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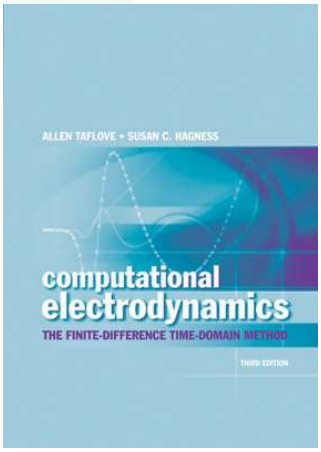
Computational Science:
Introduction to Finite-Difference Time-Domain

Rules & Procedures

Lecture Outline

- Course Overview
  - Mission
  - Course Objectives
  - Course Outline
- Policies and Procedures
  - Grading
  - Homework
  - Final Project
- Policies & Best Practices for Coding



Course Overview

Mission of This Class

The mission of this class is to begin teaching the art of computational electromagnetics using MATLAB. The course will take a slow and methodical approach to teach finite-difference time-domain (FDTD) including theory, formulation of the equations, and implementation in MATLAB.

Course Objectives

- Teach the finite-difference time-domain method.
- Teach students the art of computation and visualization in MATLAB.
- Teach best practices for developing and implementing new numerical algorithms.
- Motivate students in the areas of simulation and electromagnetics.
- Provide the students with real skills that are in high demand in industry.

Course Outline

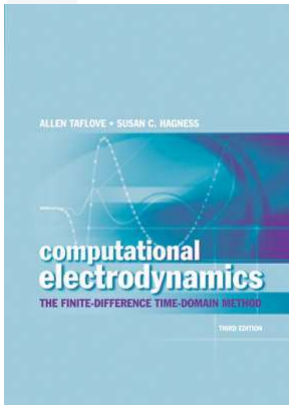
- Review of MATLAB
  - Graphics, movies, and helpful tidbits.
  - Building geometries in arrays.
- Introduction to FDTD
- One-Dimensional FDTD
  - Formulation, implementation, and examples.
- Two-Dimensional FDTD
  - Formulation, implementation, and examples.
- Advanced Concepts
  - Perfectly match layer boundary condition
  - Grid strategies and alternatives
  - Periodic structures in FDTD
  - Modeling waveguide devices
  - Three-dimensional FDTD
  - Near-field-to-far-field transformation
  - More…

Policies and Procedures

The Book

Allen Taflove, Susan C. Hagness, *Computational Electrodynamics, the Finite-Difference Time-Domain Method*, 3rd edition, Artech House, 2005.

- Good aspects of the book
  - This is the most rigorous and comprehensive book on FDTD available.
  - Many topics and references are provided.
- Drawbacks of the book
  - This is not a good book to learn FDTD from scratch.



The Syllabus (1 of 4)

- Instructor Information
  - Dr. Raymond C. Rumpf
  - E-Mail: professor@empossible.net
  - Course website: https://empossible.net/academics/emp5304/
- Prerequisites
  - Basic electromagnetics
  - Differential equations
  - Programming / MATLAB

The Syllabus (2 of 4)

- Course Objectives
  - Be able to use the FDTD method to model electromagnetic devices
  - Strengthen MATLAB and graphics skills
- Attendance
  - Attendance is required
  - Attendance is accounted for in participation grade
  - Coordinate with instructor ahead of time if you need to miss a class
  - In some cases, absence can be excused if coordinated with instructor well before the lecture is missed.

The Syllabus (3 of 4)

- Exam Policy
  - Exams represent 20% of final grade
  - Two midterm exams and one final exam
  - May be take-home or in-class
  - In-class exams, students can have a calculator and a single 8.5”x11” paper with whatever they wish
  - **Take home exams will require working FDTD codes*!!!!***
- Homework
  - **Worth 40% of final grade**
  - Homework will build on prior homework so keeping up is essential
  - Homework is due by midnight on the due date
  - Subtract 10% from homework for every day late
  - 12:01am will be considered late
  - Do you own work. Do not copy from other students.

The Syllabus (4 of 4)

- List of Topics
  - MATLAB
    - Programming and graphics
    - Representing devices on a grid
  - Finite-Difference Time-Domain
    - One-Dimensional FDTD
      - Formulation, implementation, visualization, post processing
    - Two-Dimensional FDTD
      - Formulation, implementation, PML, sources, visualization
      - Modal sources, analysis of waveguide devices
    - Advanced Topics
      - Boundary conditions, periodic structures, PML, and more.

