ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93000803 - Advanced Topics On Antenna Technologies

DEGREE PROGRAMME

09AQ - Master Universitario En Ingenieria De Telecomunicacion

ACADEMIC YEAR & SEMESTER

2023/24 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	93000803 - Advanced Topics On Antenna Technologies
No of credits	6 ECTS
Type	Optional
Academic year ot the programme	Second year
Semester of tuition	Semester 3
Tuition period	September-January
Tuition languages	English
Degree programme	09AQ - Master Universitario en Ingenieria de Telecomunicacion
Centre	09 - Escuela Tecnica Superior De Ingenieros De Telecomunicacion
Academic year	2023-24

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Francisco Eduardo Carrasco Yepez	B-417	eduardo.carrasco@upm.es	Sin horario. Appointment arranged by email
Jose Manuel Fernandez Gonzalez (Subject coordinator)	C-416	josemanuel.fernandez.gonzalez@upm.es	Sin horario. Appointment arranged by email

Adrian Tamayo Dominguez	C-418	a.tamayo@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 have a strong knowledge in basic concept about antennas, radiated fields, electromagnetic waves and basic antenna parameters

- It is recommended to know Matlab programming

4. Skills and learning outcomes *

4.1. Skills to be learned

CE2 - Capacidad para desarrollar sistemas de radiocomunicaciones: diseño de antenas, equipos y subsistemas, modelado de canales, cálculo de enlaces y planificación.

CE5 - Capacidad para diseñar sistemas de radionavegación y de posicionamiento, así como los sistemas radar.

CG1 - 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.

CG2 - 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.

CG4 - 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.

CG5 - 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.

CT1 - Capacidad para comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa.

CT2 - Capacidad para dinamizar y liderar equipos de trabajo multidisciplinares.

CT3 - Capacidad para adoptar soluciones creativas que satisfagan adecuadamente las diferentes necesidades planteadas.

CT4 - Capacidad para trabajar de forma efectiva como individuo, organizando y planificando su propio trabajo, de forma independiente o como miembro de un equipo.

CT5 - Capacidad para gestionar la información, identificando las fuentes necesarias, los principales tipos de documentos técnicos y científicos, de una manera adecuada y eficiente.

4.2. Learning outcomes

RA134 - Manejar con soltura las bases de álgebra lineal y cálculo infinitesimal necesarias para formular problemas de optimización.

RA76 - Habilidad de comunicación oral y escrita

RA208 - Conocer las bases de diseño de los sistemas de multiples antenas (MIMO)

RA207 - Tener capacidad de diseño de antenas para sistemas de comunicaciones y radar

RA206 - Conocer y evaluar los distintos tipos de antenas en función de sus especificaciones

RA119 - Conocimiento de técnicas avanzadas utilizadas en las Tecnologías de Acceso Radio

RA120 - Conocer los aspectos básicos de las tecnologías utilizadas en los sistemas de comunicaciones móviles

RA209 - Conocer los sistemas de medida de antenas y sus limitaciones

RA99 - Elaborar documentos y preparar presentaciones para difundir los resultados del proyecto de innovación.

RA210 - Tener capacidad de diseño de agrupaciones de antenas (arrays) tanto activos como pasivos

RA212 - Tener capacidad de diseño de sistemas de medida de antena en campo proximo

RA211 - Conocer los algoritmos matemáticos de los sistemas adaptativos de antena

RA10 - Saber realizar una presentación de carácter técnico, ante una audiencia de pares, que describa el trabajo realizado y sus resultados, de forma clara y bien estructurada, en el tiempo establecido, y usando un lenguaje preciso

RA51 - Conocimiento y caracterización de los elementos de los sistemas de alta frecuencia

RA50 - Capacidad de evaluar, diseñar y analizar antenas asociadas a sistemas de comunicaciones o de radiolocalización

RA52 - Capacidad de evaluar, diseñar y analizar los subsistemas de RF asociadas a sistemas de comunicaciones

* 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 theroretical 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. Telecomunciación to perform practical analysis either by the professors and for pratical 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. Planar array antennas
   3.1. Overview of planar array antennas
   3.2. Phased array antennas
   3.3. Example: Practical design of planar array antennas
4. Reflectarray and Transmitarray antennas
   4.1. Overview of reflectarray and transmitarray antennas
   4.2. Analysis and design of transmitarray antennas
   4.3. Analysis and design of reflectarray cells and reflectarray antennas
   4.4. Techniques for bandwidth improvement
   4.5. Contoured-beam reflectarrays
   4.6. Dual-reflector configurations
   4.7. Applications: Automotive radar, base station antennas, sub-mm waves, space antennas
   4.8. Terahertz reflectarrays
   4.9. New capabilities: filtering and non-reciprocal response
   4.10. Reconfigurable and beam-scanning reflectarrays
   4.11. Example: Practical design of reflectarray 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	**Presentation and objectives of the course and Antenna project topics proposal** Duration: 02:00 Additional activities	**Introduction and getting started with electromagnetic software** Duration: 02:00 Laboratory assignments		
2	**Topic 1: Printed antennas, overview of printed antennas** Duration: 02:00 Lecture	**Introduction and getting started with electromagnetic software** Duration: 02:00 Laboratory assignments		
3	**Topic 1: Printed antennas, wideband and multiband antennas** Duration: 02:00 Lecture	**Example: Practical design of printed antenna** Duration: 02:00 Laboratory assignments		**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
4	**Topic 2: Aperture antennas, overview of advanced horn antennas** Duration: 02:00 Lecture	**Example: Practical design of wideband or multiband antenna** Duration: 02:00 Laboratory assignments		**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
5	**Topic 2: Aperture antennas, overview of reflector antennas** Duration: 02:00 Lecture	**Example: Practical design of horn antenna** Duration: 02:00 Laboratory assignments		**Meeting with tutors for 1ºphase intermediate antenna project** Group presentation Continuous assessment and final examination Presential Duration: 00:00 **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
6	**Topic 3: Planar array antennas, overview of planar array antennas, phased array antennas** Duration: 02:00 Lecture	**Example: Practical design of reflector antenna** Duration: 02:00 Laboratory assignments		**Delivery at the end of the laboratory of a short report+files of reflector antenna design** Individual work Continuous assessment and final examination Presential Duration: 00:00

