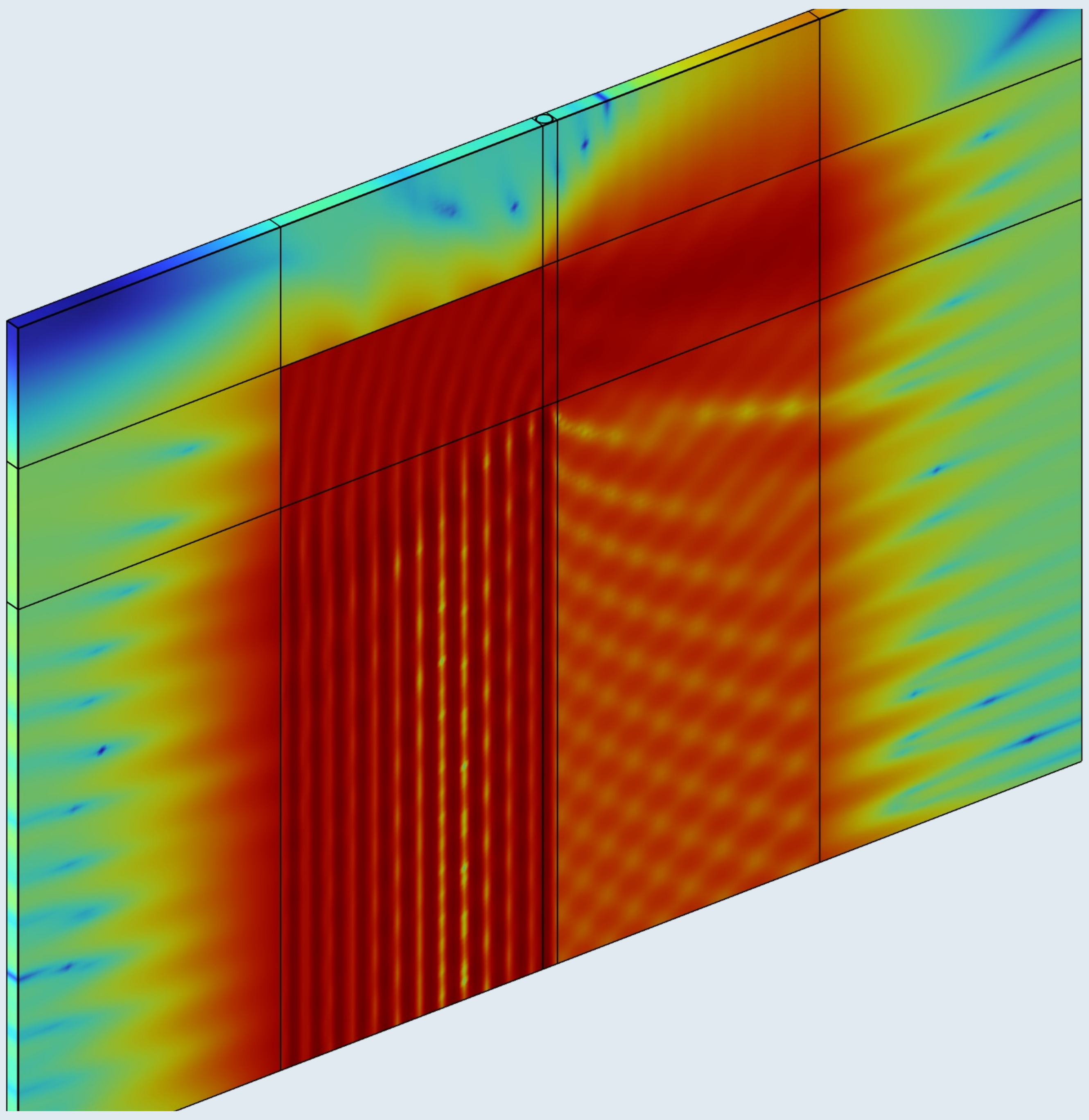

Numerical Modeling of Phononic Crystal-Based Noise Barrier

Numerical modeling of a unit cell of a phononic crystals-based Noise Barrier for highway noise reduction in idealized and in-situ conditions to study effectiveness.

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Abstract

This study conducts a comprehensive numerical investigation into ventilated acoustic metamaterial noise barriers for urban noise mitigation while maintaining air ventilation. Using COMSOL Multiphysics, a unit cell design was modeled to compute sound transmission loss (STL) and analyze acoustic bandgap frequencies. The Pressure Acoustics Module, Perfectly Matched Layers (PML), and periodic boundary conditions were employed to simulate noise barriers in an infinite domain.

