230626 - NMEE - Numerical Methods for Electromagnetic Engineering

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications
Academic year: 2020
Degree: MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019). (Teaching unit Optional)
MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Teaching unit Optional)
ECTS credits: 5
Teaching languages: English

Teaching staff
Coordinator: JUAN-MANUEL RIUS CASALS
Others: ALEXANDER HELDRING - EDUARDO UBEDA FARRE - JOSE MARIA GONZALEZ ARBESU

Prior skills

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

<table>
<thead>
<tr>
<th>Study load</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total learning time: 125h</td>
<td>39h</td>
<td>31.20%</td>
</tr>
<tr>
<td>Hours large group:</td>
<td>86h</td>
<td>68.80%</td>
</tr>
<tr>
<td>Self study:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Universitat Politècnica de Catalunya
### Content

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
</table>
| **1- Fundamentals** | **Learning time:** 6h  
Theory classes: 6h  
  - 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 |
| **2- Electromagnetic theorems and principles** | **Learning time:** 6h  
Theory classes: 6h  
  - Fundamental theorems and concepts  
  - Electric and Magnetic Field Integral equations (EFIE and MFIE) |
### 3- Numerical methods in Electromagnetics

**Learning time:** 18h  
**Theory classes:** 18h

**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 Field 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 Algorithms, Particle Swarm Optimization or Ant Colony Optimization).

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

**Learning time:** 6h  
**Theory classes:** 6h

**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.)
## 5- Efficient programming tips

<table>
<thead>
<tr>
<th>Learning time: 3h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 3h</td>
</tr>
</tbody>
</table>

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

### Qualification 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:**