Development of a Method for the Determination of Acoustical Railway Track Transfer Functions

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Problem Statement

In railway systems, vehicles are supported and guided by the track through the wheel-rail interface. Imperfections on the running surface of the wheel and the rail cause high dynamic loads. The dynamic loads lead to vibrations that are transmitted into both structures, the vehicle as well as the track, and from the vibrating structures sound is radiated into the air. This radiated sound from both the vehicle and the track can be quantified by a sound pressure level at a defined position next to the railway line.

A separation of the contributions from vehicle and track is not possible without the use of reference transfer functions that are based on pass-by sound pressure level measurements performed for a combination of track and vehicle where the vehicle is assumed to not contribute to the resulting sound pressure level significantly. However, this method is as reliable as the correctness of the underlying assumption.

Additionally, an experimental assessment of a newly developed or improved track system is not possible without extensive measurements at the track for train pass-by events with a vehicle that fulfills the fundamental assumption to not contribute to the radiated sound from vehicle and track.

The description of the acoustical performance of the two systems, vehicle and track, can be made by using acoustical transfer functions that relate the surface vibration velocity levels of the radiating subsystems with the resulting sound pressure level.

In this project, a method was developed to experimentally determine and numerically predict the acoustical transfer functions for a railway track system. The experimentally determined acoustical transfer function allows an existing track system to be assessed. The numerical prediction on the other hand is used in the design process of new railway track systems to assess and optimize their acoustical performance already during the design process without the need for extensive testing of different designs.

Experimental Approach

The objectives of the experimental approach are the determination of the dynamic properties of the railway track structure including vertical and lateral Track Decay Rates and the experimental determination of the acoustical track transfer function from vibration velocity level to resulting sound pressure level.

- The track structure is excited by a shaker in vertical as well as in lateral directions
- The track structural response is measured by accelerometers in vertical as well as in lateral directions
- The resulting radiated sound pressure level is measured by a microphone at a defined position next to the track
- Contamination of the microphone signal by the shaker noise is suppressed by a shaker housing