Parametric analysis assessed the influence of geometric configurations and acoustic incident angles on noise attenuation. Results show effective sound reduction within the 1000-2200 Hz range, without compromising ventilation. Additionally, the study evaluated the effects of finite-size barriers on STL, offering insights into real-world performance compared to idealized conditions.

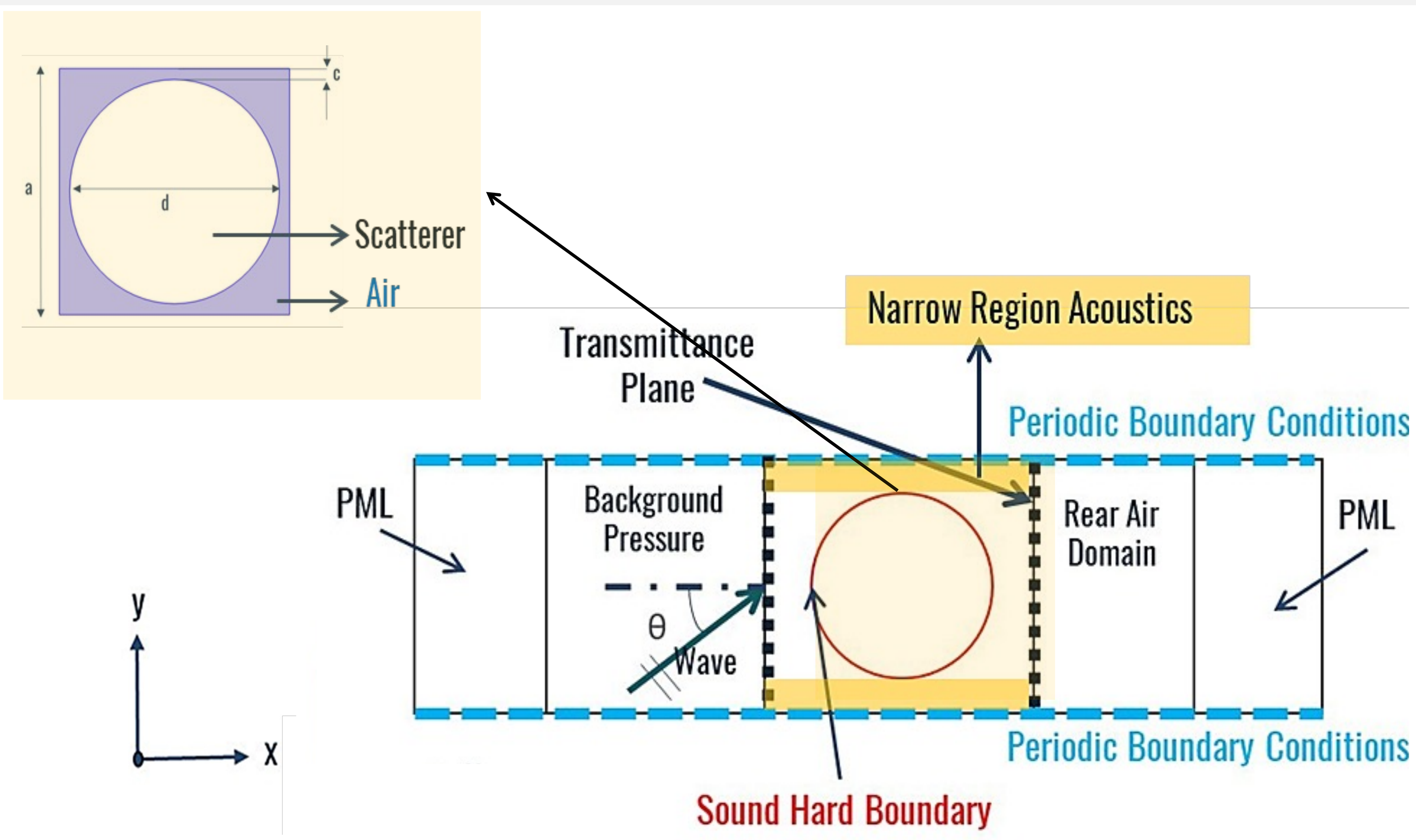

FIGURE 1: Numerical Model for Infinite Unit Cell Modeling

Methodology

The Pressure Acoustics, Frequency Domain interface in COMSOL models acoustic pressure fields and solves wave propagation equations, while Narrow Region Acoustics captures viscous and thermal boundary-layer losses in ducts. Perfectly Matched Layers (PML) simulate an infinite domain, absorbing outgoing waves to prevent boundary reflections.

Using Periodic Boundary Conditions (PBC) and Floquet periodicity, unit cells are modeled as infinitely repeating structures. A finite-element approach computes the Sound Transmission Loss (STL) for the unit cell. The proposed design uses scatterers with specific spacing for airflow, and parameters like diameter, gap, and height determine the stopband frequency for effective sound attenuation.

