



POLITÉCNICA

INTERNATIONAL
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COORDINATION PROCESS OF
LEARNING ACTIVITIES
PR/CL/001



E.T.S. de Ingenieros de
Telecomunicacion

ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93000923 - Advanced Topics On Antenna Technologies

DEGREE PROGRAMME

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

ACADEMIC YEAR & SEMESTER

2022/23 - Semester 1

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1. Description

1.1. Subject details

Name of the subject	93000923 - Advanced Topics On Antenna Technologies
No of credits	6 ECTS
Type	Optional
Academic year of the programme	First year
Semester of tuition	Semester 1
Tuition period	September-January
Tuition languages	English
Degree programme	09AT - Master Universitario en Teoría de la Señal y Comunicaciones
Centre	09 - Escuela Técnica Superior De Ingenieros De Telecomunicacion
Academic year	2022-23

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Adrian Tamayo Dominguez	C-418	a.tamayo@upm.es	Sin horario. Appointment arranged by email
Francisco Eduardo Carrasco Yopez	B-417	eduardo.carrasco@upm.es	Sin horario. Appointment arranged by email

Jose Antonio Encinar Garcinuño	B-414	jose.encinar@upm.es	Sin horario. Appointment arranged by email
Jose Manuel Fernandez Gonzalez (Subject coordinator)	C-416	josemanuel.fernandez.gonza lez@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

- It is recommended to know Matlab programming
- It is recommended to have a strong knowledge in basic concept about antennas, radiated fields, electromagnetic waves and basic antenna parameters

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.

CETFM - Capacidad de realizar un trabajo o proyecto integrando y relacionando las competencias adquiridas en las distintas asignaturas del máster, junto con la capacidad de defenderlo en público ante un grupo de personas expertas en el tema del trabajo

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

RA22 - Knowing conduct a technical presentation before an audience of peers, describing the work and results clearly and well structured, on time, and using precise language

RA25 - Handle with ease the bases of linear algebra and calculus necessary to formulate problems optimization.

RA24 - Knowledge of advanced techniques used in the Radio Access Technologies

RA9 - To evaluate and to implement RF systems and equipments.

RA28 - Know and evaluate the different types of antennas according to their specifications

RA23 - Knowing the antenna measurement systems and their limitations

RA27 - Ability to design antenna arrays (arrays)

RA30 - Ability antenna design for communications and radar systems

RA26 - Ability of oral and written communication

RA31 - To carry out novel designs and applications in the field of MIMO antennas and systems

RA29 - Knowing the mathematical algorithms of adaptive antenna systems

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

This course presents advanced concepts and techniques in antenna topics. The students will acquire the required knowledge for the analysis and design of antennas using in-house software and commercial software. These techniques cover either theoretical and practical design aspects. With this goal, the students obtain the knowledge needed to perform antenna analysis and design in the most recent antenna technology and using commercial and self-made software. The course learning method is based on the main parts of the antenna design topics based on student work and Project Based Learning methodology with the support of the professors.

All the course classes are referred to practical antenna systems. Several antenna design and optimization methods are presented in the classroom. The students will use the software packages at the Signals, Systems and Radiocommunications Department of The E.T.S.I. Telecomunicación to perform practical analysis either by the professors and for practical students projects. The students will understand the concepts of the antenna analysis and design. The students will be able to afford all the stages of the antenna design (Antenna Project). The students oral presentations of the Antenna Project allow professors and the rest of the students to learn and evaluate analysis and design projects.

