Chair of Vibro-Acoustics of Vehicles and Machines
TUM School of Engineering and Design
Technical University of Munich

Bachelor's Thesis | Master's Thesis

Virtual Characterization of High-Frequency Sound Absorption and Insulation (10–50 kHz) Using FDTD and FEM

Background

Very high-frequency sound and ultrasound in the range of 10–50 kHz are increasingly present in public and industrial environments, such as transportation hubs, workplaces, and commercial spaces. While inaudible, exposure to such frequencies can lead to neurological and physiological effects including headaches, tinnitus, fatigue, and ear discomfort (Fukushima et al., 2014; Fletcher et al., 2018a,b; Smagowska et al., 2013; Leighton, 2018; Duck and Leighton, 2018). Accurately characterizing acoustic absorption and insulation at these frequencies is technically challenging, since traditional measurement methods (e.g., impedance tube and reverberation chamber) are not designed to operate beyond 20 kHz. Therefore, there is a strong need for numerical and virtual characterization methods that can reliably predict sound absorption and transmission behavior of materials and structures in this high-frequency range. Numerical methods such as the Finite Difference Time Domain (FDTD) and Finite Element Method (FEM) offer the possibility to model wave propagation at ultrasonic frequencies with high spatial and temporal resolution. By extracting virtual equivalents of acoustic absorption coefficients and transmission loss from simulations, they enable characterization where experimental approaches are impractical or impossible.

Objectives

The goal of this thesis is to develop a virtual characterization framework for sound absorption and sound insulation in the 10–50 kHz frequency range. This will involve implementing and validating simulation methods capable of providing reliable acoustic characterization in the absence of standardized measurement techniques.

Your Tasks

- Study the fundamentals of high-frequency acoustics and the limitations of current experimental measurement methods.
- Implement FDTD and/or FEM models for wave propagation in the 10–50 kHz range.
- Define and extract virtual acoustic parameters (e.g., absorption coefficient, transmission loss) from simulation results.
- Evaluate numerical accuracy and sensitivity with respect to discretization, boundary conditions, and geometry.
- Validate the developed framework against available indirect experimental techniques.
- Document your methodology, results, and insights in a formal Master's thesis (in English).

Requirements

- Strong interest in acoustics and numerical modeling.
- Knowledge of wave propagation and PDEs (helpful but not mandatory).
- Experience in numerical simulation (FEM/FDTD) or willingness to learn.
- Programming skills in Python, MATLAB, or similar.

Contact

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Key references:

- Fukushima, A. et al. (2014). “Frequencies of Inaudible High-Frequency Sounds Differentially Affect Brain Activity: Positive and Negative Hypersonic Effects.” PLoS ONE, 9(4). https://doi.org/10.1371/journal.pone.0095464.
- Fletcher, M. D. et al. (2018a). “Effects of Very High-Frequency Sound and Ultrasound on Humans. Part I: Adverse Symptoms after Exposure to Audible Very-High Frequency Sound.” JASA, 144(4), 2511–2520. https://doi.org/10.1121/1.5063819.
- Fletcher, M. D. et al. (2018b). “Effects of Very High-Frequency Sound and Ultrasound on Humans. Part II: A Double-Blind Randomized Provocation Study of Inaudible 20-KHz Ultrasound.” JASA, 144(4), 2521–2531. https://doi.org/10.1121/1.5063818.
- Smagowska, B., Pawlaczyk-Łuszczyńska, M. (2013). “Effects of Ultrasonic Noise on the Human Body—a Bibliographic Review.” IJOSH, 19(2), 195–202. https://doi.org/10.1080/10803548.2013.11076978.
- Leighton, T. G. (2018). “Ultrasound in Air—Guidelines, Applications, Public Exposures, and Claims of Attacks in Cuba and China.” JASA, 144(4), 2473–2489. https://doi.org/10.1121/1.5063351.
- Duck, F., Leighton, T. G. (2018). “Frequency Bands for Ultrasound, Suitable for the Consideration of Its Health Effects.” JASA, 144(4), 2490–2500. https://doi.org/10.1121/1.5063578.