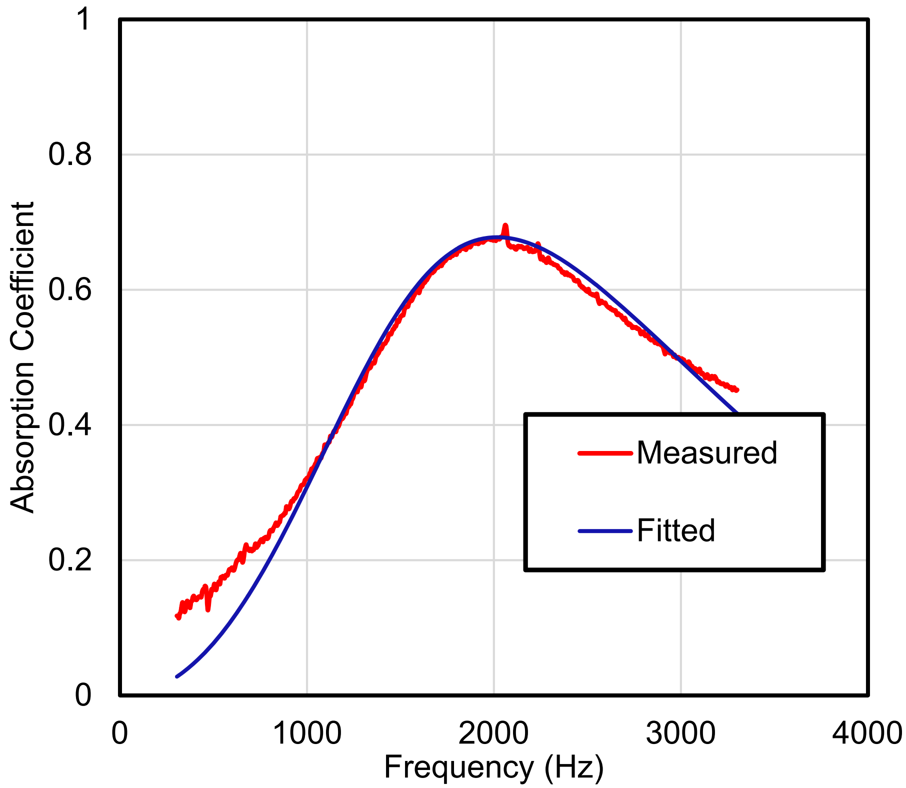
Ultra Thin MPP

- Much thinner than a traditional MPP
- Ideal for use as a fiber cover



Curve Fit to Determine Parameters



Effective Parameters

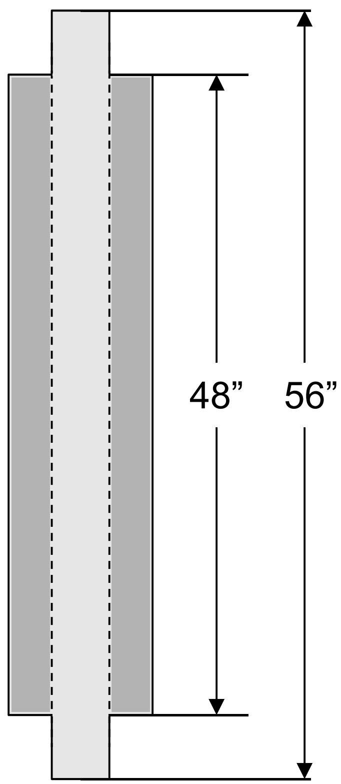
Thickness: 0.65 mm;

Hole diameter: 0.23 mm;

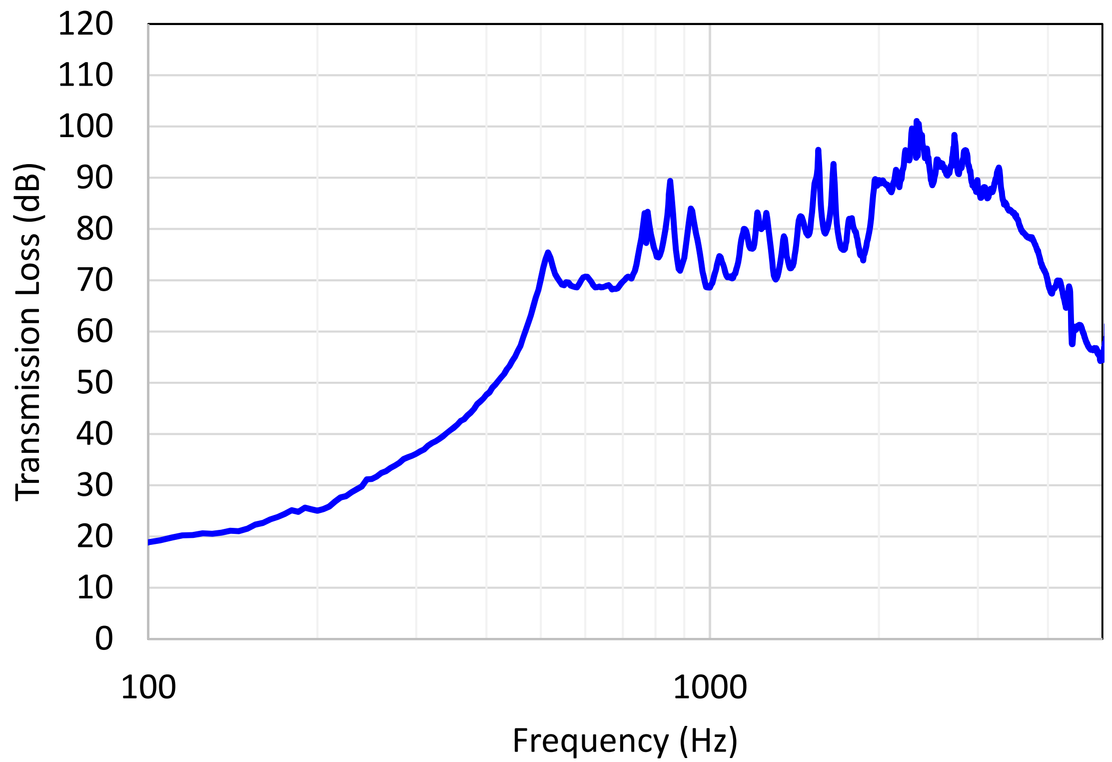
Porosity: 8.0%

Silencer with MPP

Transmission Loss Measurement



Absorptive
(Perforated, Fibrous Material)



References

1. Maa, D. Y., Theory and Design of Microperforated-Panel Sound-Absorbing Construction, *Scientia Sinica XVIII,* pp. 55-71, 1975.
2. Allam, S., Guo, Y., and Åbom, M. Acoustical Study of Micro-Perforated Plates for Vehicle Applications, *SAE Noise and Vibration Conference*, Paper No. 2009-01-2037, St. Charles, IL, 2009.
3. Allam, S. and Åbom, M. A New Type of Muffler Based on Microperforated Tubes, *ASME Journal of Vibration and Acoustics*, Vol. 133, 2013.
4. Herrin, D. W., Liu, W., Hua, X., and Liu, J., "A Guide to the Application of Microperforated Panel Absorbers," *Sound and Vibration*, Vol. 51, No. 12, pp. 12-20 (December, 2017).
5. Herrin, D. W., Liu, J., and Seybert, A. F., "Properties and Applications of Microperforated Panels," *Sound and Vibration*, Vol. 45, No. 7, pp. 6-9 (July, 2011).