5.2. Syllabus

1. Printed antennas
 - 1.1. Overview of printed antennas
 - 1.2. Wideband and multiband antennas
 - 1.3. Example: Practical design of printed antennas
2. Aperture antennas
 - 2.1. Overview of advanced horn antennas
 - 2.2. Overview of reflector antennas
 - 2.3. Example: Practical design of aperture antennas
3. Reflectarray and Transmitarray antennas
 - 3.1. Overview of reflectarray and transmitarray antennas
 - 3.2. Analysis and design of transmitarray antennas
 - 3.3. Analysis and design of reflectarray cells and reflectarray antennas

- 3.4. Techniques for bandwidth improvement
- 3.5. Contoured-beam reflectarrays
- 3.6. Dual-reflector configurations
- 3.7. Applications: Automotive radar, base station antennas, sub-mm waves, space antennas
- 3.8. Terahertz reflectarrays
- 3.9. New capabilities: filtering and non-reciprocal response
- 3.10. Reconfigurable and beam-scanning reflectarrays
- 3.11. Example: Practical design of reflectarray antennas
- 4. Planar array antennas
 - 4.1. Overview of planar array antennas
 - 4.2. Phased array antennas
 - 4.3. Example: Practical design of planar array antennas
- 5. Antenna measurement techniques
 - 5.1. Overview of antenna measurement systems
 - 5.2. Far-field and Near-field measurement techniques
 - 5.3. Source reconstruction and post-processing techniques
 - 5.4. Laboratory with Matlab

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	<p>Presentation and objectives of the course and Antenna project topics proposal Duration: 01:00 Additional activities</p> <p>Topic 1: Printed antennas, overview of printed antennas Duration: 01:00 Lecture</p>	<p>Introduction and getting started with electromagnetic software Duration: 02:00 Laboratory assignments</p>		
2	<p>Topic 1: Printed antennas, overview of printed antennas Duration: 02:00 Lecture</p>	<p>Introduction and getting started with electromagnetic software Duration: 02:00 Laboratory assignments</p>		
3	<p>Topic 1: Printed antennas, wideband and multiband antennas Duration: 02:00 Lecture</p>	<p>Example: Practical design of printed antenna Duration: 02:00 Laboratory assignments</p>		<p>Delivery at the end of the laboratory of a short report+files of printed antenna design Individual work Continuous assessment and final examination Presential Duration: 00:00</p>
4	<p>Topic 2: Aperture antennas, overview of advanced horn antennas Duration: 02:00 Lecture</p>	<p>Example: Practical design of wideband or multiband antenna Duration: 02:00 Laboratory assignments</p>		<p>Delivery at the end of the laboratory of a short report+files of wideband or multiband antenna design Individual work Continuous assessment and final examination Presential Duration: 00:00</p>
5	<p>Topic 2: Aperture antennas, overview of reflector antennas Duration: 02:00 Lecture</p>	<p>Example: Practical design of horn antenna Duration: 02:00 Laboratory assignments</p>		<p>Meeting with tutors for 1^ophase intermediate antenna project presentation+report Group presentation Continuous assessment and final examination Presential Duration: 00:00</p> <p>Delivery at the end of the laboratory of a short report+files of horn antenna design Individual work Continuous assessment and final examination Presential Duration: 00:00</p>

