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Simulating Perforations in MSC Actran

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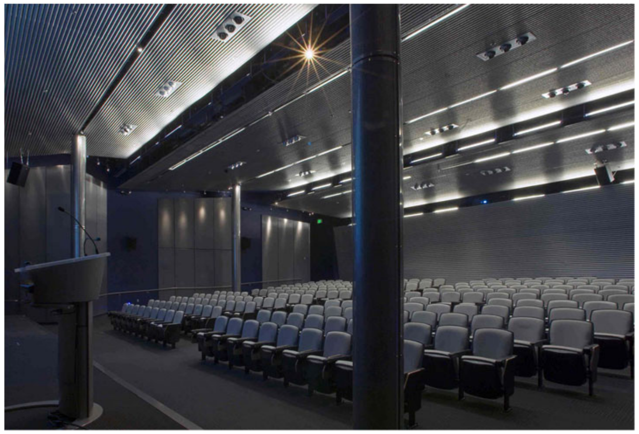
Introduction

Building Interior



Engine Enclosure

Outdoor Noise Barrier

HVAC Duct

Objectives

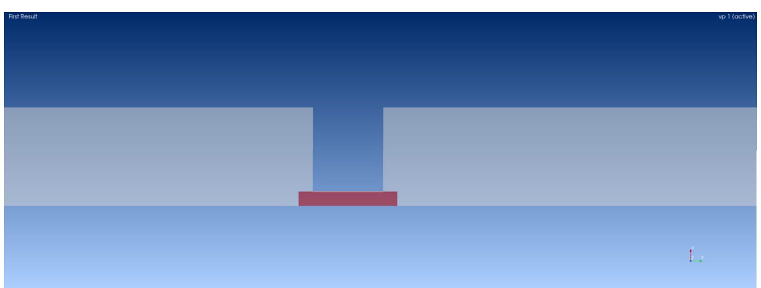
- To model different perforation geometries to better understand how the shape of the perforation affects MPP properties.
- To investigate perforate and small channel modeling capabilities in MSC Actran.

MSC Actran Visco-Thermal Effects

MSC Actran has two simplified models to simulate the visco-thermal effects.

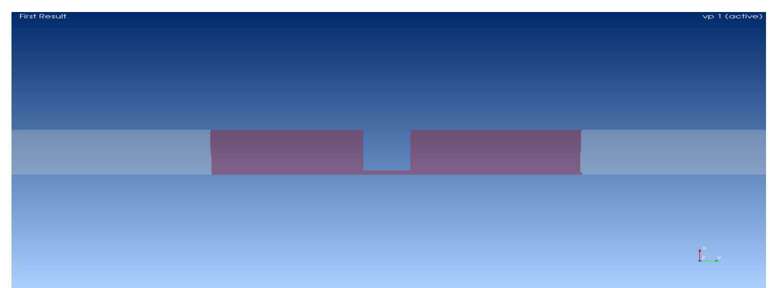
Low Reduced Frequency (LRF) Model

Uses closed form equations to model the small tubes. Geometry should be regular (cylindrical or rectangular). The code identifies the geometry and then assigns appropriate equation parameters to represent it.



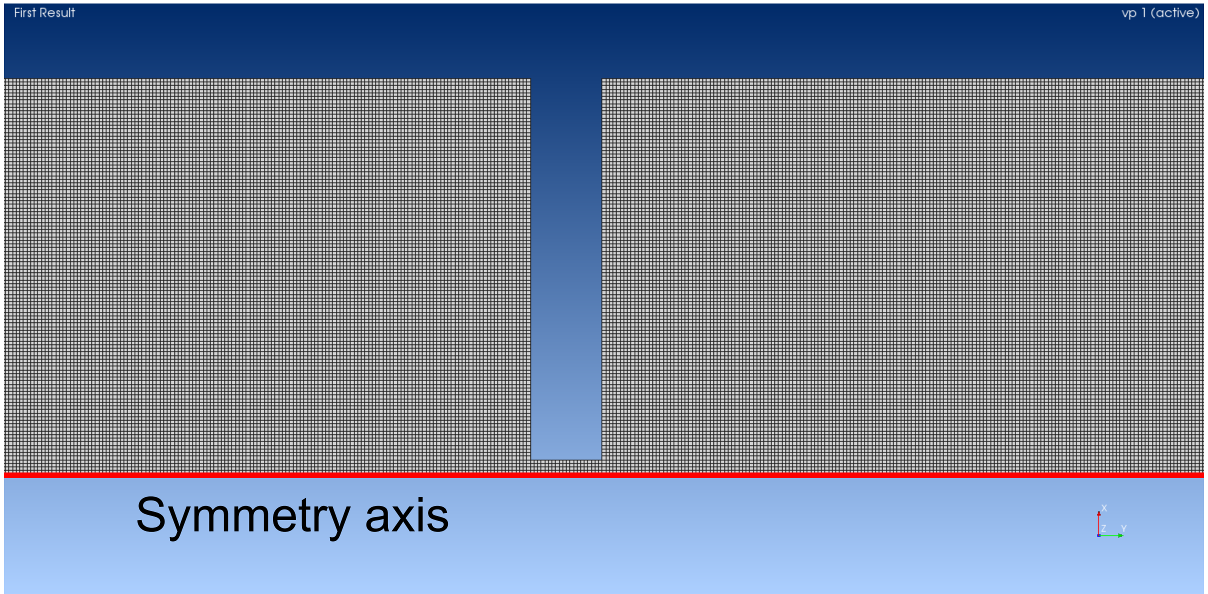
Distance-Based Linearized Navier-Stokes-Fourier (DBLNSF) model

Determines visco-thermal effects using a simplified Navier-Stokes-Fourier model. Geometry may be arbitrary.

