



POLITÉCNICA

INTERNATIONAL  
CAMPUS OF  
EXCELLENCE

COORDINATION PROCESS OF  
LEARNING ACTIVITIES  
PR/CL/001



E.T.S. de Ingenieros de  
Telecomunicación

# 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

2018/19 - Semester 1

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## 1. Description

### 1.1. Subject details

<b>Name of the subject</b>	93000923 - Advanced topics on antenna technologies
<b>No of credits</b>	6 ECTS
<b>Type</b>	Optional
<b>Academic year of the programme</b>	First year
<b>Semester of tuition</b>	Semester 1
<b>Tuition period</b>	September-January
<b>Tuition languages</b>	English
<b>Degree programme</b>	09AT - Master universitario en teoria de la señal y comunicaciones
<b>Centre</b>	09 - Escuela Tecnica Superior de Ingenieros de Telecomunicacion
<b>Academic year</b>	2018-19

## 2. Faculty

### 2.1. Faculty members with subject teaching role

<b>Name and surname</b>	<b>Office/Room</b>	<b>Email</b>	<b>Tutoring hours *</b>
Jose Manuel Fernandez Gonzalez (Subject coordinator)	C-416	josemanuel.fernandez.gonzalez@upm.es	Sin horario. Appointment arranged by email
Manuel Sierra Perez	C-418	manuel.sierra.perez@upm.es	Sin horario. Appointment arranged by email

Belen Galocha Iraguen	C-410	belen.galocha@upm.es	Sin horario. Appointment arranged by email
Manuel Sierra Castañer	C-410	manuel.sierra@upm.es	Sin horario. Appointment arranged by email
Jose Antonio Encinar Garcinuño	B-414	jose.encinar@upm.es	Sin horario. Appointment arranged by email
Francisco Eduardo Carrasco Yepez	B-417	eduardo.carrasco@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

El plan de estudios Master Universitario en Teoria de la Señal y Comunicaciones no tiene definidas asignaturas previas recomendadas para esta asignatura.

#### 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 \*

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### 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

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

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

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

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### 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. Reconfigurable and beam-scanning reflectarrays
- 3.9. Terahertz reflectarrays
- 3.10. Example: Practical design of reflectarray antennas
- 4. Planar array antennas
  - 4.1. Overview of planar array antennas
  - 4.2. Feeding networks
  - 4.3. Phased array antennas
  - 4.4. Example: Practical design of planar array antennas
- 5. Conformal array antennas
  - 5.1. Overview of conformal array antennas
  - 5.2. Example: Practical design of conformal array antennas
- 6. Antenna measurement techniques
  - 6.1. Overview of antenna measurement systems
  - 6.2. Far-field and Near-field measurement techniques
  - 6.3. Source reconstruction and post-processing techniques
  - 6.4. Laboratory with Matlab



## 6. Schedule

### 6.1. Subject schedule\*

Week	Face-to-face classroom activities	Face-to-face laboratory activities	Other face-to-face activities	Assessment activities
1	<p>Presentation and objectives of the course and Antenna project topics proposal Duration: 02:00 Additional activities</p> <p>Topic 1: Printed antennas, overview of printed antennas Duration: 02:00 Lecture</p>			<p>First team meeting+Delivery of a meeting report Group work Continuous assessment Duration: 00:00</p>
2		<p>Introduction and getting started with commercial software Duration: 02:00 Laboratory assignments</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 Duration: 00:00</p>
3	<p>Topic 1: Printed antennas, wideband and multiband antennas Duration: 02:00 Lecture</p>	<p>Example: Practical design of wideband or multiband antenna Duration: 02:00 Laboratory assignments</p>		<p>Second team meeting+delivery of a meeting report Group work Continuous assessment Duration: 00:00</p> <p>Delivery at the end of the laboratory of a short report+files of wideband or multiband antenna design Individual work Continuous assessment Duration: 00:00</p>
4	<p>1<sup>o</sup>phase intermediate antenna project Duration: 04:00 Additional activities</p>			<p>1<sup>o</sup>phase intermediate antenna project presentation+report Group presentation Continuous assessment Duration: 00:00</p>
5	<p>Topic 2: Aperture antennas, overview of advanced horn antennas Duration: 02:00 Lecture</p>	<p>Example: Practical design of horn antenna Duration: 02:00 Laboratory assignments</p>		<p>Delivery at the end of the laboratory of a short report+files of horn antenna design Individual work Continuous assessment Duration: 00:00</p>
6	<p>Topic 2: Aperture antennas, overview of reflector antennas Duration: 02:00 Lecture</p>	<p>Example: Practical design of reflector antenna Duration: 02:00 Laboratory assignments</p>		<p>Delivery at the end of the laboratory of a short report+files of reflector antenna design Individual work Continuous assessment Duration: 00:00</p>