6	<p>Topic 3: Reflectarray and Transmitarray antennas, overview of reflectarray and transmitarray antennas, techniques for bandwidth improvement</p> <p>Duration: 02:00 Lecture</p>	<p>Example: Practical design of reflector antenna</p> <p>Duration: 02:00 Laboratory assignments</p>		<p>Delivery at the end of the laboratory of a short report+files of reflector antenna design</p> <p>Individual work Continuous assessment and final examination Presential Duration: 00:00</p>
7	<p>Topic3: Reflectarray antennas, reconfigurable and beam scanning reflectarrays, Terahertz reflectarrays</p> <p>Duration: 02:00 Lecture</p>	<p>Intrduction to reflectarrays antenna design with MRADANT-UPM</p> <p>Duration: 02:00 Laboratory assignments</p>		
8	<p>Topic 4: Planar array antennas, overview of planar array antennas, phased array antennas</p> <p>Duration: 02:00 Lecture</p>	<p>Example: Practical design of reflectarray antennas</p> <p>Duration: 02:00 Laboratory assignments</p>		<p>Delivery at the end of the laboratory of a short report+files of reflectarray antenna design</p> <p>Individual work Continuous assessment and final examination Presential Duration: 00:00</p>
9	<p>1º and 2ºphase intermediate antenna project presentation+report</p> <p>Duration: 04:00 Additional activities</p>			<p>1º and 2ºphase intermediate antenna project presentation+report</p> <p>Group presentation Continuous assessment and final examination Presential Duration: 00:00</p>
10		<p>Example: Practical design of planar array antenna with Matlab</p> <p>Duration: 04:00 Laboratory assignments</p>		<p>Delivery at the end of the laboratory of a short report+files of planar array antenna with Matlab</p> <p>Individual work Continuous assessment and final examination Presential Duration: 00:00</p>
11		<p>Example: Practical design of planar array antenna with CST</p> <p>Duration: 04:00 Laboratory assignments</p>		<p>Delivery at the end of the laboratory of a short report+files of planar array antenna with CST</p> <p>Individual work Continuous assessment and final examination Presential Duration: 00:00</p>
12	<p>Topic 5: Antenna measurement techniques, overview of antenna measurement systems, Far-field and near-field measurement techniques</p> <p>Duration: 02:00 Lecture</p>	<p>Visit to anechoic chamber LEHA from ETSIT-UPM</p> <p>Duration: 02:00 Laboratory assignments</p>		
13	<p>Topic 5: Antenna measurement techniques, source reconstruction techniques and post-processing techniques</p> <p>Duration: 02:00 Lecture</p>	<p>Example: laboratory with Matlab</p> <p>Duration: 02:00 Laboratory assignments</p>		<p>Delivery at the end of the laboratory of a short report+files of measurement techniques</p> <p>Individual work Continuous assessment and final examination Presential Duration: 00:00</p>

14	<p>3^ophase final antenna project presentation+report Duration: 04:00 Additional activities</p>			<p>3^ophase final antenna project presentation+report Group presentation Continuous assessment and final examination Presential Duration: 00:00</p>
15				
16				
17				

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.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
3	Delivery at the end of the laboratory of a short report+files of printed antenna design	Individual work	Face-to-face	00:00	5%	0 / 10	CB09 CT01 CT03 CE02 CT04 CE01 CE03 CT05
4	Delivery at the end of the laboratory of a short report+files of wideband or multiband antenna design	Individual work	Face-to-face	00:00	5%	0 / 10	CT01 CB07 CT03 CT04 CE03 CT05
5	Meeting with tutors for 1 ^o phase intermediate antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CT01 CT03 CE02 CT04 CT05
5	Delivery at the end of the laboratory of a short report+files of horn antenna design	Individual work	Face-to-face	00:00	5%	0 / 10	CT01 CT03 CB06 CT04 CT05 CB10
6	Delivery at the end of the laboratory of a short report+files of reflector antenna design	Individual work	Face-to-face	00:00	5%	0 / 10	CB06 CT03 CT04 CT05
8	Delivery at the end of the laboratory of a short report+files of reflectarray antenna design	Individual work	Face-to-face	00:00	5%	0 / 10	CB07 CT03 CT04 CT06 CT05 CB10

9	1º and 2º phase intermediate antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CB09 CT01 CT03 CE02 CT04 CT06 CE03 CT05 CB10
10	Delivery at the end of the laboratory of a short report+files of planar array antenna with Matlab	Individual work	Face-to-face	00:00	5%	0 / 10	CB08 CT01 CT03 CB06 CE02 CT04 CT06 CE03 CT05 CB10
11	Delivery at the end of the laboratory of a short report+files of planar array antenna with CST	Individual work	Face-to-face	00:00	5%	0 / 10	
13	Delivery at the end of the laboratory of a short report+files of measurement techniques	Individual work	Face-to-face	00:00	5%	0 / 10	CB07 CT03 CB06 CT04 CE01 CT06 CT05 CB10
14	3º phase final antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CE02 CT04 CE01 CT06 CE03 CT05 CB10

