ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

593000604 - Antenna Technology

DEGREE PROGRAMME

59AI - Master Universitario En Comunicaciones Inalámbricas

ACADEMIC YEAR & SEMESTER

2024/25 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	593000604 - Antenna Technology
No of credits	4.5 ECTS
Type	Compulsory
Academic year ot the programme	First year
Semester of tuition	Semester 1
Tuition period	September-January
Tuition languages	English
Degree programme	59AI - Master Universitario en Comunicaciones Inalámbricas
Centre	59 - Escuela Tecnica Superior De Ingenieria Y Sistemas De Telecomunicacion
Academic year	2024-25

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Angel Martinez Jimenez	A7010	angel.martinez.jimenez@upm.es	Sin horario. See Moodle page
Alejandro Garcia Lamperez (Subject coordinator)	A7010	alejandro.garcia.lamperez@upm.es	Sin horario. See Moodle page

* 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

- Mathematics (grad level algebra and calculus, complex variable)

- Physics and Electromagnetics (basic)

- Circuits and Electronics (basic)

4. Skills and learning outcomes *

4.1. Skills to be learned

CB6 - 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

CB7 - 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

CB8 - 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

CEM01 - Adquirir la destreza para utilizar y analizar los tipos de antenas mÃ¡s empleados en los sistemas de comunicaciones inalÃ¡mbricos.

CGI02 - Comprender el procedimiento, valor y límites del método científico, siendo capaz de identificar, localizar y obtener datos requeridos en un trabajo de investigación, de diseñar y guiar investigaciones analíticas, de modelado y experimentales, así como de evaluar datos de una manera crítica y extraer conclusiones.

CGI03 - Valorar la importancia de las fuentes documentales, manejarlas y buscar la información para el desarrollo de cualquier trabajo de investigación.

CGI04 - Leer y comprender publicaciones dentro de su ámbito de estudio/investigación, así como su catalogación y valor científico.

UPM1 - Uso de la lengua inglesa

UPM4 - OrganizaciÃ³n y planificaciÃ³n /

4.2. Learning outcomes

RA28 - Understand the effect of the antenna performance in the full communications system

RA26 - Design an antenna, given some specifications

RA27 - Evaluate the performance of an antenna of system of antennas

RA13 - Acquire advanced or specialised knowledge on any of the master's subjects

RA29 - Understand the importance of systems with multple antennas in modern high performance communication systems

RA18 - RA03.- Choose the mathematical methods and tools necessary to tackle a problem and finds the solution.

RA25 - Interpret data derived from empirical observations and measurements in terms of their importance and relate them to the appropriate theory.

* 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 is part of the wireless fundamentals block of the Master on Wireless Communications, that provides a general perspective about its basic technologies. In this case, the antennas are studied, as the essential elements that are present in any wireless system. The course is especially centered on antenna designs and technologies required for modern, high performance wireless systems, like multiple-antenna blocks.

The structure of the course begins with a review of the basic parameters and specifications that define the performance of an antenna both in transmission and reception. After this, several types of classical and planar, compact antennas will be described. Then, some techniques based on multiple antennas and diversity, with big impact in the system performance, will be studied (arrays, MIMO systems, spatial multiplexing). Finally, the emergent field of millimeter-wave applications and the required antennas will be addressed.

The course will include master classes, and also the student's supervised work in the form of the design and simulation of some practical cases of antennas and systems of antennas, in the context of wireless communication systems.

5.2. Syllabus

1. Introduction
   - 1.1. Electromagnetic laws and equations
   - 1.2. Transmission line basics
   - 1.3. Antenna parameters
2. Classic antennas for mobile communications
   - 2.1. Wire antennas
   - 2.2. Aperture antennas
3. Patch antennas for wireless communications
   - 3.1. Microstrip patch antennas
   - 3.2. Stacked patch antennas

