ANX-PR/CL/001-01
LEARNING GUIDE

SUBJECT

93000929 - Computational Electromagnetics

DEGREE PROGRAMME

09AT - Master Universitario En Teoria De La Señal Y Comunicaciones

ACADEMIC YEAR & SEMESTER

2024/25 - Semester 2

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	93000929 - Computational Electromagnetics
No of credits	6 ECTS
Type	Optional
Academic year ot the programme	First year
Semester of tuition	Semester 2
Tuition period	February-June
Tuition languages	English
Degree programme	09AT - Master Universitario en Teoria de la Señal y Comunicaciones
Centre	09 - Escuela Tecnica Superior De Ingenieros De Telecomunicacion
Academic year	2024-25

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Belen Galocha Iraguen (Subject coordinator)	C-410	belen.galocha@upm.es	Sin horario. Appointment arranged by email
Miguel Angel Gonzalez De Aza	B-421	miguelangel.gonzalez@upm.es	Sin horario. Appointment arranged by email

Jesus Garcia Jimenez	B-418	jesus.garcia.jimenez@upm.es	Sin horario. Appointment arranged by email
Jorge Alfonso Ruiz Cruz	B-411	jorge.ruizcruz@upm.es	Sin horario. Appointment arranged by email
Juan Corcoles Ortega	B-415	juan.corcoles@upm.es	Sin horario. Appointment arranged by email

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

The subject - recommended (passed), are not defined.

3.2. Other recommended learning outcomes

- Discrete numerical analysis. (Análisis numérico discreto)

- Solid knowledge of numerical analysis. (Conocimientos sólidos de análisis numérico)

- Electromagnetic fields theory. (Teoría de campos electromagnéticos)

- Microwave engineering. (Ingeniería de microondas)

4. Skills and learning outcomes *

4.1. Skills to be learned

CB06 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CB08 - Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios

CB09 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo

CE01 - Analizar y aplicar técnicas para el diseño y desarrollo avanzado de equipos y sistemas, basándose en la teoría de la señal y las comunicaciones, en un entorno internacional

CE02 - Evaluar y sintetizar los resultados de un trabajo en equipo en proyectos relacionados con la teoría de la señal y las comunicaciones, en un entorno internacional.

CE03 - Valorar y contrastar la utilización de las diferentes técnicas disponibles para la resolución de problemas reales dentro del área de teoría de la señal y comunicaciones.

CT01 - Capacidad para comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa

CT03 - Capacidad para adoptar soluciones creativas que satisfagan adecuadamente las diferentes necesidades planteadas

CT04 - Capacidad para trabajar de forma efectiva como individuo, organizando y planificando su propio trabajo, de forma independiente o como miembro de un equipo

CT05 - Capacidad para gestionar la información, identificando las fuentes necesarias, los principales tipos de documentos técnicos y científicos, de una manera adecuada y eficiente

CT06 - Capacidad para emitir juicios sobre implicaciones económicas, administrativas, sociales, éticas y medioambientales ligadas a la aplicación de sus conocimientos

4.2. Learning outcomes

RA37 - The capacity to choose the most suitable methods and tools for each problem electromagnetic problem and use it solve the given problem

RA35 - Understanding the need of computational electromagnetics

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

Course Description

This course presents most of the commonly computational techniques used to solve electromagnetic problems in microwave engineering. These techniques are commonly used to a precise characterization of structures involved in the design and development of devices and antennas. These methods are presented to know their features, advantages and limitations and how or where can be used, as well as their performances against the others.

Course Goal

To reach the understanding of the need of computational electromagnetic in the design of advanced microwave devices, the features of the most common used methods, the ability of developing own codes for these designs and using properly the available tools.

Summary of intended course outcomes

At the conclusion of the course, students should be able to understand the concepts and models used in Computational Electromagnetics and also will be able to apply these to advanced engineering problems, choosing the most suitable method for them, and having the capacity of developing their own methods when required or using the available commercial tools.

By the end of the course the students will reach the abilities of:

1. Understanding the need of computational electromagnetics.
2. Knowing the most common computational techniques and methods used to analyse the microwave circuits and antennas.
3. Knowing the basis of these methods and, as consequence, the advantages and drawbacks of each of them.
4. As results of the previous, they will have the capacity to choose the most suitable methods and tools for each problem.
5. Knowing some of the commercial available tools based of these method, the capacity of choosing the most convenient tool and the basic knowledge of their use.

