INTERNATIONAL
CAMPUS OF
EXCELLENCE

POLITÉCNICA

E.T.S. de Ingenieria y Sistemas
de Telecomunicacion

ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

593000601 - Advanced Information Theory

DEGREE PROGRAMME

59AJ - Master Universitario En Comunicaciones Inalámbricas

ACADEMIC YEAR & SEMESTER

2024/25 - Semester 1

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1. Description

1.1. Subject details

Name of the subject	593000601 - Advanced Information Theory
No of credits	6 ECTS
Type	Compulsory
Academic year ot the programme	First year
Semester of tuition	Semester 1
Tuition period	September-January
Tuition languages	English
Degree programme	59AJ - 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 *
Jose Enrique Gonzalez Garcia	8415	joseenrique.gonzalez@upm.es	Sin horario.
Cesar Diaz Martin (Subject coordinator)	8210	cesar.diazm@upm.es	Sin horario.
Jose Luis Rodriguez Vazquez	8305	jl.rodriguez.vazquez@upm.es	Sin horario.

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

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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

- Digital modulations, basic source coding and line coding.

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/ Students have demonstrated knowledge and understanding providing the groundwork or opportunity for innovation in developing and/or applying ideas, often within a research context

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/Students are capable of applying their knowledge, understanding, and problem-solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study

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/Students are capable of integrating knowledge and making complex decisions, which, although based on incomplete or limited information, require reflection on social and ethical responsibilities linked to the application of their knowledge and opinions

CEM02 - Utilizar adecuadamente los códigos fuente, códigos de canal y códigos de encriptado que se necesiten en un sistema de comunicaciones inalámbrico. / Properly use the source codes, channel codes and encryption codes that are needed in a Wireless communication system.

CGI02 - Comprender el procedimiento, valor y límites del método científico, siendo capaz de identificar, localizar y obtenerdatos requeridos en un trabajo de investigación, de diseñar y guiar investigaciones analíticas, de modelado

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y experimentales, así como de evaluar datos de una manera crítica y extraer conclusiones. / Understand the procedure, value, and limits of the scientific method, being able to identify, locate and obtain data required in a research work, to design and guide analytical, modeling, and experimental investigations, as well as to critically evaluate data and extract conclusions.

CGI03 - Valorar la importancia de las fuentes documentales, manejarlas y buscar la información para el desarrollo de cualquier trabajo de investigación. / Assess the importance of documentary sources, manage them and search for information for the development of any research work.

CGI04 - Leer y comprender publicaciones dentro de su ámbito de estudio/investigación, así como su catalogación y valor científico. / Read and understand publications within their field of study / research, as well as their cataloging and scientific value.

UPM1 - Uso de la lengua inglesa / Use of the English language

UPM4 - Organización y planificación / Planning and organization

UPM5 - Gestión de la Información / Information management

4.2. Learning outcomes

RA3 - Elegir los métodos y herramientas matemáticas necesarios para abordar la solución de un problema/ Choose the mathematical methods and tools necessary to tackle the solution of a problem

RA2 - Aplicar el conocimiento adquirido a la comprensión de problemas cualitativos y cuantitativos relacionados con la codificación fuente y la codificación de canal/ Apply the knowledge acquired to the understanding of qualitative and quantitative problems related to source coding and channel coding

RA4 - Anticipar el comportamiento de un código fuente, código de canal o modelo de encriptado y su influencia en el conjunto de un sistema de telecomunicación/ Anticipate the behavior of a source code, channel code or encryption model and its influence on a telecommunication system

RA1 - Distinguir entre los códigos de canal, códigos fuente y modelos de encriptado existentes y su aplicación práctica/ Distinguish between channel codes, source codes and encryption models and their practical application

RA5 - Interpretar los datos derivados de observaciones empíricas y mediciones en términos de su importancia y relacionarlos con la teoría apropiada/ 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.

