Experimental evaluation of the effect of a surface acoustic metamaterial - Application to the reduction of roadside noise pollution

- Promotor: Robin Maffëïs (PhD Student)
- Co-promotors: Dr. Judicaël Picaut, Pr. Rubén Picó Vila
- Host laboratory: UMRAE laboratory (`https://www.umrae.fr/`)
- Campus: Gustave Eiffel University, Nantes Campus (`https://maps.app.goo.gl/usj4GdePjpJdJbon8`)
- Duration: 6 months, starting in March or April 2026
- Internship compensation in accordance with French public service rules: 600€ à 700€ monthly according to the number of worked days (`https://www.service-public.gouv.fr/particuliers/vosdroits/F32131`)

Context and problematic

Noise pollution is a major health issue in Europe, with approximately 1 in 4 people exposed to noise levels above WHO recommendations [5] [9]. As road traffic noise is the main contributor, it is necessary to reduce it using all possible means [11]. Road traffic noise is characterised by its broadband spectrum and dependence on numerous parameters, such as road surface, traffic composition and traffic speed [10] [7]. However, the performance of conventional noise reduction measures during noise propagation (noise barriers, etc.) is limited, particularly at low frequencies [6]. Nevertheless, in recent years, research has been developing around acoustic metamaterials. These are artificial materials designed to manipulate sound waves in order to achieve acoustic performance superior to that of conventional materials [1] [3] [12]. Among these characteristics, sub-wavelength absorption enables exceptional performance at low frequencies. Based on the state of the art, a solution is proposed that exploits the ground effect [2, 4] through the implementation of absorbent metasurfaces at the roadside. The principle is illustrated in Figure 1 and involves integrating a metamaterial on a surface between the sound source (*i.e.* the road) and a reception point (*i.e.* a dwelling).

Internship Objectives

Under the supervision of a PhD student and two acoustics researchers, the internship aims to experimentally test several metasurfaces optimised to reduce noise between a source and a receiver, and to compare the experimental results to numerical simulations using a Finite Element Method (FEM) with the COMSOL Multiphysics software. As part of the internship, the objective will be to organize the printing of "3D modules" of the metamaterial, which will then need to be assembled to simulate a flat surface. In association with other members of the host laboratory, the acoustics absorption properties will be controlled by a measurement in a Kundt's tube and compared to the expected values. In a second step, an experiment will be set up to represent the configuration presented in figure 1, which will allow the measurement of the acoustic treatment effect of a floor with a metamaterial, compared to a perfectly rigid floor. The experiment will be installed in the semi-anechoic chamber of the laboratory (figure 4); the measurement will involve sending an acoustic signal through an omnidirectional sound source and measuring the spectrum at the reception point; the comparison of the measurement with/without the treated surface will allow evaluating the effects of the acoustic metamaterial. Finally, the last step will be to compare the experimental results with those obtained numerically using a Finite Element Method (FEM) with the COMSOL Multiphysics software. Depending on the time available, other metamaterials may be tested.

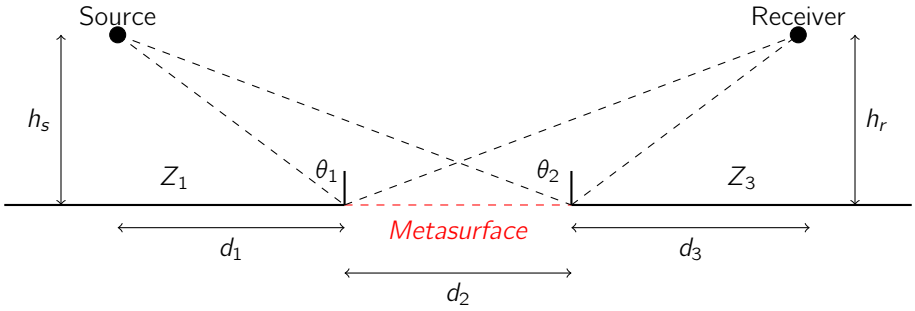

Figure 1: Schematic of sound transmission between source and receiver above a wall a finite dimension acoustical metasurface.