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
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3	Delivery at the end of the laboratory of a short report+files of printed antenna design	Individual work	Face-to-face	00:00	5%	0 / 10	CB09 CT01 CT03 CE02 CT04 CE01 CE03 CT05
4	Delivery at the end of the laboratory of a short report+files of wideband or multiband antenna design	Individual work	Face-to-face	00:00	5%	0 / 10	CT01 CB07 CT03 CT04 CE03 CT05
5	Meeting with tutors for 1ºphase intermediate antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CT01 CT03 CE02 CT04 CT05
5	Delivery at the end of the laboratory of a short report+files of horn antenna design	Individual work	Face-to-face	00:00	5%	0 / 10	CT01 CT03 CB06 CT04 CT05 CB10
6	Delivery at the end of the laboratory of a short report+files of reflector antenna design	Individual work	Face-to-face	00:00	5%	0 / 10	CB06 CT03 CT04 CT05
8	Delivery at the end of the laboratory of a short report+files of reflectarray antenna design	Individual work	Face-to-face	00:00	5%	0 / 10	CB07 CT03 CT04 CT06 CT05 CB10
9	1º and 2ºphase intermediate antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CB09 CT01 CT03 CE02 CT04 CT06 CE03 CT05 CB10
10	Delivery at the end of the laboratory of a short report+files of planar array antenna with Matlab	Individual work	Face-to-face	00:00	5%	0 / 10	CB08 CT01 CT03 CB06 CE02 CT04 CT06 CE03 CT05

							CB10
11	Delivery at the end of the laboratory of a short report+files of planar array antenna with CST	Individual work	Face-to-face	00:00	5%	0 / 10	
13	Delivery at the end of the laboratory of a short report+files of measurement techniques	Individual work	Face-to-face	00:00	5%	0 / 10	CB07 CT03 CB06 CT04 CE01 CT06 CT05 CB10
14	3 ^o phase final antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CE02 CT04 CE01 CT06 CE03 CT05 CB10

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Individual antenna project presentation+report	Individual presentation	Face-to-face	01:00	60%	5 / 10	CB08 CT01 CB07 CT03 CB06 CT04 CT05 CB10

Delivery at the end of the laboratory of a short report+files of printed antenna design.	Individual work	Face-to-face	00:00	5%	0 / 10	CB07 CE02 CT04
Delivery at the end of the laboratory of a short report+files of wideband or multiband antenna design.	Individual work	Face-to-face	00:00	5%	0 / 10	CB07 CE02 CT04
Delivery at the end of the laboratory of a short report+files of horn antenna design.	Individual work	Face-to-face	00:00	5%	0 / 10	CE02 CT04 CB07
Delivery at the end of the laboratory of a short report+files of reflector antenna design.	Individual work	Face-to-face	00:00	5%	0 / 10	CB07 CE02 CT04
Delivery at the end of the laboratory of a short report+files of reflectarray antenna design.	Individual work	Face-to-face	00:00	5%	0 / 10	CB07 CE02 CT04
Delivery at the end of the laboratory of a short report+files of planar array antenna with Matlab	Individual work	Face-to-face	00:00	5%	0 / 10	CB07 CE02 CT04
Delivery at the end of the laboratory of a short report+files of planar array antenna with CST.	Individual work	Face-to-face	00:00	5%	0 / 10	CB07 CE02 CT04
Delivery at the end of the laboratory of a short report+files of measurement techniques.	Individual work	Face-to-face	00:00	5%	0 / 10	CE02 CT04 CB07

7.2. Assessment criteria

The evaluation will check if the students have acquired the competences of the subject. Therefore, the evaluation in the extraordinary call will use the same types of evaluation techniques that are used in the evaluation of the ordinary call (EX, ET, TG, etc.) and will be carried out on the dates and times of evaluation approved by the Junta de Escuela for the current PR subject and semester, except for those activities of evaluation of learning outcomes that are difficult to grade in a final test. In this case, such evaluation activities may be carried out throughout the subject. Evaluation will assess if students have acquired all the competences of the subject. Thus, evaluation through final assessment will be carried out considering all the evaluation techniques used in continuous evaluation (EX, ET, TG, etc.), and will be celebrated in the exam period approved by Junta de Escuela for the current academic semester and year. Evaluation activities that assess learning outcomes that cannot be evaluated through a single exam can be carried out along the semester.

