Computational solution of wave problems

Project: FDTD simulation of diffraction over a building

Goal:

This project aims at getting insight in the finite difference time domain technique (FDTD). More specifically we will study the problem of discretisation of non-Cartesian surfaces in a Cartesian grid. "Special techniques" will be studied to combine efficiency and accuracy in these cases. In addition this project allows exploring the application of perfectly matched layers.

Exercise:

In this we consider a 2 dimensional problem, which implies that the objects are infinitely long in the direction orthogonal to the drawing and that the source is a line source. The source is transparent and infinitely small (*p*-source=monopole in 2 dimensions).

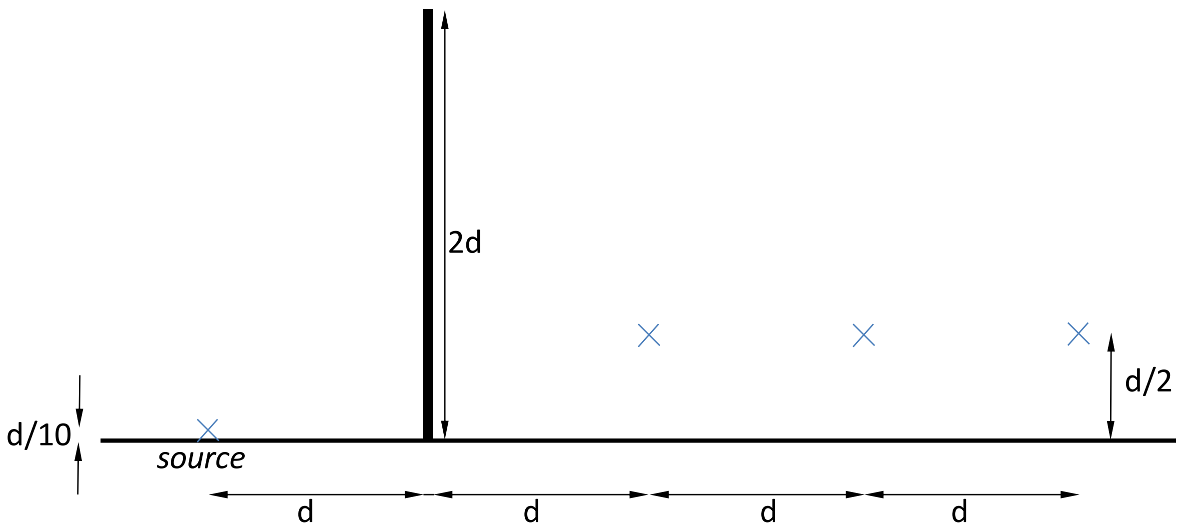
Part 1: checking the implementation of PML using the example of a thin wall

The figure below shows the basic layout of the problem. The ground surface and all objects are perfectly hard: o_n=0. The vertical screen has to be implemented to be as thin as possible.

Implement Cartesian grid FDTD with suitable non-reflecting boundary conditions to approach the openness upward and to the left and the right. Calculate the transfer function between the source and the 3 observation points marked in the figure. Subtract the transfer function in free field and compare the results with the analytical formulation for diffraction around a wedge that can be found in the chapter on geometrical methods (last chapter).

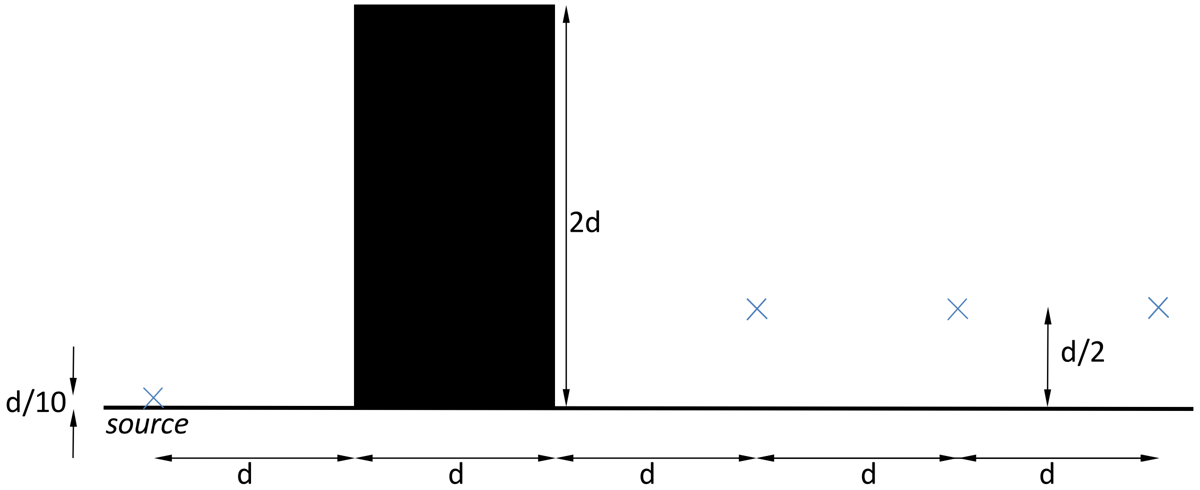
Discuss the frequency range where the result is expected to be accurate from a theoretical point of view and based on the comparison with the analytical formulation. For this, start from the roughest grid that can describe the structure, the source, and the receiver and consequently test at least one grid refinement.