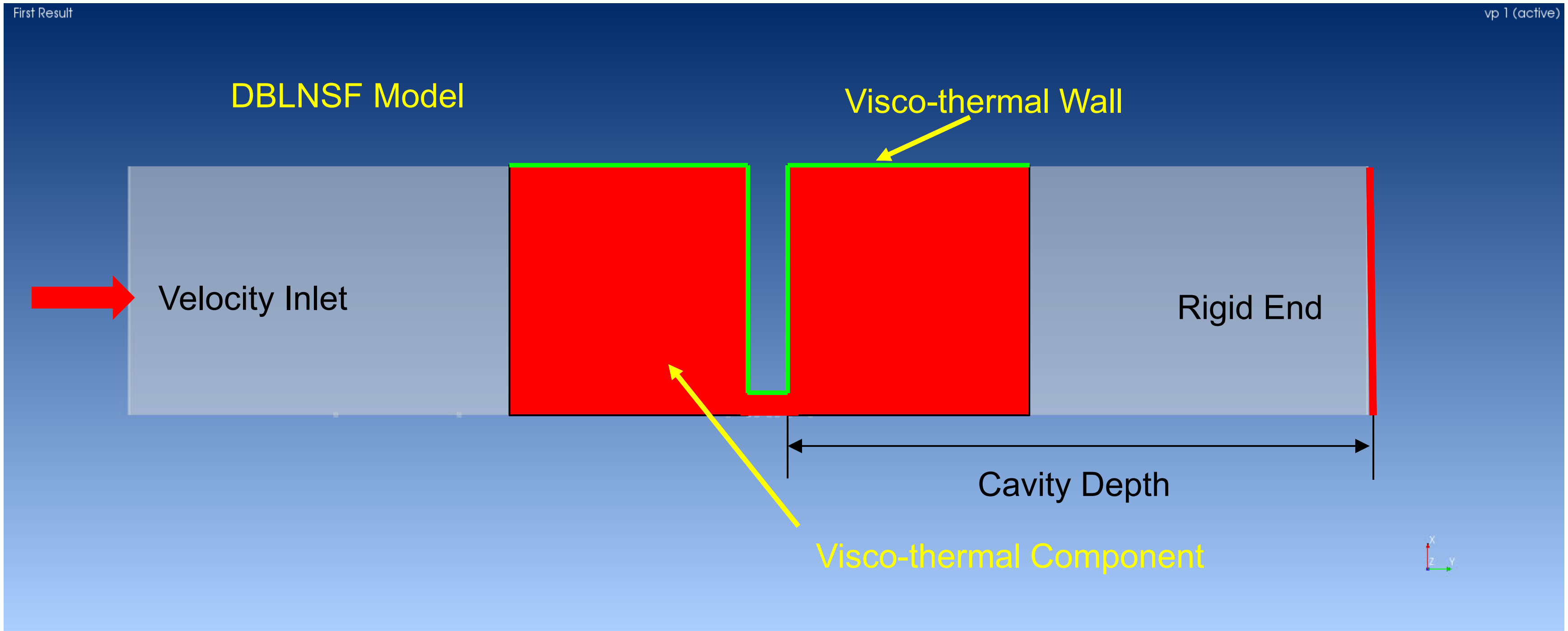


MSC Actran Axisymmetric Model

MSC Actran has built in tool to quickly create box-like geometry mesh.