5.2. Syllabus

1. Introduction
   1.1. Purpose and scope of application
2. Finite differences in the time domain
   2.1. Introduction. Basic concepts. Scope
   2.2. The one dimensional scalar wave equation. Numerical stability. Numerical Dispersion
   2.3. Maxwell equations in FDTD. Numerical stability. Numerical Dispersion
   2.4. Incident Wave Source Conditions
   2.5. Analytical Absorbing Boundary Conditions (ABC) and Perfectly Matched Layer (PML)
3. The finite element method
   3.1. Domain discretization
   3.2. Hybrid numerical-analytical methods
   3.3. Application of finite element method to microwave filter design
   3.4. Application of finite element method to antennas and arrays
4. The method of moments
   4.1. Wire Antennas Introduction to NEC. Examples

4.2. Introduction to NEC. Examples

5. The mode-matching technique

5.1. Description of the method. Relative convergence

5.2. Some examples: H-plane step in rectangular waveguide. E-plane and double-plane step in rectangular waveguide. Multiple discontinuity characterization

5.3. Some examples in device analysis

6. Physical optics and the geometrical and uniform theory of diffraction

6.1. Basic concepts for GO. Ray tracing. GTD definition. Canonical solutions of GTD over conductors. UTD

6.2. PO definition. Spectral analysis. PO projected on apertures. PTD definition

6.3. Example of ray tracing solutions: Reflectors. Introduction to Ticra GRASP. Application examples

6. Schedule

6.1. Subject schedule*

Week	Type 1 activities	Type 2 activities	Distant / On-line	Assessment activities
1	**T 1. Introduction. The need of electromagnetic modeling. Purpose and scope of application.** Duration: 02:00 Lecture **T2. Finite differences in the time domain. Introduction. Basic concepts. Scope.** Duration: 02:00 Lecture			
2	**T2. Finite differences in the time domain. The one dimensional scalar wave equation** Duration: 02:00 Lecture **T2. Finite differences in the time domain. Maxwell's Equations Time Domain. Yee paper. Numerical stability. Numerical Dispersion.** Duration: 02:00 Lecture			
3	**T2. Finite differences in the time domain. Incident Wave Source Conditions. Absorbing Boundary Conditions. Introduction to CST studio.** Duration: 02:00 Lecture **T2. Finite differences in the time domain. Application examples** Duration: 02:00 Problem-solving class			
4	**T3. The finite element method. Introducction.Domain discretization** Duration: 02:00 Lecture **T3. The finite element method. Several electromagnetic formulations.** Duration: 02:00 Lecture			
5	**T3. The finite element method. Hybrid numerical-analytical methods.** Duration: 02:00 Lecture **T3. Aplication of finite element method to microwave filter design.** Duration: 02:00			

	Lecture			
6	**T3. Aplication of finite element method to antennas and arrays.** Duration: 02:00 Problem-solving class **T3. Practical design of a microwave filter by means of the finite element method.** Duration: 02:00 Problem-solving class			
7	**T3.Practical design of an antenna/array by means of the finite element method.** Duration: 02:00 Problem-solving class **T4. The method of moments. Wire Antennas** Duration: 02:00 Lecture			
8	**T4. The method of moments. Introduction to NEC. Examples.** Duration: 02:00 Problem-solving class **T4. The method of moments. Planar antennas.** Duration: 02:00 Problem-solving class			
9	**T4. The method of moments. Introduction to Ansoft Ensemble. Application examples.** Duration: 02:00 Problem-solving class **T5. The mode-matching technique. Description of the method. Relative convergence.** Duration: 02:00 Lecture			
10	**T5. The mode-matching technique . Description of the method. Relative convergence. Some examples: H-plane step in rectangular waveguide. E-plane and double-plane step in rectangular waveguide. Multiple discontinuity characterization.** Duration: 02:00 Lecture **T5. The mode-matching technique. Multiple discontinuity characterization. Cont.** Duration: 02:00 Lecture			
11	**T5. The mode-matching technique. Some examples in device analysis. Introduction to Wapos. Application examples.** Duration: 02:00 Problem-solving class **T6. Physical optics and the geometrical and uniform theory of diffraction. Basic**			

