ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93000811 - Satellite Communications

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	93000811 - Satellite Communications
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 *
Miguel Alejandro Salas Natera	C-411	miguel.salas@upm.es	Sin horario. Ask for tutorships via e-mail.
Ramon Martinez Rodriguez-Osorio (Subject coordinator)	C-411	ramon.martinez@upm.es	Sin horario. Ask for tutorships via e-mail.

* 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

- Sistemas De Comunicaciones

3.2. Other recommended learning outcomes

- Communication electronics

- Communication networks and systems

- Radiocommunication

4. Skills and learning outcomes *

4.1. Skills to be learned

CE1 - Capacidad para aplicar métodos de la teoría de la información, la modulación adaptativa y codificación de canal, así como técnicas avanzadas de procesado digital de señal a los sistemas de comunicaciones y audiovisuales.

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

CE4 - Capacidad para diseñar y dimensionar redes de transporte, difusión y distribución de señales multimedia.

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.

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.

4.2. Learning outcomes

RA285 - Trade different alternatives of a satellite communication system considering orbits, performance, feasibility and cost

RA284 - Sizing of satellite communication systems

RA283 - Know satellite communication systems, including payload, platform, ground segment and communication services

RA288 - Get familiar with existing satellite communication systems and services, and global satellite navigation systems

RA289 - Elaborate technical reports and presentations to propose a feasible solution based on satellite communications

RA286 - Understand the impact of the satellite non-linear channel on the communication system performance

* 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

The scope of this course is to provide a complete vision of satellite communication systems, from orbits used by artificial satellites and constellations to the optimization of satellite links. Beginning with the SatCom system architecture, concepts related with orbits and constellations, satellite subsystems, communication payloads will be covered. Then, design and sizing of satellite communication links will be analyzed. Students will use all the concepts to carry out the design of a satellite communication system or the implementation of a specified service. Students will deal with advanced communication concepts, interference coordination and satellite link optimization. Course will cover GEO systems, as well as Medium and Low Earth satellites and constellations.

Different practical exercises and labs will be carried out along the course to consolidate the theoretical concepts, which will be related to existing systems. We consider the following labs or demonstration sessions along the course:

1) Mission analysis

2) Starlink user terminal

3) Communicatin payload design

4) Link budget

5) GNSS (Global Satellite Navigation System)

Some seminars and invited conferences will be organized, subject to the availability of external speakers.

In case it is feasible, a visit to a satellite control center or similar facility related to satellite communication system will be organized.

At the end of the course, students will have a clear understanding of the aspects that influence the design of a satellite communication system and will know to evaluate the fundamental trade-offs between satellite subsystems, communication payloads, ground segment, orbits and advanced transmissions concepts.

5.2. Syllabus

1. Introduction to satellite communication systems
2. Orbits and constellations used by artificial satellites
   2.1. Lab session - Mission analysis
3. Architecture of satellite communication systems
   3.1. Platform and subsystems
   3.2. Communication payload. Transponder and antennas
   3.3. Lab session - Design of a satellite communication payload
4. Ground segment: control and user stations
   4.1. Ground station architecture and station types
   4.2. Antennas and radiofrequency elements
   4.3. Lab session - Starlink terminal
5. Communication techniques used in satellite communications
   5.1. DVB-S2 and DVB-S2x transmission systems

5.2. Timing and carrier recovery techniques

5.3. Techniques to improve capacity

5.4. Techniques to improve availability

6. Design and optimization of satellite links

6.1. Propagation

6.2. Design and sizing of satelite links

6.3. Interferences and coordination

6.4. Optimization of satellite links

6.5. Lab session - Link budget

7. Multiple Access in satellite communications

8. Commercial satellite communication systems

8.1. GEO systems. HTS and VHTS

8.2. MEO systems and constellations

8.3. LEO systems and constellations

9. Global Satellite Navigation systems (GNSS)

10. Seminars

10.1. 5G services in non-terrestrial networks (NTN). Cas study: NB IoT over satellite