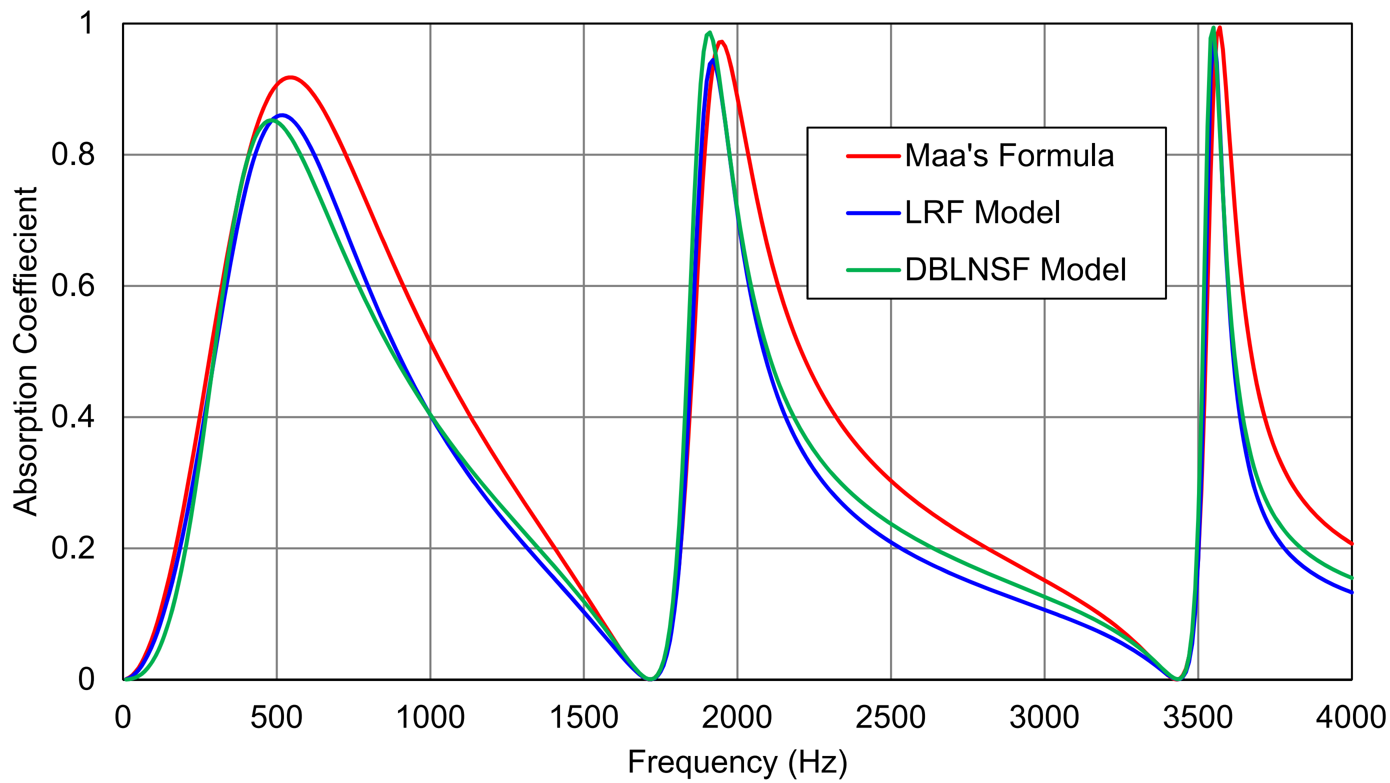


Simulation Approach Sound Absorption



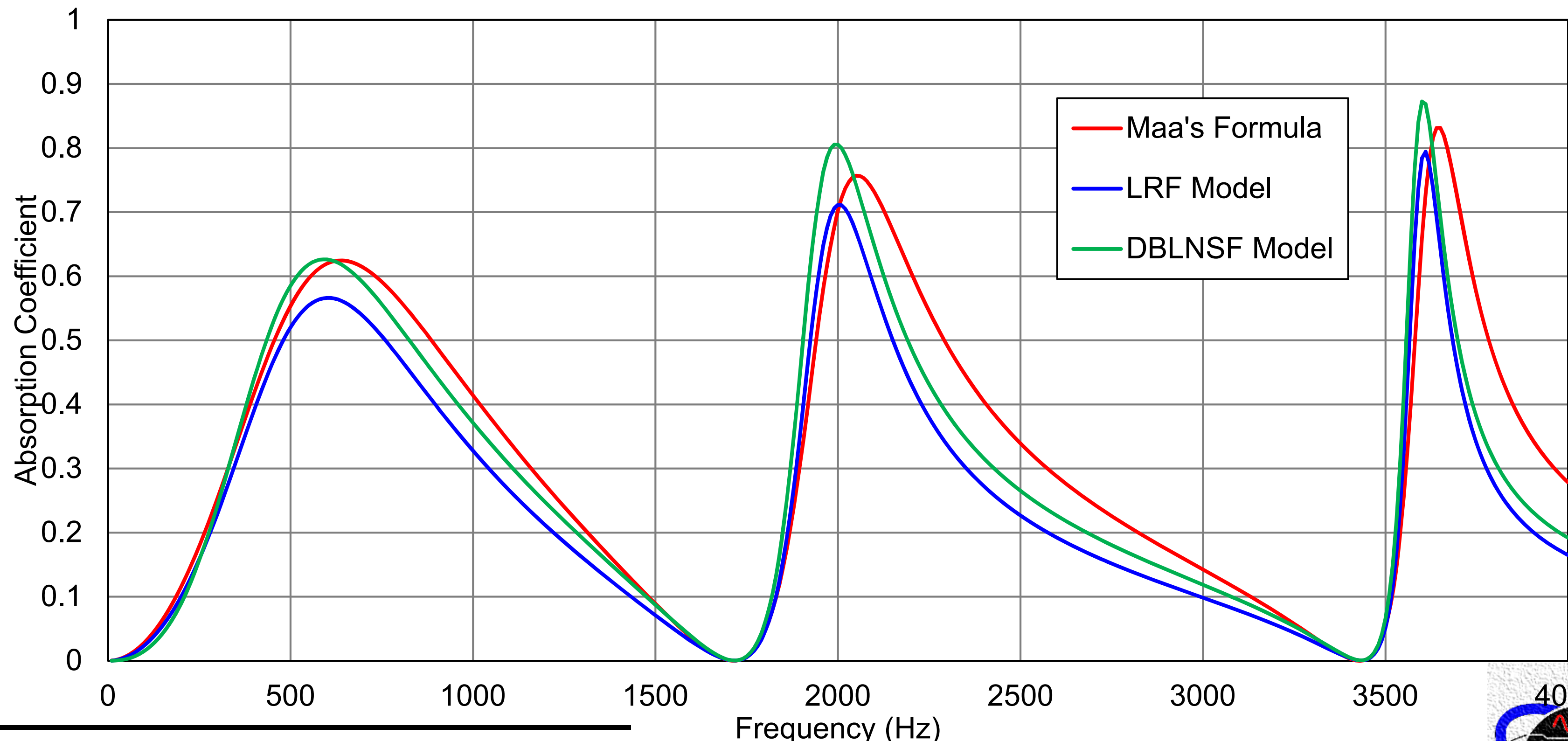
Comparison Absorption Coefficient

Cavity Depth	Hole Diameter	Model Diameter	Perforation Rate	Thickness
10 cm	0.4 mm	2.8 mm	2.0%	1 mm



Comparison Absorption Coefficient

Cavity Depth	Hole Diameter	Model Diameter	Perforation Rate	Thickness
10 cm	0.5 mm	2.8 mm	3.2%	1 mm



Method Comparison

FEM

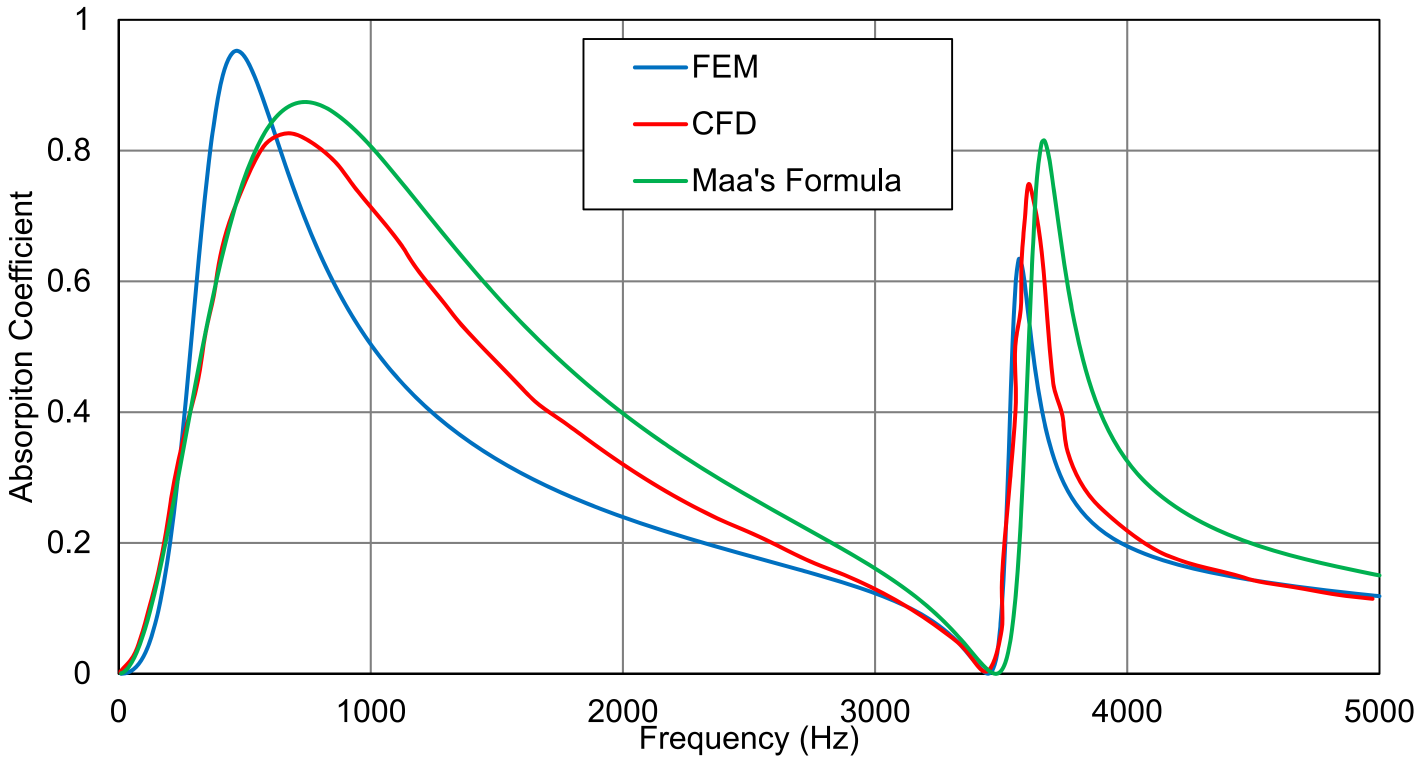
- Calculation Time: 10 min
- Frequency domain
- 2D axisymmetric

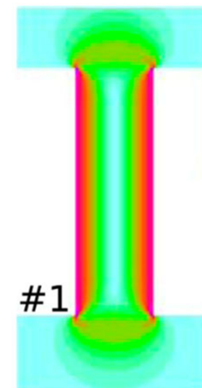
CFD (Herdtle et al., 2013)