7	<p><b>Topic 3: Reflectarray and Transmitarray antennas, overview of reflectarray and transmitarray antennas, techniques for bandwidth improvement</b></p> <p>Duration: 02:00 Lecture</p>	<p><b>Examples: Contoured-beam reflectarrays, dual-reflector configurations, applications: automotive radar, base station antennas, sub-mm waves, space antennas.</b></p> <p>Duration: 02:00 Laboratory assignments</p>		
8	<p><b>Topic3: Reflectarray antennas, reconfigurable and beam scanning reflectarrays, Terahertz reflectarrays</b></p> <p>Duration: 02:00 Lecture</p>	<p><b>Example: Practical design of reflectarray antennas</b></p> <p>Duration: 01:00 Laboratory assignments</p> <p><b>Example: Practical design of an electronically reconfigurable reflectarray cell</b></p> <p>Duration: 01:00 Laboratory assignments</p>		<p><b>Third team meeting+delivery of a meeting report</b></p> <p>Group work Continuous assessment Duration: 00:00</p> <p><b>Delivery at the end of the laboratory of a short report+files of reflectarray antenna design</b></p> <p>Individual work Continuous assessment Duration: 00:00</p>
9	<p><b>2ºphase intermediate antenna project presentation+report</b></p> <p>Duration: 04:00 Additional activities</p>			<p><b>2ºphase intermediate antenna project presentation+report</b></p> <p>Group presentation Continuous assessment Duration: 00:00</p>
10	<p><b>Topic 4: Planar array antennas, overview of planar array antennas, feeding networks, phased array antennas</b></p> <p>Duration: 02:00 Lecture</p>	<p><b>Example: Practical design of planar array antenna</b></p> <p>Duration: 02:00 Laboratory assignments</p>		<p><b>Delivery at the end of the laboratory of a short report+files of planar array antenna</b></p> <p>Individual work Continuous assessment Duration: 00:00</p>
11	<p><b>Topic 5: Conformal array antennas, overview of conformal array antennas</b></p> <p>Duration: 02:00 Lecture</p>	<p><b>Example: Practical design of conformal array antennas</b></p> <p>Duration: 02:00 Laboratory assignments</p>		<p><b>Delivery at the end of the laboratory of a short report+files of conformal array antenna</b></p> <p>Individual work Continuous assessment Duration: 00:00</p>
12	<p><b>Topic 6: Antenna measurement techniques, overview of antenna measurement systems, Far-field and near-field measurement techniques</b></p> <p>Duration: 03:00 Lecture</p>	<p><b>Visit to anechoic chamber LEHA from ETSIT-UPM</b></p> <p>Duration: 01:00 Laboratory assignments</p>		
13	<p><b>Topic 6: Antenna measurement techniques, source reconstruction techniques and post-processing techniques</b></p> <p>Duration: 02:00 Lecture</p>	<p><b>Example: laboratory with Matlab</b></p> <p>Duration: 02:00 Laboratory assignments</p>		<p><b>Delivery at the end of the laboratory of a short report+files of measurement techniques</b></p> <p>Individual work Continuous assessment Duration: 00:00</p> <p><b>Fourth team meeting+delivery of a meeting report</b></p> <p>Group work Continuous assessment Duration: 00:00</p>
14	<p><b>3ºphase final antenna project presentation+report</b></p> <p>Duration: 04:00 Additional activities</p>			<p><b>3ºphase final antenna project presentation+report</b></p> <p>Group presentation Continuous assessment Duration: 00:00</p>

15				
16				<p><b>Final exam for students with Non continuous assessment: theory and practical laboratory exam</b></p> <p>Written test Final examination Duration: 03:00</p> <p><b>Individual antenna project presentation+report for students with Non continuous assessment</b></p> <p>Individual presentation Final examination Duration: 01:00</p>

The independent study hours are training activities during which students should spend time on individual study or individual assignments.

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 subject schedule is based on a previous theoretical planning of the subject plan and might go through experience some unexpected changes along throughout the academic year.

