EE6506 Computational Electromagnetics: Jan - May 2019, Uday Khankhoje
Assignment 4, 5.04.2019, due 28.04.2019 (at 11:59pm)

1. You can solve this homework individually, or in groups of two (the same as for assignment 3). 2. Make reasonable assumptions, STATE them, and include any references you might have used. 3. Extra points are reserved for neat and systematic presentation of results. 4. Plagiarism $\Rightarrow$ Course fail (this has happened).

1. **Simulating electromagnetic filters via a 1D computational experiment:**
   Repeat the first question of the previous assignment by implementing your own 1-D FDTD. You can use a broadband source to find the resonance(s) in both structures. Then, pick any one resonance and run a narrow band source near the resonance to study it better. You must plot the transmission or reflection spectrum by taking a Fourier transform of the raw FDTD data obtained (i.e. the x-axis must be frequency). Comment on comparisons with the results of your previous simulation of the same structure using FEM. As before, justify all your choices of parameters.

2. **Modeling wave scattering using Meep**

Wave scattering is a phenomena we experience on a daily basis; be it in when we are able to receive a cellphone signal in the interior of a building, or when we are able to hear a conversation from behind an obstacle, or when we see water ripples bend around a stone. This so-called 'bending' of a wave depends primarily on the relative size of the obstacle to wavelength. In this simple experiment, you will play with this ratio and identify different regimes of wave bending using the finite-difference time-domain (FDTD) method.

Objectives

1. To identify three different regimes of obstacle size/wavelength in which wave scattering or diffraction take place. The first, when the obstacle size is much smaller than the wavelength and the wave is essentially undisturbed. Second, when the sizes are comparable and diffraction is evident. Third, when the size is larger and the obstacle effectively shadows the wave. You must experiment and find out representative ratios that characterize these regimes.
2. Produce a set of field plots (or animations, if you can be creative enough) that demonstrate these three regimes.
3. Produce a Youtube video (max. 3 minutes) as the report. This carries a total of **12** points.

Techniques

You will use **meep** to design your experiment. This software is very similar in usage as **mpb** which you used previously. First, scan through the introduction: `http://ab-initio.mit.edu/wiki/index.php/Meep_Introduction` paying particular attention to how units are defined. Next, get a grip on how to use meep by reading the tutorial `http://ab-initio.mit.edu/wiki/index.php/Meep_Tutorial`. Now, design your 2D experiment keeping in mind the following:

1. Since we can't simulate an infinite computational domain, and truncating a finite computation domain generates unphysical/numerical reflections from the borders, the entire computational domain should be encased by an absorbing boundary condition. This is implemented using Perfectly Matched Layers (**PML**), which for the purpose of this experiment, can be made to be one wavelength thick.

2. The **source** can be chosen to be a continuous-wave, point current source situated somewhere in the left half of the domain. Look up the 'source' specifications in the reference section.
3. A little to the right, place a vertical line **obstacle**. This can be made of metal, or some other material. The choice is upto you; keep the objective of the experiment in mind. Look up the 'material-type' specifications in the reference section. Play around with the vertical size of this obstacle in order to study objective (1).
4. Specify the **resolution** of the simulation. $\Delta x \approx \lambda/20$ is usually sufficient spatial resolution to produce numerically convergent solutions. Recall that in FDTD the space and time steps are linked via the Courant stability parameter: $c\Delta t/\Delta x \leq S$ (meep default is $S = 0.5$). Also recall the Nyquist sampling theorem which talks about the rate at which a time signal should be sampled. Make sure that the resolution you specify is good enough that you are actually simulating what you think you are simulating! See, for e.g. `https://www.cs.cf.ac.uk/Dave/Multimedia/node149.html`
5. **Run** the simulation for long enough that you observe a steady state solution. Remember that this is a time domain simulation, so you must wait for the source waves to travel across the computational domain.
6. Revise the meep tutorial to learn how to produce static field **plots**, as well as field animations to demonstrate the different regimes as identified in the objectives.
7. Ensure that there is a **gap** of atleast one wavelength between the source or obstacle and the PML.
8. Tip: Keep the size of the computational domain the same for all your experiments and only vary the size of the obstacle to ease comparison of the different cases.

Report

Some guidelines for preparing your video reports (total **[12]** pts):

1. The Youtube video will be evaluated as per this criteria:
   (a) A table of all parameters that you used to design your experiment **[2]**.
   (b) The meep code you used to derive your results, with a brief explanation of the main ideas in the code **[2]**.
   (c) A summary of your results **[3]**.
   (d) Explains the physics of the different scattering regimes **[3]**.
   (e) Make your video more interesting to get more credit! For example, connect the results of the experiment to some natural phenomena or an engineering problem **[2]**.
2. No robot voices are allowed in the video. There is a penalty of **[1]** pts for doing so.