Grading

Homework	40%	90% – 100% → **A**
Project	20%	80% – 89% → **B**
Midterm Exam 1	15%	70% – 79% → **C**
Midterm Exam 2	15%	60% – 69% → **D**
Participation	10%	0% – 59% → **F**

HOMEWORK IS 40%
OF YOUR FINAL GRADE!!!!!!!

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Homework Policy

- Due before midnight on due date. 12:01am is late.
- Submit a single PDF file
- Neat, organized, answers provided in the order they are asked.
- Unless specifically requested otherwise, all codes must be in an appendix placed at the end of your homework document.
- Cover page: name, ID#, date, assignment #, etc.
- Do your own work. Do not ever copy from other students.

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The Final Project

- Purpose – to learn, practice, and share something outside of what was taught in class.
- Project should be summarized in Power Point.
  - Must be complete enough that instructor can reproduce your work if needed.
- Projects will be presented during the final exam period. Duration ~10 minutes for presentation.
- May work alone or in teams, but teams must do proportionally more work.
- Must submit all electronic files (i.e. slides, codes, movies, etc.) to course instructor or project will be given a grade of zero.
- *Get started on this early!!*

Project Ideas

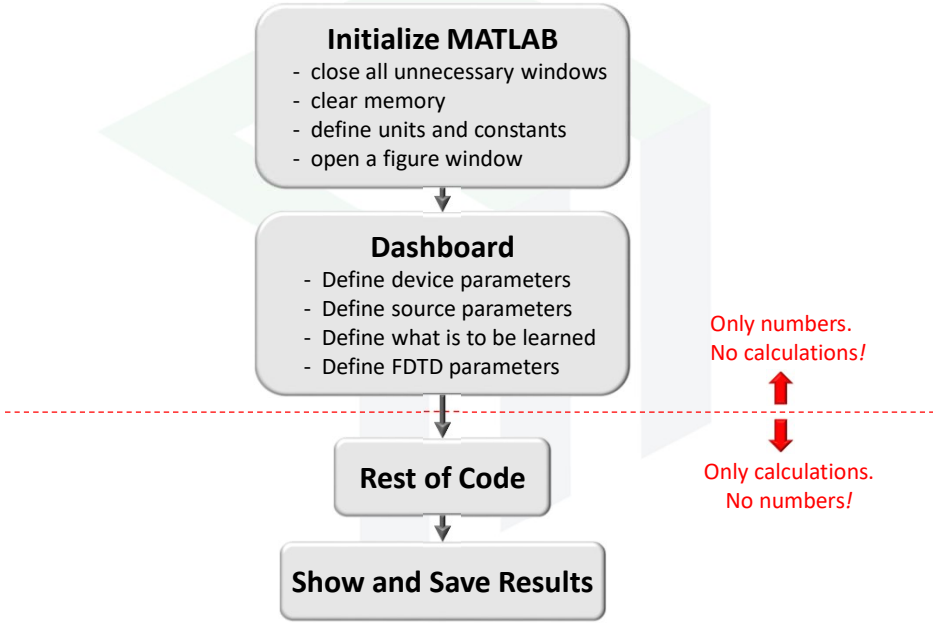
- Optimize PML parameters
- Implement a different boundary condition
- Implement higher-order accurate derivatives
- Implement a different type of source
- Model a new device
- Implement 3D FDTD
- Use FDTD to calculate a band diagram
- Do part of your research as this project*!*
- Others…

Graphics

- All figures and graphics must be of professional quality and easy to understand and use.
- The best figure is made as small as possible so that it is still neat and reads clearly
- Lines should be thick enough to be identified, but not awkwardly thick
- Fonts should be large enough to be read easily, but not awkwardly large
- All entities of the figure should be labeled and given proper units

Policies and Best Practices for Coding

Structure of the Ideal Code



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Coding Requirements

- Codes must be clean, commented, and well organized.
- Codes must follow the block diagrams in the lecture notes exactly.
- Constants must include units and as many significant digits as possible.
- Do not breakup codes into subroutines (i.e. functions) unless instructed specifically to do so.
- No calculations in the dashboard, unless absolutely necessary.
- All hard-coded numbers should appear only once within the "dashboard" at the start of your code.

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Coding Best Practices

- Do not hard code any numbers you may want to change.
- If you have to change more than one thing in your code or change something outside of your dashboard to alter a devices dimensions, material properties, etc., you are probably doing something wrong.
- Develop your codes in small increments that you can benchmark at each step.