Syllabus
ECE 5350/6350 – Fall 2019
Metamaterials and Advanced Antenna Theory
3.0 Credits

Pre-requisites:	ECE 3300
Time:	Tue/Thur 3:40 PM-5:00 PM
Location:	MEB 2555

Instructor:	Professor David Schurig
Email:	david.schurig@utah.edu
Skype:	david.schurig
Office Location & Hours:	MEB 2274, Friday 4:00-5:00PM
GE requirement:	no

Course Objectives
1. *Students will learn to use an electromagnetic simulation software package,* CST Studio Suite.

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 most disciplines of electrical engineering.

2. *Students will gain an understanding of metamaterial and advanced antenna concepts by exploring archetypical, computational, problems relevant to current research.*

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.

Catalog Course Description
This course will include topics relevant to antenna design and current research in metamaterials. Students will complete projects based on these topics. 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).

Required Texts
None

Teaching and Learning Methods
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. There will be five projects assigned, all of which will have simulation components. Students will learn the metamaterial and antenna concepts as they simultaneously explore the capabilities of the software. Deeper understanding will come from the required post-simulation analysis, answering of project questions, and written presentation of results.

Pre-requisites
The prerequisite for this course is ECE3300 or equivalent course that gives a fairly thorough introduction to electromagnetics and Maxwell's Equations (such as PHYS 3220 or 4420). Antenna Theory and Design (ECE 5324) is recommended, but not necessary to complete the projects.

Grading Policy (Evaluation Methods & Criteria)
Grades will be based exclusively on the five projects, with each submitted report accounting for an approximately equal portion of the grade. 6350 students will be graded on all five project reports. 5350 students will be graded on four projects (they will be graded on the their four highest scored project reports or may omit one report at their discretion). The project reports will be due approximately every three weeks. There will be no exams. Correct and complete fulfillment of all project reports will result in an excellent grade. Within reason, late reports will be accepted and given substantial credit. Reasonable attendance is expected but not graded.

Potential Metamaterial Projects

Material property extraction
Perform S-parameter simulations on a known material, 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 from the S-parameters. Compare with Maxwell-Garnett theory which includes only the volume fraction and component material properties.

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.

Advanced extraction and effective medium theory.
Consider branch selection failure, Kramers–Kronig theory and spatial dispersion in characterizing a metamaterial. Use CST scripting in Visual Basic to write a structure macro (for creating a more complex unit cell) and an analysis script for a more sophisticated effective medium extraction.

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

Metamaterial apertures
Design and simulate a metamaterial modulated aperture, such as those used in satellite communications (http://www.kymetacorp.com) or microwave security imaging (http://evolvtechnology.com).

Potential 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.

Tentative Schedule

Project 1	August 20 - September 5
Project 2	September 10 - September 26
Project 3	October 1 - October 24
Project 4	October 29 - November 14
Project 5	November 19 - December 5

Academic Integrity
Students may work together on projects, 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 (http://www.regulations.utah.edu/academics/6-400.html).

Americans with Disabilities Act (ADA) Statement
The Americans with Disabilities Act. 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 this class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Olpin Union Building, (801) 581-‐5020. CDS will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in an alternative format with prior notification to the Center for Disability Services. (http://disability.utah.edu)

Addressing Sexual Misconduct
Title IX makes it clear that violence and harassment based on sex and gender (which Includes sexual orientation and gender identity/expression) is a civil rights offense subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, color, religion, age, status as a person with a disability, veteran's status or genetic information. If you or someone you know has been harassed or assaulted, you are encouraged to report it to the Title IX Coordinator in the Office of Equal Opportunity and
Affirmative Action, 135 Park Building, 801-581-8365, or the Office of the Dean of Students, 270 Union Building, 801‐581‐7066. For support and confidential consultation, contact the Center for Student Wellness, SSB 328, 801-581-7776. To report to the police, contact the Department of Public Safety, 801‐585‐2677(COPS).

Wellness Statement
Personal concerns such as stress, anxiety, relationship difficulties, depression, cross-cultural differences, etc., can interfere with a student's ability to succeed and thrive at the University of Utah. For helpful resources contact the Center for Student Wellness -(https://wellness.utah.edu)

Campus Safety
The University of Utah values the safety of all campus community members. To report suspicious activity, call campus police at 801-585-COPS (801-585-2677). You will receive important emergency alerts and safety messages regarding campus safety via text message. For more information regarding safety and to view available training resources, including helpful videos, visit safeu.utah.edu.