10.2. Invited conferences

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Course presentation. Introduction to SatCom systems** Duration: 02:00 Lecture **Orbits. Kepler laws. Ephemeris. Coordinate systems.** Duration: 02:00 Lecture			
2	**Orbits. Pointing and satellite coverage. Perturbations and launch systems.** Duration: 02:00 Lecture **Orbits and constellations used by artificial satellites** Duration: 01:30 Lecture **Presentation of work in group topics** Duration: 00:30 Additional activities			
3	**Architecture of satellite communication systems** Duration: 02:30 Lecture **Architecture of satellite communication systems** Duration: 01:00 Problem-solving class			**Project: Work in group organization** Group work Continuous assessment and final examination Presential Duration: 00:30
4	**Ground segment** Duration: 02:00 Lecture **Ground segment** Duration: 01:00 Lecture **Ground segment** Duration: 01:00 Problem-solving class			
5	**Communication techniques used in satellite communications** Duration: 02:00 Lecture	**Lab: Mission anaylisis applied to a SatCom system** Duration: 02:00 Laboratory assignments		

6	**Communication techniques used in satellite communications** Duration: 02:00 Lecture **Communication techniques used in satellite communications** Duration: 02:00 Problem-solving class			**Lab manuals and/or proposed exercises** Individual work Continuous assessment Presential Duration: 00:30
7	**Design and optimization of satellite links** Duration: 02:00 Lecture **Project. Progress presentation (1/2)** Duration: 01:00 Cooperative activities **Design and optimization of satellite links** Duration: 01:00 Lecture			**Project. Progress presentation (1/2)** Group work Continuous assessment and final examination Presential Duration: 01:00
8	**Design and optimization of satellite links** Duration: 02:00 Problem-solving class	**Sizing of a satellite communication system** Duration: 02:00 Cooperative activities		
9	**Satellite communication networking** Duration: 02:00 Lecture **Satellite communication networking** Duration: 02:00 Lecture			
10	**Commercial systems. GEO. HTS and VHTS** Duration: 02:00 Lecture **Project preparation** Duration: 01:00 Cooperative activities			**Project. Progress presentation (2/2)** Group work Continuous assessment and final examination Presential Duration: 01:00
11	**Commercial systems. MEO, LEO and Big LEO** Duration: 02:00 Lecture **Project preparation** Duration: 02:00 Cooperative activities			
12	**Visit to SatCom facility (if feasible) or invited talk** Duration: 04:00 Additional activities			**Lab manuals and/or proposed exercises** Individual work Continuous assessment Presential Duration: 00:30
13	**Satellite Navigation Systems** Duration: 02:00 Lecture **Project preparation** Duration: 02:00 Cooperative activities			

14				**Project (final presentation and technical report)** Group work Continuous assessment and final examination Presential Duration: 02:00
15				
16				
17				**Exam. Theory and Case study exercise** Written test Continuous assessment Presential Duration: 03:00 **Exam. Theory and Case study exercise** Written test Final examination Presential Duration: 03:00 **Lab manuals and/or proposed exercises** Individual work Final examination Presential Duration: 00:30

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	Project: Work in group organization	Group work	Face-to-face	00:30	%	/ 10	CT4
6	Lab manuals and/or proposed exercises	Individual work	Face-to-face	00:30	15%	3 / 10	CT4 CE2
7	Project. Progress presentation (1/2)	Group work	Face-to-face	01:00	%	/ 10	CG4 CT3 CT4
10	Project. Progress presentation (2/2)	Group work	Face-to-face	01:00	%	/ 10	CG4 CT3 CT4
12	Lab manuals and/or proposed exercises	Individual work	Face-to-face	00:30	15%	3 / 10	
14	Project (final presentation and technical report)	Group work	Face-to-face	02:00	40%	3 / 10	CG4 CT3 CE4
17	Exam. Theory and Case study exercise	Written test	Face-to-face	03:00	30%	3 / 10	CE1 CE2 CE4

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
3	Project: Work in group organization	Group work	Face-to-face	00:30	%	/ 10	CT4
7	Project. Progress presentation (1/2)	Group work	Face-to-face	01:00	%	/ 10	CG4 CT3 CT4
10	Project. Progress presentation (2/2)	Group work	Face-to-face	01:00	%	/ 10	CG4 CT3 CT4
14	Project (final presentation and technical report)	Group work	Face-to-face	02:00	40%	3 / 10	CG4 CT3 CE4

17	Exam. Theory and Case study exercise	Written test	Face-to-face	03:00	30%	3 / 10	CE4 CE1 CE2
17	Lab manuals and/or proposed exercises	Individual work	Face-to-face	00:30	15%	3 / 10	CT4 CE2

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Exam. Theory and Case study exercise	Written test	Face-to-face	02:30	50%	3 / 10	CE4 CE1 CE2
Project	Group work	Face-to-face	01:00	30%	3 / 10	CT4 CG4 CT3
Lab manuals and/or proposed exercises	Individual work	Face-to-face	00:00	20%	3 / 10	CT4 CE2

7.2. Assessment criteria

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, TI, and TG). EX 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 as TI and TG will be carried out along the semester.