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5. Brief description of the subject and syllabus

5.1. Brief description of the subject

This course aims to provide students with knowledge of the principles of information processing and transmission. To this end, it presents in detail the modern techniques of source coding, channel coding and encryption. Thus, the course is divided into the following four main parts:

- The first part reviews the basic concepts of information theory, which are fundamental for understanding the rest of the course syllabus.
- After that, there is the part dedicated to source coding, which covers both lossless and lossy source coding. As an essential appendix of this part, we present the coding techniques for two of the most relevant types of signals: audio and video, including a historical overview of the strategies used in different types of communication systems and the most advanced ones used today.
- The part on channel coding reviews the basic concepts of this type of codes, as well as its difference with other types of error correction strategies, and then goes on to present the definition and operation of the block and convolutional codes in today's transmission systems.
- Finally, the most important types of cryptographic techniques and their use in modern communication systems are shown.

Next is included the **syllabus** of the course:

1. Information theory

- Measure of information
- Entropy
- Channel model
- Mutual information
- Channel capacity
- Shannon's theorem

2. Source coding: introduction

- Coding parameters

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- Source coding theorem
- Classification of codes
- Kraft inequality
- Rate-distortion theory

3. Source coding: advanced audio coding

- Audio perceptual and statistic characteristics
- Audio standards

4. Source coding: advanced video coding

- Video perceptual and statistic characteristics
- Video standards

5. Channel coding: introduction

- Code rate
- Types of codes: block, convolution
- Error control strategies: ARQ, FEC
- Generator matrices and polynomials

6. Channel coding: Simple codes

- BCH, Reed-Muller, Reed-Solomon
- Cyclic Redundancy Check (CRC)
- Low Density Parity Check Codes (LDPC)
- Hybrid Automatic Repeat Request (HARQ)

7. Channel coding: Concatenated codes

- Simple Concatenated Codes (SCC)
- Parallel Concatenated Convolutional Codes (PCCC): Turbo codes
- Serial Concatenated Convolutional Codes (SCCC)

8. Cryptography applied to wireless systems

- Plain text, cipher text, and key

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- Symmetric-key cryptography
- Asymmetric-key cryptography
- RSA Algorithm

The course also includes the following five lab sessions embedded within the theory classes:

1. P1: Basic algorithm design for source coding
2. P2: Algorithm design for advanced audio coding
3. P3: Algorithm design for advanced video coding
4. P4: Algorithm design for channel coding, block and convolution codes
5. P5: Algorithm design for cryptography applied to wireless systems

5.2. Syllabus

1. Information theory

2. Source coding: introduction

3. Source coding: advanced audio coding

4. Source coding: advanced video coding

5. Channel coding: introduction

6. Channel coding: Simple codes

7. Channel coding: Concatenated codes

8. Cryptography applied to wireless systems

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6. Schedule

6.1. Subject schedule*

Week	Type 1 activities	Type 2 activities	Distant / On-line	Assessment activities
1	**Lesson 1** Duration: 02:00 **Lesson 1** Duration: 02:00 **Lesson 2** Duration: 02:00 **Lab session Lesson 2** Duration: 02:00			**Submission Results Lab Session Lesson 2** Progressive assessment Presential Duration: 00:00
2	**Lesson 2** Duration: 02:00 **Lesson 2** Duration: 02:00 **Lesson 2** Duration: 02:00 **Lesson 5** Duration: 02:00			**Task Lesson 2** Progressive assessment Not Presential Duration: 00:00
3	**Lesson 3** Duration: 02:00 **Lesson 3** Duration: 02:00 **Lesson 5** Duration: 02:00 **Lesson 6** Duration: 02:00			