	concepts for GO. Duration: 02:00 Lecture			
12	**T6. Physical optics and the geometrical and uniform theory of diffraction. Ray tracing. GTD definition. Canonical solutions of GTD over conductors. UTD.** Duration: 02:00 Lecture **T6. Physical optics and the geometrical and uniform theory of diffraction. PO definition. Spectral analysis. PO projected on apertures. PTD definition.** Duration: 02:00 Lecture			
13	**T6. Physical optics and the geometrical and uniform theory of diffraction. Example of ray tracing solutions: Reflectors. Introduction to Ticra GRASP. Application examples.** Duration: 04:00 Problem-solving class			
14	**T6. Physical optics and the geometrical and uniform theory of diffraction. Introduction to Ticra GRASP. Application examples.** Duration: 02:00 Problem-solving class **Analysis and design work assignment . Presentation of the performed work and the obtained results.Evaluación progresiva. Actividad Presencial** Duration: 02:00 Additional activities			**Analysis and design work assignment . Presentation of the performed work and the obtained results.** Individual work Progressive assessment Presential Duration: 02:00
15				
16				**Final exam. (Progressive assessment)** Written test Progressive assessment Presential Duration: 03:00
17				**Final exam. (Global assesment)** Written test Global examination Presential Duration: 03:00 **Analysis and design work assignment . Presentation of the performed work and the obtained results.** Individual presentation Global examination Presential Duration: 02:00

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
14	Analysis and design work assignment . Presentation of the performed work and the obtained results.	Individual work	Face-to-face	02:00	40%	2 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03
16	Final exam. (Progressive assessment)	Written test	Face-to-face	03:00	60%	2 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Final exam. (Global assesment)	Written test	Face-to-face	03:00	60%	2 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05

							CT06 CE01 CE02 CE03
17	Analysis and design work assignment . Presentation of the performed work and the obtained results.	Individual presentation	Face-to-face	02:00	40%	2 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Final Exam. (Global assessment)	Written test	Face-to-face	03:00	60%	2 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03

Analysis and design work assignment . Presentation of the performed work and the obtained results.	Individual presentation	Face-to-face	02:00	40%	2 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE02 CE03

7.2. Assessment criteria

Students will be qualified by default through the same procedure: progressive evaluation, composed by the 40% of student workshops (homework), which will be explained in a presentation, and by 60% of an exam covering the most important topics of the subject.
To be accepted to the progressive evaluation the students must to attend at least to the 75% of the lectures. Students who do not meet this requirement will be qualified according to global evaluation .

Evaluation will assess if students have acquired all the competences of the subject. Thus, any evaluation will be carried out considering all the evaluation techniques used usually in progressive evaluation (EX, ET,TG, etc.).

The evaluation of those students on non-progressive assessment (global evaluation) will be composed by the 40% of student workshops (homework), which will be explained in a presentation, and by 60% of an exam covering the most important topics.

The evaluation on referred (re-sit) examination will be composed by the 40% of student workshops (homework), which will be explained in a presentation, and by 60% of an exam covering the most important topics.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Support Web Page	Web resource	A support web page will be available to provide relevant additional information to students.
David. B Davidson, "Computational Electromagnetics for RF and Microwave Engineering", Cambridge University Press, 2005.	Bibliography	Generic reference. It covers FDTD and MoM and FEM
Allen Taflove, "Computational Electrodynamics: The Finite-Difference Time-Domain Method", Artech House, 2005.	Bibliography	Reference for FDTD.
Roger F. Harrington, "Field Computation by Moment Methods", I.E.E.E.Press,1993	Bibliography	Reference for the Method of Moments.
Rebollar, Page de la Vega, Encinar, Camacho, Esteban, "Temas Avanzados en teoría electromagnética", Servicio de Publicaciones ETSI de Telecomunicación, 1992.	Bibliography	For Mode Matching.
Jianming Jin, "The Finite Element Method in Electromagnetics", John Wiley & Sons, Inc. 2002	Bibliography	It covers finite elements.
McNamara, Pistorius, Malherbe, "Introduction to the Uniform Geometrical Theory of Diffraction", Artech House, 1990.	Bibliography	It covers GO, PO, GTD, UTD.

Pyotr Ya. Ufimtsev, "Fundamentals of the Physical Theory of Diffraction". John Wiley & Sons	Bibliography	It covers GTD-UTD
Walton C. Gibson - The Method of Moments in Electromagnetics, CRC Press , 28 nov. 2007 - 288 páginas	Bibliography	Reference for the Method of Moments
C. Balanis. "Advanced Engineering Electromagnetics". john Wiley & Sons. 1989	Bibliography	Reference for GTD, UTD and PO