Course guide
230626 - NMEE - Numerical Methods for Electromagnetic Engineering

Last modified: 11/04/2025

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: 2025 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: JUAN-MANUEL RIUS CASALS

Others: Primer quadrimestre:
ALEXANDER HELDRING - 10
JUAN-MANUEL RIUS CASALS - 10
EDUARDO UBEDA FARRE - 10

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

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 Poisson integral equation.

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

Practical project 3: Fast Solvers for Integral Equations, Adaptive Cross Approximation (ACA): Implement the simplest Fast Solver (ACA) for efficient solution of the linear system that results from the discretization of integral equations.

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

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.