Results

This study explores Sonic Crystal-based noise barriers, focusing on how variations in unit cell configurations affect Sound Transmission Loss (STL). Boundary effects, diffraction, and edge effects in practical implementations reduce the barrier's effectiveness compared to ideal models.

Results show that finite models experience weaker sound attenuation due to these factors. The research aims to optimize acoustic performance through numerical simulations, using finite material properties and resonance elements. Experimental validation will support practical applications. The study highlights the importance of considering real-world factors like air damping, material durability, and environmental conditions when designing effective noise barriers.

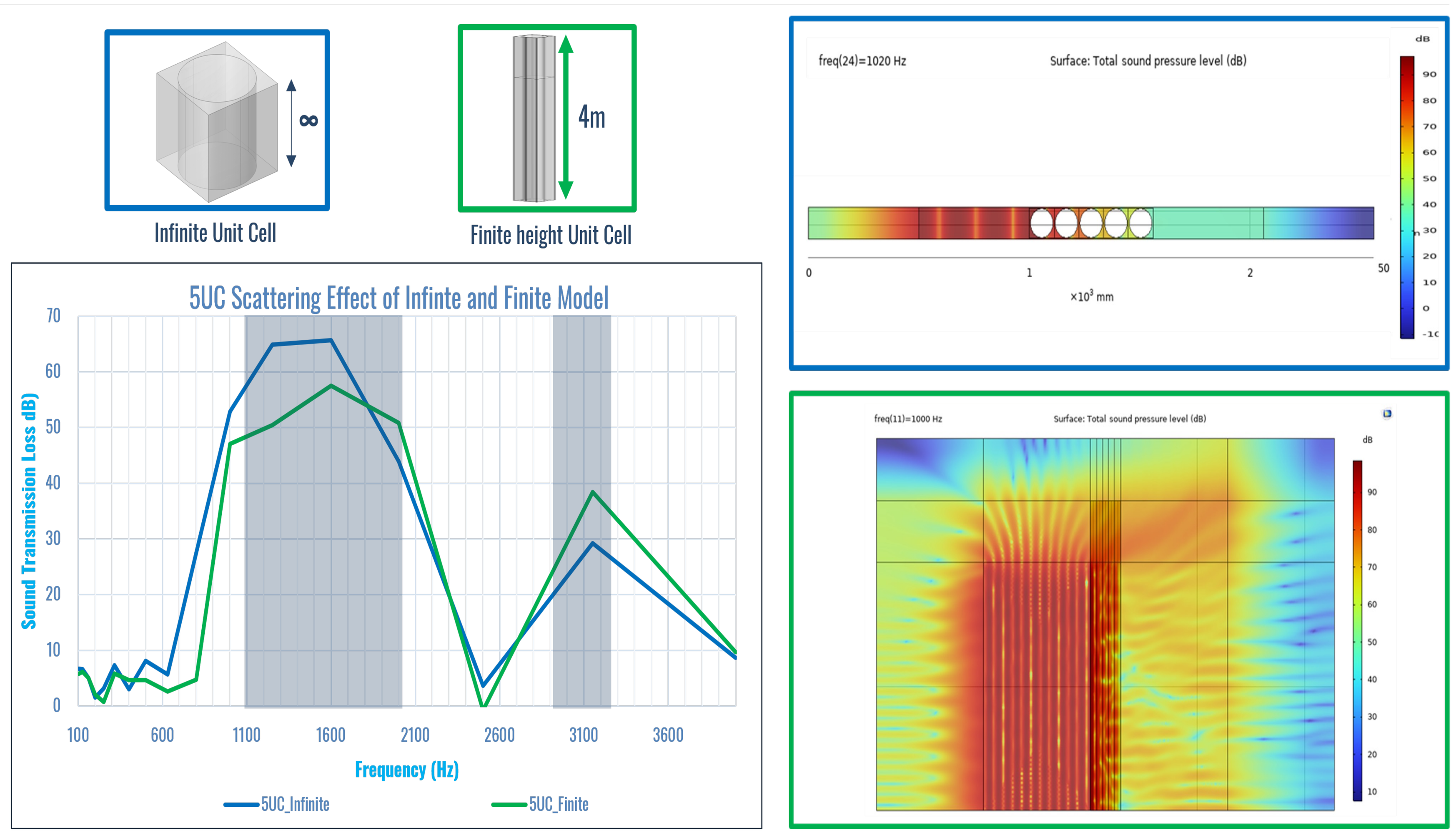

FIGURE 2: Sound Transmission Loss and Pressure Level for Infinite and Finite unit cell models with 5 scatterers along wave propagation

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Funded by the European Union