



Environmental acoustics research unit
(Université Gustave Eiffel – Cerema)

PROPOSAL FOR A PHD THESIS SUBJECT 2026

PhD thesis title

Advanced acoustic imaging technics for railway noise characterisation

Required graduate

Master – Research orientated (M2)

Required skills

Main fields: Acoustics, Vibrations

Additional fields: Signal processing, Data analysis

Description

Context

Noise emitted into the environment is a major externality of rail transport, which could slow down efforts to shift freight from road to rail. The effects of rail noise are largely negative, such as the impact on health, socio-economic consequences, and the incidence on biodiversity. Evidence of these effects is piling up and, in response, regulations are gradually being tightened at both national and European level. In this context, research seems more necessary than ever to overcome the scientific obstacles that sometimes prevent the various parties involved in tackling rail noise from taking action. The experimental characterisation of emissions under real-world conditions is a key area for improvement. The complexity of railway emissions [1] (long vehicles, multiple sources, track contributions) requires the development of advanced methods such as model inversion or acoustic imaging to accurately identify the various emission parameters. There are numerous applications, such as the diagnostic and monitoring of vehicles or infrastructure, estimating the potential for improvement offered by a solution, or feeding data into prediction models to estimate public exposure.

Scientific challenge

Experimental methods for characterising railway noise have been, and continue to be, the subject of active research within the international scientific community. Among the various possible approaches, imaging methods based on microphone arrays are of particular interest, as they theoretically enable the characterisation of noise sources in terms of spatial location, noise level and frequency content. Since the first railway-specific developments in the early 1990s [2], microphone arrays have been used operationally by research organisations and specialist engineering consultancies to identify and characterise noise sources on various types of rolling stock [3,4]. The associated processing methods are generally derived from the principle of beamforming, adapted on the one hand to the context of near-field diagnostics (focusing), and on the other hand to the non-stationary nature associated with vehicle movement (source tracking and de-Dopplerisation).

However, these methods have several limitations when applied to railway noise, particularly when characterising noise caused by wheel-rail contact. Although optimal for distinct, omnidirectional and uncorrelated point sources, they are not suited to characterising the field radiated by the track, which behaves as an extended and coherent source across a wide range of frequencies due to vibrational waves propagating over long distances from the wheel-rail contact

points [5–7]. Furthermore, they struggle to distinguish between the fields radiated by the track and those by the wheels, not only because of the proximity of the sources but also due to their directivity.

Several techniques have been proposed to overcome these difficulties, but none have fully resolved the issue. In [3], the rail is treated as a collection of small, uncorrelated sections. Although this approach takes account of the extended nature of the source, it remains limited by the source's coherent nature and, consequently, by its directivity. Methods based on plane wave focusing [5,6], in particular the wave number filtering technique (WSE) [8], have proven their effectiveness in the case of pass-by measurements but only allow for a good quantification of the noise radiated by the rail in frequency bands where wave attenuation in the rail is low and the contribution from the wheels is not dominant. The SWEAM method [6], which aims precisely to adapt the processing according to wave attenuation, is promising but has only been formulated and tested experimentally for fixed vertical excitation of the rail and without wheel contribution. The separation of rail and wheel contributions to passing noise using sparse regularisation methods has also been tested [9].

Objectives

The aim of this PhD thesis is to develop a high-performance imaging technique for characterising railway noise, in particular wheel-rail contact noise, going beyond existing methods. The specific focus is on characterising the contributions from the track (noise associated with vertical and transverse vibrations in the rail and with sleeper vibration) and separating the contributions from the track and the wheels across all frequency bands.

Methodology

A *review of the state of the art* will first enable the PhD student to familiarise themselves, on the one hand, with the mechanisms underlying the generation of wheel-rail contact noise, in particular rolling noise, and, on the other hand, with existing imaging methods. The work will then be divided into three main areas.

The first stage will involve *simulating the radiated sound field by a rail-guided vehicle pass-by in the time domain*. To this end, the student will implement existing methods and/or use the tools made available to them, in particular advanced digital vibro-acoustic models to account for the complexity of the fields radiated by the wheels and track across a wide frequency range.

The second stage will be devoted to testing and *developing imaging methods based on the simulations*. The aim is to improve the performance of existing methods for identifying the contributions of the wheels and the track as a vehicle passes-by. The characterisation of the field radiated by the track alone will be addressed first. In this case, one possible approach is to extend the SWEAM method to cases involving moving excitations and multiple waves. With regard to the field radiated by the wheels, conventional or more sophisticated methods such as CLEAN [10] can then be tested, after which the problem of separating the contributions of the wheels and the track will be addressed.

The final stage will be devoted to the *experimental validation* of the method. Trials on Lyon's tram network are being considered. The method's performance will be analysed by comparing it with simulations using real-world infrastructure and vehicle parameters.