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

14	**3ºphase final antenna project presentation+report** Duration: 04:00 Additional activities			**3ºphase final antenna project presentation+report** Group presentation Continuous assessment and final examination Presential Duration: 00:00
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	CG4 CT3 CT4 CG1 CE2
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	CT4 CT1 CT5 CG1 CE2
5	Meeting with tutors for 1ºphase intermediate antenna project	Group presentation	Face-to-face	00:00	20%	5 / 10	CT2 CT3 CT4 CT1 CG5 CE2
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	CT3 CT1 CT5 CE2
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	CT3 CT5 CG5 CG1 CE2
7	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	CT4 CG2 CG1 CE2
8	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	
9	1º and 2ºphase intermediate antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CT2 CT3 CT4 CT1 CE2

11	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	CT4 CG2 CG5 CE2
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	CT3 CT4 CT5 CG1 CE2
14	3ºphase final antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CG4 CT2 CT3 CT4 CT1 CT5 CG1 CE2

7.1.2. Global examination

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	CG4 CT3 CT4 CG1 CE2
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	CT4 CT1 CT5 CG1 CE2
5	Meeting with tutors for 1ºphase intermediate antenna project	Group presentation	Face-to-face	00:00	20%	5 / 10	CT2 CT3 CT4 CT1 CG5 CE2
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	CT3 CT1 CT5 CE2
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	CT3 CT5 CG5 CG1 CE2

7	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	CT4 CG2 CG1 CE2
8	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	
9	1º and 2ºphase intermediate antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CT2 CT3 CT4 CT1 CE2
11	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	CT4 CG2 CG5 CE2
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	CT3 CT4 CT5 CG1 CE2
14	3ºphase final antenna project presentation+report	Group presentation	Face-to-face	00:00	20%	5 / 10	CG4 CT2 CT3 CT4 CT1 CT5 CG1 CE2

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	CG4 CT3 CT4 CT1 CG5 CE2

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	CG4 CT3 CT4 CG1 CE2
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	CT4 CT1 CT5 CG1 CE2
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	CT3 CT1 CT5 CE2
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	CT3 CT5 CG5 CG1 CE2
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	CT4 CG2 CG5 CE2
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	CT4 CG2 CG1 CE2
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	CG4 CG2 CT4 CG1 CE2
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	CT3 CT4 CT5 CG1 CE2

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 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 (LP), which is a mandatory activity that cannot be recovered.
- 60% Antenna project (AP): 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.

The final grade of the course will be calculated as 0.4*LP+0.6*AP.

Due to the nature of this type of laboratory practices, in which specialized instrumentation and dedicated memories are required, the solutions of the laboratory practices will not be delivered in any case.

Any laboratory practices or antenna project delivered may require a complementary oral evaluation by the professors to validate that they have been done by the students without the help of artificial intelligence.

The evaluation of the antenna project will be done by means of the evaluation of the memory delivered in each phase and the evaluation via Moodle among the team members. 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 (LP), which is a mandatory activity that cannot be recovered.
- 60% Individual antenna project (AP) presentation + report.

Due to the nature of this type of laboratory practices, in which specialized instrumentation and dedicated memories are required, the solutions of the laboratory practices will not be delivered in any case.

Any laboratory practices or individual antenna project delivered may require a complementary oral evaluation by the professors to validate that they have been done by the student without the help of artificial intelligence.

Extraordinary call:

- 40% Report+files delivery at the end of each laboratory practices (LP), which is a mandatory activity that cannot be recovered.
- 60% Individual antenna project (AP) presentation + report.

Due to the nature of this type of laboratory practices, in which specialized instrumentation and dedicated memories are required, the solutions of the laboratory practices will not be delivered in any case.

Any laboratory practices or individual antenna project delivered may require a complementary oral evaluation by the professors to validate that they have been done by the student without the help of artificial intelligence.

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 that cannot be recovered, 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.
- Due to the nature of this type of laboratory practices, in which specialized instrumentation and dedicated memories are required, the solutions of the laboratory practices will not be delivered in any case.
- Any laboratory practices or antenna project delivered may require a complementary oral evaluation by the professors to validate that they have been done by the student without the help of artificial intelligence.

In no case, the grade of the laboratory practices and antenna project can be transferred to the grade of successive years, closing a cycle with the extraordinary evaluation.

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. Clarricoats, 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.