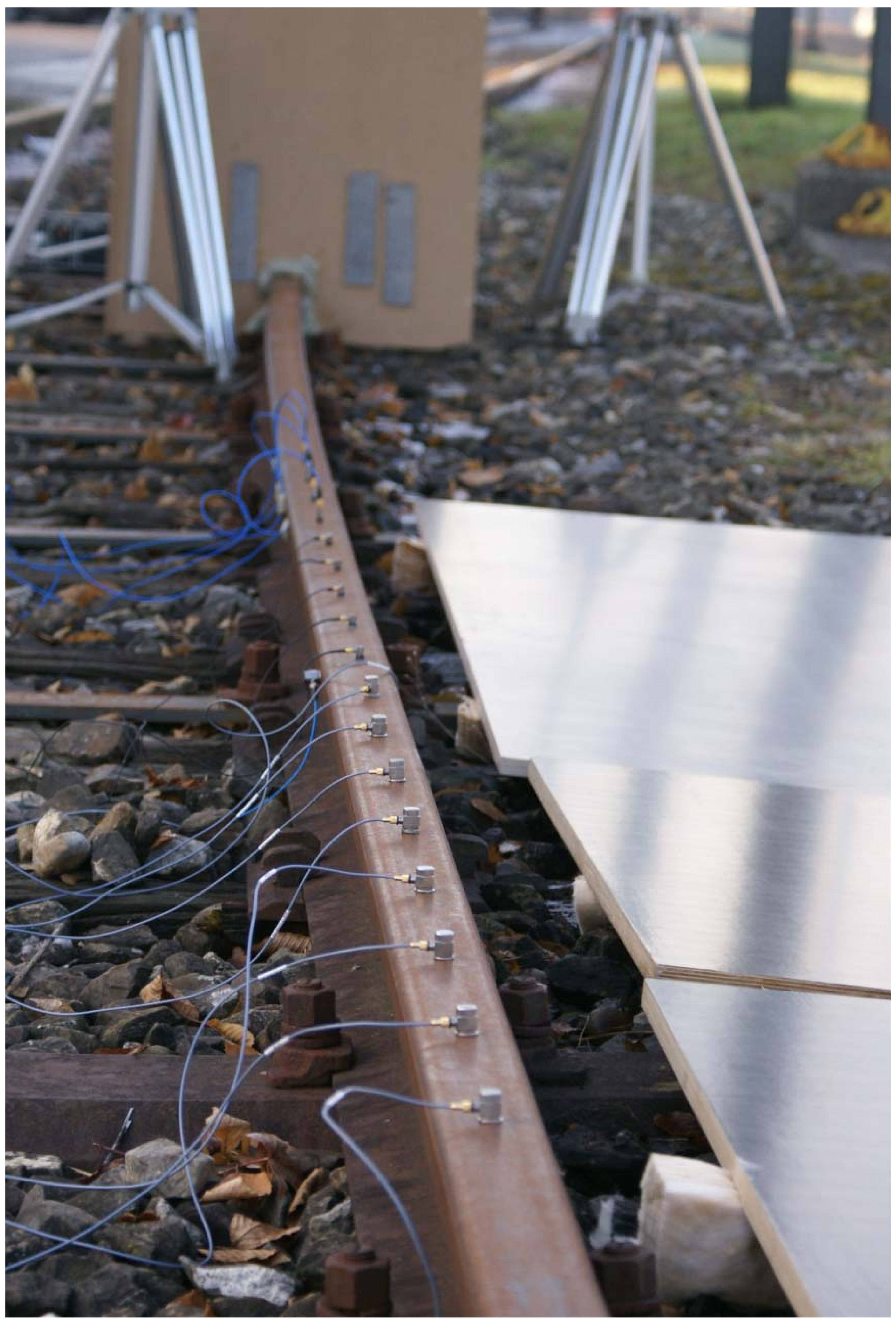

Figure 1: Experimental determination of acoustical track transfer function

Numerical Approach

In the numerical approach the sound radiation of the vibrating railway track structure is predicted by using Finite Element Modeling Techniques. The vibration velocity levels from structural dynamics simulations or from experiments are used as an input parameter for the FEM predictions.

In a first step, the resulting sound field is calculated assuming free-field conditions. In a second step the ground effect, including the ballast bed represented by an extended-reaction model, is superimposed to the predicted sound pressure field under free-field conditions.

Finally, the acoustical railway track transfer function can be derived by correlating the vibration velocity levels with the resulting sound pressure level at a defined position next to the track