EVALUATION: PROGRESSIVE AND GLOBAL

Evaluation in the ordinary period (both progressive and by global) will consist of the following items:

1. Individual homework. Subsmission of homeworks along the course and completion of the laboratory manuals. Attendance to the laboratory sessions and submission of the lab manual in mandatory
2. Project (work in group). It is carried out in student groups along the semester. Intermediate reviews will be performed along the course with presentations in class (in English). Each group will carry out a final presentation in class. Organization,, progress, oral presentation, technical document, discussion, results, proposed solution and participation will be evaluated. Internal evaluation between project members will be

considered in case needed.

3. Exam. Theory and case study exercise. Theory will consist of a set of questins covering the main concepts of the course, and no material is allowed. In the case study, students will have access to material to solve the proposed problem.

Project will consist in the analysis and/or design of a particular satellite communication system to provide a specific cutting.edge communication service (e.g. broadband access in Europe, application of massive LEO constellations for low latency Internet service, in-flight connectivity, IoT over satellite) or a particular process (e.g. evaluation of ACM strategies in DVB-S2 systems, impact of intermodulation in link quality). The calendar for the evluation is tentative: the final weeks for the progress presentations will be defined along the semester.

Progress meetings will be held along the course or when required by students. Project will include the realization of simulations, submission of technical report and oral presentation (all in English). Some in-class sessions might be dedicated to the project.

EXTRAORDINARY EXAMINATION

Extraordinary examination will be composed of the same items than the ordinary examination. The student has to re-take the items that have not been passed in the ordinary examination, and the qualifications of the individual exercises and project will be conserved if passed. In case the work in group has not been passed, an oral exam will be performed to check the understanding of the project,. In case needed, a technical report summarizing the work and tasks perfomed by the student shall be part of the project evaluation.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Satellite Communications Systems: Systems, Techniques and Technology, 5th Edition, Gerard Maral, Michel Bousquet, Zhili Sun, Wiley, 2009.	Bibliography	SatCom book

Comunicaciones por Satélite, Miguel Calvo, Ramón Martínez, Antonio García, ETSIT-UPM, 2005.	Bibliography	SatCom manual
Moodle site of the course	Web resource	Moodle site with course materials.
Satellite Communications, 4th. Ed., Dennis Roddy, McGraw Hill, 2006.	Bibliography	SatCom book
ITU Handbook on Satellite Communications, 3rd. Ed., Wiley, 2002.	Bibliography	ITU SatCom manual
ITU recommendations for propagation calculations	Web resource	
System Toolkit	Equipment	Mission analysis software available at www.agi.com (evaluation version)
Journal papers	Others	International Journal of Satellite Communications and Networking, Via Satellite, etc.
Satellite Communications Payload and System, T. M. Braun, Wiley, 2012.	Bibliography	SatCom payload book
Freeflyer	Equipment	Software tool for space mission design, analysis, and operations. Available at https://ai-solutions.com/freeflyer/.
Matlab. SatCom toolbox	Equipment	SatCom toolbox in Matlab to evaluate mission analysis, coverage, etc.
Non-Geostationary Satellite Communications Systems Edited by Eva Lagunas, Symeon Chatzinotas, Kang An, Bassel F. Beidas	Bibliography	Book on SatComs focused on NGSO constellations

9. Other information

9.1. Other information about the subject

The visit to an external facility depends on the availability of the facility and its personnel. Exact dates will be announced when confirmed. Similar constraints apply to invited conferences.

SatCom course is related to SDG 9 ("Industry, Innovation, Infrastructure") as contents deal with the design of infrastructures to increase access to ICT and broadband services. The communication technologies covered in the course provide a solution to the increasing demand of communication services worldwide that will generate new business opportunities and contribute to digital innovation and reach the digital transformation of the society.

In the project, student groups will be asked to evaluate the impact of project outcomes on different SDGs.