4	**Lesson 3** Duration: 02:00 **Lab session Lesson 3** Duration: 02:00 **Lesson 6** Duration: 02:00 **Lesson 7** Duration: 02:00			**Submission Results Lab Session Lesson 6** Progressive assessment Presential Duration: 00:00 **Submission Results Lab Session Lesson 3** Progressive assessment Presential Duration: 00:00 **Task Lesson 3** Progressive assessment Not Presential Duration: 00:00
5	**Lesson 4** Duration: 02:00 **Lesson 4** Duration: 02:00 **Lesson 7** Duration: 02:00 **Lab session Lessons 6 and 7** Duration: 02:00			**Task Lesson 4 (I)** Progressive assessment Not Presential Duration: 00:00
6	**Lab session Lesson 4** Duration: 02:00 **Lesson 4** Duration: 02:00 **Lab session Lessons 6 and 7** Duration: 02:00 **Lab session Lessons 6 and 7** Duration: 02:00			**Submission Results Lab Session Lesson 4** Progressive assessment Presential Duration: 00:00 **Task Lesson 4 (II)** Progressive assessment Not Presential Duration: 00:00 **Submission Results Lab session Lessons 6 and 7** Progressive assessment Presential Duration: 00:00
7	**Lesson 8** Duration: 02:00 **Lesson 8** Duration: 02:00 **Lesson 8**			**Submission Results Lab Session Lesson 8** Progressive assessment Presential Duration: 00:00

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	Duration: 02:00 **Lab session Lesson 8** Duration: 02:00			
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				**Final exam** Global examination Not Presential Duration: 02:00

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.

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7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
1	Submission Results Lab Session Lesson 2		Face-to-face	00:00	10%	5 / 10	UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02 UPM4 UPM1
2	Task Lesson 2		No Presential	00:00	10%	4 / 10	UPM1 UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02 UPM4
4	Submission Results Lab Session Lesson 3		Face-to-face	00:00	10%	5 / 10	UPM1 UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02 UPM4
4	Submission Results Lab Session Lesson 6		Face-to-face	00:00	10%	5 / 10	UPM1 UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02

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							UPM4
4	Task Lesson 3		No Presential	00:00	10%	4 / 10	UPM1 UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02 UPM4
5	Task Lesson 4 (I)		No Presential	00:00	10%	4 / 10	UPM1 UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02 UPM4
6	Submission Results Lab Session Lesson 4		Face-to-face	00:00	10%	5 / 10	UPM1 UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02 UPM4
6	Task Lesson 4 (II)		No Presential	00:00	10%	4 / 10	UPM1 UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02 UPM4
6	Submission Results Lab session Lessons 6 and 7		Face-to-face	00:00	10%	5 / 10	UPM1 UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02 UPM4

| 7 | Submission Results Lab Session Lesson 8 | | Face-to-face | 00:00 | 10% | 5 / 10 | UPM1
UPM5
CB6
CB8
CEM02
CGI04
CGI03
CB7
CGI02
UPM4 |

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Final exam		No Presential	02:00	100%	5 / 10	UPM1 UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02 UPM4

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Final exam		Face-to-face	02:00	100%	5 / 10	UPM1 UPM5 CB6 CB8 CEM02 CGI04 CGI03 CB7 CGI02 UPM4

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7.2. Assessment criteria

Professors will ask students to complete individual or group theoretical and practical assignments (as shown in the table Assessment activities above), which will be graded. The obtained scores will be combined to obtain the final grade of the course.

A score of 5/10 is required to pass the course. If any student obtains a grade lower than the mimum required in a given part, they can recover said part in an exceptional call in January and finally in July.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Moodle	Web resource	Files with theory, practice scripts, notes, etc.
PC + Matlab	Equipment	Necessary for the realization of laboratory practices and simulations.
Classroom with digital screen	Equipment	Necessary for the teaching of theory. How the laboratory is embedded, the classroom must have PCs with Matlab for the students.

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9. Other information

9.1. Other information about the subject

As can be seen in the schedule, the course will cover seven weeks. Please note that several non-interdependent lessons of the course will be taught in parallel.