- Calculation Time: ?
- Time domain
- Incompressible
- 2D axisymmetric

Comparison Absorption Coefficient

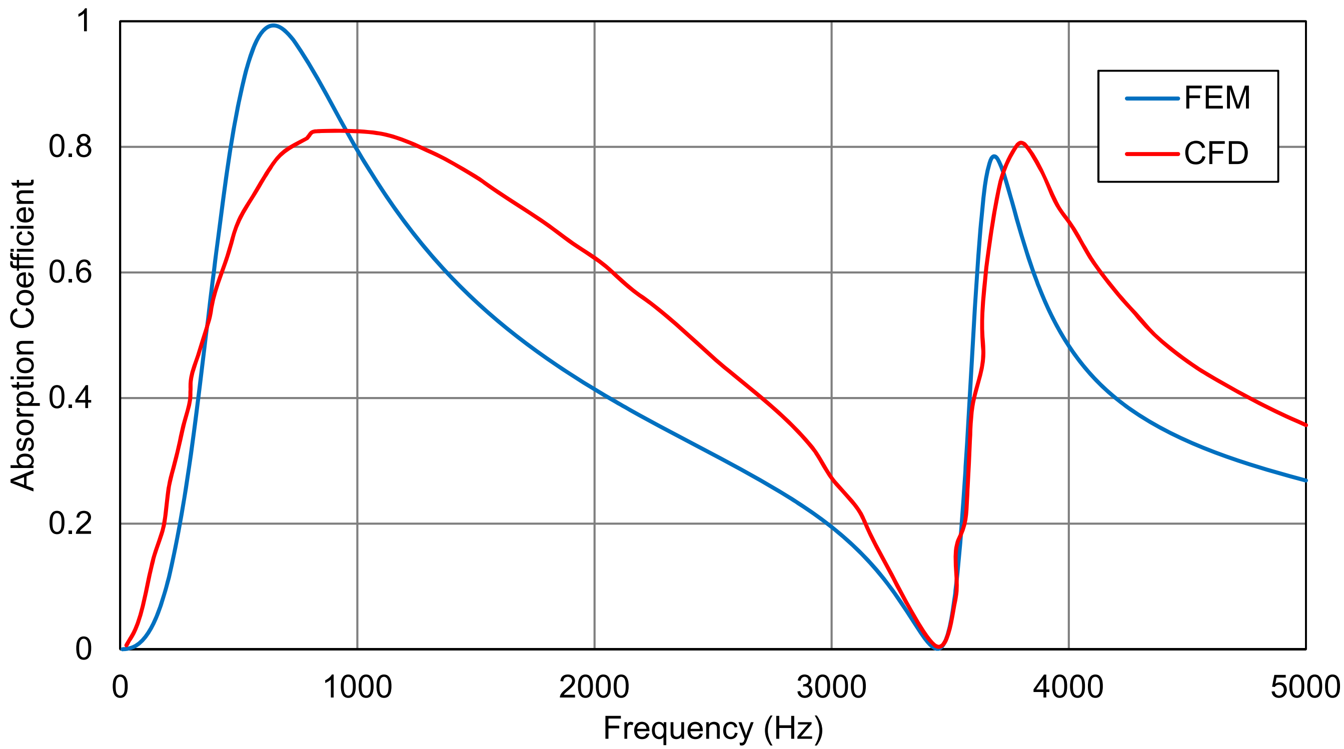
Cavity Depth	Hole Diameter	Model Diameter	Perforation Rate	Thickness
5 cm	0.22 mm	2.2 mm	1.0%	0.7 mm



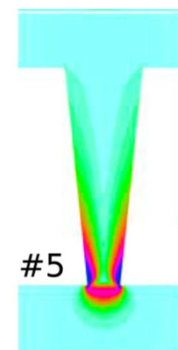


Comparison Absorption Coefficient

Cavity Depth	Inlet Hole Diameter	Model Diameter	Perforation Rate	Thickness
5 cm	0.1 mm	1.0 mm	1.0%	0.7 mm

