Learning Objectives

Students will learn to use an electromagnetic simulation software package, Microwave Studio. Microwave Studio can solve Maxwell’s Equations in very general material and source configurations with three different solvers: Finite Difference Time Domain (FDTD), frequency domain Finite Elements, and Eigen-Mode. This functionality is very useful across almost all disciplines of electrical engineering.

This tool will be used to explore topics relevant to antenna design and current research in metamaterials. Metamaterial topics may include: material parameter extraction, effective medium theory, resonant unit cell analysis, and unit cell coupling. Examples will be drawn from invisibility cloaking and negative index media. Antenna topics may include: complex antenna shapes, real array effects, co-located antenna interference, high-impedance ground-planes, and Specific Absorption Rate (SAR).

Metamaterial and antennas topics are connected not only by the tools used to analyze them, but conceptually (particularly in the case of antenna arrays). I will try to make these connections where appropriate.

Class Format

The class will meet in the a computer lab where I will typically give a brief lecture and then be accessible to answer questions and assist with the projects.

Prerequisites

The prerequisite for this course is ECE330 or equivalent course that gives a fairly thorough introduction to electromagnetics and Maxwell’s Equations (such as PHYS 3230 or 4420). Antenna Theory and Design (ECE 5324) is recommended, but not necessary to complete the projects.

Metamaterial Projects

- **Material property extraction**
  Perform S-parameter simulations on a known material (Teflon), with and without correct de-embedding. Export data and compare with theory.

- **Effective medium theory**
  Perform S-parameter simulations on a composite material. Export data and extract effective material properties. Compare with volume averaging theory.

- **Resonant unit cells**
  Perform S-Parameter simulations on a family of resonant unit cells (from the microwave invisibility cloak). Export data and extract effective material properties. Compare with desired material properties.
S-parameter failure
Prepare a unit cell model targeting low-loss *negative refractive index*. Explore S-parameter extraction failure. Export field data. Use field averaging method for material property extraction.

Unit cell coupling
Simulate varying numbers of unit cells in the propagation direction. Extract material properties and find asymptotic values.

**Antenna Projects**

Complex antenna shapes.
Increasingly antenna shapes are dictated by requirements of the packaging or platform. Simulate a complex antenna shape, the iPhone 4 GSM antenna, and determine its far field properties and input impedance both with and without a “finger” on the “death spot”.

Real antenna array effects
Coupling between elements in a real antenna array can effect current distributions and thus input impedance and radiation fields. Simulate an antenna array with real coupling. Calculate input impedance and radiation parameters and compare with an ideal array factor calculation.

Co-located antenna interference
Multiple antennas in the same package can interfere with each other. Simulate a GSM and a GPS antenna in close proximity and calculate the cross talk. Try an isolation strategy, such as placing a high-dielectric material between the antennas.

High-impedance ground-planes
Electric antennas in contact with electric ground-planes do not radiate. Model a dipole antenna on a finite-sized, high-impedance ground-plane (also known as a magnetic ground-plane) of two types - one that supports surface waves and one that does not. Calculate input impedance and radiation parameters. Compare with ideal image solution.

Specific Absorption Rate (SAR)
Model an antenna in close proximity to a human head. Export field data and calculate SAR.

**Required Texts**

None

**Assignments and Grading**

There will be approximately ten project assignments, all of which will have simulation components. For those enrolled in 6962 the assignments will include some extra work not required of the 5962 students. The assignments will be due approximately every third class meeting. The grading will be based entirely on these assignments. There will be no exams. Correct and complete fulfillment of all assignments will result in an excellent grade. If an assignment is not correct and complete the student will be notified and given the opportunity to correct the assignment. Within reason, late assignments will be accepted and given full credit. Reasonable attendance is expected but not graded.

**Academic Integrity**

Students may work together on assignments, but every student must be able to explain their submitted work. Students are expected to exhibit integrity in their conduct and are subject to the [University of Utah Code of Student Rights and Responsibilities](https://www.utah.edu/student-life/student-rights-and-responsibilities).
Students with Disabilities

The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Olpin Union Building, 581-5020 (V/TDD). CDS will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in alternative format with prior notification to the Center for Disability Services.