Benchmark case: geometrical spreading of a 2D point source

Computational details

Computational technique	the finite difference time domain (FDTD) method [3] and the transmission line matrix (TLM) method [1, 2]
Computed results	See next Section.
Programming language	Python 2.7.14 - additional packages: numpy, scipy, matplotlib, os, site.
Programming details	All details are available at `https://github.com/pchobeau/sinecity_testcases` , BSD 3-Clause License.
Code accessibility	BSD 3-Clause License
Processing details	An example, for the FDTD calcualtion, it starts from the main folder with the script `case1_geospr.py` in which the main parameters are set. The initialization of the domain (geometry, boundaries, source and receiver locations) are written in `init_fdtd_geospr.py`. The update calculation is performed in `upd_fdtd.py`. Finally, the results processed in `errors_calc3_geospr.py` which returns the time signals, the errors and the convergence plots.
Computational complexity	N.A.
Notes	It is important to note that the grid parameters have been chosen to be exact multiple from on grid to another in order to accurately compare the grids both in terms of time iteration and receiver position. Therefore, the simulations are carried out below the theoretical Courant limit, *i.e.* $\lambda = cT_s/h < 1/\sqrt{2}$. Both space and time discretization are tested. However, this verification does not account for any boundary condition.
References	[1–3]
Contributing institute	Laboratoire d'Acoustique de L'Université du Maine (LAUM), Le Mans Acoustique (LMAc), UMRAE.

Results

The absolute error$(x_i, y_i, t_n) = \left|\hat{p}_i^{\mathrm{n}} - p^{\mathrm{exact}}_{(x,y,t)}\right|$ is the absolute value of the difference between the numerical result and the analytic formulation. The norms of the error are calculated over all grid points for each spatial step.

Figure 1 shows the signals for the FDTD and the analytical solutions at each point. It is important to note that the so-called 'afterglow' [4] appearing in 2D time domain simulations, has not been compensated here. Therefore, all numerical pulses present a slow pressure decay approaching zero after the wavefront has reached the receiver, instead of fast decay to the zero.

The errors are the averaged difference between the numerical time signals and the analytical formulation. The norms are calculated over all receivers. Both methods shows second order of convergence, as shown in Figure 2. The TLM convergence appears to be more impacted than FDTD for the coarsest grids, where the order of convergence is reduced.

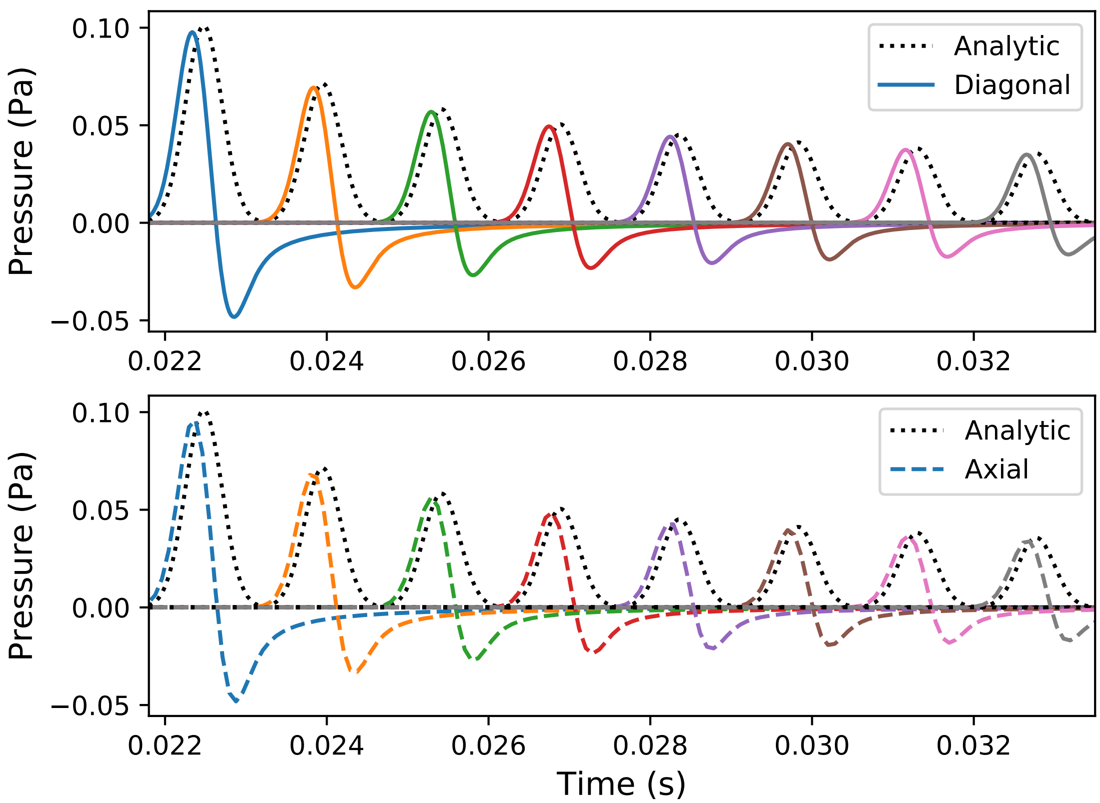

Figure 1: Time signals for the FDTD compared to analytic for $h = 0.01$ m.

