Course guides
230626 - NMEE - Numerical Methods for Electromagnetic Engineering

Last modified: 29/04/2020

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications.

Degree: MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Optional subject).
MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019). (Optional subject).

Academic year: 2020 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: JUAN-MANUEL RIUS CASALS

Others: ALEXANDER HELDRING - EDUARDO UBEDA FARRE - JOSE MARIA GONZALEZ ARBESU

PRIOR SKILLS

Algebra, differential and integral calculus and vector analysis. Electromagnetic fields and waves. Antennas.

REQUIREMENTS

None.

TEACHING METHODOLOGY

Teaching is based on lectures by teachers. Slides and computer simulation software may be used by the teachers to clarify concepts. Students may be asked to solve problems and to write simple programs in MATLAB language.

LEARNING OBJECTIVES OF THE SUBJECT

Background in advanced electromagnetics, from an engineering point of view. Understanding of electromagnetic radiation and diffraction, and ability to compute radiated and diffracted fields. Understanding of modern numerical methods for computer simulation. Ability to write simple computer programs for numerical simulation.

STUDY LOAD

Type	Hours	Percentage
Self study	86,0	68.80
Hours large group	39,0	31.20

Total learning time: 125 h

CONTENTS

1- Fundamentals

Description:
Vector calculus (review)
Maxwell's equations and boundary conditions (review)
Electrical properties of material media
Conservation of energy
Time harmonic fields (review)
Wave equation and its solutions (review)
Potentials, construction of solutions
Induced and radiated fields

Full-or-part-time: 6h
Theory classes: 6h

2- Electromagnetic theorems and principles

Description:
Fundamental theorems and concepts
Electric and Magnetic Field Integral equations (EFIE and MFIE)

Full-or-part-time: 6h
Theory classes: 6h

3- Numerical methods in Electromagnetics

Description:
Overview of numerical methods for solution of the wave equation
Integral equation methods (overview)
The Method of Moments (or weighted residuals method)
Nyström method
Linear system solution, iterative solvers and preconditioning
Acceleration techniques (Fast Solvers)
Finite differences methods and sparse matrices
Finite element methods (FEM) (overview)
Finite differences in time domain (FDTD) (overview)

Related activities:
Practical project 1: Method of moments in electrostatics: Design a 3D "quadrupole ion trap" using method of moments discretization of electrostatics integral equation and Adaptive Cross Approximation fast solver.

Practical project 2: Method of moments for wire antennas: Model a straight wire antenna with the thin-wire approximation. Discretize the integral equation with method of moments. Computation of resonant frequencies for a monopole antenna. In order to validate the software developed in this project, students will do network analyzer measurements in the laboratory.

Practical project 3: Method of moments in electrodynamics: Implement the Electric Filed Integral Equation (EFIE) in 2D for scatterers with cylindrical symmetry.

Practical project 4: Optimization. Develop cost functions and penalty criteria to optimize a Yagi-Uda antenna design to agree with antenna parameters specification. Compare the performance of local optimization methods with global ones (like Genetic Algoritthms, Particle Swarm
Optimization or Ant Colony Optimization.

Full-or-part-time: 18h
Theory classes: 18h

4- Radar Cross Section, scattering and high-frequency techniques

Description:
Radar Cross Section
Analytic solutions for canonical geometries
Diffraction of 2D TM and TE waves
High frequency diffraction phenomena
High frequency methods (from "Antenas", Cardama et al.)

Full-or-part-time: 6h
Theory classes: 6h

5- Efficient programming tips

Description:
Code profiling
Strategies for speed
Parallelization
Tunning the code
Efficient programming in MATLAB
Efficient use of memory
Examples

Full-or-part-time: 3h
Theory classes: 3h

GRADING SYSTEM

Students will solve a problem (or a few short exercises) at the end of each chapter (20%). Practical projects will also contribute to final course mark (40%). There will be a final examination (40%).
Final Mark = 0.4*(Final exam) + 0.4*(Practical projects) + 0.2*(Problems)

BIBLIOGRAPHY

Basic:
- Balanis, C.A. Advanced Engineering Electromagnetics. 2nd. John Wiley & Sons, 2012. ISBN 9780470589489.
- Griffiths, D.J. Introduction to electrodynamics. 4th. Wesley, 2012. ISBN 9780321856562.
- Cardama, Á. [et al.]. Antenas [on line]. 2a ed. Barcelona: Edicions UPC, 2002 [Consultation: 09/02/2015]. Available on: http://hdl.handle.net/2099.3/36797. ISBN 8483016257.