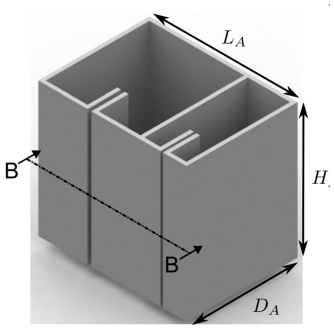

Figure 2: Schematic of the concept of the compact micro-slit absorbers [13]

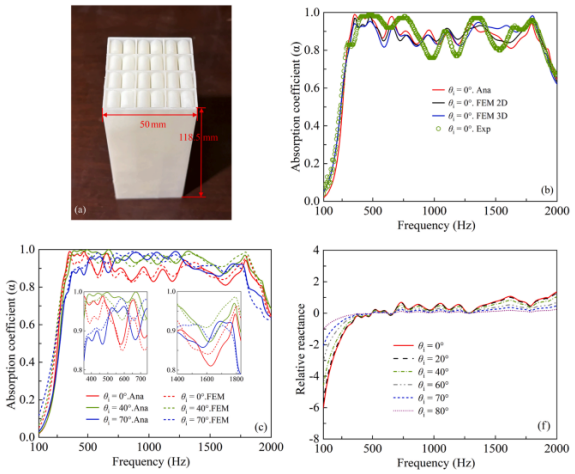

Figure 3: Schematic of the concept of the sonic crystal absorber [8]

Plan

- Short bibliography: acoustic metasurface, ground effect, road noise, scale model, experiment
- Experimentation: setting up the test bench, printing metamaterials, acoustic measurements
- Analysis: comparison of experiment data and numerical calculation

Required profile

Master's degree student or engineering school student in acoustics with an interest in environmental acoustics and experiment.

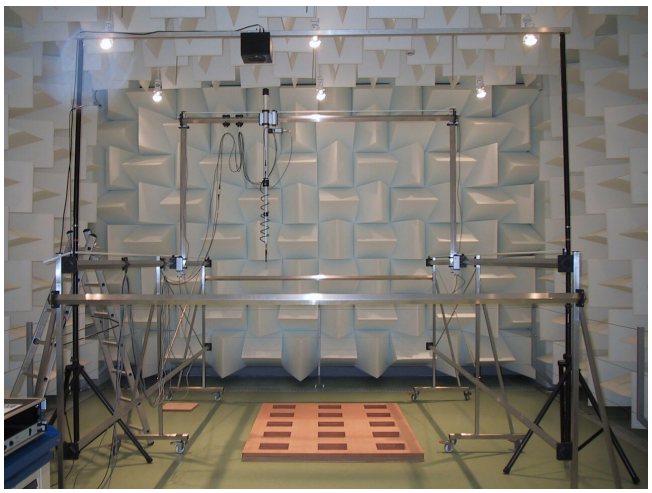

Figure 4: UMRAE's semi-anechoic chamber

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References

[1] A. Arjunan, A. Baroutaji, J. Robinson, A. Vance, and A. Arafat. Acoustic metamaterials for sound absorption and insulation in buildings. *Building and Environment*, 251:111250, 2024.

[2] K. Attenborough and T. Van Renterghem. *Predicting outdoor sound*. CRC Press, 2021.

[3] G. Aydın and S. E. San. Breaking the limits of acoustic science: A review of acoustic metamaterials. *Materials Science and Engineering: B*, 305:117384, 2024.

[4] I. Bashir. *Acoustical exploitation of rough, mixed impedance and porous surfaces outdoors*. Open University (United Kingdom), 2014.

[5] W. H. O. R. O. for Europe. *Environmental noise guidelines for the European Region*. World Health Organization. Regional Office for Europe, 2018.

[6] L. Fredianelli, L. G. Del Pizzo, and G. Licitra. Recent Developments in Sonic Crystals as Barriers for Road Traffic Noise Mitigation. *Environments*, 6(2), 2019.

[7] T. Li, R. Burdisso, and C. Sandu. Literature review of models on tire-pavement interaction noise. *Journal of Sound and Vibration*, 420:357–445, 2018.

[8] M. Liang, H. Wu, T. Yang, W. Liu, M. Ibarias, S. Marburg, and J. Sánchez-Dehesa. Metasurfaces with low-frequency broadband high absorption based on thermoviscous theoretical model and acoustic bands under wide-angle incidence waves. *Thin-Walled Structures*, page 113770, 2025.

[9] E. Peris. Environnemental nose in europe - 2020. Technical report, European Environnemental Agency, 2020.

[10] U. Sandberg and J. Ejsmont. Tyre/road noise. reference book. 2002.

[11] B. Vincent and X. Olny. Le bruit des transports, une nuisance, un impact majeur pour la population. 2012.

[12] F. Zangeneh-Nejad and R. Fleury. Active times for acoustic metamaterials. *Reviews in Physics*, 4:100031, 2019.

[13] W. Zhao, J. Wang, S. Wasala, J. Kennedy, and T. Persoons. Compact metamaterial micro-slit panel absorbers for low-frequency tonal and broadband noise control. *Applied Acoustics*, 241:111014, 2026.