Bibliography

- [1] D.J. Thompson, *Railway Noise and Vibration: Mechanisms, Modelling and Means of Control*, Elsevier, 2009. <https://doi.org/10.1016/B978-0-08-045147-3.X0023-0>.
- [2] B. Barsikow, W.F. King, On removing the Doppler frequency shift from array measurements of railway noise, *Journal of Sound and Vibration* 120 (1988) 190–196. [https://doi.org/10.1016/0022-460X\(88\)90344-6](https://doi.org/10.1016/0022-460X(88)90344-6).
- [3] M.-A. Pallas, J. Lelong, R. Chatagnon, Characterisation of tram noise emission and contribution of the noise sources, *Applied Acoustics* 72 (2011) 437–450. <https://doi.org/10.1016/j.apacoust.2011.01.008>.
- [4] C. Mellet, F. Létourneaux, F. Poisson, C. Talotte, High speed train noise emission: Latest investigation of the aerodynamic/rolling noise contribution, *Journal of Sound and Vibration* 293 (2006) 535–546. <https://doi.org/10.1016/j.jsv.2005.08.069>.

- [5] T. Kitagawa, D.J. Thompson, The horizontal directivity of noise radiated by a rail and implications for the use of microphone arrays, *Journal of Sound and Vibration* 329 (2010) 202–220. <https://doi.org/10.1016/j.jsv.2009.09.002>.
- [6] B. Faure, O. Chiello, M.-A. Pallas, C. Servi re, Characterisation of the acoustic field radiated by a rail with a microphone array: The SWEAM method, *Journal of Sound and Vibration* 346 (2015) 165–190. <https://doi.org/10.1016/j.jsv.2015.02.022>.
- [7] J. Zhang, G. Squicciarini, D.J. Thompson, Implications of the directivity of railway noise sources for their quantification using conventional beamforming, *Journal of Sound and Vibration* 459 (2019) 114841. <https://doi.org/10.1016/j.jsv.2019.07.007>.
- [8] E. Zea, L. Manzari, G. Squicciarini, L. Feng, D.J. Thompson, I.L. Arteaga, Wavenumber–domain separation of rail contribution to pass-by noise, *Journal of Sound and Vibration* 409 (2017) 24–42. <https://doi.org/10.1016/j.jsv.2017.07.040>.
- [9] E. Zea, E. Fernandez-Grande, I. Lopez Arteaga, Separation of rail and wheel contributions to pass-by noise with sparse regularization methods, *Journal of Sound and Vibration* 487 (2020) 115627. <https://doi.org/10.1016/j.jsv.2020.115627>.
- [10] R. Cousson, Q. Lecl re, M.-A. Pallas, M. B rengier, A time domain CLEAN approach for the identification of acoustic moving sources, *Journal of Sound and Vibration* 443 (2019) 47–62. <https://doi.org/10.1016/j.jsv.2018.11.026>.

Required profile

Required qualifications and skills:

- Master’s degree in acoustics and/or mechanical engineering
- Solid knowledge of structural dynamics, acoustic radiation and signal processing
- Good level in programming
- Good communication skills in English, both written and spoken
- Ability to work independently, show initiative and take on responsibility
- Analytical and problem-solving skills, as well as a genuine interest in research

Strengths:

- Experience with MATLAB and/or Python
- Previous coursework or project experience in railway acoustics or acoustic imaging
- Ability to communicate in French is an advantage
- Ability to disseminate results and engage with academic, industrial and societal networks

Doctoral school and University of registration

- Doctoral School in Mechanical Engineering, Energy Engineering, Civil Engineering, Acoustics (MEGA, <https://edmega.universite-lyon.fr/>)
- Gustave Eiffel University (<https://www.univ-gustave-eiffel.fr/>)

Location

- Uni Eiffel, Campus Lyon** (25, avenue Fran ois Mitterrand, Case24, Cit  des mobilit s, F-69675 Bron Cedex)
- Uni Eiffel, Campus Nantes** (route de Bouaye, CS4, F-44344 Bouguenais Cedex)
- Cerema – Strasbourg** (11, rue Jean Mentelin, Strasbourg-Koenigshoffen, F-67035 Strasbourg)

Supervisors

- Supervisor: Olivier CHIELLO (Gustave Eiffel University/UMRAE)
- Co-supervisor: Rapha l LEIBA (Gustave Eiffel University/UMRAE)

Salary

Gustave Eiffel University funding *via* doctoral contract, submitted to Doctoral School MEGA contest in June 2026. The candidate defends the projects in front of a Doctoral School panel.

Additional information

If interested in this project, please candidate by sending by email to Olivier Chiello and Raphaël Leiba (see contact details below) the following documents:

- Curriculum
- Cover Letter
- Grade transcripts for a Master's 2 degree or equivalent (including final classification if applicable)
- One or more letters of recommendation (if applicable)

Incomplete applications will not be considered.

Deadline: 29/05/2026

Contacts

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