Ordinary call - Progressive evaluation modality:

The progressive evaluation will consists of the following

- 40% Report+simulation files delivery at the end of each laboratory practices.
- 60% Antenna project: 20% Phase 1, 20% Phase 2, 20% Phase 3. The cross-evaluation among the team members is MANDATORY. The student who does not evaluate their classmates among the team members via Moodle will have a zero in the antenna project. The final grade for antenna project of members of the same team may be modified by the cross-evaluation process.

Ordinary call - Global evaluation method:

- 40% Report+files delivery at the end of each laboratory practices.
- 60% Individual antenna project presentation + report.

Extraordinary call:

- 40% Report+files delivery at the end of each laboratory practices.
- 60% Individual antenna project presentation + report.

Information about the Laboratory Practices:

- The skills acquired in the laboratory sessions in terms of handling antenna analysis and design tools cannot be acquired through any other type of methodology. For this reason, the completion of all the laboratory practices is a mandatory condition to pass the course. In other words, all the laboratory practices are mandatory activities.
- The completion of the laboratory sessions will be verified through the attendance to the laboratory and the delivery of the corresponding reports. In other words, it is essential to attend all the laboratory sessions and to hand in all the practical reports in order to pass the laboratory. Students who do not complete all the practical sessions will obtain a grade of NP (not presented) in the course.
- As they are mandatory activities, practices can only be carried out during the regular teaching period, in the laboratory and in the weeks scheduled in the practice calendar at the beginning of the course. It is not possible to do the laboratories telematically.
- Practices will not be recoverable due to the instrumentation necessary for the realization of the practices, the need for availability of laboratories, as well as the mandatory nature of the practices, among other logistical and academic reasons.
- The grade obtained in the laboratory practices will be used in the ordinary and extraordinary calls.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Design book	Bibliography	Antenna Theory: Analysis and Design, C. Balanis, John Wiley & Sons, 4th Edition, 2016.
Microstrip antenna book	Bibliography	Handbook of Microstrip Antennas, J.R. James, P.S. Hall, Peter Peregrinus Ltd, 1989.
Printed antenna book	Bibliography	Advances in Microstrip and Printed Antennas, K. Fong Lee, W. Chen, Wiley, 1997.
Horns book	Bibliography	Microwave Horns and Feeds, A.D. Oliver, P.J. Claricoats, A.A. Kishk, L. Shafai, IEE Electromagnetic Waves Series 39, 1994.
Reflectors book	Bibliography	Modern Antenna Design, T.A. Milligan, IEEE Press, John Wiley & Sons, 2005.
Reflectarray design book	Bibliography	Reflectarray Antennas, J. Huang and J.A. Encinar, IEEE Press, 2008.
Arrays book	Bibliography	Phased Array Antenna Handbook, R.A. Mailloux, Artech House, 2005.
Measurement systems	Equipment	Anechoic chamber LEHA from Universidad Politécnica de Madrid
CST Studio Suite	Others	Analysis and design of antenna software
Matlab	Others	Mathematical software
MOOC Videos on Antennas	Web resource	Massive Open Online Courses on Antennas available in the web (http://www.gr.ssr.upm.es/index.php/es/).

9. Other information

9.1. Other information about the subject

Students are recommended to download some software applications available in the UPM repository and in particular Matlab.

This subject can contribute to increase the awareness and training of our students in relation to the United Nations Agenda 2030 and its Sustainable Development Goals (SDGs). Some problems will show how various mathematical and electromagnetic tools are used in antenna modeling, which will allow students to become familiar with antennas for communications.

More generally, the applied concepts are used extensively in engineering and, in particular, will touch on everything related to telecommunication infrastructures (ODS 9). The course will also contribute to sub-objectives 4.4: To significantly increase the number of people with the professional and technical skills needed to access employment and entrepreneurship; and 4.7: To ensure that all students acquire the necessary theoretical and practical knowledge to promote sustainable development.