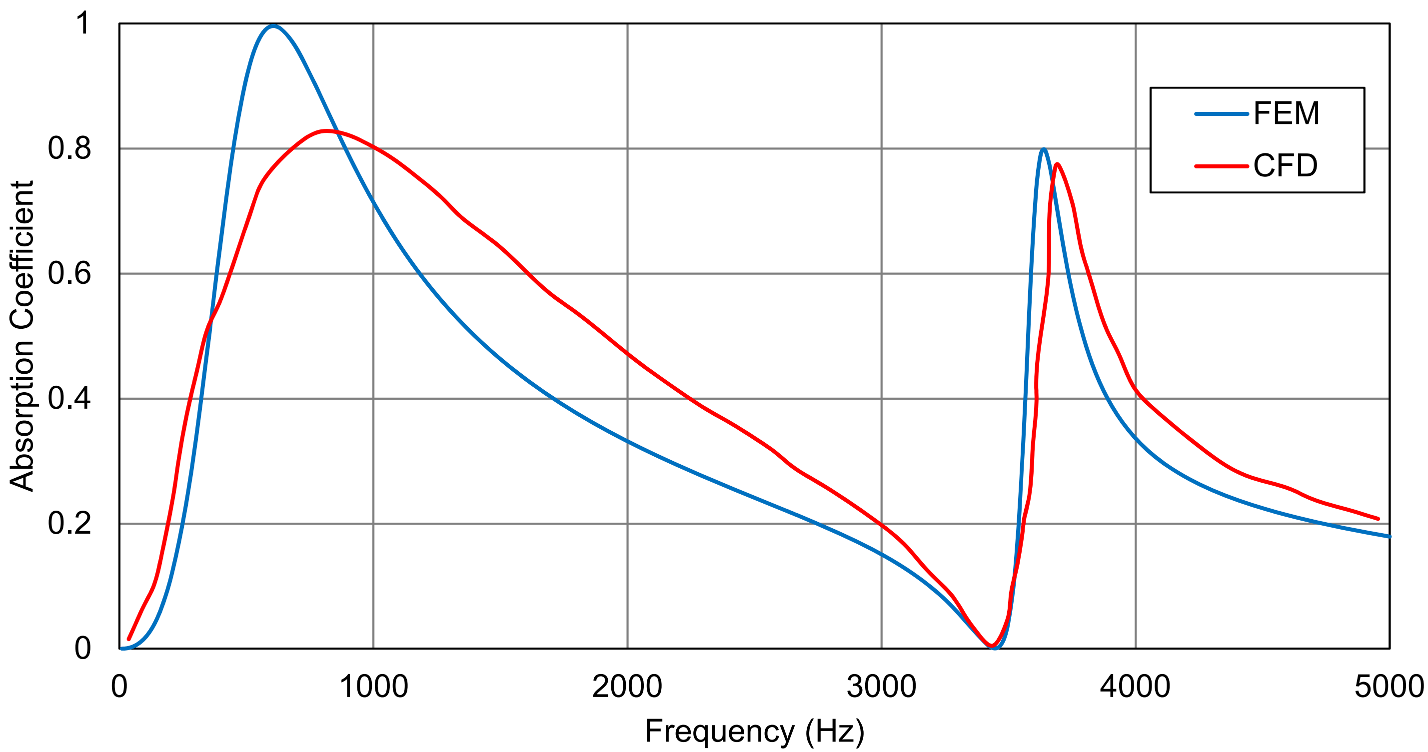


6° draft

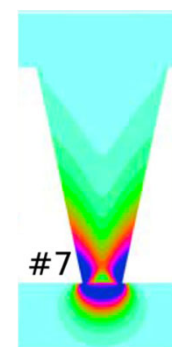


Comparison Absorption Coefficient

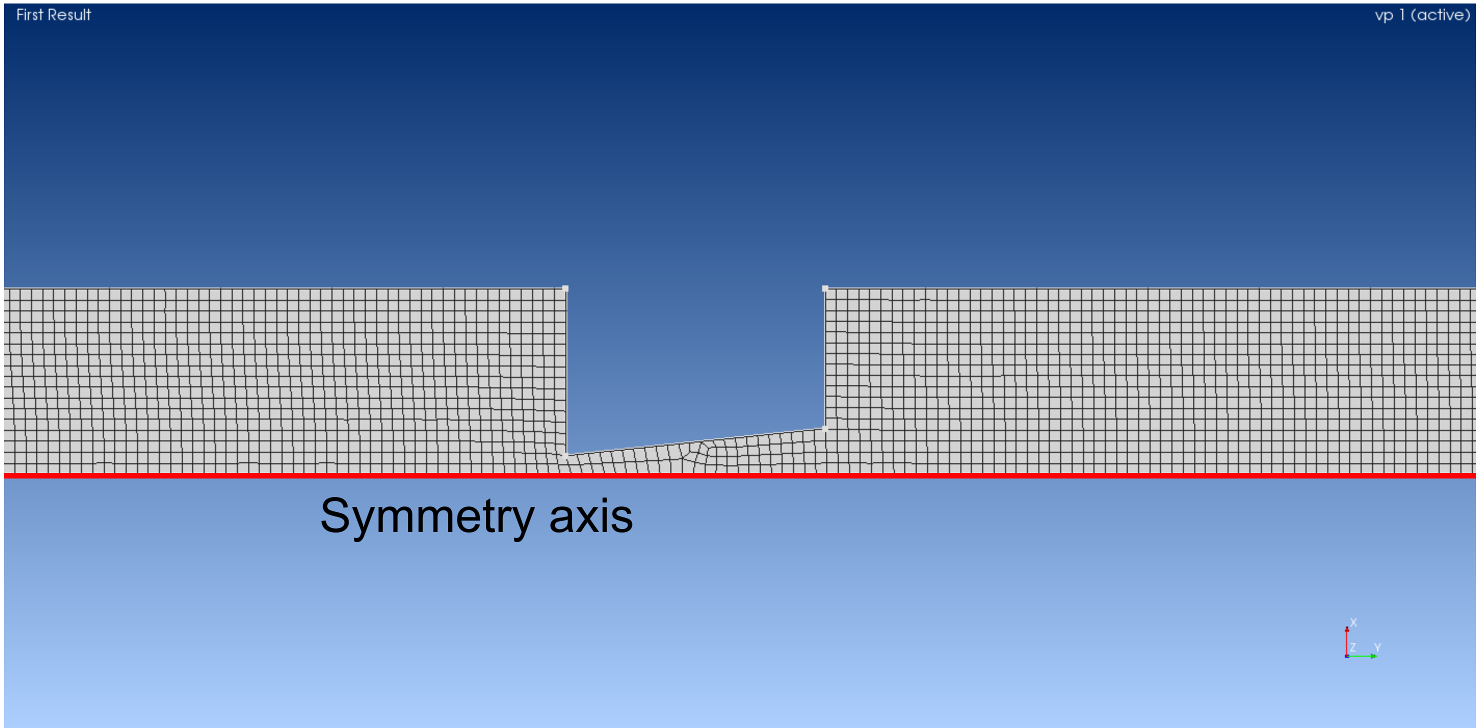
Cavity Depth	Inlet Hole Diameter	Model Diameter	Perforation Rate	Thickness
5 cm	0.13 mm	1.8 mm	0.5%	0.7 mm