3.3. Wearable antennas for communications

4. Antenna arrays and beam-forming techniques

4.1. Linear, planar, and volumetric arrays

4.2. Direction finding

4.3. Beamforming

4.4. Wideband beamforming

4.5. Adaptative beamforming

5. Multiple antenna systems (MIMO)

5.1. Introduction to MIMO

5.2. Time, frequency, and spatial diversity

5.3. Capacity in MIMO systems

5.4. Space-time coding

6. Spatial multiplexing (SDMA)

6.1. Layered space-time receiving structures: BLAST

6.2. Open-loop and closed-loop techniques

6.3. Space-time receivers

6.4. Spatial precoding

6.5. Massive MIMO beamforming, spatial multiplexing, and diversity

7. Antenna types for mm-wave applications

7.1. On-chip antennas

7.2. In-Package antennas

7.3. Antenna topologies

7.4. Adaptive antenna arrays

6. Schedule

6.1. Subject schedule*

Week	Type 1 activities	Type 2 activities	Distant / On-line	Assessment activities
1	**Unit 1: Introduction** Duration: 06:00 Lecture			**Online quiz** Online test Progressive assessment and Global Examination Not Presential Duration: 01:00
2	**Unit 2: Classic antennas for mobile communications** Duration: 04:00 Lecture	**Practical exercise** Duration: 02:00 Laboratory assignments		**Online quiz** Online test Progressive assessment and Global Examination Not Presential Duration: 01:00
3	**Unit 3: Patch antennas for wireless communications** Duration: 04:00 Lecture	**Practical exercise** Duration: 02:00 Laboratory assignments		**Online quiz** Online test Progressive assessment and Global Examination Not Presential Duration: 01:00
4	**Unit 4: Antenna arrays and beam-forming techniques** Duration: 04:00 Lecture	**Practical exercise** Duration: 02:00 Laboratory assignments		**Online quiz** Online test Progressive assessment and Global Examination Not Presential Duration: 01:00
5	**Unit 5: Multiple antenna systems (MIMO)** Duration: 04:00 Lecture	**Practical exercise** Duration: 02:00 Laboratory assignments		**Online quiz** Online test Progressive assessment and Global Examination Not Presential Duration: 01:00
6	**Unit 6: Spatial multiplexing (SDMA)** Duration: 04:00 Lecture	**Practical exercise** Duration: 02:00 Laboratory assignments		**Online quiz** Online test Progressive assessment and Global Examination Not Presential Duration: 01:00
7	**Unit 7: Antenna types for mm-wave applications** Duration: 04:00 Lecture	**Practical exercise** Duration: 01:00 Laboratory assignments		**Practical exercise (design and simulation)** Individual work Progressive assessment and Global Examination Not Presential Duration: 00:00 **Online quiz** Online test Progressive assessment and Global Examination Not Presential Duration: 01:00

				Presentation of practical exercise Individual presentation Progressive assessment and Global Examination Presential Duration: 01:00
8				
9				
10				
11				
12				
13				
14				
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.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
1	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
2	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
3	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
4	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
5	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
6	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
7	Practical exercise (design and simulation)	Individual work	No Presential	00:00	65%	/ 10	CGI02 CGI03 CGI04 CB6 CB7 CB8 UPM1 UPM4 UPM5 CEM01
7	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
7	Presentation of practical exercise	Individual presentation	Face-to-face	01:00	0%	/ 10	CGI02 UPM1 UPM4 UPM5 CEM01

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
1	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
2	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
3	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
4	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
5	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
6	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
7	Practical exercise (design and simulation)	Individual work	No Presential	00:00	65%	/ 10	CGI02 CGI03 CGI04 CB6 CB7 CB8 UPM1 UPM4 UPM5 CEM01
7	Online quiz	Online test	No Presential	01:00	5%	/ 10	CB6 UPM1 CEM01
7	Presentation of practical exercise	Individual presentation	Face-to-face	01:00	0%	/ 10	CGI02 UPM1 UPM4 UPM5 CEM01

7.1.3. Referred (re-sit) examination

No se ha definido la evaluación extraordinaria.

7.2. Assessment criteria

The evaluation is based on one or two assignments, consisting on the design and simulation of an antenna or system of antennas. At the end of the course, the student will be required to hand out a report, and present their results in a brief presentation session (during the last class).

Aditionally, the evaluation will be complemented with some online test during the course, that will allow to assess the student progress at the end of each unit.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
"Antenna Theory: Analysis and Design", Constantine A. Balanis, Wiley, 2016	Bibliography	Classic, basic textbook on antennas
"Modern Antenna Handbook", Constantine A. Balanis, Wiley, 2008	Bibliography	
"Antenna Theory and Design", W.L. Stutzman, Wiley, 2012	Bibliography	
"Fundamentals of Wireless Communication", David Tse and Pramod Viswanath, Cambridge University Press, 2005	Bibliography	Electronic version available online: https://web.stanford.edu/~dntse/wireless_book.html
"Space-Time Codes and MIMO Systems", Mohinder Jankiraman, Artech House Universal Personal Communications, 2004	Bibliography	
"MIMO Antennas for Wireless Communication: Theory and Design", Leeladhar Malviya, Rajib Kumar Panigrahi, M.V. Kartikeyan, Taylor & Francis, 2020	Bibliography	

"Adaptive antenna arrays trends and applications", S. Chandran, Springer, 2004	Bibliography	
"Antenna Theory and Microstrip Antennas", D.G.Fang, Taylor & Francis, 2010	Bibliography	Textbook centered on planar and patch antennas
"Millimeter-Wave Antennas: Configurations and Applications", Jaco du Preez, Saurabh Sinha, Springer Link, 2016	Bibliography	Textbook on mm-wave antennas
Moodle course page	Web resource	Slides, additional online resources, assessment quizzes