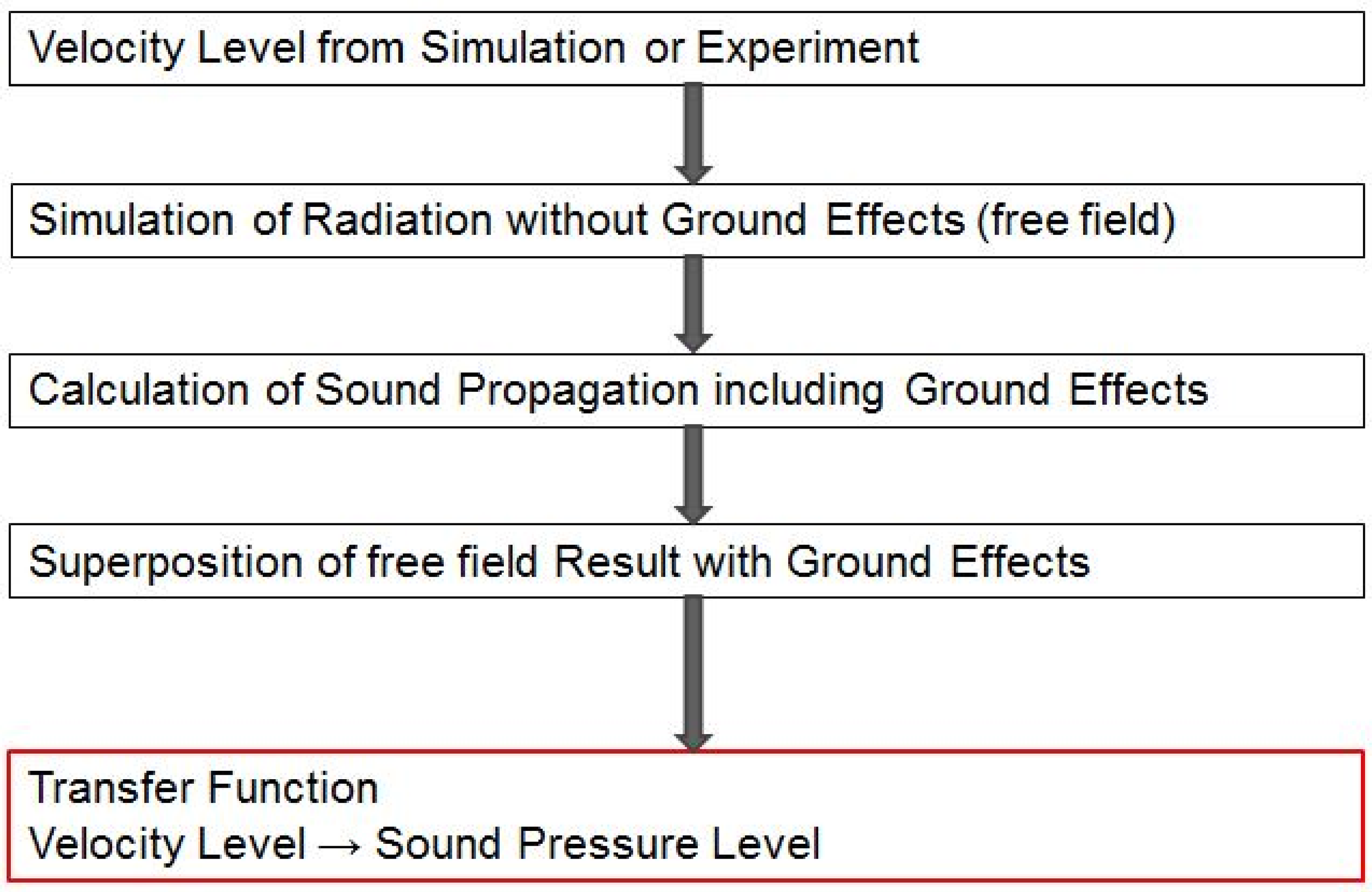

Figure 2: Workflow for numerical prediction of acoustical railway track transfer function

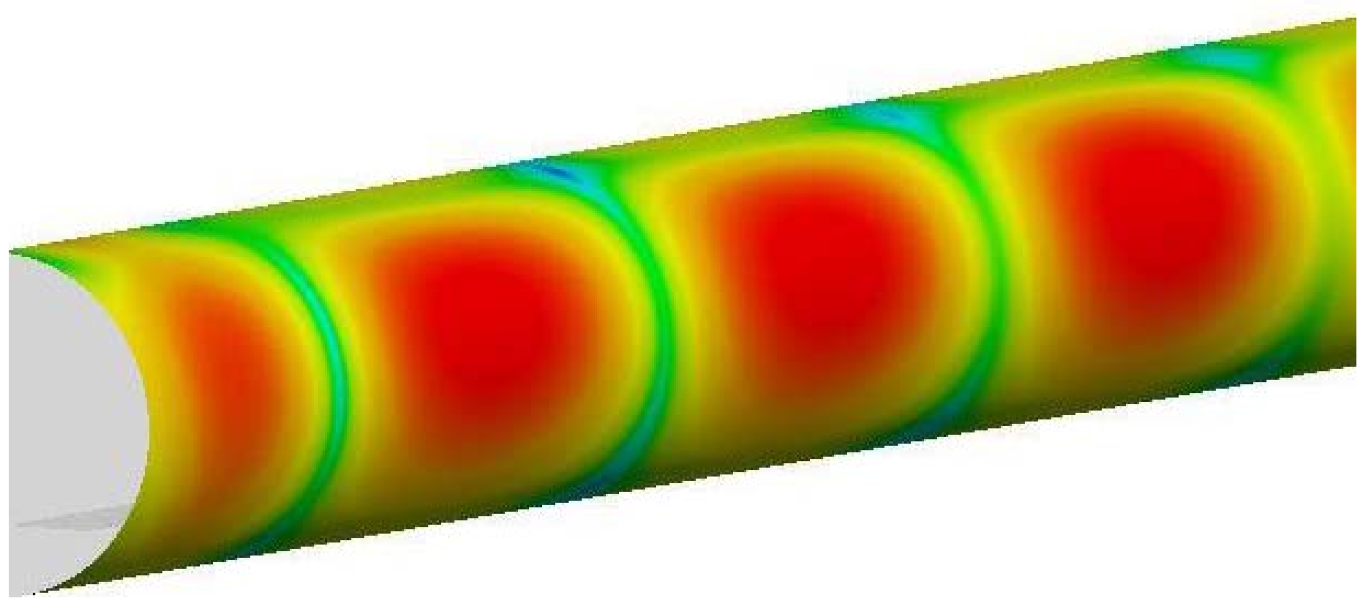

Figure 3: Calculated sound pressure field caused by rail vibration assuming free-field conditions

Future Work

The feasibility of both, the experimental as well as the numerical method to determine the acoustical railway track transfer functions has been demonstrated. First measurements have been performed at an industrial track on the campus of Empa Dübendorf.

After a successful validation of the experimental method by measurements at a representative railway track the method shall be used to improve the accuracy of the sonRAIL calculation model for railway noise.

The numerical method shall be used to assess the effectiveness of noise control strategies on existing track designs but shall also allow for optimized systems to be developed without the need for extensive design testing.

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