12° draft

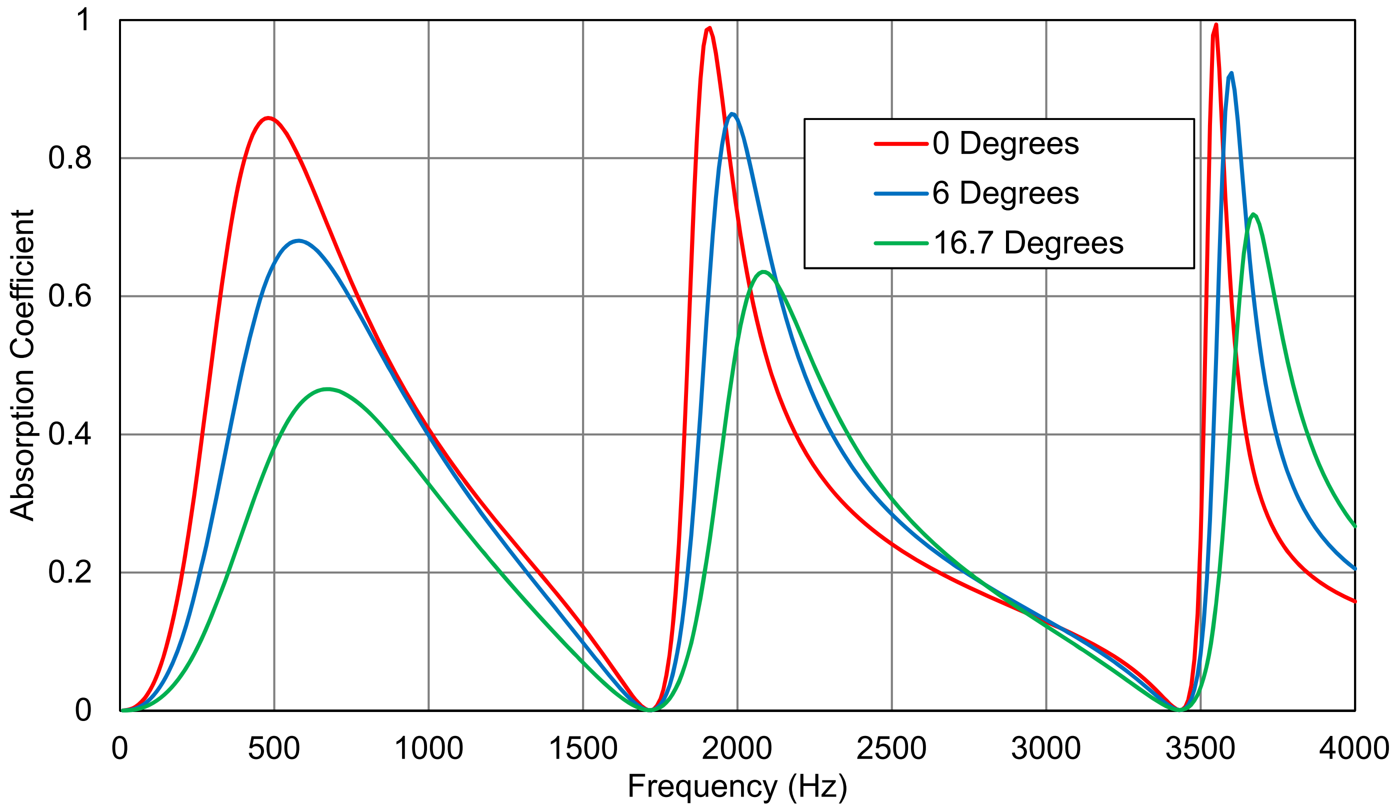


FEM Model Tapered Holes

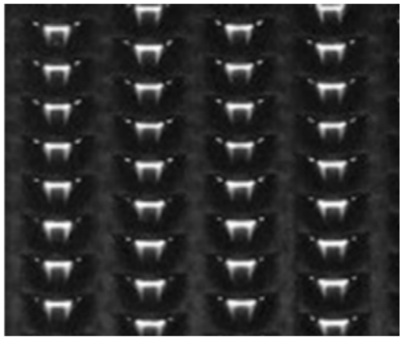


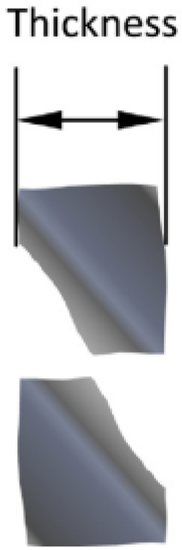
Comparison Effect of Draft Angle

Cavity Depth	Inlet Hole Diameter	Model Diameter	Perforation Rate	Thickness
5 cm	0.4 mm	2.8 mm	2.0%	1.0 mm