## 7. Activities and assessment criteria

### 7.1. Assessment activities

#### 7.1.1. Continuous assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
1	First team meeting+Delivery of a meeting report	Group work	Face-to-face	00:00	2.5%	5 / 10	CT04 CE01 CE03 CB06 CB07 CB10 CT03 CT05
2	Delivery at the end of the laboratory of a short report+files of printed antenna design	Individual work	Face-to-face	00:00	5%	5 / 10	CE02 CB09 CT04 CE01 CE03 CT01 CT03 CT05
3	Second team meeting+delivery of a meeting report	Group work	Face-to-face	00:00	2.5%	5 / 10	CB09 CB07 CT03 CT05 CT04
3	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%	5 / 10	CT04 CE03 CB07 CT01 CT03 CT05
4	1ºphase intermediate antenna project presentation+report	Group presentation	Face-to-face	00:00	15%	5 / 10	CT04 CE02 CT01 CT03 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%	5 / 10	CT04 CB06 CB10 CT01 CT03 CT05

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%	5 / 10	CT04 CB06 CT03 CT05
8	Third team meeting+delivery of a meeting report	Group work	Face-to-face	00:00	2.5%	5 / 10	CT06 CE02 CE01 CB06 CT03 CT05 CT04
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%	5 / 10	CB07 CB10 CT03 CT04 CT06 CT05
9	2 <sup>o</sup> phase intermediate antenna project presentation+report	Group presentation	Face-to-face	00:00	15%	5 / 10	CT04 CT06 CE02 CB09 CE03 CB10 CT05 CT01 CT03
10	Delivery at the end of the laboratory of a short report+files of planar array antenna	Individual work	Face-to-face	00:00	5%	5 / 10	CT04 CT06 CE02 CE03 CB06 CB08 CB10 CT01 CT03 CT05
11	Delivery at the end of the laboratory of a short report+files of conformal array antenna	Individual work	Face-to-face	00:00	5%	5 / 10	CT04 CT06 CB09 CE03 CB06 CB07 CB10 CT03 CT05
13	Delivery at the end of the laboratory of a short report+files of measurement techniques	Individual work	Face-to-face	00:00	5%	5 / 10	CT04 CT06 CE01 CB06 CB07 CB10 CT03 CT05

13	Fourth team meeting+delivery of a meeting report	Group work	Face-to-face	00:00	2.5%	5 / 10	CT04 CT06 CE02 CB07 CB10 CT03 CT05
14	3 <sup>o</sup> phase final antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CT04 CT06 CE02 CB09 CE01 CE03 CB06 CB07 CB08 CB10 CT01 CT03 CT05

### 7.1.2. Final examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
16	Final exam for students with Non continuous assessment: theory and practical laboratory exam	Written test	Face-to-face	03:00	50%	5 / 10	CT04 CT06 CE02 CB09 CE01 CE03 CB06 CB07 CB08 CT03 CT05
16	Individual antenna project presentation+report for students with Non continuous assessment	Individual presentation	Face-to-face	01:00	50%	5 / 10	CT04 CT06 CE02 CB09 CE03 CB06 CB07 CB10 CT01 CT03 CT05

### 7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Final exam: theory and practical laboratory exam	Written test	Face-to-face	03:00	50%	5 / 10	CT04 CT06 CB09 CE03 CB06 CB10
Individual antenna project presentation+report	Individual presentation	Face-to-face	01:00	50%	5 / 10	CT04 CB06 CB07 CB08 CB10 CT01 CT03 CT05

### 7.2. Assessment criteria

Students will be qualified through continuous evaluation by default. According to the Normativa de Evaluación del Aprendizaje de la Universidad Politécnica de Madrid, students willing to renounce to continuous evaluation must complete the Moodle task entitled "Renounce to continuous evaluation" before week 4 of the course (deadline will be announced in Moodle).

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.

Extraordinary examination will be carried out exclusively by the final assessment method.

Continuous evaluation:

- 40% Report+files delivery at the end of each design laboratory.

- 50% Antenna project: 15% phase 1, 15% phase 2, 20% phase 3.
- 10% team meeting reports + cross evaluation.

Final assessment and extraordinary examination:

- 50% Final exam: theory and practical laboratory.
- 50% Individual antenna project presentation+report.

## 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 Microwave Studio	Others	Analysis and design of antenna software
Matlab	Others	Mathematical software

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