Detailed sound propagation calculations outdoors

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Finite-Difference Time-Domain (FDTD) method

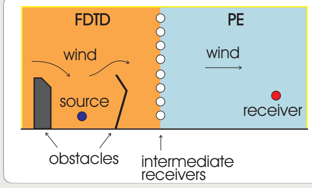
FDTD is a detailed, **wave-based sound propagation model** that solves the Linearised Eulerian Equations (LEE). It can be considered as a **complete model** for **outdoor** sound propagation applications.

Convection, refraction and scattering of sound waves by an inhomogeneous and moving atmosphere is modelled. The effect of arbitrary **wind** and **temperature fields** can be simulated, in combination with (multiple) **reflections**, (multiple) **diffractions** and **scattering** on objects. The interaction of sound waves with outdoor **ground surfaces** can be taken into account, either by using a porous-medium model or by simulating impedance planes. Very good absorbing boundary conditions (**Perfectly Matched Layers,** PML) were developed to simulate an unbounded atmosphere.

The model has been **validated** based on a number of wind tunnel experiments.

Coupling numerical methods

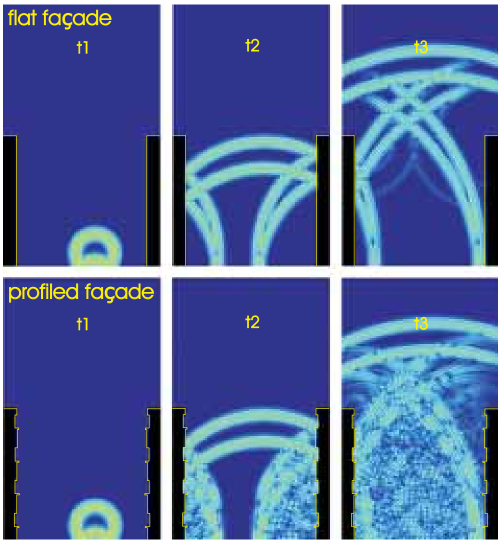
The degree of detail (and numerical cost) of FDTD is usually only needed in a limited part of the sound propagation domain. The **coupling** between FDTD and the Parabolic Equation (PE) method is interesting in outdoor sound propagation applications. PE assumes **one-way sound propagation** (from the source to receiver), taking into account range-dependent **refraction** of sound and **impedance planes**. **Large step sizes** are allowed in horizontal direction (up to several wavelengths). An application of interest is a typical **traffic noise situation**. **Computational efficiency** can be largely improved by a coupled FDTD+PE model (Act. Ac. Ac. 91, 671-679, 2005) .



Schematic representation of the one-way coupling between FDTD and PE, in a typical traffic situation. The interface between both models consists of an array of acoustical pressures.

Sound propagation in an urban environment

Sound propagation in urban areas is complex. The FDTD method was used to investigate sound propagation between adjacent city canyons (Appl. Acoust. 67, 487-510, 2006). The **width-height ratio** of the canyons seemed to be of limited importance in typical configurations. **Downwind** sound propagation significantly increases sound pressure levels in receiving canyons. **Diffusely reflecting** façades, increased **absorption** near façades and (inclined) **balconies** were shown to be beneficial for noise abatement.



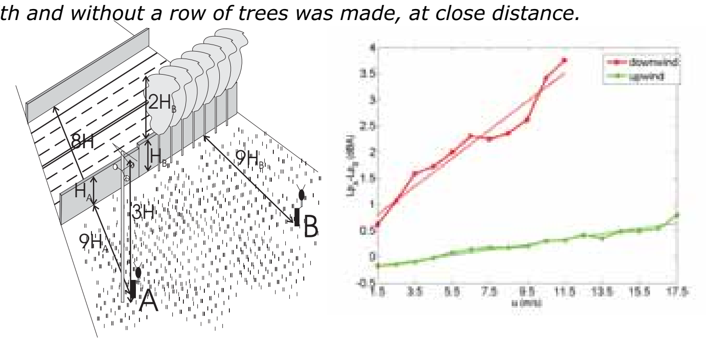
Sound field in a two-dimensional street canyon at selected times after emission of an acoustic pulse in case of a ***flat façade*** *(above, pure specular reflection) and in case of a profiled* ***façade*** *(below, both specular and diffuse reflection). With increasing time, the sound field becomes completely diffuse for the profiled façade. The numerical simulations were performed with FDTD.*

Reducing screen-induced refraction of sound by wind

The **efficiency** of common noise barriers under **downwind** sound propagation conditions is significantly **reduced**. The wind flow induces **large gradients in the wind speed** near the top of the screen. As a result, sound is **refracted** in **downward direction**, into the diffraction zone.

The use of a **vegetation screen** (row of trees) behind a noise barrier was found to be successful in this respect. The study consisted in a **wind tunnel experiment** at scale (*Act. Ac. Ac. 88, 231-238, 2002*), in an extensive **field monitoring** (*Act. Ac. Ac. 88, 869-878, 2002*) and in **numerical calculations** to optimize parameters involved (by combining CFD analysis and FDTD calculations, *Act. Ac. Ac. 89, 764-778, 2003*).

The positive effect of a row of trees behind a traffic noise barrier increases significantly with wind speed in case of downwind sound propagation. Results were drawn based on a field monitoring. A direct comparison of the sound pressure level between part of a noise barrier with and without a row of trees was made, at close distance.



Sound propagation in mountainous areas

A Green's Function PE method with a rotated reference frame (GFrPE) was used and optimized for sound propagation over several kilometers in a **valley-slope configuration** (Unterinntal region, Austria). The numerical simulations were **validated** based on combined noise and meteorological measurements. Focus was on the effect of the **relief** and of typical **temperature gradients** in mountainous areas.

Total sound pressure levels, resulting from road traffic, expressed relative to the reference receiver MP6, in case of a complex, measured temperature profile. A comparison with GFrPE simulations is made. Additional numerical calculations were made to estimate the effect of the undulation of the terrain and the effect of the inhomogeneous atmosphere.