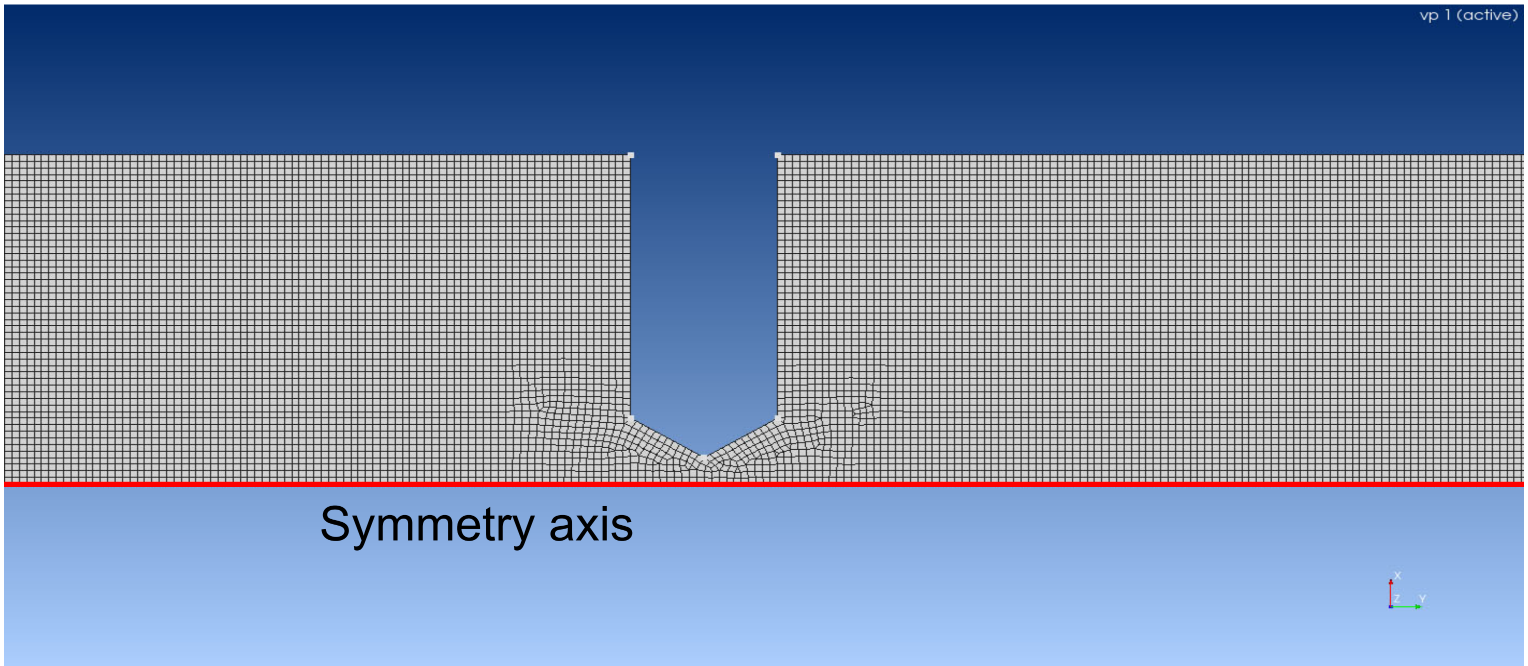


Slit Type MPP Absporbers



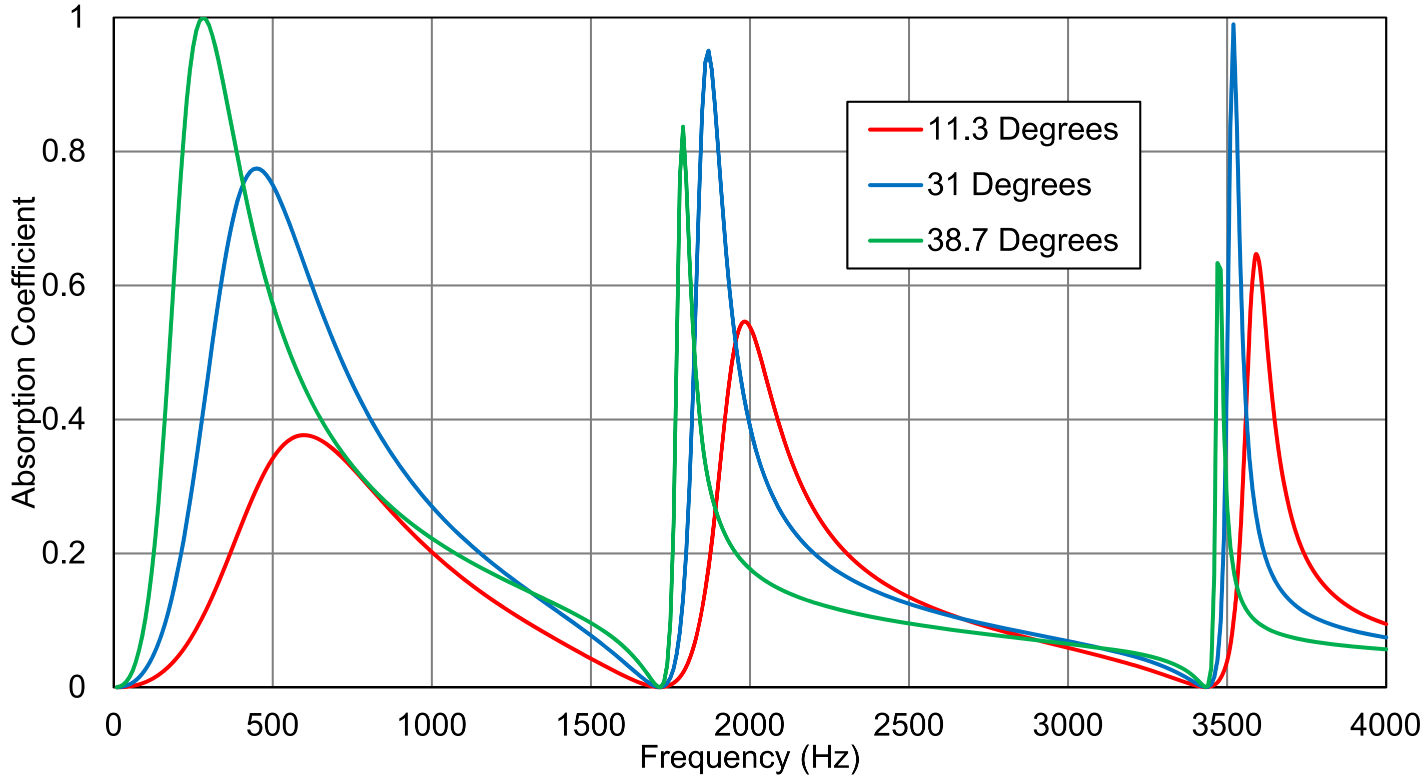


Tapered on Both Sides



Comparison Effect of Draft Angle

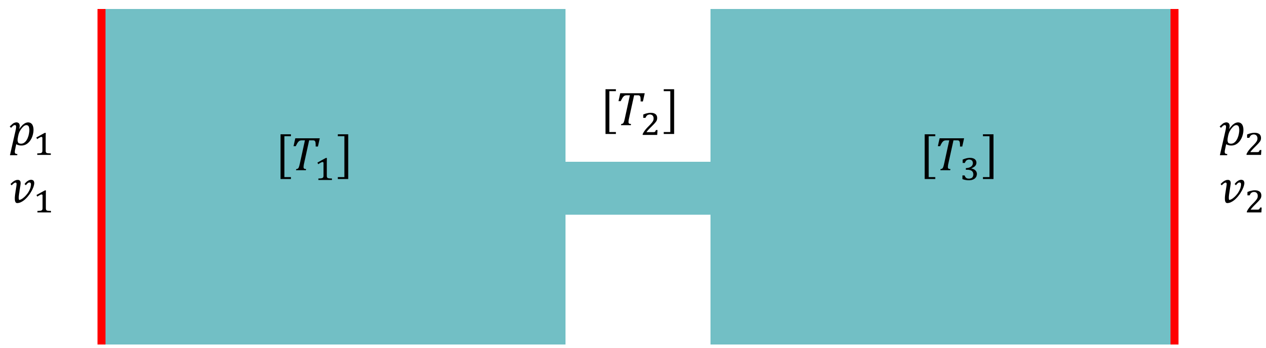
Cavity Depth	Inlet/Outlet Hole Diameter	Model Diameter	Perforation Rate	Thickness
5 cm	1 mm	5 mm	4.0%	1.0 mm



