

ETEN05 Electromagnetic Wave Propagation
Handin 2

Deadline September 23, 2016

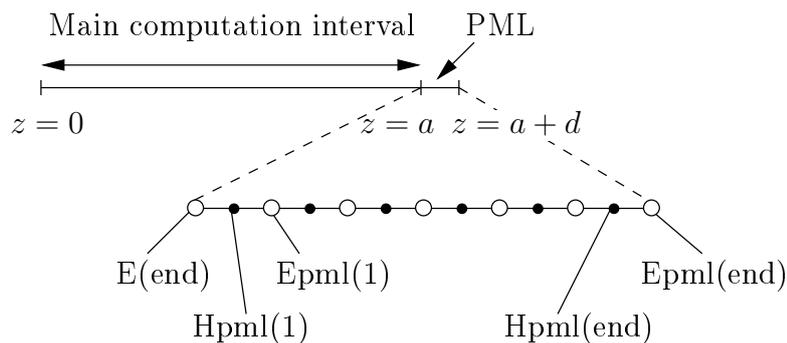


Figure 1: Geometry of the PML, please compare with the code so that you understand how the different points in the figure correspond to the matlab data. The PML is closed with a PEC, thus we set $Epml(end)=0$ for all times.

The report

The report should be produced in PDF format and submitted on the web site <http://elearning.eit.lth.se/moodle>. You may work in groups of two, and hand in a joint report (write both names clearly). Structure the report according to

Introduction Give a short introduction to the problem and the FDTD method. The target audience is your fellow students.

Experiments What are the values of your parameters and how did you decide them? How have you computed the reflection coefficient?

Results What are the results of your experiments? This section must contain the two graphs mentioned below.

Discussion A short discussion of the results.

The level of detail should be such that someone else can repeat your experiments. The total report should not be longer than a few pages. Also supply the source code you have used in an Appendix. All reports will be checked through Urkund.

Perfectly Matched Layers in one dimension

The following problem is an adaptation of Computer Project C.5-2 in Bondeson, Rylander, and Ingelström.

A 1D FDTD scheme for $0 \leq z \leq a$ has been implemented on a staggered grid; the code can be downloaded at the course web site. It includes a simple implementation of the PML absorbing boundary condition at the wall $z = a$, and the fields are excited on the boundary $z = 0$ by the boundary condition $E_x(0, t) = f(t)$. Keep the interval length a and the number of discretization points N_z fixed in all of the experiments. The exciting function is chosen as a damped sinusoid, $f(t) =$

$\exp[-(t - t_0)^2 / (t_w/2)^2] \sin[2\pi f_0(t - t_0)]$. The parameter t_0 shifts the pulse along the time axis, t_w determines its width, and f_0 is the frequency of the pulse.

The PML conductivity in the code is $\sigma_{\text{PML}} = \sigma / \epsilon_0 = \sigma^* / \mu_0$ (physical unit $[\sigma_{\text{PML}}] = \text{s}^{-1}$). A suitable order of magnitude for this is given by the estimate $\sigma_{\text{PML}} \approx c_0 / d$, where d is the physical thickness (in meters) of the PML. Note that this only gives a suitable starting point for your investigations. For the rest of the parameters, remember to check how the solutions look: is the discretization fine enough, is the simulation time enough to allow the whole pulse to be reflected in the PML etc. Remember space and time scales are related by c_0 , *i.e.*, an interval of 1 m corresponds to a propagation time of $1 \text{ m} / c_0 \approx 3 \text{ ns}$.

Two files are available on the course web site:

- `pml.m`: the base code implementing a 1D FDTD code with a PML.
- `test_parameters.m`: a short script that can be used to test the parameters going into `pml.m`.

Task

Set up a numerical experiment so that you can study the reflection of an electromagnetic wave from the PML. Choose appropriate values for a , N_z , t_0 , t_w , and f_0 . Give a precise description of how you compute the reflection coefficient. Experiment with two different conductivity profiles $\sigma_{\text{PML}}(z)$, keeping the number of PML layers constant $N_{\text{PML}} = 8$:

1. A constant conductivity profile with the value $\sigma_{\text{PML}}(z) = \sigma_{\text{const}}$ for the conductivity.
2. A quadratic profile $\sigma_{\text{PML}}(z) = \sigma_{\text{max}}[(z - a)/d]^2$, where d is the thickness of the layer in physical units, *i.e.*, σ_{max} is the conductivity at the closing PEC wall.

Make a plot of the reflection coefficient for each case, one as a function of σ_{const} and one as a function of σ_{max} . What are the optimum σ_{const} and σ_{max} ?

Feel free to investigate additional properties if you want to (although it is not a requirement), such as what is the lowest possible reflection level you can achieve, does the reflection depend on frequency, does it depend on discretization and choice of $R = c_0 \Delta t / \Delta x$?

Hint: Try to automate the computation of the reflection coefficient, so that you do not have to start the program manually for all the simulations. Once you have done this (and verified that it works!), there is no need to keep plotting the animation inside the main loop. Use the animation only to check that you have set reasonable values for your parameters.