Numerically exact simulation of sound propagation in large geometries

A computer model was developed that allows for wave based numerical simulations of sound propagation in large geometries in two dimensions. The algorithm works in the time domain and can handle different source types as well as locally inhomogenoeous atmosphere to simulate meteorological effects.

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Nowadays, the calculation of sound propagation between source and receiver is based mainly on empirical approximate formulas. As a consequence, the uncertainty of the results is rather high. Current computer power introduces the possibility of numerical simulations that are based on exact wave theory. By application of such models sound fields in complicated geometries as for instance in galleries for noise protection of inhabitants can be calculated.

Numerical sound field simulations based on classical finite elements or boundary elements have successfully been used in small geometries for about ten years. Recently, the concept of finite differences in the time domain – originally developed for the calculation of electromagnetic fields – was transferred to sound fields. This approach seems especially well suited for large regions as the computational effort increases linearly with the size of the geometry.

Within the framework of an ASTRA research project, we developed a computer model FDTD (Finite Differences in the Time Domain) to simulate sound propagation in two dimensions in the time domain. By the application of variant coordinate systems it is possible to handle different source types. In contrast to frequency domain models, FDTD allows for the investigation of the temporal evolution of sound fields. It is possible to judge the relevance of single reflections and, therefore, to determine for example the effect of an absorbing treatment. The program serves as a reference model for investigations of meteorological effects on sound propagation over larger distances. Thus, large set of test cases of different sound propagation situations and weather conditions were created. These cases serve for the calibration of simplified calculation algorithms such as ray tracing models that are developed for every day application. Moreover, parameter studies of typical diffraction phenomena have been performed (Heutschi 2003).

On behalf of the Cantonal Authorities for the Environment and Energy Basel-Stadt, the FDTD program was used to investigate different types of sound protecting measures at the Dreirosen-Bridge in Basel (Fig. 1). The computer simulations replaced costly scale model experiments and helped to minimize noise immission in the inhabited area.

Up to now, the model can handle two dimensional geometries. As the extension to three dimensions corresponds to an increase in computational effort in the order of magnitude of 1000, an intermediate "2.5-dimensional" solution has to be sought. Within the classical 2-dimensional simulation, line sources are interpreted as coherent sources. Actually, roads or railway lines with independent vehicles should be regarded as incoherent line sources. Preliminary ideas to model such sources on a statistical basis will be investigated. Furthermore, possibilities to incorporate temporally inhomogeneous atmosphere to simulate the effect of turbulences will be studied.

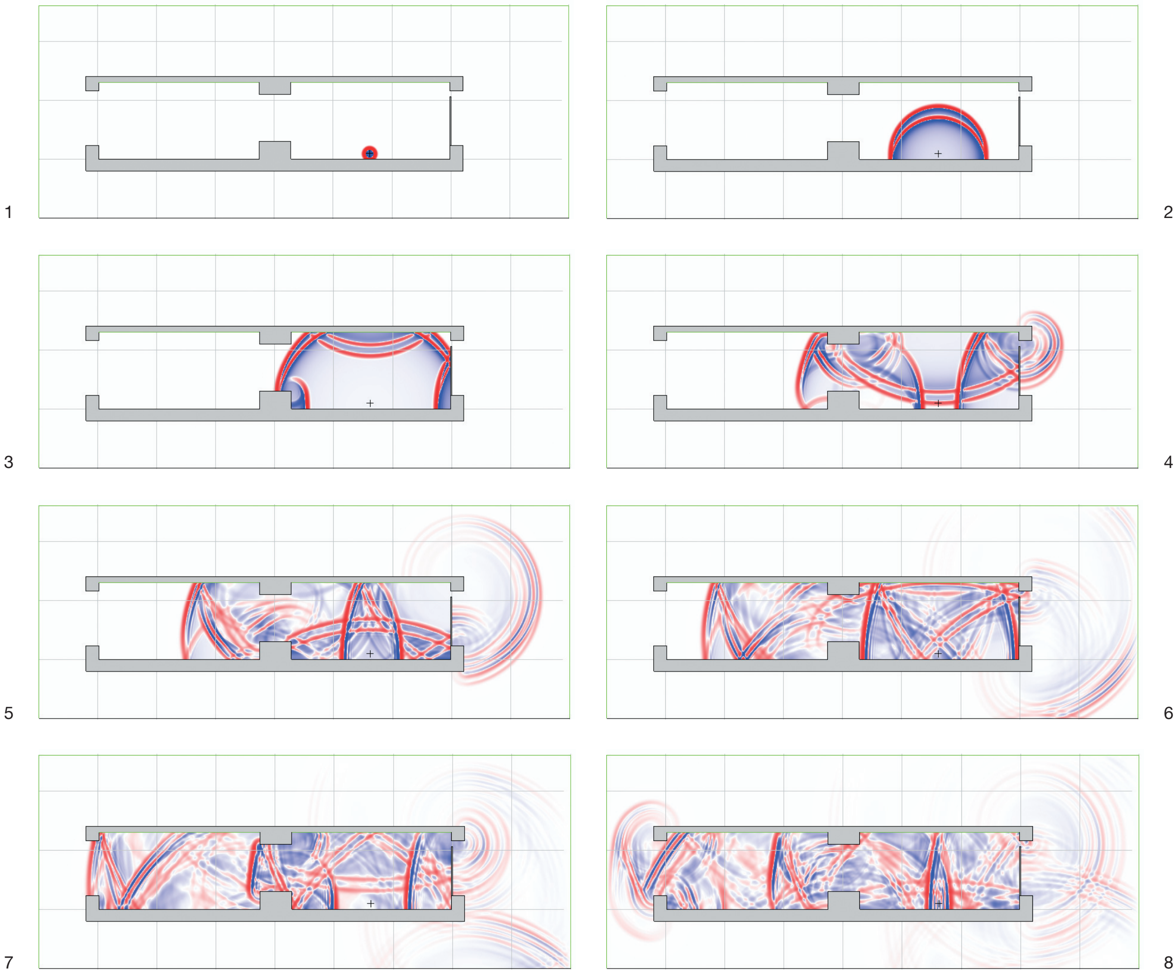

Fig. 1: *Cross sectional view of one variation of sound protecting measures at the Dreirosen-Bridge in Basel. The bridge consists of two floors whereas the highway with the sound emission to be considered here is located on the lower floor. The strength of the sound pressure is color-coded with dark red for high positive and dark blue for high negative pressure values. The immission points in question are located on the right hand side (outside the sketch). The gray lines indicate a grid of 5 m spacing. Each frame shows the temporal evolution of the sound field for an initial sound pulse emitted at the source point (marked by a cross) 0.5 m above the road surface. The time step between the frames is 12 ms.*

Support: ASTRA

Links: www.empa.ch/akustik

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References:
K. Heutschi, Acta Acustica united with Acustica, 89, 909–913 (2003)