Simulation Approach Transfer Impedance

Step 1 Determine $[T_{total}]$

$$[T_{total}] = [T_1][T_2][T_3]$$



Simulation 1 $v_1 = 1, v_2 = 0$

Simulation 2 $v_1 = 0, v_2 = 1$

MPP Transfer Impedance

Run 1

$$T^*_{11} = p_{1|v_1=1,v_2=0}$$

$$T^*_{21} = p_{2|v_1=1,v_2=0}$$

$$T_{11} = \frac{T^*_{11}}{T^*_{21}}$$

$$T_{21} = \frac{1}{T^*_{21}}$$

Run 2

$$T^*_{12} = p_{1|v_1=0,v_2=1}$$

$$T^*_{22} = p_{2|v_1=0,v_2=1}$$

$$T_{12} = T^*_{12} - \frac{T^*_{11}T^*_{22}}{T^*_{21}}$$

$$T_{22} = -\frac{T^*_{22}}{T^*_{21}}$$

$$T_{total} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix}$$

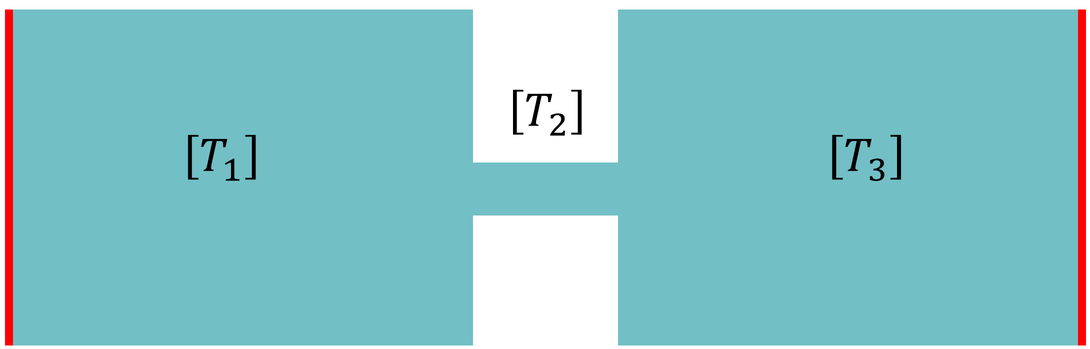
Modeling Procedure

Step 2 Determine z_{tr}

$$[T_{total}] = [T_1][T_2][T_3]$$

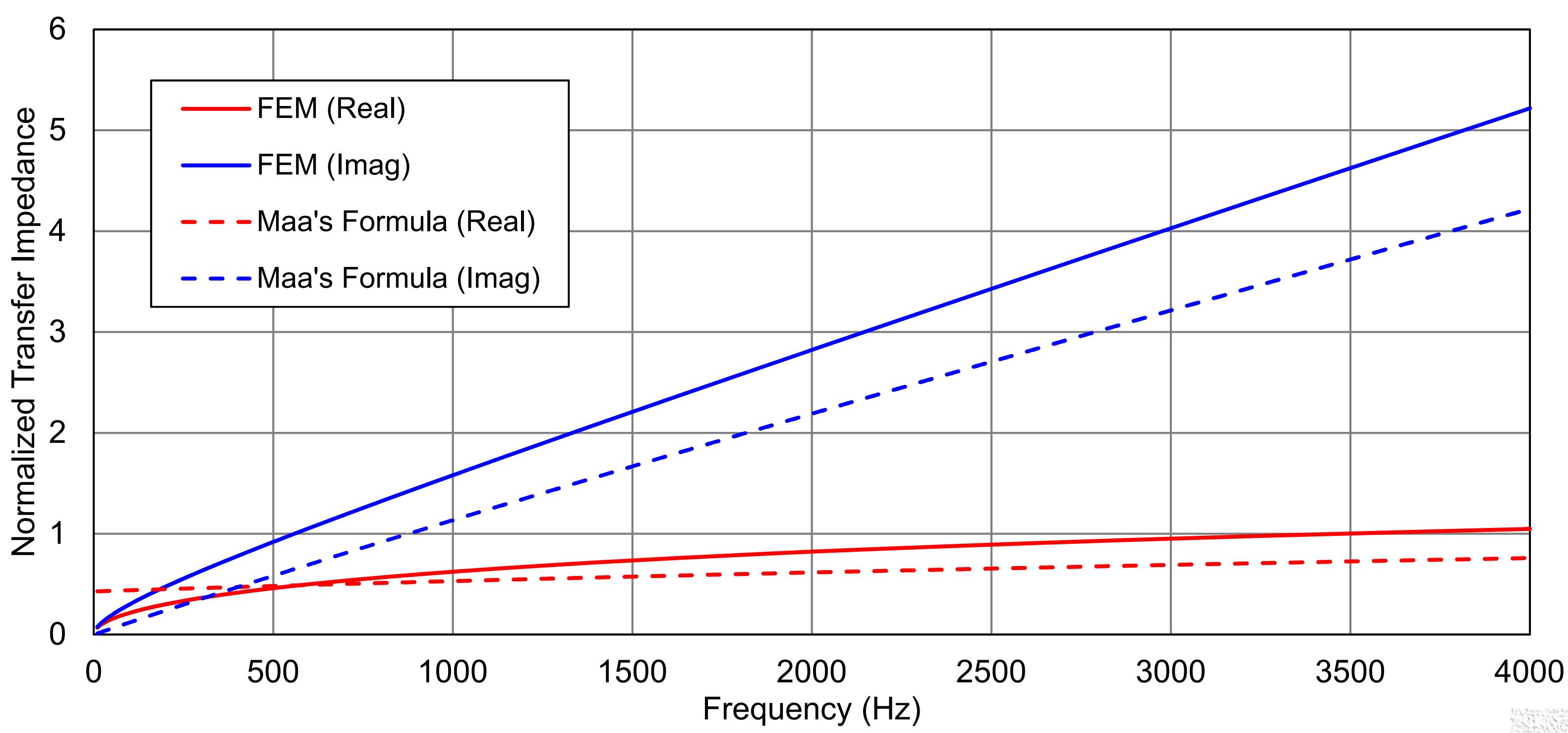
$$[T_2] = [T_1]^{-1}[T_{total}][T_3]^{-1}$$

$$[T_2] = \begin{bmatrix} 1 & \rho c z_{tr} \\ 0 & 1 \end{bmatrix}$$



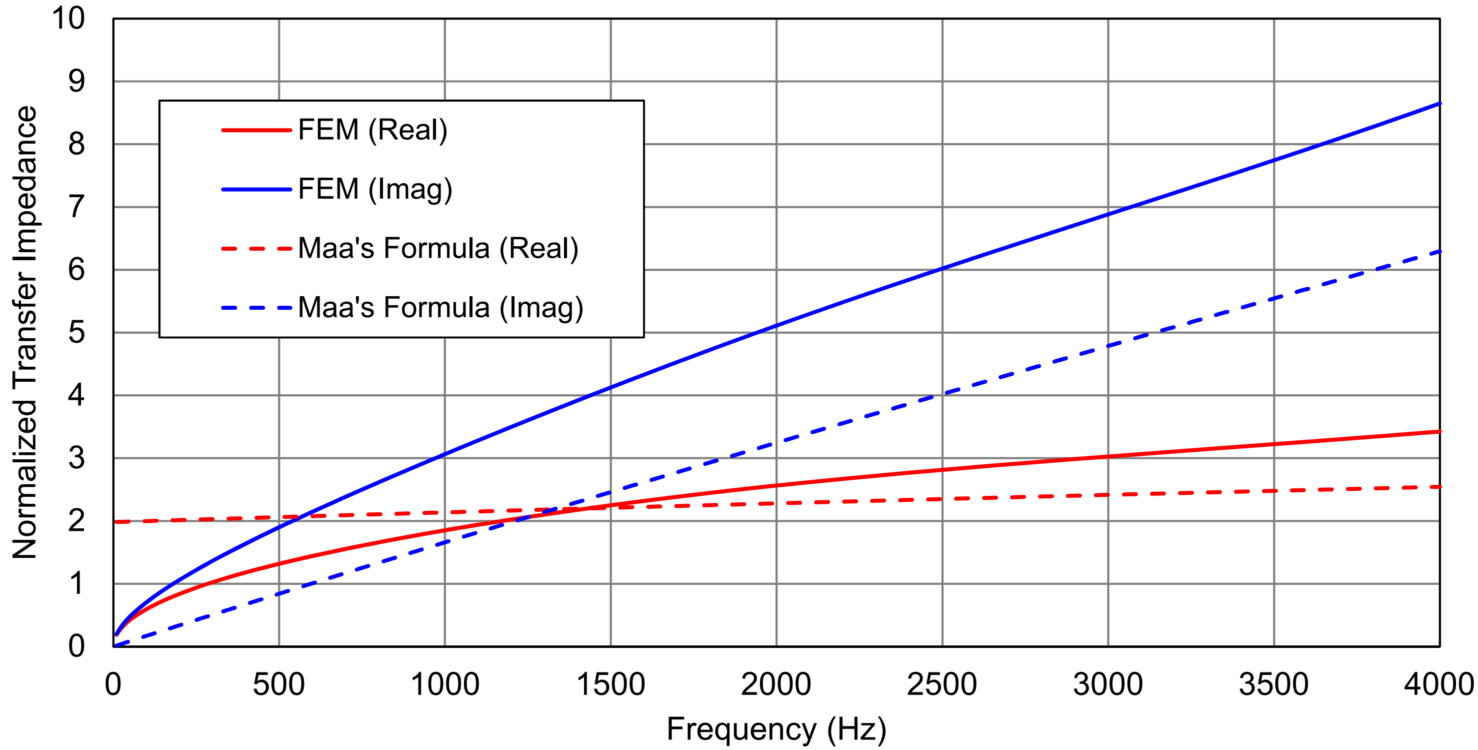
Comparison Transfer Impedance

Cavity Depth	Hole Diameter	Model Diameter	Perforation Rate	Thickness
10 cm	0.4 mm	2.8 mm	2.0%	1 mm



Case 1 Transfer Impedance

Cavity Depth	Hole Diameter	Model Diameter	Perforation Rate	Thickness
5 cm	0.22 mm	2.2 mm	1.0%	0.7 mm



Summary

- LRF and DBLNSF models may be used to model perforations in MSC Actran.
- Sound absorption predictions seem to be adequate.
- Potential analysis tool for designing new types of MPP absorbers.