Consider the parameters used for implementing the PML carefully.



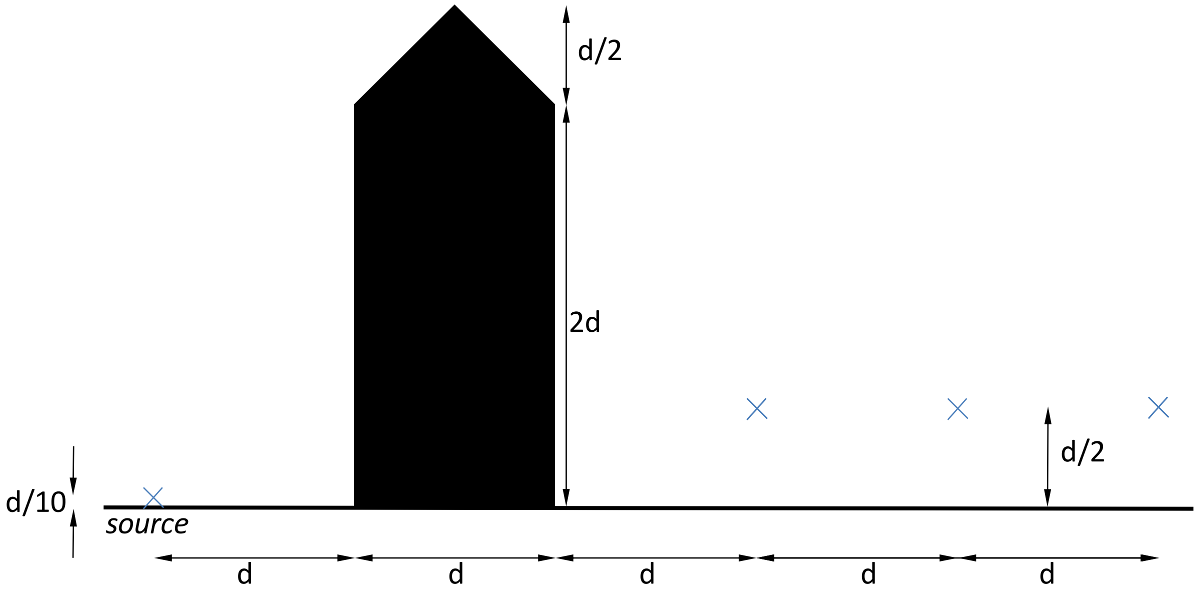
Part 2: extending to thick building and triangular roof

Now the central object is widened to become a building (figure below). Again calculate the field in the 3 observation points and compare with the previous case after eliminating the propagation in free field, which is in absence of any object or ground. Note that the distance between source and receivers has changed compared to the situation in part 1.



In a next step the roof is added (figure below). This triangular shape cannot accurately be described in the Cartesian grid so use a stepwise approximation.

Compare results to the previous case and introduce at least one refinement to observe how the discretisation affects the results.



Part 3: resolving the tilted boundary condition

Now implement one of the techniques discussed in the theory to more accurately model the non-Cartesian surface introduced in part 2. Compare the results obtained with the results from part 2 for at least two grid steps as a function of *kd*.

With this final model perform a thorough comparison of the frequency range (*kd* range) where you expect accurate results for different grid steps and contrast to the CPU time needed to perform the calculation. This result obviously depends on the computer that you are using and the available memory.

Practical

Students work in groups of 3 for this project. The deliverable is a piece of software code and a discussion (report) of the results obtained with a focus on numerical aspects. The deadline for uploading the results via Minerva is one week before the exam. During the open book exam, the project will be discussed and additional theoretical questions will emerge from this.

Hints

- The developed code does not need to be universal. Choose optimal discretisation steps for describing this specific problem.

- Try to express your results as much as possible as a function of *k.d* where k is the wave number $=2\pi/\lambda$