References

[1] P. Aumond, G. Guillaume, B. Gauvreau, C. Lac, V. Masson, and M. Berengier. Application of the Transmission Line Matrix method for outdoor sound propagation modelling - Part 2: Experimental validation using meteorological data derived from the meso-scale model Meso-NH. *Applied Acoustics*, 76:107–112, 2014.

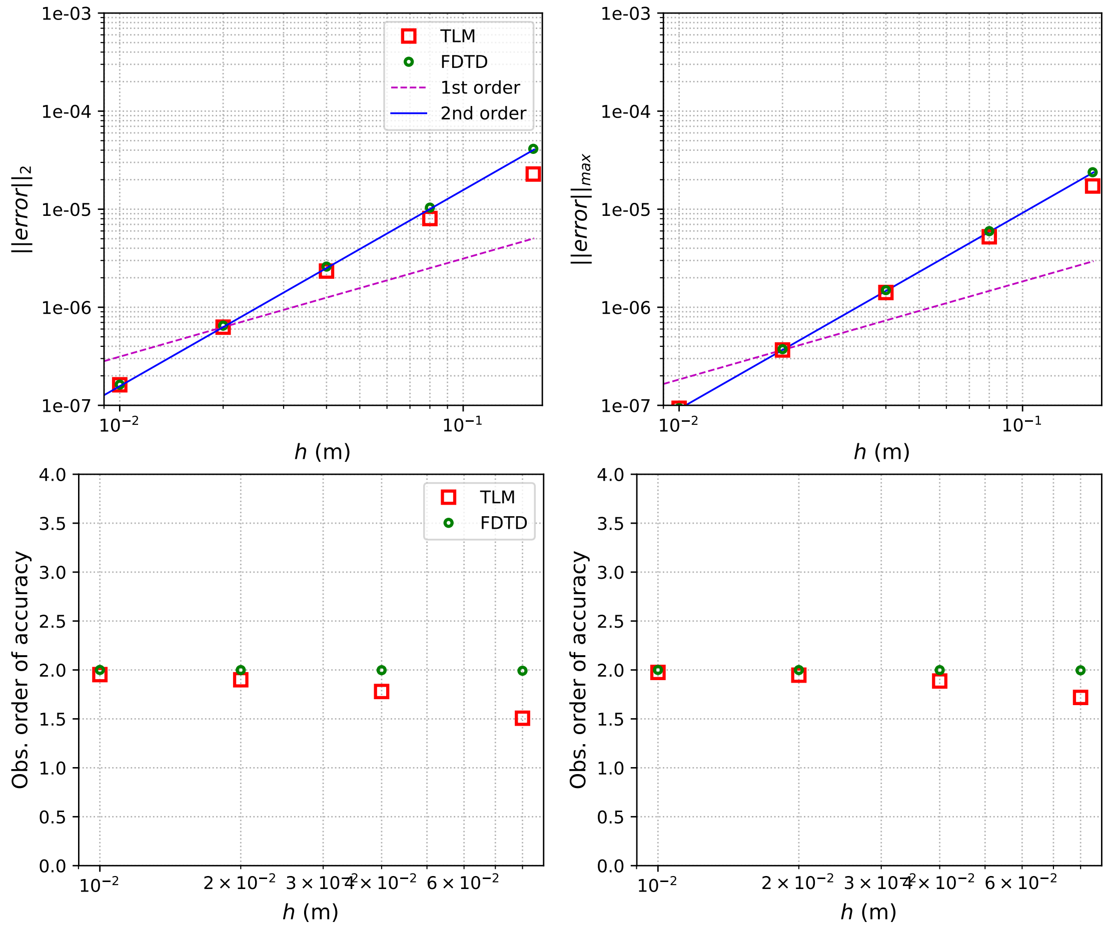

Figure 2: Two-norm and max-norm of the absolute error (top) and the corresponding observed orders of accuracy (bottom) for case 2, using the FDTD and the TLM methods.

[2] G. Guillaume, P. Aumond, B. Gauvreau, and G. Dutilleux. Application of the transmission line matrix method for outdoor sound propagation modelling - Part 1: Model presentation and evaluation. *Applied Acoustics*, 76:113–118, 2014.

[3] B. Hamilton and S. Bilbao. FDTD Methods for 3-D Room Acoustics Simulation With High-Order Accuracy in Space and Time. *IEEE/ACM Transactions on Audio, Speech and Language Processing (TASLP)*, 2017.

[4] C. Spa, J. Escolano, A. Garriga, and T. Mateos. Compensation of the Afterglow Phenomenon in 2-D Discrete-Time Simulations. *IEEE Signal Processing Letters*, 17(8):758–761, Aug 2010.